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1993

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Tune in the Editor

When you take on a job too big for yourself, you've just got to admit it. The topics in Radio Craft should cover every aspect of radio communications, but you and I know that is impossible to cover completely in a magazine of only 112 pages. Even twice as many pages would still not be sufficient. So, compromise is the order of the day!

To make maximum use of the pages available to the editorial staff, topics and projects were selected for maximum coverage and interest. How well did I do? I'm sure you'll write and let me know.

As projects go, the World Band Receiver on page 17 is tops for a shortwave listener who tunes in the popular shortwave band between 6 to 18 MHz. The discussion on the NE602 one-chip receiver front-end opens a new horizon for radio hobby designers and builders. Of course, if you want to get into amateur radio telecasting, you have the info between the covers you are now holding. Antique radio buffs get more than ample coverage and a bit of radio history is discussed.

Radio Craft is published for the electronics hobbyist who still gets a kick out of wearing headphones and listening to news broadcasts from other continents or the excitement happening around the corner as heard on a police scanner. My father did it. I did it. And my son carries on the tradition. Maybe radio got into our genes, and if it did, so much the better for us, this publication, and you, our readers!

We'd like to hear from you. Tell us what you liked and disliked.

Julian S. Martin

Julian S. Martin
Editor

Radio Craft 1993

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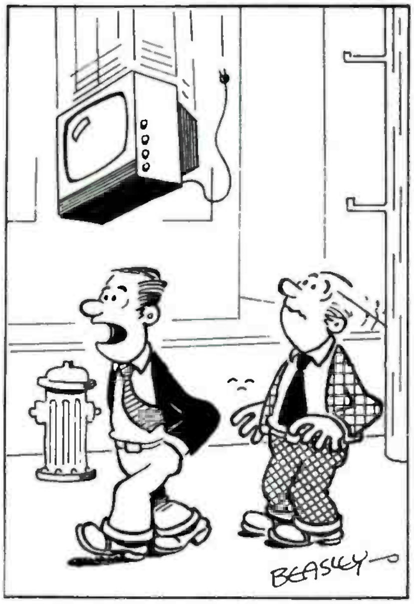
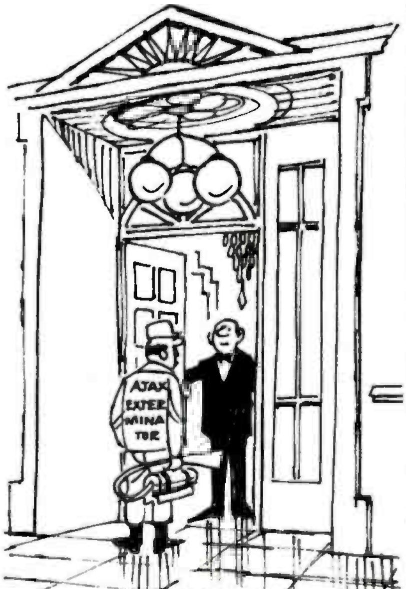
Radio Lore True & Untrue!



"If you ask me, it seems that television has lost a lot of its impact in recent years."

"Gee guys, thanks for the opportunity to work some real DX. Just think—Alpha Centauri!"

"All right Mr. Ohm, we'll name the unit of resistance after you—now, what shall we use for the symbol?"



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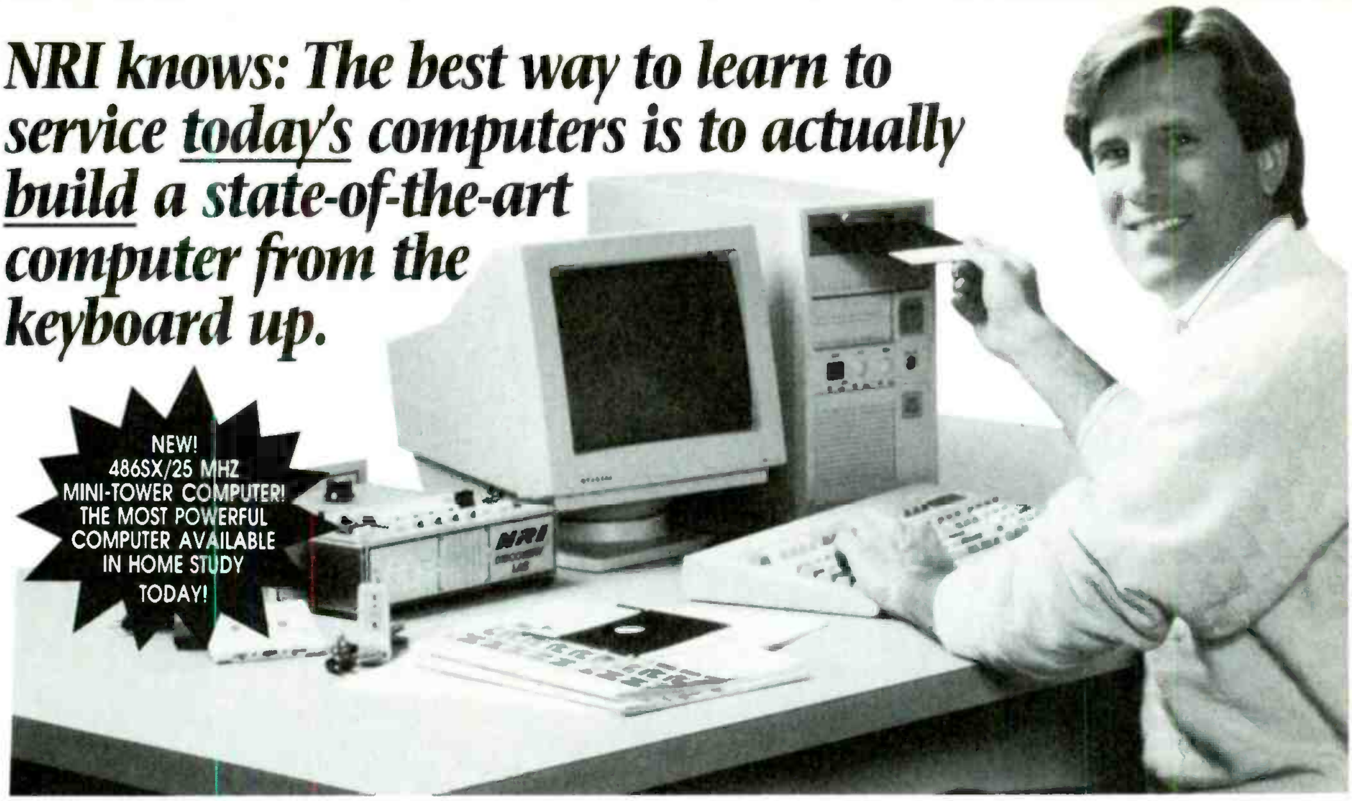

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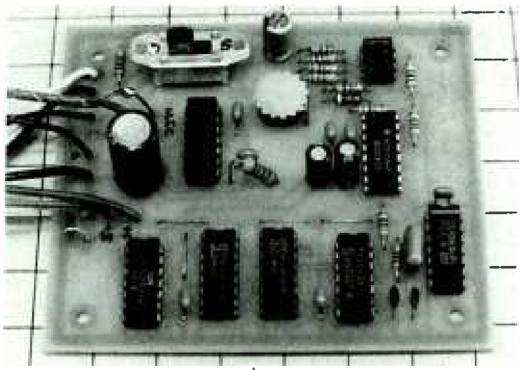
NEW PRODUCTS

VOICE SCRAMBLE KIT

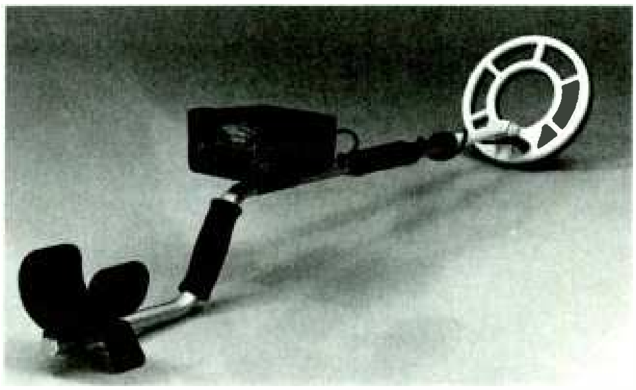
The *Voice Scrambler* kit from *Decade Engineering* converts human speech into an unrecognizable garble, allowing the hobbyist to record or transmit secure voice messages in standard media. In its descrambling mode, the device restores fully intelligible speech from the distorted recording or transmission. The design uses digital signal-processing circuitry, which requires no calibration adjustments. A single, switchable PC-board assembly works directly with the builder's cassette-tape recorder to scramble or descramble a spoken message. The supplied speaker is used as a microphone for recording. It's also possible to build a complete, secure telephone system, using a pair of Voice Scrambler kits at each end of the circuit. Each kit includes glass-epoxy PC boards, all electronic components, detailed assembly instructions that contain an explanation of the theory of operation, and a complete schematic diagram of the voice-scrambler circuit.



CIRCLE 132 ON FREE INFORMATION COUPON

The Voice Scrambler kit costs less than $35. For additional information, contact Decade Engineering, 2302 5th Street NE, Salem, OR 97303; Tel: 503-363-5143; Fax: 503-399-9747.

METAL DETECTOR



CIRCLE 191 ON FREE INFORMATION COUPON

For use in a variety of treasure-hunting applications—from deep digs to wet sand searches—the *CZ-5 QuickSilver* from *Fisher Research Laboratory* offers a visual target-ID meter, three-tone audio target ID, big-target alert, depth reading, pushbutton pin-pointing, and a built-in speaker. The unit's easy-to-read meter, which requires no programming, displays seven small-target categories. In addition, the unit's three-tone audio target ID generates a low tone to indicate a ferrous target, a medium tone for a pull tab or foil, and a high tone for a coin. A distinctive bell tone warns you of a big target. At the push of a button, the sound pitch and meter needle rise to indicate that you're approaching the target, and peak right over it. The meter gives a depth reading in inches for coin-sized objects. By flipping a switch and readjusting the ground control, you can use the CZ-5 QuickSilver for wet-sand searches. For deep-target searches, the audio-boost volume control keeps fixed, shallow-target response at a fixed level but amplifies faint, deep-target sounds.

The CZ-5 QuickSilver metal detector has a suggested retail price of $850. For more information, contact Fisher Research Laboratory, Department 6MO, 200 West Willmott Road, Los Banos, CA 93635; Tel: 209-826-3292.

CAR-STEREO AMPLIFIER

Autotek's 7040BTS is a compact, two-channel amplifier that delivers 18 watts per channel into 4 ohms, and 36 watts per channel into 2 ohms. The amplifier is equipped with a two-way input-selector switch that allows the user to take advantage of the built-in bass boost, or to bypass the boost circuit for a cleaner output. When bass boost is selected, it is fully adjustable from 0–18 dB, centered at 45 Hz. Input sensitivity ranges from 190 mV to 3.5 volts, signal-to-noise ratio is 91 dB, and the damping factor is greater than 80. Maximum cur-

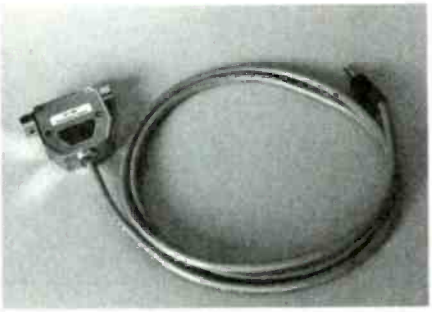
CIRCLE 124 ON FREE INFORMATION COUPON

rent consumption is 10 amps. The amplifier is fully bridgeable, and will run in mixed mono (simultaneous satellite and subwoofer) configuration. A high-value emitter resistor and a bypass diode in the unit's circuitry provide a bright musical output with virtually no crossover distortion.

The model 7040BTS car-stereo amplifier has a suggested retail price of $199. For additional information, contact Autotek, 855 Cowan Road, P.O. Box 4391, Burlingame, CA 94011-4391; Tel: 415-692-2444; Fax: 415-692-2448.

TRANSCEIVER/ COMPUTER INTERFACE CABLES

Designed to interface personal computers with all receivers and transceivers that can be controlled over a serial TTL link, *j-Com's Transceiver Control Computer Interface Cables* act as direct replacements for the manufacturers' own units, making them fully compatible with all rig-control software. Unlike manufacturer-supplied interfaces, j-Com's cables require no external power supply. The small amount of power needed can be "borrowed" directly from the computer's serial interface. Removing the external power supply significantly reduces the interface's susceptibility to RFI from the transmitter, which can affect the serial transmissions between the computer and the rig, or be transferred to the transceiver or computer. Emitted RF noise also is reduced.



CIRCLE 160 ON FREE INFORMATION COUPON

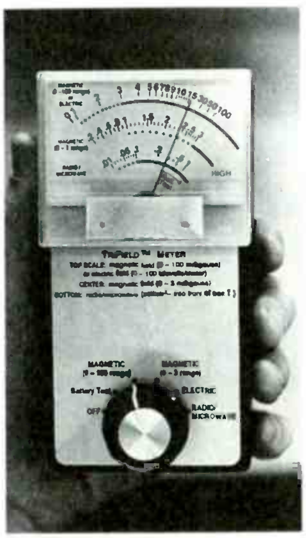
The entire interface has been sandwiched into the shielded hood of a DB-25 connector compatible with the serial interface of most PC-compatible computers. For use with computers that have the smaller-size AT connector, an optional DB-9-to-DB-25 adapter is available. The unit comes fully assembled and ready to plug in. It is available in four models: the *TC-I* for all Icom and Ten-Tec rigs; the *TC-K* for all Kenwood rigs; and the *TC-Y1* and *TC-Y2* for various Yaesu models.

All four models of Transceiver Control Computer Interface Cable are priced at $54.95 (plus $5 shipping and handling). For more information, contact j-Com, Box 194, Ben Lomond, CA 95005; Tel: 408-335-9120; Fax: 335-9121.

TRI-FIELD METER

For those who require meters that read AC electric fields, AC magnetic fields, and radio/microwaves, *AlphaLab* offers the *Tri-Field Meter*. Its measurements are made with multi-directional sensors that read field strengths in all directions simultaneously, for measuring the full magnitude of field strength. That makes measuring faster and easier, because you can accurately read total magnetic or electric field regardless of which direction the meter is pointing. The meter reads all three types of fields both numerically and with a safe, borderline/high scale that

(Continued on page 10)



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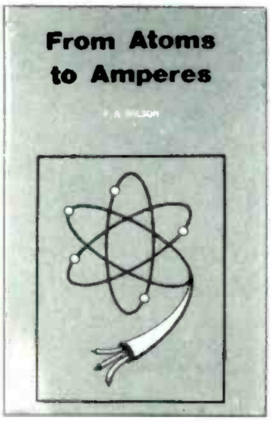

☐ FROM ATOMS TO AMPERES—BP254— $6.50

Have you ever—
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Thought the idea of holes in semiconductors is a bit much?

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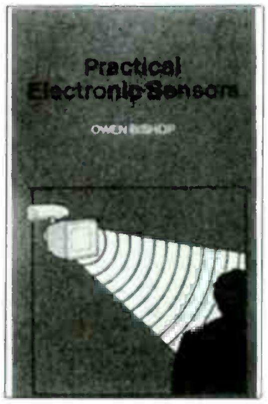
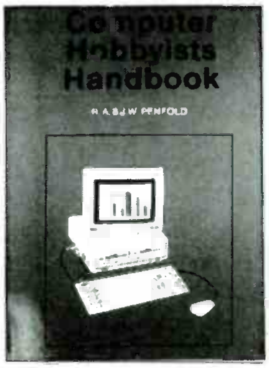


☐ PRACTICAL ELECTRONIC SENSORS—BP273—$6.95

From satellite surveillance and industrial process control to the more mundane matter of detecting when the toast is the right shade of brown, there are very few electronic circuits which do not involve a sensor of some kind. The book contains a dozen construction projects for in and around the home.

☐ COMPUTER HOBBYISTS HANDBOOK—BP251—$8.95

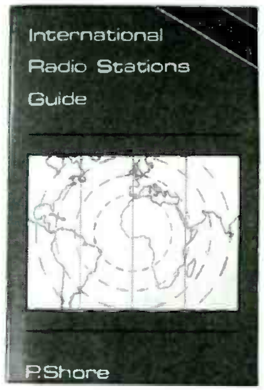
Subjects covered include microprocessors and their register sets; interfacing serial, paralley, monitor, games and MIDI ports; numbering systems, operating systems and computer graphics. While the book is aimed at the computer hobbyist, it should also prove useful to anyone who intends to use a computer to follow their interests.

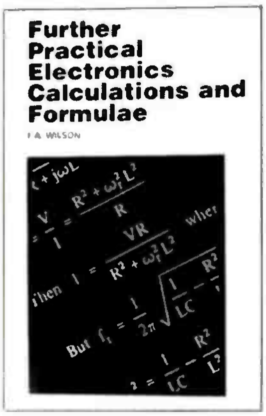


☐ INTERNATIONAL RADIO STATIONS GUIDE—BP255—$9.95

Provides the casual listener, amateur radio DXer and the professional radio monitor with an essential reference work designed as a guide for the complex radio bands.

Includes coverage on Listening to Short Wave Radio, ITU Country Codes, Worldwide Radio Stations, European Long Wave and Medium Wave Stations, Broadcasts in English and more.





☐ FURTHER PRACTICAL ELECTRONICS CALCULATIONS—BP144—$9.00

450 pages crammed full of all the formulae you are likely to need. Covers Electricity, Electrostatics, Electromagnetism, Complex Numbers, Amplifiers, Signal Generation and Processing, Communications, Statistics, Reliability, Audio, Radio Systems, Transmission Lines, Digital Logic, Power Supplies. Then there's an appendix of Conversion Factors, Mathematical Formulae and more.

☐ WIRELESS & ELECTRICAL CYCLOPEDIA—ETT1—$5.75

A slice of history. This early electronics catalog was issued in 1918. It consists of 176 pages that document the early history of electricity, radio and electronics. It was the "bible" of the electrical experimenter of the period. Take a look at history and see how far we have come. And by the way, don't try to order any of the merchandise shown, it's unlikely that it will be available. And if it is, the prices will be many times higher.

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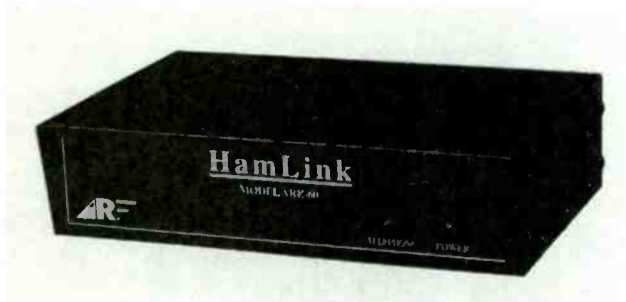
NEW PRODUCTS

(Continued from page 7)
is weighted proportional to the effect in the body. Thresholds are based on epidemiological and laboratory studies, whose results indicate that reduction of relative exposure is prudent. The compact meter comes ready-to-use with battery, instructions, and a one-year limited warranty.

The Tri-Field Meter costs $144 postpaid (in Canada, add $10 shipping). For more information, contact AlphaLab, 1272 East Alameda Avenue, Salt Lake City, UT 84102-1703; Tel: 503-621-9701. ■

HAMLINK TELEPHONE INTERFACE

With the *HamLink* telephone interface from *A.R.E.*, you can control your transceiver or receiver from any TouchTone phone in the world. The device goes between the telephone line and the computer port of your radio. HamLink can share a telephone line with an answering machine without a problem. Once in place, it can control the radio's frequency, mode, band, and scan memories, and can operate in split-mode. A secret access code prevents unauthorized use of your equipment; if you like, you can share that code with friends to let them use your gear remotely. HamLink allows you to monitor the DX frequencies and work all of the rare ones from your office. If you live in an apartment or condo where you can't have an HF station, you can put the HamLink at a friend's home or at a club station and use it by telephone. The device even has a synthesized voice that announces frequency and mode, so you always know where you are operating. You can command your radio to go to a specific frequency, or you can tune your radio in 10-Hz, 100-Hz, 1-kHz, or 5-kHz steps.



CIRCLE 108 ON FREE INFORMATION COUPON

The HamLink telephone interface costs $2669. For additional information, contact Amateur Radio Engineering, Inc., P.O. Box 169, Redmond, WA 98073; Tel: 206-882-2837.

CIRCLE 144 ON FREE INFORMATION COUPON

AM COMMUNICATIONS INTERCEPTOR

A modern version of the crystal-detector radio, the *Model R20 AM Communications Interceptor* has microwave diodes and transistors replacing the chunk of galena. Unlike a conventional radio receiver or scanner, the Interceptor responds to any strong signal present, and is stabilized by the signal it is receiving. That means that the Interceptor doesn't have to be tuned to a frequency to receive a signal. Any AM signal from 0.5 MHz to over 2.5 GHz can be intercepted without any coverage gaps. The page-sized unit is completely automatic for hands-free operation. A ten-LED bargraph provides a relative signal-level display, using 3-dB steps, for all RF signals that are detected. The detected audio output is amplified and processed using automatic level circuitry, which replaces the need for an external volume control and also protects the listener from strong signals that might produce uncomfortably loud transients. An earphone can be used to monitor the detector output.

The Interceptor can be used to check two-way radios for RF output, make RF signal-strength measurements, locate stuck transmitters, test microwave ovens for leakage (even those within the radiation leakage standards will indicate on the R20), locate RF "bugs," and listen to any AM signal including CB and two-way aircraft transmissions. Because it has no internal oscillators, it doesn't radiate any signals that could interfere with sensitive navigation or communication equipment aboard aircraft. When sweeping a room for con-

(Continued on page 12)

TRUE-RMS DMM WITH FREQUENCY COUNTER

A 4½-digit, true-rms digital multimeter from *American Reliance*, the *Model 700T* features a built-in frequency counter. The sophisticated DMM provides high measuring accuracy (0.5% basic accuracy). Functions include DC and AC voltage measurement, direct and alternating current measurement up to 20 amps, diode check, audible continuity check, and data hold. The DC voltage ranges are 200 mV, 2 volts, 20 volts, 200 volts, and 1000 volts, with resolutions of 10 µV, 100 µV, 1 mV, 10 mV, and 100 mV, respectively. The AC voltage ranges are 200 mV, 2 volts, 20 volts, 200 volts, and 750 volts with resolutions of 10 µV, 100 µV, 1 mV, 10 mV, and 100 mV, respectively. The DC and AC current ranges are 200 µA, 2 mA, 20 mA, 200 mA, 2 amps, and 20 amps with resolutions of 10 nA, 100 nA, 1 µA 10 µA, 100 µA, and 1 mA, respectively. The frequency counter measures frequencies up to 200 kHz. Its ranges are 20 and 200 kHz with attenuation of −20dB available in each range. The Model 700T has low-battery and decimal annunciators.

The Model 700T digital multimeter costs $199.95. For further information, contact American Reliance Inc., 9952 East Baldwin Place, El Monte, CA 91731; Tel: 800-654-9838 or 818-575-5110; Fax; 818-575-0801.

CIRCLE 195 ▶

AMAZING ✶ ELECTRONIC PRODUCTS and KITS

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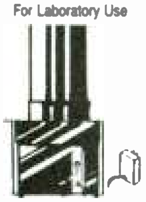

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- Kirlian Photography
- Wireless Energy Transmission
- Induction Fields
- Pyrotechnic Effects
- Corona and Brush Discharge
- Energizer for Neon Plasma Tubes

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- Anti-Gravity/Force Fields
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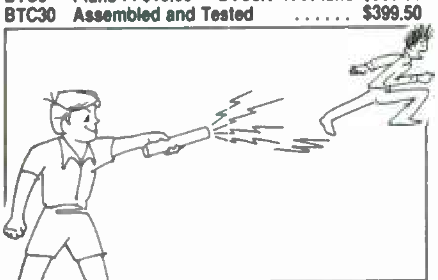
BTC3 Plans .. $15.00 BTC3K Kit/Plans $299.50
BTC30 Assembled and Tested $399.50



Shocker Force Field / Vehicle Electrifier
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MINIMAX 4 4,000 Volts, 5ma, 4.5x1.5x1" ... $19.50
MINIMAX 2 2,000 Volts, 5ma, 3.5x7/8" dia .. $14.50

Ultrasonic Blaster

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100,000V Intimidator / Shock Wand Module

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ITM2 Plans Only; Credit-able to Kit $10.00

Ion Ray Gun
- Projects charged ions that induce shocks in people & objects without any connection! Great science project as well as a **high tech** party prank.
IOG3 Plans ..... $10.00 IOG3K Kit/Plans $69.50

Invisible Pain Field Generator

Shirt pocket size electronic device produces time variant complex shock waves of intense directional acoustic energy capable of warding off aggressive animals, etc.
IPG7 Plans .... $8.00 IPG7K Kit / Plans $49.50
IPG70 Assembled $74.50

Homing / Tracking Transmitter
- Beeper device, 3 mile range.
HOD1 Plans .... $10.00 HOD1K Kit/Plans $49.50

Listen Thru Walls, Floors

Highly sensitive stethoscope mike.
STETH1 Plans ... $8.00 STETH1K Kit/Plans $44.50

3 Mile FM Wireless Mike
- ***Subminiature!***

Crystal clear, ultra-sensitive pickup transmits voices and sounds to FM radio. Excellent security system, warns of intrusion. Become your neighborhood disk jockey! Monitor children and invalids.
FMV1 Plans ..... $7.00 FMV1K Kit/Plans . $39.50

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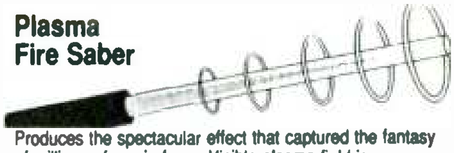
VWPM7 Plans .... $7.00 VWPM7K Kit/Plans $39.50

Plasma Fire Saber



Produces the spectacular effect that captured the fantasy of millions of movie fans. Visible plasma field is controlled by grip pressure and adjusts saber length. Active energy field produces weird & bizarre effects. Excellent for special effects. Specify photon blue, neon red, phasor green, or starfire purple.
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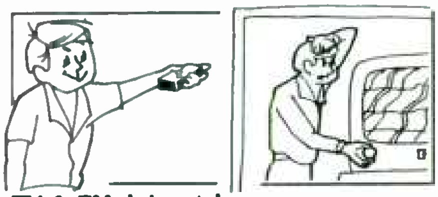

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High brightness red HeNe laser visible for miles. **Produce your own light show!** Projects a beam or red lite clearly visible in most circumstances. Can be used to intimidate by projection of a red dot on target subject. Also may be used to "listen in" using our laser *window bounce* method #LLIS1 below. **Easy to Build Modules Makes A Working Visible Laser:**
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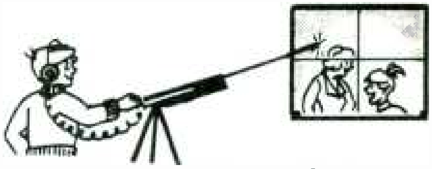

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allows you to hear sounds from an area via a lite beam reflected from a window or other similar object. System uses our ready-to-use LATR1 Laser Terminator gun site as the transmitter. The receiver section is supplied as an easy-to-build kit, including our cushioned HS10 headsets. **Order # LLIST20 System, includes our LATR1 Ready-to-Use Laser Gun Site, LLR1K Special Receiver Kit, and HS10 Headset, all for only $299.50**

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Device uses invisible infrared illumination for seeing in total darkness. Excellent for low cost night vision, along with observing lasers and other IR sources. Functional unit, many useful applications.

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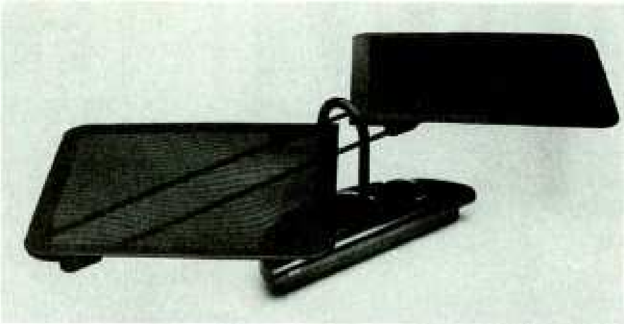
NEW PRODUCTS

(Continued from page 10)
cealed listening devices, more LED's will light on the bar-graph as the source of RF is approached.

The Interceptor costs $119. For further information, contact Optoelectronics Inc., 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Tel: 800-327-5912 or 305-771-2050; Fax: 305-771-2052.



CIRCLE 119 ON FREE INFORMATION COUPON

INDOOR TELEVISION ANTENNA

The days of the rabbit-ear antenna are over, yet you don't have to pay the high price of cable TV to get good reception, according to *Terk Technologies*. The alternatives Terk offers are the *Models TV20* and *TV10* indoor television antennas, which deliver crystal-clear VHF and UHF TV reception, and look good while doing so. (The TV20 has won both the Chicago Athenaeum "Good Design" Award and the Electronic Industries Association's Innovation's '92 Design and Engineering Award.) With a maximum height of just 5¼ inches, the antennas give users great flexibility in the placement of their TV sets.

The TV20 uses two tuned elements configured in a "complementary-symmetry" design, combined with an adjustable low-noise, high-gain amplifier, to yield the best possible reception. The two wing-like reception elements are arrayed to minimize the need for user manipulation. A built-in filter cuts down on "snow." A cable/antenna selector allows viewers to switch between the antenna and the local cable source, or any external RF source. The built-in amplifier can also be used to restore the quality of video degraded by poor cable leads. For use in areas closer to the broadcast source, the TV10 features the same complementary-symmetry design, but without the amplifier. Neither antenna is affected by the proximity of the human body, so users avoid the frustration of getting a good picture that degrades as soon as they sit back down to watch it.

The TV10 and TV20 indoor TV antennas have suggested retail prices of $24.95 and $79.95, respectively. For more information, contact Terk Technologies Corp., 233-8 Robbins Lane, Syosset, NY 11791; Tel: 516-942-5000; Fax: 516-942-TERK.

RECEIVER DOWNCONVERTER

To extend the performance of test equipment and UHF communications receivers, *Ace Communications' DC 89* 800-MHz downconverter converts the frequency range of 806–900 MHz down to 406–500 MHz. The compact unit measures just 3 × 2 × 1½ inches. Frequency stability is assured by the use of a new surface-mount prescaler/synthesizer referenced to a precision quartz-crystal clock. For added versatility the DC 89 features BNC connectors and an internal battery; The converter can even operate on handheld receivers.

The DC 89 downconverter has a suggested retail price of $89. For additional information, contact Ace Communications, Monitor Division, 10707 East 106th Street, Fishers, IN 46038; Tel: 317-842-7115; Fax: 317-849-8794.

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LASER DETECTOR

Wars tend to escalate, and the war between law-enforcement agencies and radar-detector owners is no exception. So it's not surprising that the newest police weapon—the laser speed detector—has been counterattacked by laser-gun detectors, even though the laser gun is still limited to a few scattered places in the country. *Bel-Tronics'* first entry in that market is the *LaserAlert*, which uses an adaptation of the military laser technology used in the Gulf War to detect the police laser beam and alert the driver that his speed is being detected. LaserAlert is programmed to receive only police laser and to discriminate against other laser or optical sources and electromagnetic interference that might trigger false alarms.

Resembling a standard micro-sized detector, the LaserAlert can work as a stand-alone unit or can be teamed with most three-band radar detectors to provide complete X, K, Ka, and laser coverage. It can detect both of the laser guns currently in use: the ProLaser from Kustom Signal and the LTI 20/20 from Laser Technology, Inc. Features include a three-LED alert meter, dim/dark modes, distinct audible alert, a windshield mount and a coiled power cord.

The LaserAlert laser-gun detector has a suggested retail price of $129.95. For more information, contact Bel-Tronics Limited, 20 Centre Drive, Orchard Park, NY 14127. ■

CIRCLE 157 ON FREE INFORMATION COUPON

ELECTRONICS LIBRARY

HEATH NOSTALGIA
by Terry Perdue, K8TP

As readers of **Radio Craft**, there's a good chance that you have fond memories of build Heathkits projects. As a Heath engineer for 18 years, the author of this book has an insider's view of the company behind those kits.

For many years, Heath Company was the world's largest manufacturer of electronic kits. The company started out with economical test-instrument kits that were widely used by hobbyists, service technicians, and students. Heath soon expanded their product lines to include amateur radio and hi-fi products, and later to a wide variety of other electronic products.

CIRCLE 186 ON FREE INFORMATION COUPON

Those kits were the first taste of electronics for many youngsters.

This book contains contributions from several Heath employees. Together with a chapter devoted entirely to photographs, their reminiscences provide an intimate, anecdotal history of the company.

Heath Nostalgia is available for $9.95 (plus sales tax in Washington State) from Heath Nostalgia, 4320 196th S.W., Lynnwood, WA 98036.

THE "TOP SECRET" REGISTRY OF U.S. GOVERNMENT RADIO FREQUENCIES: 8th Edition
by Tom Kneitel, K2AES

Providing the largest amount of federal frequency information assembled in a single volume, this book has become the standard reference guide used by law-enforcement agencies, private security personnel, the news media, the communications industry, and scanner hobbyists. It includes frequency listings for the FBI, DEA, Customs, Secret Service, FCC, IRS, CIA, Immigration, Coast Guard, U.S. Marshal, Treasury Department, federal prisons, national parks, the Postal Service, NOAA, the Border Patrol, FEMA, the Armed Forces, the Department of Energy, the U.S. Mint, the Bureau of Indian Affairs, the White House, the Federal Reserve, the U.S. Attorney General, the State Department, the EPA, and more. In addition, the book provides foreign-government military listings for hot spots in the Caribbean, Latin America, and the Middle East; agent's codes and lingo; military buzzwords; Canadian listings; military frequencies at civilian airports; and a listing for the secret USAF facility named on national TV as the site where UFO's are being studied and tested. The book also includes maps, monitoring tips, and by-frequency listings of key VHF/UHF channels. The 8th edition contains updated and new listings.

The "Top Secret" Registry of U.S. Government Frequencies, 8th Edition is available for $21.95 plus $3.50 shipping and handling ($4.50 to Canada) from CRB Research Books, P.O. Box 56, Commack, NY 11725; Tel: 516-543-9169, (Monday, Tuesday, Thursday, Friday: 10 AM to 2 PM); 24-hour fax: 516-543-7468. NY residents please add $2.16 sales tax.

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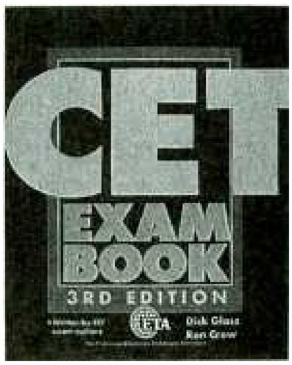
CET EXAM BOOK: 3rd Edition
by Dick Glass and Ron Crow

Written for those who are planning to take the Associate-level Certified Electronics Technician exam for the first time, as well as experienced technicians who are going for a Journeyman, Senior, or Master CET rating, this book contains all the information needed to pass the exams. After an opening chapter that explores the history of the Electronics Technicians Association (ETA) and the CET program, the book goes on to devote a chapter each to such topics as basic mathematics, electrical fundamentals, elec-



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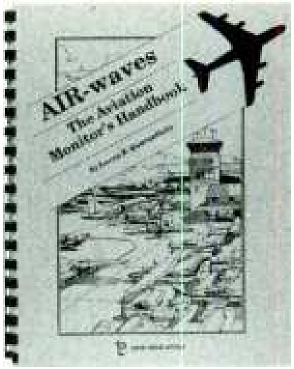
tronic components, serial and parallel circuits, semiconductors, basic circuits, decibels, antennas and wave propagation, block diagrams, digital concepts, safety, computers, and test equipment and measurements. Other chapters cover various career options in consumer electronics, industrial electronics, telecommunications, satellite TV, biomedical electronics, video distribution, radio communications, and avionics. Each chapter of the book includes a sample quiz that allows readers to gauge their progress and determine which subjects they most need to study. Practice questions and answers are followed by full explanations of all of the principles involved. The third edition has been completely revised and updated to cover every level of CET certification and each of the Journeyman options.

The CET Exam Book, 3rd Edition costs $17.95 and is published by TAB Books, Division of McGraw-Hill Inc., Blue Ridge Summit, PA 17294-0850; Tel. 1-800-822-8138.

AIR-WAVES: THE AVIATION MONITOR'S HANDBOOK
by Laura E. Quarantiello

You can experience the call of the "wild blue yonder" while keeping both feet firmly on the ground, by tuning your scanner to the aeronautical bands. Whether you're a newcomer to monitoring aeronautical communications or have been doing it for years, this book will help you better understand what is being said and why. The entire field of VHF/UHF aeronautical communications is covered, from airport identifiers to runway numbering. Readers are introduced to the daily routines of airports and flights, with clear, often chatty descriptions of air-traffic control, a flight from take-off to touchdown, a typical day on the field at an airport, how airspace is divided and arranged, departure and arrival communications with the tower, the Air Route Traffic Control Center, emergency communications, aviation weather, monitoring air-to-ground telephones, and reading aviation charts. Plenty of purely practical information is included in the



CIRCLE 141 ON FREE INFORMATION COUPON

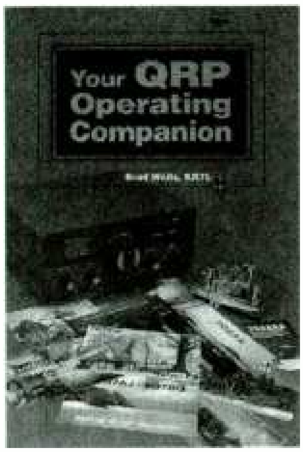
appendices, such as navigation aid identifiers, navigation equipment suffix codes, airport abbreviations, aeronautical frequency ranges, VHF frequency log, international civil aircraft tail code prefixes, a list of related magazines and books, and a pilot/controller glossary.

AIR-Waves: The Aviation Monitor's Handbook is available for $17.95 plus $2 shipping and handling ($3 foreign) from Tiare Publications, P.O. Box 493, Lake Geneva, WI 53147; Tel: 414-248-4845.

YOUR QRP OPERATING COMPANION

by Brad Wells, KR7L

The hobby of QRP—ham operating with an output power of 5 watts or less—is both challenging and exciting. Most amateur radio contests have a QRP entry class, and hundreds of hams from around the world participate. In fact, many hams have managed to work more than 100 countries QRP to QRP.



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This book is designed to help QRP'ers get the most from their hobby. No special rig or expensive and complicated equipment is needed. Taking a firm stance that skill is more important than equipment in QRP, the author shares the wealth of his many years of QRP experience to help readers make more contacts and have more fun. The opening chapter deals with the basics of QRP, including its history and various tests and contests. Subsequent chapters cover operating techniques and explain how to maximize your signal, followed by an in-depth look at propagation.

Your QRP Operating Companion costs $6.00 and is published by The American Radio Relay League, 225 Main Street, Newington, CT 06111.

TUNE IN ON TELEPHONE CALLS

Most people, operating under the false assumption that they have total privacy on the telephone, exchange personal and business secrets, wheel and deal, argue, make up, whisper sweet little nothings, conduct legal and illicit business, gossip—in other words, gab unconcernedly about all sorts of personal affairs. Yet calls made over cellular and cordless phones and other modern telecommunications devices are being broadcast over the airwaves, where they can easily be intercepted by anybody with a shortwave receiver or scanner. No technical expertise is required for such eavesdropping, but a bit of know-how helps.

Completely revised and updated to include hundreds of new frequencies, the book now has information on the 900-MHz cordless telephones.

Tune in on Telephone Calls is available for $12.95 plus $3.50 shipping ($4.50 to Canada) from CRB Research Books, Inc., P.O. Box 56, Commack, NY 11725; Tel: 516-543-9196 (10:00–2:00 EST, Monday, Tuesday, Thursday, and Friday only). NY State residents must add $1.40 sales tax.

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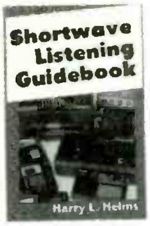

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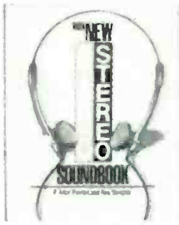

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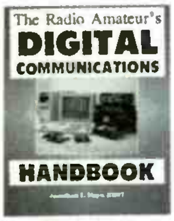

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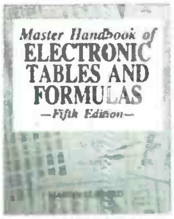

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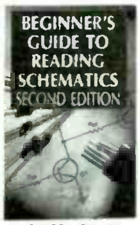

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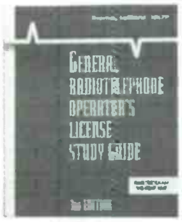

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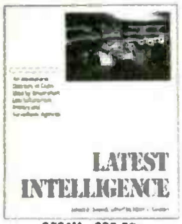

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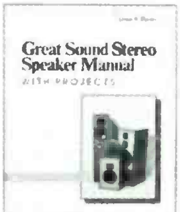

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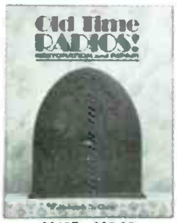

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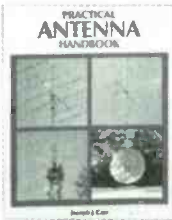

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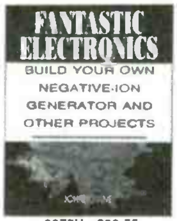

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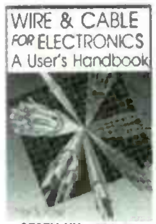

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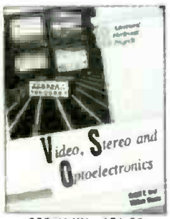

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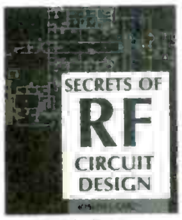

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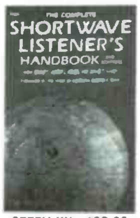

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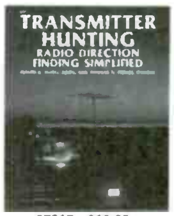

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WORLD BAND RADIO RECEIVER

JOHN PIVNICHNY, N2DCH

Build this world band receiver and enjoy performance that is superior to many store-bought models

HAVE YOU LISTENED TO WORLD band (shortwave) broadcasts and found that you enjoyed them but were disappointed because your receiver was unable to hold onto the station you wanted? Perhaps only a few minutes passed before the station faded or was swamped out by another one. If you've now become a fan of world-band radio but would like better quality reception, the SWX6 receiver is the project for you to build.

Many inexpensive world-band shortwave receivers promise a lot, but they rarely deliver. New shortwave listeners are never sure whether the problem lies in the antenna, circuitry, or if the time of day had an effect on listening conditions. Many of the inexpensive receivers suffer from poor channel selectivity, poor image frequency rejection, and drift—weaknesses that make listening a strain.

Those problems are not present in up-scale receivers like the SWX6 receiver. The SWX6 delivers performance that matches many of the high-priced rigs, but it can be built for less than $100 worth of parts with the plans in this article. Because digital frequency synthesis is not used in the SWX6, it's a good project to build if you want to learn (or get a refresher course) in the basics radio-frequency circuitry.

Leading features

Figure 1 is a simplified block diagram of the receiver. The incoming radio frequency (RF) is filtered by the bandpass filter and mixed with the output of the crystal oscillator in the first mixer. After passing through the 16.45 to 17.1 MHz filter and being amplified by the first intermediate-frequency (IF) amplifier, the signal is mixed with the output of the variable frequency oscillator (VFO) in the second mixer.

The signal is then passed through the 9.83-MHz crystal filter before being fed to the second IF amplifier, which is under the control of the AGC circuit. The detector converts the RF signal to audio and the audio

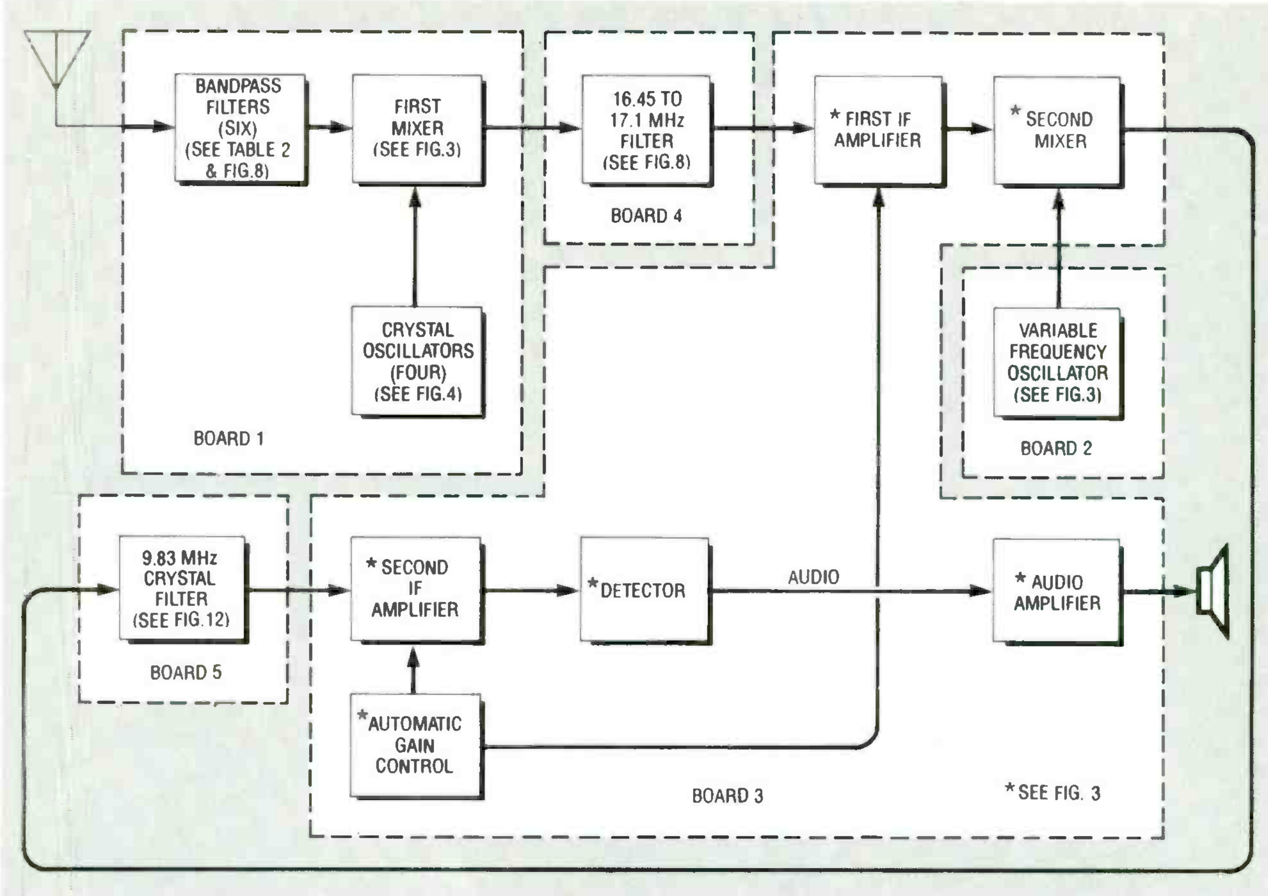


FIG. 1—FUNCTIONAL BLOCK DIAGRAM OF SWX6 RECEIVER showing the partitioning of circuits on three principal circuit boards.

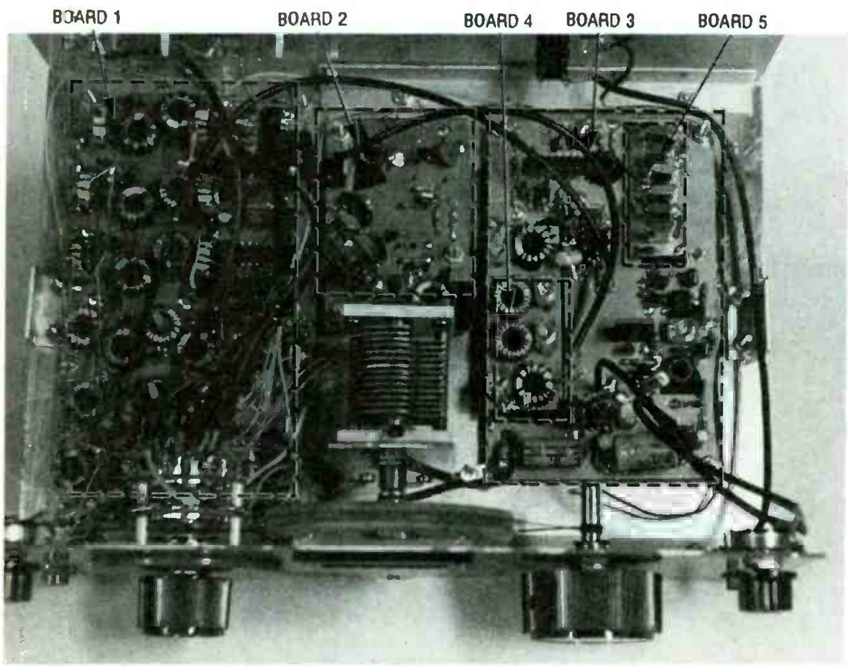


FIG. 2—VIEW OF THE INSIDE OF THE SWX6 RECEIVER showing the relative positions of the three principal and two piggy-back circuit boards.

amplifier amplifies it, giving the listener a choice of loudspeaker or headphones.

The received signal is kept essentially distortion-free by the six-pole crystal filter which provides good selectivity, bandpass filters which handle image rejection, and a very stable, low-drift analog tuning oscillator. This circuit is so stable, you will never have to readjust the dial once a station is tuned in!

The double-conversion circuitry provides ample IF gain. The fast-responding automatic gain circuit (AGC) reduces fading all the way down to an actual null. Separate bandpass filters for each of the six bands provide excellent rejection of out-of-band signals and signals at the image frequencies. As a result of all these features, this receiver is easy to operate and makes for pleasurable listening.

Figure 2 is a photograph of the inside of the prototype SWX-6 receiver showing the details of its modular construction. Conventional etched circuit boards are not used in building the SWX6. The circuitry is assembled on five blank copper-clad laminate circuit boards with the copper foil side facing up to serve as a common ground plane. Component leads pass through holes drilled in the board for interconnection and soldering on the bare side. Copper foil is removed around all drilled holes by countersinking to provide adequate isolation from ground.

The SWX6 is organized to receive six bands: 6, 9.5, 11.5, 13.5 15 and 17.5 MHz. These bands are marked on a plate behind the BAND knob. The diamond-shaped tuning bezel at the center of the panel is part of the tuning assembly that includes a moving dial behind the window and the TUNE knob to the right. There is a GAIN knob at the upper left, a speaker or headphone jack at the lower left, an AUDIO knob at the upper right, and a POWER switch at the lower right. The audio amplifier can drive either a speaker or headphones with a resistance of 4 to 16 ohms.

First mixer and IF

Figure 3 is the complete schematic for the SWX6 receiver. The first mixer converts each of the popular shortwave bands to the 16.45 to 17.1 MHz range. The heart of this stage is IC1, an MC1496 balanced modulator/demodulator. A double-balanced mixer with separate bandpass filters for each band provides excellent performance.

A separate crystal oscillator/divider is included for each band, permitting the use of inexpensive, readily available, microprocessor-timebase crystals for excellent stability. Also, separate oscillators are easier to build than a synthesizer, and they give better wideband noise performance. The schematics for these crystal oscillators are shown in Fig. 4.

For example, on band 1, to tune 5.95 to 6.6 MHz, the local oscillator must apply a 10.5 MHz signal to convert this range to 16.45 to 17.1 MHz. For this band see Fig. 4-*a*. The oscillator-tripler circuit has a 7 MHz crystal (XTAL7). It is followed by a divide-by-two inte-

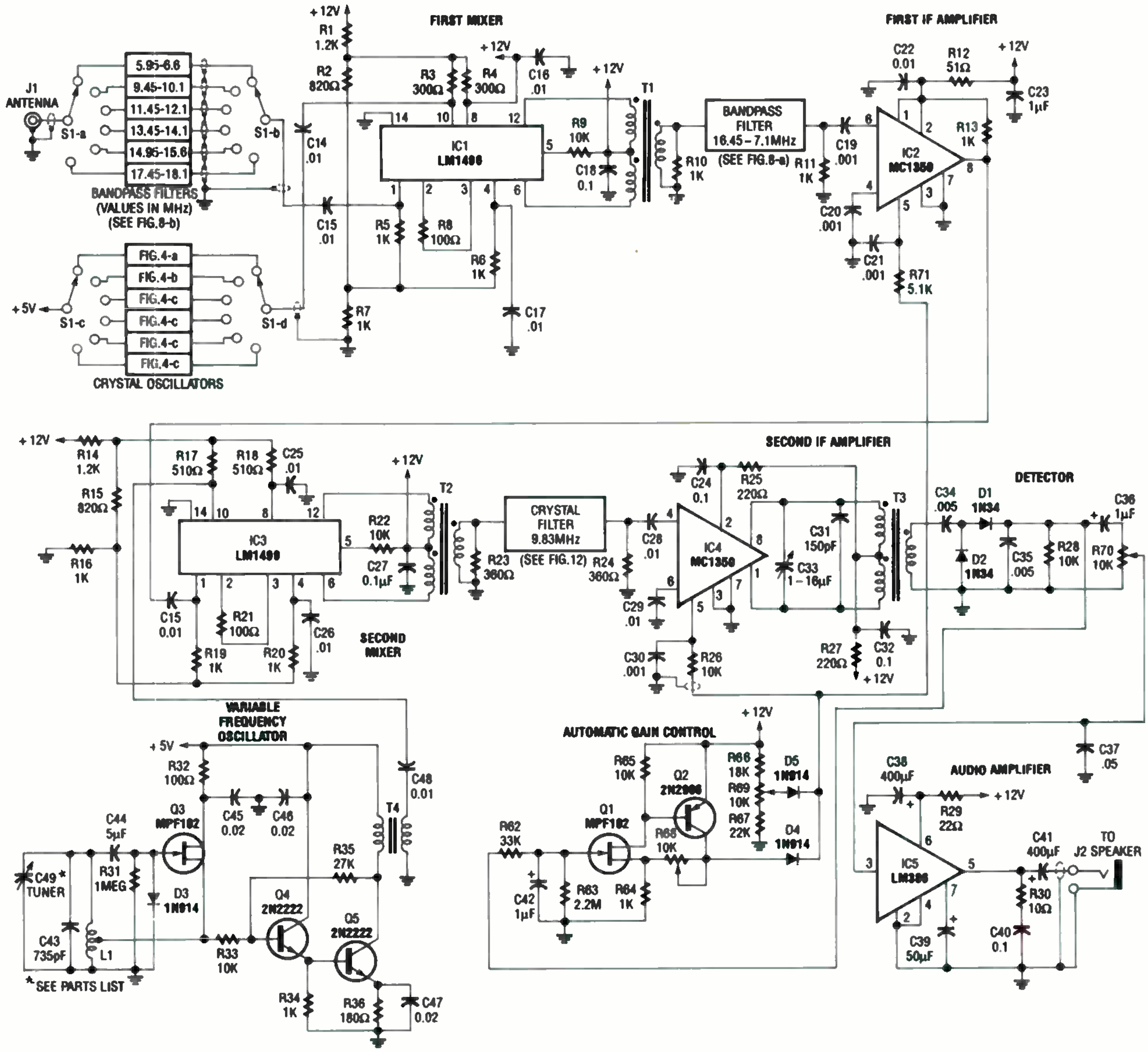


FIG. 3—SCHEMATIC FOR THE SWX6 RECEIVER with the principal functional circuits labeled. Make all connections between the contacts of switch S1-a and the bandpass filters with enameled magnet wire.

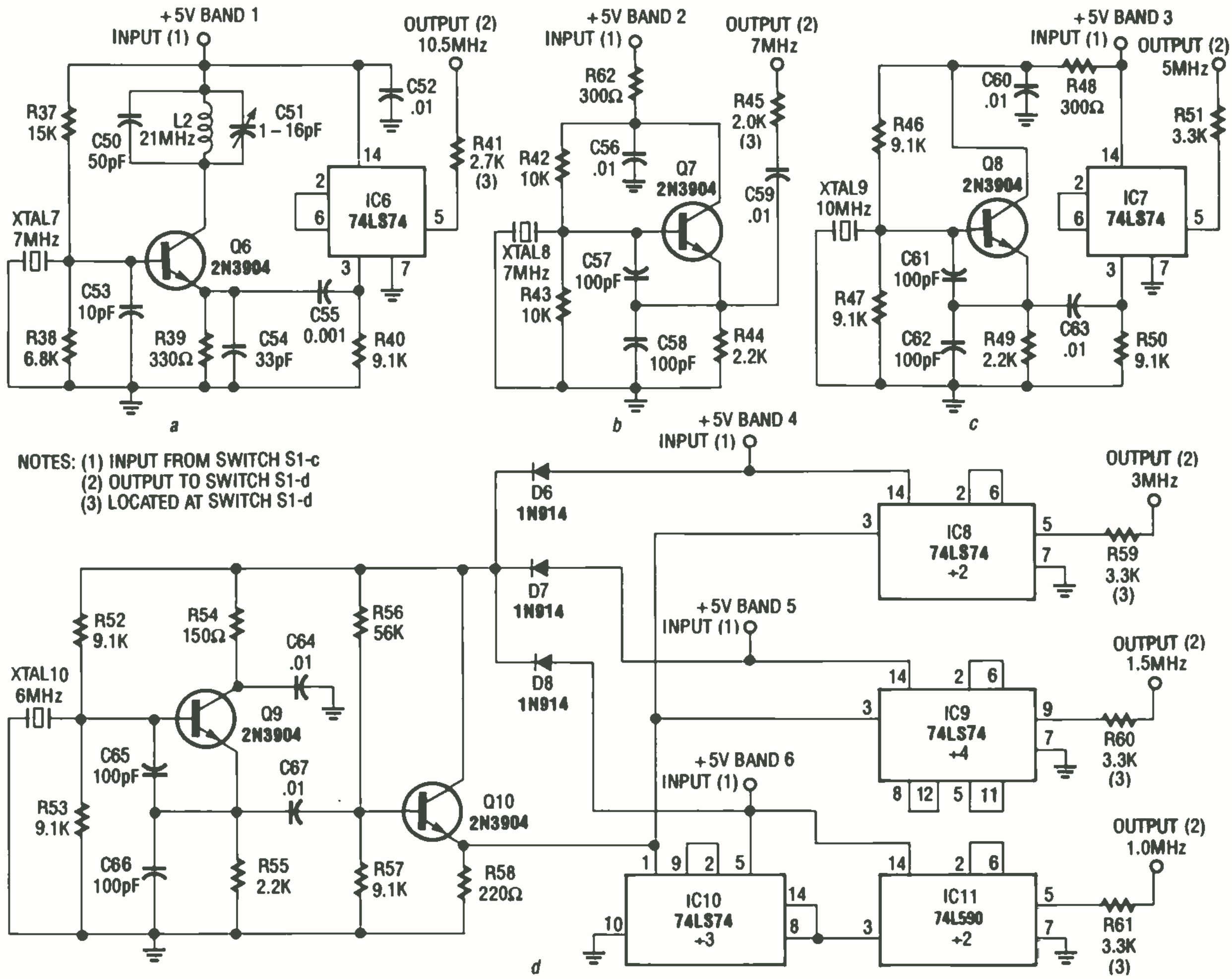


FIG. 4—SCHEMATICS FOR THE CRYSTAL-CONTROLLED oscillators that tune the six bands of the receiver.

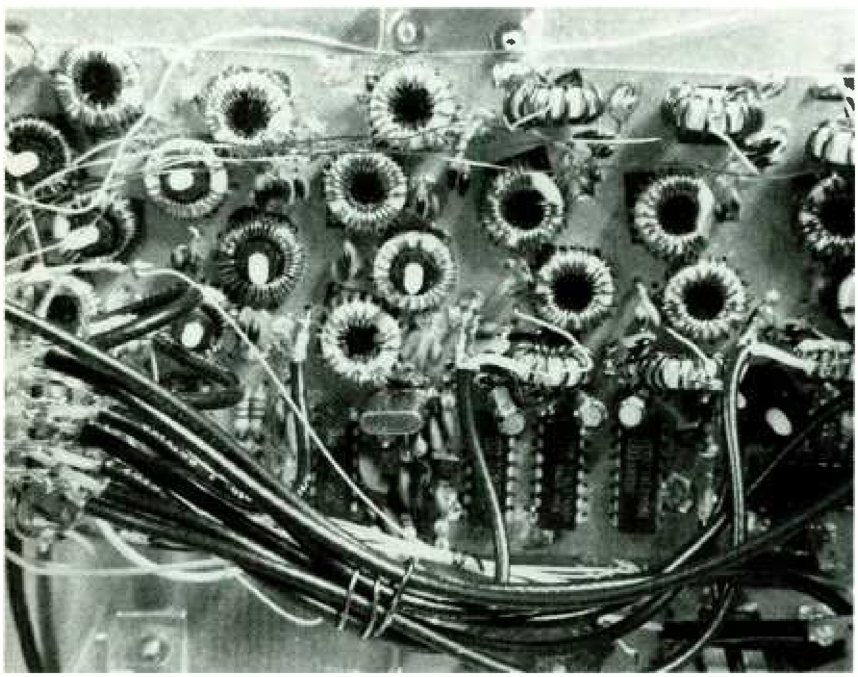


FIG. 5—FILTER/MIXER BOARD layout with coaxial cabling and other wiring to the band switch shown in foreground

grated circuit, IC6, a 74LS74. (A low-cost 10.5-MHz microprocessor-timebase crystal was not available.) Frequencies for the other bands are shown in the digrams 4-*b* through 4-*d*.

As shown in Fig. 3, the MC1350 monolithic IF amplifiers IC2 and IC4 amplify in both the first and second IF amplifier stages. The first MC1350, IC2, follows the first mixer stage and 16.45 to 17.1 MHz bandpass filter. This wideband amplifier increases the level of all signals within this 650-kHz range. Note that the gain input pins, Pin 5, of each IF amplifier are fed by the output of the AGC section. However, the first IF amplifier is fed with 5.1K resistor, R71, while the second IF amplifier is fed with 10K resistor, R26.

This difference ensures that there is more gain reduction of strong signals in the first ampli-

TABLE 1
DIMENSIONS FOR CIRCUIT BOARDS AND ENCLOSURE PANELS

Function	Length (in.)	Width (in.)
Circuit boards *1*		
1. First mixer bandpass filters, oscillators	6	3 ¼
2. Variable frequency oscillator	3	2
3. General circuitry	5	3
4. 16.45 to 17.1 MHz filter	3	1
5. 9.83 MHz crystal filter	2 ⅜	1
Enclosure panels *2*		
1. Top and bottom	10	7
2. Front and back	9.9	3.5
3. Two sides *3*	7	3.5

Notes *1:* Blank single-sided copper-foil laminate
2: 0.060-inch thick sheet aluminum
3: Allow for insetting the side panels

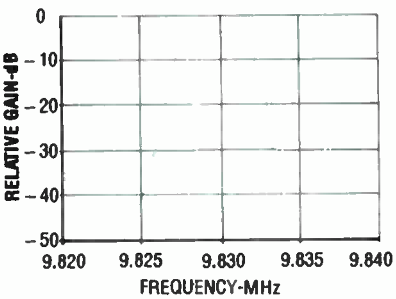


FIG. 6—CRYSTAL FILTER RESPONSE curve showing relative gain in decibels vs. frequency in kiloherz.

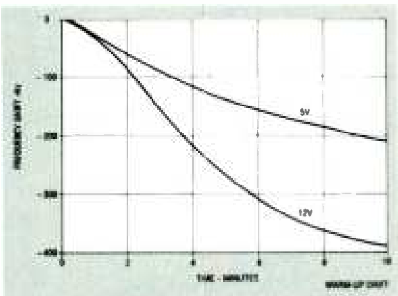


FIG. 7—CURVE SHOWING DRIFT IN FREQUENCY of tuning oscillator during 10-minute warmup period.

fier, thus preventing possible overloading of the input of the second IF amplifier. Gain reduction will occur whether it is due to the manual GAIN control R69 on the front panel, or automatically due to AGC response on reception of strong signals or those that fade in and out.

One filter per band

A separate bandpass filter for each band removes image signals and ensures that any signal outside the desired band is sharply reduced prior to mixing at the first oscillator. Further rejection occurs in the first IF bandpass filter prior to any amplification. Only signals in the selected band get through.

The separate bandpass filters for each of the bands are built on board 1, the largest of the five circuit boards in the receiver (see Fig. 1) shown in Fig. 5. This filter-mixer board measures 3 ¼ × 6-inches and it contains the oscillator/divider circuits for each band and the first mixer circuit. (Schematic diagrams for the bandpass filters are included along with a table of component values for the six bands later in this text.)

The tuning oscillator and isolation amplifier are built on board 2, a 2 × 3-inch board, and the general circuitry is built on board 3, a 3 × 5 inch-board. The two smaller boards (4 and 5) with coils and crystal holders are mounted piggy-back on board 3.

The three principal circuit boards are mounted on the aluminum baseplate for the enclosure. The front, back, top and side panels are also cut from the same sheet aluminum and joined with aluminum angle stock, nuts and bolts.

The crystal filter response curve showing relative gain in decibels vs. frequency in megahertz is shown in Fig. 6. This curve helps to explain why stations can be received so clearly as you tune across them. There is essentially no adjacent-channel feed-through. Stations are received loud and clear, limited only by propagation strength, not by the wide limits of a ceramic IF filter like those found in inexpensive receivers.

Construction procedure

The first step in the construction of the SWX6 receiver is to cut the five circuit boards to size. These are cut from copper-clad laminate circuit board stock in accordance with Table 1. Carefully drill 0.060-inch holes in the four corners of the three largest boards for later mounting to the chassis baseplate with screws and nuts stacked for use as standoffs. Set the boards aside for later parts-placement planning and lead-hole drilling.

It is also advisable to cut (or have cut) the enclosure panels from the 0.050-inch thick sheet aluminum stock to the sizes specified in Table 1. Drill or form a 1½ × ½-inch dial window in the front panel on the center line ½-inch down from the top.

Plan the location of all panel-mounted components (e.g., rotary BAND switch, GAIN and AUDIO potentiometers, TUNE dial) in the front panel and drill or form their mounting holes. Drill or form the holes for mounting the antenna jack in the back panel.

Cut the ½-inch aluminum angle stock to size, and drill all the holes in all the panels and angle stock necessary to bolt the panels together to form a secure enclosure. Assemble it after you have completed mounting all of the panel-mounted components and circuit boards, and completed all board-to-board and board-to-panel component wiring.

You might want to complete the tuner assembly before building the circuitry. Holes must be drilled in the baseplate to mount the tuning capacitor and in the front panel to mount the bezel and the dial window on opposing sides of the cutout in the front panel. A complete section covering this part of the

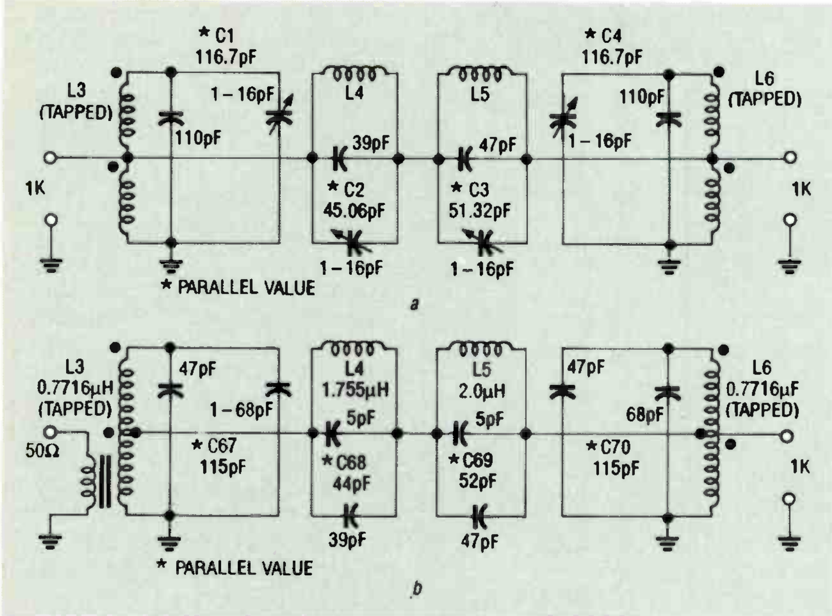


FIG. 8—SCHEMATICS FOR THE BANDPASS FILTER for the 16.45 TO 17.1 MHz band, a, and the five other bands, b.

project is given further on in the text. You might also want to finish painting some of the aluminum enclosure panels before mounting any of the components on them.

Electronic circuitry

It is recommended that the receiver be built as a series of modules that are individually completed and tested before final assembly and wiring. None of the circuits in this receiver is particularly challenging, and construction should be well within the skill level of the amateur who works with care and attention to detail.

Printed circuit boards were not used to build the SWX6 receiver circuitry so it will be necessary for you to plan the locations of all components on the boards before doing any assembly and soldering. After establishing a component layout pattern, drill all of the holes necessary to insert the leads of the components through the boards.

The components are mounted on the copper-clad surface of the board by drilling 0.040-inch holes at the proper

Parts List

All resistors are ¼- watt, 5 % unless otherwise specified.

R1, R14—1200 ohms
R2, R15—820 ohms
R3, R4, R48—300 ohms
R5, R6, R10, R11, R13, R16, R19, R20, R34, R64—1000 ohms
R8, R21, R32—100 ohms R9, R22, R26, R28, R33, R42, R43, R65—10,000 ohms
R12—51 ohms
R17, R18—510 ohms R23, R24—360 ohms R25, R27, R58—220 ohms
R29—22 ohms
R30—10 ohms R31—1 megohm
R35—27,000 ohms
R36—180 ohms
R37—15,000 ohms
R38—6,800 ohms
R39—330 ohms
R40, R46, R47, R50, R52, R53, R57—9100 ohms
R41—2700 ohms
R44, R49, R55—2200 ohms
R45—2000 ohms
R51, R59, R60, R61—3300 ohms
R54—150 ohms
R56—56,000 ohms
R62—33,000 ohms
R63—2.2 megohms
R66—18,000 ohms
R67—22,000 ohms
R68—10,000 ohms, trimmer
R69, R70—10,000 ohms, potentiometer.
panel-mount
R71—5100 ohms

Capacitors

C1, C4—116.7 pF (110 pF in parallel with 1—16 pF trimmer, Mouser 24PX016 or equivalent)
C2—45.06 pF (39 pF in parallel with 1—16 pF trimmer, Mouser 24PX016 or equivalent)
C3—51.32 pF (47 pF in parallel with 1—16 pF trimmer, Mouser 24PX016 or equivalent)
C5, C7, C9, C11, —66pF (56pF in parallel with 10 pF)
C6, C10—49.7 pF (47 pF in parallel with 2.7 pF)
C8—68 pF
C12, C13—180 pF
C14, C15, C16, C17, C22, C24, C25, C26, C28, C29, C48, C52, C56, C59, C60, C63, C64, C67—0.01μF
C18, C24, C27, C32, C40—0.1μF
C19, C20, C21, C30, C55—0.001μF
C23, C36, C42—1.0 μF, electrolytic
C31—150 pF
C33, C51—1—16 pF trimmer, Mouser 24PX016 or eqliuivalent
C34, C35—0.005μF
C37—0.05μF
C38, C41—400μF, electrolytic
C39—50μF, electrolytic
C43—735 pF (three 220 pF in parallel with 75 pF, silvered mica or NPO ceramic
C44—5 pF, ceramic NPO
C45, C46, C47—0.02μF
C49—10—140 UNIT air dielectric tuning, Fair Radio Sales No. C12/T784 or equivalent (surplus item)
C50—50 pF
C53—10 pF
C54—33 pF
C57, C58, C61, C62, C65, C66—100 pF
C67, C70—115 pF (47 pF in parallel with 68 pF)
C68—44 pF (39 pF in parallel with 5 pF)
C69—52 pF (47 pF in parallel with 5 pF)

Semiconductors

IC1, IC2—MC1496 balanced modulator/demodulator (Motorola) or equivalent
IC3, IC4—MC1350 monolithic IF amplifier(Motorola) or equivalent
IC5—LM386 audio amplifier (National Semiconductor) or equivalent
IC6, IC7, IC8, IC9, IC11—74LS74 Dual D flip-flop (Texas Instruments) or equivalent
IC10—74LS90 decade counter, (Motorola) or equivalent
Q1, Q3—MPF102 N-channel FET transistor
Q2—2N3906 PNP transistor
Q4, Q5—2N2222 NPN transistor
Q6, Q7, Q8, Q9, Q10—2N3904 NPN transistor
D1, D2—1N34
D3, D4, D5, D6, D7, D8—1N914

Crystals

XTAL1, XTAL2, XTAL3, XTAL4, XTAL5, XTAL6—9830.4 MHz
XTAL7, XTAL8—7.0 MHz
XTAL9—10.0 MHz
XTAL10—6.0 Mhz

Switches

S1—four-pole, six-position rotary, Mouser 10WR046 or equivalent
S2—slide, panel-mounted, power

Transformers

T1, T2—16 turn 30 AWG trifilar on FT37-61 core, Amidon or equivalent
T3—10 turn, 26 AWG trifilar on T37-2 core, Amidon or equivalent

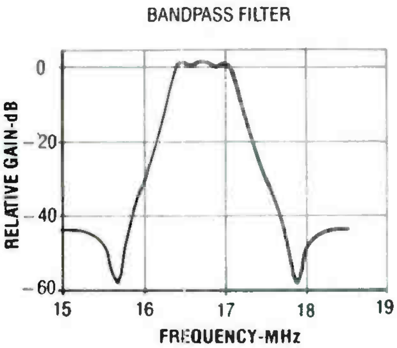


FIG. 9—CHARACTERISTIC CURVE FOR BANDPASS FILTER showing relative gain in decibels vs. frequency in megahertz.

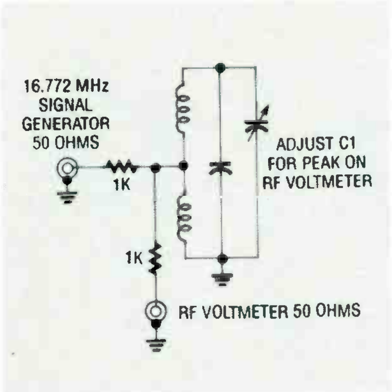


FIG. 10—TEST SETUP TO TEST THE END CAPACITOR.

TABLE 2—BANDPASS FILTER DATA

Frequency (MHz)				No. turns on T-50-6 core			
Band	f_c	f_{lo}	f_{hi}	L3, L6	L4	L5	Link turns
1. 5.95 – 6.6	6.267	5.257	7.456	36	50	61	6
2. 9.45 – 10.1	9.770	8.738	10.924	23	34	38	3
3. 11.45 – 12.1	11.770	10.728	12.914	19	29	31	2
4. 13.45 – 14.1	13.771	12.723	14.907	16	24	27	2
5. 14.95 – 15.6	15.272	14.218	16.403	14	21	23	2
6. 17.45 – 18.1	17.772	16.714	18.897	12	19	20	1

Parts List

T4—primary 25turns 26 AWG, secondary 5 turns 26 AWG on FT-37-43 core, Amidon or equivalent

Inductors

L1—12 turns 18 AWG on T-50-6 core (3 turns tapped from ground end), Amidon or equivalent

L2—18 turns, 26 AWG on T-30-10 core, Amidon or equivalent XXX

L3, L6—13 turns, 18 AWG on T-50-6 core (6 ½ turns tapped from ground end) Amidon or equivalent

L4—21 turns , 22 AWG on T-50-6 core, Amidonm or equivalent

L5—22 turns, 22 AWG on T-50-6 core, Amidon or equivalent

Connectors

J1—coaxial jack, SO239 or equivalent

J2—phone jack, mono

Miscellaneous:

28 T-50-6 powdered-iron toroid cores, Amidon or equivalent, six aluminum panels, 0.060-inch thick cut per Table 1, five copper-foil covered circuit boards cut per Table 1, four feet of RG-174/U coaxial cable, tuning capacitor mounting bracket (see text), 30 inches of ½ × ½-inch aluminum angle stock, reels of enameled magnet wire—18, 26, and 30 AWG, insulated hookup wire, 0.25-inch thick acrylic plastic, 4 × 4-inch for pulley (see text), 0.10-inch thick acrylic plastic for bezel, dial window, and rotary switch plate (see text), 30 inches of nylon cord, four knobs for front-panel manual controls, four rubber feet with self-tapping screws, No. 4-40 nuts bolts as required, solder

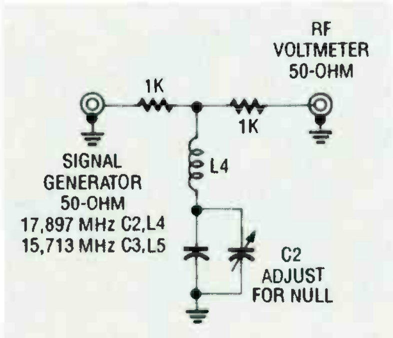


FIG. 11—TEST SETUP TO ADJUST CAPACITORS C2 and C3.

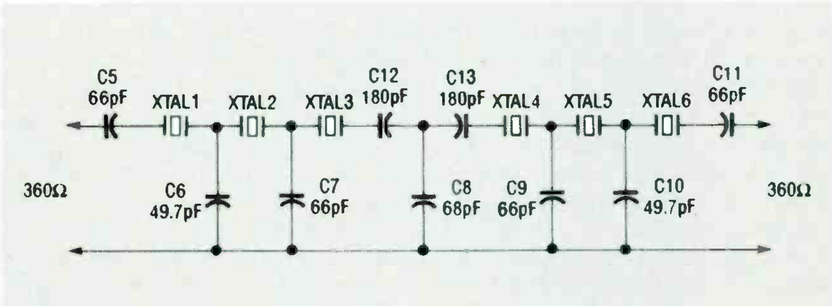


FIG. 12—SCHEMATIC FOR CRYSTAL FILTER showing the interconnection of 9830.4 kHz crystals and individual or parallel capacitors where needed to achieve desired values.

locations for all leads with a No. 60 drill. Countersink all holes with a ⅛-inch drill to remove the copper foil back to a radial distance of at least 0.050-inch around the drilled holes to provide suitable isolation and insulation around the leads. It will be necessary to drill rows of holes for mounting the IC's.

Component interconnection is done on the back or bare side of the substrate with the wire from the component leads. In cases where the leads are of insufficient length to span the distances required, 30 AWG insulated hookup wire should be used.

Build the audio amplifier first, and then work back toward the antenna terminal: second IF amplifier and detector, automatic gain control, second mixer and so on until you get back to the first mixer.

To test the audio amplifier, put your finger on the input jack and listen for the AC hum with the headphones. For a more precise indication of its performance, feed in an audio signal and verify with an AC voltmeter that the gain is 40 with the volume control set full open.

Referring to Fig. 3, build the second IF amplifier and detector. The variable capacitor across the output transformer, C33, should be set by feeding a 9.83 MHz signal into the input of IC4 at pin 4. With a DC voltmeter on the detector to automatic gain control (AGC) line, tune for a peak.

Variable-frequency oscillator

Build the variable-frequency oscillator (VFO) circuit on board 5, the 2 ⅜ × 1-inch board listed in Table 1. The peak radio-frequency output voltage of the VFO amplifier measured at C48

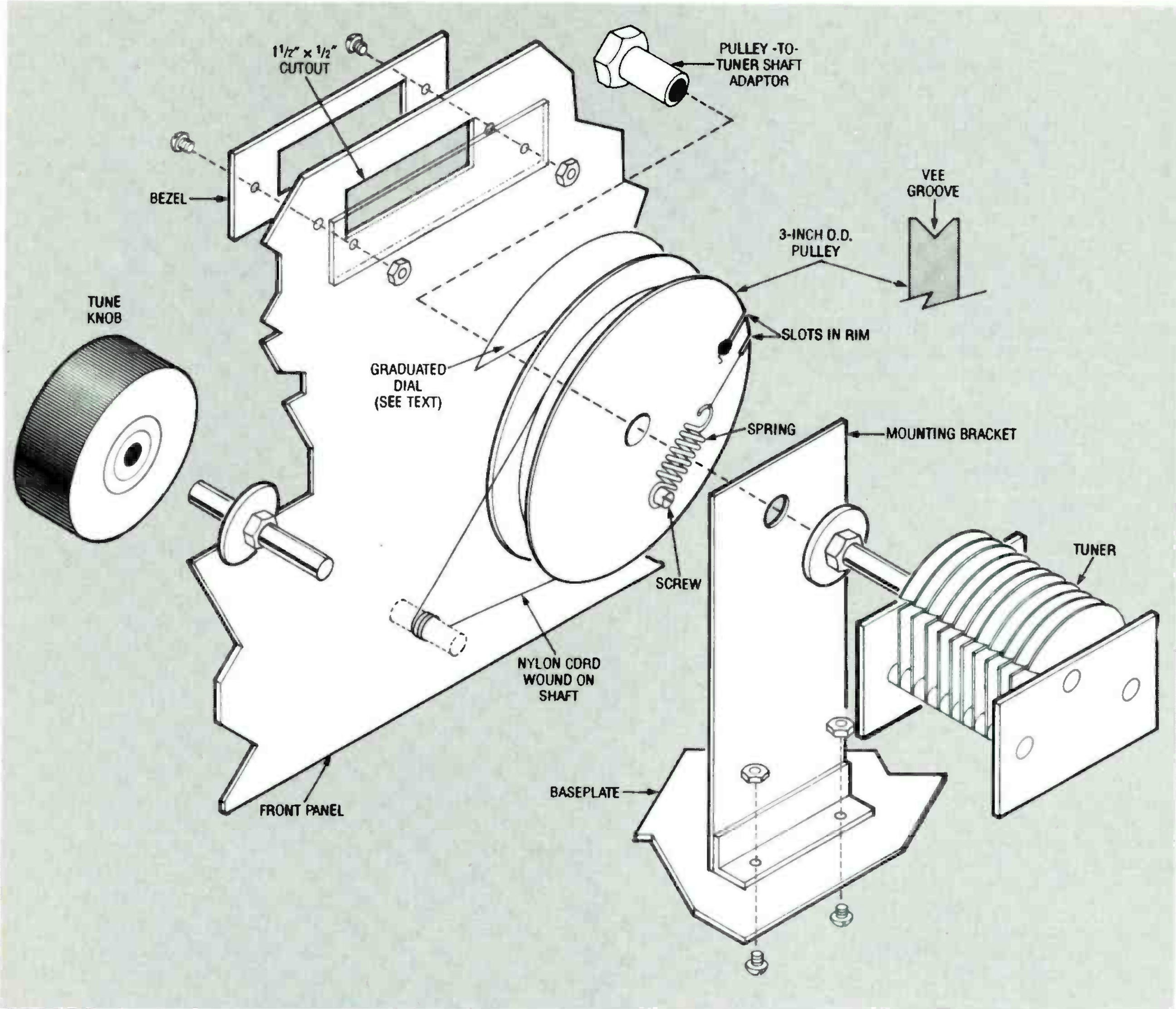


FIG. 13—EXPLODED VIEW OF DIAL DRIVE and tuning assembly with locking bearing.

should be 300 millivolts. Stability can be checked by monitoring the circuit with a frequency counter from a cold start. A typical drift curve for this circuit is shown in Fig. 7.

For optimum stability, the VFO should be powered by a 5-volt DC supply rather than the 12-volts used elsewhere in the receiver. A three-terminal 5-volt regulator on the output of the 12-volt supply can provide the 5-volts. The frequency of the VFO should be set to 6.670 MHz with the dial set at 0 by adjusting the turn spacing on L1. This can be checked later by listening for WWV at 10 MHz on band 2 (9.5) or 15 MHz (15) on band 5.

Bandpass filter

After the second mixer is complete, you will have a tunable receiver covering the 16.45 to 17.1 MHz range. Now build and install the 16.45 to 17.1 MHz bandpass filter. Refer to the schematic, Fig. 8-a. Build this bandpass filter on board 4, a 1 × 3-inch piece of copper-clad, single-sided board stock so that it can be easily removed. See Table 1.

The crystals need not be matched if they are certified to be within the proper tolerance and purchased from a reliable vendor. Solder the crystals and disc capacitors in place, interconnect them, and mount the filter on the main circuit board with bare hookup wire.

To restrict the signals reaching the second mixer to the 16.45 to 17.1 MHz band, the 16.45 to 17.1 MHz bandpass filter is placed ahead of the first IF amplifier. Figure 8-a is the schematic for this filter and Fig. 8-b is the schematic for the six other bandpass filters. All of the bandpass filters are wound on T-50-6 powdered-iron toroid cores, selected to have inductance Q's over 200. Ceramic capacitors are specified for use in the filters. Four variable capacitors are in parallel with fixed capacitors to form C1 through C4 in the 16.45 to 17.1 bandpass filter to set those capacitance values precisely.

Figure 9 is a plot of the bandpass characteristic for the 16.45 to 17.1 MHz filter. The relatively steep skirts in this filter are produced by the two parallel resonant circuits (C2, L4 and C3, L5 in Fig. 8-a) in the center series arm. This is the most important bandpass filter in the receiver and it must be aligned correctly.

Check the filter in the receiver by listening with the headphones for a stable signal within the 16.45 to 17.1 MHz range. The 11th harmonic at 16.5 MHz of the band 5 (refer to Fig. 4-d) oscillator/divider output of 1.5 MHz will be satisfactory.

Tune across the band while monitoring the DC voltage on the detector AGC line. The voltage should rise very rapidly to more than 5 volts, hold steady, and then drop rapidly to zero. With a frequency counter connected to capacitor C48 and a voltmeter calibrated in decibels on the AGC line, verify that your filter output matches the curve in Fig. 9.

Obtain an RF signal generator and an RF voltmeter. Mount the four inductors on the copper-clad side of the 1 × 3-inch board 4. Then connect the end capacitors (fixed and variable) as shown in Fig. 10. To check the LC resonant circuit at each end, set the RF generator to the filter's mid frequency (16.772 MHz) and adjust the 1—16 pF capacitor in parallel with the 110 pF capacitor that forms C1 for a peak reading (parallel resonance) on the RF voltmeter.

Now connect inductor L4 and the two capacitors forming C2 (a 39 pF capacitor in parallel with a 1 to 16 pF capacitor) shown in Fig.11. Set the RF signal generator for 17.897 MHz, and adjust for a null (series resonance). Repeat this step with L5 and C3 tuning for a null at 15.713 MHz. Then without changing capacitor settings, connect the filter components in their final positions as shown in Fig. 8-b. Frequencies for the other bands are shown in Table 2.

The first mixer converts each of the popular shortwave bands to the 16.45 to 17.1 MHz range. The mixer in this receiver is a double-balanced mixer.

Filter construction

Build the four crystal-controlled oscillators that tune the six bands of the receiver by referring to the schematics in Fig. 4. Note that 7 MHz-crystals are used in both the band 1 and 2 oscillators (XTAL 7 and XTAL 8), but a 10 MHz crystal (XTAL9) is used in the band 3 oscillator (Fig. 4-c). The oscillator in Fig. 4-d is able to provide three different frequencies because of its output countdown circuitry (IC8, IC9, IC10 and IC11).

Filter details are given in Table 2. Filters are built with fixed-value capacitors and tuning is accomplished by adjusting the position of the wire turns on the toroid cores. Compressing the turns to less than 360 degrees of the toroid's circumference increases their inductance and lowers their resonant frequency.

For example, compressing a coil whose turns are spread out over 360° down to about an angle of coverage of about 120 degrees increases the inductance 75%, shifting the frequency 32% lower. Follow the procedure outlined for the first IF bandpass filter, but use the frequencies listed in Table 2. Filter components are mounted directly on the 6 × 3 ¼-inch circuit board 1. (See Figs. 1 and 2.)

Automatic gain control

Refer to Fig. 3 and build the automatic gain control (AGC) circuit last. It allows this receiver to cope with a wide range of signal strengths while the listener tunes across the band. The volume control knob can be left in a fixed position and all tuning can be done with the TUNE control.

Set the 10K potentiometer, R68, for 5 volts DC at the cathode of diode D5 with no signal input to the receiver. This level will increase to about 6 volts in the presence of strong signals, causing a reduction in the gain of the IF amplifiers. Refer to Fig. 12 and build the 9.83 MHz crystal filter on board 5 whose dimensions are given in Table 1.

Precision tuning dial

Cut and bend a mounting bracket for the air-dielectric tuning capacitor C49 from aluminum stock and drill a hole in it to accept the capacitor shaft and two holes at its base flange ¼ inch back from the front edge so it can be mounted to the baseplate as shown in Fig. 13. (Capacitor C49 is part of the variable-frequency oscillator circuit.)

Mount tuning capacitor C49 on the bracket positioned about 1¼ inches behind the front panel as shown in Fig. 13. The tuning capacitor is rotated by an assembly shown in Fig. 13 consisting of a 3-inch diameter pulley turned by a nylon cord wound over the tuning knob spindle and located in the vee groove of the pulley.

The pulley can turned from sheet plastic in a lathe or a suitable one might be obtained from electronic salvage. Two slots cut in the edge of the pulley allow the cord ends to pass through the wall of the vee-groove for fastening. A small spring at one end keeps the cord in tension over the pulley. A screw in the edge of the pulley approximately 120° away from the slots will anchor the other end of the spring. Fasten the pulley to the tuner shaft with a suitable adapter.

A pattern for the precision dial is given here. It can be photocopied from the the magazine page and cemented to the front face of the dial pulley as shown in Fig. 13 and 14. Cut a suitable bezel from ⅛-inch sheet plastic to form an appropriate frame for the dial window. The inside of the bezel should be cut and filed to match the 1½ × ½-inch cut-

(Continued on page 112)

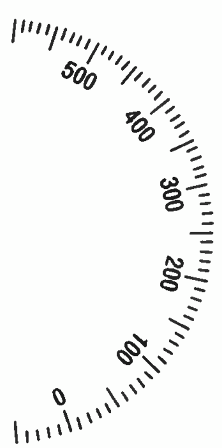


Fig. 14—PRECISION DIAL for tuning capacitor C49.

BUILD THIS

AMATEUR TV TRANSMITTER

Add TV transmission to your radio shack.

RUDOLF F. GRAF and WILLIAM SHEETS

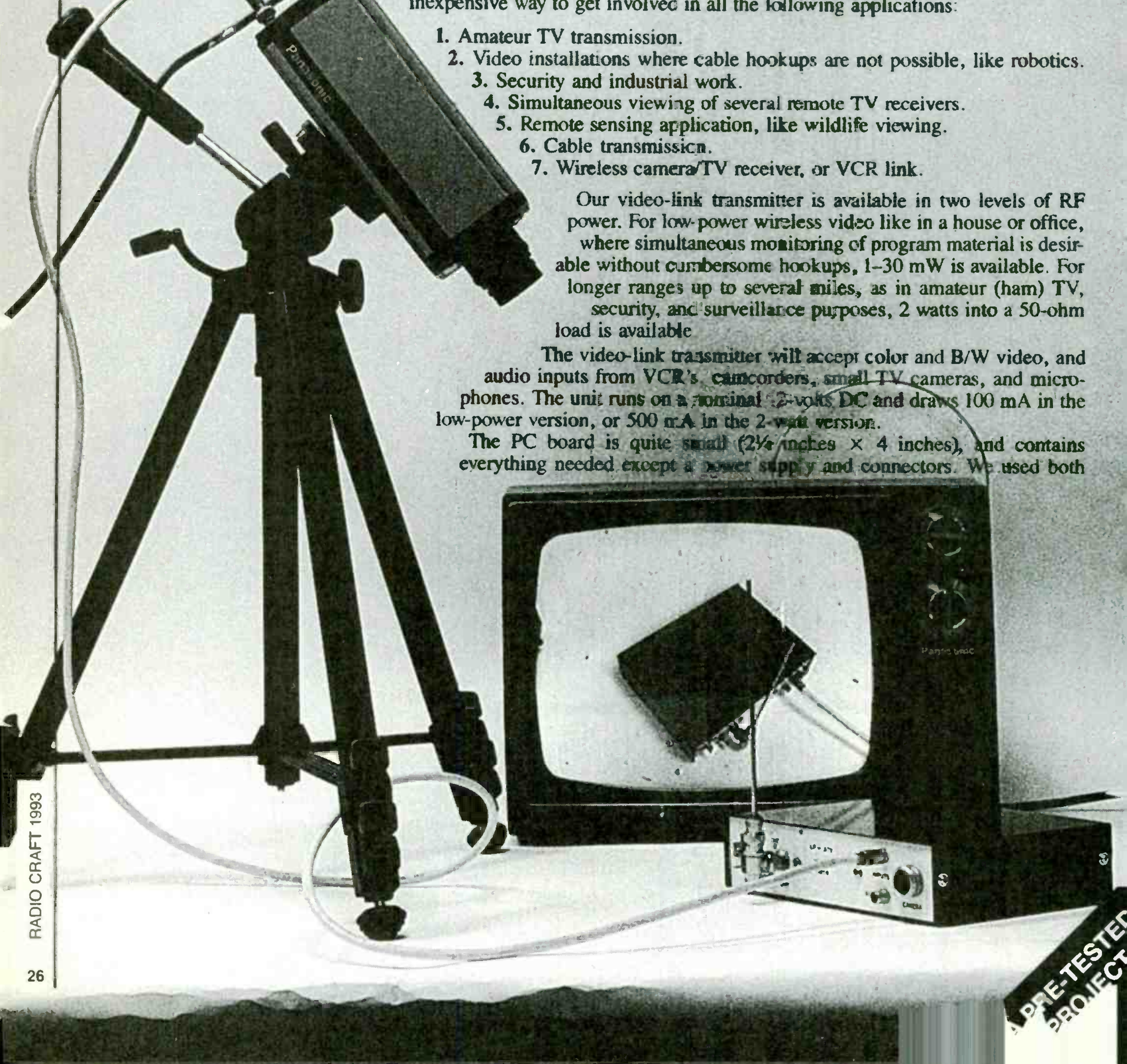
HOW WOULD YOU LIKE TO TRANSMIT COMPLETE VIDEO, EITHER COLOR OR BLACK-AND-WHITE, with accompanying audio, either through coaxial cable, or to a remote receiver? Hold your breath, because it's all possible with our video-link transmitter, an inexpensive way to get involved in all the following applications:

1. Amateur TV transmission.
2. Video installations where cable hookups are not possible, like robotics.
3. Security and industrial work.
4. Simultaneous viewing of several remote TV receivers.
5. Remote sensing application, like wildlife viewing.
6. Cable transmission.
7. Wireless camera/TV receiver, or VCR link.

Our video-link transmitter is available in two levels of RF power. For low-power wireless video like in a house or office, where simultaneous monitoring of program material is desirable without cumbersome hookups, 1–30 mW is available. For longer ranges up to several miles, as in amateur (ham) TV, security, and surveillance purposes, 2 watts into a 50-ohm load is available.

The video-link transmitter will accept color and B/W video, and audio inputs from VCR's, camcorders, small TV cameras, and microphones. The unit runs on a nominal 12-volts DC and draws 100 mA in the low-power version, or 500 mA in the 2-watt version.

The PC board is quite small (2¼ inches × 4 inches), and contains everything needed except a power supply and connectors. We used both



subminiature and surface-mount components because they perform well at RF, requiring simple tuneup without complex test equipment. In fact, a good tuneup can be achieved with only a VOM and a TV receiver.

Readers may be familiar with the author's previous article on an RF video-link (February, 1986, **Radio-Electronics**). Since then, many improvements have been made. The new transmitter is easier to tune, uses three slug-tuned coils instead of air-wound, and has a double-sided PC board for better shielding and grounding. Additionally, better transistors were substituted in the new design, which also has an integral power amplifier, and audio/video gain controls for easier interfacing. Linearity control was added to optimize video quality.

Liability

Be warned: The 2-watt version is intended for educational purposes, legitimate TV broadcasting, amateur TV, and industrial, and scientific purposes. It can transmit several miles, so those intending to use our design must have a Technician-class amateur-radio license.

Carrier frequency

As Fig. 1 shows, transistor Q1 and the surrounding circuitry is a crystal-controlled oscillator operating at ⅛ the video frequency, from 52.5 to 62.5 MHz. After being multiplied by four through frequency-doublers Q2 and Q3, the output covers 420–500 MHz, overlapping the 430-MHz ham TV band and the lower UHF (300 MHz–3 GHz) TV channels.

First, the frequency is doubled to 105–125 MHz by Q2, and then to 210–240 MHz by Q3. With some modifications, higher or lower frequencies are possible, but with lower power above 500 MHz, and higher power below 420 MHz. Double-tuned interstage networks suppress unwanted harmonics. Then, Q4 doubles Q3's output to the final carrier frequency, which is injected into transistor Q5.

In the low-power version, Q5 modulates the carrier by V_{cc}. The RF (1–30 mW, depending on coupling) is taken from Q5's collector and fed to either a cable or a 6–inch whip antenna. In the high-power version, Q6 and Q7 form a high-gain RF power amplifier, and adjustable matching networks are used in the circuit for optimum tuneup.

Instead of matching networks, a tuned strip-line design was contemplated, but at 420–500 MHz, it would have occupied too much PC-board area. Broadband RF chokes, surface-mount (tantalum chip) capacitors, and careful design strategy avoided possible low-frequency spurious oscillations. We ended up with a very stable, efficient, reproducible circuit having no UHF "horrors."

Modulator

The audio input at J1 will accept a wide range of voltage levels; 10 mV (typical microphone output) to 1 V (line input) is fed to audio-amplifier Q8. The audio-gain control adjusts for optimum modulation of Q9, a Colpitts *V*ariable *C*ontrol *O*scillator (VCO) producing 4.5-MHz FM audio subcarrier, which is fed to video amplifier Q10, where it is then combined with the video from J3.

The video input at J3 may be 0.5- to 1.5-volts peak-to-peak, negative sync, while the video-gain control prevents Q10 and Q11 from video overload. Current-source Q10 and amplifier Q11 feed modulator Q12, which is capable of producing video having a 12-volt swing, and can drive a load up to 1 amp. Its bandwidth at −3 dB is in excess of 10 MHz, assuring crisp picture detail.

In the high-power version, Q12 is a power supply to Q6 and Q7, effectively amplitude modulating the RF carrier. In the low-power version, Q5 is modulated in the same manner. A linearity control adjusts Q12's operating point for optimum modulation linearity. The Q-point must be properly set; otherwise, video clipping will occur, producing "burned-out" picture highlights (white areas) and loss of detail. Other Q-point problems could include sync "buzz" in the audio, and loss of picture stability in extreme cases.

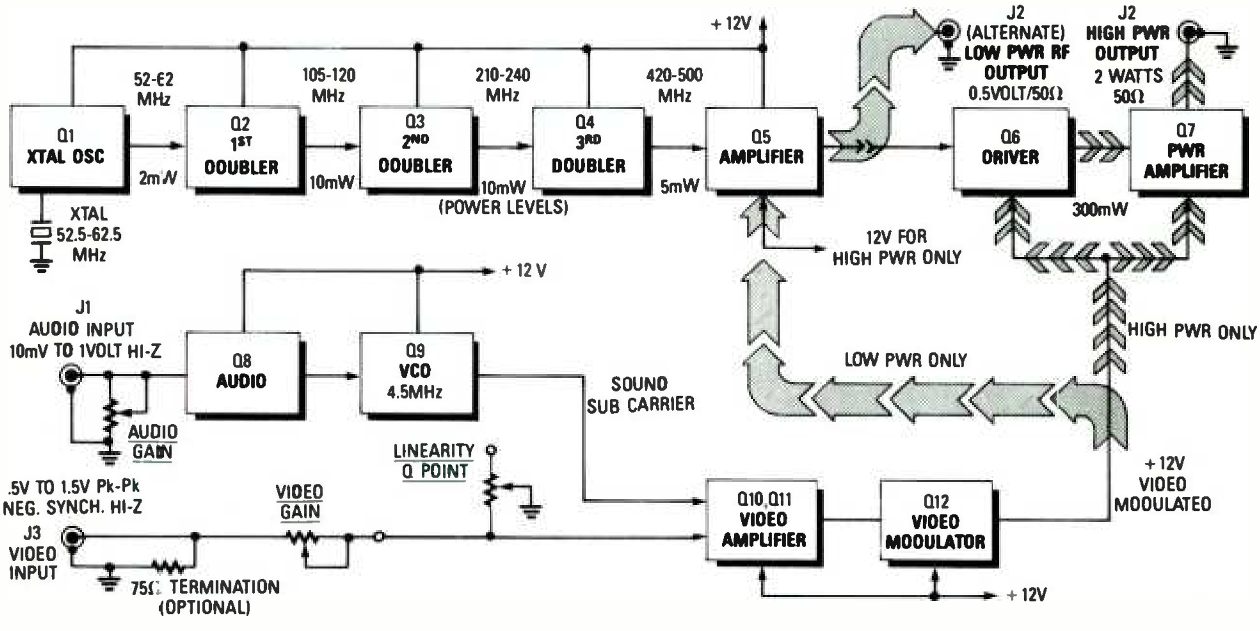
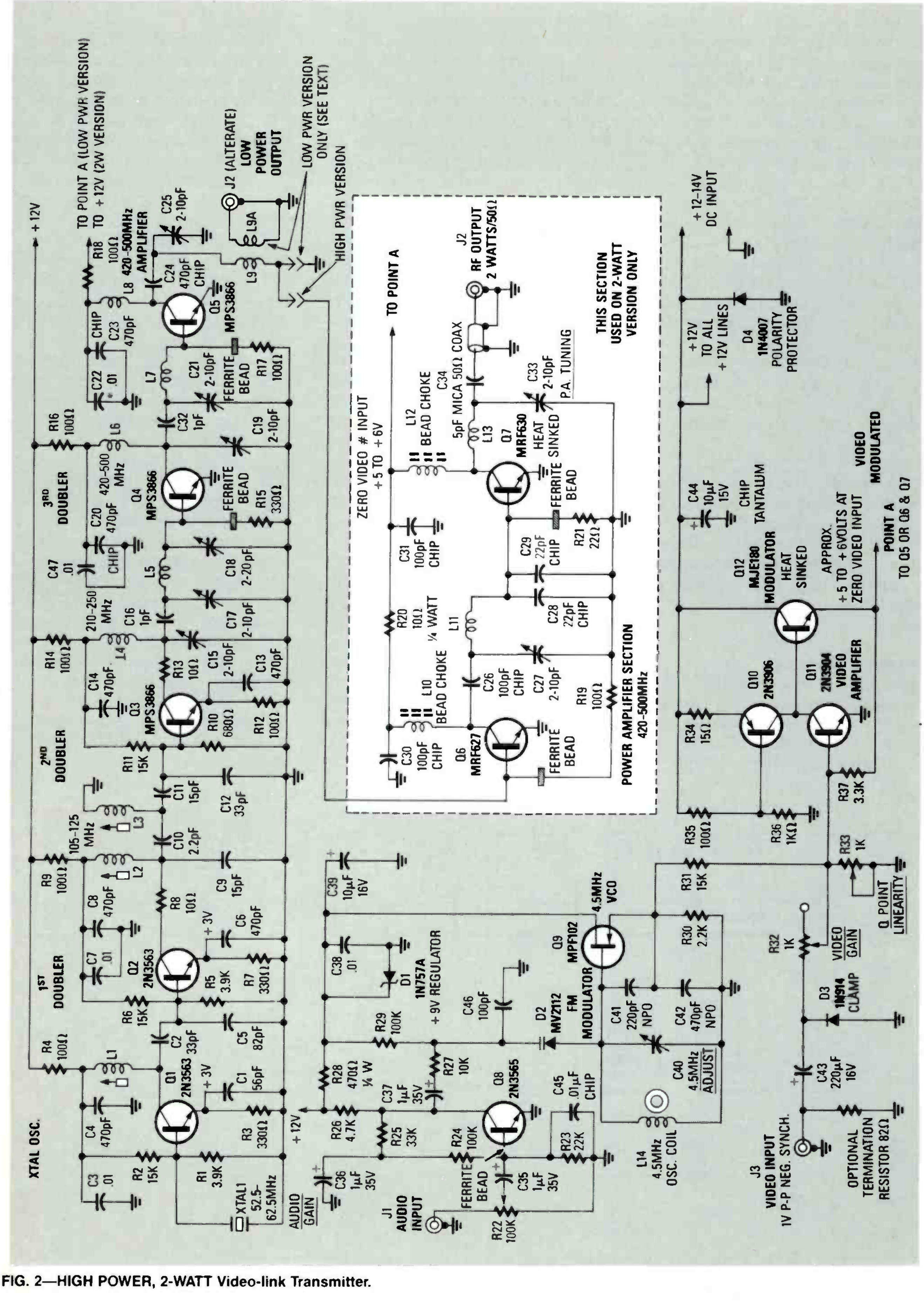


FIG. 1—VIDEO-LINK TRANSMITTER CAN BE CONFIGURED for either low-power, or high-power operation.



28 FIG. 2—HIGH POWER, 2-WATT Video-link Transmitter.

Frequency doublers

Referring to Fig. 2, VHF transistor Q1 is biased at 10 volts and 5 mA, with the Q-point set by resistors R1, R2, and R3. Crystal XTAL1 is series-resonant, "bypassed" to ground. At the crystal's resonant frequency (between 52.5 and 62.5 MHz), Q1 is a common-base amplifier. Tank (tuned circuit) L1/C2, in series with C5, together with about 1–2 pF of stray capacitance, form a load for the collector of Q1.

Once Q1 starts oscillating, its collector current is typically 5–10 mA, and depends on the tuning of L1. Here, C3 and C4 bypass the "cold" end of L1 solidly to ground for AC. Internal collector-to-emitter (C-E) feedback occurs in Q1 via the intrinsic 2-pF C-E capacitance. Here, C1 forms a voltage divider to feed the collector back to the emitter. Note that C1 is not for emitter bypass, but is part of the feedback network of oscillator Q1.

A portion of the voltage across tank L1/C2, and C5, is fed to Q2 by the voltage division between C2 and C5. Next, Q2 and its associated circuitry is a frequency doubler, where a large drive signal from Q1 causes rectification in Q2's emitter-to-base (E-B) junction, which produces considerable harmonic generation.

At twice the oscillator frequency, C5 has low impedance; keeping the impedance low in Q2's E-B circuit by using a large value (82 pF) for C5 also helps produce efficient harmonic generation. Biasing for Q2 is the same as Q1, via R5, R6, and R7. Bypass C6 adds stabilization, as does C7 and C8.

Tank L2/C9 is tuned to twice the crystal frequency. R9 supplies DC to Q2. A slug in L2 tunes the tank, while C10 couples RF energy at 2 times the crystal frequency to a second tank L3/C11/C12, also tuned to twice the crystal frequency. Using dual tanks assures good selectivity, and improved rejection of unwanted frequencies; that's important for a clean transmitter signal. Next, R8 in Q2's collector suppresses any self-oscillation tendencies at unwanted, parasitic UHF.

Frequency doubler Q3 (MPS3866, 400-MHz, medium power, 1-W, plastic) is fed at 105–125 MHz from the junction of C11 and C12. Here, R10, R11, and R12 bias Q3. The RF level at Q3's base is quite high, and that affects Q3's biasing, while the collector current runs at 10–15 mA.

Note that Q3 offers better performance at 250 MHz than the 2N3563's used for Q1 and Q2; Q3 doubles the frequency to between 210 and 250 MHz. Except for frequency, Q3 operates similarly to Q2. Then, R13 suppresses UHF parasitics, and L4/C15 form a bandpass filter tuned to twice the input frequency. At 250 MHz, C1 (for Q1) and C3 (for Q2) are ineffective, whereas C14 is sufficient. Finally, R14 feeds DC to Q3.

Note in tank L4/C15 that C15 is variable and L4 is fixed. Slug tuning is no longer practical because L4 has too few turns. Energy is coupled through C16 to tank L5/C17/C18, which forms a double-tuned bandpass filter at 210–250 MHz. Then, C17 is for RF tuning, while C18 will optimize matching into Q4, the last (third) doubler.

Figure 3 shows how a ferrite bead is slipped over one lead of R15, which causes a high series-impedance at RF, yet passes DC without attenuation, thereby completing the base circuit DC path for Q4. The bias is now supplied entirely by the drive signal; no extra DC bias is applied. The emitter of frequency-doubler Q4 is directly grounded, because bypassing emitter circuits at 420–500 MHz is difficult without some loss of RF gain; however, a low value of R15 keeps DC stability adequate.

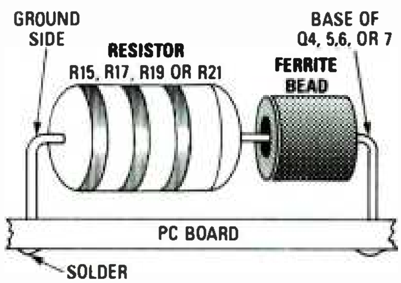


FIG. 3—SLIP RESISTOR LEAD through ferrite bead. The bead inductor causes a high series impedance at RF, yet passes DC without attenuation.

Tank L6/C19 (a short length of wire) operates at 420-500 MHz. Both C19 and C20 provide low-frequency video and RF bypassing, while C29 bypasses UHF; they also stop any stray low-frequency gain in Q4. Tantalum-chip C20 is the only type effective at 420 MHz, and provides a solid RF ground for the "cold" end of L6.

The 420–500-MHz at Q4's collector is fed to tank L7/C21, via C32, which matches Q4's collector circuit to Q5's low base impedance; together with L6/C19 they form a double-tuned UHF circuit. The ferrite bead and R17 provide a low DC impedance, but a high RF impedance to the base of amplifier Q5.

Low-power version

The UHF signal is amplified to about 30 mW by Q5. Choke L8 keeps RF energy out of the DC power supply. C22 and C23 bypass video and UHF, respectively. Note that if Q5 is video modulated (the low-power version) then C22 must be deleted, because it would cause loss of high-frequency video components; moreover, R18, which limits the supply current to Q5, must be returned to Q12's emitter. Tantalum-chip C24 couples RF output, yet blocks DC (and video, if applicable) from the tank circuit L9/C25.

In the 1–30-mW version, L9 couples the RF output to the secondary link of wire L9A, which then transfers the RF to output jack J2A (Alternate). Note that J2A and L9A are not used in the 2-watt version. Output power is limited depending on the proximity of the link L9A to L9.

High-power version

In the 2-watt version, L9 matches to the base of driver Q6, and Q5 is fed straight, unmodulated +12-V DC. The full 30-mW drive from Q5 drives Q6. The ferrite bead and R19 provide a high RF impedance, and low DC resistance at Q6's base. Since a ferrite bead looks more like a high resistance rather than a reactance at high frequencies, the effective Q is very low. That prevents the possibility of parasitic oscillations that could occur if a conventional-type solenoid-wound RF choke were used.

Here, C27, L11, and tantalum-chips C28 and C29 match Q6's collector impedance to Q7. RF-choke L10 is made with three turns of wire wound through a ferrite bead, in a toroidal fashion. That results in a low Q, about 1000 ohms resistance, and again avoids possible parasitics.

Tantalum-chip C26 is used to minimize stray inductance, and couples RF energy from Q6 to Q7. Now, C30 and C31 bypass UHF to ground while looking like a high impedance at 20 MHz or lower, so the video component of the modulating power supply voltage is relatively unaffected. Note

PARTS LIST

Resistors; all are ⅛ or ⅒-W, 5%
R1, R5—3900 ohms
R2, R6, R11, R31—15,000 ohms
R3, R7, R15—330 ohms
R4, R9, R12, R14, R16–R19, R35—100 ohms
R8, R13—10 ohms
R10—680 ohms
R20—10 ohms, ¼-W
R21—22 ohms
R22—100K-ohms potentiometer
R23—22,000 ohms
R24, R29—100K ohms
R25—33,000 ohms
R26—4700 ohms
R28—470 ohms, ¼-W
R30—2200 ohms
R32, R33—1000-ohm potentiometer
R34—15 ohm
R36—1000 ohms
R37—3300 ohms

Capacitors
C1—56 pF, NPO, ceramic disc
C2, C12—33 pF, NPO, ceramic disc
C3, C7, C19, C22, C38, C47—0.01µF, ceramic disc
C4, C6, C8, C13, C14—470 pF, NPO, ceramic disc
C5—82 pF, NPO, ceramic disc
C9, C11—15 pF, NPO, ceramic disc
C10—2.2 pF, NPO, ceramic disc
C15, C17, C19, C21, C25, C27, C33—2-10-pF, trimmer
C16, C32—1 pF, NPO, ceramic disc
C18—2-18 pF, or 2-20-pF-trimmer
C20, C23, C24, C45—470 pF, ceramic chip
C26, C30, C31—100 pF, ceramic chip
C28, C29—22 pF, ceramic chip
C34—5 pF, silver mica
C35–C37—1 µF, 50 V, electrolytic
C39—10 µF, 16 V, electrolytic
C40—3-40 pF, trimmer
C41—220 pF,NPO, ceramic disc
C42—470 pF, NPO, ceramic disc
C43—220 µF, 16 V, electrolytic
C44—10 µF, 16 V, tantalum chip
C45—0.01 µF, ceramic chip
C46—100 pF, NPO, ceramic disc

Semiconductors
Q1, Q2—2N3563, transistor
Q3–Q5—MPS3866, transistor
Q6—MRF559, or MRF627 transistor
Q7—MRF630, transistor
Q8—2N3565, transistor
Q9—MPF102, transistor
Q10—2N3906, transistor
Q11—2N3904, transistor
Q12—MJE180, transistor
D1—1N757A, diode
D2—MV2112, varactor diode
D3—1N914, diode
D4—1N4007, diode

Inductors
L1–L14—See table 1.

Other components
XTAL1—52.5-62.5 MHz

Note: Kits for this project are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804. Two different kits are available; one is a low-power, the other is a high-power version. Those kits include the PC board and everything on it, except jacks, connectors, batteries, power-supply components, and case. Those are not included, because individual hobbyists may have their own preferences and interface requirements. The author recommends that those components be obtained at another supplier.

The Video-Link transmitter, Radio-Electronics, February 1986, plus a reprint of the article, costs $79.95, plus $3.50 shipping and handling. Crystals can be purchased separately from Crystek Corporation, PO Box 06135, Fort Myers, FL 33906.

that Q6 draws about 130 mA at modulation peaks (sync tips).

Also, Q6 supplies between 300- and 500-mW drive to Q7, an MRF630 (Q6 and Q7 are similar in their operation). RF-choke L12 functions exactly the same as L10. Collector matching-network L13/C33, together with mica C34 match the 50-ohm load impedance to the optimum collector load-impedance needed by Q7. Note that a 50-ohm load must always be present at J2, otherwise Q7 may be damaged. A tolerance of ±50% (25–100 ohms) is permissible here; however, optimum performance is obtained with a 50-ohm load.

Suitable 50-ohm coax must be connected from C34 (on the PC board) and J2, with short connections (a ¼-inch or so). Any length of coax can be used, but for the best results, keep it short. We used RG174/V PVC type, but teflon coax (RG188/U) would be better. From J2, a standard coax (RG8U, RG58/U, etc.) will do. Remember, feedline loss must be avoided as it can be very high at 420 MHz and up.

Video feed

Input video from J3 (standard 1-V p-p negative sync.) is fed through C43 to clamp-diode D3. Note that C43 is apparently incorrectly polarized; that is to allow for video equipment that may have a DC component of up to 16 volts at the video output. If you do not expect to encounter that, you can reverse the polarity of C43—if you wish. When turned around, the low reverse voltage (0.6 V) appearing across it doesn't seem to do any harm. Diode D3 clamps the maximum negative input level to −0.7 V, and avoids serious over-modulation at the sync tip levels. If you wish, you can DC couple from J3 directly into R32, the video-gain control, if your equipment interface permits. Also, note the optional 82-ohm termination (R32A) is not on the PC board, but is soldered across J2. Use it unless you're in a situation where loop-through (several other video loads in parallel) is required. It was not placed on the PC board so that possibility would not be compromised.

Video-gain control R32 feeds the base of video-amplifier Q11. Video-amplifier Q11's collector is fed by current-source Q10, which is biased by R34, R35, and R36 to about 50-mA of collector current. That permits Q11's collector to supply plenty of drive to modulator Q12, and eliminates the need for a low-value decoupling resistor from Q11's collector to the power-supply rail (+12V); therefore, Q12's base can approach V_{cc}, and allows a higher positive swing of Q12's emitter than a resistor from Q11 to +12V would permit, due to Q12's base-drive needs.

Modulator Q12, an MJE180, is configured as an emitter follower. It must supply all the current to Q6, Q7 (or Q5), have a low supply impedance, and high slew rate. The low impedance is necessary for both full RF power output, and to control the parasitic-oscillation tendencies in power amplifiers Q6 and Q7. The load tends to be capacitive due to the bypassing from C26 (somewhat), C30, and C31.

In tests, Q12 can supply nearly 12 volts of video into a 10-ohm load, at 1.2 amps; therefore, Q12 must be heat sinked. To establish both Q-point, video gain, and bandwidth, R37 provides feedback around the modulator; however, R33 sets the exact Q-point (voltage seen at point A, Q12's emitter), under zero-drive conditions at about 5- to 6-volts DC, to Q6 and Q7. R33 is adjusted for maximum undistorted symmetrical video at point A, while R32 controls video drive to Q11. Supply bypassing must be effective at Q12's collector due to the high current and fast waveforms handled. The main supply bypass, C44, a 10-µF, 15-volt, tantalum chip was used because standard electrolytics are somewhat less effective.

Power feed

DC power is fed to the transmitter at J4. Diode D4, a 1N4007, is provided to serve as reverse-polarity protection. It's cheap insurance against inadvertent damage to Q6, Q7, Q10, Q11, and Q12, should the negative and positive leads of the power supply be reversed by accident. Diode D1 is connected directly across J4. The 12-volt supply (11–14 V is OK) may come from Nickel-Cadmium batteries, an auto's electrical system, or any kind of AC-operated power supply.

Audio feed

Audio is fed to gain control R22 from jack J3. Input level should be between 10 mV and 1 volt at high impedance, allowing direct interfacing with most microphones, or other audio sources. From R22 the audio is coupled through C35 to Q8, which is biased from R23, R24, and R25. Bypass C36 will prevent audio degenerative feedback, and loss of gain. Collector-load R26 supplies DC to Q8, while C37 blocks DC and couples audio through R27 to the frequency modulator.

Note that no pre-emphasis (high-frequency boost) has been used. If you want to use it, for better high-frequency audio response, change C37 to 0.001 µF, and set the gain-control R22 up higher to compensate for loss. The author found that pre-emphasis was unnecessary for most applications.

Audio is coupled to the varactor-diode D2, an MV2112, where R29 biases D2 at 9 V. The varactor diode varies its capacitance at an audio rate from 56 pF at 4 V, to about 33 pF at 9 V. The capacitance of D2 appears across 4.5-MHz oscillator coil L14. Then, Q9, an MPF102 FET, together with C41, C42, C40, and L14 form a Colpitts RF oscillator operating at 4.5 MHz. Trimmer C40 is used to set the frequency to exactly 4.5 MHz, while toroidal coil L14 is used to minimize stray magnetic field generation.

The audio voltage on the DC bias causes D2 to change capacitance, which shifts the oscillator frequency causing frequency modulation (FM) of the 4.5-MHz generated in Q9, the Colpitts oscillator. Bias for Q9 is provided by R30, while R31 couples the audio subcarrier (4.5-MHz FM) into the video amplifier, which modulates it and the video onto the RF.

Zener-diode D1, R28, and C38 and C39 (which provide bypass) supply a regulated 9-V DC voltage to Q9, and varactor D2. The regulation prevents oscillator drift if the supply voltage were to vary. A frequency counter can be connected to point A to set C40 to exactly the value needed for 4.5-MHz audio subcarrier.

Assembly hints

As long as the author's design is exactly duplicated, you shouldn't encounter any *off the wall* UHF problems, so follow these suggestions without compromise:

1. As you assemble this project, use only the parts specified in the Parts List because ultra-high frequency circuits are sensitive to changes in component type and value. Also follow the author's parts placement as closely as possible.

2. Lead lengths should be kept short. Handle the surface-mount components and ferrite beads with extra care. The 1/10-watt resistors and miniature NPO ceramics should have short leads, and close component spacing.

3. Wind your own slug-tuned coils with available materials, rather than using commercial, hard-to-get factory-made types. That gets rid of the coil headaches. If the dimensions are followed, no problems should result. As shown in Fig. 4, you'll find that the coils are easy to wind, and the largest ones have only eight or nine turns of wire. In fact, several are only loops or pieces of wire because the inductors required at 420–500 MHz are usually in the 0.01 to 0.1-microhenry range.

4. Pay particular attention to supply bypassing. We have incorporated a tantalum chip capacitor to guarantee good bypassing. By keeping everything compact, and by using a shielded, double-sided PC board with good RF bypassing, all the possible "horrors" associated with VHF and UHF circuitry can be done away with.

5. The PC board is compact and parts are small, so a small iron with a pointed tip is recommended, especially for soldering the chip capacitors.

6. Use only 0.062-inch thick epoxy-fiberglass PC-board materials. Other materials and thicknesses could be used, but may result in different tuning conditions, and stray capacitances. Don't use paper-base phenolic materials; they're too lossy at UHF frequencies.

7. Transistor Q12 must be heat-sinked because it must dissipate up to 3 watts. The method shown in Fig. 5 has proven adequate if at least 1-ounce copper is used. On the other hand, Q7 is adequately heat-sinked if the metal case is soldered to the PC-board ground plane.

8. Solder as many component leads as possible (that pass through the ground plane) to the top and bottom of the board. In particular, the ground lugs on all trimmer capacitors should be soldered on both sides, and also the resistors that have one side connected to ground. That's especially important around Q4–Q7.

9. Use chip capacitors where specified. Do not substitute ordinary leaded capacitors.

10. Keep all component leads as short as possible, and as close to the board as possible.

Parts installation

Figure 6 shows the Parts-Placement diagram for the TV transmitter. First install all resistors and then diodes D1 and D3. Don't forget the ferrite beads on R15, R17, R19, and R21. Next install all disc ceramics (0.01 µF and 470 pF), and then the NPO capacitors. Now install potentiometers R22, R32, and R33, soldering the grounded side of R22 and R33 to both sides of the PC board. Install all trimmer capacitors. Note that C18 and C40 are different from the rest. Solder ground tabs of all trimmers to both top and bottom of the PC board. Install transistors Q1 through Q5, and Q8 through Q11, but don't install Q6, Q7, or Q12 yet.

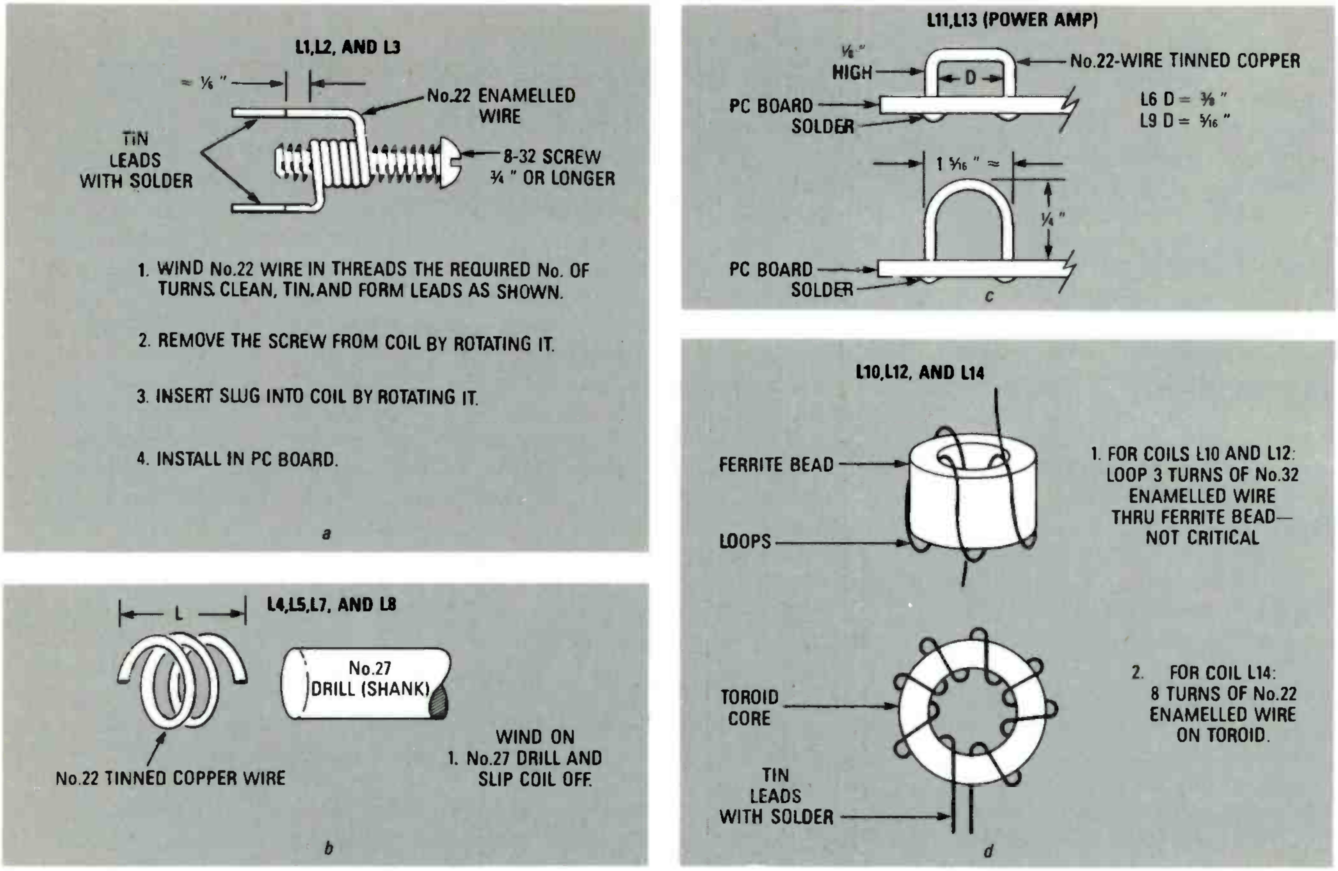


FIG. 4—IF YOU WANT TO CONSTRUCT THE COILS BY HAND, you have to wind them on the threads of a screw (*a*), the shank of a drill bit (*b*), using measured bends (*c*), or around a ferrite bead (*d*).

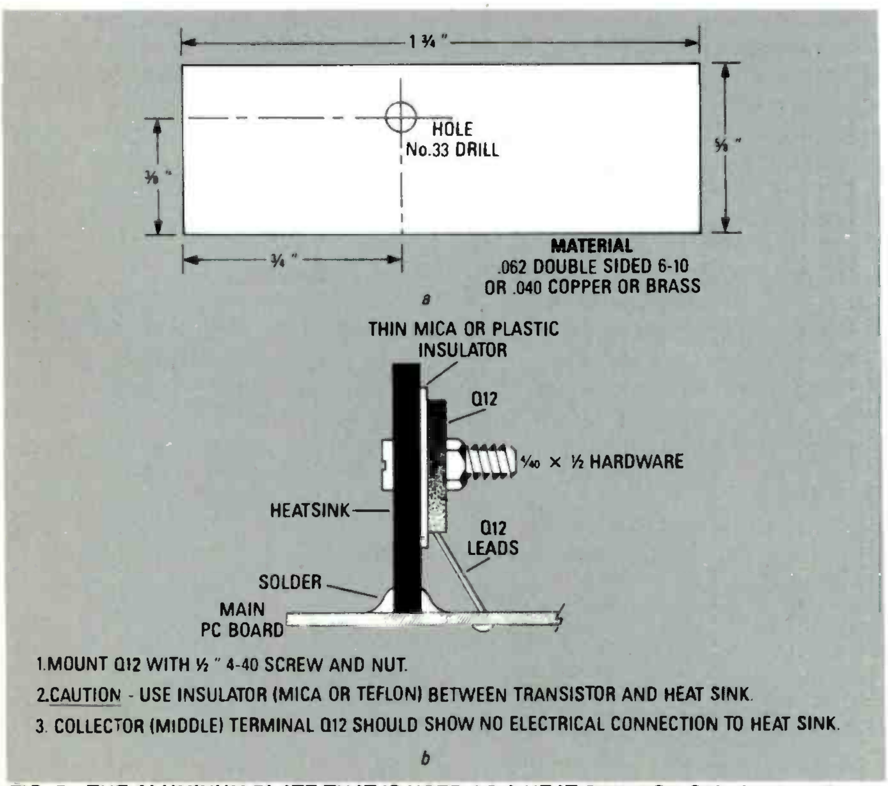


FIG. 5—THE ALUMINUM PLATE THAT IS USED AS A HEAT SINK FOR Q12 also functions as an RF shield for transistors Q6 and Q7.

Wind and install L1 through L9, and L14. If you're building the low-power version, leave out any components associated with Q6 and Q7, except L9; go ahead with the modification shown in Fig. 7, and be sure to omit C22. Install chip capacitors C22, C24, C44, and C20.

Check the PC board for shorts, solder bridges, and trim away any excess foil with a sharp knife (*X-acto* type or equal). Make sure that excess foil on the top side is not touching any component leads that are not intended to be grounded. Slight mis-registration of the top foil during PC fabrication may cause that.

Now install Q12 and its heat sink. Note that the heat sink also serves as an RF shield for Q6 and Q7 (if used). Be sure to solder the heat sink where it butts against the PC board. Note that Q12's case should be insulated from the heat sink. Use a TO-220 insulator (cut to size), or a scrap of mica, mylar, polyethylene, or teflon tape used in plumbing work.

You are now ready to test the main part of the board. If you're construct-ing the 2-watt version, Q6, Q7, and any associated components will be installed only after the rest of the PC board is tested.

Testing

After checking your work, measure the DC resistance between V_{CC} and ground; it should be greater than 200 ohms. If it's lower than that, check your work again for the cause before proceeding any further.

Next, install the slugs in L1, L2, and L3 if you haven't already done so. The slugs should be initially set fully inside the coils. Set R22, R32, and R33 about halfway between extremes of rotation. Set trimmer C40 and all other trimmer capacitors to half mesh. Final settings will depend on the operating frequency, coil-construction technique, and application.

Apply +12 volts after connecting the negative-supply lead to the PC-board ground plane. Immediately observe power-supply current; if it's over 130 mA, there may be a problem. If anything smokes or gets too hot, immediately remove the power and find the problem before proceeding.

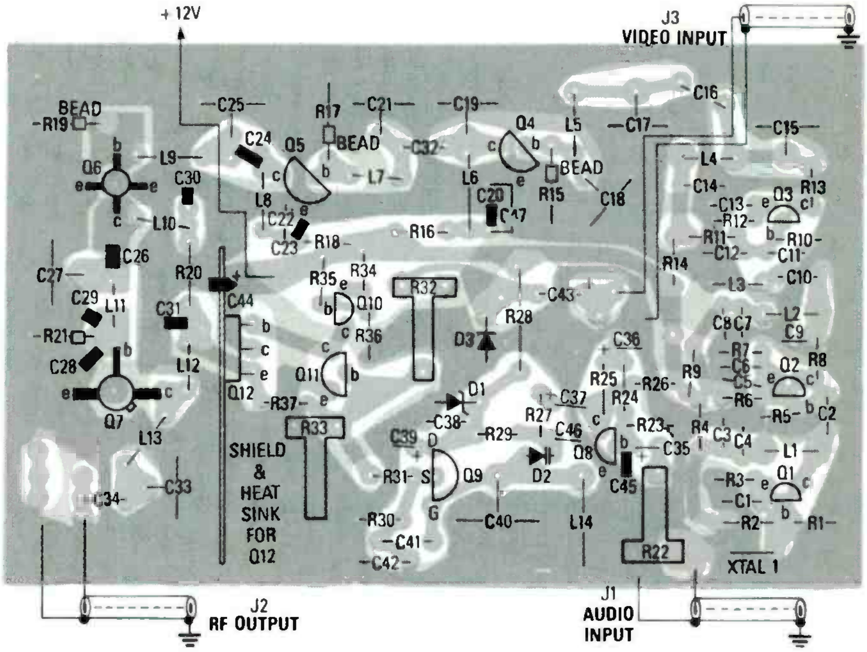


FIG. 6—PARTS PLACEMENT DIAGRAM shows capacitor chips (C20, C23, C24, C26, C28, C29, C30, C31, C45) mounted on the solderside, as is Q6.

If all seems OK, connect a VOM (preferably an analog meter) across R3, and then R7. You should read between 1.5 and 3-volts DC. Next connect the VOM across resistor R12 Q3;you should read 1 volt or less. Now connect the VOM between point A (emitter of Q12) and ground. Verify

TABLE 2—COIL DESCRIPTIONS L1-L14

COIL	FREQ. RANGE MHz	NO. TURNS & LENGTH	WINDING FORM	NOTES
L1	420-450 (HAM TV) 450-500 (VIDEO LINK)	9½ 8½	8-32 SCREW THREAD	NO. 22 ENAMEL WIRE
L2	420-450 450-500	4½ 3⅓		
L3	420-450 450-500	5½ 3½		
L4	ALL	3 TURNS ¼" LONG	NO. 27 DRILL (0.144" DIA) SPACE TURNS	MADE WITH NO. 22 TINNED COPPER
L5	ALL	4 TURNS ¼" LONG		
L7	ALL	1½ TURNS ⅟₁₆" LONG		
L8	ALL	2½ TURNS ⅛" LONG		
L6, L9, L11, L13	ALL	PER FIG. 1	NONE (PC BOARD)	
L10, L12	ALL	PER FIG. 1	FERRITE BEAD	NO. 32 ENAMEL WIRE
L14	4.5 MHz (NTSC SOUND SUBCARRIER)	8 TURNS NO. 22 ENAMEL	TOROID	NO. 22 ENAMEL WIRE

NOTE: Due to individual winding technique and normal circuit tolerances, L1, L2, L3 and L14 may require one turn more or less than shown in Table 1. L4, L5, L7 and L8 may have to be squeezed or spread lengthwise. All dimensions are taken from average of several working units. Individual units vary somewhat from given dimensions due to tolerances, winding techniques, and installation.

that adjusting R33 through its full range will vary the voltage at point-A between less than 5 volts to greater than 11 volts. Set R3 for full voltage (greater than 11 volts) at point A for now.

Measure the voltage at Q8's collector; about 4 to 7 volts is OK. Next measure the voltage across D1; it should be between 8- and 10-volts DC. If it is more or less, that indicates a problem in Q8, Q9, or the associated circuitry. Check for 8- to 10-volts across D2. If it reads 1 volt, D2 is installed backwards or is shorted.

If all is good up to this point, install crystal XTAL1, connect a VOM across R7, and apply power. Tuning the oscillator is done as follows: Slowly back L1's slug out of the winding. You'll find that the voltage across R7 will suddenly increase, then slowly decrease as the slug is tuned. Adjust the slug for maximum voltage (3 to 5 volts), then back out the slug for about a 10% drop to ensure stable oscillation. As a check, a frequency counter connected to the junction of C2 and C5 should indicate the crystal frequency. An unstable reading indicates that the crystal is not controlling the frequency. If that's the case, try re-adjusting L1.

Here's how to tune the 1st doubler. Connect the VOM across R12, and adjust L2 and L3 for maximum voltage (about 1 to 2 volts). If adjusting the L1 and L2 slugs doesn't peak the voltage, then add or subtract a turn from the coil as required, after first checking C9, C10, C11, and C12 for correct values.

Here's how to tune the 2nd and 3rd doublers. Connect an RF probe to the junction of L9 and R19, or to the junction of C25 and L9 if you're building the low-power version. Figure 5 shows you how to build an RF probe if you don't already have one. Adjust C15, C17, C18, C19, C21, and C25 for a maximum reading. You should be able to obtain at least 1.5 volts of RF energy at the junction of R19 and L9 for the high-power version, and about 2 volts at the junction of C25 and L9 for the low-power version. If everything looks good, that checks out stages Q1 through Q5.

To adjust the RF output for the low-power version connect a 47-ohm resistor to J2A (Alternate). Adjust C25 and the position of L9A (Alernate) with respect to L9 for maximum output. Don't couple L9A too close to L9—just enough for about 1 volt across the 47-ohm resistor.

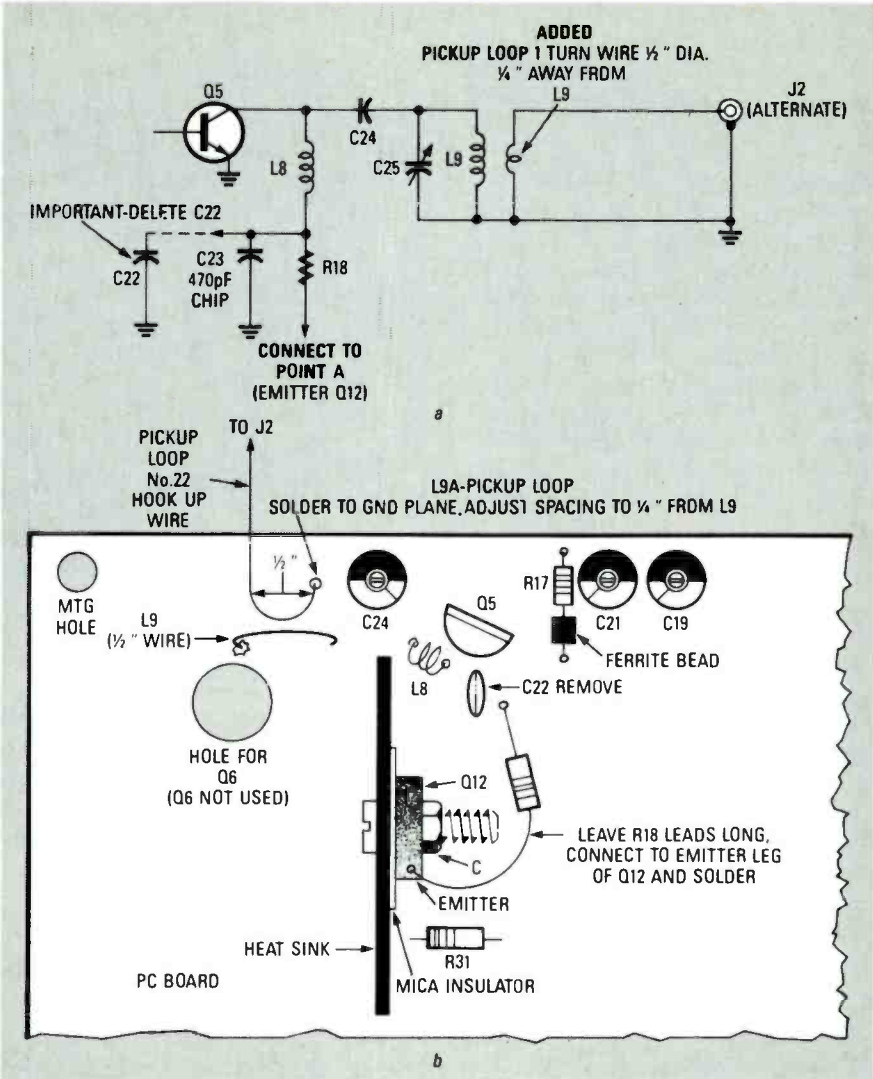


FIG. 7—TO OPERATE THE UNIT AT LOW POWER you should follow schematic (*a*) and assembly modification (*b*).

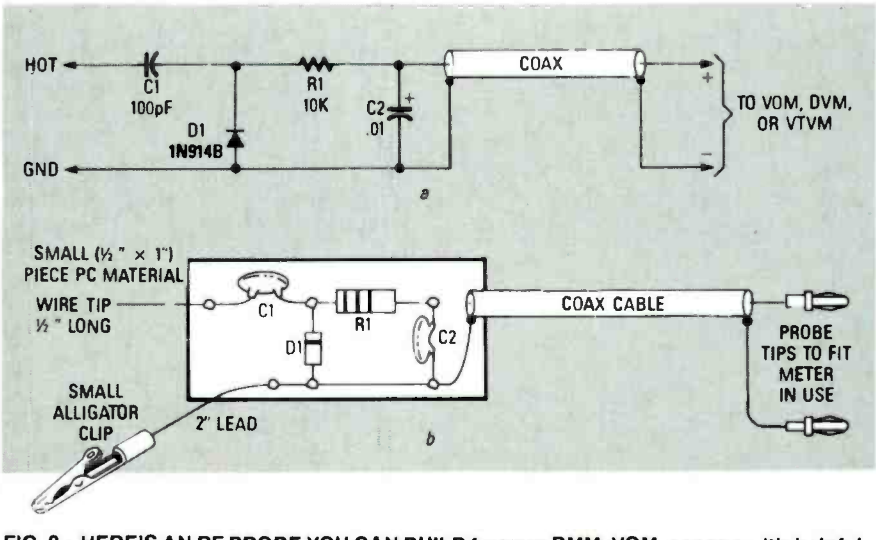


FIG. 8—HERE'S AN RF PROBE YOU CAN BUILD for your DMM, VOM, or scope. It's helpful in adjusting the transmitter for peak power.

Final assembly

If you're building the 2-watt version, now is the time to install Q6 and Q7, and then L10 through L13. You may now install the chip capacitors C26, C28, C29, C30, and C31, but don't overheat them! Make sure that the PC board is tinned in the areas where chips are installed. The best way to install them is to first tack-solder one side to hold it down, solder the other side, and then go back and resolder the first (tack-soldered) side.

Figure 9 shows you how to solder chip components. Use a 25-watt iron with a pointed tip. Fine-point needle-nose pliers or tweezers should be used to manipulate the chip capacitors.

Finally, install C34 and a suitable length of small-diameter 50-ohm coax to J2. Check all joints for solder bridges. Make sure that the metal case of Q7 is soldered to the ground plane (top side), and connect its leads to the PC-board underside using as little lead length as possible.

Apply power and quickly adjust C25, C27, and C33 for maximum power into a 50-ohm load connected to J2. You can use a 47-ohm, 2-watt carbon resistor, or the dummy load which can be assembled as shown in Fig 10. An RF probe can be connected to the hot side of the resistors (center conductor of connector) to read the RF voltage, but an RF power meter is nice to have.

WHERE TO BUY

The following kits are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804:

Low-Power Kit w/ATV crystal for operation on 439.25 MHz, $84.95 plus $3.50 shipping and handling.

2-Watt Kit w/ATV crystal for operation on 439.25 MHz, $110.00 plus $3.50 S/H.

1-Watt Kit w/ATV crystal (uses 9-volt) for operation on 439.25 MHz, $112.00. New 5-Watt Kit being prepared for market—write for prices. Extra crystals for CH14, CH15, CH16, CH17 or CH8 and ATV freqs. for 421.25, 426.25 and 434 MHz operation, $7.50 plus $3.50 S/H. Crystals can be purchased separately from Crystek Corporation, PO Box 06135, Fort Myers, FL 33906. Kits do not include jacks, connectors, batteries, power-supply components, or case.

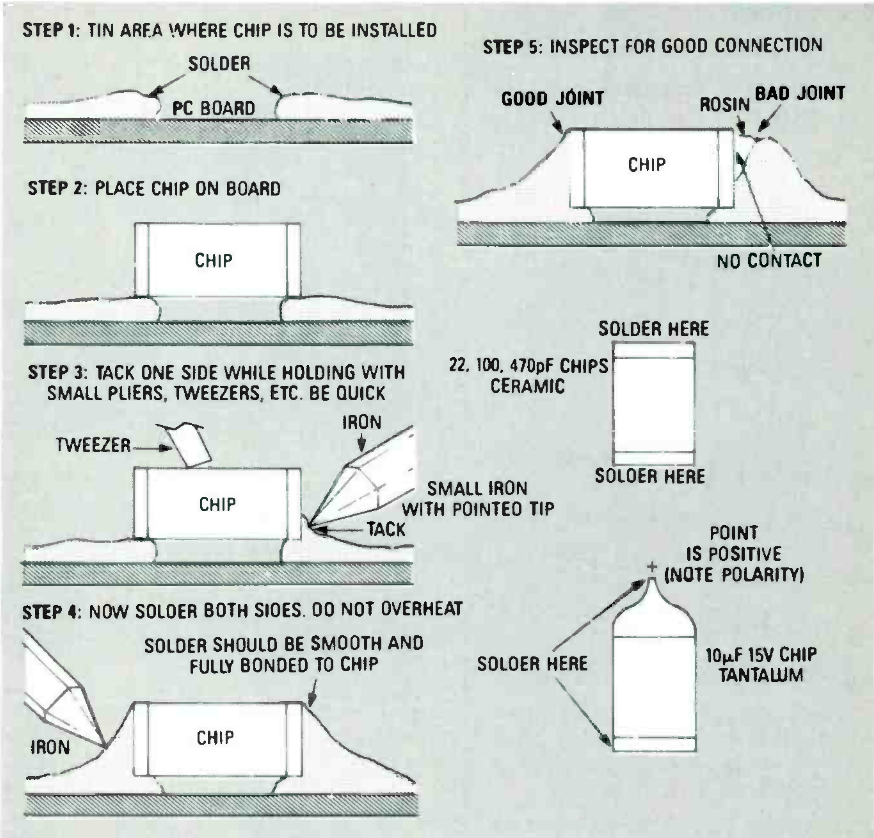


FIG. 9—IF YOU FOLLOW THESE STEPS when soldering the chip components to the PC board, you'll have no problems with them.

You should get at least 1.5 watts (about 8.5-volts RMS) into the 50-ohm load, which should become warm when operating. Power-supply current will be about 500 mA. Now adjust R33 for an output voltage about half that, or a quarter the power as read on the power meter, if used. Leave the RF load connected as you proceed to the next step.

For either the low- or high-power unit, adjust R33 for about +6 volts at point A (emitter of Q12). Connect a frequency counter to point A, and adjust C40 for exactly 4.500 MHz. Now apply video and audio signals to J3 and J1, respectively. Watch the transmitted image on a TV receiver tuned to the transmitter frequency; adjust the video gain (R32) for best picture contrast and stability, then adjust the audio level (R22) until its level is comparable to a commercial station. Now alternately adjust R32 and R33 for maximum video contrast without seeing any side effects such as instability, audio buzz, or other evidence of clipping. You may also wish to go over all tuning adjustments again for best results. The finished PC board is show in Fig. 11.

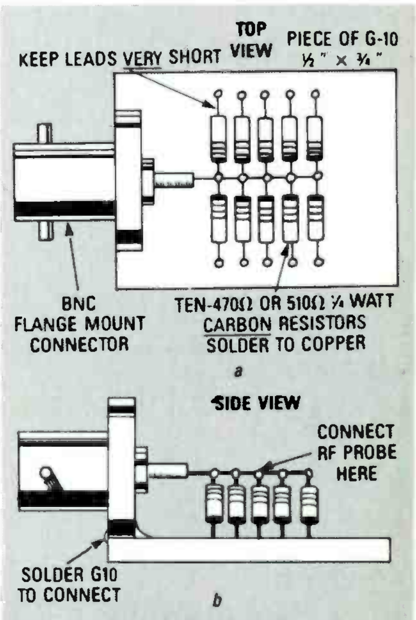


FIG. 10—A DUMMY LOAD SHOULD BE USED while adjusting the power output.

Enclosure

Mount the PC board in a shielded metal-case, as shown in Fig. 12, and connect leads from the board to suitable jacks for J1, J2, or J2A, and J3.

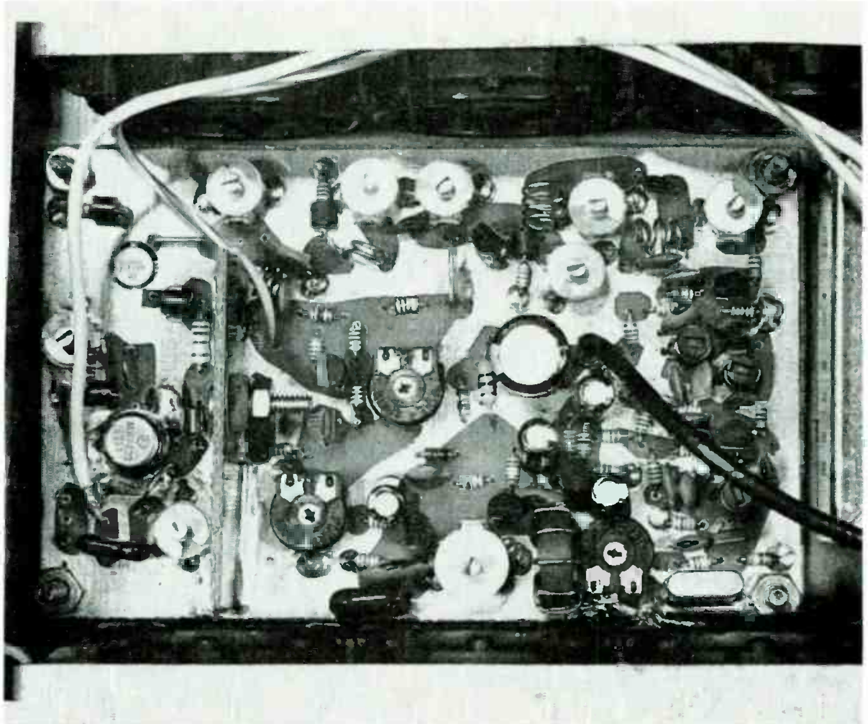


FIG. 11—THE FINISHED PC BOARD has a neat, clean appearance. Sloppy workmanship can not be tolerated on this circuit layout.

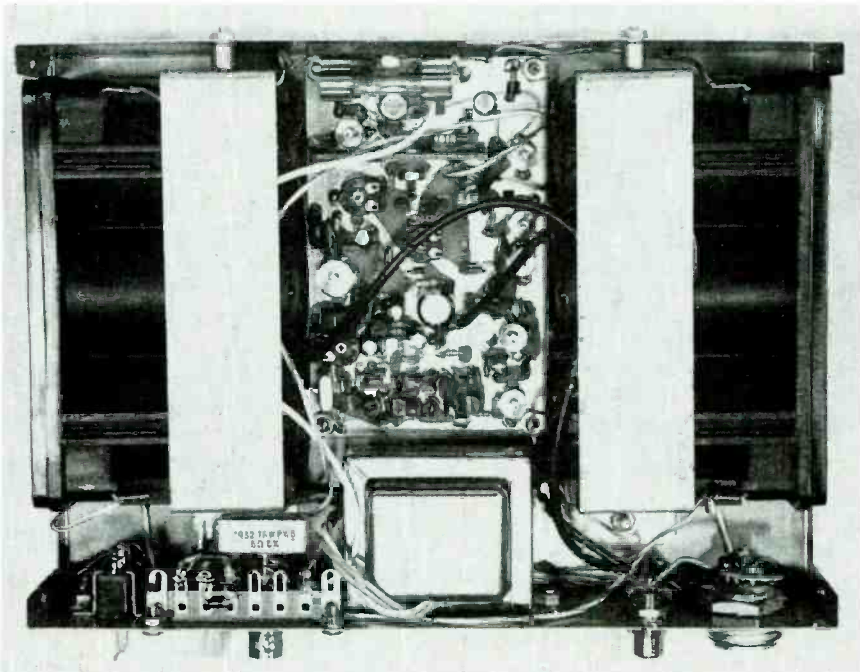
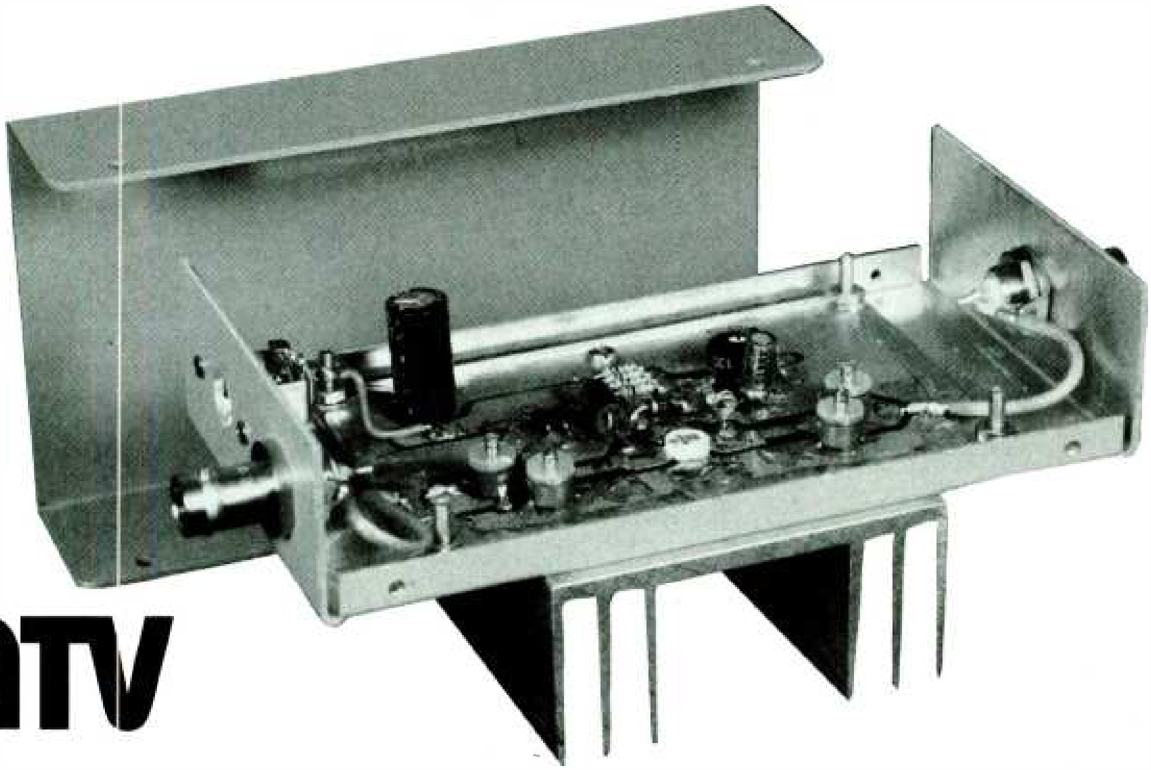


FIG. 12—The AUTHOR'S PROTOTYPE USED 2-Ni-Cd BATTERY PACKS, one on either side of the PC board, which makes the transmitter portable. You'll also notice a power transformer and associated circuitry used for running the transmitter off household AC-line voltage.

Also provide a suitable connector for the 12-volt supply, if desired. The transmitter case can house an AC supply, or batteries for portable operation. Use the right size *Ni-Cd* batteries to handle the 100-mA drain (low power), or 500-mA drain (2-watt unit). Use a BNC-type fitting for the antenna jack, J2.

A suitable antenna would be a 6-inch whip or a center-fed dipole, 12-inches long. For amateur TV, a linear amplifier may be installed between J2 and the antenna for greater power output. For the low-power version, use the 6-inch whip antenna. ■

Build this linear amplifier to boost the output of an amateur television transmitter from 2 to 10 watts



ATV Linear Amp

RUDOLF F. GRAF and WILLIAM SHEETS

THIS ARTICLE DESCRIBES THE DEsign and construction of an amplifier that can increase the power output of the amateur television transmitter just described in the previous article in this issue. That transmitter had a nominal 2-watt peak output. However, with this linear amplifier, the transmitter's output can be increased to 10 to 15 watts over the frequency range from 420 to 480 MHz. (The power output will be slightly less up to 500 MHz, and slightly more below 420 MHz.)

The amplifier should also be useful for amateur FM at 450 MHz as a power booster for 1- or 2-watt handheld portable transceivers, provided that a suitable switching relay is added.

Referring to the schematic in Fig. 1, the amplifier has a single Motorola MRF654 RF power transistor (Q1) as the active element. RF input power is fed to J1, where C1, C2, and L1 form an adjustable matching network to transform the low input impedance of Q1 (typically 3 ohms) to about 50 ohms. (L1 and L3 are part of the PC board etching, so you should not make changes in the design of the foil pattern.) Base bias for Q1 is fed through R2 and L2. Ferrite choke L4 supplies 13.2-volts DC to the collector of Q1. For optimum performance, Q1 should have a low-impedance load, so L3, C3, and C4 transform the nominal 50-ohm load (the coaxial line to the antenna) to 2.6 ohms.

Although Q1 is designed for FM service, it can function as a linear amplifier if it is forward-biased with about 0.6-volt to an idling current (when no signal is present) of 50 to 100 milliamperes. Good linearity is important, because it is handling an AM signal with video modulation. Also, the matching networks should have adequate bandwidth (about 10 MHz) to avoid cutting the higher video frequencies. Poor linearity will show up as sync compression, sync buzz in audio, or video level clipping.

Bias for Q1 is provided by diode D1. It's important that D1 be thermally connected to Q1 so that Q1 and D1 are at nearly the same temperature to avoid thermal runaway. That is done by soldering one lead of D1 directly to the emitter lead of Q1, and keeping D1 in contact with the

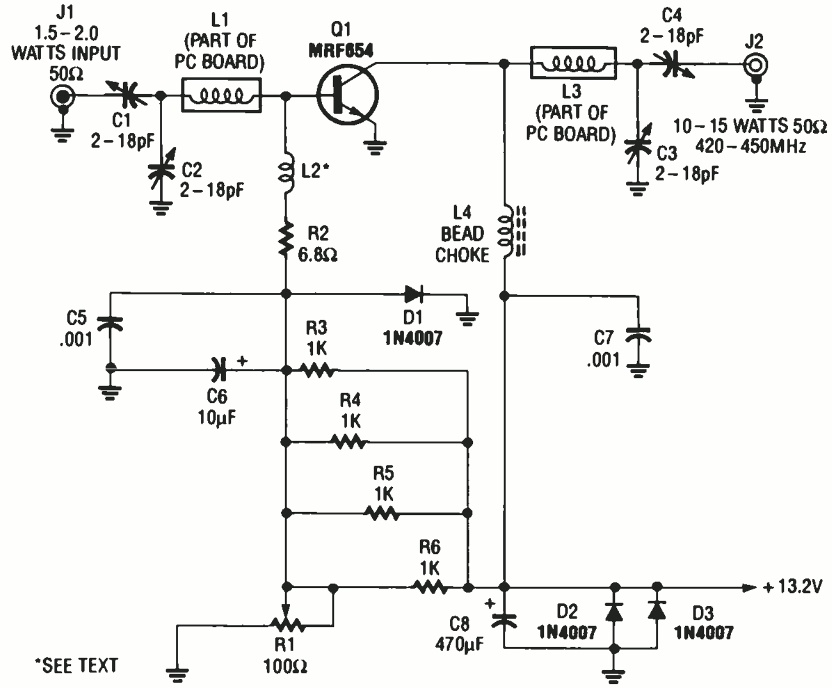


FIG. 1—LINEAR AMPLIFIER SCHEMATIC. The amplifier has a single Motorola MRF654 RF power transistor (Q1) as its active element.

PC board foil around Q1. Capacitors C5 and C6 provide broadband bypassing of D1, and L2 and R2 feed DC bias into the base of Q1. Coil L2 is a low-Q broadband choke that prevents parasitic oscillation.

Potentiometer R1 is adjusted so that, in the absence of an input signal to J1, the amplifier draws about 125 milliamperes from a 13.2-volt DC supply. Capacitors C7 and C8 perform broadband bypassing in the collector circuit, and D2 and D3 provide reverse-polarity protection in the event of power-supply spikes or accidental misconnection. A 3-amp fuse, not included on the PC board, is desirable in the positive lead of the power supply.

Construction

The linear amplifier is constructed on a G-10 0.062-inch epoxy fiberglass double-sided PC board. Note that one side of the PC board is a ground plane with no components or traces on it. That is absolutely essential to the operation of this circuit. The PC board traces have capacitance and inductance that are incorporated into the design of the amplifier. Inductors L1 and L3 are two examples, as are the mounting pads for C1, C2, C3, and C4, which offer significant capacitance to ground. Therefore, it is important that you do not modify the foil pattern provided. You can buy the PC board from the source given in the Parts List.

Figure 2 is the parts-placement diagram. All components are mounted on the component side of the board and soldered to their respective pads with zero lead length, except as in the specialized instructions that follow. Refer to Fig. 3 for details concerning those specialized instructions.

A number of grounding wires must be passed through holes in the board and soldered on both sides to connect the top and bottom ground planes together. All of those points are designated on the board with a "G." A short length of excess component lead can be used. Wrap a length of 3/16-inch copper-foil tape around all four outside edges of the PC board, fold it over, and then completely solder it on both sides.

Variable capacitors C1 and C4 must have their leads bent at 90° angles and soldered flat against the board. However, insert the leads of variable capacitors C2 and C3 through holes in the board and solder them on each side. The leads of potentiometer R1 must also be bent at 90° angles and soldered flat against the board. Bend the leads of electrolytics C6 and C8 at right angles so they are flush with their cases, and solder them to the PC board. Trim the leads as short as possible.

Coil L2 is actually just one lead of R2 (a 6.8-ohm resistor) formed into a 2½-turn inductor. Wrap the lead 2½ times around an ⅛-inch thick nail or similar form. When soldering it to the board, make sure that you raise the coil part of the lead slightly above the board so that it doesn't touch the copper trace below it.

Two chip capacitors are used

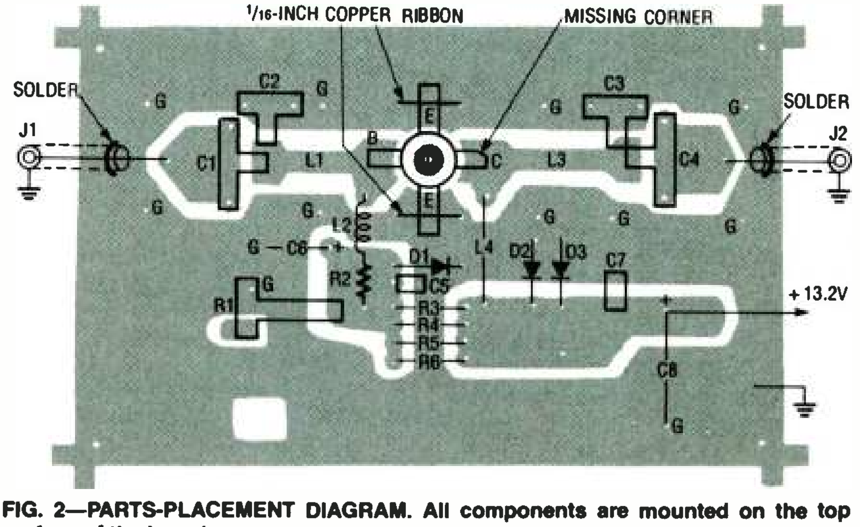


FIG. 2—PARTS-PLACEMENT DIAGRAM. All components are mounted on the top surface of the board.

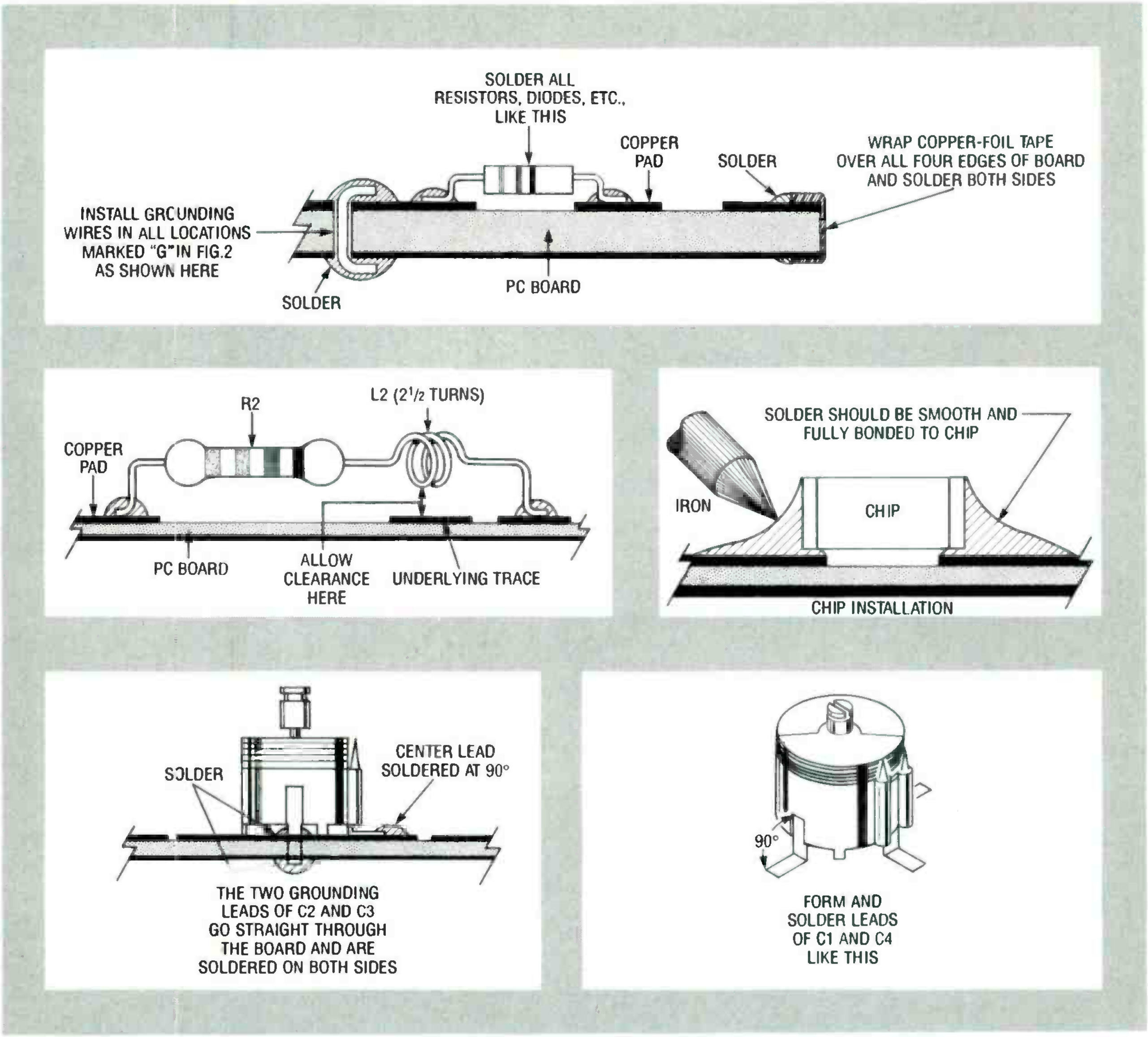


FIG. 3—CONSTRUCTION DETAILS. **Because of the high frequencies involved, certain aspects of the design are very critical.**

in this project (C5 and C7). To install them properly, first tin the area where the chip is to be installed, and then place the chip on the board. Hold the chip down with the tip of a small screwdriver and tack solder one side to the tinned surface. After one side is tacked in place, tack solder the other side. After both sides are tacked in place, permanently solder both sides as shown in Fig. 3.

Now install Q1. Note that a hole is drilled in the board for Q1, large enough so that no part of Q1's case touches the board. Look for the lead that's missing a corner, and position that lead as indicated in Fig. 2. There are two larger holes near each emitter lead of Q1. Thread a short length of copper foil, $\frac{1}{16}$-inch wide (cut from foil tape) through those holes and solder it to both sides of the board after Q1 is installed. The copper solidly grounds both emitter leads to the top and bottom ground planes (see Fig. 4).

After Q1 is soldered in place, mount the PC board inside the case, as shown in Fig. 4, so that the bottom of Q1 is level with the outside surface of the case. Use a metal case for proper shielding. Mount the board with the four corner mounting holes and 4-40 or 6-32 screws. Use washers or available spacers that will allow the proper fit for Q1. Drill a hole in the heatsink for Q1's 8-32 threaded stud, and deburr the hole so that the bottom of Q1 mounts flush. Secure the heatsink with an appropriate nut and lockwasher.

Make sure that Q1 fits in its mounting hole and that no part of it, except for the four ribbon leads, touches the PC board. There must be no mechanical stress on Q1's leads. If Q1 is off-center or cocked at an angle to the PC board, the stud might break off when the mounting nut is tightened.

The heatsink for Q1 should be at least a $\frac{1}{16}$- or $\frac{1}{8}$-inch aluminum plate measuring about $3\frac{1}{2}$

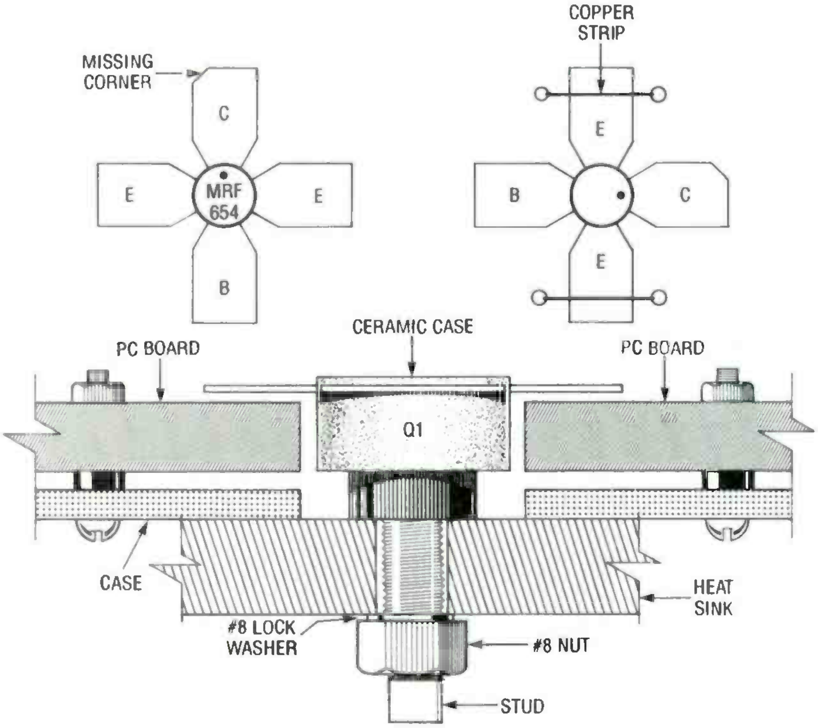


FIG. 4—Q1 IS INSTALLED so that no part of its case touches the board. Heatsinking is very important.

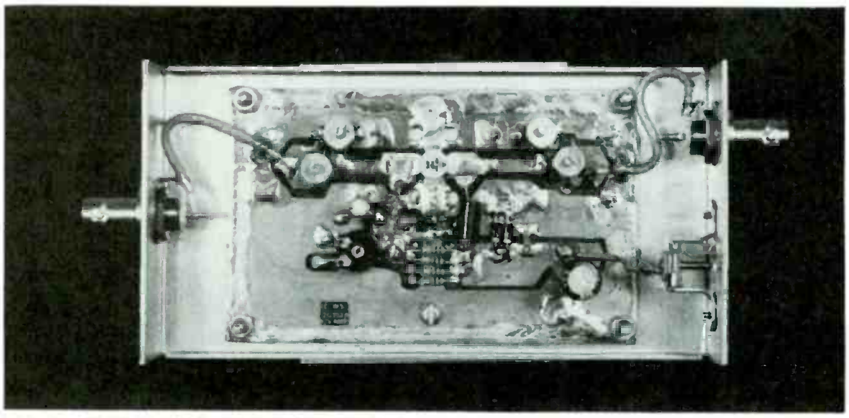


FIG. 5—THE AUTHOR'S PROTOTYPE. A metal case provides superior shielding.

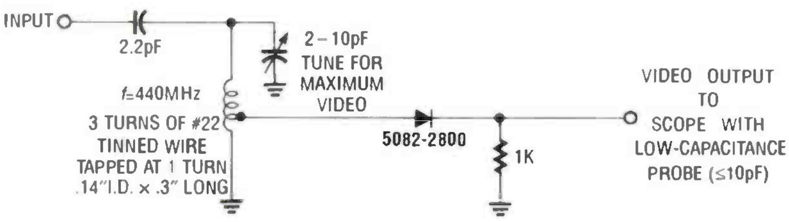


FIG. 6—THE AMPLIFIER can be monitored for linearity with this video-detector circuit and an oscilloscope.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.

R1—100 ohms, potentiometer
R2—6.8 ohms
R3–R6—1000 ohms

Capacitors

C1–C4—2–18 pF trimmer
C5, C7—0.001 µF, 50 volts, chip
C6—10 µF, 16 volts, electrolytic
C8—470 µF, 16 volts, electrolytic

Semiconductors

D1–D3—1N4007 diode
Q1—MRF654 transistor

other components

L1, L3—part of PCB etching
L2—one lead of R2 wrapped 2½ times around a ⅛th-inch thick nail (see text)
L4—VK200-19-4B bead choke (Ferroxcube)
J1, J2—BNC connector

Miscellaneous: PC board, metal case, heatsink, hardware, 15 inches of copper-foil tape, coaxial cable, wire, solder, etc.

Note: The following items are available from North Country Radio, P.O. Box 53 Wykagyl Station, New Rochelle, NY 10804:

- **Linear amplifier kit (includes PC board, all parts, case, heatsink, hardware, copper-foil tape, coaxial cable, and connectors)—$79.50**
- **ATV transmitter kit (includes all parts, case, 439.25-MHz crystal, and all connectors)—$125.00**
- **Additional crystals for the ATV transmitter (channels 14, 15, 16, 17, or 18)—$7.50 each For same price: crystals for ATV frequencies 421.25, 426.35 and 434.00 MHz**

Add $3.50 shipping and handling to any order. New York residents must add appropriate sales tax.

× 5 inches. The heatsink temperature should not exceed 140°F (60°C) during amplifier operation. If the amplifier runs too warm, replace the heatsink with a larger one. A suitable heatsink is included with the kit available from the source given in the Parts List.

Connectors J1 and J2 can be BNC- or N-type. Do not use type F connectors because the impedance is not satisfactory at 400 to 500 MHz. Use a short length of miniature coaxial cable to connect J1 and J2 to the PC board. Figure 5 shows the inside of the author's prototype.

Alignment

After carefully inspecting the board, set R1 fully counterclock-

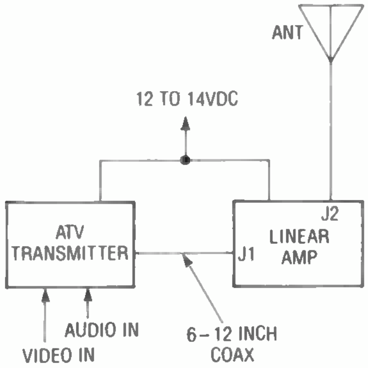
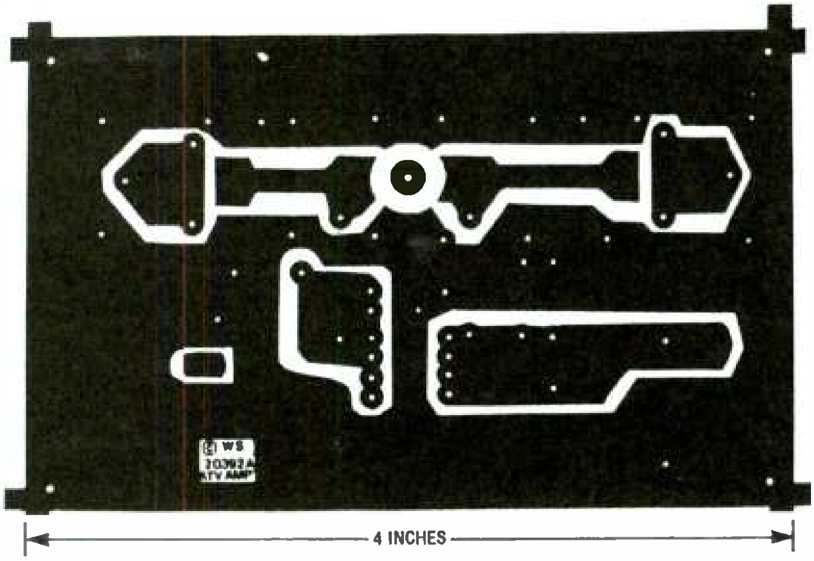


FIG. 7—THE TRANSMITTER connects to the linear amplifier with a short coaxial cable, and the antenna is connected to the amplifier.



COMPONENT SIDE for the linear amp.

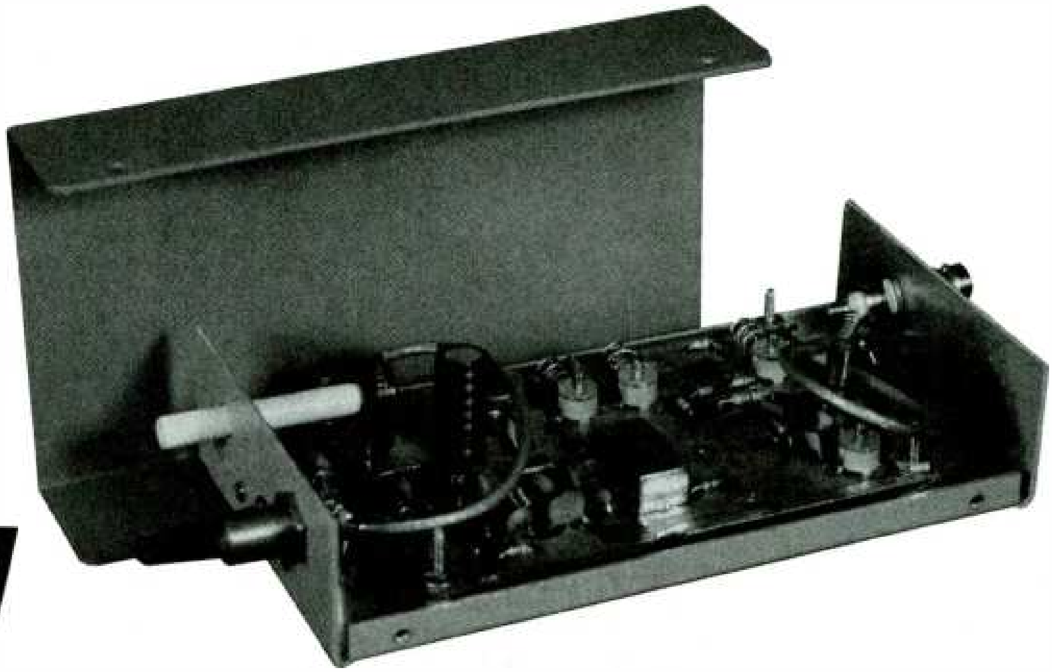
wise and connect a regulated 3-amp, 13.2-volt DC supply, observing proper polarity. An ammeter must be installed in series with the positive lead unless the power supply has a built-in meter. Connect a suitable wattmeter (0–25 watts) and a 50-ohm dummy load to J2. (Do not use an antenna, because the circuit might radiate interference during tests.) Make sure your wattmeter and load are both functional at 400–500 MHz (many CB and ham-radio meters are unsatisfactory at those frequencies). Do not yet connect anything to J1. Adjust R1 so that the amplifier draws 100 to 125 milliamperes (do this very quickly).

Next, apply RF drive of 1.5 to 2 watts to J1 and slowly tune C1 and C2 until the amplifier draws about 1 ampere. Quickly adjust C3 and C4 for maximum RF output. Now go back and adjust C1 and C2 for maximum RF output. Now readjust C3 and C4. Repeat that procedure until a maximum RF output is obtained. You should obtain 10 to 15 watts or more from J2, and the amplifier will draw about 1.5 to 2.2 amperes. Check to see if any part is overheating. Now vary the drive to J1; the RF output should smoothly follow the input, if it is correctly tuned.

For amateur TV use, the amplifier can be monitored for linearity with a video detector on the output and an oscilloscope. Fig. 6 shows a suitable detector for that purpose.

Figure 7 shows how to connect the transmitter (from the June and July 1989 issues of **Radio-Electronics**) to the linear amplifier. The best performance is obtained by adjusting R33 in the transmitter so that initially there is an output of 3 to 5 watts from J2 with no video input. Check to see that the output varies smoothly with R3. Then adjust R32 and R33 for the best video performance without sync clipping or white clipping. Slight adjustments of R1 in the linear amplifier might be needed for optimum linearity. Do not overdrive the amplifier, or sync clipping and degraded video will occur. ■

Receive amateur TV signals on a standard TV with our low-noise downconverter.



ATV Downconverter

WILLIAM SHEETS and RUDOLF F. GRAF

YOU CAN RECEIVE AMATEUR TV SIGnals on a standard TV receiver with our inexpensive ATV downconverter. The downconverter converts the 420–450 MHz ATV band, which is several channels below the lower limit of the UHF band, to channel 3 or 4 for viewing on virtually any TV. The downconverter has a low-noise preamplifier stage and a double-balanced passive mixer for good performance and a wide dynamic range. That is necessary with today's crowded UHF bands. The converter draws about 27 milliamperes from a 13.2-volt DC source, so it can be used in portable and mobile applications. An extra IF stage gives an overall gain of about 25 dB.

Circuitry

Figure 1 is a block diagram of the downconverter. It consists of three active stages and a passive diode double-balanced mixer. The input signal is first filtered so that only signals centered around 430 MHz are fed to Q1, an RF amplifier with a 20-dB gain and a noise figure of 1.5 dB. Q1 is an NEC 25137 gallium-arsenide field-effect transistor, or GaAsFET. The amplified signal in the 420–450 MHz range is fed to a double-tuned bandpass filter. The overall bandwidth of the RF stage is about 12 MHz, which is sufficient to cover the most frequently used part of the ATV band (426–439 MHz) without retuning. For operation over the entire 420–450 MHz band, you may have to repeak the filters to tune in weak signals.

The amplified signals are mixed by a diode double-balanced mixer with an oscillator signal (generated by Q2) that is nominally 60–70 MHz lower than the received frequency. A 2-dB pad is used between the oscillator and mixer to reduce interaction. The IF output from the mixer is fed to a low-pass filter that cuts off at about 100 MHz. That reduces UHF signal feedthrough. Amplifier Q3 boosts the IF signal at 60 or 66 MHz (channel 3 or 4) by about +15 dB. The output of Q3 is fed to the TV receiver being used as an IF amplifier.

Figure 2 shows the schematic of the downconverter. The input signal from J1 is applied to a tap on L1, the input (antenna) coil. L1 is nominally a 3-turn coil and the tap is at ¾ turn so that the voltage applied from J1 is stepped up four times. Capacitor C1 tunes L1 to resonance, and is also connected to gate 1 of Q1.

Capacitors C3 and C4 provide

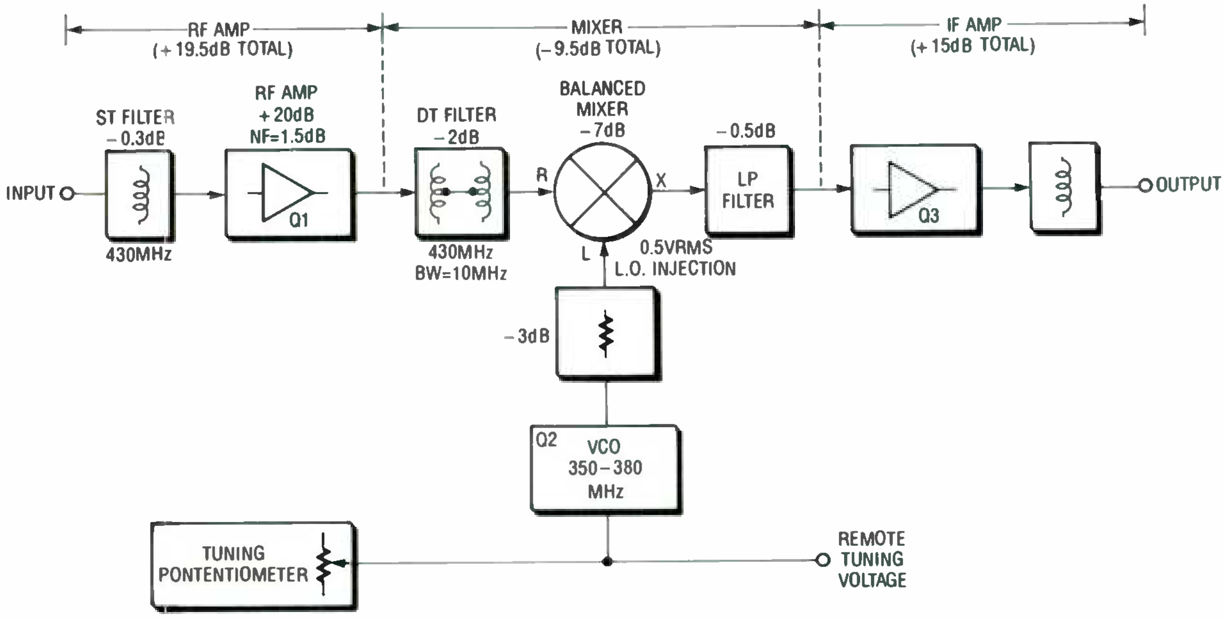


FIG. 1—DOWNCONVERTER BLOCK DIAGRAM. It consists of three active stages and a passive diode double-balanced mixer.

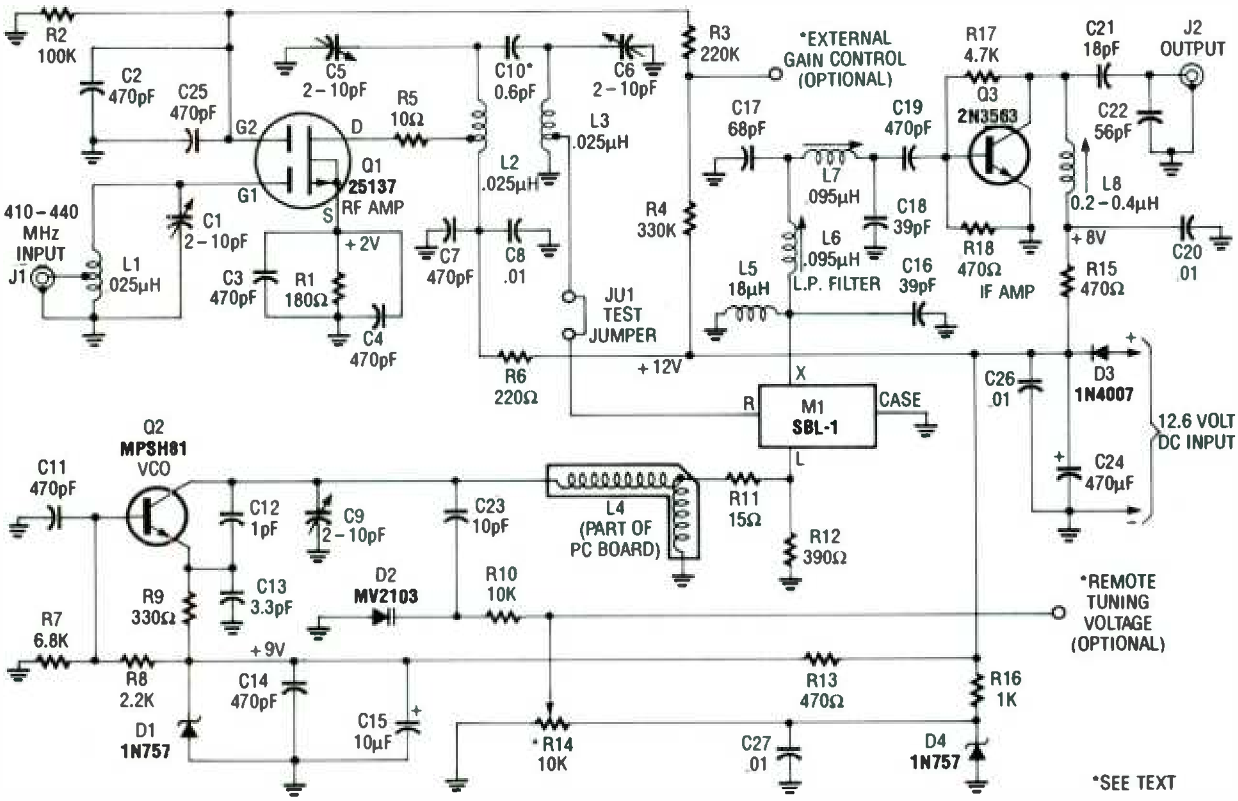


FIG. 2—DOWNCONVERTER SCHEMATIC. The input signal from J1 is applied to a tap on L1. Capacitor C1 tunes L1 to resonance and passes the signal to Q1, an NEC 25137 GaAsFET.

RF bypassing for the source of Q1, and R1 provides self-bias for Q1. Gate 2 of Q1 is biased by network R2, R3 and R4. An external gain-control signal (which is usually not required) can be applied to the junction of R3 and R4 if it becomes necessary to reduce the gain of the converter on very strong signals. A DC voltage of +6 volts will cause full gain, and −6 volts will cause nearly a −40-dB reduction in gain. The voltage can be derived from an AGC circuit, if necessary, but a potentiometer can also be used. Capacitor C2 provides RF

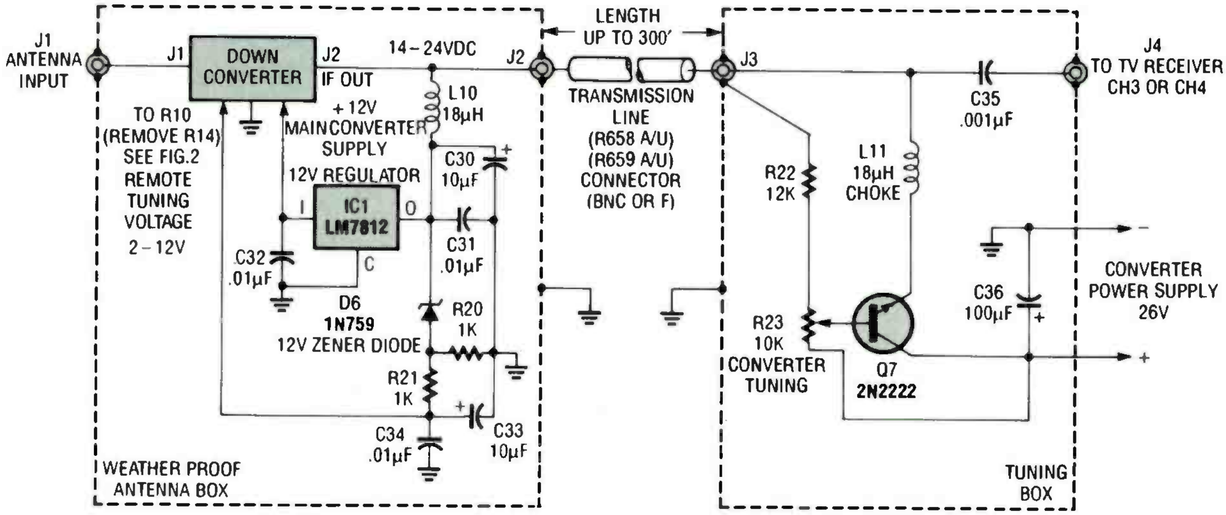


FIG. 3—THE DOWNCONVERTER can be supplied with an external DC voltage for remote-control tuning.

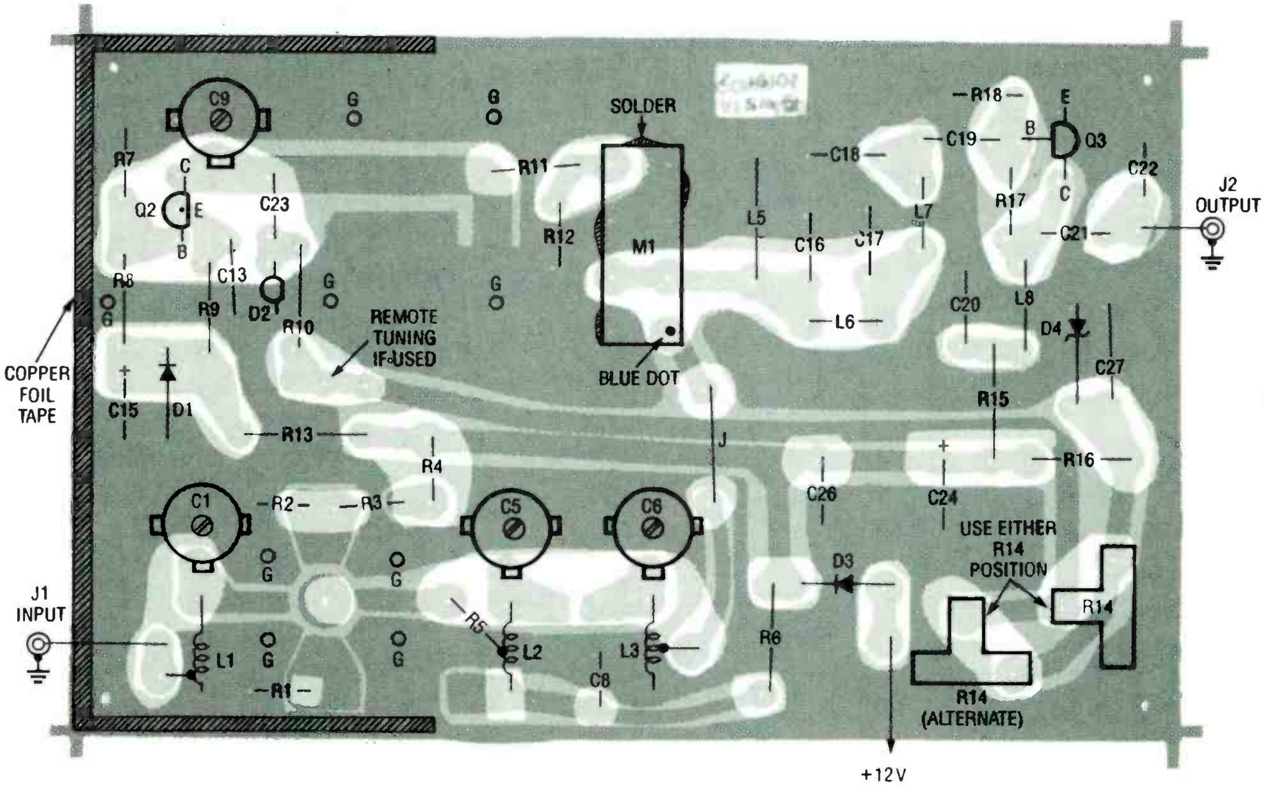


FIG. 4—PARTS-PLACEMENT DIAGRAM. This layout must be followed exactly to duplicate the performance of the downconverter. Some components mount on the solder side of the board as shown in Fig. 6.

grounding for gate 2 of Q1, and R5 reduces any UHF parasitic oscillations. The drain of Q1 is connected to a tap on L2, which is part of the bandpass filter network. Capacitors C7 and C8 provide RF grounding for the cold end of L2. DC bias is fed through R6. Under normal conditions, the drain pin of Q1 will be at +10 to +11 volts DC.

Capacitor C10 couples the signal from the first tuned circuit (C5-L2) to the second tuned circuit (C6-L3). The value of C10 is very small (0.6 pF); it determines the degree of coupling between L2 and L3. It is made from a small piece of PC board material and is mounted on the bottom of the main board. A signal from a tap on L3 is fed via test jumper JU1 to mixer M1. The local oscillator (L.O.) signal from Q2 is also fed to the mixer.

Transistor Q2 is the local oscillator, for which R13, D1, C14, and C16 provide a stabilized 9 volts DC. Because Q2 is a PNP transistor, it allows the collector to be DC grounded, which is an advantage in this type of oscillator circuit. Resistors R7 and R8 provide base bias for Q2, C11 provides a solid RF ground

PARTS LIST FOR THE ATV DOWNCONVERTER

All resistors are 1/8-watt, 5%, unless otherwise noted.

R1—180 ohms
R2—100,000 ohms
R3, R4—220,000 ohms
R5—10 ohms
R6—220 ohms
R7—6800 ohms
R8—2200 ohms
R9—330 ohms
R10—10,000 ohms
R11—15 ohms
R12—390 ohms
R13, R15—470 ohms, 1/4-watt
R14—10,000 ohms, potentiometer with shaft
R16—1000 ohms
R17—4700 ohms
R18—470 ohms

Capacitors

C1, C5, C6, C9—2–10 pF trimmer
C2–C4, C7, C11, C14, C25—470 pF, chip
C8, C20, C26, C27—0.01 µF, disc
C10—0.6 pF (must be handmade, see text)
C12—1 pF, NPO disc or chip
C13—3.3 pF, NPO disc or chip
C15—10 µF, 16 volts, electrolytic
C16, C18—39 pF, NPO disc
C17—68 pF, NPO disc
C19—470 pF, disc
C21—18 pF, NPO disc
C22—56 pF, NPO disc
C23—10 pF, NPO disc
C24—470 µF, 16 volts, electrolytic

Semiconductors

D1, D4—1N757A Zener diode
D2—MV2103 varactor diode
D3—1N4007 diode
Q1—25137 GaAsFET (NEC)
Q2—MPSH81 NPN transistor
Q3—2N3563 NPN transistor

Other components

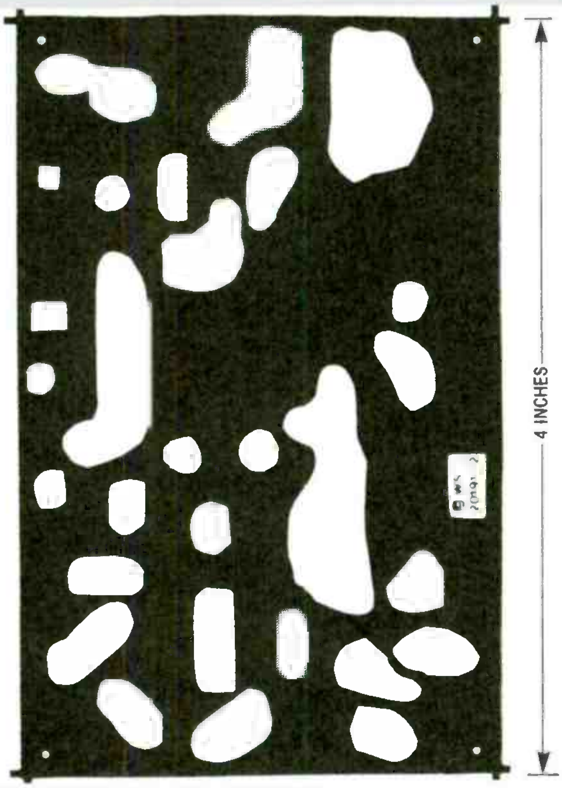
L1–L3—3 turns of 20 AWG tinned wire (approx. 0.025 µH, see Fig. 5)
L4—part of PC board etching, see text
L5—18 µH RF choke
L6, L7—8 turns of 22 AWG enameled wire wound on No. 8 screw (approx. 0.095 µH, see Fig. 5)
L8—9½ turns of 22 AWG enameled wire wound on No. 8 screw, with ferrite slug (see Fig. 5)
M1—MCL SBL-1 mixer
J1, J2—F connector

Miscellaneous: PC board, 3/16-inch copper-foil tape, coaxial cable, project case, 12.6-volt DC power supply, solder, etc.

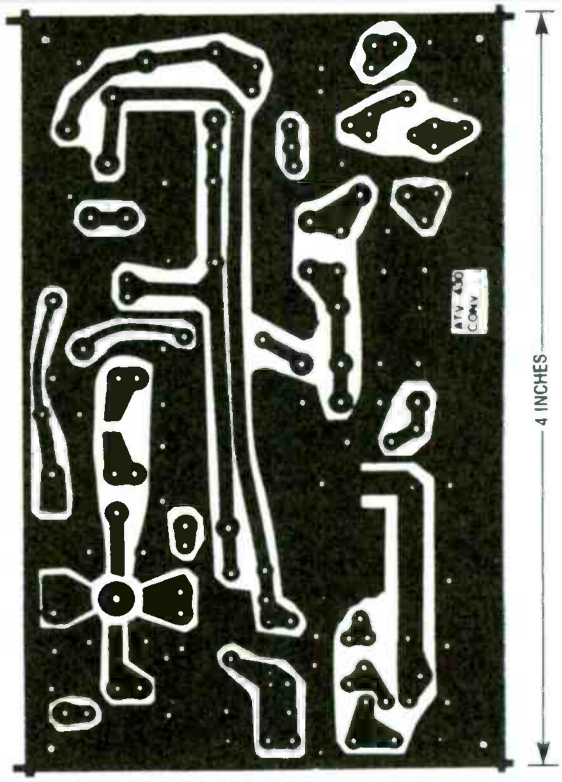
Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, New York 10804:

- **A kit of parts to build the downconverter (includes PC board and all parts that mount on it, J1 and J2, and wire to wind all inductors (metal case and power supply not included)—$59.50 + $3.50 S&H (Note that none of the parts shown in Fig. 3 are included with the downconverter kit.)**
- **Metal case as shown—$12.50**
- **2-watt ATV transmitter kit with a 439.25-MHz crystal—(see previous story)—$110 + $3.50 S&H**
- **A 1.0-watt, 9-volt transmitter kit with a 439.25-MHz crystal—$112 + $3.50 S&H**

See previous stories on ATV for complette offerings and prices.



COMPONENT SIDE FOIL PATTERN.



SOLDER SIDE FOIL PATTERN.

for the base of Q2, and R9 provides emitter bias. Nominal current through Q2 is about 5 to 6 milliamperes. Capacitors C12 and C13 provide a feedback network for Q2.

Components C9 and L4 (a length of microstrip line etched on the PC board), together with

C23 and varactor diode D2, form a circuit that can be tuned via the bias on D2 over the range of 350 to 390 MHz, depending on the setting of C9. Therefore, Q2 will oscillate over that frequency range, because positive feedback is provided by C12 and C13, and Q2 acts as a grounded-base amplifier. Oscillator output is taken through R17 and R12 to mixer M1. The level at terminal L of the mixer is about 0.3 volt RMS. Resistor R11 is connected to a tap on L4, which also provides bias return for the collector of Q2, because it is at DC ground.

The output from mixer M1 at 60 to 70 MHz (the difference frequency between received signal and L.O. frequency) appears at mixer terminal X. There is about a 7-dB loss in the mixer. Coil L5 provides a DC return for the mixer IF port. A low-pass filter made up of C16, L6, C17, L7, and C18 eliminates any remaining UHF signal components appearing at terminal X. Transistor Q3 is an IF amplifier stage, which is biased by R13, R14, and R15 to a V_{CE} of 8 volts and a collector current of about 8 mA. Tuned circuit L8, C21, and C22 can be tuned to either channel 3 or 4. The signal from the low-pass filter is coupled to Q3's base via C19. Transistor Q3 provides about a 15-dB gain; its output signal appears at J2. Power for the downconverter is supplied through D3, which protects against reverse voltages, and C24 and C26, which bypass RF and noise.

Resistor R10 couples DC bias to D2 supplied from tuning-potentiometer R14. Components R16, D4, and C25 provide 9-volts DC for that purpose. If desired, R10 can be supplied with external DC for remote-control tuning, or to allow the downconverter to be mounted close to the antenna. That is commonly done to reduce transmission-line losses between the antenna and converter—losses run high at 450 MHz unless very expensive transmission line, such as ½-inch hard line, is used. If you are planning on remote-controlling the converter, install R14 so it's easy to move.

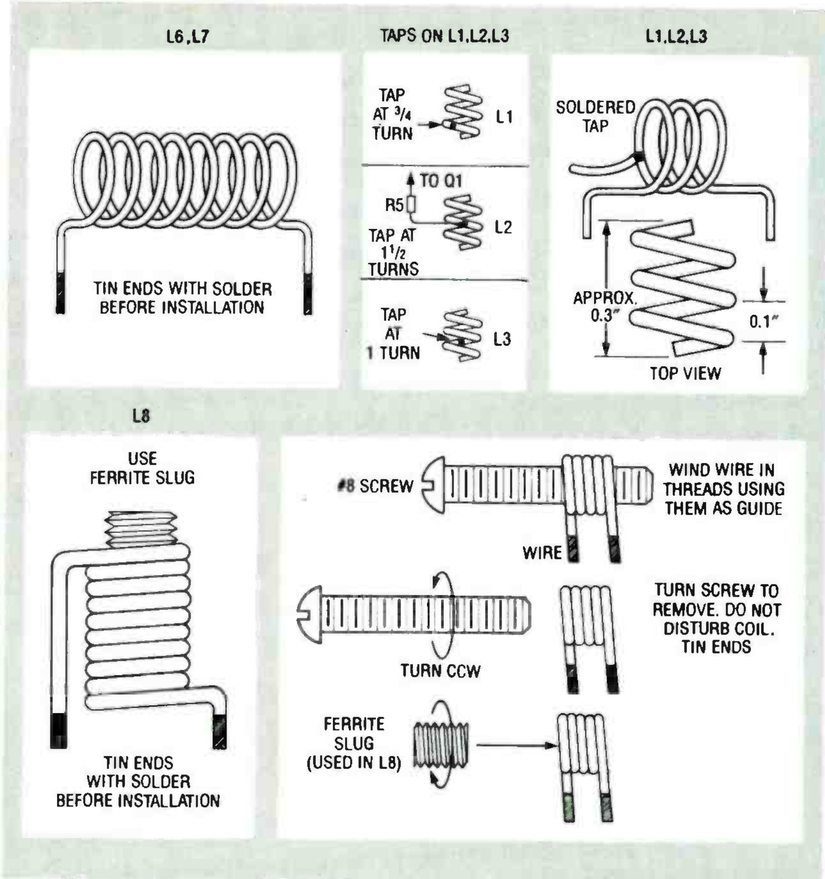


FIG. 5—COILS L1, L2, AND L3 are three turns each of 20 AWG tinned wire wound around a No. 8 screw and stretched to 0.3 inch. The lead from J1 has its center conductor soldered to L1 at ¾ turn from the grounded end. Resistor R5 is soldered 1½ turns from the end of L2 that connects to R6, C7, and C8. Coil L3 is tapped at 1 turn from the grounded end. Coils L6 and L7 are 8 turns each of 22 AWG enamelled wire wound on a No. 8 screw. Coil L8 is 9½ turns of 22 AWG enamelled wire wound on a No. 8 screw with a ferrite tuning slug added.

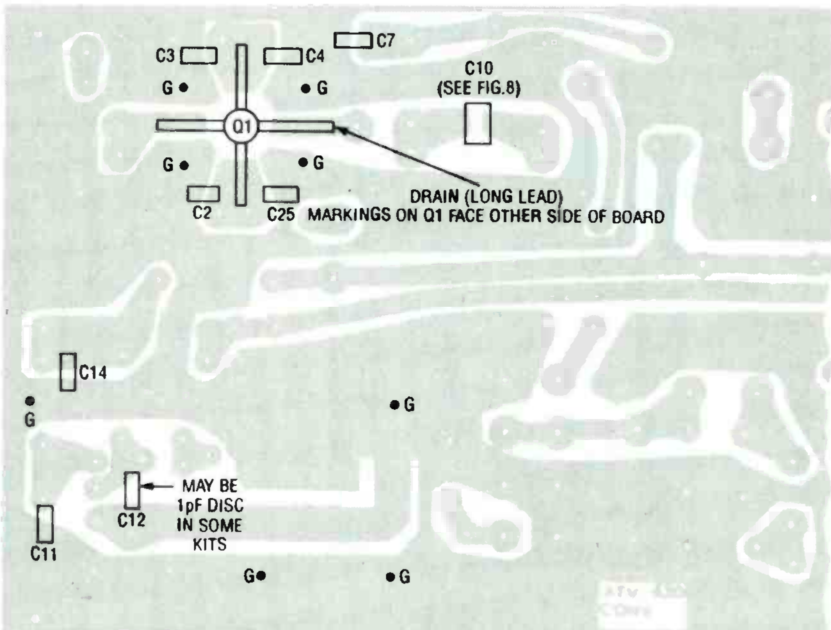


FIG. 6—ALL CHIP CAPACITORS, C10 (see Fig. 8), and Q1 mount on the solder side of the board. The markings on Q1 face the component side of the board.

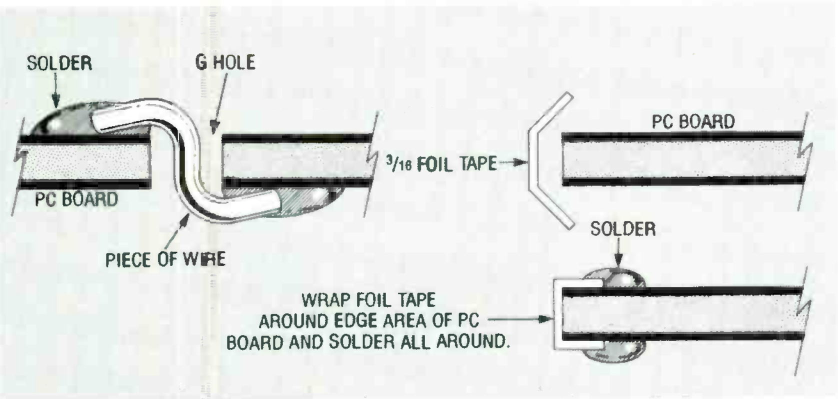


FIG. 7—ALL HOLES MARKED "G" in Fig. 4 must have jumper wires passed through them that are soldered on both sides of the PC board as shown here. Also, both sides of the board must be grounded together with copper-foil tape as shown.

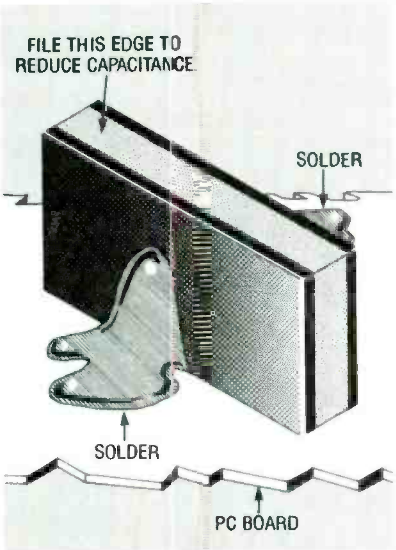


FIG. 8—TO MAKE C10, take a small square of G-10, 0.062-inch PC board material and trim it to a 3/16-inch square. Install it on the solder side of the board in the location shown in Fig. 6.

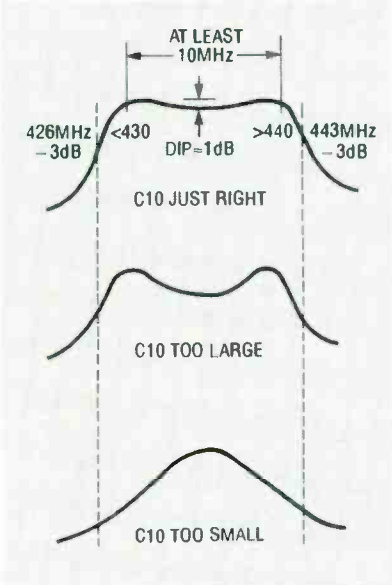


FIG. 10—PEAK THE CONVERTER for a response as shown here. By trimming C10 with a file you can experiment with the coupling and resultant bandpass shape.

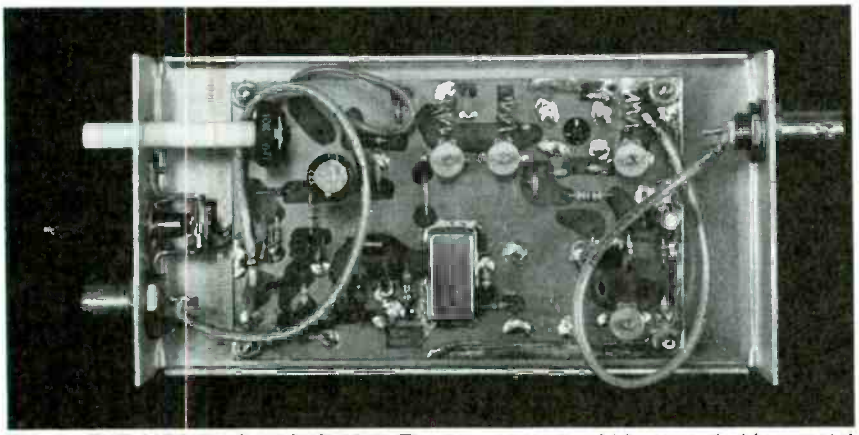


FIG. 9—THE AUTHOR'S PROTOTYPE. The converter should be mounted in a metal box, weatherproof if outdoor use is intended.

Figure 3 shows how J2 can be connected to a long coaxial transmission line that runs to the ATV receiver station. The cable is isolated from ground and can therefore carry a DC voltage. The DC voltage is impressed on the cable as follows: A nominal 26-volt power source at the ATV receiver station is connected to Q7, a 2N2222 NPN transistor used as an emitter-follower. Resistors R22 and R23 produce a variable voltage of 14 to 26 volts at the base of Q7, whose emitter will follow the voltage. Power is supplied to the cable through L11, and by varying potentiometer R23, the voltage applied via R22 to the cable at J3 can be adjusted between 14 and 24 volts. Capacitor C35 prevents any DC voltage from appearing at J4.

The DC voltage is taken off the cable via the 18μH RF choke L10. Capacitors C30 and C31 remove noise from the DC voltage and provide an RF ground. Positive voltage is fed to the downconverter via the cable's center conductor and the outer shield serves as the negative supply lead: it is grounded to the case and ground foil.

The DC input is fed to D6, a 12-volt Zener diode (a 1N759 can be used). Capacitors C33 and C34 filter any noise from the voltage which will be 12 volts less than the voltage on the coaxial transmission line (+14 to +24 volts), or +2 to +12 volts DC. That is fed to R10, which feeds the tuning voltage to the downconverter varactor. By varying the DC voltage on the transmission line between +14 and +24 volts, not only can the downconverter be powered, but it can be remotely tuned to a desired frequency as well.

Note that the components shown in Fig. 3 are not part of the downconverter board, and they are used only if remote operation is required.

Construction

The PC board material (G-10, 0.062 inch thick glass epoxy) and layout must be followed exactly to duplicate the performance of the downconverter. The stray capacitance, coupling between elements, and L4 are all integrated into the design of the board. Any layout deviations can change those specifications. The foil patterns are provided for you to make your own board, and the parts-placement diagram is shown in Fig. 4.

First install resistors R1–R13, and R15–R17. Next, install all capacitors except the chip capacitors and C10. Install mixer M1, and then wind and install coils L1, L2, L3, L5, L6, L7, L8.

Coils L1, L2, and L3 are three turns each of 20 AWG tinned wire wound around a No. 8 screw as a form (see Fig. 5) and then stretched to a length of 0.3 inch with the turn spacing evenly maintained. All three of those coils must be tapped as shown in Fig. 5. The lead from J1 (which can be coaxial 50-ohm line) has its center conductor soldered to L1 at $\frac{3}{4}$ turn from the grounded end. Resistor R5 is soldered $1\frac{1}{2}$ turns from the end of L2 that connects to R6, C7, and C8. Coil L3 is tapped at 1 turn from the grounded end.

Coils L6 and L7 are 8 turns each of 22 AWG enamelled wire wound on a No. 8 screw. The screw is removed after winding the coil. Coil L8 is $9\frac{1}{2}$ turns of 22 AWG enamelled wire, wound the same way as L6 and L7. However, after winding, the No. 8 screw is removed and a ferrite tuning slug is screwed into the winding as shown in Fig. 5. RF choke L5 is installed as if were a resistor.

Install Q2, Q3, D1, D2, and D3. Now install the chip capacitors. Chip capacitors require special installation procedures—and they all mount on the solder side of the PC board. Figure 6 shows where all of the chip capacitors, C10 (which we'll get to in a moment), and Q1 are mounted on the solder side of the board. As for the chip capacitors, first tin the area on the PC board where a chip is to be installed. Then hold the chip in place with the tip of a small screwdriver or tweezers and tack solder one side. After it's tacked in place, fully solder both sides of the chip.

Now install Q1, whose long lead is the drain. Make sure you use a grounded iron and work in a static-free area. Treat Q1 as you would a delicate CMOS IC. The tuning potentiometer (R14) can be mounted in different positions for added flexibility; it can be mounted off the board for remote tuning purposes.

Make sure all holes marked "G" in Fig. 4 have jumper wires passed through them and soldered on both sides of the PC board as shown in Fig. 7. Also, both sides of the board must be grounded together with copper foil tape, also as shown in Fig. 7. Once the tape is in place, solder both sides.

Next make capacitor C10. Take a small square of G-10, 0.062 material (the same as the PC board material) and trim it to a $\frac{3}{16}$-inch square. Install it on the solder side of the board as shown in Fig. 8. Connect coaxial 50-ohm cables to J1 and J2, and DC power leads to D3 and ground. Set trimmer capacitors C1, C5, and C6 to about 20% of maximum, and set C9 to about 80% of maximum. If you use R14, it can be set halfway. If R14 is not used, R10 should be temporarily connected to a supply of about +8 volts. Figure 9 shows the author's prototype.

Tune up

Tuning consists of peaking the tuned circuits for best reception. Using a frequency counter connected across R12, adjust C9 for a nominal frequency of 370 to 375 MHz. If installed, R14 should vary that by about ±15 MHz. If R14 is not installed, 0 to +12 volts applied to R10 should do the same. The oscillator might stop if less than 2 volts is applied to R10—which is acceptable as long as you can obtain a frequency range of 30 MHz.

Connect the converter to a TV set tuned to channel 3 and to an external antenna for ATV reception. Find a signal and peak L1, L2, and L3 for the best picture. You can also use an RF signal generator tuned to 435 MHz if no on-the-air signal is available. As a last resort, you can also peak L1, L2, and L3 on noise.

It is also possible to experimentally peak the converter on UHF channels 14, 15, or 16 if no other signals are available. Set C9 for a L.O. frequency of around 410 to 420 MHz. Note: This is only to see if everything works if there's no other way to obtain an ATV signal and you have no access to a signal generator. You will later have to re-peak the converter to 420 to 450 MHz.

If a sweep generator is available, simply peak the converter for a response as shown in Fig. 10. By trimming C10 (use a file on the edge of it) you can also experiment with the coupling and resultant bandpass shape. You can also do this with a calibrated RF signal generator and a receiver and/or RF voltmeter, but this will take more time.

The converter should be mounted in a weatherproof metal box, if outdoor use is intended. A metal box reduces stray signal pickup, and also protects the converter from damage.

If you will be remote-tuning the converter (as was shown in Fig. 3), the converter should be mounted right at the antenna or very close to it. That permits a short cable from J1 to the antenna, reducing signal losses. The converter can then be mounter as far as 300 feet from the TV monitor. ■

Build an Aviation-Band Receiver

Join a growing throng of listening enthusiasts who regularly tune in commercial air-to-ground and ground-to-air aeronautics communications.

BY FRED BLECHMAN

If, like many scanner enthusiasts and ham operators, you are interested in listening in on all the excitement manifest in aeronautic communication, but lack the equipment to pursue your interest, then perhaps the *Aviation Receiver* described in this article is for you. The Aviation Receiver, designed to tune the 118–135-MHz band, features exceptional sensitivity, image rejection, signal-to-noise ratio, and stability. The receiver is ideally suited to listening in on ground and air communications associated with commercial airlines and general aviation.

Powered from a 9-volt transistor-radio battery, it can be taken along with you to local airports so that you won't miss a moment of the action. And even if you're nowhere near an airport, this little receiver will pick-up the air-to-ground and ground-to-air communications of any plane or ground facility within about 100 miles!

Circuit Description. Figure 1 shows a schematic diagram of the Aviation Receiver—a superhetrodyned AM (amplitude modulated) unit built around four IC's: an NE602 double-balanced mixer (U1), an MC1350 linear IF amplifier (U2), an LM324 quad op-amp (U3), and an LM386 audio amplifier (U4).

In operation, an antenna that plugs into J1 picks up the AM signal. That signal is then coupled through C1 to a three-section, tuned-filter network, consisting of L1–L5 and C2–C6. Signals in the 118–135-MHz VHF (very high frequency) range are coupled through C7 to a VHF transistor (Q1), where the signals are amplified. From there, the signals are fed through C8 to the input of U1 (the NE602 double-balanced mixer), which in this application serves as a local oscillator. A variable inductor (L6) and its associated capacitor network set the local-oscillator frequency at 10.7-MHz higher than the incoming 118–135-MHz signals. A tuning network, consisting of varactor diode D1 and potentiometer R1, allows the local-oscillator frequency to be tuned across about 15 MHz.

The 10.7-MHz difference between the received signal and the local-oscillator frequency (*i.e.*, the intermediate frequency or IF) is output at pin 4 of U1 to a 10.7-MHz ceramic filter (FIL1). The filter is used to ensure a narrow pass band and sharp signal selectivity.

The output of FIL1 is amplified by Q2 and then fed through C16 to U2 (an MC1350 IF amplifier), which, as configured, also offers automatic gain control (AGC), as we'll see shortly. The amplified 10.7-MHz IF signal is peaked using variable transformer T1. The AM audio is then demodulated by diode D2. After that, the audio is fed in sequence through the four sections of U3 (an LM324 quad op-amp).

Note that a portion of U3-a's output signal is fed back through resistor R25 to the AGC-control input of U2 at pin 5. That signal is used to automatically decrease the gain of U2 when strong signals are present or to automatically increase U2's gain for weak signals. That keeps the output volume of the circuit within a comfortable listening range regardless of the strength of the incoming signals.

The receiver circuit also contains a squelch circuit that is controlled by potentiometer R3, which is used to kill random noise below a selected threshold level. When properly set, the squelch control virtually eliminates background noise, so that all you hear are incoming signals that can be brought up to a usable level. Potentiometer R2 controls the overall volume fed through C26 to U4, an LM386 low-voltage audio-power amplifier. Due to the overall design and squelch control, the audio output is quite low in background noise, and yet it's capable of driving simple communications speakers or earphones to excellent volume levels.

Construction. The Aviation Receiver was assembled on a printed-circuit board, measuring about 4 × 4¾ inches. Figure 2 shows a full-size template of that printed-circuit board's layout. A kit of parts (which includes an etched and pre-drilled, printed-circuit board, but no case) is offered by the supplier listed in the Parts List.

Although most of the parts for this project are commonly available through conventional electronic-

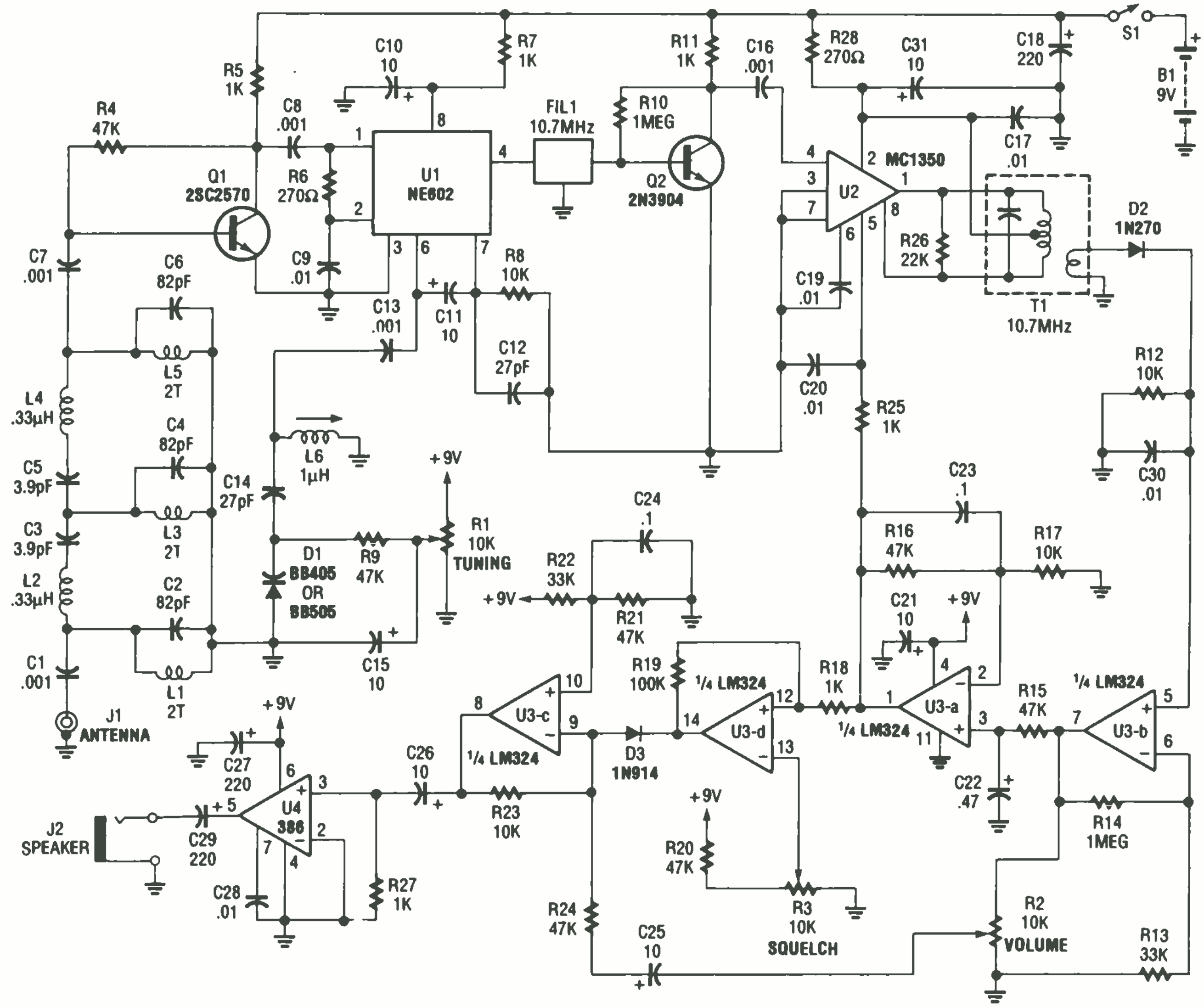
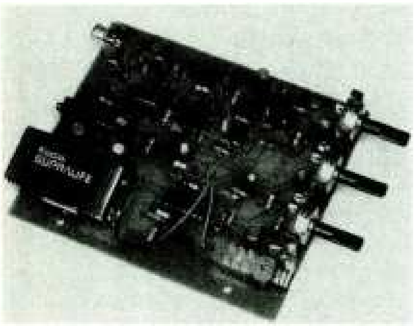


Fig. 1. The Aviation Receiver—a superheterodyne unit, built around four IC's—is designed to receive AM signals in the 118–135-MHz frequency range.



All of the components for the Aviation Receiver (including the 9-volt transistor-radio battery that powers the circuit) mount on a single printed-circuit board.

components suppliers, a source for some of the more difficult to find parts is given in the Parts List for those who prefer to do their own shopping. If you opt to gather your own parts or you plan to use what you have on hand, keep in mind that the circuit-board layout was designed to accommodate components of specific dimensions in some cases; jacks J1 and J2, switch S1, transformer T1, and all three potentiometers, for example. To ease the pain of obtaining those parts, a "Special Parts Kit" is also available from the listed source.

Also note that either of the Siemens parts specified in the Parts List for varactor diode D1 will work, but both may be difficult to find from hobbyist sources. However, the second unit (BB505) is available from Allied Electronics.

However you go about collecting the parts for this project, don't even think about building the receiver circuit without the printed-circuit board. At the frequencies involved, the placement of every wire and part, and every part value is critical for trouble-free performance.

Once you've obtained all of the components and the board for the Aviation Receiver, construction can begin. A parts-placement diagram is shown in Fig. 3. When assembling the project, take special care that polarity-sensitive components (electrolytic capacitors, diodes, and transistors) are installed properly. Just one part installed *backwards* can cause grievous harm!

Begin by installing the passive components (jumper wires, resistors, capacitors, and inductors). Follow that by installing the active components; diodes, transistors, and IC's. Once the active components have been in-

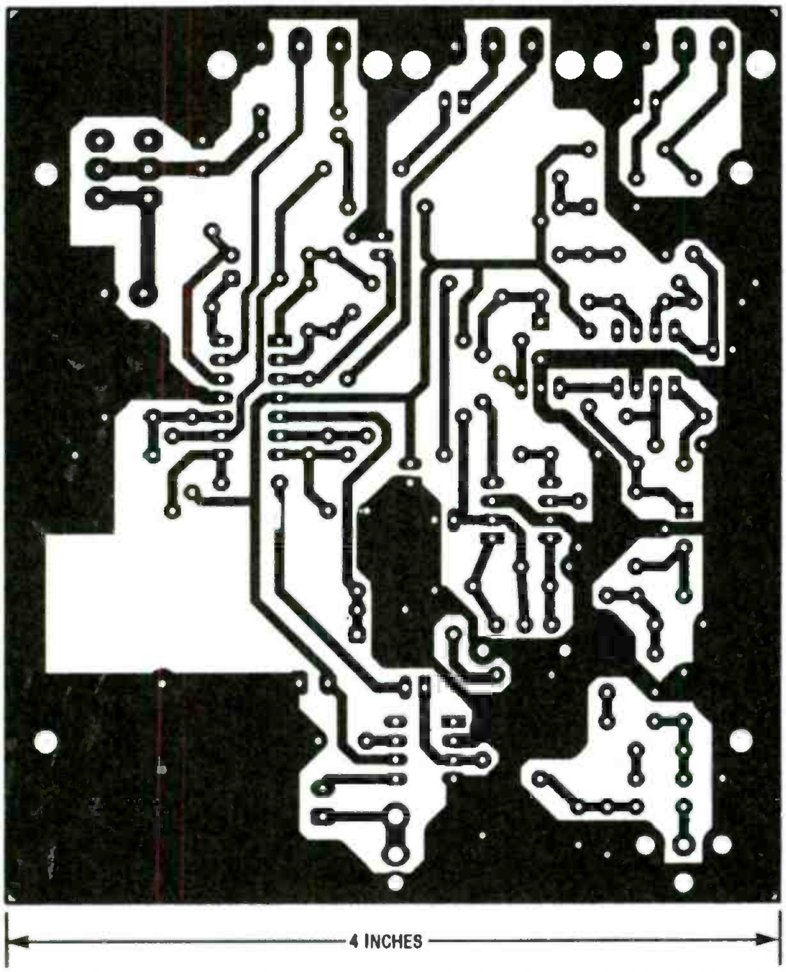
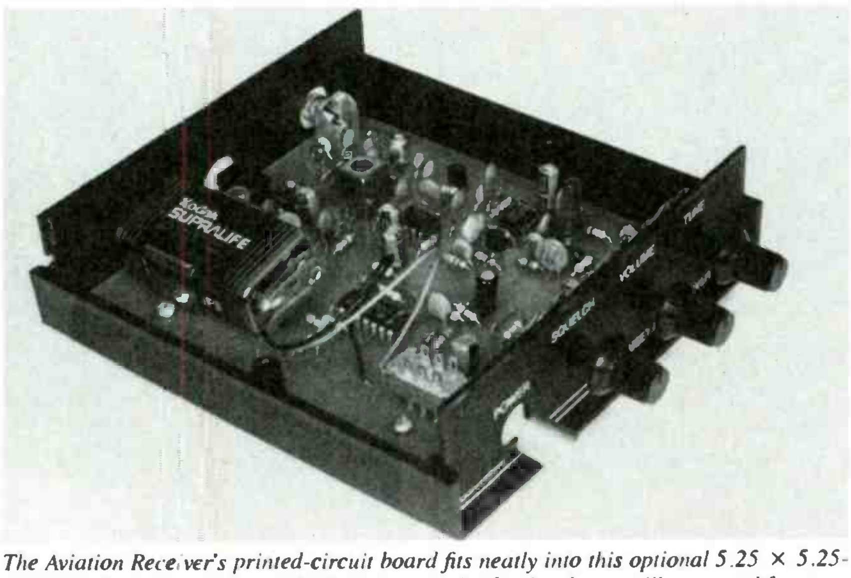


Fig. 2. Here's a full-size printed-circuit pattern for the Aviation Receiver. The printed-circuit board can be purchased as part of a full-blown kit or separately from the supplier listed in the Parts List.



The Aviation Receiver's printed-circuit board fits neatly into this optional 5.25 × 5.25- × 1.5-inch custom cabinet (which comes with knobs, hardware, silk-screened front and back panels, as well as rubber mounting feet).

stalled, check your work for the usual construction errors: cold solder joints, misplaced or misoriented components, solder bridges, etc. Once you've determined that the circuit has been correctly assembled, it's time to consider the enclosure that will house your receiver.

The receiver's circuit board can be housed in any enclosure that you choose. However, if you prefer, an optional case and knob kit for the receiver is available from the supplier listed in the Parts List. The optional case is supplied with neatly lettered front and rear panels, knobs, rubber feet, and mounting screws.

If you choose a case other than the one available from the listed supplier, it will be necessary to drill holes in the front and rear panels of the enclosure to accommodate the controls (S1, R1, R2, R3) and the jacks (J1 and J2). Once drilled, the front and rear panels of the enclosure can be labeled using dry-transfer lettering.

The antenna for the Aviation Receiver can be as simple as a 21-inch length of wire, or you can get a fancy roof-mounted aviation antenna. If you are near an airport, you'll get plenty of on-the-air action from the wire antenna, but if you're more than a few miles away, a decent roof-mount antenna offers a big improvement.

Alignment and Adjustment. Aligning the Aviation Receiver consists of nothing more than adjusting the slug in the local-oscillator coil (L6) for the center of the desired tuning range, and peaking the IF transformer (T1). The receiver can be calabrated using a VHF RF signal generator, frequency counter, or another VHF receiver by setting R1 to its mid-position; remember that you want to set the local-oscillator frequency 10.7-MHz higher than the desired signal or range to be received. Then, using a non-metallic alignment tool—a metal tool of any kind will drastically detune the coil, making alignment almost impossible—adjust L6 (the LO coil) until you hear aircraft or airport communications.

Once you are receiving aircraft or airport frequencies, adjust T1 for the best reception. Typically, T1 is adjusted 2–3 turns from the top of the shield can. If you don't have any signal-reference equipment for alignment, and are not yet hearing airplanes, your best bet is to pack up the receiver and the necessary alignment tools, and head for the nearest airport! If the airport has no control tower, visit a gen-

WHAT YOU CAN EXPECT TO HEAR

No matter where you live, you will be able to receive at least the airborne side of many air-traffic communications. If you know where to tune, you can hear any aircraft that you can see, plus planes a hundred miles away and more, since VHF signals travel "line of sight." An airliner at an altitude of 35,000 feet and in the next state is probably still line-of-sight to your antenna.

Similarly, whatever ground stations you may hear are also determined by the line-of-sight character of VHF communication. If there are no major obstacles (tall buildings, hills, etc.) between your antenna and an airport, you'll be able to hear both sides of many kinds of aviation communication. Be prepared for them to be fast and to the point, and for the same airplane to move to several different frequencies in the span of a few minutes!

At most metropolitan airports, pilots communicate with the FAA on a "Clearance Delivery" frequency to obtain approval or clearance of the intended flight plan, which is done before contacting ground control for taxi instructions.

From the control tower, ground movements on ramps and taxiways are handled on the Ground Control Frequency, while runway and in-flight maneuvers near the airport (takeoffs, local-traffic patterns, final approaches, and landings) are on the Tower Frequency. ATIS, or "Automatic Terminal Information System," is a repeated broadcast about basic weather information, runways in use, and any special information such as closed taxiways or runways. Such a broadcast offers an excellent steady signal source for initial adjustment of your receiver, if you are close enough to the airport to receive ATIS.

Approach Control and Departure Control are air-traffic radar controllers that coordinate all flight operations in the vicinity of busy metropolitan-airport areas. When you hear a pilot talking with "Jacksonville Center" or "Indianapolis Center," these are regional ATC (Air Traffic Control) centers. The aircraft is really en route on a flight, rather than just leaving or approaching a destination. A pilot will be in touch with several different Regional Centers" during a cross-country flight.

Airports without control towers rely on the local Unicom frequency for strictly advisory communications between pilots and ground personnel, such as fuel service operators. The people on the ground can advise the pilot what they know about incoming or outgoing aircraft, but the pilot remains responsible for landing and takeoff decisions. Typical Unicom frequencies are 122.8 and 123.0 MHz.

The FAA's network of FSS (Flight Service Stations) keeps track of flight plans, provides weather briefings and other services to pilots. Some advisory radio communication takes place between pilots and a regional FSS. If there is an FSS in your local area, but no airport control towers, the FSS radio frequency will stay interesting. ■

PARTS LIST FOR THE AVIATION RECEIVER

SEMICONDUCTORS

U1—NE602 double-balanced mixer, integrated circuit (Digi-Key)
U2—MC1350 linear IF amplifier, integrated circuit (Allied 858-3011)
U3—LM324 quad op-amp, integrated circuit (Digi-Key)
U4—LM386 low-voltage audio-power amplifier, integrated circuit (Digi-Key)
Q1—2SC2570 or 2N5179 NPN UHF transistor (Allied 858-1041)
Q2—2N3904 general-purpose NPN silicon transistor (Digi-Key)
D1—BB405 or BB505 varactor diode (Siemens, Allied 586-0610)
D2—1N270, 1N34, or similar germanium diode
D3—1N914 silicon diode

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1–R3—10,000-ohm PC-mount potentiometer
R4, R9, R15, R16, R20, R21, R24—47,000-ohm
R5, R7, R11, R18, R25, R27—1000-ohm
R6, R28—270-ohm
R8, R12, R17, R23—10,000-ohm
R10, R14—1-megohm
R13, R22—33,000-ohm
R19—100,000-ohm
R26—22,000-ohm

CAPACITORS

C1, C7, C8, C13, C16—0.001-µF, ceramic-disc
C2, C4, C6—82-pF, ceramic-disc
C3, C5—3.9-pF, ceramic-disc
C9, C17, C19, C20, C28, C30—0.01-µF, ceramic-disc
C10, C15, C21, C25, C26, C31—4.7- to 10-µF, 16-WVDC, electrolytic
C11—10-pF, ceramic-disc
C12, C14—27-pF, NPO ceramic-disc
C18, C27, C29—100- to 220-µF, 16-WVDC, electrolytic
C22—0.47-µF, 16-WVDC, electrolytic
C23, C24—0.1-µF, ceramic-disc

INDUCTORS

L1, L3, L5—1½-turns #24 to #30 gauge wire
L2, L4—0.33-µH, inductor (Digi-Key M9R33-ND)
L6—0.1-µH, 3½-turn, slug-tuned coil (Digi-Key TK2816)
T1—10.7-MHz, shielded transformer (Mouser 421F123)

ADDITIONAL PARTS AND MATERIALS

FL1—10.7-MHz ceramic filter (Digi-Key TK-2306)
S1—SPST switch, PC mount
J1—RCA jack, PC mount
J2—Subminiature phone jack, PC mount
B1—9-volt transistor-radio battery
Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

Note: The following items are available from Ramsey Electronics, Inc., 793 Canning Parkway, Victor, NY 14564; Tel. 716-924-4560: A complete kit of parts (AR-1BP), including printed-circuit board (but not the case or control knobs), $24.95; an etched and drilled printed-circuit board only (AR-1PCBP), $10.00; a Special Parts Kit (AR-1SPKBP) containing all semiconductors, R1–R3, all inductors, S1, J1 and J2, and FIL1, $14.50; Custom case and knob set (C-AR-1BP), $12.95. Please add $3 for orders under $20. All orders are subject to $3.95 postage/handling charge. New York State residents, please ad appropriate sales tax.

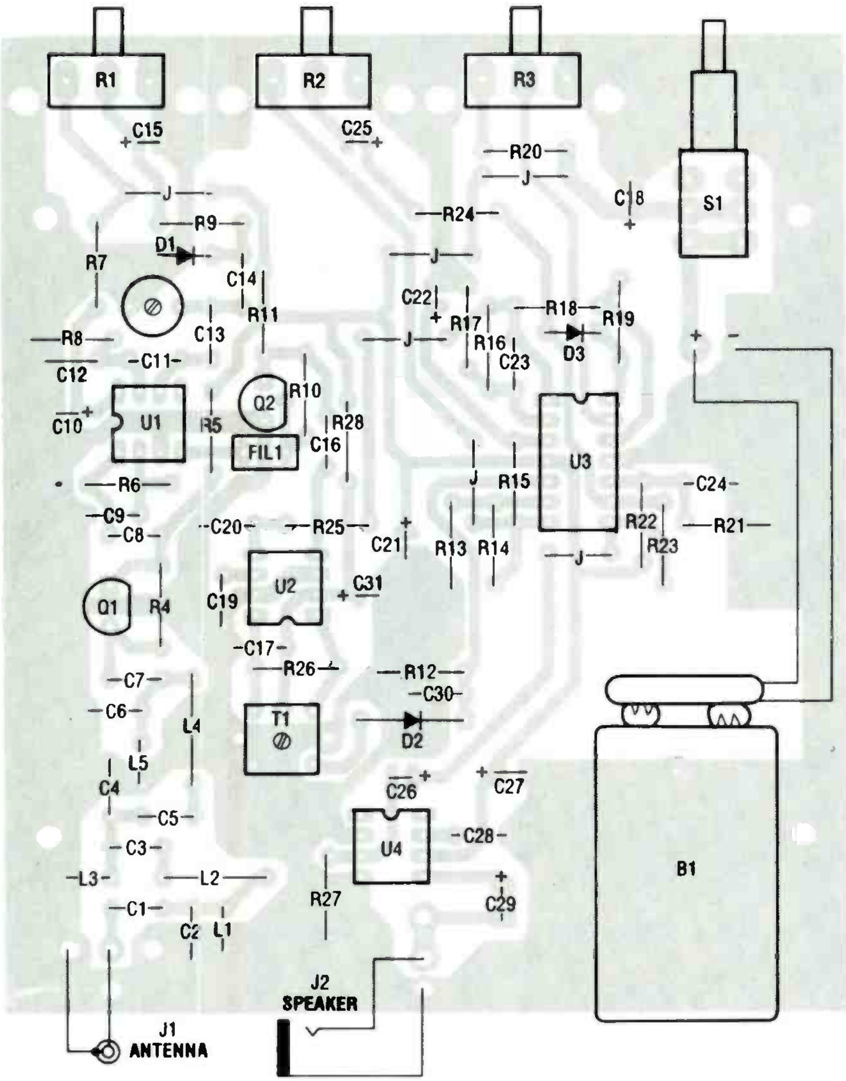


Fig. 3. Use this parts-placement diagram as a guide when assembling the printed-circuit board

eral aviation service center on the airport grounds, and ask which are the most active frequencies. Then adjust L6 and R1 until you hear the action.

A ground-service operator or private pilot may be willing to give you a brief test transmission on the 122.8 Unicom frequency. Remember, also, that if your airport has ATIS transmissions, you can get a steady test signal as soon as you are within line-of-sight of its antenna. (See the sidebar for explanation of Unicom and ATIS.)

Use. Plug an antenna into J1 and a 4- to 8-ohm speaker or earphone into J2. Turn on the Aviation Receiver by closing S1. You may or may not hear background noise. Turn R2 (the SQUELCH control) fully counterclockwise. Then rotate R2 clockwise until you hear a "pop" and some background noise; then back it off slightly (counterclockwise) past the pop. You are now in squelch mode.

With pilots and controllers talking so briefly, you will need to get used to tuning your receiver. As you sweep across the band (via R1), listen for a sound, then rock back and forth slightly to tune it in clearly.

Troubleshooting Suggestions. If the receiver does not work at all, carefully check the obvious things first; battery polarity, soldering of the battery wires and switch, and the connections to the speaker jack. Also, be sure to check that you've correctly installed all of the jumpers. If the circuit's operation is erratic, a solder connection is usually the culprit, or there could be a break in the antenna or speaker wire.

Pay special attention to the orientation of all IC's, transistors, diodes, and electrolytic capacitors. Also, be sure that C11 and C12 in U1's oscillator circuit are of the right values. Local-oscillator operation can be verified with a simple VHF receiver or frequency counter. Remember that the local oscillator should be set to a frequency 10.7 MHz above the desired listening range. If the oscillator works, only a defective or incorrectly installed part can prevent the rest of the receiver circuit from functioning. ■

PILOT AND CONTROLLER TALK

Don't blame the Aviation Receiver if all you hear are short bursts of words that don't make a lot of sense at first. Aviation communication is necessarily quick and brief, but clear and full of meaning. Generally, pilots repeat exactly what they hear from a controller, so that both know the message or instructions were correctly interpreted. If you are listening in, it's hard to track everything said from a cockpit, particularly in big city areas. Just to taxi, takeoff, and fly a few miles, a pilot may talk with 6 or 8 different air-traffic-control operations within a few minutes, all on different frequencies.

Here's the meaning of just a few typical communications:

"Miami Center, Delta 545 heavy out of three-zero for two-five." Delta Flight 545 acknowledges Miami Center's clearance to descend from 30,000 feet to 25,000 feet. The word "heavy" means that the plane is a jumbo jet, perhaps a 747, DC-10, or L-1011.

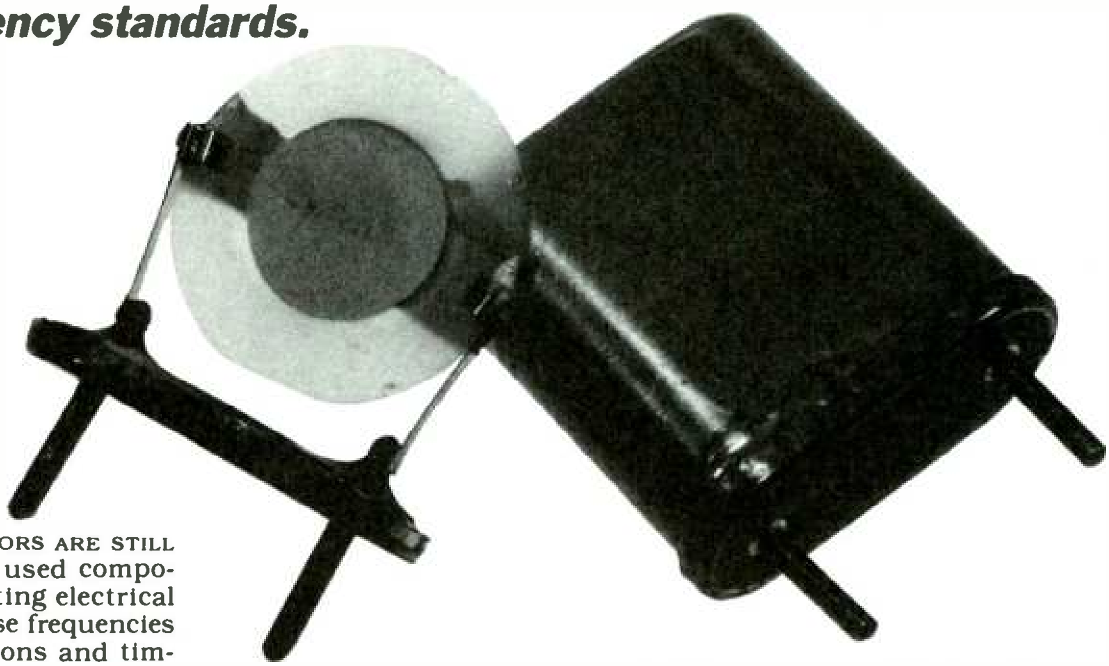
"Seneca 432 Lima cleared to outer marker. Contact tower 118.7." The local Approach Control is saying that the Piper Seneca with the N-number, or "tail number" ending in "432L" is cleared to continue flying an instrument approach to the outer marker (a precision radio beacon located near the airport), and should immediately call the airport radio control tower on 118.7 MHz. That message also implies that the controller does not expect to talk again with that aircraft.

"Cessna 723, squawk 6750, climb and maintain five thousand." A controller is telling the Cessna pilot to set the airplane's radar transponder to code "6750," climb to and level off at the altitude of "5000 feet."

"United 330, traffic at 9 o'clock, 4 miles, altitude unknown." The controller alerts the United Airlines flight of radar contact with some other aircraft off to the pilot's left at a "9 o'clock" position. Since the unknown plane's altitude is also unknown, both controller and pilot realize that it is a smaller private plane not equipped with altitude-reporting equipment. ■

Learn the fundamentals of crystal resonators —how and why they work in oscillators and frequency standards.

DAN BECKER



CRYSTAL OSCILLATORS

CRYSTAL RESONATORS ARE STILL the most widely used components for converting electrical energy into precise frequencies for communications and timing. Among the many instruments, products, and systems that depend on crystals to produce their precise, stable frequencies are frequency counters, radio transmitters, electronic navigation systems (transmitters and receivers), TV sets, and VCR's.

This article reviews the fundamentals of crystal resonators. Because of their utility and low cost, it emphasizes those made from quartz—how and why they work. The distortion of crystal resonators by the application of an alternating voltage across its faces is explained by the piezoelectric effect. Although synthetically produced quartz is still the leading material for manufacturing piezoelectric resonators, many other natural and man-made materials exhibit similar properties.

The information presented here is an introduction to the second installment in this series addressing the design and application of crystal-controlled oscillators such as the Colpitts, Pierce, and Butler. These oscillators, originally designed as vacuum-tube oscillators, have been adapted to transistors, and they include crystal resonators.

Armed with the information we'll present on the mechanical and electrical properties of crystal resonators, you'll have a better understanding of how to purchase and use low-cost crystals in your experiments or electronic projects.

Properties of crystals

The starting point in this subject is crystallography, the study of the form, structure, properties, and classification of crystals. This specialized subject linking physics, chemistry, geology, and mechanical engineering, is usually touched on only briefly in formal electronics engineering courses. With the wealth of subject matter to cover, instructors rarely say much about crystal resonators except to note that they are readily available components and can be viewed as electrically equivalent to high-Q LCR tank circuits.

Crystallography deals with lattices, bonding, and the behavior of slices that have been cut at various angles with respect to the crystal's axes. The mechanical properties of crystal lattices permit the important piezoelectric effect. Sections of crystal blanks that have been cut and polished according to well known rules vibrate when alternating voltages are applied across their faces.

The dimensions of the crystal slice—particularly its thickness and where and how it was cut from the blank— determine its electrical and mechanical properties. Other factors are the form of the electrodes and how the crystal is supported.

A resonant crystal's behavior can be simulated as either a parallel or series tank circuit with capacitors, an inductor, and a resistor. As tank circuits, crystals have figures of merit or Q's that are orders of magnitude superior to those of discrete-component resonant circuits.

Piezoelectric effect.

To understand how and why a crystal resonates as a tank circuit, it is necessary to understand the *piezoelectric effect*. Occurring in both man-made and natural crystals, there are two reciprocal modes to this effect. The first, as shown in Fig. 1-*a*, is the generation of a voltage between the opposite faces of a piezoelectric crystal as a result of stressing the crystal along its longitudinal axis.

The stress can take the form of squeezing (compression), stretching (tension), twisting (torsion), or shearing. In fact, if the crystal is stressed periodically, the output voltage will be alternating. This effect can be seen by observing needle swing on a high-impedance voltmeter or as an alternating wave on an oscilloscope.

The second mode, shown in Fig.1-*b*, is the mechanical deformation of the crystal caused by the application of a voltage across the opposite faces of the crystal. The degree of deformation will depend on the characteristics of the drive signal as well as those of the crystal cut. The application of an AC signal will produce periodic longitudinal, shearing or flexural motion.

In Fig. 1 the electrodes make the electrical connection to an external drive or output circuit. Here the thickness of the electrodes has been exaggerated; in practical resonators they are thin films of metal deposited on the opposing faces of the thinnest section of crystal, similar to the plates of a ceramic-disc capacitor.

The piezoelectric mode shown in Fig. 1-*a* is applied in crystal microphones, strain gauges, and receiving elements in depth sounders, for example. In those applications they are known as transducers. By contrast, the applications for the mode illustrated in Fig. 1-*b* include frequency standards for telecommunications, as frequency generators, and as time standards in watches, clocks and timebase generators. That mode is also applied in ultrasound generators and cleaning machines, and the transmitting elements of depth sounders, where they are also known as transducers. In depthsounders and ultrasonic diagnostic equipment, the transducer can function both as a transmitting and receiving element.

The piezoelectric effect is exhibited by many natural and man-made crystals; the most important natural crystals are quartz, Rochelle salt, and tourmaline. There are also many man-made piezoelectric elements such as ADP, EDT, and DKT that are used as filters and transducers. However, synthetic quartz is still the most widely used material for oscillator frequency control because of its permanence, low temperature coefficient, and high mechanical Q.

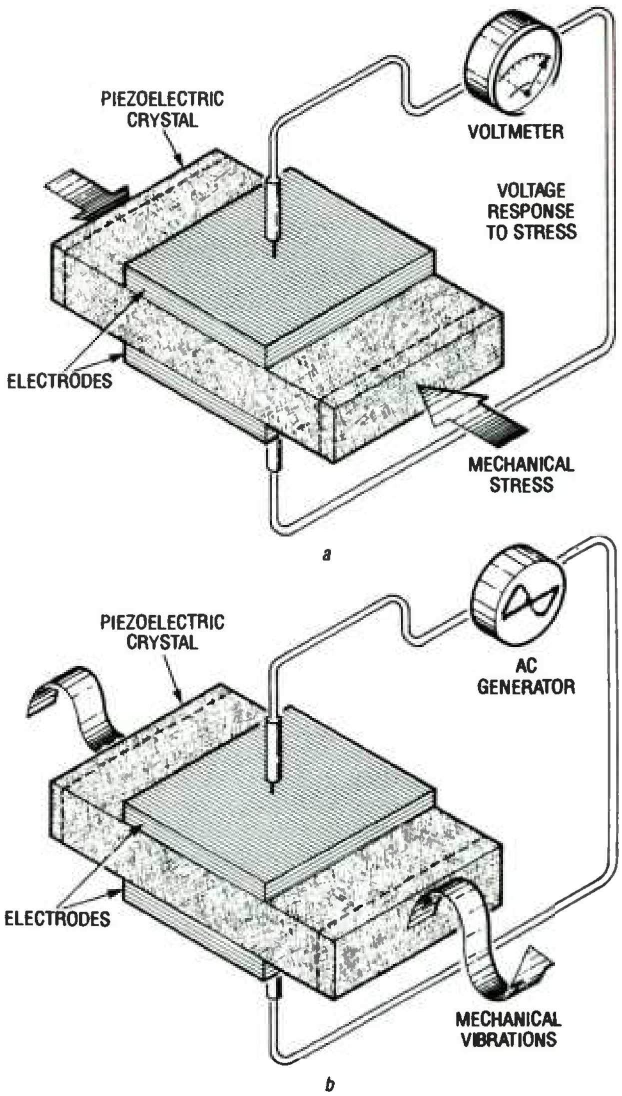


FIG. 1—THE PIEZOELECTRIC EFFECT IS RECIPROCAL. Stressing the crystal will generate a voltage which causes the meter needle to jump, a, and applying an alternating electrical signal across the electrodes will cause the crystal to be mechanically deformed, b.

Crystal resonance

The mechanical resonant frequency of a crystal can be determined by applying an alternating voltage from a signal generator (whose range extends

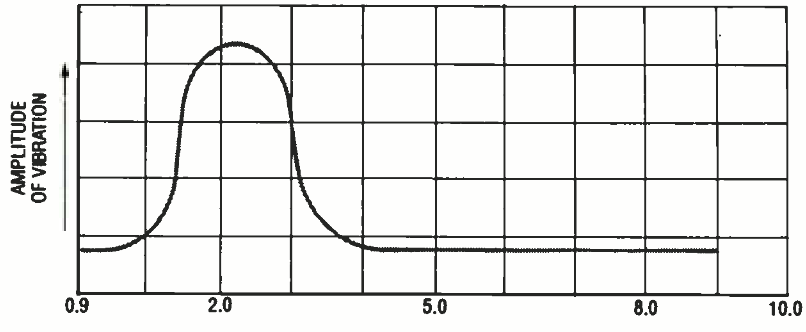


FIG. 2—A CRYSTAL'S RESONANT FREQUENCY can be determined by sweeping the input frequency until an amplitude peak representing mechanical resonance is seen on an oscilloscope.

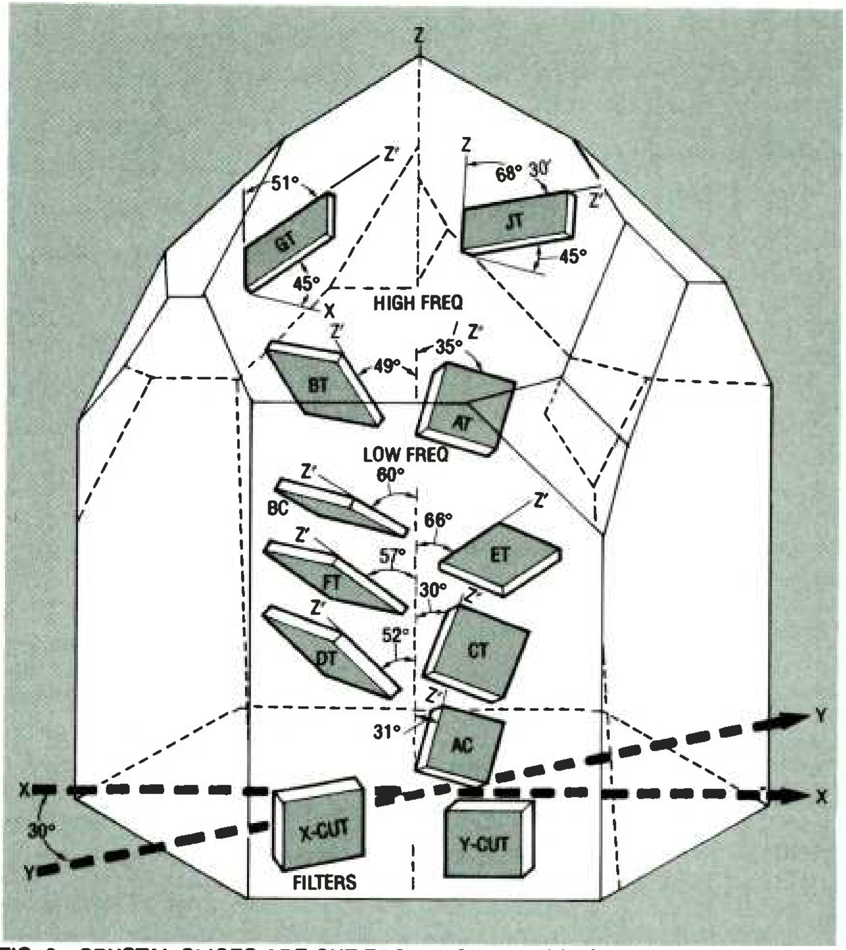


FIG. 3—CRYSTAL SLICES ARE CUT FROM A QUARTZ blank at different angles with respect to the axes to yield different mechanical and electrical characteristics.

over the likely resonance frequency) across the crystal faces. As shown graphically in Fig. 2, the applied frequency is slowly changed while observing the amplitude of the trace on an oscilloscope, the resonant frequency of a piezoelectric crystal under test can be found visually. The mechanical resonance of the crystal shown occurs at about 2.2 kHz.

The mechanical vibrations within a piezoelectric crystal slice are called *bulk acoustic waves* (BAW's). In general, the thinner (and smaller) the crystal slice, the more rapid will be the mechanical vibrations and the higher will be its resonant frequency.

Figure 3 is a perspective drawing showing various crystal cuts from a quartz blank. The orientation of the cut with respect to the blank's major crystallographic axes strongly influences its piezoelectric properties and temperature stability.

There are three principal crystal axes: X, Y, and Z (known as the *optical axis*). Figure 3 shows some of the most popular cuts and how they are oriented with respect to each other. They are designated by two letter symbols. Examples are AT, BT, CT, DT, ET, AC, GT, and JT. The angles shown relate the edges of the cuts to the blank's principal axes.

Each cut has special characteristics. The AT cut is the most popular for high-frequency and very-high frequency crystal resonators. The AT cut exhibits high frequency shear and produces a fundamental in the 800 kHz to 25 MHz range. However, it overtones (to be discussed later) permit operation up to 200 MHz. The CT and DT cuts exhibit low-frequency shear and are most useful in the 100- to 500-kHz range. The MT cut vibrates longitudinally and is useful in the 50- to 100-kHz range while the NT cut flexes and has a useful range under 50 kHz.

Practical resonators

Figure 4 is a drawing of a typical crystal resonator with its protective case or can removed. The crystal resonator is sliced, cut, and polished as a disk. It has one deposited metal electrode on each face, about 1000 angstroms thick. Electrode metal can be gold, silver, aluminum or other suitable metal. The resonator is supported on each edge at *nodal points*, places where the support will provide least damping of the vibrating crystal. Flexible support struts bonded to each side of the crystal connect the electrodes to base pins.

Crystal manufacturers refer to the complete assembly of

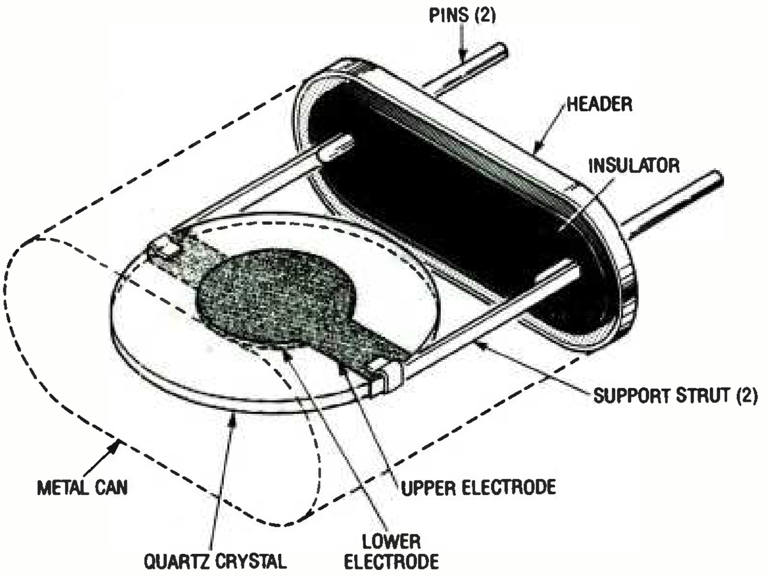


FIG. 4—A QUARTZ-CRYSTAL RESONATOR with its case removed. The silvered electrodes are on opposite sides of crystal disk and the disk is supported at its nodal points.

crystal, support, and case as a *holder*. The insulated pins in the base of the holder are for external electrical connections. The flat metal case is either soldered or welded to the base to form a hermetic seal. Sealing is typically done in a vacuum chamber which might also contain an inert gas such as nitrogen to provide additional protection for the crystal against contamination. It is essential that all moisture be removed from the case. The removal of air from the holder reduces the crystal's mechanical load and affects its resonant frequency.

Series and parallel resonance

Crystal resonators can be modeled near resonance with the equivalent circuit shown in Fig. 5. The series combination L_s, C_s, and R_s represent the electrical equivalent of the vibrational characteristics of the crystal by itself. The inductance L_s is the electrical equivalent of the crystal mass that is effective in vibration, C_s is the mechanical equivalent of the effective mechanical compliance, and R_s represents the electrical equivalent of mechanical friction.

This equivalent circuit is modified, however, when the crystal is mounted in the crystal holder. As a result, the equivalent circuit of the mounted crystal is the parallel circuit shown in Fig. 5. Capacitor C_p represents the electrostatic capacitance between the crystal electrodes and the stray capacitance associated with the holder when the crystal is not vibrating.

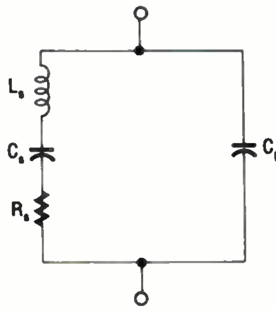


FIG. 5—IN AN EQUIVALENT CIRCUIT FOR A CRYSTAL resonator, L_s, C_s, and R_s represent the crystal, and C_p represents the capacitance of electrodes and holder.

At series resonance, the reactances of C_s and L_s cancel out, leaving resistor R_s and a small amount of capacitive reactance from static capacitor C_p. At a frequency slightly above series resonance, f_s, the reactance of C_p cancels out and the crystal looks resistive. The value of this resistance is called the *equivalent-series resistance*. Manufacturers usually specify only a maximum value of ESR because precise values are seldom needed in oscillator design. Crystals made to operate at series resonance are called *series-resonance crystals*.

A series-tuned circuit is capacitive below its series-resonant frequency f_s and inductive above it. The series-resonant frequency is given by:

$$f_s = \frac{1}{2\pi\sqrt{L_sC_s}}$$

At some frequency f_p, which is higher than f_s, the crystal will act as a parallel-tuned circuit because the now inductive series branch resonates with C_p. Crystal resonators made to oscillate above series resonance are called *parallel-resonance crystals* or *load-resonance* crystals. The parallel resonant frequency is:

$$f_p = \frac{1}{2\pi\sqrt{L_sC}} \quad \text{where}$$

$$C = \frac{C_sC_p}{C_s + C_p}$$

Crystal resonators intended for parallel-resonance operation include a specification called the *load capacitance*, abbreviated C_L. Typically 10 to 100 picofarads, it is called load capacitance because it is the capacitance value that the oscillator circuit presents to the crystal, that is, the crystal's load.

Load capacitance can be approximated as a 10 to 100 picofarad capacitor in series with a series-resonant circuit (the crystal). If the load capacitance is decreased, the resonant frequency of the total circuit (crystal plus load capacitor) will increase. As frequency increases, the crystal becomes more and more inductive. Most oscillator circuits call for an inductive crystal resonator. Therefore, parallel resonance crystals are very popular.

Series vs. parallel.

In an oscillator circuit a parallel-resonance crystal is usually more stable than a series-resonance crystal. The parallel-resonance crystal's change in inductive reactance per change in frequency ($\Delta X/\Delta f$) is greater above series resonance than at series resonance. This sharpens the tuning of the feedback network. Therefore, noise signals higher or lower than the resonant frequency are quickly damped out. This prevents *off-frequency oscillation.*

Figure 6 summarizes crystal resonator characteristics by plotting reactance vs. frequency. In the parallel resonance region, the magnitude of the crystal's resistance increases above its ESR value. Manufacturers usually refer to this as the crystal's maximum resistance with load capacitance or, the crystal's *load resistance.*

The frequency at which the inductive reactance abruptly changes to capacitive reactance (and resistance approaches a maximum), is called *anti-resonance.* It is not specified in data sheets for most oscillator applications.

Table 1 gives typical values for a selection of crystal resonators. The columns headed C_s, L_s, and R_s are the series values and C_P represents parallel capacitance. The C_L column is load capacitance and the R_L column is load resistance.

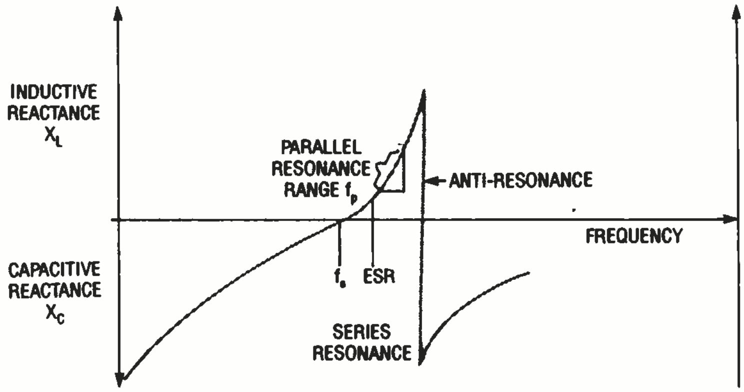


FIG. 6—CHARACTERISTICS OF CRYSTAL RESONATORS: parallel resonance, and series resonance are shown.

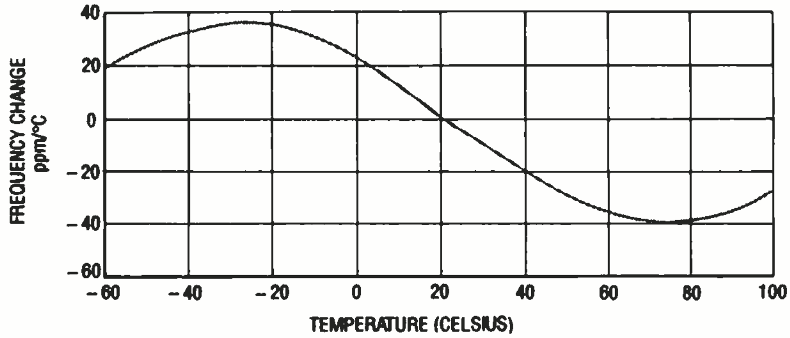


FIG. 7—Plot of frequency change with respect to temperature for a typical AT-cut crystal resonator.

that for high frequency oscillation, the quartz wafer must be very thin. This fact makes it difficult to manufacture crystal resonators with fundamental frequencies much above 30 MHz because the crystal is so thin that it is exceptionally fragile and conventional cutting and polishing could result in high production cost.

TABLE 1
TYPICAL VALUES FOR A CRYSTAL EQUIVALENT CIRCUIT

CRYSTAL f(MHz)	C_S (pF)	L_S (mH)	R_S (ohms)	C_P (pF)	C_L (pF)	R_L (ohms)
0.100	0.004	633	62k	4	20	90k
1.0	0.028	905	388	7	32	575
10	0.028	9.0	16	7	32	24
20	0.028	2.2	40	7	Series Resonance	
80	0.0012	3.3	50	7	Series Resonance	

Other characteristics.

The relationship between a quartz crystal's thickness and resonant frequency is expressed as $h = 65.5/f_R$, where h is the thickness in inches, and f_R is the resonant frequency in kilohertz. This formula says

Some crystal resonator manufacturers get around this problem by using chemical etching to achieve thinner slices of quartz. This has made it possible to achieve fundamental frequencies up to about 350 MHz, but this process is more costly and it increases the cost of those resonators.

Resonant frequencies higher than 30 MHz have been obtained by making use of harmonically related vibrations that occur simultaneously with the fundamental vibration. The harmonics are odd multiples of the fundamental (3, 5, 7 and 9) and they are referred to as *overtones* because they are not true harmonics. The tradeoff is that special provisions must be made in oscillator circuits to enhance those overtone frequencies.

Manufacturers can process a crystal so that one overtone is stronger than the others. Typically, overtone crystals are available for the 3rd, 5th, 7th, or 9th mode of vibration. Thus a 30-MHz, third-overtone crystal actually has a 10-MHz fundamental, but the crystal is cut to enhance its third mode. Low-cost overtone crystals with frequencies up to 200 MHz are available as standard commercial products. More expensive chemically-milled resonators can have overtones up to about 500 MHz.

Temperature stability

A crystal's resonant frequency changes with temperature. Crystal manufacturers express temperature-related changes in parts per million per degree Celsius (ppm/°C). Figure 7 is a plot of resonant frequency change with temperature for a typical low-cost AT-cut crystal.

When a desired operating temperature is specified, a manufacturer fabricates the crystal so that its optimum stability point (zero ppm/°C on Fig. 7) corresponds to that temperature. For low cost units, this is 25°C.

To find the maximum frequency change, locate the ppm/°C value corresponding to the given temperature. Next, multiply ppm by the nominal operating frequency (in megahertz). For example, at -20°C, a crystal can have a +38 ppm/°C rating. If its resonant frequency is specified to be 10 MHz (at 25 °C), its resonant frequency will increase by 380 Hz when its temperature drops to -20°C (38 ppm × 10 MHz).

For most practical circuits this represents a minor frequency change. However, if strict frequency control is required in any application, a crystal oven or temperature-compensated oscillator (TCXO) should be included.

Calibration tolerance.

A crystal's true frequency might not be exactly the same as the value stamped on its case. The error depends upon the crystal's calibration tolerance. Moreover, its calibration tolerance is specified at one specific temperature, usually 25°C. For example, expect a 10-MHz crystal with a ±25 ppm/°C calibration tolerance to have a resonant frequency within ± 250 Hz of 10 MHz when operating at 25°C.

Aging

Aging is a gradual change in a crystal's resonant frequency with respect to time. It is usually specified in parts per million per year (ppm/year). Typical values range from 3 to 10 ppm/year. For example, a 10-MHz crystal with an aging rate of 10 ppm/year can change by 100 hertz per year. One cause of aging is the redistribution of particles of quartz and embedded grinding compound that were not removed by careful cleaning.

These microscopic materials remain within the holder after hermetic sealing and are redistributed as a result of resonator vibration. Thus aging is directly affected by the power input or drive level.

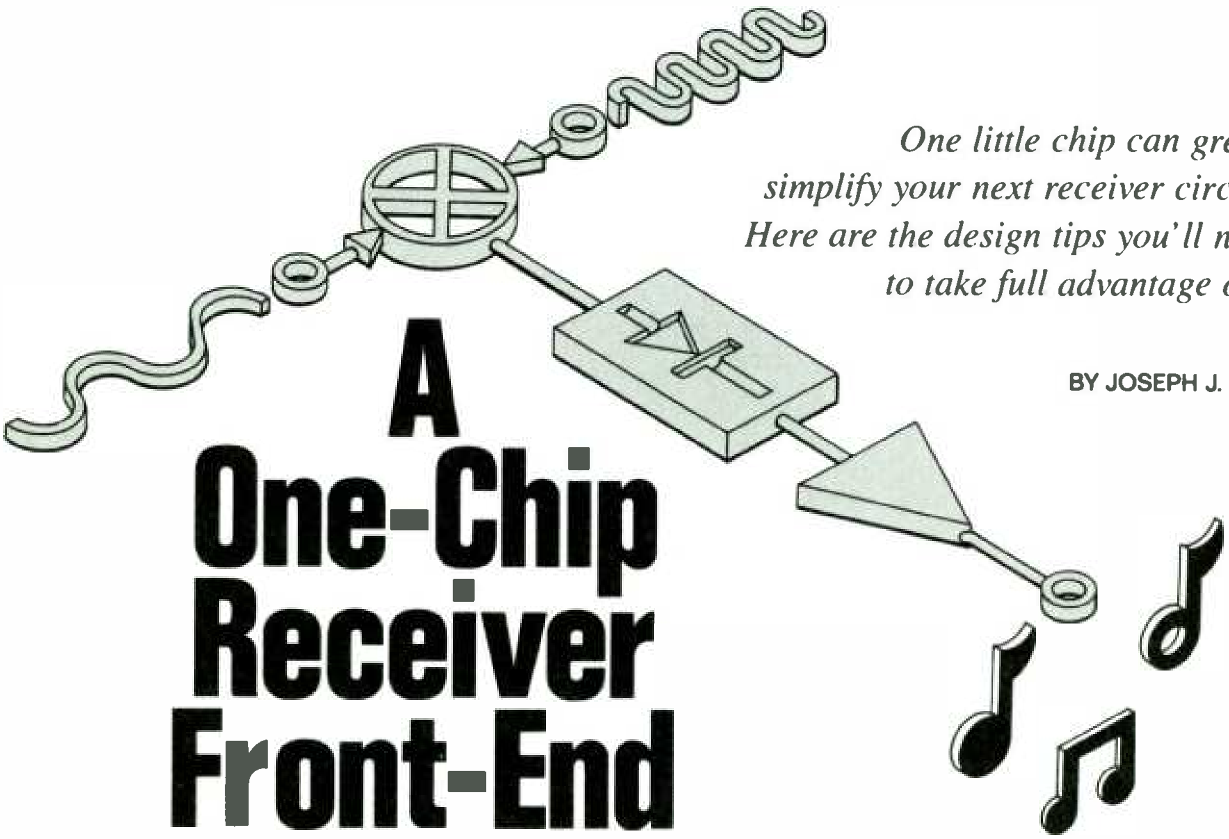
In addition, slow leaks in the hermetic seal can allow air, moisture and contaminants into the case which will shift the resonant frequency. Stresses on the electrodes and changes in atmospheric pressure that flex the outer walls of the case can also contribute to the aging of a crystal.

Power dissipation.

As with any object that is vibrating at its resonant frequency, the vibrations can quickly build to a destructive level. To maintain temperature stability and to avoid damaging the crystal resonator, each crystal has a recommended maximum drive level. Typical maximum values range from 5 milliwatts at low frequencies to 0.1 milliwatt at high frequencies because high-frequency crystals are thinner than low frequency crystals.

Standard holders

The holders were standardized by a military specification years ago, and they are still referred to as HC numbers (for HC-XX/U) to identify resonator type and size. Crystal resonators are available from stock with resonant frequencies from about 70 kHz to 200 MHz. Specials can be ordered as custom items. We wish to acknowledge the assistance of Royden Freeland of International Crystal Mfg., Co. Oklahoma City, OK, in checking this manuscript for accuracy. ■



A One-Chip Receiver Front-End

One little chip can greatly simplify your next receiver circuit. Here are the design tips you'll need to take full advantage of it.

BY JOSEPH J. CARR

Every now and then chip manufacturers come up with a truly neat new product. Old timers in electronics fondly remember the introduction of the Signetics 555 chip as one of those breathtaking devices, and that chip is still a "best-seller." The Signetics NE602 single-chip frequency converter also falls into that "stellar" class. Depending on the circuit configuration, it can be used as a frequency converter in receivers or transmitters, a spectrum analyzer, a complete receiver front-end from very low frequencies up to the mid-VHF region, or even a complete receiver. Furthermore, the NE602 chip is, unlike many radio-frequency (RF) devices, in that it's relatively easy for hobbyists to tame and use with limited test equipment.

The basis for the NE602 is the heterodyning process used in most modern radio receivers, and in other products. In heterodyning, two signals are mixed together in a nonlinear mixer circuit (see Fig. 1) to produce a collage of output frequencies including both the input signals (f_1 and f_2), plus the sum ($f_1 + f_2$) and difference ($f_1 - f_2$) frequencies. In point of fact, the harmonics of f_1 and f_2 also mix, so the output of a frequency mixer can be characterized by:

$$f_O = mf_1 \pm nf_2$$

where n and m are integers (1, 2, 3, etc.).

In a radio-receiver mixer, one of the frequencies (say f_1) will be an RF signal from a distant station, while the other frequency (f_2) is generated by an oscillator in the receiver (called the "Local Oscillator," or "LO"). The purpose of making the frequency conversion is to selectively translate any incoming frequency to a single Intermediate Frequency (IF). This is advantageous since the rest of the receiver need only supply the bulk of its gain and selectivity at the intermediate frequency. That keeps the receiver's cost low and its design simple. Nearly all modern broadcast radio, communications, and television receivers use this process, and are thus called superheterodyne receivers.

The NE602. The Signetics NE602 chip provides mixer and local oscillator stages in a single package The NE602N is the eight-pin DIP package, while the NE602D is the Surface-Mounted Device (SMD) version. The NE602AD and NE602AN are improved versions of the basic NE602 units.

The mixer in the NE602 is a Gilbert Transconductance Cell (GTC), so it qualifies as a Double-Balanced Mixer (or DBM). GTC's are so useful that they are used in various analog multipliers and amplitude modulators. When you explore the arithmetic of the process they perform, you find that they are all multiplication circuits (*i.e.*, the functions of the two input signals are multiplied to get the output signal), so it is not surprising that the GTC finds its way into mixer service.

Unlike other DBM circuits, which are usually made with diodes, the GTC is based on active devices such as transistors. The principal advantage of transistor construction is that the circuit has very good sensitivity (down to the microvolt level), while at the same time (unlike other mixers) it suppress the LO and RF signals in the output. Other mixers pass those signals along to the output, so the circuit design must incorporate some means for selecting the desired sum or difference signal. Furthermore, by not passing the high amplitude local-oscillator signal to the output, the NE602 can directly drive another receiver stage without overdriving it.

The sensitivity of the NE602 is truly startling for a device that does not

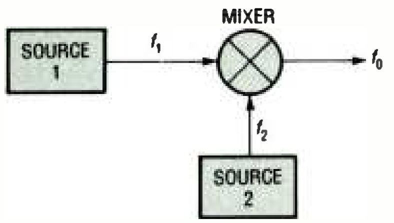


Fig. 1. In the heterodyning process two signals (f_1 and f_2) are combined by a nonlinear mixer circuit to produce the sum ($f_1 + f_2$) and difference (f_1-f_2) output frequencies plus their harmonics.

include an RF amplifier. Since the device is quite capable of handling signals down to the microvolt level, it is a candidate for use as a receiver front-end without any additional circuitry. The NE602 will handle signals up to −15 dBm, and prefers to see signals at −25 dBm or less. These signal levels are neither terribly high nor terribly low (in a 50-ohm load, −25 dBm equates to about 12.5 millivolts, which is high for a received radio signal, but low for other frequency-translation applications).

The NE602 devices seem to trade-off dynamic input-signal range (*i.e.*, the difference between lowest and highest signal amplitude that can be accommodated) for spectrally purer output. The GTC mixer in the NE602 is capable of operation to about 500 MHz.

The internal oscillator consists of a single, high-frequency NPN transistor that will oscillate to 200 MHz or so. The base and emitter terminals are available to the outside world, so the transistor can be incorporated into the external-circuit design. The collector circuitry and DC-bias network are built into the chip, so the circuit designer does not have to bother with the "housekeeping" chores of circuit design.

The pinouts for the NE602N, shown in Fig. 2, are as follows: pins 1 and 2 are the differential RF inputs, pin 3 is ground, pins 4 and 5 are the push-pull outputs (either alone will also serve as a single-ended output), pin 6 is the oscillator-transistor base terminal, pin 7 is the oscillator-transistor emitter terminal, and pin 8 is the power-supply terminal.

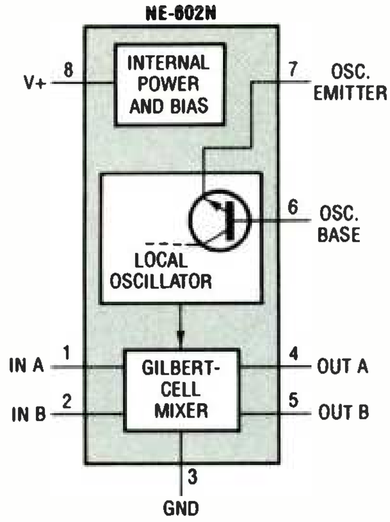


Fig. 2. This block diagram of internal NE602 circuitry reveals the two basic sections of the chip. Note that the local oscillator section is just a transistor.

Power Connections. The NE602 is a low-voltage, low-current device. It requires a DC supply voltage of between 4.5 to 8 volts DC and will generally draw less than 3 mA. It works well with a 5-volt supply, but may be stressed if a 9-volt battery is used without precautions. Figure 3 shows several different popular DC-power configurations.

In Fig. 3A, we see the use of a simple RF choke to decouple the power supply from the NE602. The RF choke and the decoupling capacitor (C1) prevent RF from the NE602 from reaching other stages, or vice-versa. The RF choke should be 2.5 mH if the frequencies are under 3 MHz, 1 mH from 3 to 30 MHz, and 30 to 100 μH for VHF signals. As always in such situations, the decoupling capacitor and RF choke should be mounted as close as possible to the body of the NE602. The supply voltage in this instance must be strictly limited to 4.5 to 8 volts.

The circuit of Fig. 3B is somewhat more popular, and more practical. In that circuit, DC power is supplied to the NE602 through a 100-ohm resistor while C1 acts as a decoupling capacitor. A variant of the same theme, shown in Fig. 3C, allows an NE602 to operate from a 9-volt battery or other 9-volt power source. The resistor provides a small voltage drop to reduce the voltage received by the NE602.

In some circumstances, it is prudent to provide some voltage regulation to the NE602 device. In automotive applications, for example, the voltage can normally range from 11 to 14.5 volts and can run as high as 18 volts if the car's voltage regulator fails. Further, regulation is good for projects that rely on household current for power, as the AC-line voltage can range from 105 to 127 volts.

In such circumstances, the circuit in Fig. 3D can be used to regulate and reduce the voltage from a 12-volt (or higher) DC supply. In Fig. 3D, the voltage is regulated by a 400-mW or 1-watt Zener diode that limits the voltage applied to pin 8 of the NE602. Use

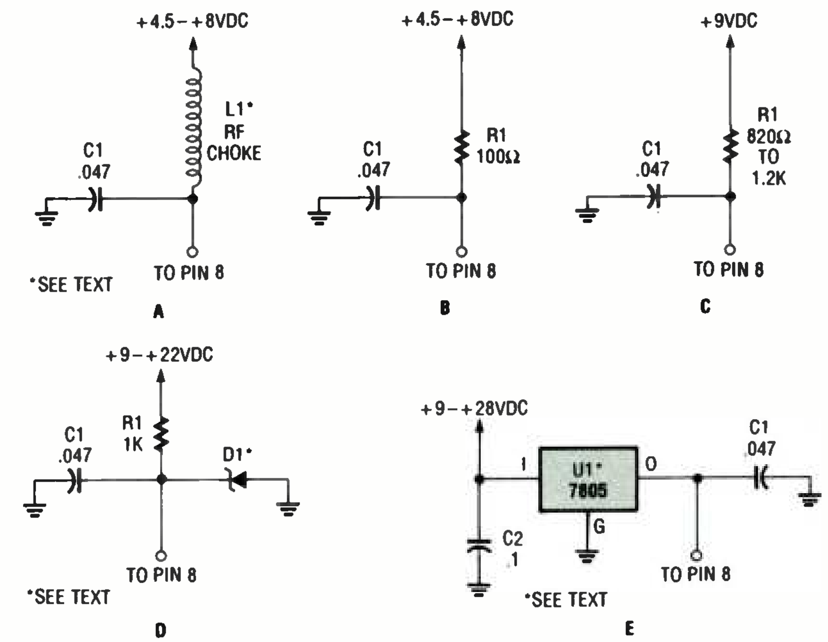


Fig. 3. These are just some of the DC power-circuits suitable to drive the NE602. Note that all of them contain at least one capacitor to suppress RF noise.

a 5.6-volt, 6.8-volt, or 8.2-volt Zener diode for D1.

Alternatively, use a circuit such as the one in Fig. 3E. There we see the use of a 7805 three-terminal IC voltage regulator. The 7805 is a bit of overkill because it can handle 750 or 1000 mA (depending on the package), so you can use the TO-5 or TO-99 low-power version, or a 78L05. You can also use 7806 or 78L06, but the output voltage will be 6 volts not 5. As in the other cases, the decoupling capacitor, C1, should be placed near the NE602. Note that a noise-immunity capacitor (C2) is also used at the input of the voltage-regulator chip.

Input Circuits. The NE602 uses differential inputs called IN A (pin 1) and IN B (pin 2). However, either one can be used alone to serve as a single-ended input. The input impedance of the NE602 is on the order of 1.5k at lower frequencies, and is somewhat lower than that in the VHF region. Keep in mind that AC circuits tend to work best when the source and load impedances are matched. An implication of this requirement is that 50- or 75-ohm antenna inputs have to be transformed to 1,500 ohms for best efficiency.

Figure 4 shows several different basic input configurations for the NE602. Those circuits are not the only ones that will work, but they are popular. The circuit in Fig. 4A can handle a high-impedance (1.5k), single-ended input, such as when the NE602 is used as a frequency converter in some project other than a radio receiver, or when the receiver design uses an RF amplifier or RF preselector ahead of the NE602. The signal is coupled through C1 (which is used for DC blocking) to pin 1 on the NE602. The alternate input, pin 2, is unused so it is bypassed to ground through a decoupling capacitor.

Figures 4B, 4C, and 4D are used for cases where the source impedance is lower than the NE602 input impedance, for example in a radio receiver where the standard antenna impedance is either 50 or 75 ohms (the former predominates). In Fig. 4B the impedance is matched by the split capacitor circuit composed of C_A and C_B. The series combination of those two capacitors must resonate inductor L1 at the desired frequency.

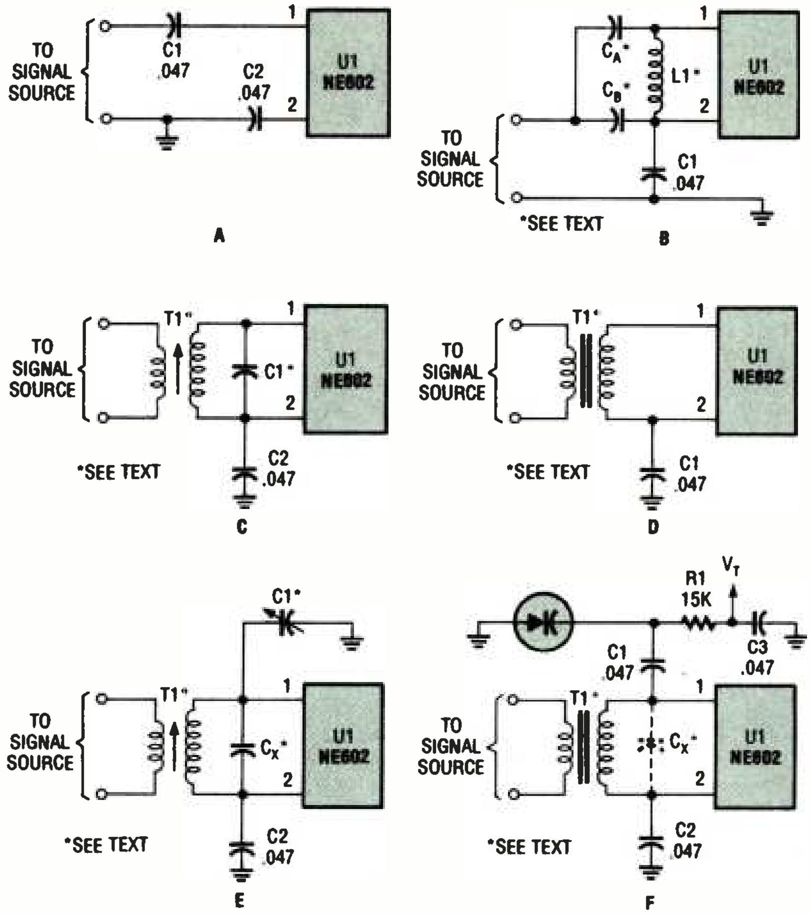


Fig. 4. Here are a few of the many possible RF input circuits for the NE602. Just about any tuned or broadband circuit will work.

Thus, that circuit is most useful in single-frequency applications. The coil and the transformers used in the circuits that follow can be wound on coil forms or on torroidal ("doughnut" shaped) cores.

Another version is shown in Fig. 4C. There the impedance is matched by the turns ratio of the input transformer, T1. Capacitor C1 is used to resonate the secondary of T1 at the desired frequency. If C1 is made variable, then the input can be tuned over a frequency range that is determined by the range of C1.

The circuit of Fig. 4D has an untuned, broadband RF transformer at its input so it can handle a wide band of input signals. These transformers are typically built on torroidal cores with bifilar-wound turns. The turns ratio of T1 determines the impedance ratio according to:

$$N_P/N_S = \sqrt{Z_P/Z_S}$$

where N_P is the number of turns in the primary, N_S is the number of turns in the secondary, Z_P is the impedance reflected to the primary of T1, Z_S is the impedance connected across the secondary of T1. If you work the arithmetic for 50 ohms and 1.5k, the values turn out such that N_P/N_S is 0.183, so inverting, we find that (to make the impedance transformation) the secondary needs 5.5 turns for every turn in the primary.

Figure 4E shows the use of a different sort of tuned input transformer. In that circuit, the main tuning capacitor for the secondary is connected between the junction of pin 1 and one end of T1's secondary and ground. As long as capacitor C2 is also in the circuit, this connection effectively places the capacitor in parallel with the secondary winding of the transformer, but is a little more amenable to most variable capacitors (which are mechanically designed to be grounded when mounted). A padder capacitor, C_X, may be connected either across C1, or directly in shunt with the transformer winding as shown. That capacitor will set the minimum capacitance of the circuit, and helps

C1 resonate with the inductance of T1. In typical applications, C_X will set the frequency of the bottom of the band when C1 is fully meshed (*e.g.*, at maximum capacitance), and then C1 "bandspreads" across the desired band as it is tuned.

A modern variation on Fig. 4E is the voltage-variable scheme shown in Fig. 4F. There the variable capacitor is replaced with a voltage-variable capacitance diode, also called a "Varactor." Such diodes have a junction capacitance that is a function of the applied reverse voltage. When the tuning voltage (V_T) is changed, it will change the capacitance of D1, and in turn changes the resonant frequency of the circuit.

NE602 Output Circuits. The output impedance of the NE602 is typically 1.5k (the same value as for the input impedance). The output terminals (labeled OUT A and OUT B back in Fig. 2) are a push-pull pair, but can be operated in a single-ended fashion simply by placing a DC blocking capacitor on the output you wish to use (either pin 4 or 5) and ignoring the remaining one (as shown in Fig. 5A). Unlike the equivalent input circuit, the unused output terminal does not need to be bypassed to ground.

The output circuit in Fig. 5B uses a broadband RF transformer (similar to that used back in Fig. 4D). The turns ratio of the transformer should be set to reflect 1.5k back to the primary as a function of the load impedance. Again, if the 50-ohm standard impedance is used, then a 5.5:1 turns ratio is required. A tuned version of that circuit is shown in Fig. 5C.

Another single-ended circuit is shown in Fig. 5D. That one is based on a ceramic IF filter or a crystal filter (FIL1). The filter is one of the standard very low cost 455-kHz or 10.7-MHz IF filters used in broadcast radios. One can also use a 5.5-MHz, 8.83-MHz, or 9-MHz crystal filter, or 455-kHz, 260-kHz or 500-kHz mechanical filters (if you want to spend big bucks).

Local-Oscillator Circuits. For a superhetrodyne receiver to work properly, the local-oscillator frequency must be set so that mixing it with the desired RF will produce the desired intermediate frequency (which can be either the sum or difference of the two). For example, in an AM superheterodyne radio designed for a 455-kHz IF, when the user wants to receive a station on 1240 kHz, the local-oscillator signal must be either 1695 kHz (because 1695 minus 1240 is 455) or 785 kHz (because 1240 minus 785 is 455). Usually the LO is selected to be above the operating frequency (but that's not a requirement), so the sum of RF and IF is used. In direct conversion "autodyne" receivers, the LO is on or very near the radio frequency.

In an NE602 circuit the LO can be either internal or external, as required. In Fig. 6A, we see the connection scheme for an external LO circuit. The LO signal is coupled to pin 6 through a DC blocking capacitor. The signal should have an amplitude on the order of 700 mV peak-to-peak.

Internal variable-frequency oscillators (VFO) are shown in Figs. 6B and 6C. The circuit in Fig. 6B is a Hartley oscillator, as indicated by the feedback being obtained from a tap on the tuning inductor, L1. The version shown in Fig. 6C is a Colpitts oscillator, which is identified by the feedback network being a tapped capacitive voltage divider consisting of C2 and C3. A parallel-mode crystal oscillator

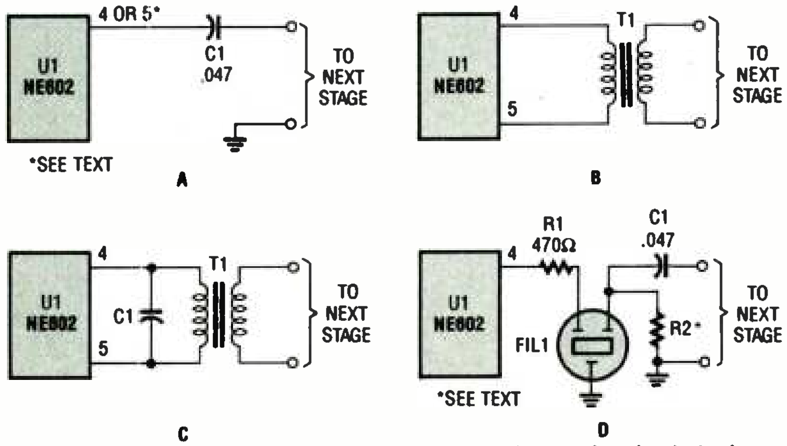


Fig. 5. If the NE602 is used as a mixer, its output must be tuned to the desired intermediate frequency. If the IC is used for direct conversion, you only need to AC couple its output.

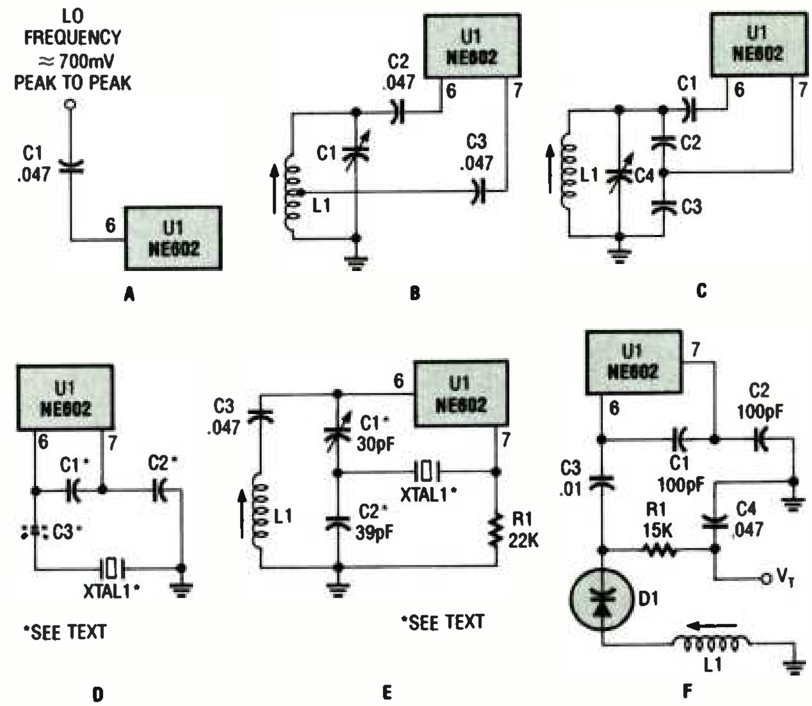


Fig. 6. Just about any standard oscillator (such as a Colpitts or Hartley configuration) can be used to generate the LO frequency needed by the NE602.

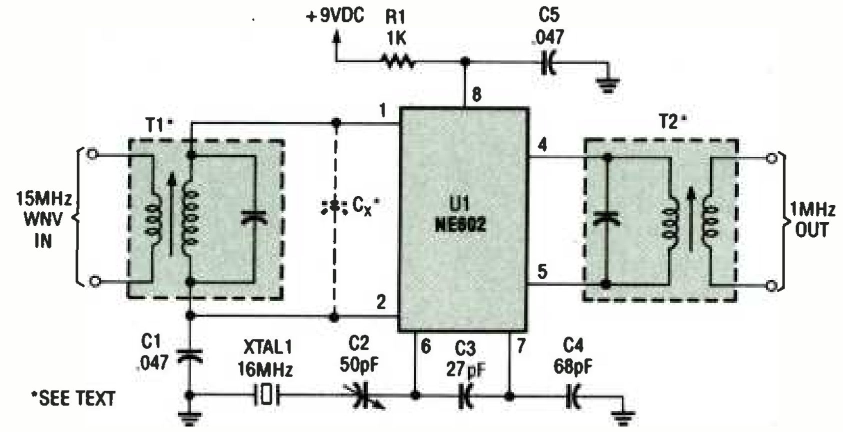


Fig. 7. This simple frequency converter mixes the 16-MHz WWV/WWVH signal with a 15-MHz signal from the LO to convert it down to 1 MHz so it can be heard on an AM-band receiver.

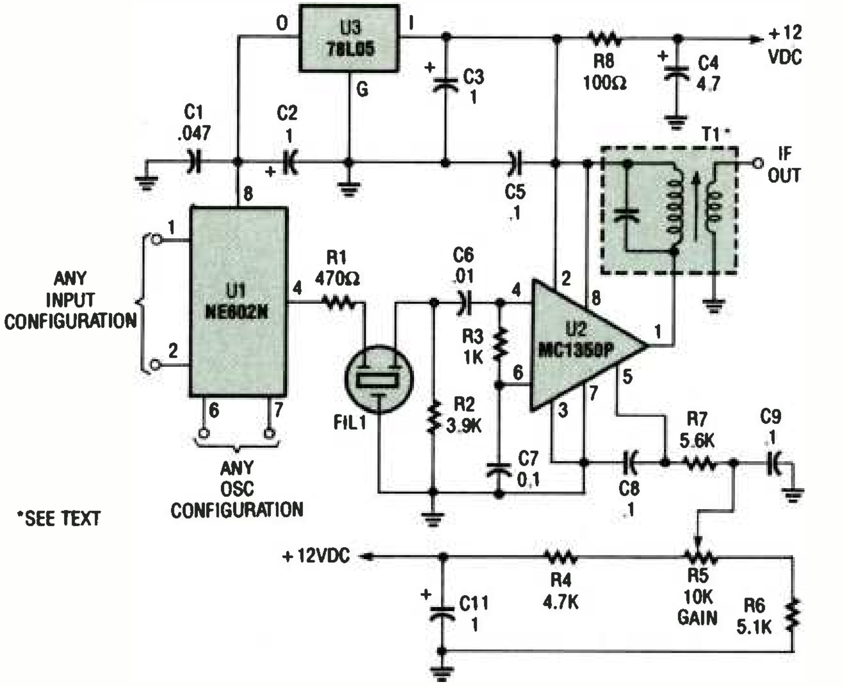


Fig. 8. This superheterodyne-receiver front end shows how valuable the NE602 can be in an RF circuit. By combining this circuit with any of the input and LO circuits presented earlier, you'll be well on your way to having a complete receiver.

for fundamental frequencies (0.8 to 20 MHz) is shown in Fig. 6D. The values of the capacitors are approximately:

$$C1 = 100/\sqrt{f}\ \text{pF}$$
$$C1 = 1000/f\ \text{pF}$$

When specifying crystals for this application, ask for parallel-mode operation on the desired frequency, with a load capacitance of either 20 or 30 pF. The optional variable capacitor shown (C3) will allow you to fine-tune the circuit's resonant frequency. This method is typically used on fixed-frequency radios.

A circuit for an overtone oscillator is shown in Fig. 6E. This circuit is used for low-VHF applications. The inductor must be set to resonate at the overtone frequency (*i.e.*, the desired LO frequency) with the series combination of C1 and C2. The crystal is a third-overtone type, so be sure to specify the overtone frequency desired, not the fundamental frequency or the circuit won't work as you desire or as you expect it to.

Finally, a voltage-variable LO circuit is shown in Fig. 6F. In the circuit, a varactor diode is used to tune coil L1 to the desired frequency. Capacitors C1 and C2 are connected to make this circuit into a Colpitts circuit not too unlike the one in Fig. 6C.

Applications. This article would not be complete without a few applications for the NE602. The ones we'll discuss are not exhaustive, but are selected to be representative of the different jobs the chip can do.

A basic frequency converter is illustrated in Fig. 7. The circuit is a WWV/WWVH-to-AM-broadcast-band converter. The circuit converts the 15-MHz WWV/WWVH frequency to 1 MHz—the middle of the AM-broadcast band. The 16-MHz local oscillator is a fundamental crystal type. A 16-MHz LO frequency was selected because 16-MHz crystals are used in personal computers, and as such are sold by a wide variety of mail-order and local parts distributors.

The input circuit is tuned by an RF transformer who's secondary resonates at the RF. Either a regular cylindrical coil form or torroidal form may be used. Alternatively, a 10.7-MHz IF transformer—the sort that has the resonating capacitor in a hollow space in its base—can be modified for this use. The capacitor must be crushed, and the debris cleared out, so that an external capacitor (C_X) can be used. These same tips apply to the output transformer, T2. Although designed for one particular application, the circuit can be used for any number of receiver needs.

Figure 8 shows a combination of IC's that can be used to make a conventional superheterodyne receiver. In the circuit, frequency conversion is performed by an NE602 augmented with any of the standard input and LO configurations presented. The output circuit is the ceramic filter type shown earlier. The IF amplifier is a 60-dB gain circuit based on the MC1350P IC, operating at 455 kHz. Potentiometer R5 acts as a sensitivity or gain control by providing an adjustable DC bias to pin 5 on the MC1350P.

Because of the high frequencies involved there are two basic rules to follow when building the circuits. First, keep all leads and wire between components short. Second, if you'll be using printed-cirtcuit board construction, create a ground plane around the circuit to use for all ground connections.

The NE602 is a unique device that makes a wide variety of RF projects open to those who are not deeply skilled in RF design. Try it, you'll like it. ■

Making The Connection

Make the right connection between a wire antenna and your rig.

BY JOSEPH J. CARR

There is large amount of information on wire antennas available to receiver users. However, two related topics that seem lacking in coverage, or at least jumbled up with other material, are antenna-construction and termination. In this article, we will take a look at both topics. As we proceed, keep in mind that the information applies to nearly all wire antennas, not just the types mentioned.

Types of Wire Antennas. The variety of wire antennas around is mind boggeling, but they fall into two basic categories. One group is like the Marconi-style antenna, shown in Fig. 1A, consisting of a single-wire radiator, usually made of insulated or uninsulated No. 14 or No. 12 wire placed high in the air. The antenna is typically supported by a set of end insulators and rope supports. One end of the antenna is connected to a piece of insulated wire (called the "downlead"), which is connected to the rig (receiver, transmitter, or transceiver).

Related antennas include the random-length wire antenna, long-wire antenna (both resonant and nonresonant types), windoms, Tee-antennas, and top-hat antennas to name a few. They are all different, but have one similarity: they consist of a single radiator element connected to a single-wire downlead that is connected to the radio rig.

Someplace before the downlead enters the house, a protective lightning arrestor is connected to the circuit. The lightning arrestor is used to bypass as much of a lightning strike as possible to ground. The ground wire connected to the lightning arrestor is made of heavy wire or braid cut as short as possible, and is connected at the other end to a ground rod driven into the ground. Always follow local electrical and safety codes for the ground rod, which in most cases means you should use an 8-foot copper-clad steel rod. Those little 4-foot ground rods are not terribly good for lightning protection, so don't depend on them.

The downlead is connected directly to the rig's antenna terminal. A second ground, which may go to the same ground lead as the lightning arrestor ground, is used to improve the RF performance of the radio antenna.

The other basic type of antenna is shown in Fig. 1B. That antenna is a dipole. Such antennas consist of two wire radiators fed by a two-conductor cable such as twin-lead, twisted-pair or, most commonly, coaxial cable. When coaxial cable is used, the center feed point may be either a special center insulator or a BALUN (BALanced UNbalanced) transformer. Again, end insulators and rope supports hold the antenna in the air. As with all antennas, a lightning arrestor is used to protect the house and rig.

End and Center Insulators. End insulators are used to electrically isolate the wire radiator from the support rope. In addition, they provide a certain amount of mechanical strength in the connection between the radiator wire and the rope supports. They may be made of glass, glazed ceramic, or a synthetic material such as nylon or Teflon.

Figure 2 shows one popular shape of the classic ceramic end insulator. Most of those sold in stores today are made of synthetic material, although used ceramic and glass insulators can be frequently seen at hamfests.

Two synthetic end insulators are shown in Fig. 3. The larger one shown can be used for high-power ham-radio transmitter antennas as well as general-receiver antenna use. It provides a much larger degree of isolation between the wire and the supports (which presumably reduces end effects). The smaller unit is used for smaller transmitter antennas, and general shortwave-receiver antennas.

A pair of popular center insulators are shown in Figs. 4 and 5. The type shown in Fig. 4 has an SO-239 UHF

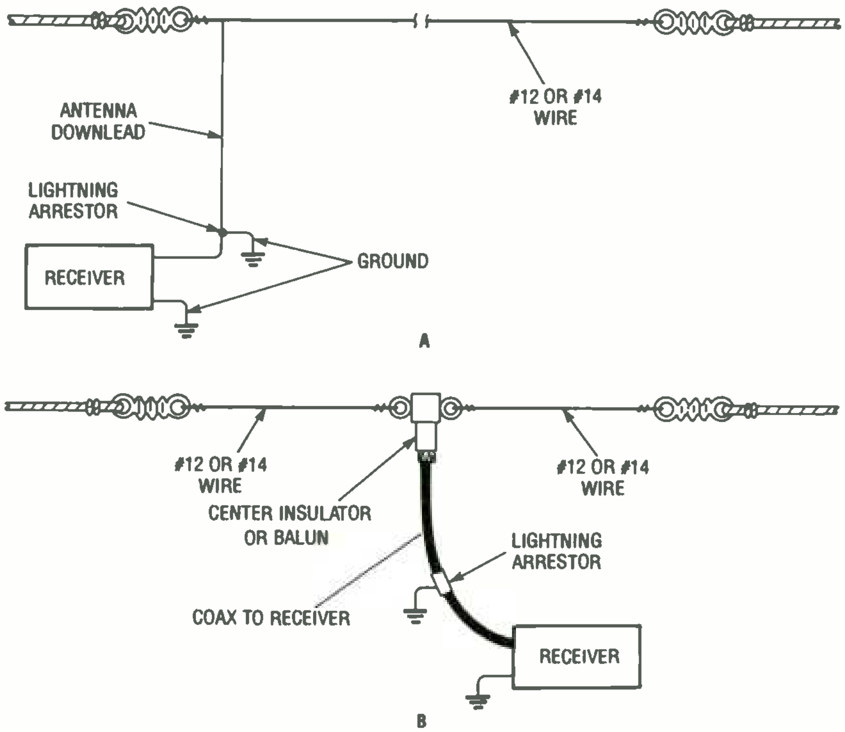


Fig. 1. The two most common antenna types—the Marconi-style antenna (A) and the Hertzian "balanced" antenna (B)—are shown here. Note the additional radiator in B.

Fig. 4. Some center insulators have "pigtails" on each side that the radiators need to be soldered to. The antenna's downlead attaches to the connector at the bottom of the insulator.

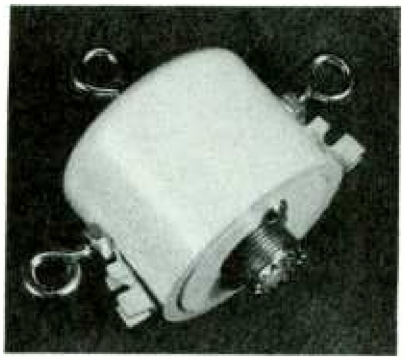


Fig. 5. This type of center insulator has crimp-on lugs for a good electrical connection. These center insulators sometimes contain BALUN transformers.

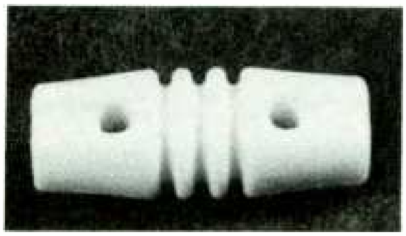


Fig. 2. End insulators come in different styles. Here is a "classic" end insulator made of glazed ceramic. Some can still be found at ham shows today.

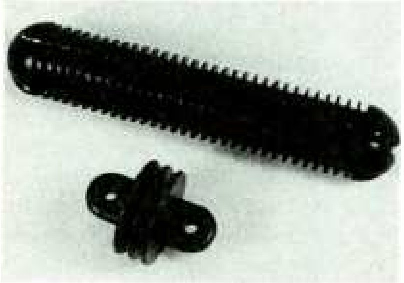


Fig. 3. The modern end insulators are typically made of a synthetic material such as nylon. That makes them fairly resilient

coaxial connector, that can mate directly with the PL-259 coaxial connectors used on many antenna feedlines. The radiator elements are connected to heavy-duty, solid-copper wire "pigtails" protruding out each end of the center insulator. (Connections for this type of center insulator will be discussed later.) A different form of center insulator is shown in Fig. 5. In that type of insulator, a hollow body of PVC-like plastic material contains connections for the SO-239 coaxial cable. The wires are connected to, and supported by, a pair of screw/eye terminals on either side.

Some center insulators contain BALUN transformers. For ordinary dipoles use 1:1 BALUN transformers; for folded dipoles use 4:1 BALUN's.

Using Insulators. There are two goals to keep in mind when making connections to either end insulators or center insulators. First, you want a strong, reliable mechanical connection that won't come loose under the buffeting the antenna will receive. Winds and weather can take a terrible toll on wire antennas, so a good, reliable connection is mandatory. The second goal is to make a good electrical connection—after all is said and done, the antenna is still an electrical device connected to an electronic circuit.

A minor point to make is to avoid kinks. Radiator wire is either hard-drawn copper wire or copper-clad steel wire (*e.g.*, Copperweld), so keep in mind that it kinks up very easily. In fact, experienced antenna erectors claim that gremlins or RF demons exist whose main function in the universe is to put permanent kinks in wire. When the wire kinks, it is nearly impossible to get the kink out of the wire so that it looks good again. The antenna will still perform well, but the spot where the kink occurred will always remain.

Let's deal with end insulators first. Figure 6 shows how to make a connection to an end insulator. Although only one style insulator is shown here, the method for the other styles shown earlier is identical.

The first step in connecting the antenna wire to the insulator is to pass the wire through one of the holes in the insulator. Leave 6 to 8 inches of free wire. Next, double the free end of the wire back on itself, and wrap it around the main body of the wire six to eight times; leave about ¾- to 1-inch of loop to permit the insulator to move freely. If a downlead is required, as it will be on one end of a Marconi-style antenna, then strip away about 2 inches of its insulation, and then wrap the bare downlead wire around the main antenna wire four to eight times.

The final step is to solder all the con-

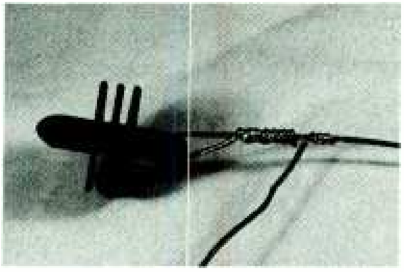


Fig. 6. To make a connection to an end insulator, you first insert some wire into an eyelet, twist it over on itself 6–8 turns, and then solder.

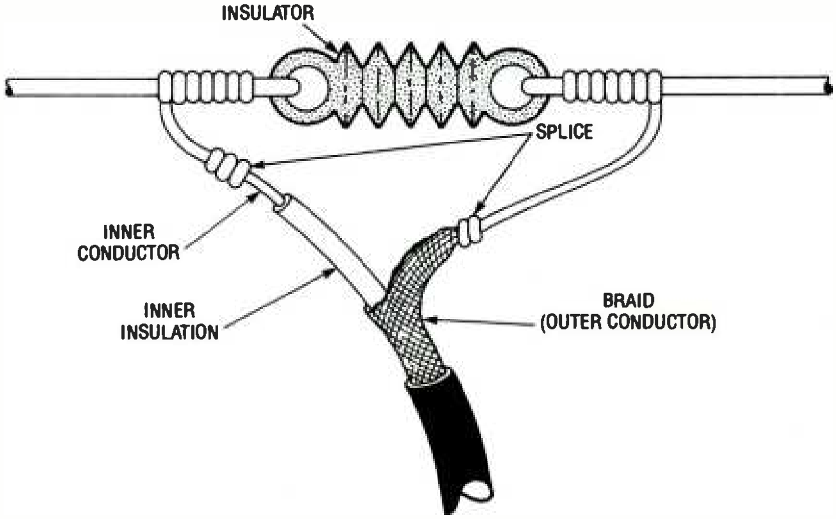


Fig. 7. The split-coax method of making center connections shown here is not advisable, as the connection is prone to corrosion.

nections. The purpose of the solder is not to add mechanical strength, but to ensure the electrical connection in the face of potential corrosion. Use either 50/50 or 60/40 lead/tin resin-core solder. Use solder marked "resin core," "radio/TV," or "electronic" solder. Under no circumstances use acid-core solder! That solder will eat the antenna wire away. It is marked "plumber's" solder, or something similar. Also avoid coreless solder. It can only be used with separate acid-core flux, and is useless to wire-antenna constructors.

Use at least a 150-watt soldering iron or soldering gun. A small pencil-type iron (typically less than 75 watts) is not suitable for this purpose. Heat the joint thoroughly, and then apply the solder so it completely coats the wire of the support splice and the download splice. You may find that the area where you apply the iron will turn out well coated with solder, but other areas aren't wetted at all, so be sure to turn the wire over and solder all surfaces.

Apply caution when soldering. Solder must be very hot to melt, and the wire junction and its vicinity (even the insulator) will try to "sink" the heat, so don't touch it with your bare hands! It can cause painful first- and second-degree burns. Handle the wire and the insulator with insulated pliers, or some other heat-handling tool.

The procedure for connecting a center insulator depends on the type of center insulator that is used. Figure 7 shows the use of an ordinary end insulator as a center insulator for a dipole or other balanced antenna. The two wire radiators are spliced onto the insulator in the normal manner for end insulators. The coaxial cable is stripped such that its center insulator and conductor are each routed to one of the antenna radiators, while the braid (outer conductor) is routed to the other. Both are spliced to their respective radiator elements. One popular method is to use the pigtails left over from making the two support splices as electrical connections for the coaxial cable.

In some cases, the body of the coaxial cable is wrapped around the center insulator and tied off with string, cord, or fishing line in order to provide mechanical support for the connections. If you use the "split coax" method, then a strain relief is essential.

The method shown in Fig. 7 is not recommended. It is mechanically weak, and open to the weather. It is common to find water infiltration into the coaxial cable, which deteriorates its performance. It is better to use a regular center insulator or a BALUN transformer.

The type of center insulator shown back in Fig. 4 has heavy, solid copper-wire pigtails protruding from inside the insulator. Before beginning the splice, you must tin the pigtails. That is, heat up each one with a soldering iron and spread a thin coating of solder over them. They should look silver plated and smooth after they are tinned.

The antenna wire is laid alongside each copper pigtail, and in contact with it, and is then passed through the hole in the insulator, doubled back on itself, and then wrapped around both the pigtail and its own main body six to eight times. It thus resembles an ordinary end insulator support splice, except for the pigtail in the core. Finally, using a soldering iron or gun, solder the splice thoroughly in the same manner as for support splices.

The method for connecting the other type of center insulator (shown back in Fig. 5) is similar to the technique for an end insulator. You pass the antenna wire through an eyelet, and leave about 8 to 10 inches of wire free when you pass it through. Then wrap the wire back on itself until you have about 5-inches of the free end left. The end left over is then connected to the terminal lugs fastened to the eyelet. It is prudent to pull the lug away from the body of the insulator so it can be later crimped and soldered without melting the plastic body. Pass the end of the wire all the way into the terminal past both sets of flanges, and then crimp the flanges over the wire with long-nose pliers in order to form a good mechanical joint. Next, solder the terminal and wire together.

The Rig End. There are a variety of connectors used for connecting antennas to receivers and transmitters. If the connector on your antenna compliments the one on your receiver, you just have to plug them together. If the two connectors do not mate, you could just buy an adapter to bridge the connection.

Some receivers are equipped with a two- or three-station screw terminal instead of a connector. On a two-screw terminal block, one screw (often labeled "ANT" or "A") is for the antenna and the other (labeled

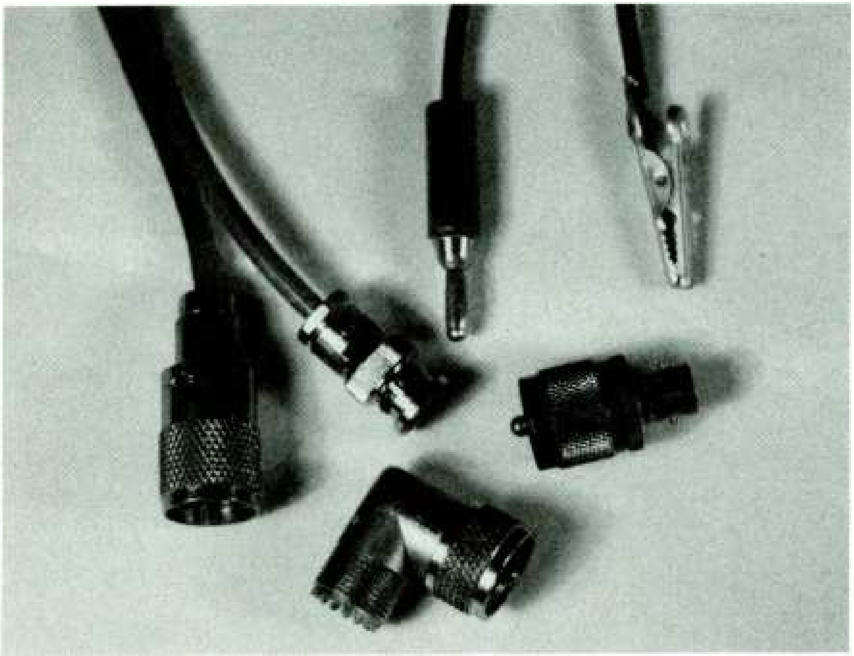
Fig. 8. The rear panel of this shortwave receiver can accept coax, lug-terminal, or bare-wire downlead terminations. In a pinch, a banana plug could be pushed into the 50-ohm socket for single-wire antennas.

"GND," "GRND," or "G") is for the ground connection.

The screws on units equipped with three-terminal antenna blocks are typically labelled "A1," A2," and "G." Those sets can use a balanced transmission line, such as twin-lead, parallel line or twisted pair line, but are most often connected to a single-wire line. When a single line is used, the input can be converted into an unbalanced one by connecting a wire jumper between terminals A2 and G (*i.e.*, by strapping one side of the antenna connector to ground).

The method of choice for connecting any such wires is through the use of neat cable-ends, or spade lugs. However, if you must use just the exposed wire, take the time to strip the end of the downlead about ⅜ inch, and then form it into a loop that has a diameter slightly larger than the body of the screw terminal. If the wire is stranded, then tin the stripped end to prevent it from fraying and shorting to the adjacent terminal. Place the loop under the screw in the direction of tightening for the screw (clockwise). The idea is to cause the loop to close on itself under the screw when the screw is tightened. If you place the loop under the screw in the counterclockwise manner, then it will open when the screw is tightened.

Figure 8 shows the rear panel of one of my shortwave receivers. There are three connections present: 50-ohm antenna, "Hi-Z" antenna, and ground. The 50-ohm antenna input is an SO-239 UHF connector for coaxial-cable fed antennas, while the Hi-Z input is for single-wire downleads. In many cases, it is found that the two are connected together inside the receiver, so which one to use is a moot point. However, if needed, it is possible to connect a single-wire antenna directly to an SO-239 coaxial connector by placing a banana plug on the end of its downlead. If the "Hi-Z" terminal is used, then use a spade lug on the end of the downlead.



These connectors are commonly used to link the downlead to a receiver or transmitter. From left to right they are the PL-259 UHF coaxial connector, the BNC coaxial connector, the banana plug, and the alligator clip. The coaxial adapters in the foreground are a PL-259-to-SO-239 male-to-female right-angle adapter (left) and an SO-239-to-BNC adapter (right).

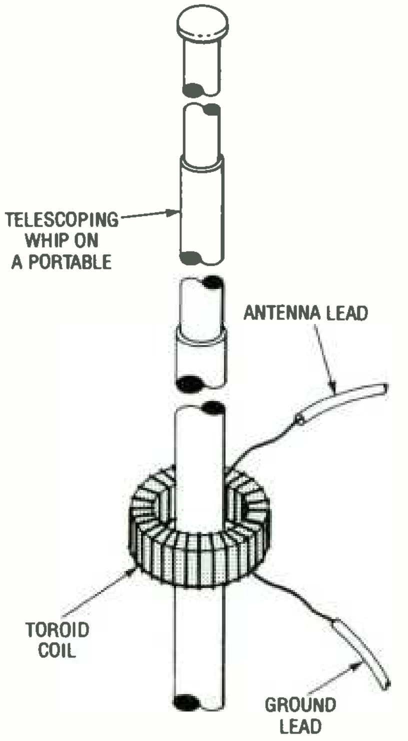


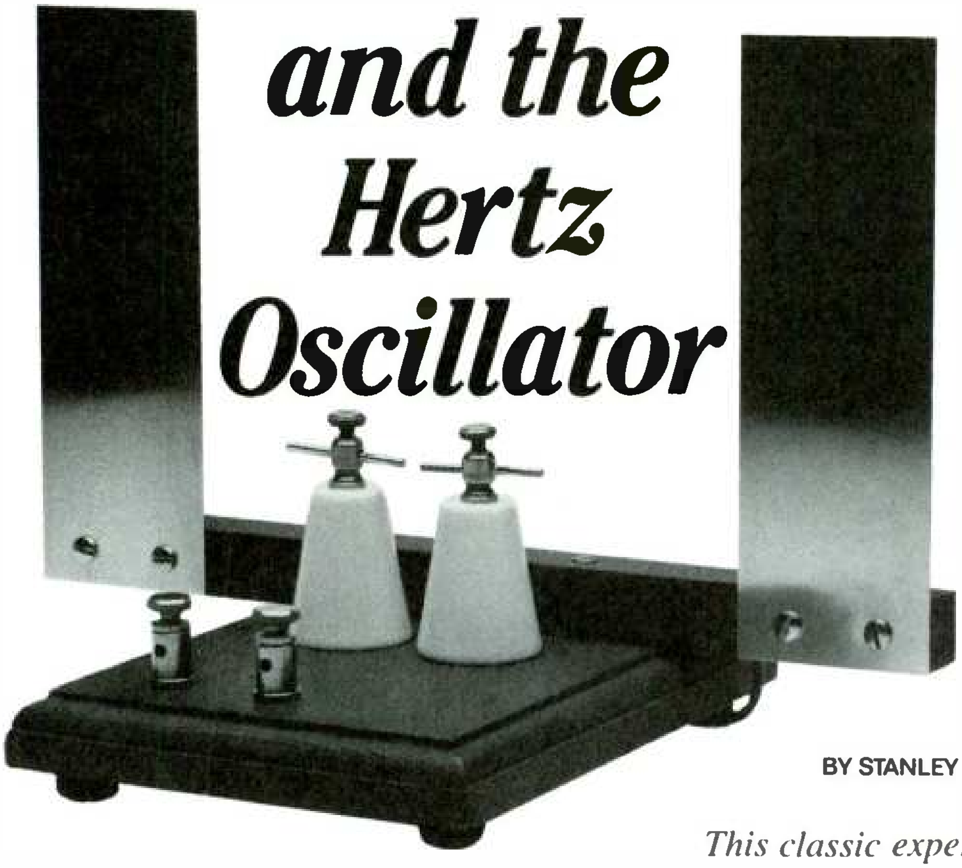
Fig. 9. This method of coupling a single-wire antenna to a portable shortwave radio equipped with a telescoping-whip antenna sometimes works. Other times, it just overloads the receiver

A means for connecting a single-wire antenna to a portable shortwave radio is shown in Fig. 9. Of course, you could use an alligator clip on the end of the downlead, and connect it directly to the whip antenna of the radio. But that may cause damage to the radio if static charges build up on the antenna. The method shown uses inductive coupling to avoid that.

The coil is wound on a toroidal core that has an inside diameter that will just fit loosely over the bottom portion of the whip antenna when the coil is wound. That usually means a T37 or T50 core. For low bands (less than 7 MHz), use about 20 turns of No.-26 enameled wire over the core; for higher bands (greater than 7 MHz), use 8 to 10 turns of No.-26 enameled wire. Connect one end of the coil to the downlead, and the other to the ground lead.

Be careful when adding an external antenna to a portable shortwave radio. Some of them already provide compensation for their small telescoping whip antennas. If an external antenna is used, then signal levels may prove excessive causing the radio to overload. ■

Electric Waves and the Hertz Oscillator



BY STANLEY A. CZARNIK

This classic experiment by Heinrich Hertz proved Maxwell's theory of electromagnetic waves.

By the middle of the 19th century, certain regularities in the behavior of electricity were becoming obvious to experimenters everywhere. Following the work of Coulomb, Oersted, Ampere, Faraday, and others, it was clear that an electric current created a magnetic field, that a magnetic field in motion near a conductor created a current, and that a current in one circuit could induce a current in another circuit. It was also known that electric charges attracted and repelled each other according to a law similar to the one associated with gravitation (the inverse square law)

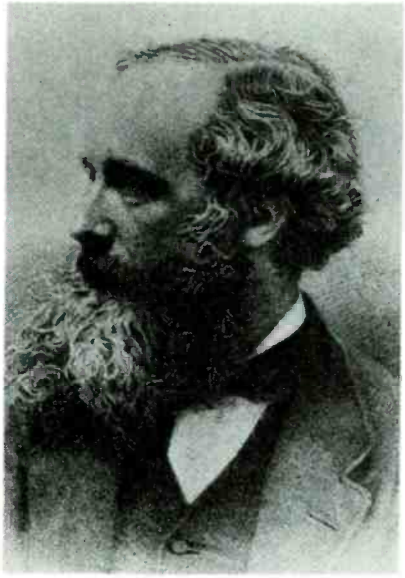
But questions remained. For example: How did the electric and magnetic forces move through space? One popular explanation involved the analogy between electricity and gravitation. Theorists imagined a charge (or mass) located at one point exerting an instantaneous influence on another charge (or mass) at some other point. No manifest connection had to exist between the two points. This old and somewhat mystical idea was known as "action at a distance."

Another theory was suggested by Michael Faraday. He postulated about "lines of force," the kind made visible by sprinkling iron filings on a sheet of paper placed over a magnet. The idea of lines of force stimulated the interest of another Englishman, James Clerk Maxwell, one of the greatest mathematical physicists ever. Ultimately, that interest was to become a theoretical representation of the electromagnetic wave.

The evolution of Maxwell's thinking on the matter passed through a number of preliminary phases and is (as it always was) quite complicated. The following should be considered only a very short summary of the points relevant to the rest of our story.

It had been known for a time that localized electrical activity occurred in insulators, like the air in a Leyden jar capacitor. Maxwell was the first to suggest that a current moving through such an insulator was a current of a special kind. He called it a displacement current. The reasoning ran like this: If an electric force applied to a dielectric (like air) was varied continuously, the result would be a wave of electric displacement. The periodic displacement wave would be accompanied by a periodic magnetic force. When the two were taken together, the result was an electromagnetic wave.

Next, the question of velocity came up. By the middle of the 19th century, the speed of light was known both from astronomical observations and from direct terrestrial experimentation. In 1849, Hypolyte Louis Fizeau calculated it by using a rapidly rotating toothed wheel and a mirror to reflect the light back to the wheel. Since the light was blocked by one of the teeth on its return journey, the speed of light could be calculated from the size and



James Clerk Maxwell (1831-1879) was the first to formulate a consistent mathematical representation of electromagnetic waves.

spin of the wheel and the distance of the mirror.

Now, following the work of Wilhelm Weber and Friedrich Kohlrausch on the speed of an electric disturbance along a wire, Maxwell was able to calculate the velocity of displacement currents in a dielectric. The numbers corresponded closely with those obtained for the speed of light.

The scientist pressed ahead to what was, for him, the obvious conclusion: the fundamental identity of electrical disturbances and light. As he phrased it: "light consists in the transverse undulations of the same medium which is the cause of electrical and magnetic phenomena." The idea was developed further and acquired a formidable mathematical representation in the important paper "A Dynamical Theory of the Electromagnetic Field" published in 1864.

Heinrich Hertz. Maxwell's electromagnetic theory was expressed as an arrangement of equations. But just what sort of physical system might correspond to the mathematical constructions was not clear. He failed to provide a circuit capable of generating the electromagnetic waves. Maxwell's model was difficult to visualize and the lack of experimental verification created a certain skepticism among many of Europe's leading physicists.

The experimental illustration of the electromagnetic theory did not come until 1888, nine years after Maxwell's early death at the age of 48. The necessary electrical apparatus was put together by a young German scientist, Heinrich Hertz.

Heinrich Rudolf Hertz was born in Hamburg, Germany, on February 22, 1857. His family was both cultured and prosperous; he had three younger sisters and one younger brother. Hertz's practical skills became evident at an early age. By the time he was twelve, he had wood-working tools and a workbench. Later, he obtained a lathe and used it to build various physical instruments. His paternal grandfather studied natural philosophy and had a small private laboratory. While still in his boyhood, Hertz was able to acquire some of his ancestor's scientific equipment.

Heinrich Rudolf Hertz (1857-1894) provided a reproducible experimental illustration of Maxwell's theories. The work was carried out in a lecture hall at the Technische Hochschule at Karlsruhe, Germany, in 1888.

Hertz studied at the University of Munich and then at the University of Berlin, where he came under the influence of the great German physicist, Hermann von Helmholtz. After completing his education, Hertz took a teaching position at the University of Kiel in 1883. It was at Kiel that Hertz found the time to make his first deep study of Maxwellian electrodynamics.

Like many of his contemporaries, Hertz found Maxwell's ideas and equations hard to understand. Indeed, at one point, the unusual mathematical difficulties nearly forced him to give up all hope of forming any consistent conception of Maxwell's models. But he persisted. In the spring of 1884, he wrote in his diary: "Hard at Maxwellian electromagnetics. Nothing but electromagnetics. Hit upon the solution to electromagnetics this morning."

Further Reading

The Identity of Light and Electricity, Heinrich Hertz, *Popular Science Monthly*, Volume 38 (December 1890): pages 179-188.

"Some Possibilities of Electricity," William Crookes, *Fortnightly Review*, Volume 52 (1892): pages 173-181.

Electric Waves, Heinrich Hertz, Macmillan, 1893

Pioneers of Electrical Communication, Rollo Appleyard, Macmillan, 1930.

"Action at a Distance in Classical Physics," Mary Hesse, *Isis*, Volume 46 (1955): pages 337-353

"James Clerk Maxwell," J.R. Newman, *Scientific American*, Volume 192 (June 1955): pages 58-71.

"Heinrich Hertz," Philip and Emily Morrison, *Scientific American*, Volume 197 (December 1957): pages 98-106. ■

The school at Kiel had no physics laboratory. So, when Hertz was offered a professorship at the *Technische Hochschule* at Karlsruhe, with its well-equipped Physical Institute, he accepted. Hertz found some high-voltage induction coils in the equipment collection. The transformers were just what he needed to build a real, working, experimental illustration of Maxwell's theories.

Given the complicated mathematical symbolism which inspired it, the extreme simplicity of Hertz's oscillator system is remarkable. This is what he did. He connected a strong battery of Bunsen cells to the primary windings of an induction coil equipped with a mercury interrupter. The secondary of the coil was attached to two large spheres or plates of zinc mediated by a spark gap. The two large conductors amounted to a radiating dipole antenna. In a sense, the two conductive ends of the Hertz's dipole were actually the inner and outer foils of a disassembled Leyden jar. There was no ground connection. For a detector or resonator, Hertz used a simple loop of wire the ends of which were separated by a very small spark gap.

The Experiment. Hertz set up his novel oscillator at one end of the Karlsruhe lecture hall; the resonator was placed at the opposite end. The room lights were extinguished and the scientist permitted his eyes to become accustomed to the dark. When the transmitter was switched on, a series of tiny electrical flashes became visible at the spark gap of the resonator.

Here were the electromagnetic waves he wanted. But, how fast were they moving? Hertz had no oscilloscopes or electronic test equipment of any kind, so direct measurements were impossible. Instead, he worked with the wavelengths. He set up a sheet of zinc against a wall to reflect the signals. Then, by studying the patterns of interference between the waves going out and the one coming back, he was able to calculate the wavelength and finally the speed of propagation. Hertz found no evidence for the mysterious and instantaneous action at a distance. The velocity of the waves was not infinite; it was finite; it was the speed of light.

The young physicist had verified a very difficult theory with a very simple demonstration, and the illustrative power of the experiment cannot be over-estimated. Hertz phrased it like this: "There are many friends of nature interested in the problem of light who are capable of comprehending simple experiments, but to whom Maxwell's theory is still unintelligible."

The Project. With an induction coil, low-voltage DC power supply, and a few scraps of wood and metal, you can build a functional replica of the Hertz oscillator and transmit electromagnetic signals to an ordinary AM radio. Like Hertz's original construction, the unit makes use of no electronic components whatsoever. The system goes together quickly; for those of you who have not yet worked with high-voltage apparatus, the beautifully simple Hertz oscillator is an excellent place to begin.

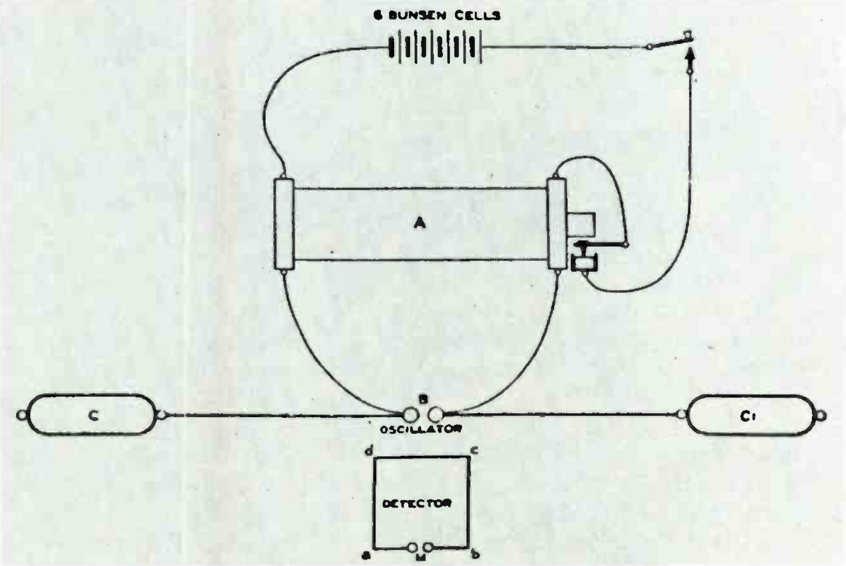
The cylinder-shaped high-voltage transformer shown in the photograph has been featured in this magazine before (June 1989 and March 1990); the earlier article also appears in the 1990 edition of the Electronics Hobbyist Handbook. It's an automobile ignition coil plus interrupter and runs on about 12 volts.

The particular unit shown, to the best of my knowledge, is no longer available on the regular commercial market. However, almost any high-voltage induction coil equipped with low-voltage DC input terminals and a make-and-break vibrator mechanism will work just fine. Coils of this type are currently available from Fisher Scientific, a laboratory supply company in Chicago; see the Parts and Materials List for more information. The coil from Fisher is a bit more powerful than the typical auto ignition unit.

PARTS LIST FOR THE HERTZ-OSCILLATOR EXPERIMENT

AM radio
Binding posts (4)
DC power supply, low-voltage
Induction coil (see text)
Porcelain insulators, or equivalent (2)
Narrow metal rods (2)
Rubber feet (4)
Brass or aluminum sheet metal, 2 × 6 inches (2 pieces)
Telegraph key, or equivalent
Wooden block, 5 × 7 inches
Wooden stick, 10 × ¾ inches
Wood screws, machine screws, threaded rod, solder, soldering lugs, hook-up wire, etc.

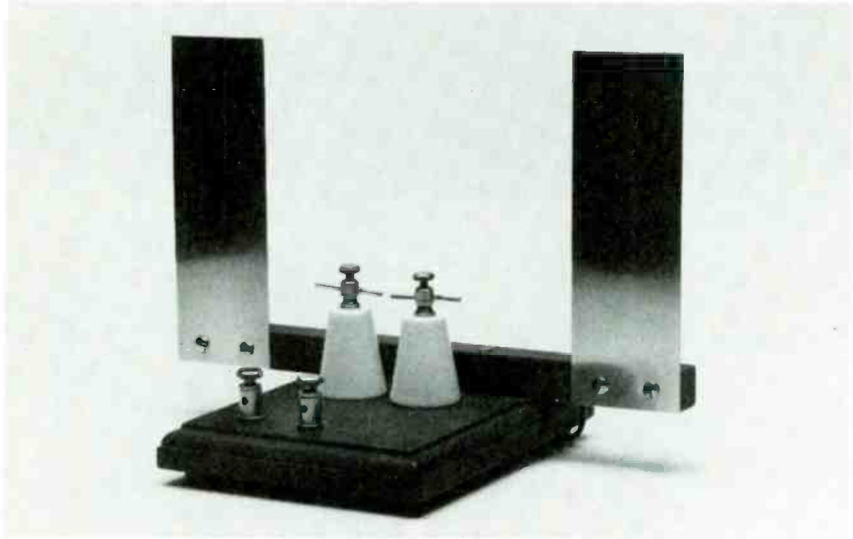
Induction coils, enclosed in a hardwood box and equipped with an adjustable vibrator mechanism, are available from Fisher Scientific, Educational-Materials Division, 4901 W. LeMoyne Street, Chicago, Illinois 60651 (Telephone: 1-800-621-4769, or, within 312 area code, 378-7770. The catalog number is S-43525 and the price is $112.00. Add $5.00 for shipping and handling. IL residents must add appropriate sales tax.



Given the complicated mathematical symbolism that inspired it, the extreme simplicity of Hertz's electromagnetic oscillator is remarkable. The high-voltage output of an induction coil (A) is connected to a radiating dipole antenna (C and C'), the two parts of which are separated by a spark gap (B). For a resonator, Hertz used a loop of wire (a, b, c, and d), the ends of which form a very small spark gap (M).

Construction. Obtain a block of wood about 5-inches wide, 7-inches long, and ¾-inch thick. Somewhere near one of narrower ends of the block, drill two holes for the input terminals. Remember that this device runs on high voltage; do not place the input terminals too close together. The space between the binding posts should be somewhat larger than the maximum size of the spark available from the induction coil.

The appearance of the oscillator is improved by doing all of the wiring on the underside of the baseboard so now might be a good time to attach four small rubber feet to the bottom of the block to provide space beneath



The oscillator described in this article is similar to the original built by Hertz over 100 years ago. A dipole antenna made of two metal sheets is connected in parallel to a spark gap and a pair of high-voltage input terminals. The unit measures 7 inches high, 10 inches wide, and about 7 inches long. The wooden base and crossbar have been stained.

The size of the oscillator spark gap depends in part on the power of your induction coil. A small coil will call for a 1/8- to 3/8-inch air break. A larger coil may require more space. The spark gap terminal posts should be at least 1½-inch apart.

the wood for the necessary connections.

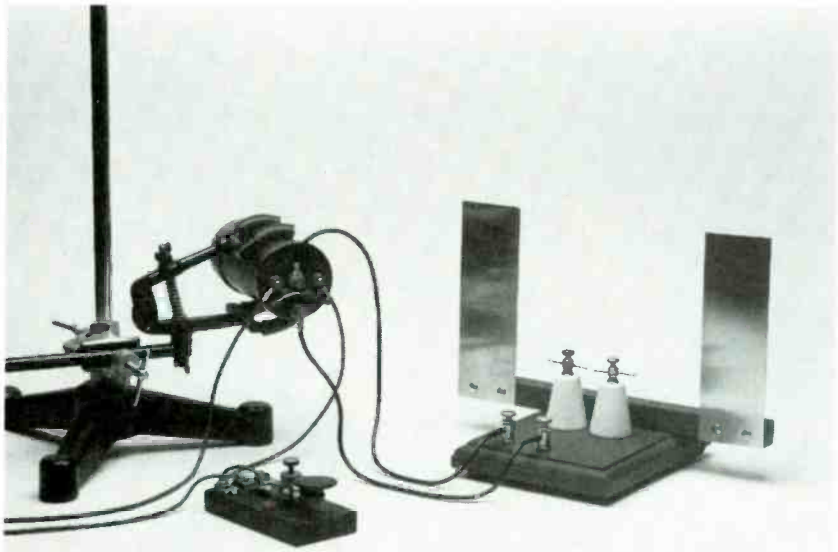
Next, somewhere near the center of the block, drill two holes for the oscillator spark gap. Those holes should be at least 1½-inch apart. A very powerful induction coil may require a still larger separation.

The size of the spark gap must be to some extent adjustable. The easiest way to do that is with two short metal rods held in place by a couple of small binding posts. The spark gap in the photographs is mounted on a pair of old-fashioned porcelain insulators. I just happened to find a few, covered with dust, sitting on a shelf in my workshop; perhaps you can locate something similar. The arrangement is fastened to the baseboard with two threaded rods cut to the proper length and furnished with soldering lugs.

Now you'll need two rectangular sections of brass or aluminum sheet metal for the dipole antenna. Small pieces of sheet metal are often available at certain large hobby shops. Each piece should be about 2-inches wide and 6-inches long. Drill two small holes near one narrow end of each piece. Next, obtain a piece of wood about 10-inches long and ¾-inch square. Drill two holes near each end of the stick to match the holes in the metal rectangles. Attach the metal to the wood with machine screws. Don't forget to equip each side of your antenna with a soldering lug. Fasten the antenna to the baseboard with a couple of wood screws as shown in the photographs.

Finally, warm up your soldering iron, locate some heavy-gauge insulated hook-up cable, and wire up the oscillator. The high-voltage input terminals, the spark gap, and dipole antenna are all connected in parallel. Make certain that all wires are kept as far away from each other as possible. If the connecting wires get too close, you are liable to wind up with an unwanted spark gap underneath the oscillator.

Operation. Locate your induction coil and connect the primary windings to an appropriate DC power supply. Most Induction coils run on about 6 to 12 volts. The low-voltage input circuit should be provided with some sort of momentary switch; a telegraph key is ideal. Next, set the oscillator spark gap to a distance of about ¼ inch. With a very small coil (like the one in the photograph), the best operational gap may be even smaller. With a larger transformer, the distance may have to be increased. Finally, connect the high-voltage sec-



Here's one way of setting up your electromagnetic wave generator system. The low-voltage input to the induction coil is controlled with a momentary switch, in this case, a telegraph key. The high-voltage output goes directly to the oscillator. The circuit requires no ground connection.

ondary of the coil to the terminals of the oscillator. Keep the low-voltage input wires at least 1 or 2 inches away from the high-voltage output cables. The system requires no ground connection.

Obtain an ordinary AM radio, turn it on, and set the tuner to almost any stationless position on the dial. Place the radio anywhere within several feet of the oscillator. Now, switch your system on and depress the telegraph key. You will hear a loud, scratchy, static buzz over the radio as sparks leap across the gap on the oscillator. If the radio doesn't buzz or if the sound is very weak, the oscillator spark gap is probably too big. A word of warning: **do not** under any circumstances attempt to adjust the spark gap when the oscillator is running.

Set the radio to some other place on the dial. When you press the key, you will still hear the buzz. That happens because the Hertz oscillator is not transmitting on a single frequency. The electromagnetic radiation you're producing does not take the form of a smooth, continuous wave. It's a series of pulses, each of which consists of a highly damped sinewave. In a pulse of that kind, the amplitude of each successive oscillation is smaller than the amplitude of the preceding one. Typically, the decrease follows a logarithmic pattern.

A tiny modification will allow you to actually see the electromagnetic signal as well as hear it. Obtain a small fluorescent tube and lay it down within 3 or 4 inches of the oscillator's dipole antenna. Place the tube so that its length is parallel to the flat surface of the two upright metal sheets of the dipole. (If the tube is placed in a perpendicular position, you may not get the effect you're looking for.) Now, when you operate your oscillator, the tube will flash!

Once again, do not touch the oscillator when the system is in operation, the entire unit is alive with high-voltage; if you make contact with any of the conductors, you will receive a strong and possibly dangerous electric shock. So, please be very careful when performing this experiment.

Conclusion. Heinrich Hertz is sometimes credited with the invention of the first primitive system of wireless communication, *i.e.*, spark telegraphy. But that perception is actually a reflection of our modern historical vantage point in place of his own. Hertz never devoted a lot of attention to the practical potentials of electromagnetic-wave technology. The reason for that is clear. What Hertz was after from the very beginning was experimental proof of Maxwell's theories and a refutation of the theories of instantaneous action at a distance. The creation of a new type of communications device was never his goal or a part of his plan.

Of course, it didn't take long for other natural philosophers to begin thinking about things to come and the implications of Hertz' experiment. One such person was that master of speculation and Victorian visionary, William Crookes. In 1892, he wrote: "Here is unfolded to us a new and astonishing world—one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence." ■

GUGLIELMO MARCONI

BY JAMES P. RYBAK

Marconi's wireless telegraph signals not only spanned the seas, they helped save lives as well.

A large, somber crowd was at Pier 54 in New York that dreary evening of April 18, 1912. Although hesitant at first, Guglielmo Marconi allowed police to clear a path through the crowd so he could see the 712 dazed and injured survivors of the S.S. Titanic tragedy as they came off the S.S. Carpathia, which had rescued them from the icy sea.

Marconi wireless equipment and operators on board the supposedly "unsinkable" Titanic had transmitted a shocking distress message in the early morning hours of April 13. The Titanic had struck an iceberg on its maiden voyage and was sinking rapidly. Less than three hours after the collision, the luxury ship, which "even God himself could not sink," was on the bottom of the North Atlantic. Of the 2229 passengers and crew members, 1517 perished.

Marconi was, at the same time, both distressed by the enormity of the tragedy and proud that his equipment and his operators had made possible the rescue of so many. He also undoubtedly remembered that he, too, had been scheduled to be a passenger on that fateful Titanic voyage to New York but had been forced to change his plans. The world now would hail Marconi as a hero for having made possible the rescue of the Titanic's 712 survivors.

This public attention provided Marconi with a certain amount of optimism. For many years, he had tried to stress the value of wireless in providing safety for ships on the high seas. Now, perhaps, his message would be more widely appreciated. Let's follow the long road he traveled to get his message across.

A Native of Italy. Guglielmo Marconi was born on April 25, 1874 in Bologna, Italy, to a family which enjoyed more than moderate wealth and local public recognition. His father, Giuseppe, managed a very successful family estate. Guglielmo's mother, Annie, was Scotch-Irish and had influential relatives in England. She and her English kin later would provide valuable help to Guglielmo in launching his career.

As a young boy, Marconi was not very interested in school work but did like to invent or make things. He would entertain himself by taking things apart to see what made them work. Guglielmo also enjoyed building replicas of mechanical devices or scientific experiments he had seen or about which he had read. These activities were encouraged by his mother, but discouraged by his father who considered them to be a waste of time and money.

In 1887, when Guglielmo was thirteen, he entered the Leghorn Technical Institute where he very quickly became interested in the study of science, especially electricity. That same year, coincidentally, Heinrich Hertz experimentally demonstrated the existence of the electromagnetic waves predicted in 1864 by James Clerk Maxwell.

Marconi did very well in his science studies. He persuaded his mother to hire a Professor Rosa to tutor him on electricity at home. However, science was Marconi's only interest, so he was not able to pass the entrance examinations to the University of Bologna.

Annie Marconi used her influence and persuasive personality on Professor Augusto Righi at the University of Bologna to get permission for Guglielmo to use the science laboratory over which Righi had control. Righi was a highly respected expert on the topic of electromagnetic waves, but apparently did not tutor Guglielmo directly or work with him on experiments. Marconi eagerly read books from the University library on electricity and telegraph systems.

Inspiration Comes. Marconi was on a holiday in 1894 when he read of the electromagnetic wave experiments of Hertz in an article written by Righi as an eulogy to Hertz. This article established the thought in Guglielmo's mind that possibly electromagnetic waves could free telegraphy from the wires and submarine cables, which at that time constrained its use.

Finding out if electromagnetic waves could be used to communicate at a distance became an obsession for Marconi. His mother allowed him to use two large rooms on the top floor of their house as a laboratory. She also helped persuade Guglielmo's father to provide (albeit grudgingly) the money necessary for the batteries, wire, and other equipment Guglielmo needed.

Mr. Marconi remained reluctant to spend money to promote his son's "foolish activities." After all, hadn't Professor Righi questioned Guglielmo's ability to accomplish anything significant in a field of science in which the boy had so little real knowledge?

Marconi started by repeating Hertz's experiments. His oscillator was an induction coil equipped with four spheres for the spark discharge, similar to that he had seen in Righi's laboratory. The frequency of the oscillations was in what we, today, would call the VHF range.

The detector he used with his receiving coil was a Branly coherer, similar to that used by Oliver Lodge. The coherer provided much greater sensitivity than the spark-gap equipped loop of wire Hertz had used. Marconi placed a curved metal detector behind his oscillator to direct the waves toward the detecting circuit.

Before long, Marconi was able to cause a bell, located thirty feet away, to ring when the oscillator was keyed. Through trial-and-error experimentation, he was able to increase the sensitivity of the coherer significantly over what others had achieved.

Distances Increase. The following spring, Marconi took his experiments outdoors. Connecting metal plates to the oscillator's spark gap lowered the frequency and strengthened the intensity of the oscillations produced. Similar plates were connected to each side of the coherer.

By chance, Marconi found that if one of the metal plates was elevated high in the air and the other was laid on the ground, the range at which oscillations could be detected increased to over one-half mile. Marconi's older brother and one of his father's employees became his assistants in these long range experiments.

Soon, the elevated plates at the oscillator and detector were replaced by long vertical wires. The plates which had lain on top of the ground now were buried. This arrangement increased the distance at which signals could be received to one and one-quarter miles. An intervening hill was found to be no barrier to the reception of the signals.

The combination of using lower-frequency oscillations and using the Earth as an element in his antenna system were crucially important achievements. Guglielmo Marconi had accomplished much by the fall of 1895.

Giuseppe Marconi was becoming impressed with the results he saw and changed his attitude toward his son's activities from opposition to support. He must have thought the boy might just be on to something.

Guglielmo realized that he needed to patent his wireless telegraph system. He was convinced that others, more knowledgeable concerning electromagnetic waves than he, undoubtedly also saw how these waves could be used in a telegraphy system. His father knew people who could help obtain an Italian patent and his mother's relatives had contacts in British scientific and governmental circles to help him there.

Marconi had wanted the Italian government to have the first opportunity to benefit from his work, but his offers were declined by the Ministry of Posts and Telegraphs. It is very likely the Italian Navy would have been interested in wireless telegraphy, but Marconi never approached them with the idea.

Off to England. Guglielmo was twenty-one when he and his mother went to England in February of 1896. Their arrival started out badly with customs officials carelessly damaging some of Marconi's wireless equipment. Perhaps this damage was deliberate because the customs inspectors suspected Guglielmo was some kind of spy or saboteur. Marconi's unwillingness to explain the purpose of his equipment to the officials undoubtedly increased their suspicions.

The first tasks Marconi undertook were the repair of his equipment and the filing for a British patent on his wireless system. Next, a letter of introduction to William Preece, Chief Engineer for the British Post Office was obtained through the help of a relative. The Post Office was the official provider of telegraph service in England and Preece, himself, had been experimenting with an inductive system of wireless telegraphy for some time.

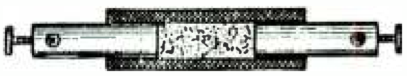


Fig. 1. The Branly coherer consisted of loosely packed coarse metal filings between two metal plugs in a non-conducting tube.

After meeting with Preece, Marconi was invited to give a demonstration of his wireless system to Post Office officials in July. Marconi set up his equipment on two roof tops located only a few hundred yards apart, but with tall buildings blocking direct view. The successful transmission of signals impressed the Post Office officials. They then requested additional demonstrations over longer distances.

The next formal demonstration by Marconi occurred in September of 1896 with officials of the War Office and the Admiralty joining the Post Office observers. Captain (later Sir Henry) Jackson was one of the persons in attendance. He had been conducting wireless tests since 1895 and in August had succeeded in sending signals between two ships located several miles apart.

The chief purpose of the September experiments was to demonstrate the feasibility of directional control of wireless signals. Marconi placed parabolic reflectors behind both his transmitting and receiving antennas. He successfully transmitted his short wavelength signals over a distance of one and three-quarters miles.

A Public Demonstration. The press and public were invited to a lecture on wireless by Preece and a demonstration of Marconi's equipment in December of 1896. A black box contain-

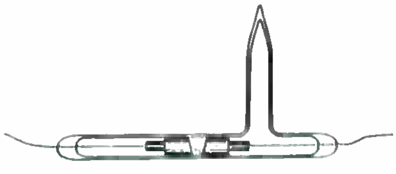


Fig. 2. Marconi improved the coherer by using a mixture of very fine nickel and silver particles between two tapered silver plugs in an evacuated glass tube.

ing an oscillator activated by a telegraph key was held by Preece as Marconi walked around the auditorium carrying another black box containing a receiver connected to a bell. To the amazement of the audience, whenever Preece closed the telegraph key, the bell in Marconi's box rang clearly for all to hear.

Now Marconi became a public celebrity. The press proclaimed Marconi the "inventor of wireless." This regard for Marconi's accomplishments was not shared by all, however.

Those familiar with recent scientific achievements knew that Hertz had shown how to generate the electromagnetic waves in 1887 and that Branly had observed "coherer action" in 1890. A number of people knew of Captain Jackson's work as well.

In addition, many scientists knew that Oliver Lodge had used similar equipment to send signals a distance of sixty yards before Marconi had even begun his own experiments. Lodge did not have the foresight to see the importance wireless might have for long distance communications and had not pursued his work toward that goal. Lodge did, however, obtain patents that would result in problems for Marconi many years later.

Another demonstration was held in March of 1897. This time longer wavelengths were used in conjunction with wire antennas raised some 120 feet above the ground by means of kites and balloons. This arrangement resulted in signals being received over a distance of four and one-half miles.

In May of 1887, Marconi demonstrated that wireless signals could span significant lengths across water by sending signals between the shore and an island in the Bristol Channel, a distance of 8.7 miles. This was a crucial test because the submarine cable that normally provided communications to the island had failed several times in recent months. Repairing the cable was costly both in time and in money so Marconi's system must have appeared as an excellent alternative.

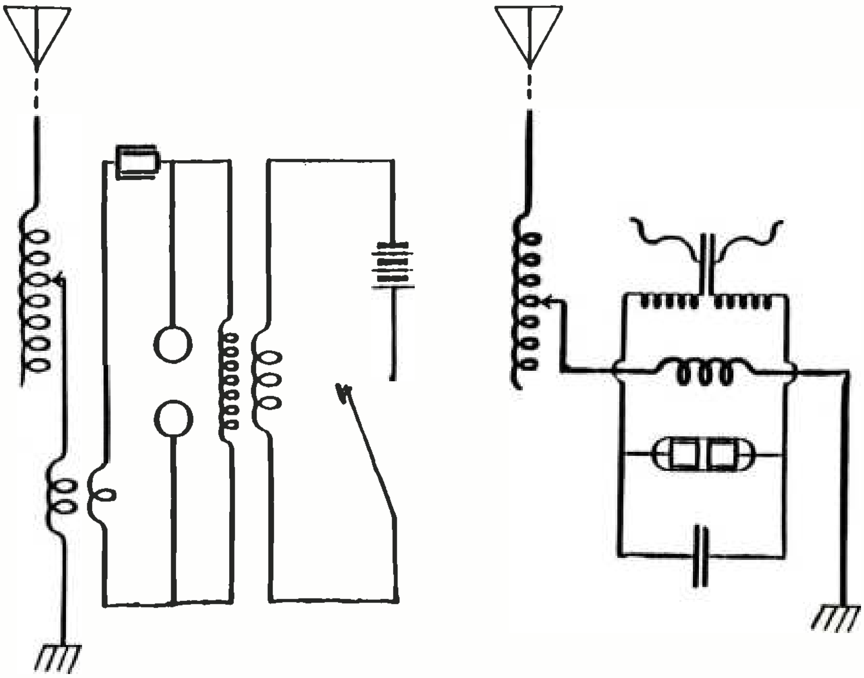


Fig. 3. Adding a "jigger" transformer in both the receiver and transmitter antenna circuits was one of Marconi's early attempts at tuning.

Marconi Goes Commercial. The Wireless Telegraph and Signal Co. Ltd. was established in July of 1897. It was the first of numerous commercial enterprises Marconi would form over the years for the development and sale of his wireless technology. In 1899, he changed the name of his company to The Marconi Wireless Telegraph Co. Ltd.

A major goal Marconi had in mind was to show the value of wireless for communicating with ships. In 1897, he returned home to Italy to convincingly demonstrate that wireless could communicate between naval warships. The Italian Navy soon adopted the Marconi wireless system. By the end of 1897, Marconi also had demonstrated that a wireless station he had established on the Isle of Wight in the English Channel could maintain communications with nearby ships.

Much favorable publicity came to Marconi when he operated a wireless transmitter from a boat to provide coverage of the 1898 Kingstown Regatta for a Dublin newspaper. Some seven-hundred messages sent over distances ranging from ten to twenty-five miles enabled the newspaper to out-do its competition in reporting the results of this very popular summer event. The manner in which the race was reported made as much news as the regatta itself.

Marconi was even more in the public limelight in the summer of 1898 when his wireless equipment enabled Queen Victoria to communicate regularly with her son (who one day would become King Edward VII) while he was on a yacht recuperating from an injury. The yacht was located only two miles away, but out of sight, from the residence on the Isle of Wight where the Queen was staying. Wireless provided the only rapid means of communication. For sixteen days, the press marvelled at the accomplishments of Marconi's equipment as 150 messages passed between the Queen and her son.

While Marconi's demonstrations were highly successful and public acclaim was widespread, customers for his equipment were few. It was clear that even more convincing demonstrations of the capabilities of wireless were needed.

The next goal in Marconi's plan was to show that wireless could form a communications bond between England and the Continent. On March 27, 1899, Marconi sent the first message from his newly erected station at Wimereux, near Boulogne, in France to his English station at South Foreland, a distance of thirty-two miles. A number of French officials in attendance sent messages of greetings to their counterparts in England. This event generated for Marconi much additional publicity and good will, but, unfortunately, little that he could take to the bank.

A Need for Tuning. Marconi had shown that wireless could span distances that made it useful for commercial purposes. One major problem persisted, however. The untuned spark-gap transmitters generated extremely broad-band signals.

Two stations could communicate with each other without trouble. However, when a third station transmitted simultaneously, havoc ensued with each station effectively "jamming" the others so that messages were indecipherable. What was needed was some way for enabling transmitters to generate only one frequency and for ensuring that the receiving stations respond to only the signals desired.

Marconi had been aware of the need to provide such tuning for some time. His first efforts in 1897 involved coupling the receiving antenna to the coherer by means of a high-frequency transformer, or "jigger" as he called it, instead of the direct coupling previously used. The initial results were disappointing.

Continued experimentation resulted in the use of a split secondary transformer winding and the addition of a capacitor. Limited receiver tuning now was achieved, provided an antenna of the proper length was used. A small amount of transmitter tuning also was achieved when a jigger was used to couple the transmitter to its antenna. This tuning arrangement was patented by Marconi in 1898.

Still, the degree of transmitter and receiver tuning provided was not enough. Marconi's work continued. He was aware of and refined some of the tuning or "syntony" principles Oliver Lodge had demonstrated as early as 1889. Lodge had continued his own efforts and had obtained a patent in 1897 on a tuned antenna system for wireless telegraphy. Lodge's tuning system, like Marconi's, did not provide all the frequency selectivity needed.

Marconi's work ultimately resulted in the use of an effective antenna coupling circuit, which employed a tapped inductance together with a variable capacitor. That allowed both the transmitting and receiving antennas to be tuned to the precise frequency desired. In addition, and equally importantly, Marconi's system also provided tuning for both the oscillator circuit in the transmitter and the coherer circuit in the receiver. The ability to confine the transmitted power to a narrower bandwidth not only allowed multiple stations to transmit simultaneously, but it also increased the distance over which the signal could be received.

Marconi applied for a patent on his tuning technique to establish and protect his commercial rights to its use. He was awarded British patent number 7777 (commonly referred to later as the "Four Sevens" patent) on April 26, 1900.

Eleven years later, Marconi would find that his legal position was not as solid as he had hoped. The principal features of Oliver Lodge's 1897 patent (albeit, with many improvements) clearly were incorporated in Marconi's tuning system. Lodge was prepared to defend his legal priority in court. To avoid lengthy and expensive legal proceedings that would probably be decided in Lodge's favor, the Marconi Company in 1911 purchased the rights to the 1897 patent from Lodge.

Marconi still believed that the first significant commercial market for wireless telegraphy would be the shipping industry. But to interest ship owners, it would have to be shown that truly long-distance wireless communication was possible and reliable.

A Bold Plan. In 1900, the Marconi International Marine Communication Company was established to develop a commercial maritime-communication network. Despite the fact that the Company's finances were being stretched to the limit by the cost of worldwide marketing activities, which were producing distressingly few orders, Marconi proposed the grandest demonstration of all. He told the Company's directors that he wanted to build two high power stations with the goal of having signals span the Atlantic Ocean!

Marconi's goal seemed far too extreme. Due to the curvature of the Earth, the two stations were separated by the waters of the Atlantic, which effectively formed an obstacle, approximately two hundred miles high and incredibly thick. That meant he'd have to aim his signals tangential to the Earth's surface and hope for the best. At the time, the mathematical theory developed concerning the propagation of electromagnetic waves indicated that propagation slightly beyond the horizon was possible due to refraction. However, beyond a certain point the waves would travel away from the Earth's surface toward outer space, never to return.

Marconi already had achieved significant over-the-horizon propagation of signals, however. He was convinced that trans-Atlantic signaling would be possible if sufficient transmitter power were used.

The two sites initially chosen by Marconi for his stations were Poldhu, on the southwest tip of England, and Cape Cod, Massachusetts. John Ambrose Fleming (who later would develop the diode detector "valve" or "tube") was given the job of designing the necessary high power transmitters. His design utilized cascaded spark-gap resonant circuits driven by a 25-kilowatt alternator. Such transmitter power had never before been achieved.

The receiver's detector consisted of a glass tube with mercury placed between the ends of two conducting rods. At the time, this detector was called a "self-restoring coherer." However, the oxide film on the mercury actually produced a form of rectifier, rather than coherer, action. A telephone earpiece was connected to convert the hoped-for detected signals into audible sound.

The antenna selected consisted of an inverted wire cone 200 feet high supported by 20 wooden poles arranged in a circle. The design was

Books of Interest

Syntony and Spark—The Origins of Radio, by Hugh G.J. Aitken, Princeton University Press, 1985.

A History of the Marconi Company, W.J. Baker, St. Martin's Press, 1971.

Marconi—The Man and His Wireless, Orrin E. Dunlap, The Macmillan Company, 1937.

Wireless Telegraphy, Sir Eric Eastwood, John Wiley and Sons, 1974.

Guglielmo Marconi: 1874–1937, Keith Geddes, Her Majesty's Stationery Office, London, 1974.

Marconi, W.P. Jolly, Stein, and Day, 1972.

My Father Marconi, Degna Marconi, Frederick Muller Ltd., London, 1962.

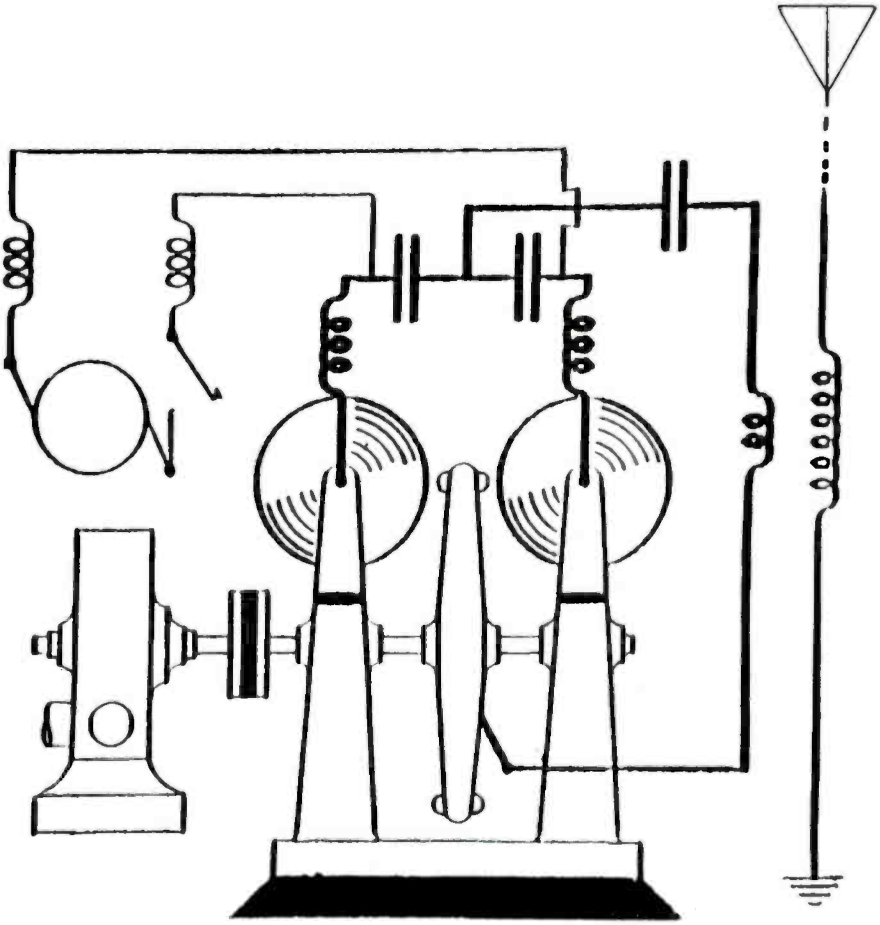


Fig. 4. After Marconi developed the "rotating-disc discharger," dependable trans-Atlantic signaling became a reality.

mechanically unstable and a storm destroyed the Poldhu antenna before tests could be begun.

Marconi then changed his plans, settling on one-way transmissions from Poldhu. The new antenna at Poldhu was simpler and sturdier, but less efficient. It consisted of a fan-shaped array of 50 wires supported by a horizontal wire stretched between two poles. The array was nearly 160 feet high and 200 feet in width. Newfoundland, the closest North American land mass, now was selected as the reception site.

Marconi and two assistants sailed for Newfoundland in late November of 1901. Bad winter weather and little available time would not allow a sophisticated receiving antenna to be built. The simple vertical wire antenna they planned to use would be supported by the kites and balloons they brought with them. The winter season provided better propagation conditions for wireless signals, but the frequent storms would make raising and maintaining their wire antenna a difficult proposition.

Upon arriving in Newfoundland, Marconi paid a visit to the Governor and the Premier who immediately offered him their full cooperation. Marconi chose a hill overlooking the city of St. John's as the site for his experiments.

The Poldhu station was instructed by a cable message to send the letter "S" in Morse Code continuously for several hours each day beginning on December 11. The weather that first day was bad, however. The hydrogen-filled balloon used to lift the antenna rose and plunged violently before finally breaking loose and being lost. No signals were copied.

The storm continued throughout the following day. A kite used to raise the antenna soon was torn away due to the violent winds. A second kite then was employed to raise the 500-foot long antenna wire and it, too, seemed likely to be lost at any moment.

Success! Marconi listened intently for the signals from Poldhu. For what seemed to him like an eternity, nothing was heard. Then suddenly, at 12:30 p.m., Marconi handed the telephone earpiece to his assistant. Both men could hear the faint but unmistakable repetitive pattern of three clicks followed by a pause. Before long, the signals were lost in static.

Signals from Poldhu also were received at 1:10 and 2:20 p.m. on that historic afternoon of December 12, 1901. The twenty-seven year old Marconi now knew that his goal of a worldwide wireless-communication network was attainable.

Equipment for accurately measuring the wavelength of the transmitted signals was not available. Marconi estimated the wavelength to be approximately 366 meters while some of his engineers thought the wavelength could have been as long as 3000 meters. These wavelengths correspond to frequencies of 820 kHz and 100 kHz, respectively.

A press release describing Marconi's accomplishment was issued on December 14. While the news was believed and applauded by many members of both the general public and the scientific community, others were skeptical. Marconi's personal integrity was not questioned. Rather, some thought that the ears of Marconi and his assistant had been deceived by their enthusiasm. Unquestionable proof of the signal reception was what the skeptics demanded.

The news also caused some unexpected negative reaction. The Anglo-American Telegraph Company, owner of a cable and wire telegraphy system, had been granted a legal monopoly over all telegraph communications in Newfoundland. The Marconi Company was threatened with legal action if it did not cease its Newfoundland activities immediately. Marconi quickly accepted an invitation by the Province of Nova Scotia to move his facilities to Glace Bay on Cape Breton Island.

Positive Proof Provided. In January of 1902, Marconi arrived in England to plan his next experiments. He erected an antenna and set up wireless receiving equipment on the steamship Philadelphia in preparation for its February voyage to the United States.

Marconi's plan was to receive signals from Poldhu as the ship steamed westward with reliable witnesses on hand. The signals would be recorded on a Morse inker tape and verified by the ship's captain.

During the daylight hours of the ship's voyage, signals were received to a distance of 700 miles west of Poldhu. After dark, however, complete messages were received to a distance of 1550 miles and the "S" signals were copied to a distance of 2100 miles. Now Marconi had the undeniable verification of his experiments the skeptics demanded.

It must not be assumed that these successful experiments led immediately to a reliable trans-Atlantic wireless service. Propagation conditions were unpredictable and constantly changing. When signals did span the distance, messages usually had to be repeated numerous times before being received in their entirety. Wireless still could not compete successfully with cable telegraphy. More development was necessary.

A Global Network. The Marconi Company also began to see its goal of a worldwide communication system for ships attain reality in 1902. By the end of that year, seventy ships had been outfitted with Marconi equipment. The Company established twenty-five land-based stations around the world, including several along the Atlantic coast of North America, to communicate with ships carrying its wireless equipment.

One legal problem had to be overcome, however, before significant revenues could be generated. The British Post Office held a government-established monopoly on the handling of telegraph messages of any kind in the British Isles. It was illegal for any other organization or person to send telegraph messages for a fee.

To circumvent that monopoly, the Marconi Company rented, rather than sold, its equipment to ship owners. The rental fee included the services of a trained operator and the right to communicate with the Marconi shore stations. Since the Marconi Company did not charge for individual messages, it did not violate the law.

This rental arrangement also enabled the Company to increase its business by prohibiting ships not carrying Marconi equipment from communicating with its strategically located land-based stations or with Marconi equipped ships. Only in the case of distress calls would a Marconi station communicate with a non-Marconi equipped ship.

Bigger and Better Antennas. To allow construction of a larger antenna, Marconi moved his Nova Scotia station to a new plot of land less than two miles from Glace Bay in 1905. The maximum daytime range of the signals now increased to 1800 miles, but this still was insufficient to provide dependable trans-Atlantic communications with Britain.

Purely by accident, Marconi noticed in 1905 that a long antenna wire lying on the ground at Poldhu provided better reception when its free end pointed away from the Nova Scotia station. This fortunate observation led to the development of the "bent aerial" array of long wires. Not only was this new antenna design directional, it also was a more efficient antenna for transmitting and receiving long wavelengths. Marconi had the Nova Scotia antenna modified to this new design and achieved very good results.

The site at Poldhu was not large enough for construction of this new directional antenna. Marconi, therefore, chose a new site at Clifden in western Ireland. In addition to the directional antenna, the Clifden site was outfitted with a 300-kilowatt transmitter.

Marconi then worked to improve the last weak element in his system: the transmitter spark. The pulses of damped oscillations produced by the existing transmitter designs were coupled back and forth several times between the spark and the antenna. This caused considerable electromagnetic energy to be dissipated in the spark, producing erosion of the spark gap contacts and reducing the useful radiation.

The problem was overcome when Marconi developed the "rotating-disc discharger." This design was very efficient and could be used to produce virtually undamped oscillations, either in a continuous train or in pulses. The inherently narrower bandwidth of these nearly undamped oscillations increased the effectiveness of the transmitter and receiver tuning and reduced interference between stations.

A Reliable System Achieved. The combination of the improved disc discharger mechanism together with the directional antenna resulted in a system which enabled (reasonably) dependable two-way communication between Glace Bay and Clifden, both day and night. Marconi now began his first commercial wireless telegraphy system between the two continents in October of 1907.

Over 10,000 words were sent the first day, alone. Marconi charged five cents per word for press-service usage and ten cents per word for other users. The cable telegraphy companies had been charging twenty-five cents per word. While the Company claimed a sending rate of twenty words per minute, poor conditions often necessitated numerous repetitions of the messages, resulting in a much lower effective rate of transmission.

Safety for Ships. While the establishment of commercial trans-Atlantic wireless telegraphy provided the Company with badly needed revenue, Marconi's greatest personal satisfaction undoubtedly came from the increased safety his wireless equipment provided ships. Marconi was an avid sailor and clearly understood the need for wireless at sea.

No longer were people on the high seas without a means of obtaining help when disasters struck due to storms, fires, icebergs, running aground, or mechanical failures. In the few short years since its inception, wireless telegraphy already had come to the rescue of imperiled passengers and crews on numerous occasions.

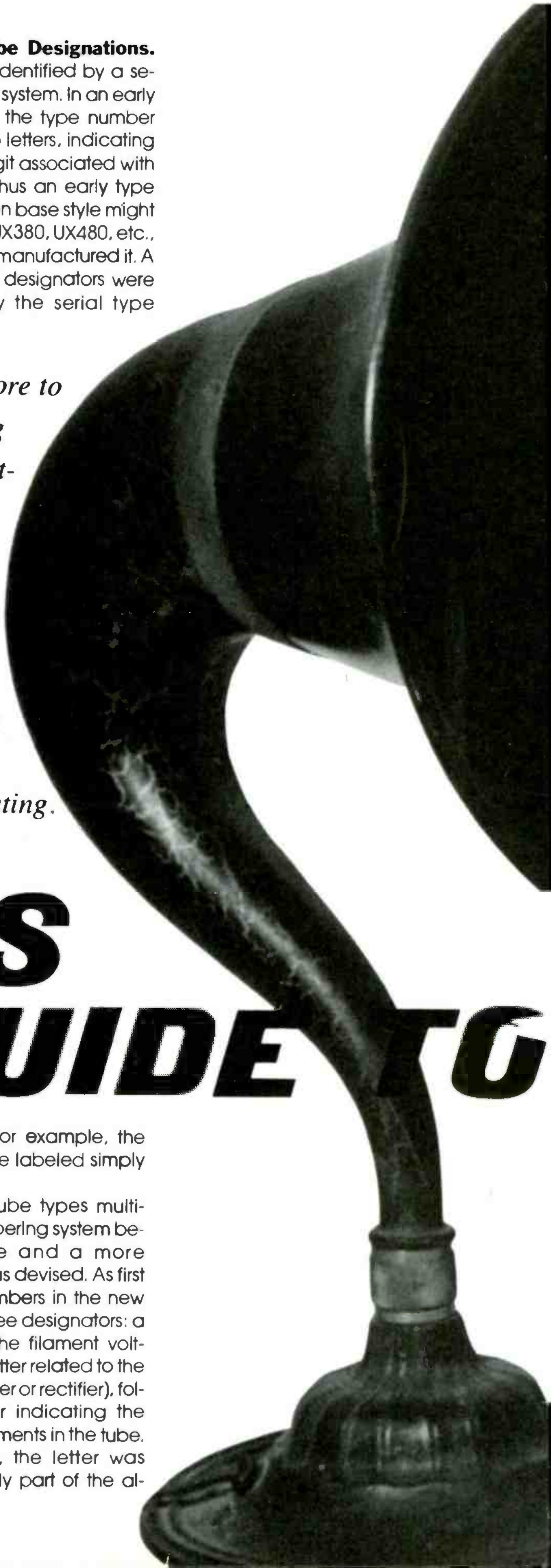
The first use of wireless to effect a maritime rescue occurred on March 3, 1899 when the steamship R.F. Mathews ran into the East Goodwin lightship in the English Channel during a heavy fog. Marconi equipment enabled a message to be sent to the nearby South Foreland lighthouse, bringing lifeboats to the rescue. While this was a relatively small event, it was indicative of the role wireless would play in the future.

(Continued on page 110)

BUYER'S GUIDE TO

BY MARC ELLIS

There's a lot more to radio collecting than just collecting radios! Here's a guide to the different types of radio-related collectibles, and what makes each of them so fascinating.



Most people who enter the fascinating hobby of antique-radio collecting begin by acquiring the radio sets themselves. But it isn't possible to continue that activity very long without also becoming a collector of related items. For example, those who are interested in repairing their radios and keeping them running (and most of us fall into that category) must also collect tubes, parts, and servicing information. And what radio collector can resist picking up old magazines and catalogues containing all the related promotional material?

For some, the radio-related collectibles become as important as the sets themselves—or perhaps more so. Others tend to pick up only what they need for practical purposes and, perhaps, to add a little color to the radio room. If you're new to the hobby, you probably don't yet know where you stand, but this article will give an orientation that will help you make up your mind and add more spice and good fortune to your house-sale and flea-market forays by giving you more items to look for!

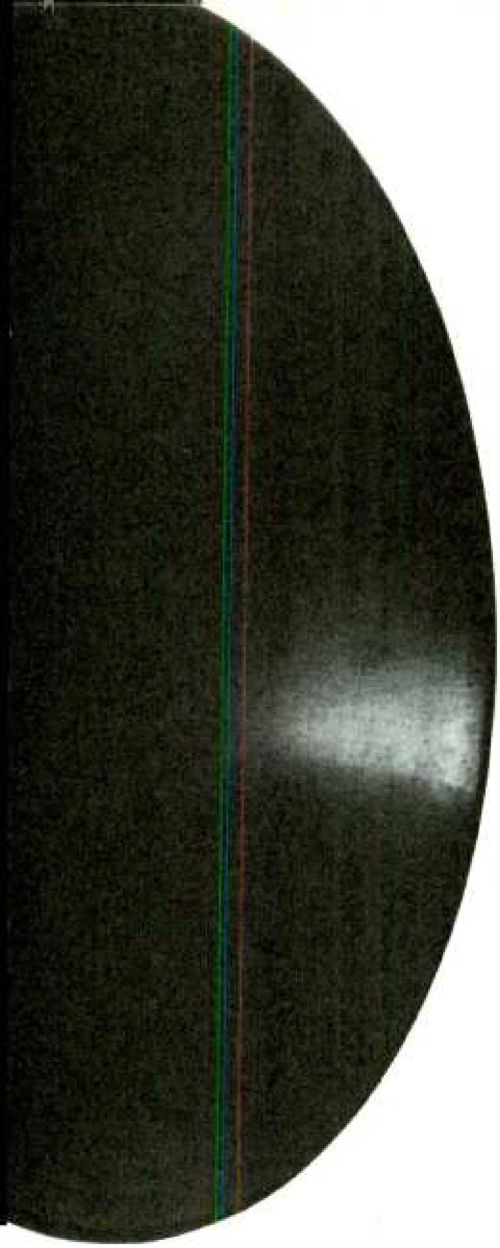
Collecting Radio Tubes. No matter how little you might care about radio-related collectibles, you won't be able to avoid an involvement with radio tubes. The evolution of radio receivers was very much tied to the evolution of new tube types. Once you gain an understanding of the latter, you'll be in a much better position to understand—and date—the radios you already own, and those you'll find in the future.

Tubes also make extremely interesting collectibles in their own right. While tubes dating from the earliest days of radio (such as the DeForest audion) are rare, and seldom seen outside of museums, those dating from the beginnings of radio broadcasting (early 1920's) are easier to find because they were mass produced.

Understanding Tube Designations. At first, tubes were identified by a serial-type numbering system. In an early form of the system, the type number was prefixed by two letters, indicating base style and a digit associated with the manufacturer. Thus an early type 80 having a common base style might be labeled UX280, UX380, UX480, etc., depending on who manufactured it. A little later, the initial designators were dropped and only the serial type number was used (for example, the above tube would be labeled simply "80").

In the 1930's, as tube types multiplied, the serial-numbering system became inadequate and a more sophisticated one was devised. As first introduced, type numbers in the new system contained three designators: a number identifying the filament voltage, followed by a letter related to the tube function (amplifier or rectifier), followed by a number indicating the number of active elements in the tube. For amplifier tubes, the letter was chosen from the early part of the al-

RADIO COLLECTIBLES



phabet; for rectifiers, from the latter part of the alphabet.

For example, the 6C6 has a 6-volt filament; is an amplifier; and contains 6 active elements (a filament, a cathode, three grids and a plate). On the other hand, a 5Z3 has a 5-volt filament; is a rectifier; and contains three active elements (a filament and two plates). The 6D6 and 5Y3 (an amplifier and a rectifier, respectively) perform functions similar to the tubes just discussed, but have different operating characteristics. That is reflected by the differences in identifying letters.

Physical Changes in Radio Tubes. The evolution of *physical* tube characteristics is also of interest to the collector. The glass envelopes of the earliest tubes were like those of contemporary light bulbs; pear shaped with a pointed seal at the top. Later, following trends in light-bulb design, the seal was moved to the bottom of the tube so that it could be hidden in (and protected by) the base.

Still later, in the 1930's, pear-shaped envelopes gave way to the "double-dome" or "ST" style. And a little later in the same decade, more compact tube designs made it possible to release new types (and some older ones) in the "bantam" or "GT" style. That envelope was much shorter than previous ones, straight sided, and had a rounded top. Some manufacturers released the same types in metal-enclosed glass envelopes, having roughly the same outer dimensions as the "GT" style.

Tube bases also changed over the years. Brass gave way to bakelite as a base material, and the original short-pin, bayonet-lock style was changed to the longer-pin type that engaged with friction contacts in the tube socket. Some transition-period tube bases had the longer, friction-contact pins, but could also bayonet-lock into the older sockets.

Tube cartons can be as interesting to collectors as the tubes they contained. From the plain generic-looking styles of the early 1920's to the colorfully lithographed ones of later years, they can make a very interesting display.

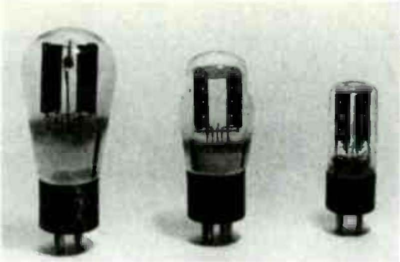
A detailed discussion of radio-tube history is beyond the scope of this article. But for more information on tubes from the early years of broadcasting through the early 1930's, check your back issues of **Hands-on Electronics**. You'll find the *Ellis On Antique Radio* columns of February, March, and April 1987, as well as May, 1988, to be very helpful.

John Rider's Mighty Manuals. As mentioned a little earlier, your preoccupation with printed radio literature will begin almost immediately after acquiring your first few sets. Because once you start working on the radios, you'll want to acquire schematics and other servicing information.

There are individuals and organizations who will look up information and photocopy it for you for a nominal fee. But if you have the space and the inclination, you can build your own personal library of original service data.

In my opinion, the best way to do that is to begin acquiring volumes of John Rider's *Perpetual Trouble Shooter's Manual*. Rider began publishing the manual some time in the late 1920's or early 1930's, and added a new volume to it approximately every year (with some breaks during World War II).

Each new book provided schematics and service information for virtually every radio released since publication of the prior one. The complete set contains 23 hefty tomes covering radios from the early 1920's through the early 1950's.



These three versions of the familiar type-80 tube show the evolution of bulb styles. At far left is an original pear-shaped bulb; in the center is an "ST" (double-dome) style; and at the right is a "GT" (straight-sided) bulb.

Rider volumes still turn up regularly at antique-radio swap meets and hamfest flea markets, and they're easy to spot. Look for a distinctive dark-blue binder with a quaint cover illustration of an antenna strung between two towers. A separate Rider series, similarly bound, covered television sets—but they are plainly marked as such, and you can avoid them (unless, of course, you are into early TV's).

The Rider manuals of most practical interest to collectors are probably volumes 1 through 13. (The latter bears a 1942 copyright, and covers the last of the pre-war radios). However, if you look at the Rider set as a collectible in its own right, you'll obviously want to acquire as many of the volumes as possible.

Price and Availability. The earliest volumes in the set (1 thru 4 or so) don't seem to turn up very often, and are expensive. The volumes towards the end of the series are also hard to come by. I suspect that the manuals declined in popularity towards the end of the run, and not as many were printed. Asking prices for the more common volumes seem to be from six to fifteen dollars each, depending on the mood of the owner.

Rider also published an abridged version of volumes one though five, complete in one book that is bound uniformly with the rest of the set. It was probably intended for repairmen who got into the business some years after the series was instituted and didn't have as much need for the earliest data. The abridged version is much more common than the individual volumes, and would be a good alternative for those who can't find the latter. I've seen it priced at about $40.00.

Though I didn't realize what I was buying at the time, I was lucky enough to purchase the complete volumes 1-3 bound in one book. It was originally offered by RCA as part of a tube deal, and the binder is the same physical size and type as that used in the standard Rider manuals. However, the cover is red instead of blue and shows a vacuum tube instead of the traditional antenna and towers. I've never seen another one like it.

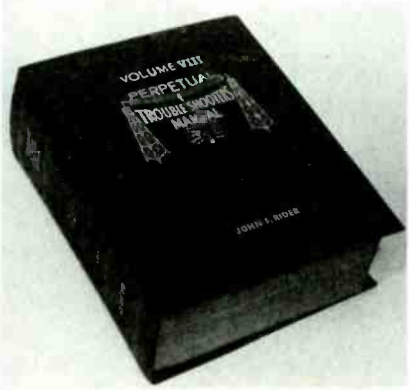
Finding Your Way Through Rider's. Without an index, locating sets in Rider's is something of a pain in the neck. You're pretty much reduced to *guestimating* the year that your set was manufactured, then looking it up, trial and error fashion, in the volumes that most closely correspond. Since the books tend to be big, heavy and clumsy, doing so can be an unpleasant task.

Every few years, Rider published an index for the books that had been released up to that time; they were in softbound pamphlet form. The indexes don't seem to turn up as often as the manuals, but some have been made available in reprint form by *Antique Electronic Supply* (688 W. First St., Tempe, AZ). Current prices are $17.95 for the index to Volumes 1-15 (205 pages, spiral bound) and $7.95 for the index to volumes 16-22 (48 pages, spiral bound).

An interesting alternative to the Rider indexes is offered by *The P.R. Mallory Radio Service Encyclopaedia*—a radio-receiver index compiled for the purpose of recommending the correct Mallory controls, capacitors, or vibrator for every model. But each entry also includes the correct Rider's reference!

Colorfully lithographed radio-tube cartons can be as interesting as the tubes they once contained.

My *Sixth Edition* was copyrighted 1948 and, I suspect, is based on the Rider index to Volumes 1-15, which appeared in 1947. If you can find one of them, you may be able to get it for very little money since its value is not generally known (mine cost two bucks!). Some time after purchasing it, I bought a serviceman's assortment of Mallory controls in a metal storage cabinet. The cabinet had a compartment obviously intended to accept the manual—which must have been included with the deal.



Rider's "Perpetual Trouble Shooter's Manual" series is not only the most exhaustive reference source available to collectors today, but is also a collectible item in its own right.

The Supreme Series. Another source of schematics and service information was the "Most-Often Needed" series offered by Supreme Publications. Like Rider, Supreme released a new compilation each year. But while Rider published huge binders covering virtually every set ever produced, Supreme published relatively slim soft-cover books containing an

P.R. Mallory Radio Service Encyclopaedia (Sixth Edition) stores behind compartment containing assortment of Mallory controls. The manual contains an index to Rider's through about volume 15.

edited assortment of material on the most popular models.

To my mind, the Supreme manuals are more valuable as practical references than as collectibles. The first volume, which bears a 1941 copyright date, covers 1926 to 1938 sets. From then on, they came out every year with a gap during World War II. The manuals were published at least into the late 1960's.

The 1926-1938 volume was reprinted by Supreme more than once over the years, and copies turn up quite often at hamfests and antique-radio meets. It's a good starter book for the beginning antique-radio collector, providing information on the more common sets. But keep in mind that its approximately half-inch thickness covers a time span that would be represented by three feet or more of Rider volumes.

It's worth noting that most of the Supreme manuals are available, in reprint form, from ARS Enterprises, P.O. Box 997, Mercer Island, WA 98040. When last I looked, the 1926-1938 volume—and the subsequent individual-year volumes through 1959—were priced at $17.00 each. Later volumes were $5.00, and a master index was available at $8.00. Write them for current information.

The first "Supreme" manual covers common sets from 1926 to 1938, and has been reprinted many times over the years. It is a great "starter" reference book for beginning collectors.

Generic Servicing Books.

Although we've covered collections of service information for specific sets, there are some generic books on servicing that are not only useful, but collectibles in their own right. And since they were very popular volumes when originally published, there are still a number around to be discovered today.

For example, watch for the radio books published by McGraw-Hill during the 1920's, 1930's, and 1940's. They have easy-to-spot, drab-green bindings with gold-lettered titles on the spines. The volumes by Moyer and Wostrel (including *Practical Radio* and *Radio Construction and Repairing*) are interesting relics of the 1920's.

For insights into radios of a later period, keep an eye open for *Principles and Practice of Radio Servicing* by Hicks. Editions of that book were published in 1939 and 1943.

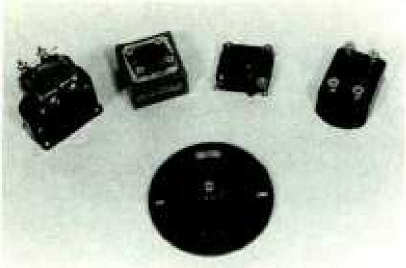
Two classics of the 1930's, both by Alfred A. Ghirardi, should be on every collector's shelf. *Modern Radio Servicing*, published by Murray Hill Books, is packed with practical information on troubleshooting 1930's-era sets. The edition on my own shelf bears a 1935 copyright, but there may have been subsequent revisions and expansions. *Radio Physics Course*, published by Radio Technical Publishing Co., has a more theoretical slant and will help you understand the "why" of vintage radio circuitry. My copy, a second edition revised in 1933, was printed in 1937.

No discussion of vintage servicing books would be complete without mentioning the many contributions by John F. Rider of *Perpetual Trouble Shooter's Manual* fame. Most of those are relatively short books focused on specific aspects of servicing, and were published by Rider himself. Look for such titles as *Servicing Superheterodynes*, *Practical Testing Systems*, *The Oscillator at Work*, and various titles in the *An Hour a Day With Rider* series.

Other Printed Materials. Vintage trade and hobby periodicals contain articles and advertising that will help you to understand the equipment that you're collecting and the context in which it was used. A list of the well-known and little-known titles in that area would be endless, but watch for publications such as *Radio News* and Gernsback's own *Radio Craft* and *Short Wave Craft*. Also interesting are private or "house" publications produced for dealers and servicemen by the manufacturers of radios and radio components.

Vintage trade and hobby periodicals help you better understand your early equipment and the context in which it was used.

Be sure not to neglect non-electronics magazines, either. The ones targeted for middle-class or carriage-trade readers contain elaborate display advertising for expensive consumer goods such as radios, automobiles and cameras. Old issues of



These interesting parts from the early 1920's include Rauland audio transformer (far left); a Dubilier RF transformer (far right); a CLE-RA-TONE tube socket with original box (top center); and a vernier dial (bottom center).

The National Geographic are still fairly easy to find, and are a very rich source of such advertising. I've found a lot of fascinating information on the sets in my collection in old issues of that publication.

Anything like a complete discussion of collectible printed materials relating to antique radio would be impossible in an article of this scope. The volume of books, periodicals, catalogues, instruction manuals, promotion pieces, and other types of advertising—aimed at both the general public and the electronics professional—is huge.

My advice is keep your eyes open at the book stores and swap meets. If a piece interests you and you can afford it, make the purchase. I continue to enjoy all of the printed items I've picked up over the years.

Parts: Collectible and Otherwise. Most of the collectibles covered so far have a definite dual purpose. They're not only interesting in themselves, but also useful—or even necessary—for radio maintenance and repair. Oddly enough, that isn't always the case with radio parts. The collectible ones tend not to be the ones most needed for practical radio service, while the ones needed to keep the radios running tend not to be collectibles. Admittedly, I've made something of a forced distinction here, and there'll be plenty of exceptions, but let me explain what I mean.

I associate collectible parts and accessories with the radios of the 1920's period. During that era, many people built their own sets from plans published in books and magazines. The parts, much larger in size than the comparable electronic components of today, were individually packaged, advertised, and sold.

There were many competing manufacturers, and they vied with each other in the extravagance of their performance claims and the colorfulness of their advertising and packaging. The parts themselves, crafted of bakelite, glass, silk- or cotton-covered wire, and polished or brightly painted metal, were definitely made to be looked at. Among the parts of interest to collectors are knobs, dials, tuning capacitors, audio- and radio-frequency transformers, tube sockets, rheostats, resistors, plugs, and jacks.

1920's-era radio-parts advertising sometimes resembles today's advertising for high-performance auto parts.

People bought parts not only to build new sets, but to improve the performance or convenience of existing sets. Parts in the latter category included not only straightforward components such as vernier-dial drives and "high-fidelity" audio transformers, but also a colorful assortment of more fringe apparatus, such as antenna substitutes, variable grid leaks, self-adjusting filament rheostats, and multiple-headphone adapters.

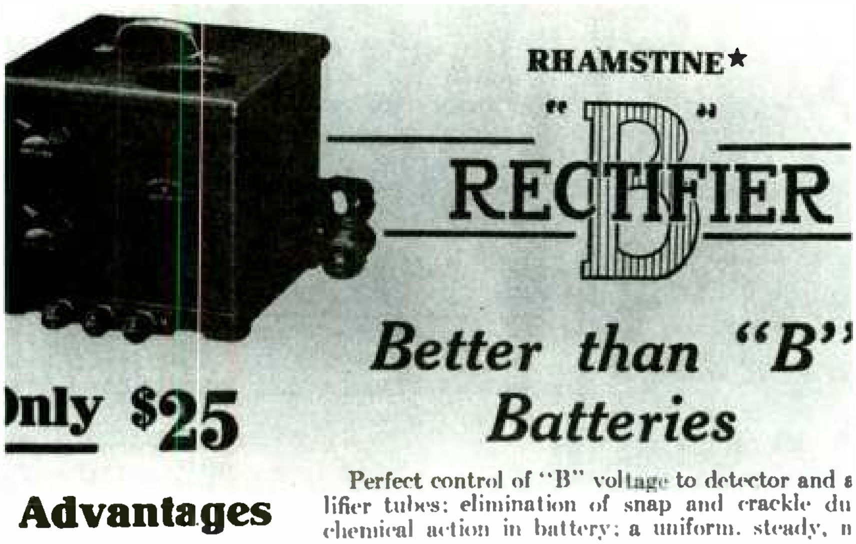
The radio sets of that era were so simple, and the parts so basic and generally well-made, that breakdowns due to component failure were relatively uncommon. It's true that restorers of 1920's radios sometimes have to deal with such problems as burned-out audio transformers and grid-leaks whose resistance has escalated over the years. But most performance difficulties can be traced to poor contacts caused by dirt and corrosion, not a part failure. Therefore, parts that have been acquired as collectibles can generally stay on the display shelf.

The Changes of the 1930's. I've always thought that the marketing of radio parts in the 1920's had a lot in common with the marketing of certain kinds of auto parts today; particularly the ones intended to improve performance or convenience and simple enough to be installed by the "backyard mechanic" set. But by the 1930's, radio receivers had become much more complex. Most sets were factory built, rather than home made—and the average radio listener was less apt to be in the market for parts to improve performance.

As you might expect, then, radio parts became more functional in physical design. They were being made to do their jobs, and not especially to be looked at. But with increased circuit complexity and higher component operating voltages, parts failures were, and are, much more common in the more-modern sets.

It's certainly true that proper resistors, capacitors, transformers, speakers, and other components suitable for use in repairing vintage radios are becoming harder and harder to come by. So most radio collectors acquire them as they can. But parts for repairing 1930's-and-later sets could hardly be called collectibles. They're usually not displayed, but stored in drawers and cabinets until needed.

Special radio furniture was designed to provide storage for the early battery set, its power sources and the other accesories required for its operation. Such furniture can be used to display the most prized items in your collection.



Battery eliminators and chargers were heavily marketed prior to the introduction of AC-powered sets. There are many still around to be discovered today.

Batteries, Chargers, and Eliminators. Vintage accessories can add yet another colorful and fascinating dimension to your collection of radio items. This is another category so rich in collecting potential that even a partial list of possibilities would be difficult to compile. But, just as in the case of parts, your most interesting "finds" are apt to date from the 1920's.

One important group of accessories is associated with the batteries used to power most radios of that period. First of all, there are the batteries themselves although—because of the corrosive chemicals they contained—not many of them survive today. The lead-acid storage "A" batteries used to light the filaments were generally 6-volt automobile types. However, I've seen special versions designed for radio use; some had beautiful teakwood outer cases incorporating handles for easy carrying.

The "B" and "C" batteries that provided plate and grid-bias power were generally of the non-rechargeable dry-battery type. Today, they are probably harder to find than the filament batteries because they were thrown away when exhausted. Those that were kept were generally quickly rendered unsightly after the chemicals inside ate their way through the outer casing. Yet, for some unaccountable reason, some of those dry batteries have survived (though quite dead, of course) in good cosmetic condition. Most have colorful, lithographed wrappers, and certainly look interesting when displayed along with examples of the radios they once powered.

Battery chargers and eliminators also make interesting collectibles. Both of those types of units plugged into normal, commercial, AC-power lines. The former—scaled-down versions of the commercial types then in use—made it possible for radio enthusiasts to replenish their "A" batteries at home—thereby, avoiding the discomfort and the danger of lugging them to the neighborhood gas station. The latter actually took the place of "A" and/or "B" and "C" batteries.

A word to the wise: avoid the temptation of trying to operate one of your prized battery sets from a vintage battery eliminator. The regulation of the old units was generally far from ideal even when new. Today, after many years of aging, the values of the carbon resistors and controls used to establish the correct voltages may be nowhere near original specification. The result could be dangerously high voltages that might well pop tube filaments and/or burn out AF-transformer windings.

Modern battery eliminators, using semiconductor regulators, are available from several sources. They provide stable, well-filtered DC power that is not only safer for your set, but will make it perform better.

Before leaving the subject of battery-radio accessories, I'd like to touch on a couple of other collectible categories that you might find of interest. With battery condition so crucial to proper set operation, most radio owners equipped themselves with some kind of a battery tester. The typical tester was a "watchcase" style meter housed in a highly chromed, round case a few inches in diameter. Some models tested for voltage; some for current; and some for both. They came in a variety of brands and styles, and an assortment of them makes a fine addition to any collection of sets from that period.

Finally, you might like to look for special radio furniture. Back in the 1920's, a typical radio installation consisted of the radio unit itself, plus a separate speaker, an array of batteries, possibly a charger, and/or eliminator. The natural setting for that novel, and very important, collection of apparatus was the family living room. But some housewives understandably felt it to be an eyesore. The answer, for many families, was a cabinet that would house all that stuff much like the hi-fi system organizers on the market today.

The typical unit contained compartments for storing (and concealing) radio, batteries, speaker, charger, etc. Many took the form of a drop-leaf desk, with the drop leaf serving as the radio operating table when open. If you can find one of those, and have the space to show it off properly, it can be a focal point for your collection—providing display space for some of your most prized pieces.

Reproducing Equipment. This could easily be one of the largest and most important categories in your collection of radio accessories. But why do I consider such things as headsets and speakers to be accessories? Because, back in the 1920's, such items were generally not packaged with the radio, but sold separately, much as hi-fi components are today. If the radio manufacturer offered them for sale, they might be purchased along with the set, or they might not. There were many makers competing for the set-buyer's dollar, and the buyer might well be tempted by a better price, a style more to his or her liking, or claims of improved performance.

The earliest speakers in common use with broadcast sets were of the horn type. The sound-reproducing unit within the base of most horns was essentially an overgrown earphone. The sounds were produced by vibrations induced in a metal diaphragm by the action of a pair of electromagnets. The horn then acted as an acoustical amplifier, very much in the manner of a megaphone.

Though they all worked the same

way, the physical appearances of horns varied quite a bit. Some were made of wood; some of metal; some of what appears to be a paper-based composition material. The neck of the horn might be straight, curved, or of the familiar goose-neck shape that has become the *cliche* of what an antique radio horn should look like.

By the mid 1920's, a more sophisticated form of radio speaker had begun to appear. In that type, the electromagnets acted not on a diaphragm, but on a rod-like metal armature. The rod was attached to the apex of a paper cone much like that of the cone speakers with which we are familiar today. Because of the direct transfer of sound vibrations to the cone, the new speakers had improved fidelity and power.

With some speakers of that type, such as the Crosley *Musicone*, the paper cone (mounted within a protective frame) was exposed, decorated, and intended to be looked at. With others (the RCA Models 100 and 103 are good examples), the cone was concealed within a decorative enclosure.

I also once owned a 1920's-era speaker (made by Sonora) mounted within a box containing a wooden horn-like structure. Unfortunately, though, I never looked inside—so I can't make a definite statement about what the sound-producing unit was like. But I strongly suspect that it was "earphone style."

You're obviously going to need a few of those speakers if you intend to play the larger battery sets in your collection. But you'll also find that a display featuring horn and cone speakers will be a sure-fire attention-getter. The different sizes, shapes and styles lend themselves to interesting and attractive groupings.

No discussion of early reproducing equipment would be complete without touching on the subject of headsets (otherwise known as earphones). The collector who gets involved with the said items can certainly have lot of fun acquiring examples produced by famous manufacturers such as Baldwin, Brandes, Murdock, Western Electric, and Dictaphone. Headsets are still fairly easy to find at radio swap meets and, as antique equipment goes, tend to be reasonably priced.

I've found that headsets without a head inside are really difficult to display (my best success so far has been to suspend them by cup hooks from the bottoms of shelves). And, since the differences from model to model are fairly subtle to the non initiated, collections of those units almost always seem to have a "ho-hum" appearance. If you like headsets, though, don't let me discourage you!

Though they don't turn up very often, phonograph-conversion units should also be mentioned. Those devices are similar to the earphone-type devices that drive horn speakers. However, they're made to fit on the arm of an acoustical phonograph in place of the normal needle unit, making it possible to use the "acoustical labyrinth" within the phonograph cabinet as a kind of a radio horn gone to heaven.

Horn-type speakers of the 1920's took many shapes and forms; two typical horn speakers are the ones made by Music Master (left) and Dictagraph (center). Cone-type speakers, like the Crosley unit (right), began to appear by the middle 1920's.

Vintage Test Equipment. As you've seen, many of the pieces we've discussed so far have an obvious dual purpose. They're useful for repairing and operating vintage radios, and they're also valuable collectibles in themselves. But, odd as it may seem, I don't consider most antique test equipment to be in that category.

Such apparatus can really be wonderful to look at with its Bakelite panels, hardwood cases, engraved dials, and quaint meter styles. However, by today's standards, much of it isn't worth a darn as test equipment. First of all, design concepts have improved by quantum leaps since the vintage equipment was made. Secondly, test equipment that has been used and stored (under unknown conditions) for over half a century isn't exactly equipment you'd want to rely on. Component values may well have changed and user abuse taken its toll.

Diehard radio buffs who feel that old radios should be fixed with old equipment have a legitimate position, and I can see how they might derive quite a bit of enjoyment from the practice. In fact, I can think of a couple of situations (to be discussed) where the old equipment might be quite valuable. But I'd strongly suggest checking calibration and accuracy against reliable modern equipment (borrowing it, if necessary) before relying on the relic instruments.

Most types of antique test equipment that you're apt to find have counterparts familiar to any electronic experimenter of today. Electronic technicians of the 1920's, 1930's, and 1940's used multimeters, tube testers, and RF and audio oscillators similar in function, if not in design, to the ones used now. You'll even come across vintage oscilloscopes, although the units will not generally predate the late 1930's.

One type of commonly seen vintage test equipment, the set tester, really has no modern equivalent. It was used to expedite the diagnostic process back in the days when radio chassis could be large and heavy monsters indeed. The set tester made it possible to measure voltages and currents at the tube socket connections—while the set was running and without removing it from the cabinet.

To use the tester, the tube in question

Early multimeters are visually interesting, and also useful when checking set voltages against manufacturers original specs (see text).

was removed from the set, a special adapter (having a cable running to the tester) was plugged into the tube socket, and the tube was plugged into a socket on the adapter. Now, at the touch of a lever or button, measurements could be made on any desired tube pin using the meters built into the tester.

Most such testers were also set up to be used as normal multimeters, receiving input from standard test probes instead of the special adapters. The set tester often made it possible for a serviceman to arrive at an accurate diagnosis, and sometimes even effect a repair, without removing the radio from the customer's home.

Equipment You Can Use. Which kinds of early test equipment do I feel could be useful for repairing antique radios today? I'd recommend a late 1930's or early 1940's multimeter having 1000-ohm-per-volt sensitivity for DC measurements and an RF oscillator that will hit frequencies as low as 100 kHz or so.

The multimeter will hardly take the place of your modern one, but it will come in handy when you're checking voltage readings in a set against values published in a manufacturer's chart. The reason: all voltmeters load down the circuits they are measuring, making the measured voltage lower than the voltage present without the tester in the circuit. Less sensitive meters (having a lower ohms-per-volt figure) load down the circuit more, and reduce the voltage more than do meters of greater sensitivity.

That's why the ohms-per-volt rating of the meter used to do the original testing is generally specified on the "normal" voltage charts. Use a meter of the same sensitivity specified by the manufacturer and you'll have a better chance of matching his readings. Since many of the early charts specified a 1000 ohms-per-volt meter, it's a nice idea to have one on hand.

The least expensive pocket multimeter in the Radio Shack catalogue today has a 2000 ohms-per-volt rating, and more serious multimeters of even average quality are rated at least 20,000 ohms-per volt. So the best way to get a 1000 ohms-per-volt unit would be to look for a vintage model.

The RF oscillator with the low-frequency range will be helpful in aligning IF transformers of early superheterodyne receivers. They were often tuned to much lower frequencies than the modern "standard" of 455 kHz. That's why modern units often don't go low enough!

In Conclusion. I'd like to stress one more time that a relatively short article such as this one can't even begin to cover all possible radio-related collectibles. What I've tried to do is orient those who might be new to the field by touching most of the important bases. To find out more, my advice is get involved and start collecting! ■

Antique Radio

By Marc Ellis

THE MYSTERY IS SOLVED

A while back, I described a mysterious-looking Philco gadget owned by reader Larry Lovell. Larry send a picture and wanted some information about the device. But beyond observing that it looked like some kind of a wireless remote-control unit, I wasn't able to be of much help. So I appealed to the readers for assistance, and your letters have been coming in a steady stream every since!

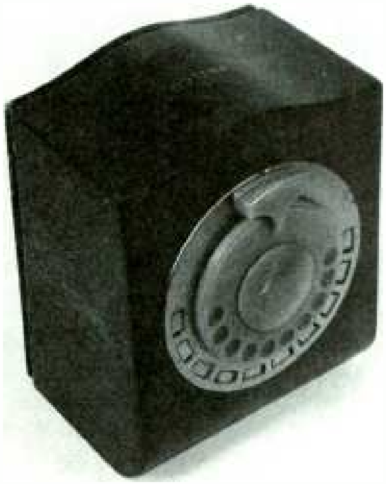
Starting with the bottom line, the little Philco unit really *is* a wireless remote-control unit for a radio receiver. Dubbed the "Mystery Control," the gadget contains a one-tube radio transmitter that sends out pulses from a built-in telephone-style dial. When picked up by a special receiver within the radio, the transmitted pulses control the station-selection and volume of the receiver.

But I don't want to get too far ahead of our story. Thanks to Larry, who graciously loaned me the device for a while so I could take detailed photos; and thanks to the many readers who sent schematics, service notes, and other information, I have enough material to devote this entire column to the Philco Mystery Control.

The story you are about to read was pieced together from all of the material I've received from readers so far. But each individual contribution will be recognized at the end of the article.

System Overview. The Philco Mystery Control system was introduced with two top-of-the-line 1939 sets: Models 39-55 (standard broadcast) and 39-116 (broadcast and shortwave). Those two console sets appear to be very similar in design, except that the "116" included a stage of RF amplification, accompanied by slightly more sophisticated audio circuitry.

Operating on a self-contained battery pack, and with no electrical connection to the radio, the Mystery Control generated a pulsed radio signal. Depending on the number of pulses sent (as determined by the telephone-style rotary dial), the control could be used to select any of eight pre-tuned stations in the standard broadcast band.



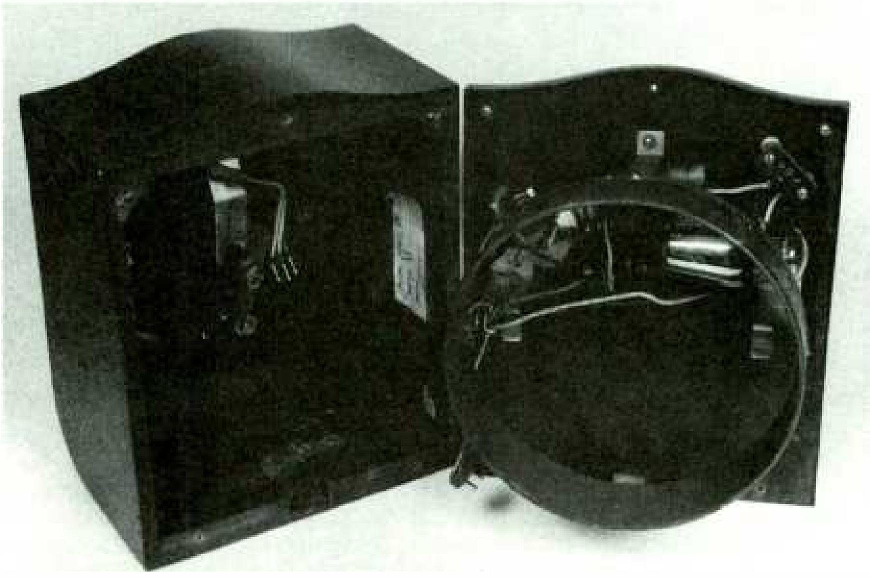
The Mystery Control as received from reader Larry Lovell.

The Mystery Control could also make volume adjustments and—when a listening session came to an end—shut off the set's power. However, for reasons that will be explained later, the set had to be turned *on* manually.

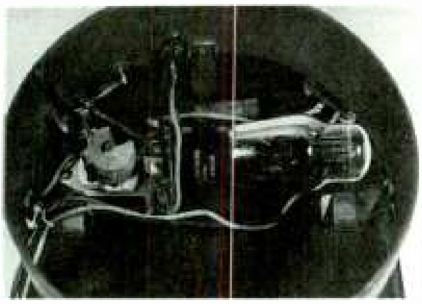
The signals from the Mystery Control unit operated the radio via a special "control amplifier" built into the set. That amplifier received the radio-frequency signal pulses from the control unit and converted them into DC pulses strong enough to operate an on-board stepping relay (similar to the ones used in a pre-electronic dial telephone exchange). That relay, in turn, controlled both an eight-position station-selector switch and a reversible motor that drove the volume control and power switch.

The nominal range of the control system was 25 feet. However, the receiver stage of the control amplifier had a sensitivity control that could be adjusted to shorten the unit's range if electrical interference was causing false triggering. The sensitivity could also be increased if conditions (such as the presence of large metal objects) were attenuating the control signal.

The control unit and control amplifier could be adjusted to work on any frequency between 350 and 400 kHz. In that way, according to the manufacturer, two Mystery Control radios operating in the same home, or apartment building, could be set up on different frequencies. Otherwise, signals from your neighbor's control box might retune your set to *Blondie and Dagwood* while you were trying to listen to the philharmonic.



Opening the cabinet reveals the oscillator circuitry mounted on the rear cover (right). The batteries were housed within the cabinet, below the dial mechanism.



A type-30 tube is mounted within the large oscillator coil. A trimmer capacitor, visible at the left of the tube socket, controls the oscillator frequency.

That last feature strikes me as mostly wishful thinking on the part of the manufacturer. I don't happen to have a price reference for the Mystery Control receivers, but they were top of the line to begin with, and the additional cost of the remote-control circuitry would make purchasing one of those sets quite a large investment indeed. The likelihood of the same family owning a couple of them—or even of two sets being located within 25 feet of each other in the same apartment building—seems very small indeed!

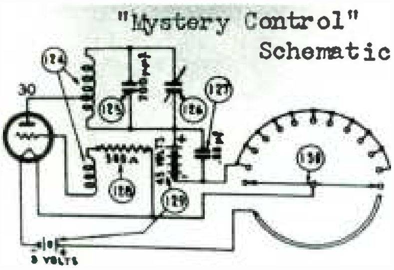
Inside the Box. The Mystery Control is housed in a nicely finished, wooden cabinet bearing the Philco logo. To get inside, one takes out the four wood screws holding the rear cover in place. Removing the cover separates the control box into its two basic sub-assemblies: the telephone dial, which is built into the cabinet, and the RF oscillator (or transmitter), which is mounted on the back cover. The batteries were housed under the dial, with short plug-in cables providing the necessary electrical connections between units.

The operation of the dial is conventional. Rotating the dial plate counter-clockwise winds a spring that returns the plate to the resting position when released. As the plate turns, it drives a gear train that actuates electrical switching and pulsing mechanisms. A small rotating governor regulates the pulse rate at about 12 per second.

The oscillator uses a type-30 tube in a simple tuned-plate, untuned-grid circuit. All of the parts are secured to the back cover, with the tube and associated components mounted within the large coil assembly. The battery pack inside the cabinet provided 45 volts for plate power and 3 volts to light the tube. In a moment, you'll see why it was necessary to feed 3 volts to what was normally a 2-volt filament.

Control-Box Operation. The control box has no on/off switch because power is controlled through the movement of the dial. With the dial in its "resting" position, both batteries are disconnected from the circuit. But as soon as the dial is rotated towards the finger stop, an internal switch closes, completing the circuit from the filament to its battery and lighting the tube. The overvoltage on the filament is necessary so that the tube will heat instantly and be ready for operation as soon as the dial is released.

With the release of the dial, the filament switch remains closed, but an additional "pulsing" switch goes into operation as the dial returns to resting position. That switch alternately completes and breaks the tube's grid-return circuit, turning the oscillator on and off. The number of on/off cycles, or pulses, completed by the switch depends—of course—on how far the dial was rotated counter-clockwise prior to release.



This is the schematic diagram of the Mystery Control as found in Rider Manual Volume 9.

The molded-plastic dial plate has ten finger positions. Rotating the dial by means of the position closest to the finger stop causes two pulses to be generated, the next closest position creates three pulses, and so on to a maximum of eleven pulses.

Once the dial has returned to rest, both switches return to the "open" position, cutting off all power to the circuit. The action is completed so quickly that the tube filament is in no danger of burnout from overvoltage. And, in fact, so little power is used that the manufacturer claimed that the service life of the batteries was essentially the same as its shelf life.

Inside the Radio. The "control amplifier," located inside the radio cabinet, contains two RF tubes (types 78 and 6J7) to receive and amplify the pulsed signal from the control box and an AVC (automatic volume control) tube (type 6ZY5) to detect the signal and smooth out signal-strength variations.

Finally, a *thyratron* rectifier (2A4) converts the relatively weak signal pulses into DC pulses that are strong enough to operate the coil of the stepping relay. No wire antennas are used at the control box or control amplifier; the large coils forming the tuned circuits act as a loop antenna, radiating and receiving enough signal energy to maintain communications.

The operation of the thyratron rectifier tube is analogous to that of the silicon-controlled rectifier in common use today. Think of it as an electronically actuated relay, triggered by a small electric current and capable of switching a much larger one. Thus, the weak pulses impressed on the thyratron grid from the AVC tube make and break the current flowing through the thyratron's plate circuit and the stepping-relay coil.

On the dial, the two finger positions closest to the stop (generating two and three pulses, respectively) control (via the stepping relay) an electric motor coupled to the volume control. Dialing the first position increases volume; dialing the second position reduces it. In both cases, the spring-loaded finger stop must be depressed before the dial is released.

That prevents the final pulse in the series from cutting off, thereby keeping the motor running. When the desired volume level is reached, the listener lets go of the finger stop, the pulse is completed, and the motor stops.

In order to shut off the radio, the listener dials for reduced volume and keeps the finger stop depressed so that the control rotates past the minimum volume setting. That actuates a switch, mounted on the volume control, that cuts off all power to the radio and control amplifier. Since the control amplifier is now unpowered, no further remote control of the radio is possible; power must be turned on manually to begin another listening session.

The remaining eight finger locations on the dial are used to select from eight pre-tuned stations. When any of those locations are dialed, the stepping relay drives a three-pole switch, picking out one of eight positions. One pole of the switch selects the correct oscillator coil; another selects the matching antenna-padding capacitor; and the third lights an indicator lamp on the front panel corresponding to the selected station.

And that about sums up what I've been able to learn about Larry Lovell's "Mystery Control." At some future time, maybe I'll have an opportunity to discuss the associated radios, but now I'd like to recognize the many readers who contributed information to this column!

Our Contributors. W.J. Brown (Thomaston, ME) sent schematic diagrams and offered some personal memories of a "Mystery Control" radio that his family purchased in 1939. He kept the set going until about five years ago, when a tragedy occurred: the chassis was accidentally dropped while the electrolytic capacitors and dial cord were being replaced.

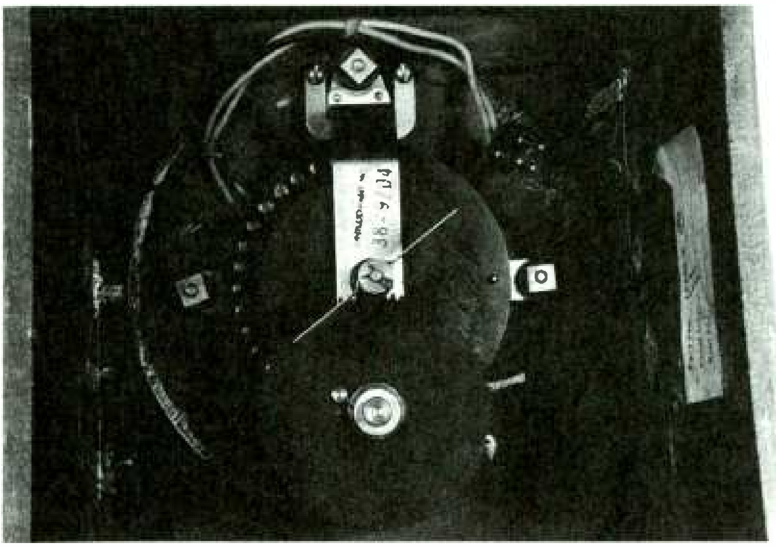
Robert E. Chapman (Ventura, CA), who was an active service technician (Minneapolis-St. Paul area) in the late 1930's, worked on several of those radios. He considered the design of the Philco set to be very advanced for its time, and contributed several interesting technical details to the story you've just read.

Frank Krantz, who retired after 54 years as a radio repairman, now repairs old sets as a hobby. After identifying the control unit for us, he included some interesting information on Philco model and part numbers. For one thing, Frank confirmed an earlier remark of mine about the model numbers. He agrees that prefixes were used to indicate year of manufacture (for example, a model 37-620 was made in 1937), but says that the system was only used from 1937-1942.

Warren Baker (Albany, NY) tells us that the telephone-type dial on the control unit may have evolved from a similar station-selector dial on an earlier model. The earlier dial was mounted directly on the cabinet, and was *not* part of a remote-control system.

Ray Shetrone (Fort Myers, FL) also remembers the control unit well. His interest in radio dates from the early 1930's, when his dad was operating a radio and appliance repair shop in Baltimore, Ohio (the shop is still operating today under the family name). Ray speaks ruefully of the many "golden oldies" he and his dad dismantled for parts over 50 years ago!

J. Beck (Zion, IL) sent along an informative article on the Mystery Control system (from a 1939 *Lincoln Engineering School* publication). He also identified some of the Philco radio models that used that control unit and says that he picked up one of them (a Model 39-55) at a flea market, intending to strip it for parts. When he realized what he had, however, he canceled the tear-down and located a control unit for the radio. Restoration is now proceeding.



This rear view of the dial assembly shows the gear train, governor, and some of the pulsing contacts.

I'm also indebted to the following people for technical literature on the Philco Mystery Control system: Alfonso E. Patron sent Philco service notes covering the Models 39-55 and 39-1 16 all the way from Mazatlan, Mexico.

Larry Kenan (Westlake Village, CA) contributed a very informative article he wrote in 1984 for *Radio News*, the journal of the Arizona Antique Radio Club. Larry credits Rider *Perpetual Troubleshooter's Manual* Volume 9 (Philco Models 39-55 and 39-1 16) for much of his information.

And Scott Holderman (Sherman Oaks, CA) sent along a write up on the Mystery Control taken from a special supplement to Rider Volume 9.

Finally, I'd like to credit the unsung heros of this article: the people who wrote Larry Lovell directly with information about the mystery control. Larry mentioned that he had received letters from several retired radio servicemen, and other antique-radio enthusiasts. Just as I sat down to write this, I realized that I should have contacted him to get their names. But my deadline looms and I have to get the column in the mail. Many thanks, guys, and sorry, but you'll have to be anonymous for now!

The Following Month.

The following month, I challenged the readers with a Philco "mystery" unit of my own: a small (about 5-inches tall), highly-chromed device that looked like a miniaturized version of a 1920's radio speaker. I had been able to identify the unit by thumbing through Morgan McMahon's well-known book *A Flick of the Switch*, and suggested that any sharp-eyed reader should be able to do the same.

The Readers Write! Since then, your letters have been pouring in, and it's all been fascinating. Some readers have sent in educated guesses about what those units had to be; others remembered using—or servicing—them in days gone by. Many people have taken the trouble to Xerox and send along schematics, service notes, advertisements, and other types of documentation.

Last month, I devoted the entire column to going over the information I received about the first item—a wireless remote control for a Philco receiver, which had been appropriately named by the manufacturer "The Philco Mystery Control." This month, let's tackle the second item.

First, credit for the guesses! The most creative ones came from two readers—both, as it happens, from New

York State. Ron Laguardia thought the device might be a speaker for a police car siren or PA system. But Bob Schaumleffel had a different slant; to him, it looked like a cigarette lighter.

Less colorful, but correct, guesses were received from Andrew Mooradian (Winchester, MA), George Rutkay (Brampton, Ontario, Canada), Clyde Clymer (Weiser, ID), Michael Johnson (St. Gabriel, LA) and Randy Rago (Brooklyn, NY)—all of whom felt that the unit had to be a microphone.

The Living Room Wonder. Now it seems that that type of Philco microphone had at least two different applications: the one I'd already identified from Morgan McMahon's book—and another previously unknown to me. Reader Raymond Ives (Cameron Mills, NY) explains the first application in a letter containing some reminiscences from his teenage years."

Says Raymond, "The Philco *Wotizzit* pictured in your December column brought me back to about 1940. I was just then becoming a teenager. Two of the most memorable items in my parents' house were the upright piano and the Philco.

"The piano, though memorable, was unremarkable. But the Philco, a stately console, was then a modern-day wonder! In addition to the usual multi-band reception, it also featured automatic record changing and *light-beam* sound transmission from record to amplifier.

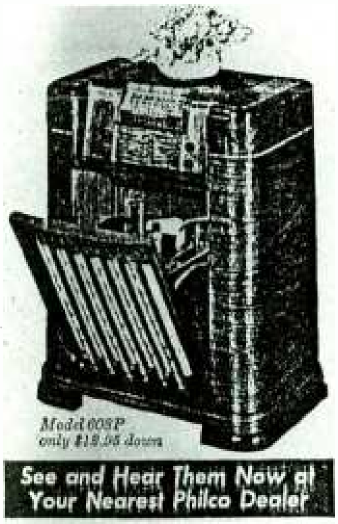
"A constant light source was directed towards a mirror that was mounted on the stylus assembly. The reflected light, modulated by the motion of the stylus, was captured by a photo-sensitive device and the resultant signal amplified by the system.

"That feature effectively reduced hiss and scratch. Unfortunately it also effectively reduced many highs and much brilliance. However, that fit in beautifully with the boomy sound, which was 'cool' during that era.

"Mounted on the turntable was another *tone-arm*. This arm was mechanically guided and its stylus was a steel cutter designed to record an audio track on a lacquer coated aluminum disk. The home entertainment center was also a recorder! And that brings us back to the Philco *wotizzit*. Resting on top of the console was a brown enameled, round (about 4.5 inches in diameter) device with a flock-covered grill of metal window screening. The speaker inside was really the dynamic microphone for our home entertainment center with the built-in recorder. Thanks for jogging my memory!"

No longer a mystery, this is the little speaker-mike that caused all the comment!

A number of other people shared their personal memories of that Philco console, including Victor Manno (New York, NY), James B. Salinia (San Antonio, TX), Gary Kendall (Grafton, WI) and Mark S. Cockrill (Seattle, WA). Others who were able to identify the Philco console were Milivoj Rudan (Stoney Creek, Ont., Canada), Jerry L. Johnson (of Radio Reproductions, Ft. Worth, TX)—who included a Xerox of an original ad for the console—Larry Baker (San Angelo, TX), Reno Ruggere (Shillington, PA), and Bill Johnson (Atlanta, GA).



Reader Jerry L. Johnson, sent in this photocopy of an advertisement for the Zenith 41-608 console. The model illustrated here didn't include the recording option.

Larry also correctly identified the "Philco Mystery Control" for us.

Walter Eismann identified the microphone and sent along a shot of the one in his collection. He found his example in much the same way I found mine—by carefully scrutinizing the contents of boxes of obscure junk at a local flea market. Walt has an extensive collection of antique radio items, and offers to correspond with readers having questions about the hobby, provided that they include an S.A.S.E. Write him at 1659 W. 6th Ave., Eugene, OR 97402.

Finally, let's have a round of applause for the four intrepid sleuths who followed up my hint and located the Philco *Model 41-608 Radio-Phono-Recorder* console (9 tubes, 1941) on page 133 of *A Flick Of The Switch*. If you have that book, turn to page 133 now, and you'll see what Richard Spratley (Chesapeake, WA), Andy Czymbor (Burt, MI), Jack Beltz (Bartlett, IL) and James Salinia (see above) have already discovered. The shadowy shape sitting on top of the console is obviously the silhouette of our Philco microphone, and is what first gave me the clue to its true function.

This is Randy Eppmethe's Crosley Model 148CP. Randy designed and crafted the cabinet himself.

The Philco Phone. Along with all of the letters telling me about the Philco home-recording console came a few that surprised me. They advised me of yet another product using that microphone—one I hadn't heard of. The first letter came from George A. Fathauer, the "son" half of the father-and-son team that operates Antique Radio Supply of Tempe, Arizona.

George was kind enough to send along a good Xerox of an advertising brochure for the Philco Phone, a basic intercom system for the home or small office. The master station for that little system looked like a table model AC/DC radio; the remote units looked like—you guessed it—our little microphone!

Ben Tillson (Brewster, MA) also remembers those microphones (or speaker-mikes, as they must have been in this application) as remote units for the Philco intercom. And R.J. Wopshall (Toledo, OH) has a complete working system. R.J. says that his system has two styles of remote units: chrome-plated ones with locking, on/off slide-type, call switches; and brown-painted ones with non-locking, spring-loaded, call switches.

He theorizes that the chrome-plated remotes were for use in the kitchen or bath. But I'm wondering if the units were made with different finishes so that a person could quickly identify which ones had the locking switches and which had the spring-loaded ones. And perhaps the remotes with locking switches could be left in permanent "listen" mode for monitoring nurseries or sickrooms.

Since my own unit is chrome-plated and has a locking slide switch, I'm beginning to wonder if it wasn't manufactured as an intercom remote rather than a recording microphone. You'll recall that Ray Ives, whose letter I quoted earlier, spoke of the microphone for his family's recording unit as being "brown painted."

Maybe somebody will write in and shed more light on the subject. And speaking of light, are there any readers in the audience who can send more information about the "beam of light" playback system mentioned in Ray's letter? It would certainly be an interesting subject for a column. In fact, if anyone living in the metropolitan Chicago area has one of those sets and would be willing for me to come over and take some pictures of it, please drop me a line!

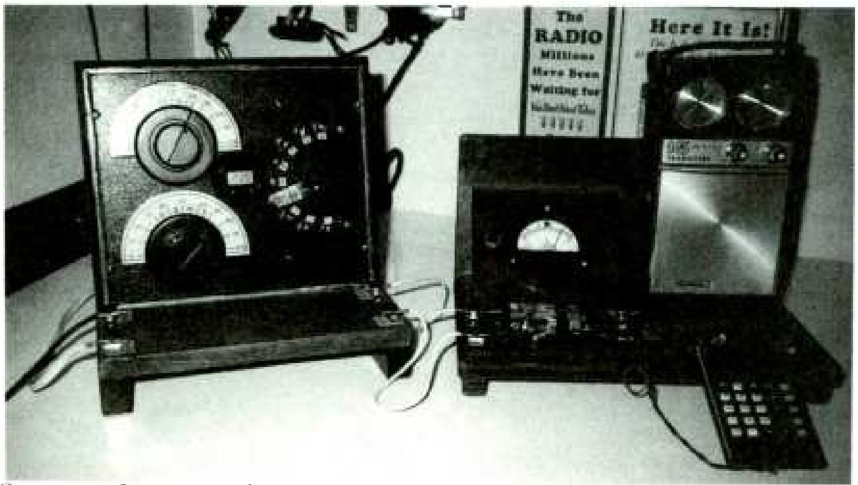
Before leaving the subject of the little Philco microphone, I'd like to acknowledge a postcard from Hal Leary (Montrose, CO). Hal recalls that Philco sold the microphone as an accessory for attachment to any radio receiver so that you could use the set as a PA system and be the life of the party. So far, though, he's the only person who has reported on that particular use for the product. Does anyone know more about it?

This illustration of the Philco Phone came from a photocopy of an advertising brochure contributed by Antique Electronic Supply Co.

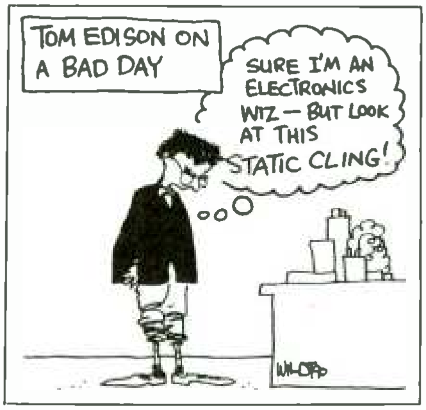
Mysteries Old and New. Two readers sent their comments about the "Philco Mystery Control" a little too late to be included in last month's column. Raymond Musick (Oklahoma City, OK) remembers seeing a Wichita, Kansas department-store salesman, stationed on the sidewalk and armed with a control unit, change stations on a radio displayed in one of the store windows. Quite impressive to the passersby! Eric Taylor (1365 10th Ave., #6, San Francisco, CA 94122) sent a copy of a very complete discussion of the Philco control as printed in *Audel's New Electric Library* Volume 9 (1949 edition). If anyone has one or more of the other eleven volumes in this set, Eric would like to hear from you.

Richard Spratley, one of the people who identified the Philco microphone in *A Flick of the Switch*, wrote that he enjoyed reading about the Philco "thingumajigs" and enclosed a picture and description of a "thingumajig" of his own.

Since several readers have asked me to include more mysteries in the column, I'm going to run the photo and hold back the explanation. Can any of the more astute gadgeteers in the crowd figure out what Dick is up to here? If you're not sure what's going on, send in a good creative guess—the wilder the better! I'll acknowledge all responses, and print the answer, in a future issue. One hint: the antique-looking object at the left is a crystal set. ■



Can anyone figure out Dick Spratley's mystery project? Here's a hint: The device at the left is a crystal radio receiver.



By Joseph J. Carr, K4IPV

Collecting Antique Ham Gear

One of the many interesting aspects of amateur radio, and one that is indulged by increasing numbers of hams, is collecting antique ham gear. Or, excuse me, in order to stay in context ...antique "wireless" communications equipment. Although my own modest collection includes a lot of non-ham gear, I also have a number of different ham rigs.

Collecting old radios extends way beyond amateur radio, as the popularity of Mark Ellis' *Antique Radio* column attests. But hams have a slight advantage. Although anyone can collect both receivers and transmitters, licensed hams can put the transmitters on the air (in most cases)—but don't try it with a spark-gap rig!

ANTIQUE HAM GEAR

It is now April, and the hamfest season has already started in some areas of the country (in fact, with the various Winterfests around the country, the season never really ends); the mammoth Dayton Hamfest is nearly on us. Next month, the hamfesters really get serious, and bargains come out of basements and garages.

The happy hunting grounds for antique ham-gear collectors is the old-fashioned hamfest. "Tail-gaters" and table-gaters (Fig. 1) abound, and their selection is both highly variable and enticing. Every hamfest has a different selection, although there is a certain similarity from one year to the next. In some cases, you will see the same rigs at successive hamfests. That situation may indicate that the guy didn't sell it last time, or that he bought it and someone is making him resell it—fast (XYL's have a habit of viewing hamfesters as playing a game of musical electro-junk).

Fig. 1. Antique hand-gear collectors find much to choose from at an old-fashioned hamfest, where "tail-gaters" and table-gaters abound, and their selection is both highly variable and enticing. The tempo, however, is very relaxing.

WHAT'S OUT THERE

A wide variety of equipment can be found on the antique-radio market. Figure 2 shows a World War I vintage receiver owned by a friend of mine. That gem probably costs a pretty penny, but some similar models may show up on the market at a cost that is quite attractive. Radios of that sort may be a simple crystal set with a vacuum-tube audio amplifier to boost the sound. Or it may be a regenerative detector and audio amplifier.

One of my own units is shown in Fig. 3. That radio is a tuned radio-frequency (TRF) model made in the mid-1920's. It has a nice wooden cabinet that looked a whole lot nicer after I stripped and refinished it. There are a lot of different TRF radios on the market, although most of them are not communications receivers. In fact, a lot of ham-radio receivers were homebrew, or kit built, and are therefore a bit cheaper than factory-built radios.

When you get into the 1930's, the sophistication of radio receivers begins to increase. Those radios look and feel a whole lot like post-WWII radios, although the tube line up will be different. By the late 1930's, crystal filters, bandspread controls, and other niceties were routinely used on amateur-radio rigs. Also available from that era are commercial and maritime radio equipment. Brand names to look for include Hammarlund (HQ-100, HQ-120, HQ-129), Hallicrafters (S-20R, S-40B, SX-28), National (NC-1, HRO), RCA Radiomarine, McMurdo-Silver, and others.

Some models may be both pre-WWII and post-

Joseph J. Carr, K4IPC writes a column for amateur radio buffs in every monthly issue of Popular Electronics magazine. His topics are timely and human. Here's a sample.

Fig. 2. A wide variety of equipment can be found on the antique-radio market. This World War I vintage receiver (circa 1919) likely costs a pretty penny, but some similar models may show up on the market at very attractive prices.

WWII, depending on the design. The Hallicrafters SX-28, for example, is available in three configurations. The straight SX-28 is a pre-war design, and used phenolic coil forms (which caused a little bit of temperature-sensitive frequency drift). The SX-28A, on the other hand, was built after World War II. It used ceramic coil forms and that improved the thermal drift a great deal.

During World War II, there was a military model that was part of a communications truck. The truck was a "deuce-and-a-half" (2½ tons, for you non-military types) that included a BC-610 transmitter, two SX-28-series receivers (two operating positions), and had a 5000-watt power generator towed along behind.

After World War II, a new series of tube-type receivers was built, although many of the designs were the same as pre-war receivers. By the mid to late 1950's, receivers such as the Hallicrafters SX-100 (Fig. 4) were available. Those receivers used glass-envelope miniature vacuum tubes.

The type of vacuum tubes used in the radio receiver will give some hint as to the age of the unit. Figure 5 shows several types of older vacuum tube. Shown are the glass envelope four and five pin tubes used in the early to late 1920's. The four-pin tubes were triodes, while the five-pin tubes were mostly tetrodes. By the early 1930's, tubes like those shown in Fig. 6—some having a grid cap on the top of the glass envelope—began to appear. Most of them were four-, five-, six-, or seven-pin types.

CAUTION! Receiving tubes have a grid cap, and some people believe that it is safe to test the radio by touching the grid cap. **DON'T DO IT!** If the coupling capacitor is shorted, a high voltage may be present at that point. Also, if the tube is a transmitting type, then the cap is not a "grid cap," but rather it is a high-voltage plate cap and can deliver quite a jolt!

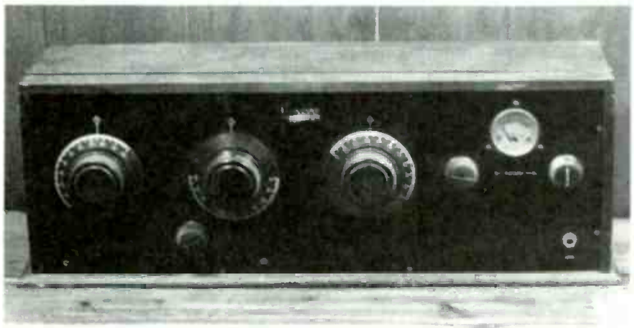


Fig. 3. This 1920's vintage tuned radio-frequency (TRF) receiver has a nice wooden cabinet. Many TRF radios on the market are not communications receivers.

Fig. 4. By the mid to late 1950's, receivers such as this Hallicrafters SX-100 receiver, which used glass-envelope, miniature vacuum tubes, were available.

In the mid-1930's, the octal tube (see Fig. 7) became available. Some of the early types were glass envelope tubes, while later versions were metal envelope (as shown). The key feature is eight pins on the base of the tube. Those units have a plastic prong (or a small ridge) on the bottom of the base that serves as a keyway. That keyway matches a slot on a hole in the accompanying socket.

Older tubes used a pair of large pins to mark pin 1 and the higher numbered pin. But octal tubes have evenly spaced pins that are all the same size. The keyway on the prong is what guides the tube correctly into the socket. Octal tubes that have a type number beginning with "6" have 6.3-volt filaments, while type numbers beginning with "12" are 12.6-volt filament types.

There is another version of the octal socket that had eight pins, as other octals, but the pins are wire-like. The center prong on the base is specially designed with a groove that fits into a locking socket. Thus, such tubes are called *locktal* tubes. Most locktal tubes have type numbers that begin with a "7."

For factory-built rigs, the tubes serve as a ready guide to the approximate era of manufacture. Those tubes also indicate the earliest that a homebrew rig could have been built. But hams often used older tubes than the "state-of-the-art," so a receiver could have been built in the mid-1930's, but use four-pin tubes of ten years earlier.

So far, we have talked mostly about ham-radio receivers. Transmitters are also on the market, and often at prices that are less than the equivalent receiver. We've covered old transmitters in this column before, so won't do it again in depth. But the transmitter part of ham collecting is very much a part of the hobby. You commonly can find CW-only, AM-CW, and AM-CW-SSB rigs from the 1920's to the 1960's.

A WORD OF WARNING

Older transmitters can be put on the air if they meet present-day standards. Be careful of vacuum-tube transmitters built in the 1930's and before, for they may not have the stability

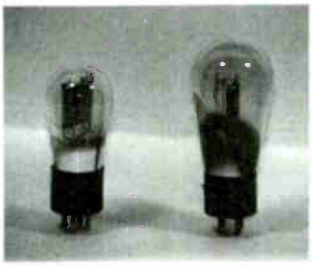


Fig. 5. Here are some glass-envelope four-pin (triodes) and five-pin (mostly tetrodes) tubes used in the early to late 1920's.

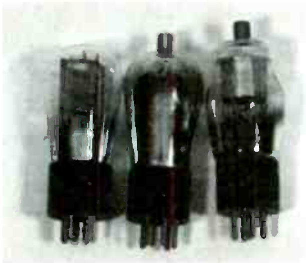


Fig. 6. By the early 1930's, four-, five-, six-, or seven-pin tubes like these (some having grid caps) began to appear.

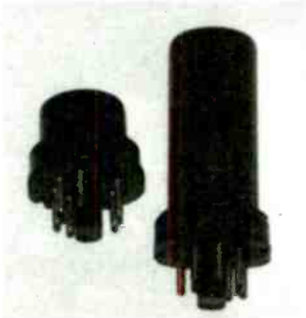


Fig. 7. In the mid-1930's, octal tubes became available. Some versions were glass-envelope tubes, while later versions were metal-envelope types.

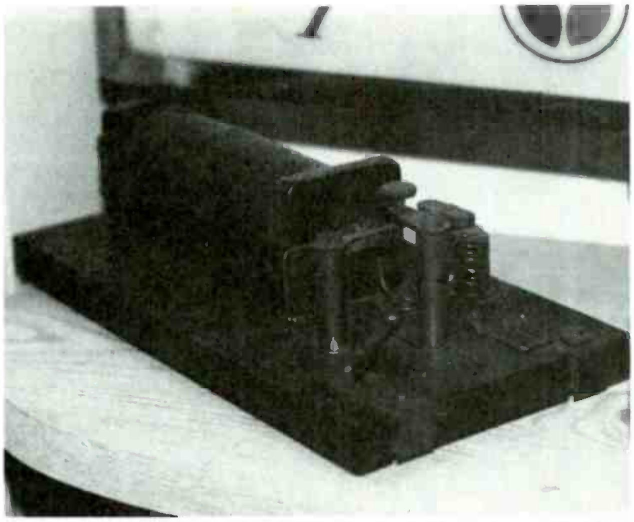


Fig. 8. Is this a piece of communications gear or quack medical equipment? Does anyone know for certain?

to stay in the band. Also, never use a spark-gap transmitter on the air; they tear up the airwaves for megahertz around the alleged operating frequency. For more modern transmitters, be sure that the rig is in good repair before going on the air. Bad tubes, dried out power-supply filter capacitors, and other defects can put out a 571 CW signal, or a screeching, humming AM voice signal.

Don't risk an F.C.C. "Notice of Violation" for a test. Use a dummy load first, and listen for the tone on a nearby receiver. Repair any defects before going on the air.

COLLECTING ACCESSORIES

A collateral-collecting activity is scooping up ham radio accessories. Perhaps the most common accessory collected is telegraph keys. From old brass "straight keys" to "North Atlantic" cold-weather keys, to semi-automatic "bugs," the old-fashioned telegraph key is a popular keepsake of another era (and one that can still be used on "straight key night" contests).

Other amateurs collect microphones, while still others collect the add-ons such as antenna tuners, Q-multipliers, Select-O-Jects, and other devices.

WHATZITS?

One of the little joys of collecting antique ham gear is finding those things that no one can identify. Figure 8 shows an electrical device (radio?) that some say is a part of a spark-gap transmitter, while others say it is a quack medical device of the early 1900s. I prefer the latter explanation, but some disagree. Does anyone know for certain? By the way, there were many quack electrical devices offered because no one regulated them.

Besides, electricity was new, miraculous and wonderful, so people thought it could cure anything...and unethical pseudo-physicians were happy to accommodate them. ■

COP TALK: Understanding Police Communications

BY LAURA QUARANTIELLO

Listen in on and understand the communications of your local public servants to get the real scoop on what's happening in your area.

There is no public-safety service more monitored by scanner hobbyists than law-enforcement communications. Ninety percent of scanner owners have local-police frequencies stored somewhere within the memory of their scanners. Whether you live in a small town regulated by the County Sheriff's Office, or a large metropolis patrolled by city police, the law-enforcement channels are the most actively monitored band of frequencies you will encounter on your scanner.

"To Protect and Serve" has long been the police officer's motto and nowhere is this truism more evident than through the day-to-day communications of a modern police force at work. From the most heinous of crimes—murder—to burglary reports, to traffic control, to helping a lost youngster home after dark, the police officer's job is one of the most fascinating of services to monitor. It allows the scanner owner to listen in on the excitement, the danger, the boredom, and the drudgery of the serving officer on the beat. No one who listens can fail to come away with less than high respect for the men and women who wear "the badge."

Smaller Communications Systems. Today's modern police department keeps in touch via two-way radio, an ever-present link between the dispatcher at headquarters and the uniforms on the street. Calls are dispatched instantly; license, registration, and warrant checks are just seconds away via the radio microphone; officers responding to calls can be updated enroute; and cover units can be requested, all at the touch of a switch. The law enforcement officer is never far from information or help with a radio at hand.

Most police-radio systems are composed of one-frequency "simplex" equipment, in which all radios transmit and receive on the same frequency, and so are unable to do both at the same time. That presents a problem during moments of heavy communications traffic or emergency situations, where multiple units are all attempting to transmit at once, causing the characteristic "squeal" so often heard when units "step-on" and cover each other. That can be avoided by using a two-frequency semi-duplex system, which allows the dispatcher to receive incoming calls while transmitting.

Small police departments utilize one main dispatch frequency, while others such as the Los Angeles Police Department find it necessary to divide their channels up to cover different divisions and beat areas. In addition to dispatch, most departments utilize an inquiry channel through which officers request license, registration, wants, and warrant checks, freeing up the dispatch frequencies for other traffic.

Tactical or "Tac" channels are used by detectives and undercover officers for surveillance operations and by officers on high risk warrant service. Tactical frequencies may also be used for car-to-car communications between officers, however this is most often performed on a separate channel known and identified over the air simply as "Cars."

(Turn to page 98)

More Advanced Systems. Many communications systems today use repeaters. Repeater-based systems allow mobile-unit signals to be retransmitted, often from a higher elevation (such as a mountain top) permitting greater range. Vehicular-extender systems, which use a repeater in each mobile unit, serve the same function, but are prone to interference.

"Mobile Data Terminals" (or MDT's) are the latest wave of high-tech to hit law-enforcement communications. Mobile data terminals are laptop computers located in police patrol units from which license and vehicle-identification checks can be requested directly from the main computer rather than tying up a dispatcher. Routine calls can also be dispatched, allowing officers to see the complete call history on the laptop screen.

Since the communications occur in standard computer bursts, similar to packet-radio communications, they also free up a voice frequency. Baud rates of 9600 are common for MDT's. On a scanner radio, MDT signals sounds like the familiar buzz of a data channel—rather loud and annoying—however it has been speculated that with the proper computer software, MDT information can be monitored by civilians.

"Computer aided dispatching" (or CAD) systems also save dispatchers considerable time and effort by doing much of the work for them. A typical CAD system works something like this: First a police department receives a call for service from a citizen. Second, the police telephone operator who answers the call enters the basic information into a computer, which matches the call location with a geographic database file and routes it to the appropriate dispatcher. It is also possible that the computer might assess the availability of officers for that particular beat and might suggest assigning one to the call. The system might also be programmed to search local, state, or national databases to determine if the persons involved in the call are listed. Additionally, information about prior calls for service from that address are compiled. Last, the computer sends all of this information to the dispatcher responsible for that geographic area and the pertinent information is passed-on to the selected patrol unit by radio or MDT.

Those patrol units with the forest of antennae atop the roof are probably equipped with "automatic vehicle locating," or AVL. AVL is the pinnacle of dispatching control because it allows the headquarters dispatcher to see the location of all units on a computer-generated map of the city. This is done through the use of Loran-C radio by comparing two or more signals and triangulating a position from them. The technology allows a dispatcher to instantly send the closest unit to a call and to know the location of an officer who is not answering his radio and possibly in need of assistance. This system is still experimental and many cities are unable to meet the costs of such technology.

TABLE 1—STANDARD 10-CODES

Code	Meaning	Code	Meaning
10-1	Receiving Poorly	10-18	Urgent
10-2	Receiving Well	10-19	Contact ________ .
10-3	Stop Transmitting	10-20	Unit Location
10-4	Okay	10-21	Telephone Call
10-5	Relay Information	10-22	Cancel
10-6	Busy	10-23	Arrived at Scene
10-7	Out of Service	10-24	Finished Assign.
10-8	In-Service	10-25	Meet ________ .
10-9	Repeat	10-26	ETA is ________ .
10-10	Negative	10-27	Request License Info
10-11	________ in Service	10-28	Request Veh. Info
10-12	Stand by	10-29	Check Records
10-13	Report ________ conditions	10-30	Use Caution
10-14	Information	10-31	Pick Up
10-15	Message Delivered	10-32	Units Requested
10-16	Reply to Message	10-33	Officer Needs Help
10-17	Enroute	10-34	Correct Time

There are a wide variety of tabletop and handheld scanners available that can be used to monitor police communications. So shop around to find the one that suits you best.

Law Enforcement Communications Frequency Ranges

37.02 – 37.40	471.4625 – 471.8125
39.02 – 39.98	482.3125 – 483/1375
44.02 – 42.94	483.1625 – 483.4375
44.62 – 45.05	483.4625 – 484.8125
46.10 – 46.55	489.1625 – 489.4375
154.025 – 154.115	494.3125 – 495.1370
154.560 – 154.950	495.1625 – 495.8125
154.960 – 154.995	500.3125 – 501.1380
155.010 – 155.400	501.1625 – 501.4375
155.415 – 155.500	501.4625 – 501.8130
155.730 – 156.150	506.3125 – 507.1625
156.150 – 156.240	507.1625 – 507.3125
158.730 – 158.955	810.000 – 816.000
158.985 – 159.030	821.000 – 824.000
453.0125 – 454.000	855.000 – 861.000
460.0125 – 460.5625	861.000 – 869.000
471.1625 – 471.4625	

Many police departments are making a serious attempt to keep unwanted listeners from eavesdropping on their communications by installing scramblers. The National Security Agency recommends the DES (Digital Encryption System) encryption method, which changes voice to digital code, unrecognizable on a scanner and widely viewed to be an unbreakable means by which agencies can secure their communications. DES utilizes 720,000,000,000,000,000 different

(Continued on page 108)

TRACKING DISTANT SIGNALS

By monitoring the VHF low-band for skip, you could easily make some wonderful long-distance contacts.

BY LAURA QUARANTIELLO

The transmissions were weak, scratchy and, more often than not, lost behind the other voices on the frequency. I'd been listening to 33.7 MHz for two days now and still had failed to hear any information that would help me to identify the station speaking. It had become a minor obsession over the past couple of hours to positively identify the distant fire-department dispatches.

Unfortunately, given the changing nature of the atmosphere, it was likely that when I woke up the next morning and turned on the radio, 33.7 MHz would be silent and the transmissions gone. To understand how a long-distance transmission can appear and disappear like that, we'll have to do a quick study of radio-wave propagation—the near magic of what happens to a radio wave once it heads off into the atmosphere.

One Little Wave. When a radio signal or wave leaves the antenna of a transmitter, it becomes, in theory, two distinct parts: a ground wave that travels along the surface of the Earth and a sky wave that travels out into the sky. The ground wave travels a short distance before it becomes absorbed by the Earth, but the sky wave is much more resilient and that's the wave low-band, distant-transmission listeners tune-in to.

The sky wave travels on its merry way, high up into the wild blue yonder, until it encounters the ionosphere. That layer of the Earth's atmosphere, some 150 to 200 miles high, is constantly bombarded by the Sun, which charges the ionized gases of the ionosphere. When a sky wave hits that layer of charged gas, it is partially reflected. Some of the part of the wave that is not reflected is absorbed by the gas, and the remainder flies into deep space. The portion that is reflected returns to Earth at an angle, which means that it comes down many thousands of miles from its point of origin. That phenomenon is known as "skip."

Skip is almost a mystical thing, affected by sunspots, weather, and even the time of year. It can also be a scanner enthusiast's best friend if you know how to take advantage of it.

Equipment. You don't need a control room full of radios in order to receive VHF skip transmissions. In fact, any scanner that will search the range of 30–50 MHz will do nicely. Having a search feature is important, because you'll definitely want to program-in short ranges of frequencies and let the scanner do the work.

An outdoor antenna is not mandatory, but it will improve your chances of hearing transmissions tenfold. A good all-band ground-plane antenna does nicely, but a beam antenna can have advantages if you are searching for transmissions from a specific direction. Since the prevailing atmospheric conditions have the most to do with reception, whatever you use should pull in some signals, so give it a try.

Frequency guides are a great resource if you're serious about identifying the stations heard. For example, a complete set of *Police Call* magazine's frequency directories is invaluable for tracking down domestic public-safety stations. For military stations, try a federal frequency directory such as Tom Kneitel's *Top Secret Registry of US Government Frequencies.* A good map book of the United States is also handy.

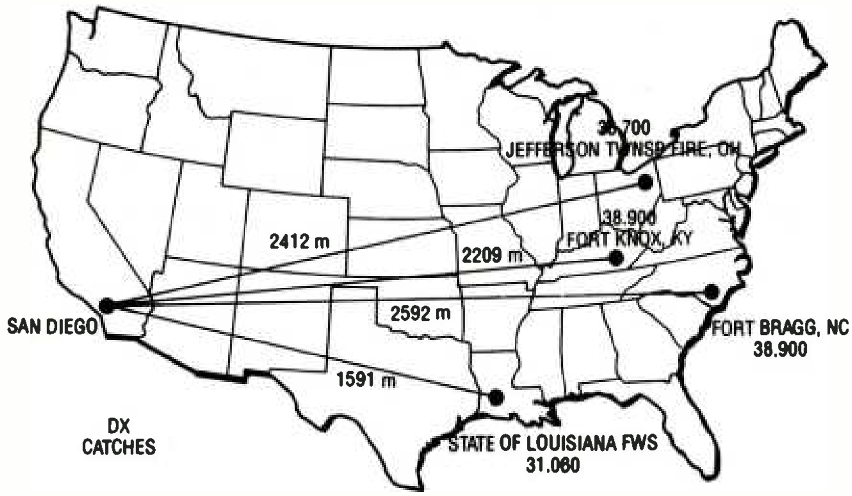


Fig. 1. As you can tell from these catches logged by the author, skip can really help you pull-in transmissions from all over the country.

Finding Skip. Frequencies on the low band—30 to 50 MHz—are most affected by skip because of their long wavelengths. Frequencies on the higher VHF bands tend to skip less. I don't consider 50 MHz the absolute top of the possible skip range. Occasional forays above 50 MHz have netted some interesting catches, but for the best results, "go low."

Searching through the basement of the VHF band, your chances improve drastically. On a good day, it isn't unusual to hear communications from thousands of miles away, sometimes even from Central America, Canada, or overseas. The key to hearing all this is knowing when and where to listen.

Since skip is affected primarily by the actions of the sun, it almost goes without saying that daytime is the best time to listen. Try between 9 A.M. and 7 P.M., or whenever local dusk occurs. If you're shortwave equipped, listen at 18 minutes past each hour for propagation reports from WWV on 2.5, 5, 10, 15, or 20 MHz. The solar flux number they give reflects the amount of ionization of the ionosphere's F2 layer, and so the possibility of picking up long-distance transmissions.

I target specific frequencies, which I check for communications. For instance, 38.9 MHz is a popular military range-control frequency that I have programmed into my regular scan bank. If I hear communications on this channel, I know that skip is present and set-up search ranges to see what other frequencies might be active.

Try programming in the range from 30.0 to 31.0 MHz and set your scanner to scan between these two values. This is about as low as typical scanners will receive and is a good place to start. Here you'll come across business communications, forestry reports, power and water utilities, and some public safety and military communications. If you find active distant stations here, work progressively higher. On some days only a small swath of frequencies will be affected, and on others you won't know where to tune first because of all the activity.

The region between 31 and 33 MHz is a super place to look for military communications, as are the 38–39 MHz and 40–42 MHz areas. Fire departments can be found primarily between 33–35 and 37–38 MHz. Highway patrol, a good target for beginners, can be found operating between 42–43 MHz. These ranges will get you started. Take a look at the back of an issue of *Police Call* for their Consolidated Frequency List, which will further guide you.

Don't be afraid to experiment and seek ranges beyond the norm for skip. I frequently scan from 49.0 to 49.7 MHz, just below the cordless telephone/baby monitor band, which yields up such catches as military-range communications (like Camp Pendleton, California at 49.0 MHz), and tactical operations (such as Army Explosives Ordnance Disposal on 49.7 and 49.8 MHz). You never know what you'll find: I occasionally even hear live horse-race announcements on 41.725 MHz.

During the Gulf War, scanner monitors reported heavy communications activity all across the low band from American and foreign troops in Saudi Arabia. Voices from Central American stations, Panama, Honduras, and the Dominican Republic are regularly heard engaged in US military operations. Furthermore, lots of counter-drug missions take place on the low band, as well as a large amount of fire communications. Fish and Wildlife officers, whose activities often take them far from normal radio range, can often be heard talking on frequencies between 31 and 32 MHz.

Identifying Stations. The first order of business when you come across an active frequency is to take down some of the information you hear coming across the speaker. Call signs, place names, and unit ID's are all helpful. More than once I've tracked down a frequency user by tracing city names through a map book.

Here's an example: say, 42.12 MHz is active with a dispatcher calling herself "San Diego." Looking up San Diego in a map book will reveal a California location. Drag out volume nine of *Police Call*, check all the licenses under 42.12 MHz and you'll find a listing for the California Highway Patrol San Diego Office.

Military stations can be difficult if call signs such as "Alpha Six Echo" are used, but if you listen long enough you might hear the base name or a unit number. When that happens, check a federal frequency book for active stations on the frequency to get you closer to a positive ID.

DX'ing Low Band. Searching for distant signals (DX'ing) can be an engrossing, frustrating, exciting, and highly variable hobby.

As I predicted, the 33.7-MHz signal I mentioned did fade away by the time I listened again the next morning. It was three weeks before I finally heard the signal strong enough to warrant some serious listening. With a little more attention I had my catch in no time: Jefferson Township Fire Department, Ohio.

If local communications are getting too routine and you'd like to explore how other services across the country handle their communications, "go low" and give low-band skip monitoring a try. ■

WARC 92

STANLEY LEINWOLL

RF Spectrum Prepped for Next Century

REPRESENTATIVES OF COUNTRIES with a stake in telecommunications met recently in Torremolinos, Spain, to reallocate parts of the radio-frequency spectrum for satellite and space communications services in the 21st century. But the meeting had its share of contention as national delegations clashed over frequency redistribution.

The World Administrative Radio Conference (WARC-92), held from February 3 through March 3, allocated frequencies for many different concepts related to satellite and spacecraft to Earth communications. Some proposed systems that require special frequencies are only vague concepts, but others could be started even before the turn-of-the-century. Consider these possibilities:

- A cordless telephone system that will permit you to dial another phone anywhere on earth using a constellation of 77 low-orbiting satellites. This system would also permit you to phone, page, or send fax messages from airplanes, ships at sea, or moving cars.
- A satellite system that directly broadcasts strong, clear, non-fading radio signals to home receivers worldwide with compact-disc quality reception.
- A satellite television system that beams clear, sharp images directly to your home that are better than those received directly from terrestrial TV transmitters or cable.

WARC-92 also allocated Earth and space exploration frequencies, including those required to establish a lunar colony, and for a manned expedition to Mars. In addition, WARC-92 allocated an additional 790 kHz of RF spectrum to high-frequency broadcasting (HFBC), and adopted a resolution calling for a future conference to plan HFBC.

Nationalistic squabbles beset the conference that allocated frequencies for 21st-century telecommunications

Tough allocation decisions

Although many of WARC-92's accomplishments read like a chapter from Star Trek, they did not come easily. Participants found that attendance was strenuous, some delegations were highly contentious, and the results of certain sessions were confusing.

WARC-92 reallocated frequencies in different parts of the electromagnetic spectrum ranging from high frequency (HF— 3 to 300 MHz) all the way up to the extra-high frequency (EHF—above 150 GHz).

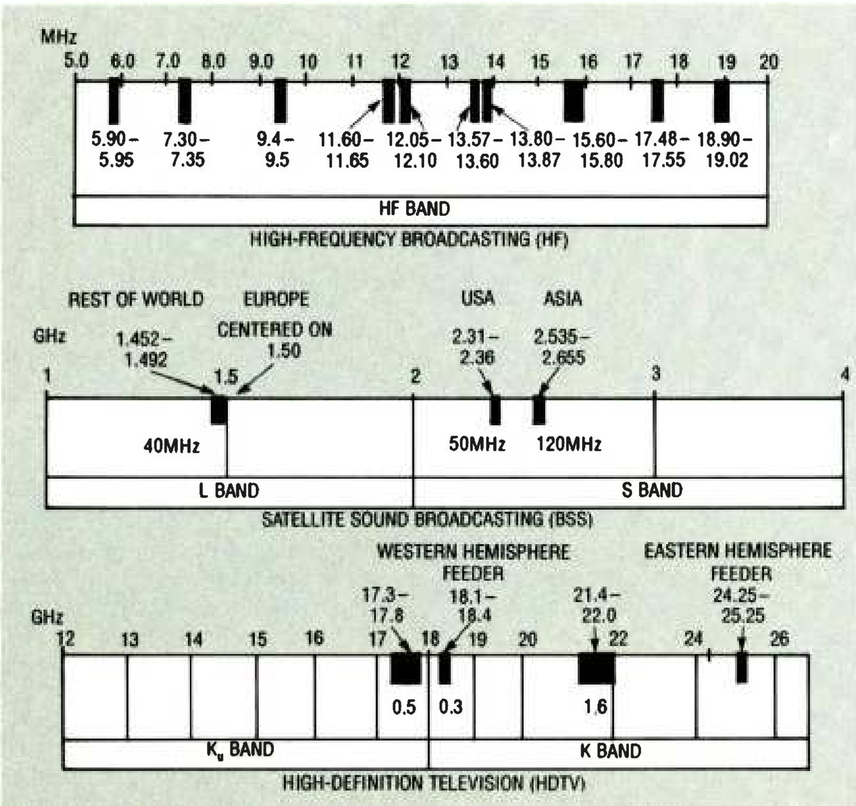
Conference accomplishments

WARC-92's accomplishments include:

1. *High-frequency (HF) allocations.* Figure 1 shows the additional frequency allocations made for high-frequency broadcasting. Four conditions were imposed on those allocations:

- They were limited to single-sideband (SSB) only.
- Their use is subject to planning procedures of future WARC's.
- They were allocated to the *fixed* and where appropriate, the *mobile* services until April 1, 2007.
- Existing *fixed* and, where appropriate, *mobile* services can continue on a low-power, national, and non-interference basis taking into account existing HF-broadcasting schedules.

A future planning WARC will probably be scheduled for 1995 or 1996. In preparing for this important radio conference, the United States Delegation proposed the expansion of the shortwave broadcasting bands by an additional 1125 kHz in Europe, Africa, and Asia, and 1325 kHz in the Americas. But a large bloc of developing countries from Latin America, sub-Saharan Africa, and Asia steadfastly refused to reallocate that amount of the RF spectrum to broadcasting.



FREQUENCY ALLOCATIONS IN THREE REGIONS of the RF spectrum.

The bloc pointed out that the HF bands below 10 MHz are used extensively in their countries for internal point-to-point communication, and they are extremely congested. Consequently, those developing countries were adamant about releasing large amounts of spectrum below 10 MHz. To avoid the possibility that HF broadcasting would not get *any* additional spectrum during WARC-92, an eleventh-hour compromise was struck, and a total of 2000 kHz was reallocated in the bands below 10 MHz.

Mindful that the amount of spectrum reallocated to HF broadcasting was insufficient, the United States Delegation declared that WARC-92 failed to make adequate provision for that service, particularly below 10 MHz. The delegation announced that it "reserves the right to take the necessary steps to meet the HF needs of its [U.S.] broadcasting service."

The extension bands will become available to HF broadcasting on April 1, 2007. They will be planned, and can only be used in the SSB mode.

2. *Satellite sound broadcasting (BSS)*: The issues here produced a genuine tug-of-WARC. The conference was divided from the outset on allocation of frequencies. Most Europeans wanted the more economical and propagationally suitable L-Band, with an allocation around 1.5 GHz. However, the U.S. was firmly opposed to that allocation became military aeronautical services are now operating in that band. The U.S. wanted the allocation in the S-band, around 2.3 GHz. Other countries, notably, China, Russia, Japan, India, and Pakistan, wanted the BSS allocation to be around 2.5 GHz. (See Fig. 1)

In the end, BSS allocations were made in all three bands on a regional basis. In the U.S., satellite sound broadcasting is allocated in the 2.31- to 2.36-GHz band. However, China, Russia, Japan, India, Pakistan, and several other Asian countries will use the 2.535- to 2.655-GHz band. The rest of the world will use the 1.452- to 1.492-GHz band. All of those uses will be limited to digital audio broadcasting (DAB). WARC-92 agreed that the upper 25 MHz of each band can be used immediately, provided that suitable coordination procedures are followed.

3. *High-definition television (HDTV)*. This service ran into problems similar to those encountered in BSS, and there was no agreement on worldwide allocations. Instead, Europe, Africa, and Asia will use the 21.4- to 22-GHz band, and the Americas will use the 17.3- to 17.8-GHz band. Feeder links will be in the 18.1- to 18.4-GHz band in the Americas, and 24.25- to -25.25-GHz band elsewhere. (See Fig. 1) These bands will become available on April 1, 2007. Prior to that date, HDTV could be implemented, provided that existing services are protected.

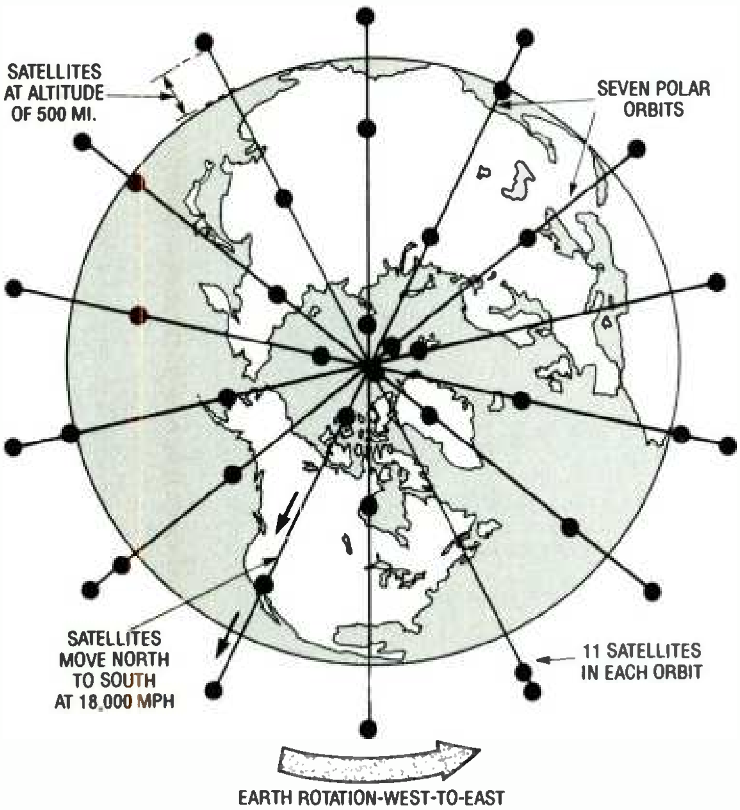
4. *Mobile satellite service, and aeronautical public correspondence (APC)*. The services that most excited WARC-92 attendees occur in the frequency bands assigned for telephony, worldwide paging, and fax services using many continually orbiting rather than geostationary satellites.

In 1990 Motorola proposed a global telephone system called Iridium (see box). The APC system would enable passengers on commercial airlines to make phone calls or send FAX messages anywhere on earth. Frequencies for these services were allocated in bands between 300 MHz and 3.0 GHz, and they include allocations for a future public land-mobile telecommunications service (FPLMTS). That service would, among other services, permit anyone in a moving automobile with a car phone to call anywhere on Earth.

Although some worldwide exclusive allocations were made, the interregional jousting that took place in BSS and HDTV also affected the mobile satellite service. Once many of these systems are implemented, it will be necessary for the systems to carry dual standard equipment. For example, an airplane crossing the Atlantic must carry equipment that operates in the frequency bands allocated for the Western as well those allocated for the Eastern hemisphere. The world's electronic equipment manufacturers can expect to stay busy for years to come meeting the demand for equipment that will operate at the many WARC-92-allocated frequencies.

(Continued on page 108)

GLOBAL TELEPHONE NETWORK OF 77 SATELLITES



IRIDIUM TELECOMMUNICATIONS NETWORK would have 77 moving satellites in seven polar orbits at a 500-mile altitude.

Iridium, a proposed global cellular telephone network, would put 77 relay satellites in earth orbit. Those moving transceivers or "cell sites" would be supported by 20 or more ground stations connected to terrestrial telephone lines. The system promises worldwide telephone, paging and fax service.

Unlike existing telecommunications satellites that remain in a fixed position 22,300 mile above the equator, Iridium's satellites would orbit the earth at an altitude of 500 miles. The 77 satellites would be launched and synchronized in seven polar orbits with 11 satellites in each orbit.

Moving from north to south at 18,000 miles per hour, the satellites would behave like electrons orbiting the nucleus of an atom. The earth will rotate west to east under this "shell" of satellites. As a result, at least one satellite will be in position above the horizon ready to transmit and receive calls at all times. Moreover, the low-altitude orbits will permit half-watt pocket phones to be used.

This ambitious scheme, proposed by Motorola Inc., has received frequency spectrum allocations although it has not yet been authorized by the FCC. In addition to revenues expected from telephone, fax, and paging services, Motorola envisions considerable work in making the satellites, ground station equipment, and pocket telephones. Critics, however, say that Iridium will have to play catch-up with existing cellular telephone services, and it will be too expensive to be profitable. ■

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FIBER OPTICS OPENS LONG ISLAND TO DDS

An 8000-mile fiberoptic "electronic superhighway" that could provide digital data services (DDS) to homes in the metropolitan New York region has been proposed by Long Island-based Cablevision. In addition to initial coverage in Nassau and Suffolk counties, Bronx, and parts of Brooklyn could be served.

The network could deliver video on demand, home shopping and banking, interactive games, and "telecommuting" for those employees who work out of their own homes.

Fiberoptic cables made up of bundles of hair-thin glass fibers will carry pulses of laser light. Capable of transmitting far more messages than much larger copper cables, the system will convert digital signals from various sources into to light pulses at one end and will then reconvert them back to digital data at the other end without the need for a modem.

Cablevision expects to compress the data to provide as many as 1100 channels initially. The fiberoptic optic cables will be run to within 1000 feet of each home being served, and each cable will serve a cluster of only 750 homes. Because the cables will be underground, the system will be less susceptible to outages and interference than cable strung on telephone poles.

Under the plan, conventional coaxial cable will carry the signals from the fiberoptic cable terminal into each home. Over short distances, the coaxial cable is capable of meeting the needs of each home.

Cablevision plans to start with only 77 channels and use the extra capacity for two-way, interactive programming. Cablevision Chairman Charles Dolan will only generalize about the possible services at this time.

Under Cablevision's ambitious plan, 100,000 homes on Long Island could be connected by early 1994. The network is expected to reach the rest of Cablevision's 1.1 million customers in the tri-state area by the end of 1995. ■

POOR MAN'S CELLULAR PHONE GETS FREQUENCIES

In September, 1992 the FCC allocated 22 MHz of bandwidth in three chunks for use by "emerging technologies," clearing the way for personal communications services (PCS)—the so-called "poor man's cellular phone"—to come into its own. Voice and data services based on a PCS microcell network, as well as other "future mobile services," are to have use of the frequencies between 1.85 and 1.99 GHz, 2.11 and 2.15 GHz, and 2.16 and 2.2 GHz.

Now that the bandwidth is available, the next challenge for PCS suppliers is to clarify their positions in relation to the cellular phones and paging services already in use.

Also in question are the rights of "incumbent users" of the three designated bands. According to the latest FCC figures, approximately 24,000 licensees already maintain about 29,000 microwave links, with channels ranging in width from 800 kHz to 10 MHz. Those licensees, who are now using the bands for public and private microwave communications, are up in arms.

As a compromise, the FCC has set up a minimum transition period of three years, during which current users and PCS providers are to negotiate relocation terms on their own. At the end of the transition period, current users would retain equal claims to the spectrum, with the exception of cases in which there is radio interference between operations. If a PCS provider needs the frequencies, he is expected to work out a voluntary relocation settlement with the incumbent user. If they are unable to reach a relocation agreement, the PCS provider can ask the FCC for an involuntary relocation (state and local government agencies are exempt)—at a cost. The PCS provider must pay all relocation expenses, build the new facilities, and test them to ensure that they are compatible with the old frequencies. According to FCC commissioner Sherrie Marshall, "Making new users pay to move existing users provides an incentive to share." ■

COP TALK

(Continued from page 98)

computer codes, which can be changed hourly if desired to foil even the best computer hacker.

Scrambled communications are more the domain of federal agencies than city police departments, however you will recognize some of them by loud static that sounds like your squelch control has been turned off, or the high-pitched gibberish of speech inversion.

Another communication method becoming popular is the trunked system. More and more law-enforcement departments are making the move in order to reduce radio interference and allow clearer communications. Trunked radios are licensed in the 800–900-megahertz band, utilizing five to twenty channels.

Monitoring trunked police frequencies is not difficult, despite the claims of police departments that their systems are secure from listeners. Simply program all of the system frequencies into your scanner and lock out the data channel, which buzzes and howls so much that you'll easily identify it. That channel is changed daily and sometimes as much as twice a day so don't forget to lock out that channel and unlock the old one as necessary. Leave off the delay feature. As soon as communications end on one frequency they will shift to another immediately.

Frequencies. Public-safety 800-megahertz frequencies are usually full of activity because they are sometimes shared by various services (such as public works, and the fire and medical services) as well as the police. For that reason you'll need a quick hand to bypass the other conversations and stay with the police communications.

In addition to the 800-megahertz band, you will find police communications between 153–160 megahertz, 450–460 megahertz, and 500–512 megahertz (see boxed text entitled "Law-Enforcement Communications Frequency Ranges" for the specific ranges). A current volume of *Police Call* magazine for your area (available at any Radio Shack) will list the frequencies in use for your local department. General scanning through those frequency ranges, though more time consuming, is often the best way to find active frequencies, including unlisted undercover or detective operations.

Departments across the country number their frequencies and many times refer to them as F1, F2, or Frequency 7, Frequency 10, etc. Very seldom will an officer or dispatcher mention a frequency on the air; for security, it is coded ("Unit 230 Sam, switch to Frequency 6."). A good amount of bandscanning will enable you to eventually track down the frequency.

Radio Codes. To the uninitiated, the sentence "35 Paul 3 is Code Four at this location with one 10-16. Roll an 11-85." is sheer nonsense, but to a monitor familiar with the codes of the San Diego County Sheriff's Department, Unit 35 Paul 3 (the number three City of San Marcos patrol unit on duty) just informed dispatch that no further help is needed, he has one prisoner in custody and is requesting a tow truck.

Radio codes like these provide dispatchers and police officers a shorthand way of getting their message across clearly. They also afford a certain amount of message security. Local radio hobbyists should have a list of codes used in your area (a good place to inquire about this is a Radio Shack store). Note that each county, and sometimes each department have their own codes.

In addition to standard 10-Codes, each state has their own vehicle codes, health and safety codes, and business and professions codes. Section 10851 of the California Vehicle Code pertains to stolen vehicles, therefore an officer referring to a stolen car over the radio would call it a "10-851." These codes are often available in the law section of your local library. Some of the more common codes appear in Table 1.

There is nothing quite so heart-stopping (or sad) as hearing the call "Officer Down!" come from the radio, but, thankfully, more often than not the calls you will listen to will be about routine alarms, abandoned vehicles, traffic stops, and field interrogations. An average day is never just an average day for a police officer.

You never can be sure of what you will hear and maybe that is part of the allure of monitoring police communications, a chance to glimpse behind the badge without actually being in the line of danger. So, turn on your scanner and ride along! ■

WARC '92

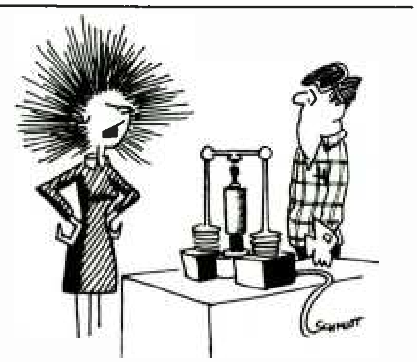
continued from page 103

WARC-92's notable statistics

WARC-92 was attended by more than 1400 delegates from 127 countries, and there were several hundred observers from 31 regional and international organizations. The conference produced six million pages of text weighing 28 tons. There were two all-night sessions on the last two days of the conference, and when the conference concluded, most of the participants weren't clear about what decisions had been made, particularly in the sound-broadcasting satellite service, BSS.

A total of 81 declarations were made at the end of the conference. A declaration is a statement by a country's delegation that is appended to the Final Acts of the Conference, calling attention to an issue of particular concern to that delegation. Perhaps the most telling declaration was entered by the French Delegation; it set the tone for the conclusion of WARC-92. It expressed reservations about the number and complexity of the texts adopted within the short time of WARC-92, and it was concerned about possible interpretations which would not conform with the final consensus of the conference.

[Editor's Note: Stanley Leinwoll, director of engineering in U.S. for RFE/RL, was a member of the United States Delegation to WARC-92.] ■



"Marvin, your 'spark transmitter' just undid a fifty-five dollar perm!"

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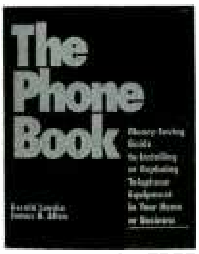
The Phone Book; by Gerald Luecke and James B. Allen. Prompt Publications, Howard W. Sams & Company, 2647 Waterfront Parkway East Drive, Indianapolis, IN 46214-2012; Phone: 317-298-5710; Fax: 317-298-5604; $16.95.



CIRCLE 222 ON FREE INFORMATION COUPON

This book explains the basic principles of telephones and how they work. It also provides guidelines to help you evaluate existing phone systems.

According to Luecke and Allen, a telephone installed in your home by the phone company, or a complete phone system installed in your office by a private contractor can be expensive and involve long waiting periods for service.

This book will help you avoid those problems. It includes instructions and extensive illustrations on how to install a single phone or complex, multi-line systems. Detailed information is also given on modular installations, wiring new systems, installing business, private home, and apartment installations as well as modem operation. A separate chapter covers troubleshooting and system checks. Ω

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GUGLIELMO MARCONI
(Continued from page 79)

Many Lives Saved. During the next ten years, wireless provided assistance to the victims of at least ten major maritime disasters. While hundreds of lives were saved, the value of wireless at sea had not received a high level of public recognition. This would change, however, following the collision of the White Star Line's S.S. Republic with the Italian steamship Florida on January 23, 1909.

The Florida rammed the Republic in a dense fog 26 miles southwest of Nantucket. The Republic's wireless room and dynamo were badly damaged, but the wireless equipment was unharmed. The Marconi operator used emergency batteries to send out the distress call. A nearby land station picked up the call for help and alerted ships in the area.

The Republic's sister ship, the S.S. Baltic, was 200 miles away and responded at top speed, reaching the collision site within twelve hours. The Republic's wireless had to guide the Baltic through the still-thick fog. The Baltic safely took on all 1690 passengers from the two wrecked ships. The severely damaged Florida struggled to New York under escort, but the Republic sank near Martha's Vineyard.

Fortunately, the loss of life due to the collision was limited to six. Marconi and his wireless operators were heroes in the public mind. However, more disasters would have to occur before all ships would be required to carry wireless equipment.

The Titanic Tragedy. As mentioned earlier, the disaster that earned Marconi and his wireless the greatest acclaim was the sinking of the S.S. Titanic. Partly because it was the largest and grandest ship ever launched and partly because the passengers included celebrities and socialites of great renown. It's no wonder that the world's focus was on the Titanic as it began its maiden voyage from Southampton to New York on April 10, 1912.

Wireless enabled the Titanic to receive warnings concerning the ice field that laid ahead on April 12, although the warnings apparently were not taken seriously. After its collision with an iceberg, the Titanic sent out a wireless distress call which summoned help from the S.S. Carpathia. The Carpathia's sole wireless operator, though officially off-duty, fortunately had returned to his wireless equipment before going to bed and heard the Titanic's signals from 58 miles away.

Regrettably, the help came too late for the over 1500 who perished. How many hundreds more could have been saved if the wireless operator of the S.S. Californian, which lay stopped in the water only ten miles from the Titanic because of the ice, had not gone to bed leaving his ship deaf to the stricken vessel's calls for help?

International laws would soon be established requiring all major vessels to carry wireless equipment and maintain continuous monitoring of the airwaves for distress signals. Marconi and all the world could only wish that the value of wireless equipment at sea had been realized sooner. ■

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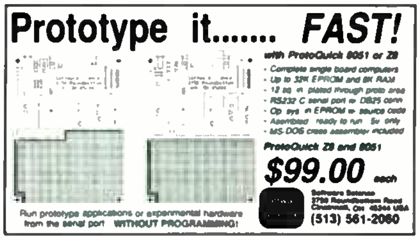

WORLD BAND RECEIVER

continued from page 25

out in the front panel, but there are no restrictions on the outside dimensions of the bezel. Be sure the bezel sidewalls are wide enough to permit it to be fastened to the front panel with screws and nuts.

Paint the dial window bezel before assembling it to the front panel. In the prototype, the clear plastic was painted black to match the color of the knobs.

Scribe a vertical line on the piece of clear plastic to be used as a window over the rotary dial and behind the slot cut in the front panel. With a sharp black felt-tip pen carefully trace over the scribed line so that it will appear as a distinct hair line to serve as the cursor.

Place the painted bezel on the outside of the front panel and the scribed window on the inside (with the cutout window in the front panel between them) and assemble them with screws and nuts. Wind on the nylon drive cord as shown in Fig. 13 and fasten it to the spring.

Power supply

The prototype SWX6 receiver was powered by a regulated 12-volt power supply. The receiver draws about 75 milliamperes, so any source of 12 volts, including batteries, at that current level can be used. Provision must be made, however to obtain the 5 volts DC to power the variable frequency oscillator.

Enclosure finishing

Assemble the three principal circuit boards to the base plate of the enclosure with No.4-40 machine screws and two No. 4-40 nuts used as spacers in the positions shown in the photograph Fig.5.

Complete all wiring. Make the connection from the antenna jack J1 to the wiper of switch S1-a with RG-174/U coaxial cable, and make all connections from the six terminals of switch S1-a to the six filters (detailed in Table 2) with enamel-coated magnet wire. Then make all connections from the output side of the filters to the contacts of S1-b with RG-174/U coaxial cable. Also, connect the S1-b wiper contacts to capacitor C15 with RG-174/U coaxial cable.

Make the following connections with insulated wire:

- Five volts to the wiper of S1-c
- Six terminals of S1-c to each of the oscillators shown in Fig. 4
- The six output connections from the oscillators S1-d

Make the following connections with RG-174/U coaxial cable:

- Wiper of switch S1-d to C14
- Electrolytic capacitor C41 to speaker/headphone jack J2

Enclosure assembly

Mount the front and back panels on the base panel with angles, nuts and bolts. The side panels should be assembled with angles set so they are concealed behind the left and right edges of the front and back panels, under the left and right edges of the top panel, and over the side edges of the baseplate.

In the prototype, dry-transfer labels were applied to identify the manual controls. A separate circular plastic band switch plate was used to identify the band positions on the multideck switch. (This plate can be easily changed if you want to change the band positions or frequencies.) Clear lacquer was applied over the dry labels to protect them. Install four rubber feet on the bottom of the base plate with sheet metal screws to prevent the exposed screw heads from scratching the table on which the receiver is located. ■

"This isn't the mother ship! I told you we were riding the wrong beam in!"

Countersurveillance

Never before has so much professional information on the art of detecting and eliminating electronic snooping devices—and how to defend against experienced information thieves—been placed in one VHS video. If you are a Fortune 500 CEO, an executive in any hi-tech industry, or a novice seeking entry into an honorable, rewarding field of work in countersurveillance, you must view this video presentation again and again.

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Please rush my copy of the Countersurveillance Techniques Video VHS Cassette for a total cost of $53.95 each (which includes $4.00 postage and handling)

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The professional discussions seen on the TV screen in your home reveals how to detect and disable wiretaps, midget radio-frequency transmitters, and other bugs, plus when to use disinformation to confuse the unwanted listener, and the technique of voice scrambling telephone communications. In fact, do you know how to look for a bug, where to look for a bug, and what to do when you find it?

Bugs of a very small size are easy to build and they can be placed quickly in a matter of seconds, in any object or room. Today you may have used a telephone handset that was bugged. It probably contained three bugs. One was a phony bug to fool you into believing you found a bug and secured the telephone. The second bug placates the investigator when he finds the real thing! And the third bug is found only by the professional, who continued to search just in case there were more bugs.

The professional is not without his tools. Special equipment has been designed so that the professional can sweep a room so that he can detect voice-activated (VOX) and remote-activated bugs. Some of this equipment can be operated by novices, others require a trained countersurveillance professional.

The professionals viewed on your television screen reveal information on the latest technological advances like laser-beam snoopers that are installed hundreds of feet away from the room they snoop on. The professionals disclose that computers yield information too easily.

This advertisement was not written by a countersurveillance professional, but by a beginner whose only experience came from viewing the video tape in the privacy of his home. After you review the video carefully and understand its contents, you have taken the first important step in either acquiring professional help with your surveillance problems, or you may very well consider a career as a countersurveillance professional.

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To obtain the information contained in the video VHS cassette, you would attend a professional seminar costing $350-750 and possibly pay hundreds of dollars more if you had to travel to a distant city to attend. Now, for only $49.95 (plus $4.00 P&H) you can view ***Countersurveillance Techniques*** at home and take refresher views often. To obtain your copy, complete the coupon or call,