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NOVEMBER 1983 / $2.50

SPECIAL ISSUE: RECEIVERS

- Dr. Ulrich Rohde on EMI/RFI receiver design requirements
- optical FM receiver
- time domain reflectometer
- modern communication receiver design
- time and frequency standards
- weekend project: simple shortwave broadcast receiver

BUILD THIS COMPACT SSB RECEIVER

hr

focus on communications technology

ICOM 271A/471A

The New Generation of Base Stations

25 watts / switchable AGC / 32 full-function memories / 2-color fluorescent display / subaudible tones / CW monitor / and RIT readout make the IC-271A and IC-471A all-mode base stations the most advanced on the market.

32 Full Function Memories. Each memory holds frequency, offset, offset direction, mode, and subaudible tones. Frequency, tones and offset are selected by rotating the main tuning knob.

Subaudible Tones. Subaudible tones are selected by rotating the main tuning knob. These tones may then be stored into memory along with the frequency, offering ease of operation.

Dual VFO's. ICOM's dual VFO system is now even more versatile with the ability to transfer from memory to VFO. This allows frequencies from the tunable memories to transfer directly into another memory without moving a VFO to the new frequency first.

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Scanning. Scanning of memories, programmable band scan, and mode scanning are available and easy to use.

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✓ 157

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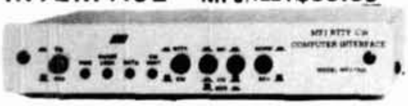

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Tells whether to shorten or lengthen antenna for minimum SWR. Measure resonant frequency, radiation resistance and reactance.
New Features: individually calibrated resistance scale, expanded capacitance range (±150 pf). Built-in range extender for measurements beyond *scale readings. 1-100 MHz. Comprehensive* manual. Use 9 V battery. 2x4x4 in.

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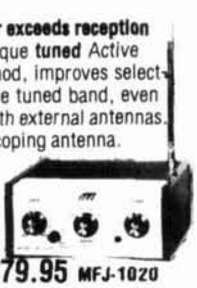

$79.95 MFJ-1020

POLICE/FIRE/WEATHER 2 M HANDHELD CONVERTER

Turn your synthesized scanning 2 meter handheld into a hot Police/Fire/Weather band scanner! $39.95 MFJ-313

144-148 MHz handhelds receive Police/Fire on 154-158 MHz with direct frequency readout. Hear NOAA maritime coastal plus more on 160-164 MHz. Converter mounts between handheld and rubber ducky. Feedthru allows simultaneous scanning of both 2 meters and Police/Fire bands. No *missed calls. Crystal controlled.* Bypass/Off switch allows transmitting (up to 5 watts). Use AAA battery. 2¼x1½x1½ in. BNC connectors.

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VHF SWR/WATTMETER

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Low cost VHF SWR/ Wattmeter! Read SWR (14 to 170 MHz) and forward/ reflected power at 2 meters. Has 30 and 300 watts scales. Also read relative *field strength. 4x2x3 in.*

1 KW DUMMY LOAD

MFJ-250 $34.95

Tune up fast, extend life of finals, reduce QRM! Rated 1KW CW or 2KW PEP for 10 minutes. Half rating for 20 minutes, continuous at 200 W CW, 400 W PEP. VSWR under 1.2 to 30 MHz, 1.5 to 300 MHz. *Oil contains no PCB.* 50 ohm non-inductive resistor. Safety vent. Carrying handle. 7½x6¾ in.

24/12 HOUR CLOCK/ ID TIMER

MFJ-103 **$34.95**

Switch to 24 hour GMT or 12 hour format! Battery backup maintains time during power outage. ID timer alerts every 9 minutes after reset. Switchable *seconds readout. Elapsed timer. Just start clock* from zero and note time of event up to 24 hours. Bright blue .6" digits. Alarm with snooze function. Synchronizable with WWV. Lock function prevents mis-setting. Power out, alarm on indicators. Black. 5x2x3 in. 110 VAC, 60 Hz.

DUAL TUNABLE SSB/CW FILTER

MFJ-752B $89.95

Dual filters give unmatched performance! The primary filter lets you peak, notch, low pass or high pass with extra steep skirts. Auxiliary filter gives 70 db notch, 40 Hz peak. Both filters tune from 300 to 3000 Hz with variable bandwidth from 40 Hz to nearly flat. Constant output as bandwidth is varied; linear frequency control. Switchable noise limiter for impulse noise. Simulated stereo sound for CW lets ears and mind reject QRM. Inputs for 2 rigs. Plugs into phone jack. Two watts for speaker. Off bypasses filter. 9-18 VDC or 110 VAC with *optional adapter, MFJ-1312, $9.95.*

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TS-930S

"DX-traordinary"... superior dynamic range, auto. antenna tuner, QSK, dual NB, 2 VFO's, general coverage receiver.

A superlative, high-performance, all solid-state HF transceiver, that covers all Amateur HF bands, and incorporates a 150 kHz to 30 MHz general coverage receiver having an excellent dynamic range.

TS-930S FEATURES:

- 160-10 Meters, with 150 kHz-30 MHz general coverage receiver. Covers all Amateur frequencies, plus WARC, on SSB, CW, FSK, and AM. UP conversion digital PLL circuit.
- Excellent receiver dynamic range. Typical two-tone dynamic range, 100 dB (20 meters, 50-kHz spacing, 500 Hz CW bandwidth).
- All solid-state 28 volt operated final amplifier. Lowest IM distortion. Power input 250 W on SSB/CW/FSK, 80 W on AM. SWR/ Power meter.
- Available with AT-930 automatic antenna tuner built-in, or as an option. Covers 80-10 meters, including WARC bands.
- CW full break-in. CMOS logic IC, plus reed relay. Switchable to semi break-in.
- Dual digital VFO's, 10-Hz steps, includes band information.
- Eight memory channels. Stores frequency and band data. Internal battery memory back-up, est. 1 yr. life. (Battery not Kenwood supplied.)
- Dual mode noise blanker. NB-1, with threshold control, for "pulse" noise. NB-2 for "woodpecker."
- SSB IF slope tuning, allows independent adjustment of the low and/or high frequency slopes of the IF passband.
- CW VBT and pitch control. VBT tunes out interfering signals. CW pitch control shifts IF pass-band and beat frequency. "Narrow-Wide" filter switch.
- Tuneable, peak-type audio filter for CW.
- AC power supply built-in.
- Fluorescent tube digital display (100 Hz resolution, modifiable to 10 Hz) with digitalized sub-scale, in 20-kHz steps.
- RF speech processor.
- One year limited warranty.
- SSB monitor circuit.

Optional Accessories:

- AT-930 Auto. antenna tuner.
- SP-930 External speaker with selectable audio filters.
- YG-455C-1 (500 Hz) or YG-455CN-1 (250 Hz) plug-in CW filters for 455 kHz IF.
- YK-88C-1 (500 Hz) CW plug-in filter for 8.83 MHz IF.
- YK-88A-1 (6 kHz) AM plug-in filter for 8.83 MHz IF.
- SO-1 commercial grade TCXO.
- MC-42S UP/DOWN hand mic.
- MC-60A deluxe desk mic.
- MC-80 desk top UP/DOWN mic.
- MC-85 multi-function desk mic.

TS-430S

"Digital DX-terity"... General coverage, Superior dynamic range, 2 VFO's, 8 memories, Scan, Notch, COMPACT!

Combines compact styling with state-of-the-art circuit design and performance.

TS-430S FEATURES:

- 160-10 meters, with 150 kHz-30 MHz general coverage receiver. Covers all Amateur frequencies, plus WARC. UP-conversion digital PLL circuit.
- USB, LSB, CW, AM, and FM (optional) all mode.
- Compact lightweight design. Only 10-5/8 (270) W x 3-3/4 (96) H x 10-7/8 (275) D, inches (mm); only 14.3 lbs. (6.5 kg.).
- Superior receiver dynamic range with Dyna-Mix high sensitivity direct mixing system.
- 10-Hz step dual digital VFO's. Operate independently, include band and mode information. Dial torque adjustable. Step switch for 10-Hz or 100-Hz steps. A=B switch shifts "B" VFO to "A" VFO frequency and mode, or vice versa. VFO LOCK switch. RIT for VFO or memory. UP/DOWN manual scan with optional UP/DOWN microphone.
- Eight memories store frequency, mode, and band data. 8th memory stores RX/TX frequencies independently.
- Lithium battery memory back-up. (Est. 5 yr. life.)
- Memory Scan.
- Programmable automatic band scan width.
- IF shift circuit for minimum QRM.
- Tuneable notch filter, built-in.
- Narrow-wide filter selection on SSB and CW (filter optional).
- Speech processor, built-in.
- All solid state. Input rated 250 W PEP on SSB, 200 W DC on CW, 120 W on FM (optional), 60 W on AM. Operates on 12 VDC or on 120 VAC, or 220/240 VAC with optional PS-430 AC power supply.
- Fluorescent tube digital display indicates frequency to 100 Hz (10 Hz modifiable).
- All-mode squelch circuit, built-in.
- Built-in noise blanker.
- RF attenuator (20 dB).
- VOX circuit, plus semi break-in with side-tone.

Optional accessories:

- PS-430, PS-30 or KPS-21 AC power supplies.
- SP-430 external speaker.
- MB-430 mobile mounting bracket.
- AT-250 automatic antenna tuner, 160-10 m, incl. WARC.
- AT-130 compact antenna tuner, 80-10 m, incl. WARC.
- FM-430 FM unit.
- YK-88C (500 Hz) or YK-88CN (270 Hz) CW filters.
- YK-88SN (1.8 kHz) SSB filter.
- YK-88A (6 kHz) AM filter.
- MC-42S UP/DOWN hand mic.
- MC-55 (8P) mobile mic.
- MC-60A deluxe desk mic.
- MC-80 desk top UP/DOWN mic.
- MC-85 multi-function desk mic.

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TRIO-KENWOOD COMMUNICATIONS

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contents

REFLECTIONS

Thank You

Thank you for responding to the reader survey published in the September issue. I want you to know how very valuable your comments are to me. You are providing to us at *ham radio* an understanding of your needs, likes, and dislikes.

As we go to press, we have not yet "closed the books" on this survey; survey forms and letters continue to arrive daily in considerable quantity. In reviewing the forms that have been returned, I already see important trends which together with the survey compilation, will be detailed in a future issue. In general, readers are telling us to continue to provide a technically superior magazine and not to succumb to the temptation of trying to offer "something for everybody." This was clearly brought out in one of the many letters that accompanied the survey forms:

I cannot resist writing to tell you how grateful I am that you have gone back to the original aims of ham radio. *I had originally subscribed to the magazine because of the technical content and I am so pleased to see a return to the more technically oriented articles. The fact is that there are already three other magazines devoted to operating news and 'beginner' type construction articles — we don't need one more. I am sure that your general reader response will confirm that there is a need for material that has some body to it and which can be used for future reference....*

Taking all of the responses (so far) into account, I promise to follow a policy I adopted several years ago while editor of another magazine (*rf design*): *always try to inform, not impress.* Now, I have to admit that some of our past articles did not exactly meet that criterion, and I plead guilty with explanation. In the publishing industry it's not unusual for an editor to be working with the content of four or more issues in various stages of development at the same time. But by pushing the schedule ahead with excellent material received from our readers, I'll be able to improve the quality of *ham radio*. I've just finished editing some exciting new material to be included in the early 1984 issues.

While on the subject of articles, I'd like to ask all prospective authors to remember that the most important reason for writing and publishing a manuscript is to communicate — be it an idea or a complete system down to the last diode. Sometimes it helps to ask a friend to read your manuscript with a critical eye. If there's something he or she doesn't understand, chances are that others will have the same problem. Before you start, I firmly believe that it's always a good policy to make a single-sided, single-page outline on the proposed subject. Don't write another word until you really like the outline. It's much easier to modify an outline than to cut and paste or start a manuscript all over after you've gotten into it. By all means, once you like the outline, stick with it, taking one section or thought at a time — in order. This makes the job considerably easier.

The kitchen sink. Yes, I've found a few of them in some of the manuscripts. There is a tendency among some of us (and I am not excluding myself) to try to squeeze everything you possibly can into a five-printed-page article. Please believe me, you can save some material for another article or a book or even an encyclopedia. We at *ham radio* can help out in many ways. Send for our well-written six page *Author's Guide.* It will provide you with many helpful hints for producing your manuscript (hint number 1: type your manuscript, double-spaced). Drop me a line with your outline and I will try to respond ASAP with suggestions.

Just a final word on artwork. Penciled sketches are fine. We normally redraw all schematics, block diagrams, etc., unless you happen to follow our drafting style and produce camera-ready artwork (some authors do). Photographs should be black and white, 35 mm or larger. Use the best photographic techniques you can master (clean backgrounds, good lighting, logical presentation) and don't hesitate to seek professional assistance. Remember, if accepted, your work will adorn the pages of a widely, worldly circulated magazine.

There we have it. I've thrown the kitchen sink into this editorial. Let me just say thanks again for your support. Please keep reading the magazine; we'll keep trying to improve and expand it to meet your needs.

Rich Rosen, K2RR
editor-in-chief

Morse Keyers & Trainers by AEA

AEA produces the finest Morse keyers and trainers in the world. All AEA keyers operate with any standard keyer paddle and offer selectable monitor tone, selectable dot and dash ratios, full weighting and selectable dot and/or dash memory. In addition, all our keyers offer full, semi-automatic or straight key modes. The keyers and trainers are keypad controlled which significantly reduces the complexity of operation for all the features offered. Each keyer has separate + and - keyed outputs for keying any modern transmitter. All keyers and trainers operate from 12 VDC (or 117 VAC with optional model AC-1 wall adaptor) which makes them ideal for portable operation. AEA microcomputer-based products are all subjected to a full burn-in and test prior to shipment, as well as being designed for maximum R.F. immunity.

NEW BT-1

The **BT-1 Basic Trainer** is a hand-held computerized unit which teaches the code one character at a time at 18 or 20 words per minute. The BT-1 contains a self-paced training program that allows serious students the possibility of learning Morse to 20 wpm in as little as one month! Each character represents a separate practice session in which the character is first introduced by itself, and then presented 50% of the time along with all previously learned characters. There are no tapes to memorize, wear out, or break. No programming skills are necessary; the BT-1 is very easy to use. The tone oscillator can also be keyed for sending practice. An earphone jack is provided for private listening. The BT-1 will go as high as 99 WPM in 1 WPM increments. A battery operated version, the BT-1P, is available with wall charger and internal NICAD batteries.

NEW KT-3

The **KT-3 Keyer-Trainer** unit uses the teaching program used in the BT-1 trainer. In addition, the KT-3 features a full function Morse automatic keyer for keying any modern transceiver, or for sending practice. Speed range is 18-99 wpm for transmitting and 1-99 wpm for training.

KT-2 Keyer Trainer

The **KT-2 Keyer-Trainer** is a computerized keyer with all the features shown above, plus a Morse proficiency trainer. It is designed to increase your existing code as quickly as possible. The unit can be set for beginning practice speed, ending practice speed, and duration of practice. The microcomputer does all the rest by gradually increasing the speed during the practice time selected. You can even select between fast code (Farnsworth) or slow code methods. The characters are sent in 5 letter groups, or random word lengths. Two levels of difficulty can be selected; common Morse characters or all English Morse characters. A 24,000 character answer book is provided for the 10 separate starting positions. There is also random practice mode for which no answers are available.

CK-2 Contester™

The **CK-2 Contester™ Keyer** is the lowest cost automatic keyer available featuring an automatic serial number generator for contesting. The CK-2 keyer features a large 500 character message memory that can be soft-partitioned into as many as 10 sections. An exclusive AEA edit mode makes it possible to correct mistakes made while entering messages or to insert words into previously established messages. Two different speeds can be set for fast recall in addition to a stepped variable speed control. The CK-2 features an automatic message repeat mode with variable delay-before-repeat for automatic CQ transmissions or TVI testing.

MM-2 MorseMatic™

The **MM-2 Morsematic Keyer** represents the most sophisticated paddle keyer ever designed and features two powerful microcomputers. The Morsematic incorporates virtually all the features (except the preset and stepped variable speeds) of both the CK-2 and KT-2 shown above. In addition, the MM-2 offers an exclusive automatic beacon mode which is invaluable for meteor scatter, moonbounce scheduling, or beacon operation.

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presstop de W9JUV

THE VOLUNTEER EXAM PROGRAM FOR AMATEURS WAS ESTABLISHED officially September 22, when the FCC acted on PR Docket 83-27. The biggest surprise was the Commissioners' decision to use 13 regional Volunteer Examiner Coordinators instead of one national VEC, with a VEC in each U.S. call area plus one each for Alaska, the Pacific islands and the Caribbean. The decision to go with regional VECs is being widely interpreted as a direct slap at the ARRL, whose last-minute introduction of a demand that VECs be compensated for their efforts after assuring the FCC they could handle it gratis caused much consternation at the Commission.

Exam Administration Fees Are Specifically Prohibited by the Report and Order, in a section reportedly written by the FCC's legal staff and based on the enabling legislation. The League is lobbying on Capitol Hill for a bill that would legalize fee collection, but Senator Goldwater has come out strongly against such fees and without his support it's unlikely that it can receive much support in either house.

Three-Person Examining Teams Are Still Required for the Technician and higher class exams. All but Technician will require that all three team members be Extra Class. Specifically, 13 as well as 20 wpm code tests plus Elements 4(A) (Advanced and Extra) and 4(B) (Extra) must be administered by a team consisting of three Extra Class licensees.

Negotiations With Groups Wishing To Become Regional VECs will be opened by the FCC on December 1. Since some areas will respond more quickly and have an acceptable examiner organization in place more rapidly than others, it appears almost certain that the program will be up and running in some parts of the country long before it will be in others.

LAUNCH OF THE STS-9 SPACECRAFT IS STILL SET FOR OCTOBER 28, with W5LFL due to begin his 2-meter operation from space a few days later as outlined in September Presstop. Late-breaking information will be made available via recorded messages on various special phone lines, including ARRL--(203) 666-0688, Westlink--(213) 465-5550, and the Johnson Spaceflight Center--(713) 483-2477. In addition, Electra (Bearcat) is making its toll-free line (800) SCA-NNER available as a mission progress hotline to Amateurs as well as other VHF listeners for the duration of the STS-9 mission.

The Most Up-To-Date STS-9 Information Will Probably Be From W5RRR, the Space Center Radio Club station. It will be on the air before and after working hours plus weekends, using 28600, 21375, 14280, and 3845 kHz, all +/- QRM. Operation on OSCAR 10 is possible.

Retransmission Of Space Shuttle Transmissions By Amateurs has been authorized by the FCC in response to several petitioners. However, Amateurs wishing to perform this service must first get permission from NASA.

FCC ACTION ON THE "NO-CODE" AMATEUR LICENSE is unlikely until early 1984, according to Washington sources. There is also considerable speculation that the rebuff the League took on the Amateur licensing program is a harbinger of a pro No-Code decision when the Commissioners do finally consider that thorny issue.

The Widely Heralded Air Force Letter Opposing No-Code was apparently only a statement by some Air Force MARS people that their MARS appointments (which do include HF band operations) would require CW ability, and was not a statement of official Air Force policy. In addition, no basis has been found for a recently circulated rumor that the CIA had told the FCC that a No-Code license "would not be in the national interest."

2-METER USE BY FISHING BOATS IN PUGET SOUND is concerning Amateurs in the Pacific Northwest. Reminiscent of similar episodes during the height of the CB boom, when some truckers discovered readily available 2-meter rigs offered them a refuge from the bedlam of channel 19, the fishermen are using 2 meters for "private communications channels" to discuss matters inappropriate for the regular marine band or which they want kept secret from others not "in the know." It appears the operation was set up by someone knowledgeable, since the fishermen have pretty well avoided use of active Amateur frequencies.

The FCC Has Been Informed And Is Actively Monitoring the illegal operations. At least a dozen of the pirate stations seem to be active.

When The FCC's Program To Involve Amateurs In Enforcement will get under way seems up in the air at the moment. Despite earlier hopes it would be in operation by this fall, there has apparently been little progress on it in the last few months.

"WB23XYZ" AND "AB84C" WILL BE LEGITIMATE CALLSIGNS for California Amateurs during July and August, 1984. California Amateurs with "6" in their callsigns have been authorized by the FCC to use either "23" (for 23rd Olympiad) or "84" (for 1984) instead of "6" during the period of the Olympic games in California next year.

Amateur Involvement In The Olympics Is Progressing Well, with plans now firm to have Amateur HF stations operating from all three Olympic villages. Tentative agreements are already well along with a number of countries to waive their restrictions on third-party traffic, to enable their Olympic athletes to keep in touch with home via Amateur Radio.

PIZZA ORDERING BY AMATEUR RADIO WAS BRIEFLY LEGALIZED by a recent, short lived FCC policy relaxation. The change, in effect for only a few weeks in September, was another effort to resolve on-going conflicts over what constitutes prohibited communications. It has since been rescinded and the Part 97.114(c) restrictions remain in effect.

comments

cable choice

Dear HR:

The article, "Inexpensive Hardline Connectors," by WB4GCS (May, 1983) was read with considerable interest. Mr. Sanford's connector may work very well in his particular application, but there are many other considerations and problem areas to be evaluated. I will try to outline some of them.

Do not assume all cables are alike. Using 1-inch cable as a reference, there are at least three major varieties with center conductor diameters ranging from 0.19 to 0.24 inch. If scaling to 3/4-inch cable, there are at least five major varieties. Choose the piece that will mate with the center conductor carefully.

The center conductor should be securely captured. I recommend that the inner portion of the barb fitting be threaded. This is similar to what is used on commercial connectors, and will assist in retarding conductor migration.

The center conductor should thread onto the connector by at least 1/2 inch, particularly if any power is contemplated. If one lives in an area of temperature extremes, the use of cable with a solid copper center conductor should be avoided. The different coefficients of expansion between the aluminum sheath and the copper conductor can lead to all kinds of failures. The copper-covered aluminum center conductor was developed to alleviate this. This is a prime reason the commercial connector manufacturers use materials that exhibit expansion coefficients similar to the cable.

Mr. Sanford's paragraph on using an anti-corrosion compound cannot be stressed too strongly. Failure to do so can cause the cable to self-destruct in less than a year in certain environments. (Contact an electrician or electrical supply house for the brand names available in your area.)

Results must be taken with a grain of salt. If a certain homebrew connector works for your particular project, by all means use it. Up to approximately 150 MHz, just about anything will work reasonably well and give a return loss of 14 dB (VSWR 1.5) or better. Commercial connectors readily achieve return losses of better than 25 dB and virtually immeasurable insertion loss. The 1-inch cables that I am familiar with have a loss per 100 feet of from 0.4 to 0.5 dB at 150 MHz and 0.75 to 0.95 dB at 450 MHz. This can go a long way toward putting power where it belongs.

One final caution about the cable. Use only fresh cable, the source of which you are certain. If possible, find out the upper frequency limit of the CATV system in which it is used. Most new systems are operating to 400 MHz or higher and are using cable with excellent characteristics well past 500 MHz. There are, however, many varieties of older design cable that are being passed off to hams by unscrupulous individuals at fleamarkets. Many of those cables deliver horrible performance above about 200 MHz. When going up through the UHF bands, verifiable results require sophisticated test equipment and thorough attention to detail. Even more insidious is the type of cable that does not have the foam dielectric bonded to the sheath and inner conductor. Any water ingress will then migrate completely throughout the cable. This will quickly turn a kW station into QRP level ERP even at 20 meters! For high power, at least 3/4-inch cable should be used to reduce the possibility of high-voltage RF flashover.

I am personally all for the use of 75-ohm hardline and am designing my station for its use. It is produced by the millions of feet, is reliable and reasonably priced even when new. Hams have been getting ripped off for years by sticking to 50-ohm cable. If you don't have the time or mechanical dexterity to produce a connector, contact your local CATV engineer. You will probably be pleasantly surprised to find what is available for the asking.

Carl Huether, KM1H
Pelham, New Hampshire

freebies

Response to our recent offers of supplementary materials has been tremendous — our thanks to all who wrote. Copies of the World Press List, the NASA Tech Brief, and the RTTY-Atari™ program are still available; send a large SASE (with 20¢ in stamps for the press list, 37¢ for the tech brief, and 54¢ for the program) for copies of one or all. A sampling of recent letters follows. — Editor

Dear HR:

I enjoyed the article "RTTY and the Atari™ Computer" by Dave King, K5VUV. Hopefully I can figure out a way to interface into the computer serial port on my Atari 400, rather than use the Atari interface module, which costs more than the computer!

Chuck Hastings, KB3QU
Annapolis, Maryland

Dear HR:

I really enjoyed "RTTY and the Atari™ Computer." Although my recently-purchased computer is a TRS-80C,™ I believe I can use the interface. Please send the program listing.

P.B. Johnson, VE7DHM
Sooke, British Columbia

Dear HR:

Please send me a copy of the NASA tech brief.

Thank you for a fine publication. I am particularly interested in Forrest Gehrke's series on phased verticals, having used and worked with them with moderate success for some time. This is the first definitive article on the subject to appear in the Amateur literature.

Arthur J. Conebeer, W6DRL
Laguna Beach, California

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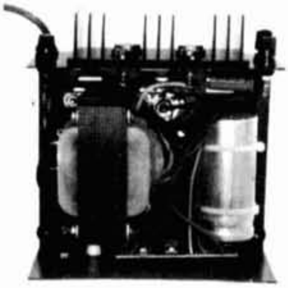

INSIDE VIEW — RS-12A

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RS-4A	3	4	3¾ x 6½ x 9	5
RS-7A	5	7	3¾ x 6½ x 9	9
RS-7B	5	7	4 × 7½ × 10¾	10
RS-10A	7.5	10	4 x 7½ x 10¾	11
RS-12A	9	12	4½ x 8 x 9	13
RS-20A	16	20	5 x 9 x 10½	18
RS-35A	25	35	5 x 11 x 11	27
RS-50A	37	50	6 x 13¾ x 11	46

RS-M SERIES

MODEL RS-35M

- Switchable volt and Amp meter

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H x W x D	Shipping Wt (lbs)
RS-12M	9	12	4½ x 8 x 9	13
RS-20M	16	20	5 x 9 x 10½	18
RS-35M	25	35	5 x 11 x 11	27
RS-50M	37	50	6 x 13¾ x 11	46

VS-M SERIES

MODEL VS-20M

- Seperate Volt and Amp Meters
- Output Voltage adjustable from 2-15 volts
- Current limit adjustable from 1.5 amps to Full Load

MODEL	Continuous Duty (Amps) @13.8VDC	@10VDC	@5VDC	ICS* (Amps) @13.8V	Size (IN) H x W x D	Shipping Wt (lbs)
VS-20M	16	9	4	20	5 x 9 x 10½	20
VS-35M	25	15	7	35	5 x 11 x 11	29
VS-50M	37	22	10	50	6 x 13¾ x 11	46

RS-S SERIES

MODEL RS-12S

- Built in speaker

MODEL	Continous Duty (Amps)	ICS* Amps	Size (IN) H x W x D	Shipping Wt (lbs)
RS-7S	5	7	4 x 7½ x 10¾	10
RS-10S	7.5	10	4 x 7½ x 10¾	12
RS-10L(For LTR)	7.5	10	4 × 9 × 13	13
RS-12S	9	12	4½ x 8 x 9	13
RS-20S	16	20	5 x 9 x 10½	18

More Details? CHECK—OFF Page 118

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compact SSB receiver

Bigger isn't always better. Here's a small, easy-to-build unit that performs much like a full-sized receiver

This simple, compact receiver has a lot of grown-up features: a built-in speaker, automatic gain control, good sensitivity, wide dynamic range, and the potential for excellent selectivity. Add a small voltage-probe antenna and you can cast off the *feedline and take the receiver with you.*

Most of the necessary components are readily available and inexpensive; modular design allows you to chose your own packaging. All board layouts, photos, and diagrams are provided, and any builder with modest experience should find construction no problem at all.

circuit description

In many respects, this circuit is similar to others described in recent Amateur literature.[1,2] However, it has some practical features which offer a great deal of flexibility.

Fig. 1 shows the main receiver board. A switchable 20-dB attenuator provides RF gain control to prevent receiver overload. Q1 is a grounded-gate RF amplifier which provides 10 dB of gain ahead of mixer Q2. Q2 is a single-ended MOSFET mixer. This stage is coupled to bandpass filter FL-1 by means of T1, a broadband matching transformer. Either a mechanical or crystal filter can be employed by choosing the appropriate turns-ratio. The filter's output is terminated by resistor R_F. Since the filter is not mounted on the circuit board, physical size is not a factor in filter selection.

Q3 is the receiver's gain IF stage. Gain is controlled by a simple audio-derived AGC system. Diodes replace Q3's source resistor in order to bias gate-2 negative with respect to gate-1. This extends the AGC attenuation range.[3] IF transformer T2 is capacitively coupled to product detector Q4. The transformer's secondary is not used. A toroidal LC circuit can replace this transformer for non-standard IF frequencies. IF frequencies from 455 kHz to 9 MHz and beyond can be employed without board modification.

Product detector Q4 is an active circuit which provides audio pre-amplification ahead of the gain control. U1, the audio amplifier, is an LM-386. This IC provides a voltage gain of 200 and delivers 400 mW of power into an 8-ohm load. A 10-ohm series resistor in the output line protects miniature 200 mW speakers from damage.

The AGC system is a simple audio-derived limiter.[4] A diode samples the output of U1 and sends a negative voltage to dc amplifier Q5/Q6. The output of Q6 is set for a resting bias of +4 volts under no-signal conditions. When a strong signal appears, this voltage drops to as low as +0.5 volts, reducing Q3's gain. Resistor R_D sets the AGC sampling level. The value of R_D is selected for best AGC action. Capacitor C_A is optional, but recommended for SSB operation since it slows release time.

The VFO shown in **fig. 2** is a near-copy of a W7ZOI/W5IRK circuit.[5] This design provides excellent performance. The Hartley JFET oscillator drives a single MOSFET buffer/amplifier. VFO-output is coupled to the mixer through a broadband trans-

By Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825

The completed receiver can be packaged to suit the builder. This 20-meter version features a signal-strength meter and a built-in voltage probe antenna system. The illuminated frequency pointer is an LED that has been filed to shape and polished.

former. Builders desiring a thorough treatment of the design along with temperature compensation information should refer to current editions of the *ARRL Handbook*.

Figs. 3A, B, and **C** show BFO circuits. These provide plenty of output at the high input impedance presented by Q4. The 455 kHz version employs a ceramic resonator instead of a crystal. These devices are considerably cheaper, and much easier to "rubber." Frequency adjustment is accomplished with a small 60 pF trimmer. The high-frequency version uses standard crystals, and oscillates easily in the 3-12 MHz range.

Fig. 4 shows an optional tuned voltage probe antenna circuit. The telescoping rod antenna is coupled directly to the Hi-Z end of L1. A dual-gate MOSFET provides pre-amplification and impedance matching for the rod. Pre-amp output is transformed to 50 ohms through a broadband transformer. The longer the rod antenna, the more broadband the response. On 20 meters, a 2-foot (60-cm) rod allows coverage of the entire phone band. On 75, a 4-foot (120-cm) rod covers around 50 kHz. The antenna and pre-amp can be mounted in a receiver case, or remoted from the exterior of a structure or vehicle.

Finally, **fig. 5** shows a simple regulator and pilot

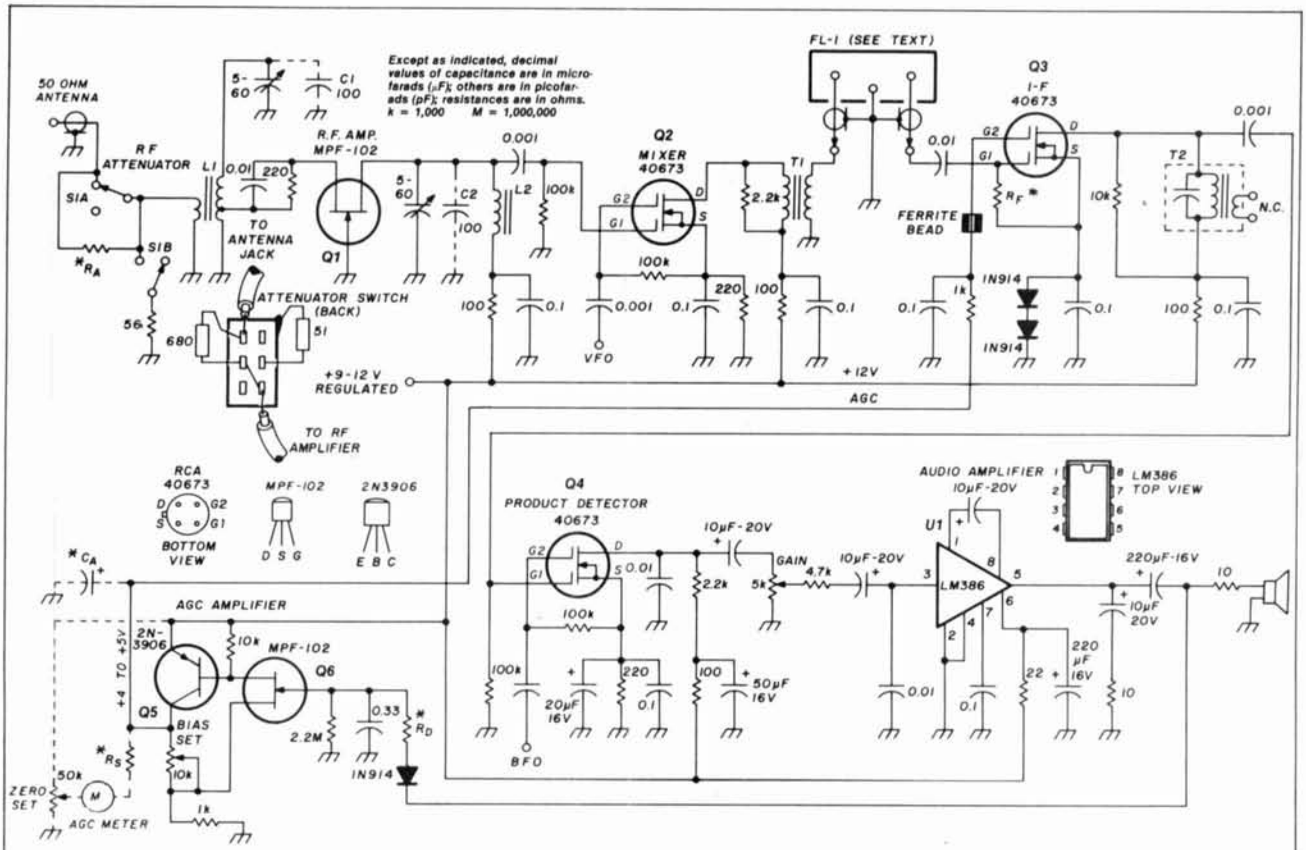

fig.1A. Main receiver board schematic.

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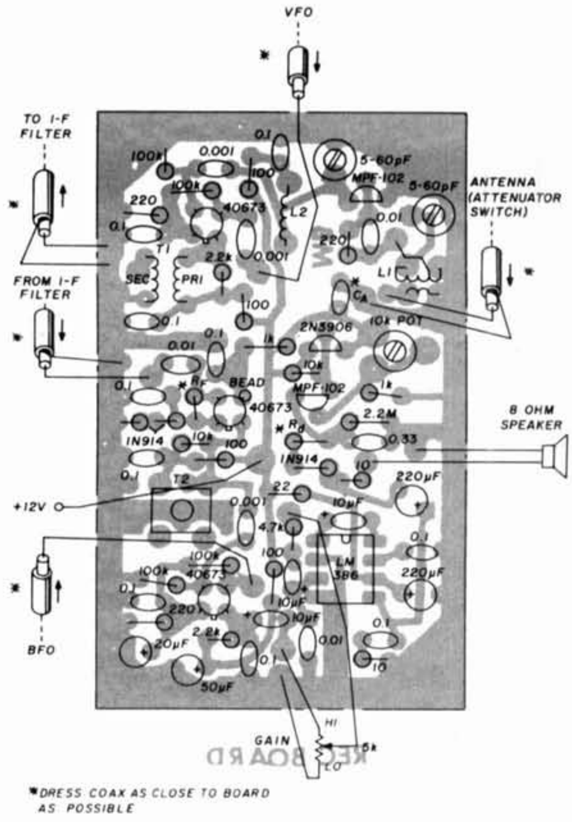


80-meter operation	
C1,C2	100 pF
L1	2 feet of No. 36 on a T37-2 core: tap 1/3 up from grounded end, add 5-turn link for antenna on ground end
L2	same as L1 except omit tap and link
20-meter operation	
C1,C2	not used
L1	28 turns of No. 28 on T37-2 core: tap at 8 turns, add 2-turn link for antenna on grounded end
L2	same as L1 except omit tap and link
455-kHz Mechanical filter i-f plan	
FL1	455-kHz mechanical filter. Collins F455FD series, or Kokusai MF-455-ZL-21H (MHZ Electronics). Install recommended resonator capacitors at the filter
RF	2.2K for most filters
T1	1:1 turns ratio broadband transformer: lightly twist together two 1-1/2-foot lengths of No. 36, and wind on a FT37-43 core
T2	J.W. Miller No. 2067, or virtually any 455 kHz miniature transformer from the junk-box (secondary not used)
9-MHz crystal filter i-f plan	
FL1	KVG XF-9B, Atlas 9.0 USB/CW (MHZ Electronics), McCoy, etc. Provide resistive termination per manufacturer's instructions. Terminate input at filter, terminate output by means of resistor "rf" on gate No. 1 of the i-f amplifier stage
RF	same value as filter termination resistor, usually between 300 and 820 ohms
T1	2:1 turns ratio broadband transformer: primary, 15 turns No. 28 on FT37-43 core; secondary, 8 turns No. 28
T2	any miniature 10.7 MHz. i-f transformer (secondary not used). Will need additional 15-22 pF across primary to resonate at 9 MHz. Use pads provided on underside of the board
other variable component values	
Ca	Sets AGC speed. Not needed for fast action, 2.2-4.7 μF for slower action
Ra	Sets level of rf attenuation; 680 ohms provides approximately 20 dB of attenuation
Rd	Sets AGC drive. May vary from 10-50K, see text for set-up information
Rs	Sets meter sensitivity. 50 μA movement requires 20K; less sensitive movements require less

fig. 1B. Parts layout for main receiver board.

LED circuit. The LM-7812 holds the operating voltage at 12 volts, protects the modules from damage, and keeps noise out of the system.

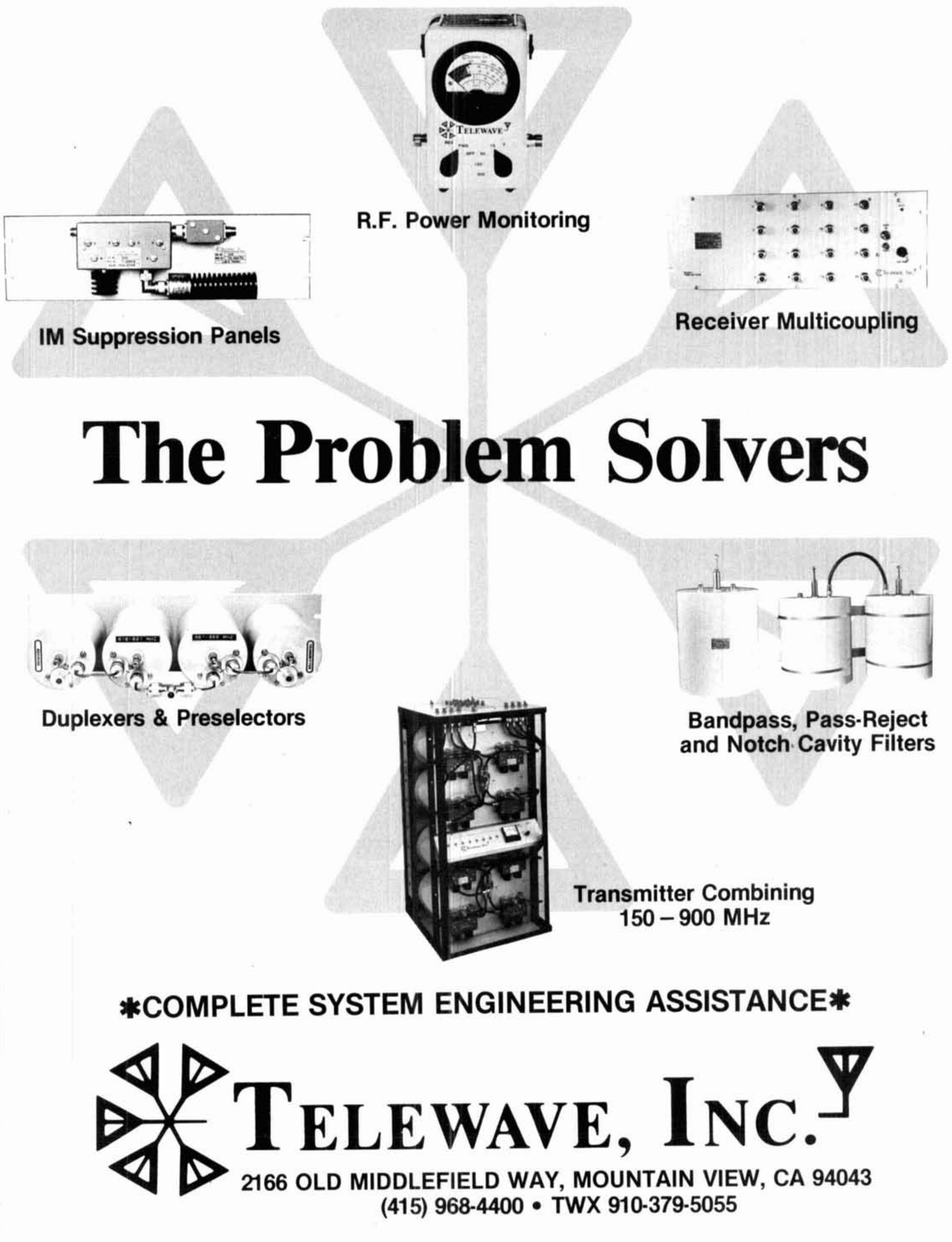
construction

The entire receiver chain, RF amplifier through audio, is contained on one main circuit board. Because oscillators require shielding, they are built separately. Optional circuits such as the regulator and antenna pre-amp are also separate, since some builders may choose to omit them.

Original artwork for my boards was prepared on transparent acetate stock using Radio Shack rub-ons. Boards were prepared with the General Cement positive developer system and pre-sensitized board. You can use this same system by applying lift-film to pull the board patterns from this article. Pre-etched boards are also available from Radiokit.[6]

Component density is fairly high on all of these boards. Miniature parts should be used wherever possible to prevent crowding. Choosing small tantalum audio coupling capacitors, low voltage bypasses, 1/4- or 1/8-watt resistors, and compact elec-

Good things can come in small packages. This 75-meter net monitor is almost dwarfed by its AC adapter.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trolytics will result in attractive and uncluttered boards. Shielded and unshielded wires should also be small in diameter and flexible. Most components are available at Radio Shack stores or by mail-order through Radiokit.[6] I reduced construction costs considerably by drawing on a parts inventory built from junked circuit boards and surplus grab-bags.

Coils are much more difficult to prune after they are installed on the circuit board. For that reason, all tuned circuits are wound, tacked together with solder, and checked for resonance with a grid-dip meter prior to actual board construction. A length of hook-up wire is used to link-couple the grid-dipper to the toroids. Each tuned circuit is then marked and set aside for later installation.

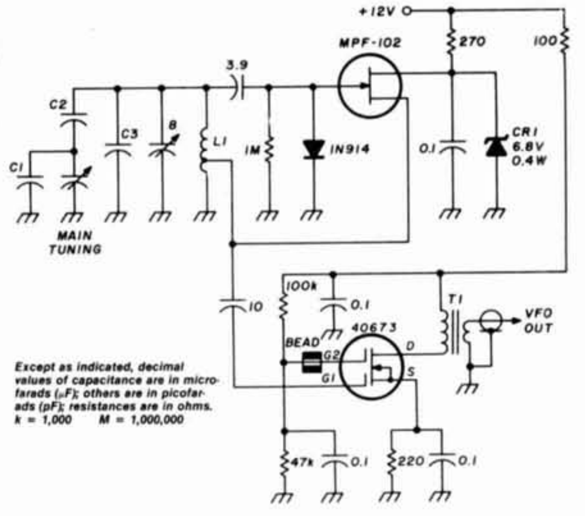
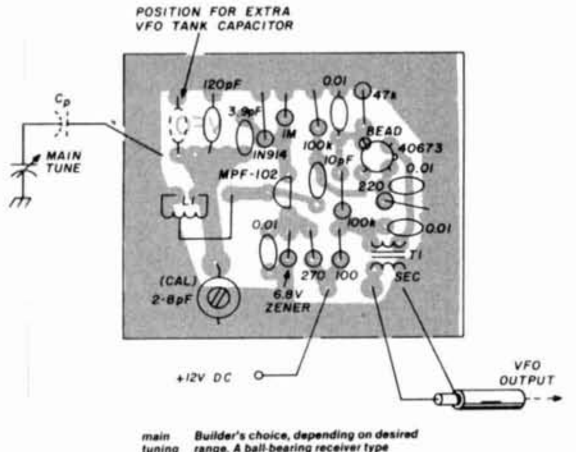


fig. 2A. VFO board schematic.



main tuning	Builder's choice, depending on desired range. A ball-bearing receiver type capacitor is preferred.
T1	4:1 broadband transformer: primary, 18 turns No. 28 on FT37-43 core; secondary, 5 turns No. 28

5-5.5 MHz VFO range (80/20 meters, 9 MHz i-f)

C1-C3	A combined value of approximately 120 pF
L1	30 turns No. 28 on T50-2 core; tap 8 turns from ground end

3.045-3.545 MHz VFO range (80 meters, 455 kHz i-f)

C1-C3	A combined value of approximately 220 pF
L1	35 turns No. 28 on T50-2 core; tap 9 turns from ground end

fig. 2B. VFO board and parts layout.

Oscillators are constructed first, since they are needed to test the main board. Special attention is given to mechanical stability, especially while constructing the VFO. Cement firmly in place anything that can move or vibrate. Upon completion, check for oscillation and proper output level.

When selecting a VFO main-tuning capacitor, look for a "ball-bearing" type with a good vernier drive (either built-in or added on). Variables and vernier drives are available from several sources including Radiokit and BCD Electro.[7] Select fixed capacitors for the VFO tank with the main tuning capacitor mounted in the receiver case. This provides mechanical stability during component substitution. Values for C1, C2, and C3 are juggled until the desired tuning range and dial linearity is obtained. During this process, a frequency counter and pocket calculator are very helpful. The counter provides an accurate measure of the oscillator frequency, and the calculator adds and subtracts the IF frequency to give the actual receive frequency. If a counter is not available, a good general coverage receiver will suffice.

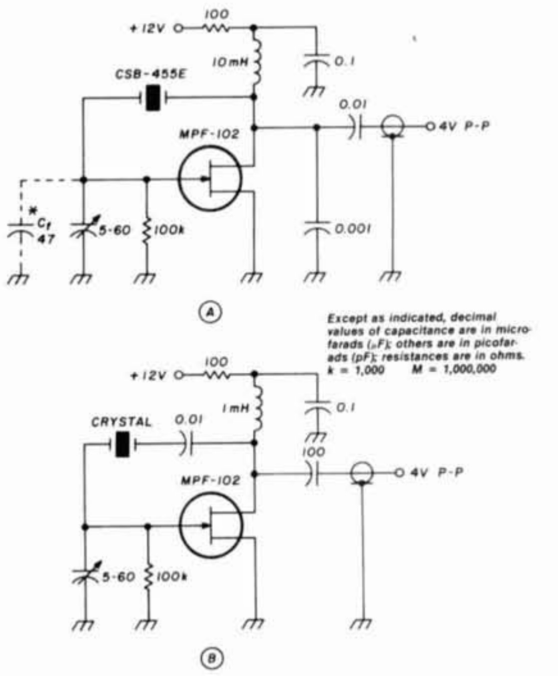
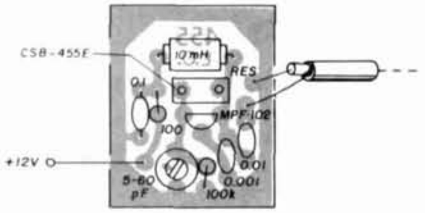


fig. 3A. 455 kHz BFO board schematics.

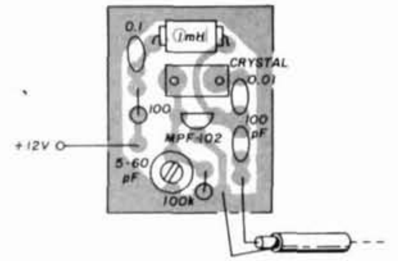
After final installation of all frequency determining components, mount the VFO board in place and mark dial calibrations on the front panel. While full shielding of the VFO is desirable, this may be difficult in compact packages like the "Micro-75" shown in the photo on page 13. In practice, some VFO leakage does not appear to degrade performance.

Construction of either BFO board is simple. After assembly and testing, a "can" or small box is constructed to shield the board. Unlike the VFO, the BFO must be fully shielded to prevent birdies and common-mode detector noise. Tin flashing, two-sided board, or aluminum all make good boxes. Two small holes are needed for the leads, plus an access hole for tuning the trimmer. Install the shielded BFO in the receiver case.



C1	47 pF, may be required to pull oscillator to 453.6 kHz. Add to foil side of the board
RFC	10 mH miniature choke, J.W. Miller 70F102A1 or equivalent
crystal	Radio Shack 455 kHz ceramic resonator (272-1303)

fig. 3B. Ceramic resonator 455 kHz BFO.

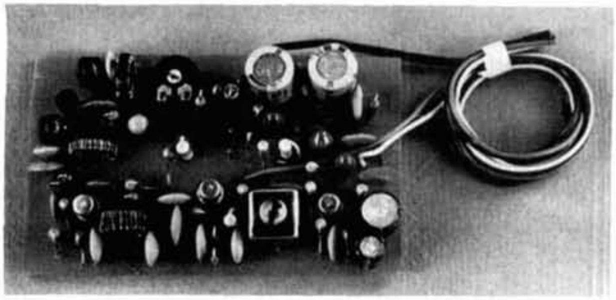


RFC	1 mH miniature choke, J.W. Miller 70F103A1 or equivalent
crystal	30 pF load capacitance, miniature holder

fig. 3C. Crystal oscillator BFO.

Since the main board is more complex than the others, it is constructed one stage at a time. Start with the audio and AGC sections, and work back to the RF amplifier. This keeps the process orderly, and allows stage-by-stage inspection. It also leaves installation of vulnerable toroid inductors until last.

A number of frequency plans are possible for this receiver. Here are some construction tips for the two versions I have built.



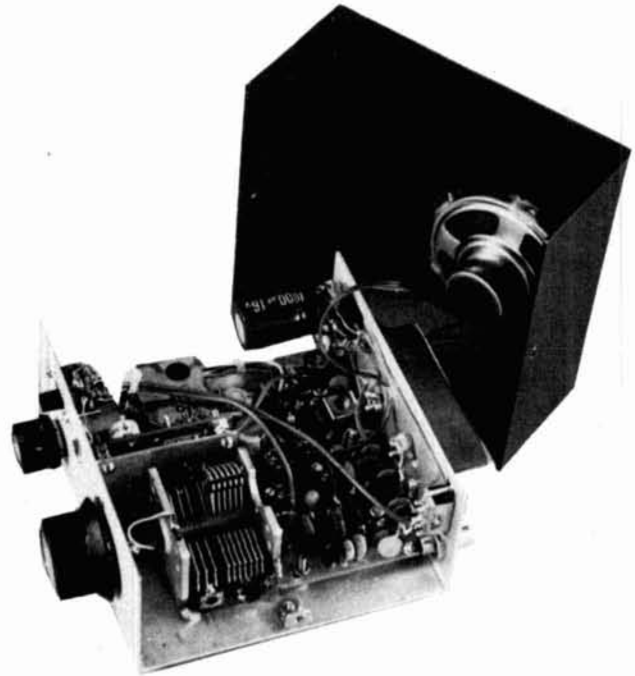
With the exception of the oscillators, all receiver circuitry is contained on the main board. Interconnecting leads for the speaker, volume control, and DC power are salvaged rainbow-wire.

The "Micro-75" receiver is based on a 455 kHz IF. Most 455 kHz designs use a mechanical filter. A 1:1 input transformer and a 2.2 K value for R_F matches most of these devices. If external resonating capacitors are required, install them at the filter. A data chart for most Collins filters appears in current editions of the *ARRL Handbook*. T2 can be any miniature 455 kHz can. Avoid using the 455 kHz IF above 40 meters, since insufficient image rejection will be available at the higher frequencies.

The 20-meter portable uses a 9 MHz IF. High-frequency IF's generally employ a crystal filter. This requires a 4:1 input transformer and a 300 to 800 ohm output termination. When termination numbers are not available, use a 560 ohm resistor for R_F. For transformer T2, use any 10.7 MHz miniature can and add 15 - 22 pF of padding to lower the resonant frequency. This capacitor can be installed beneath the board on the extra set of pads provided for this purpose.

Coil data is supplied for 80- and 20-meter operation. For operation on 40, 30, and 15 meters, a survey of other receiver articles will provide LC values close enough to get started. The T37-2 forms are quite small. Preparing the 20-meter inductors is easy enough, but concentration and a steady hand are needed to wind the 75-meter versions. I used No. 36 wire for these because it was available, but there is room on the form to substitute No. 34. All toroid coils and transformers are glued to the board after installation to prevent excess movement and lead breakage. Note that the 100 pF padding capacitors are installed for the 75-meter front-end only.

Oscillator inputs and mounting pads for resistor R_D require solder-pins on the top side of the board. (Small flea-clips or discarded resistor leads are fine for this purpose.) After all components are mounted, wires for interconnections are installed. Cut all leads



Total shielding of the VFO may not be possible in small packages like this one. This does not seem to degrade performance. The BFO should always be fully shielded. Note the bandpass filter mounted on the rear panel to save interior space.

on the long side to facilitate dressing during final assembly. Ground-loops are always a possibility when modules are interconnected. To prevent this, ground shielding at one end only.

receiver check-out and alignment

Final assembly can begin after the main board is completed. In my prototypes, the bandpass filter is

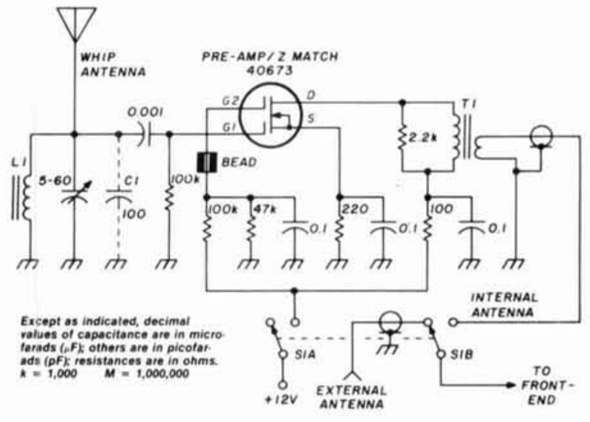
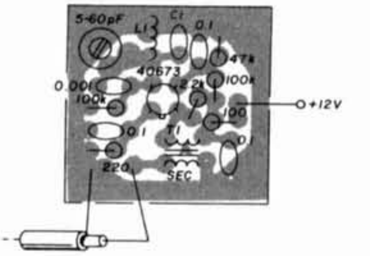


fig. 4A. Voltage probe antenna board schematic.

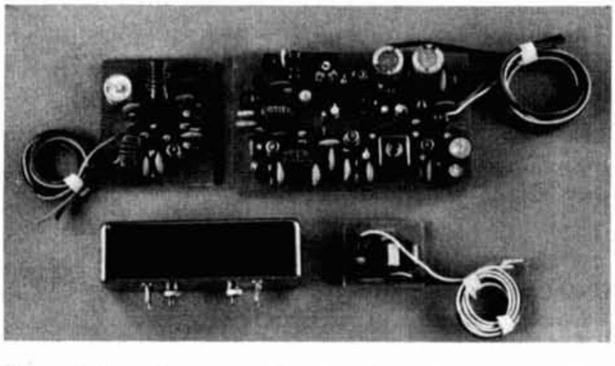


C1 100 pF on 80 meters, not used on 20 meters
L1 Same as corresponding L2 on main receiver board
T1 6:1 turns ratio broadband transformer; primary, 18 turns No. 28 on FT37-43 core; secondary, 3 turns

fig. 4B. Parts layout for voltage probe antenna.

externally mounted on the back panel of the receiver case. This saves interior space and eliminates the need to fabricate a mounting bracket. All jacks, the RF attenuator, gain control, and speaker are mounted prior to board installation. The board itself is mounted on short spacers with No. 2-56 hardware. Leads are then trimmed to length and connected to their destinations.

Initial testing and alignment is quite simple. Connect a resistance substitution box or a calibrated 50K pot to the terminals provided for resistor "Rd". A value of 10K is fine for initial testing. Advance the receiver gain control to about 3/4 volume, and apply power to all three modules. A very soft hiss from the speaker indicates that no serious shorts are present. Adjust the "bias-set" for a resting AGC voltage of + 4 volts, as measured at the top end of the potentiometer. Tune the IF through its range, looking for a slight noise peak to indicate resonance. Finally, peak the RF amplifier. If everything is working and the band is open, the receiver will come to life. RF trimmers should show two signal-peaks as they are rotated through 360 degrees. This confirms that resonance is within the trimmer range, and not off to one



The main board, two oscillator boards, and a bandpass filter are the basic modules required to build one of these receivers. Interconnecting wires are salvaged rainbow-wire and mini-audio cable.

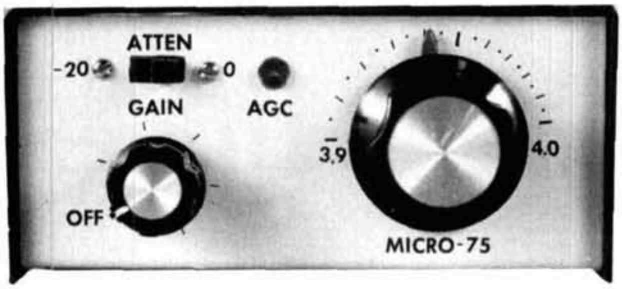
side. Stagger tune the RF stage to provide even sensitivity across the entire tuning range of the radio.

To determine the correct value for R_D, tune in an extremely strong signal and vary the resistance until AGC action is smooth. Too much AGC produces overshoot. This is a condition where the AGC overresponds, producing a "pumping" effect. Too little AGC allows the audio amplifier to go into distortion. The best value should fall somwhere between 10K and 50K. Install the nearest standard-value resistor.

This design has one quirk that might cause alarm during the testing phase. Extremely strong signals will sound fuzzy at low volume, yet miraculously clear up when the gain is increased. This is because AGC is derived from the audio output, and the AGC's ability to control the IF is pre-empted by the manual gain control at very soft listening levels. Fuzziness at low volume indicates overloading. A 20-dB RF attenuator is included in the receiver-chain to correct this condition. In practice, it becomes second nature to switch in the attenuator when the band is open and signals are strong.

options

The most important addition is the regulator circuit described earlier in **fig. 5**. This provides cheap insurance for a project well done, and cleans up dirty power sources like automotive electrical systems and inexpensive AC adapters. Since these are the sources I use most often, both of my receivers are regulated. Mount the LM-7812 on the interior of the back panel, and use the positive output lead as a tie point for all of the module power leads. If hum persists with your AC adapter, it could be that the ripple is dipping below the regulating range of the LM-7812. If this happens, install a 10-ohm resistor in series with adapter's plus-lead or get a new adapter with more output voltage.



Simplicity of design is reflected in the front panel of this 75-meter net monitor. In place of a signal-strength meter, an LED peak-indicator illuminates at full audio output to indicate AGC action.

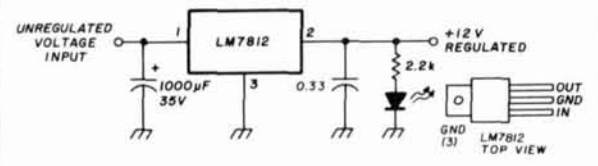


fig. 5. Regulator schematic.

The optional meter circuit shown in **fig. 1** is not a full blown S-meter, but does measure relative signal strength. Almost any sensitive movement can be adapted to this circuit with the appropriate value of R_S. Use care while experimenting, since accidently grounding the AGC line destroys the 2N3906.

The voltage probe antenna circuit is a great addition when the receiver is going to be taken along as a portable. This circuit board is mounted inside the cabinet of my 20-meter prototype and connected to a short collapsible whip that extends through the top of the case (the 75-meter receiver uses one as an external accessory). The pre-amp components are very similar to those used in the receiver front-end, and the same techniques apply for construction. A DPDT switch on the back panel applies power and brings the pre-amp on line for portable use. The antenna trimmer is accessible through the back of the cabinet, since peaking is quite critical and may require readjusting from time to time. (It's a thrill to hear VK's and ZL's rolling in on a 2-foot [60 cm] whip while sipping coffee at the kitchen table!)

conclusion

This is a very functional receiver design, easy to construct from available parts. The unusually flexible circuit allows selection of alternate frequency-plans without board modification. Many of the features one would expect to find in a full-sized communications receiver are included.

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6. Etched circuit boards, parts, and kit for the "Compact SSB Receiver" are available from Radiokit, Box 411, Greenville, New Hapmshire 03048.
7. Variable capacitors and other parts available from BCD Electro, P.O. Box 119, Richardson, Texas 75080.

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designing a modern receiver

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Most general-coverage receivers have, up till now, been designed around commercially available IF filters. The popular 9 MHz approach performs well but exhibits a variety of internally generated spurious products when used in a general coverage mode. The chart in **table 1** shows some of these products and how they impact on received frequencies. (Products produced in the premixing schemes of local oscillators have not been considered in this example.)

While the design trend has been to use up-conversions with first IF's higher than the highest frequency to be received (typically 35 percent higher for improved image rejection), performing a system design for the frequency scheme of a multi-conversion receiver has been considered a complicated mathematical analysis beyond the ability of the average Amateur. This need not be so; this article provides the reader with the tools necessary for understanding the design process more fully.

In a receiver, mixers provide undesired output products in addition to their sum and difference frequencies. These products are called intermodulation products. This phenomenon is complicated by the increased front-end bandwidth requirement referred to as general coverage as well as by the IF bandwidth requirement. If a multi-mixer situation exists, such as in a multiconversion receiver, the problem is further aggravated, as initial unwanted products from one mixer combine with those of another, creating a multitude of "birdies" (unwanted interference that sounds like the whistling of a bird) at the final IF output. Regardless of whether a receiver is dedicated or general coverage, the problem of intermodulation products has to be carefully understood and weighed against system parameters so that the fewest possible "birdies" are internally generated and heard within the passband of the receiver.

predicting IMDs

Let's look at some analytical tools the system designer uses to determine these products. Assume we're going to design a fixed-frequency receiver for 70 MHz (**fig. 1**). With a local oscillator of 90 MHz, the receiver will have a first IF of 160 MHz using an up-conversion mixing technique. (The second conversion of this receiver is not discussed here in order to simplify this case.) To use the mixer product chart (**fig. 2**) normalized frequencies must be calculated. Dividing the design frequency by the local oscillator frequency generates the first normalized number:

$$\frac{f_1}{f_2} = \frac{70}{90} = 0.778$$

Dividing the first IF by the local oscillator frequency generates the second normalized number:

$$\frac{f_{i\text{-}f}}{f_2} = \frac{160}{90} = 1.778$$

With this information and the mixer product chart, find the locus point (the intersection of a system of lines which satisfies one or more given conditions) for the two ratios, as shown in **fig. 3**. The chart in **fig. 2** shows all products produced not only by the fundamentals, but also by multiples of the signal and oscillator frequencies present in the mixer stage, and correspond to the second, third, fourth, fifth, and sixth harmonics of the two mixed signals.

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The **order** of the **product** is determined by the sum of the harmonic orders involved. For example, $5f_1 \pm 2f_2$ is a seventh-order product (regardless of the mathematical operation involved) because it involves the fifth harmonic of f_1 combined with the second harmonic of f_2. Higher-order products are also present, but they are usually of a sufficiently low level so as not to cause problems. Any line that crosses the locus point corresponds to a product which is identified on the edge of the chart.

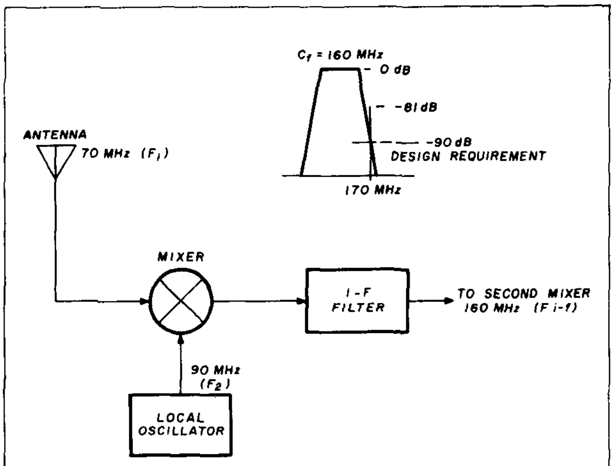

fig. 1. Finding in-band intermodulation products dictates choice of IF center frequency as well as the shape factor of the IF filter, in order to meet system requirements.

Values of f_1 and f_2 can be substituted and the interference can be anticipated and avoided. If the locus point is examined closely, one can be assured that there are no in-band products in this case, but analyzing the areas adjacent to the locus point indicates some out-of-band spurs (spurious, unwanted products) which will have to be suppressed by the IF filter to the level specified in the requirement. By knowing their order (given by the chart), their predicted amplitude can be found (in our case, 170 MHz). The seventh and ninth-order products ($5f_1 - 2f_2$ and $5f_2 - 4f_1$) are predicted to be 81 dB below the IF level (typical manufacturer prediction). The IF filter will have to provide 9 additional dB of attenuation at 170 MHz to accomplish a system requirement of 90 dB as shown in **fig. 1**. A simpler method of finding these products can be achieved by using the charts in **tables 2** and **3**. The chart shown in **table 2** is for mixers used in an additive mode (B + A) where A and B are the mixing frequencies and $B > A$. The chart shown in **table 3** is for mixers used in a subtractive mode (B − A) with the same conditions applying. If using the same example, and substituting f_1 for A and f_2 for B, the same ratio can be obtained.

$$\frac{f_1}{f_2} = \frac{A}{B} = \frac{70}{90} = 0.778$$

We then use **table 2**, since the mixer in our example operates in the additive mode, and find the corresponding products as indicated in **fig. 4** ($5A$-$2B$ and $5B$-$4A$). If the numerical values of A and B are inserted in these formulas, the same resultant values can

table 1. Examples of spurious frequencies present in receiver using 9 MHz IF.

OPERATING FREQUENCY MHz	LOCAL OSCILLATOR FREQUENCY MHz	BFO FREQUENCY MHz	LOWEST ORDER SPURIOUS PRODUCT EQUAL TO i-f	TYPICAL CARRIER LEVEL (μV) FOR 10 dB $\frac{S+N}{N}$		
				ADJACENT FREQUENCIES MAXIMUM	TYPICAL	SPURIOUS FREQUENCY TYPICAL
3.0025	12.0025	9.0025	3LO-3BFO	0.3	0.2	2.0
3.6030	12.6030	9.0025	5LO-6BFO	0.3	0.2	2.0
5.4035	14.4035	9.0025	5LO-7BFO	0.3	0.2	6.0
6.0033	15.0033	9.0025	3LO-4BFO	0.3	0.2	30.0
9.0025	18.0025	9.0025	LO-BFO	0.4	0.2	Receiver Blocked
11.2550	20.2550	9.0025	4LO-8BFO	0.4	0.2	8.0
12.0050	21.0050	9.0025	3LO-6BFO	0.4	0.2	300 for 3dB $\frac{S+N}{N}$
13.5000	4.5000	8.9975	2LO	0.5	0.3	Receiver Blocked
14.99916	5.99916	8.9975	3LO-BFO	0.5	0.3	8.0
18.0000	9.0000	8.9975	LO	0.5	0.3	Receiver Blocked
20.9975	11.9975	8.9975	3LO-3BFO	0.6	0.4	0.5
21.5970	12.5970	8.9975	5LO-6BFO	0.6	0.4	2.0
23.3965	14.3965	8.9975	5LO-7BFO	0.6	0.4	8.0
23.99667	14.99667	8.9975	3LO-4BFO	0.6	0.4	2.0
25.1960	16.1960	8.9975	5LO-8BFO	0.6	0.4	4.0
26.9975	17.9975	8.9975	LO-BFO	0.6	0.4	30.0
29.2450	20.2450	8.9975	4LO-8BFO	0.6	0.4	6.0

be obtained with this method, which is usually preferred. If this receiver were not designed for a fixed frequency, you can imagine what a job it would be to evaluate all the higher-order products generated by using this method.

computers speed the analysis

Today, computer programs are used successfully to help designers anticipate potential problems. In our example, a TI-59 programmable calculator is used to perform this tedious task. (A program listing is included in **table 4** for those wishing to work out their own problems.)

This program finds all combinations of (m × LO) ± (n × RF) and prints those frequencies that fall in the center of the IF by actually indicating "IF" in the printout. Those frequencies that fall within the predetermined IF bandwidth but are not exactly in the center are also reported in the printout by the indication "**BW**" (**fig. 6**). The sample program in **fig. 6** shows how our 70 MHz fixed-frequency receiver may be analyzed using this method. If the 90 MHz LO is entered into the user-defined key A, the 70 MHz RF into B, the 160 MHz IF into C, and the IF bandwidth we wish to analyze into D (50 MHz), a report is obtained by depressing key E′, indicating that we are ready to run the program with the entered data as shown in **fig. 5**. If a mistake occurred in the process of entering the information, new data can be entered by repeating the above process with no alteration to the actual program. We can now run our analysis by depressing key E. A complete list of products will be automatically printed as shown in **fig. 6**. The process takes approximately four minutes to analyze all cases

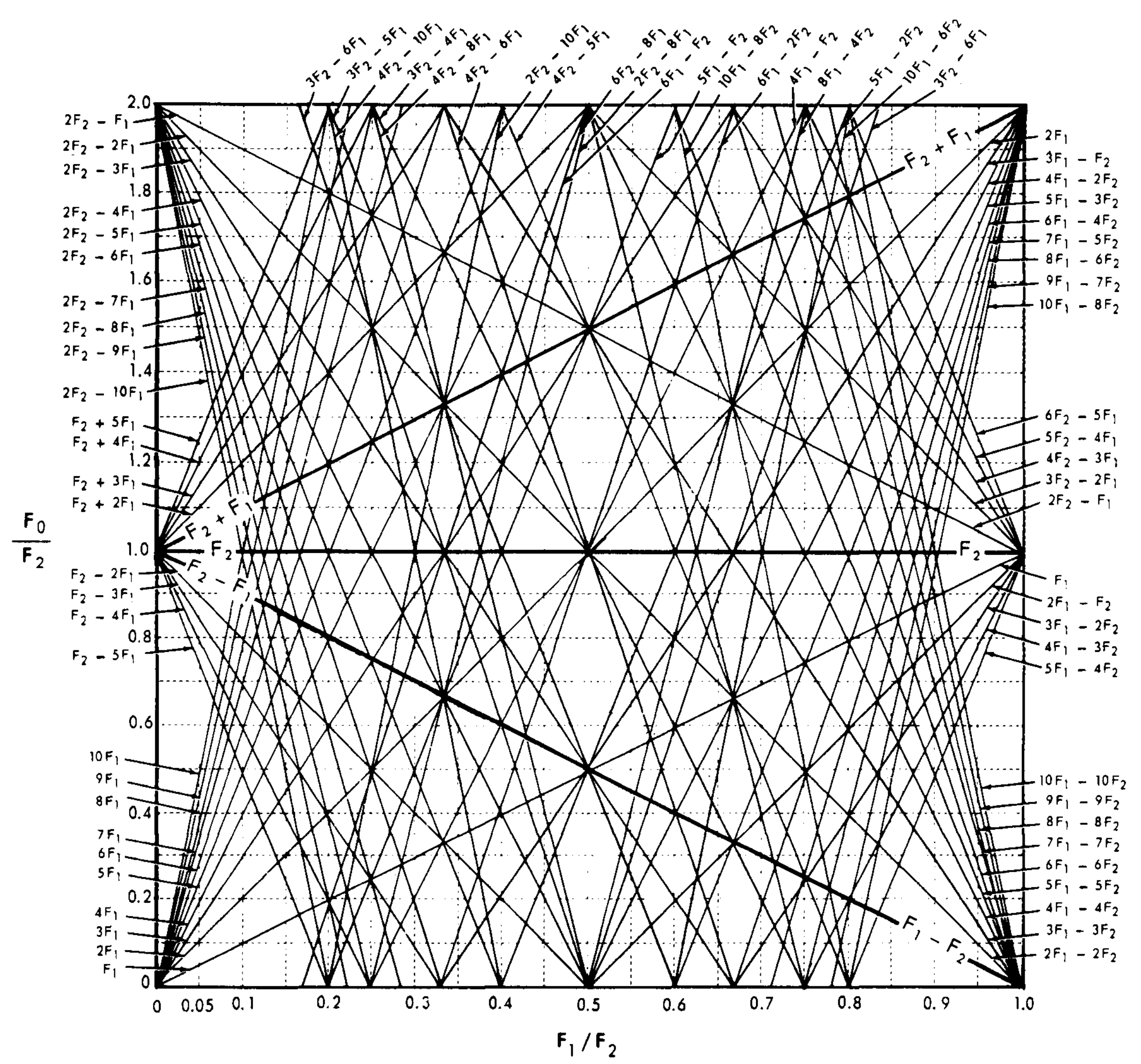

fig. 2. Intermodulation products chart.

of m and n within the 50 MHz bandwidth. This may seem to be a long time, but not if we compare the time expended in manually searching the product chart in **fig. 2**.

This *program can be recorded on two magnetic* cards. For those with a TI-59, **table 4** shows the actual listing of the intermodulation products program. Partitioning (OP 17) is 479.59. **Table 5** lists the procedures necessary for running the program. The amplitude *of the undesired products identified* depends on their particular order number (m + n). Most products of the seventh order or higher will be at least 60 dB down from the IF level, and are usually not considered to cause problems. Unless different instructions are entered, the program will automatically calculate all products to the twelfth order (6 × LO) ± (6 × RF) *(no user inputs to A′ and B′ are* required). If a different resolution is desired, the two keys should be addressed accordingly. The execution time of this program is a direct function of the product order and the IF bandwidth required by the user.

a system design for a general coverage communications receiver

In the following pages we will consider a system design for a general coverage HF receiver with a wide input bandwidth (28 MHz). Unlike the dedicated single frequency receiver analyzed in the above, this wideband receiver presents a considerably more

table 2. Mixer IMD chart, additive mode.

I-F FREQUENCY OUTPUT = B+A (CONDITIONS B>A)

R = A/B	ORDER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000	B	B - A	B±2A	B±3A	B±4A	B±5A	B±6A	B±7A	B±8A	B±9A	B±10A	B±11A	B±12A	B±13A	B±14A
0.072															2B-13A 15A
0.077														2B-12A 14A	
0.083													2B-11A 13A		
0.091												2B-10A 12A			
0.100											2B-9A 11A				
0.111										2B-8A 10A					
0.125									2B-7A 9A						
0.143								2B-6A 8A							
0.154															3B-12A 14A-B
0.167							2B-5A 7A							3B-11A 13A-B	
0.182													3B-10A 12A-B		
0.200						2B-4A 6A						3B-10A 11A-B			
0.222											3B-8A 10A-B				
0.250					2B-3A 5A					3B-7A 9A-B					4B-11A 13A-2B
0.273														4B-10A 12A-2B	
0.286									3B-6A 8A-B						
0.300													4B-9A 11A-2B		
0.333				2B-2A 4A				3B-5A 7A-B				4B-8A 10A-2B			
0.364															5B-10A 12A-3B
0.375											4B-7A 9A-2B				
0.400							3B-4A 6A-B							5B-9A 11A-3B	
0.429										4B-6A 8A-2B					
0.445													5B-8A 10A-3B		
0.500			2B - A 3A			3B-3A 5A - B			4B-5A 7A-2B			5B-7A 9A-3B			6B-9A 11A-4B
0.555														6B-8A 10A-4B	
0.571											5B-6A 8A-3B				
0.600								4B-4A 6A-2B							
0.625													6B-7A 9A-4B		
0.667					3B-2A 4A-B					5B-5A 7A-3B					7B-8A 10A-5B
0.715												6B-6A 8A-4B			
0.750							4B-3A 5A-2B							7B-7A 9A-5B	
0.800									5B-4A 6A-3B						
0.833											6B-5A 7A-4B				
0.858													7B-6A 8A-5B		
0.875															8B-7A 9A-6B
1.000		2B 2A		3B- A 3A- B		4B-2A 4A-2B		5B-3A 5A-3B		6B-4A 6A-4B		7B-5A 7A-5B		8B-6A 6A-6B	

table 3. Mixer IMD chart, subtractive mode.

I-F FREQUENCY = B-A (CONDITION B>A)

R = A/B	ORDER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.000	B	B±A	B±2A	B±3A	B±4A	B±5A	B±6A	B±7A	B±8A	B±9A	B±10A	B±11A	B±12A	B±13A	B±14A
0.063															15A
0.067														14A	
0.072													13A		
0.077												12A			
0.083											11A				2B-13A
0.091										10A				2B-12A	
0.100									9A				2B-11A		
0.111								8A				2B-10A			
0.125							7A				2B-9A				
0.133															14A - B
0.143						6A				2B-8A				13A - B	
0.154													12A - B		
0.167					5A				2B-7A			11A - B			
0.182											10A - B				3B-12A
0.200				4A				2B-6A		9A - B				3B-11A	
0.214															13A-2B
0.222									8A - B				3B-10A		
0.231														12A-2B	
0.250			3A				2B-5A	7A - B				3B-9A	11A-2B		
0.273												10A-2B			
0.286							6A - B				3B-8A				
0.300											9A-2B				4B-11A
0.308															12A-3B
0.333		2A				2B-4A 5A - B				3B-7A 8A-2B				4B-10A 11A-3B	
0.364													10A-3B		
0.375									7A - 2B				4B-9A		
0.400					4A - B				3B-6A			9A - 3B			
0.416															11A-4B
0.429								6A-2B				4B-8A			
0.445											8A-3B				5B-10A
0.455														10A-4B	
0.500	A			3A - B	2B-3A		5A-2B	3B - 5A		7A - 3B	4B-7A		9A-4B	5B - 9A	
0.545															10A-5B
0.555												8A-4B			
0.571									6A-3B				5B-8A		
0.600						4A-2B				4B-6A				9A-5B	
0.625											7A-4B				6B-9A
0.667			2A - B				3B-4A	5A-3B				5B-7A	8A-5B		
0.700															9A-6B
0.715										6A-4B				6B-8A	
0.750					3A-2B				4B-5A			7A - 5B			
0.778														8A-6B	
0.800							4A-3B				5B-6A				
0.833									5A-4B				6B-7A		
0.858											6A - 5B				7B-8A
0.875													7A - 6B		
1.000				2B-2A		3B-3A		4B-4A		5B-5A		6B-6A		7B-7A	

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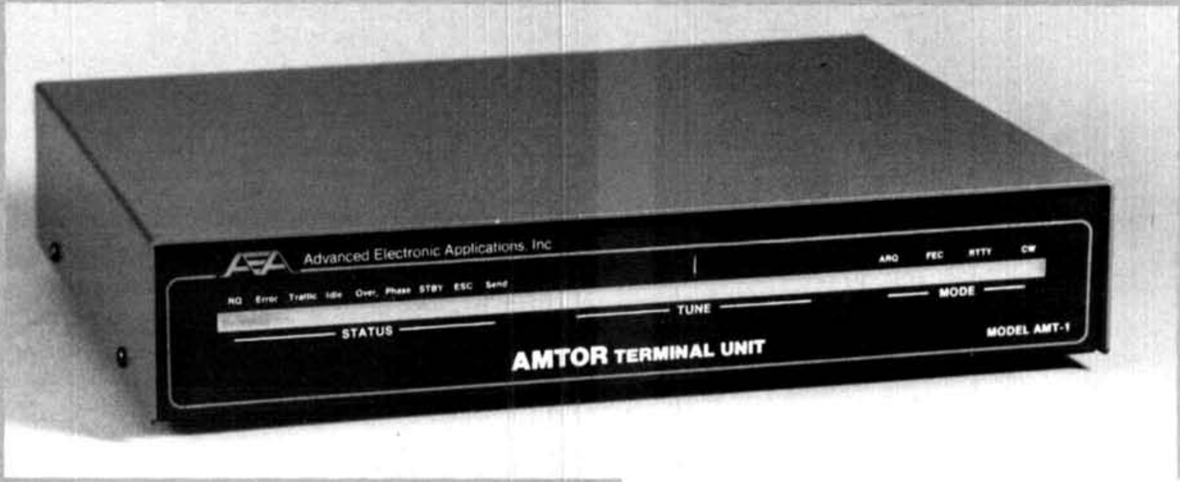

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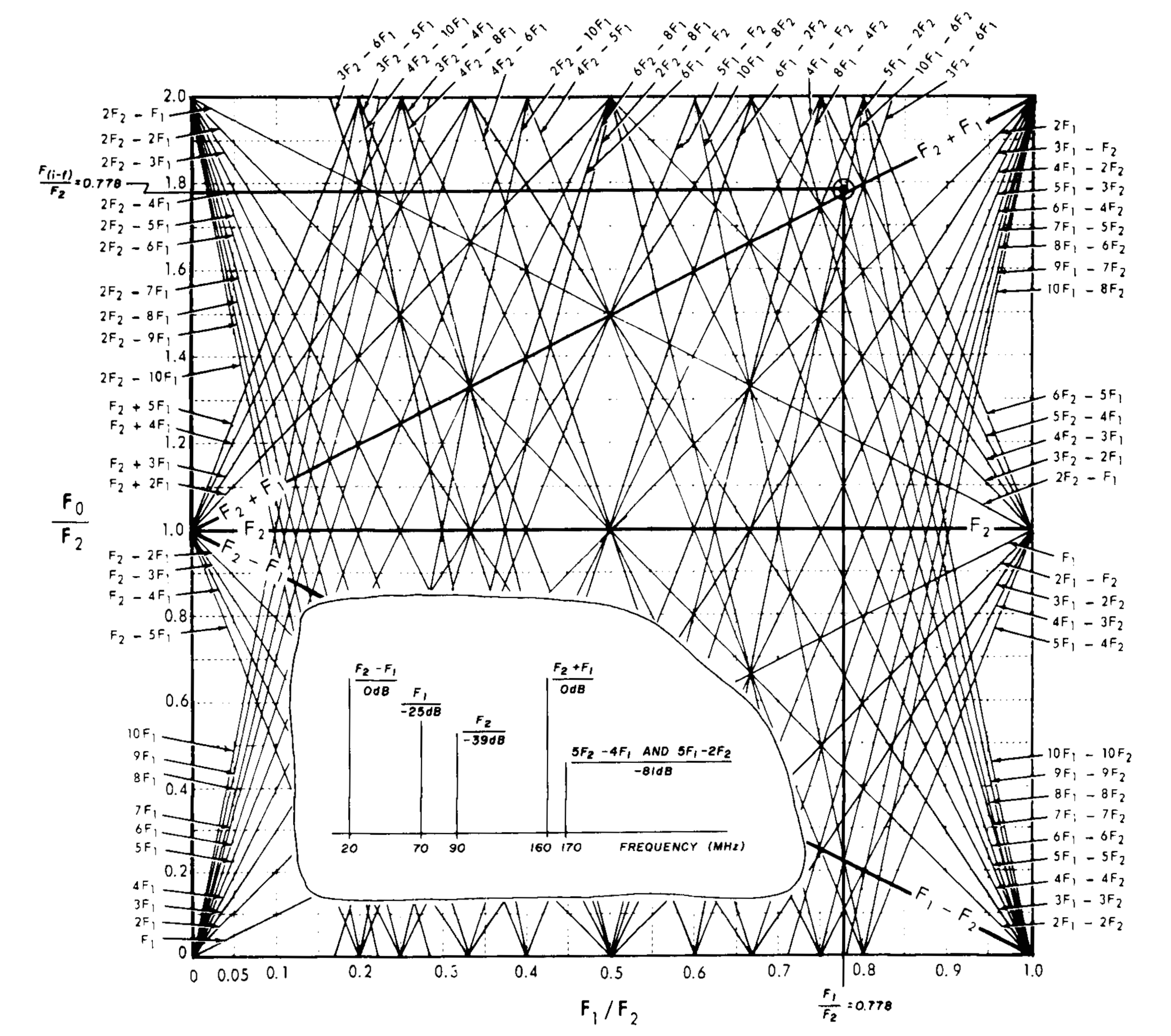

fig. 3. The intersection of the vertical and horizontal lines corresponding to $\frac{f_1}{f_2}$ and $\frac{f_{(IF)}}{f_2}$ (locus point of normalized frequencies) indicates the in-band intermodulation products. The out-of-band spurious outputs that happen to be in the vicinity of the IF frequency can also be verified by looking at the products adjacent to the locus point.

complex product analysis problem, because of the many different cases that could be created within the input bandwidth. The problem is further increased if a double-conversion approach is used, since products generated in the first IF can multiply in the second IF. The designer should use good judgment in the initial choice of frequencies, since no computer or chart can take the place of good engineering procedures.

The design objectives are a communication receiver covering 2 to 30 MHz, with good image rejection, having a minimum of unwanted products. Looking at **fig. 7**, a double conversion approach is considered with an up-conversion first IF compatible with commercially-available monolithic crystal filters at 75 MHz. A phase-locked synthesizer used as the local

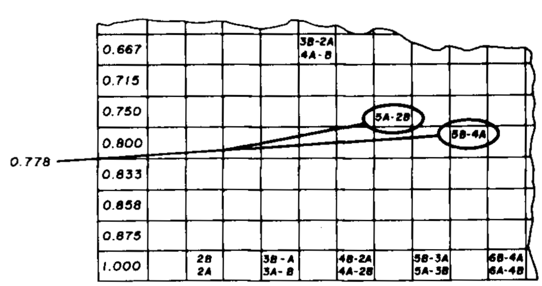

fig. 4. The same results can be obtained as with our previous example by using the intermodulation chart from table 2. Ratio $\frac{A}{B} = 0.778$ which points to a 7th and 9th order product (5A-2B and 5B-4A).

oscillator for the first mixer must be tunable in 10 kHz steps over this range. Fine tuning is achieved in the second conversion stages with another synthesizer which provides frequency resolution of 100 Hz within the 10 kHz steps.

A 9 MHz second IF was chosen because of the availability of good crystal-lattice filters at that frequency. Two sideband filters are used in this IF. The system will be analyzed using the previously described charts; the TI-59 computer program will be used to perform the calculations.

Fig. 8 shows the mathematical model for this receiver. An RF signal within a 2.000 to 30.000 MHz range is injected into the first mixer, where it subtracts from the first local oscillator frequency and

CONDITIONS	
6.	× LO
6.	× RF
90.	LO
70.	RF
160.	IF
50.	BW

fig. 5. Depressing Key E′ will print out all conditions entered by the operator.

table 5. User instructions for the TI-59 intermodulation products program.

STEP	DESCRIPTION	ENTER	PRESS
1	Input the highest LO harmonic of interest*	m	A′
2	Input the highest rf harmonic or interest*	n	B′
3	INPUT LO FREQUENCY	LO	A
4	INPUT rf FREQUENCY	rf	B
5	INPUT i-f FREQUENCY	i-f	C
6	INPUT BANDWIDTH Centered at i-f	BW	D
7	PRINT CONDITIONS ENTERED		E′
8	RUN PROGRAM		E

*Progam finds all combinations of mxLO ± n × rf and frequencies that are equal to the i-f chosen (=i-f) and those that lie within the i-f bandwidth (*BW).*

*If no input, a sixth order will be automatically analyzed.

USER DEFINED KEYS	
A	LO
B	rf
C	i-f
D	BW
E	RUN PROGRAM
A′	m
B′	n
C′	NOT USED
D′	NOT USED
E′	CONDITIONS REPORT

table 4. Listing of the TI-59 program for intermodulation products. Partitioning is 479.59.

```
000  76 LBL
001  11  A
002  42 STO
003  03  03
004  91 R/S
005  76 LBL
006  12  B
007  42 STO
008  04  04
009  91 R/S
010  76 LBL
011  13  C
012  42 STO
013  06  06
014  91 R/S
015  76 LBL
016  14  D
017  42 STO
018  07  07
019  91 R/S
020  76 LBL
021  15  E
022  43 RCL
023  06  06
024  75  -
025  43 RCL
026  07  07
027  55  ÷
028  02  2
029  95  =
030  42 STO
031  13  13
032  85  +
033  43 RCL
034  07  07
035  95  =
036  42 STO
037  14  14
038  68 NOP
039  68 NOP
040  68 NOP
041  68 NOP
042  68 NOP
043  68 NOP
044  76 LBL
045  19 D'
046  43 RCL
047  01  01
048  65  ×
049  43 RCL
050  03  03
051  85  +
052  43 RCL
053  02  02
054  65  ×
055  43 RCL
056  04  04
057  95  =
058  50 I×I
059  42 STO
060  05  05
061  71 SBR
062  01  01
063  15  15
064  43 RCL
065  01  01
066  65  ×
067  43 RCL
068  03  03
069  75  -
070  43 RCL
071  02  02
072  65  ×
073  43 RCL
074  04  04
075  95  =
076  50 I×I
077  42 STO
078  05  05
079  71 SBR
080  01  01
081  15  15
082  01  1
083  94 +/-
084  44 SUM
085  01  01
086  97 DSZ
087  08  09
088  19 D'
089  43 RCL
090  11  11
091  42 STO
092  01  01
093  85  +
094  01  1
095  95  =
096  42 STO
097  08  08
098  01  1
099  94 +/-
100  44 SUM
101  02  02
102  97 DSZ
103  09  09
104  19 D'
105  43 RCL
106  12  12
107  42 STO
108  02  02
109  85  +
110  01  1
111  95  =
112  42 STO
113  09  09
114  91 R/S
115  43 RCL
116  06  06
117  32 X:T
118  43 RCL
119  05  05
120  67  EQ
121  01  01
122  45  45
123  43 RCL
124  13  13
125  32 X:T
126  43 RCL
127  05  05
128  77  GE
129  01  01
130  32  32
131  92 RTN
132  43 RCL
133  14  14
134  32 X:T
135  43 RCL
136  05  05
137  22 INV
138  77  GE
139  01  01
140  60  60
141  92 RTN
142  00  0
143  00  0
144  00  0
145  71 SBR
146  01  01
147  80  80
148  43 RCL
149  19  19
150  69 OP
151  04  04
152  43 RCL
153  05  05
154  69 OP
155  06  06
156  98 ADV
157  92 RTN
158  00  0
159  00  0
160  71 SBR
161  01  01
162  80  80
163  43 RCL
164  18  18
165  69 OP
166  04  04
167  43 RCL
168  05  05
169  69 OP
170  06  06
171  98 ADV
172  92 RTN
173  00  0
174  00  0
175  00  0
176  00  0
177  00  0
178  00  0
179  00  0
180  43 RCL
181  15  15
182  69 OP
183  04  04
184  43 RCL
185  01  01
186  69 OP
187  06  06
188  43 RCL
189  16  16
190  69 OP
191  04  04
192  43 RCL
193  02  02
194  69 OP
195  06  06
196  92 RTN
197  00  0
198  00  0
199  00  0
200  76 LBL
201  10 E'
202  98 ADV
203  98 ADV
204  43 RCL
205  23  23
206  69 OP
207  03  03
208  43 RCL
209  24  24
210  69 OP
211  04  04
212  69 OP
213  05  05
214  43 RCL
215  15  15
216  69 OP
217  04  04
218  43 RCL
219  01  01
220  69 OP
221  06  06
222  43 RCL
223  16  16
224  69 OP
225  04  04
226  43 RCL
227  02  02
228  69 OP
229  06  06
230  43 RCL
231  21  21
232  69 OP
233  04  04
234  43 RCL
235  03  03
236  69 OP
237  06  06
238  43 RCL
239  22  22
240  69 OP
241  04  04
242  43 RCL
243  04  04
244  69 OP
245  06  06
246  43 RCL
247  17  17
248  69 OP
249  04  04
250  43 RCL
251  06  06
252  69 OP
253  06  06
254  43 RCL
255  20  20
256  69 OP
257  04  04
258  43 RCL
259  07  07
260  69 OP
261  06  06
262  98 ADV
263  98 ADV
264  91 R/S
265  00  0
266  00  0
267  00  0
268  00  0
269  00  0
270  76 LBL
271  16 A'
272  42 STO
273  01  01
274  42 STO
275  11  11
276  85  +
277  01  1
278  95  =
279  42 STO
280  08  08
281  91 R/S
282  76 LBL
283  17 B'
284  42 STO
285  02  02
286  42 STO
287  12  12
288  85  +
289  01  1
290  95  =
291  42 STO
292  09  09
293  91 R/S
```

CONDITIONS		CONDITIONS	
3.	× LO	0.	× LO
6.	× RF	2.	× RF
150.	* BW	140.	* BW
2.	× LO	1.	× LO
5.	× RF	1.	× RF
170.	* BW	160.	= IF
5.	× LO	2.	× LO
4.	× RF	0.	× RF
170.	* BW	180.	* BW
4.	× LO		
3.	× RF		
150.	* BW		

fig. 6. Depressing Key E on the TI-59 will run the intermodulation product program within the specified conditions indicating the same problem areas 5RF-2LO and 5LO-4RF as previously determined with the intermodulation charts. Other problems are also indicated within the IF bandpass but are not considered in our example for reasons of simplicity.

produces a 75.000 MHz IF. This local oscillator is configured as a synthesizer operating from 77.000 to 105.000 MHz in 0.01 MHz (10 kHz) steps. This dictates the bandwidth of the first IF to be 10 kHz minimum, from 74.995 to 75.005 MHz in order for the second local oscillator to be able to provide fine tuning in the second IF. A 75 MHz tandem monolithic filter from Piezo-Technology Inc. can be used in this application. If $RF = A$ and $LO = B$, two ratios $\frac{A}{B}$ can be created: R minimum and R maximum.

$$R_{MIN} = \frac{2.000}{77.000} - 0.025$$

$$R_{MAX} = \frac{30.000}{105.00} = 0.285$$

We will use the mixing product chart (**table 3**) for subtraction since our IF is 75 MHz, and find the entire band between R_{MIN} and R_{MAX} as shown in **fig. 8**. Any product indicated within this band could be a potential problem for the corresponding received frequency.

A look at the chart indicates a series of problems (7A, 6A, 5A, 4A, 3A, 2B-5A, with the worst one at 3A). If the TI-59 program is used, we can verify this case as shown in **fig. 8**. At first we can say that the third harmonic of one of the two mixing signals could be quite powerful and could indeed produce a problem, but a closer look at the system indicates that the offending frequency A, is actually a received frequency and chances are very good that a distant 25 MHz station has a level of insignificant third harmonic (75 MHz) appearing at the antenna of our receiver.

The problem is further diminished by our receiver's preselector, which greatly attenuates at 75 MHz. The same conditions apply to the other products indicated by the chart. They present even a better case since they are further removed from the received frequencies. This is a case where judgment is more important than all our tools, which are only used to warn of possible problems.

The case would be different, however, if the B signal were the offender, as 3B would have been the third harmonic of the local oscillator, which can be of relatively high amplitude and cause interference.

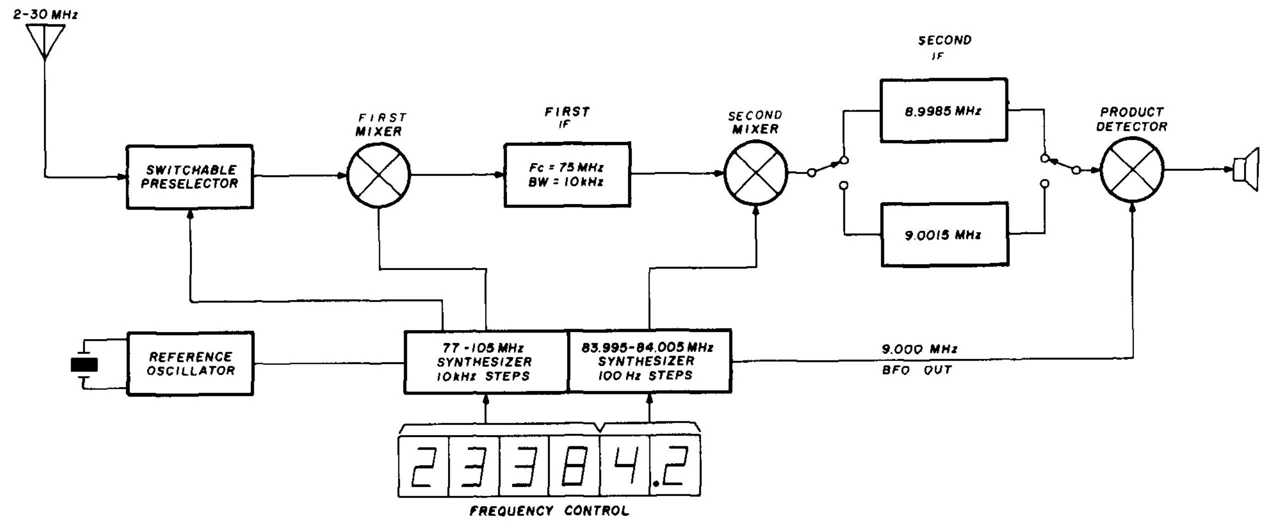

fig. 7. Communications receiver block diagram. The first IF is 75 MHz with a second IF of 9 MHz. A two-loop synthesizer is used to provide coarse and fine tuning.

The filtered first IF range of 74.995 to 75.005 MHz is further mixed with the second local oscillator operating in 0.0001 MHz (100 Hz) steps over the 10 kHz range of 83.995 to 84.005 MHz, providing fine tuning for the receiver. If R_{MIN} and R_{MAX} are found for the second IF a new band of interest can be located on our chart, as shown in **fig. 8**.

$$R_{MIN} = \frac{74.995}{83.995} = 0.89285076$$

$$R_{MAX} = \frac{75.005}{84.005} = 0.89286352$$

Since the range to be covered is only 10 kHz, the band is very narrow and in reality is expressed by the same number (0.892) because the chart extends to only three decimal places. The IF is centered at 9.000 MHz and its bandwidth is determined by the two single-sideband filters. For simplicity, the minimum corner frequency (−3 dB) of the lower filter and the upper corner frequency for the higher filter were chosen, determining a total bandwidth (−3 dB) of 0.0051 MHz (5.1 kHz for both sidebands). **Fig. 8** clearly indicates that there is no problem except for a thirteenth order product which can be ignored. Since the band is so narrow and close to the 1.000 ratio which presents quite a few problems, the computer

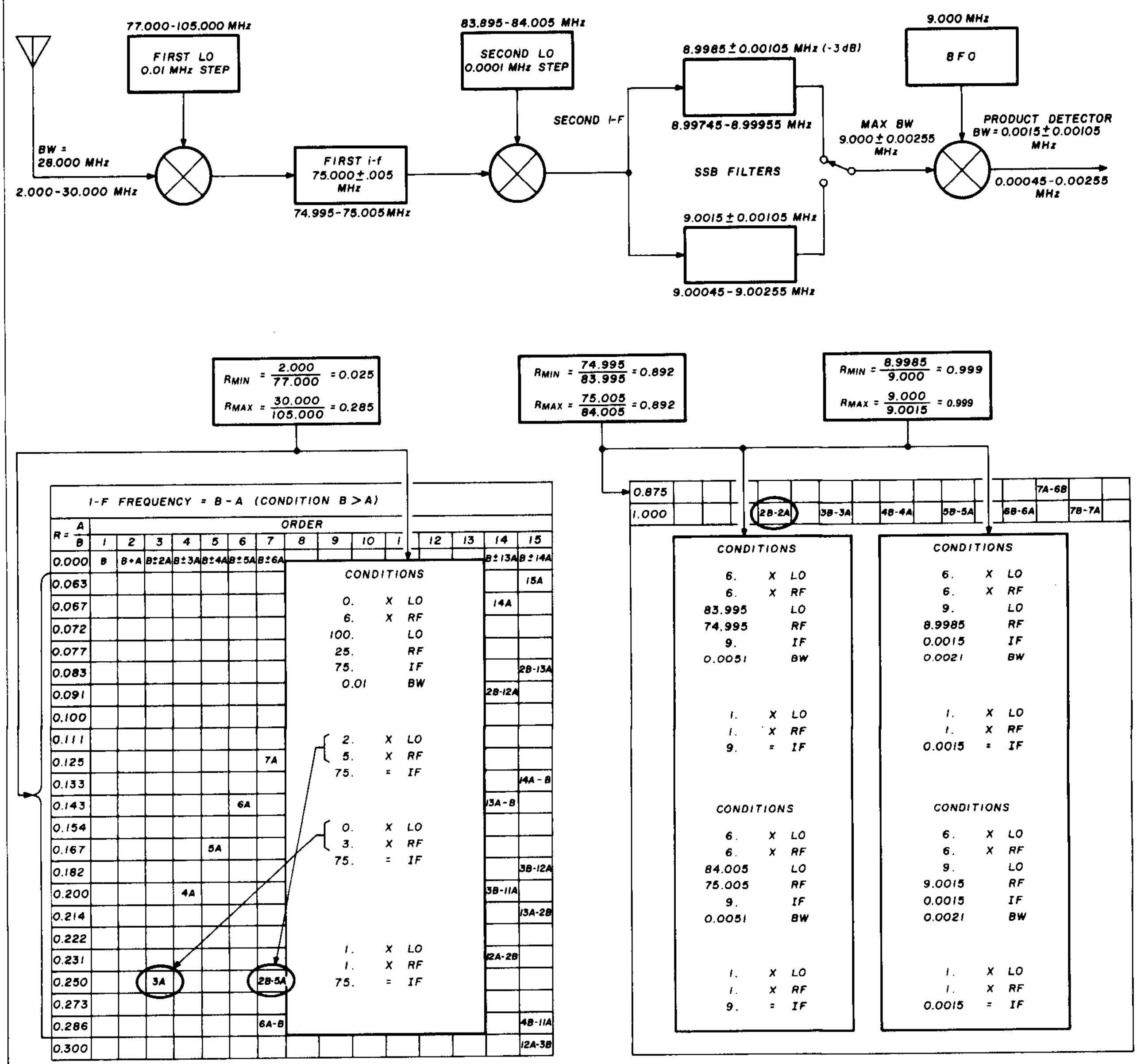

fig. 8. System analysis for a double conversion, general-coverage communications receiver with a first IF at 75 MHz and a second IF at 9 MHz.

CONDITIONS	
7.	× LO
7.	× RF
83.995	LO
74.995	RF
9.	IF
0.0374	BW
1.	× LO
1.	× RF
9.	= IF

fig. 9. TI-59 program indicates no intermodulation problem in the second IF of the double-conversion communications receiver. The −60 dB bandwidth (0.0374 MHz) of the filters was used for a worst-case analysis.

is used to completely insure safety. Unless othewise instructed, the program will not point out the thirteenth product as it is programmed to only calculate products to the twelfth order. If the order is increased to 14, the computer will indicate that there is no case for a 7A-6B within the ratio range.

In analyzing the second IF in **fig. 8**, a total bandwidth of 0.0374 MHz (37.4 kHz) is considered to insure complete freedom from intermodulation products within the slopes of the 8-pole filters used in this IF (37.4 kHz is the −60 dB total bandwidth of the two filters), as shown in **fig. 9**. It can be seen from this analysis that the charts can be used only as a guideline. For a more in-depth analysis, the TI-59 program or some other means of calculation must be used to obtain precise answers.

Up to this stage no real interference problems have been encountered. The last conversion is from 9.000 MHz ± 0.00255 MHz to audio between 0.00045 to 0.00255 MHz (450 Hz to 2.550 kHz) in both single-sideband filter cases. The conversion takes place in a third mixer (product detector), as shown in the example (**fig. 10**).

$$R_{MIN} = \frac{8.9985}{9.000} = 0.999833$$

$$R_{MAX} = \frac{9.000}{9.0015} = 0.999833$$

These identical ratios locate the intermodulation band to be analyzed as very close to the 1.000 ratio in the chart and with a −3 dB bandwidth of 0.0021 MHz (2.1 kHz). No problems are found for either one of the single-sideband filters. However, if the −60 dB bandwidth (0.0374 MHz) of the 8-pole filters is used for the TI-59 computer program, the 2B-2A problem circled in **fig. 8** becomes evident at the 3 kHz point in the slopes of our filters. This is true for either sideband filter as shown in **fig. 11** and the resulting *audio distortion can be cured only by improving the shape factor of the filters, in our case by* doubling the number of poles to 16 for each one of the single-sideband filters.

Another way to cure this problem would be to introduce a lowpass filter in the audio portion of our receiver which will cut off all frequencies beyond the 2.55 kHz which is the highest frequency passed by the filters. A practical cut-off point would be at 2.8 kHz. The first method is preferred, however, because it also provides better adjacent-channel rejection, improving overall receiver selectivity.

conclusion

In performing this analysis for the design of a double-conversion general-coverage communica-

CONDITIONS		CONDITIONS	
6.	× LO	6.	× LO
6.	× RF	6.	× RF
9.	LO	9.	LO
8.9985	RF	9.0015	RF
0.0015	IF	0.0015	IF
0.0038	BW	0.0038	BW
2.	× LO	2.	× LO
2.	× RF	2.	× RF
0.003	* BW	0.003	* BW
1.	× LO	1.	× LO
1.	× RF	1.	× RF
0.0015	= IF	0.0015	= IF

fig. 10. The TI-59 program indicates a 2B-2A product within the bandwidth of the 8-pole single sideband filters.

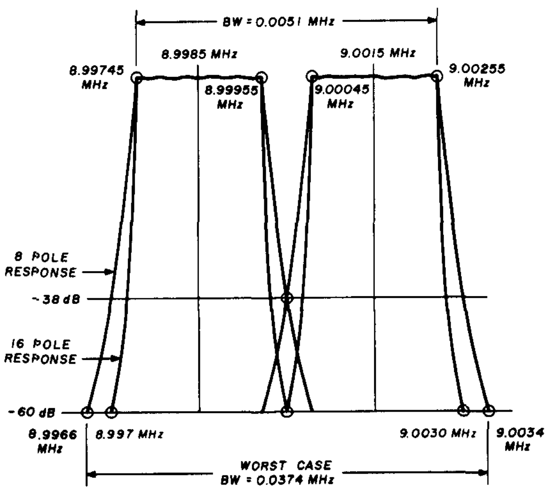

fig. 11. Bandwidth characteristics of the 8-pole single-sideband filters used in the communications receiver. 16 pole filters could be used to eliminate a 2B-2A audio product as well as to improve the total selectivity of the receiver.

tions receiver, we have shown that the design meets the requirements which introduces a minimum of intermodulation problems. We can now proceed with confidence to the circuit design of our receiver. All frequency mixing techniques used in communications receivers generate unwanted products within their outputs, and the fact remains that any configuration chosen is simply the best compromise in the opinion of the designer. The problem of intermodulation distortion within a receiver's scheme can be minimized by performing a careful analysis, such as explained in this article.

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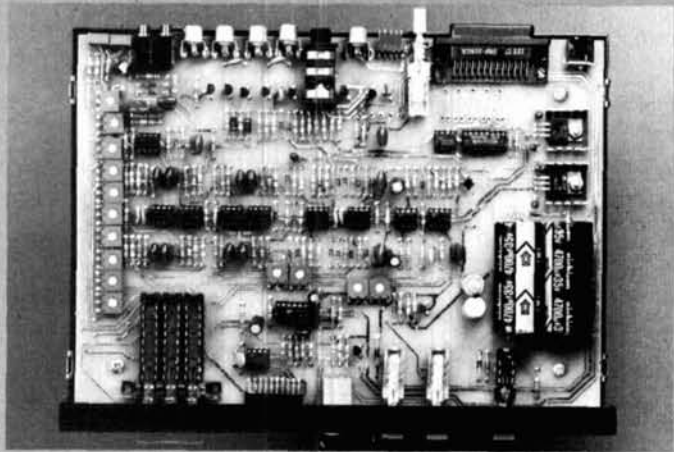
ham radio

CHAMPAGNE RTTY/CW on a Beer Budget



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time and frequency standards: part 1

Accurate measurement requires accepted standards, precision electronics, and an understanding of atomic physics

Radio Amateurs are probably more concerned about frequency than about any other electrical parameter. However, when discussing frequency, it is important to remember that the reciprocal of frequency is *period*, and that this is expressed in units of time. Because of this relationship, accurate frequency standards must be based on accurate time standards. This two-part article gives a brief historical overview of this field, examines the more common methods of determining frequency and time standards, discusses the advantages and limitations of each, and also succinctly describes some commercial equipment employed in these areas. Part 1 addresses VLF single-frequency comparison techniques; part 2 will cover multiple-frequency VLF techniques and other more advanced systems.

The World Administrative Radio Council (WARC) has set aside five bands for standard frequency and the time signal emissions as shown in **fig. 1**. The carrier frequencies for such broadcasts should be maintained accurately enough so that the average daily fractional frequency deviations from these internationally designated standards for measurement of time intervals do not exceed $\pm 1 \times 10^{-10}$. The map in **fig. 2** shows numerous radio stations used for time-frequency determination (TFD). Stations that provide strong signal transmissions to North America are listed in **table 1**. Other stations that can be received elsewhere in the world are listed in **table 2**.

LF time and frequency systems

The majority of American and international "VLF" standards stations transmit within the VLF (10 to 30 kHz) and LF (30 to 300 kHz) bands, respectively.

In the early part of this century, both systems were used for long-range communication between colonies and parent countries, and by navies for general trans-oceanic communication. Then, as now, the advantages of VLF and LF systems included reliability with very little signal attenuation, even over vast distances.

In many instances these systems were replaced with HF systems that used smaller antennas. But many novel VLF antenna systems have been built; some consist of long cables strung across valleys or volcanic craters, from towers several hundred meters tall. One such system in Cutler, Maine, radiates 1 MW of power using a "top hat" supported by twenty-six masts, each approximately 300 meters in height. This installation covers over two square kilometers and has a radial ground system of buried copper wire that totals over three million meters in length.

Interest in LF band communications was revived

Band No.	Designation	Frequency Range
4	VLF (Very Low Frequency).	20.0 kHz ± 50 Hz.
6	MF (Medium Frequency).	2.5 MHz ± 5 kHz.
7	HF (High Frequency).	5.0 MHz ± 5 kHz. 10.0 MHz ± 5 kHz. 15.0 MHz ± 10 kHz. 20.0 MHz ± 10 kHz. 25.0 MHz ± 10 kHz.
9	UHF (Ultra High Frequency).	400.1 MHz ± 25 kHz. (satellite).
10	SHF (Super High Frequency).	4.202 GHz ± 2 MHz (satellite space to earth). 6.427 GHz ± 2 MHz (satellite earth to space).

fig. 1. International standard time and frequency radio assignments.

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during World War II, with the evolution of the Radux navigational system, in which low-frequency carriers demonstrated exceptional stability.

Since the mid-1950s there has been great progress in the development of LF communications. Work by Pierce, Mitchell, Essen, and Crombie showed a 100 to 1000 time improvement in frequency compared to existing HF techniques. Early in the 1960s, more stable atomic frequency standards began to take the place of crystal oscillators, and confidence in the

table 1. "Standard" VLF stations receivable in the United States (10.0-30.0 kHz).

station	frequency	location
GBR	16.0 kHz	Rugby, England
NAA	17.8 kHz	Cutler, Maine
NPG	18.6 kHz	Jim Creek, Washington
NPM	23.4 kHz	Laulaulei, Hawaii
WWVL	20.0 kHz and 19.9 kHz	Fort Collins, Colorado
NSS	21.4 kHz	Annapolis, Maryland
NBA	24.0 kHz	Balboa, Canal Zone

table 2. Worldwide VLF stations.

station	frequency	location
JG2AS	40.0 kHz	Kemingawa, Japan
OMA	50.0 kHz	Podebzady, Czechoslovakia
WWVB	60.0 kHz	Fort Collins, Colorado
MSF	60.0 kHz	Rugby, England
HBG	75.0 kHz	Pranginis, Switzerland
DCF-77	77.5 kHz	Mainflingen, Federal Republic of Germany
CYZ-40	80.0 kHz	Ottawa, Canada
FTA-91	91.15 kHz	St. Andre de Corcy, France

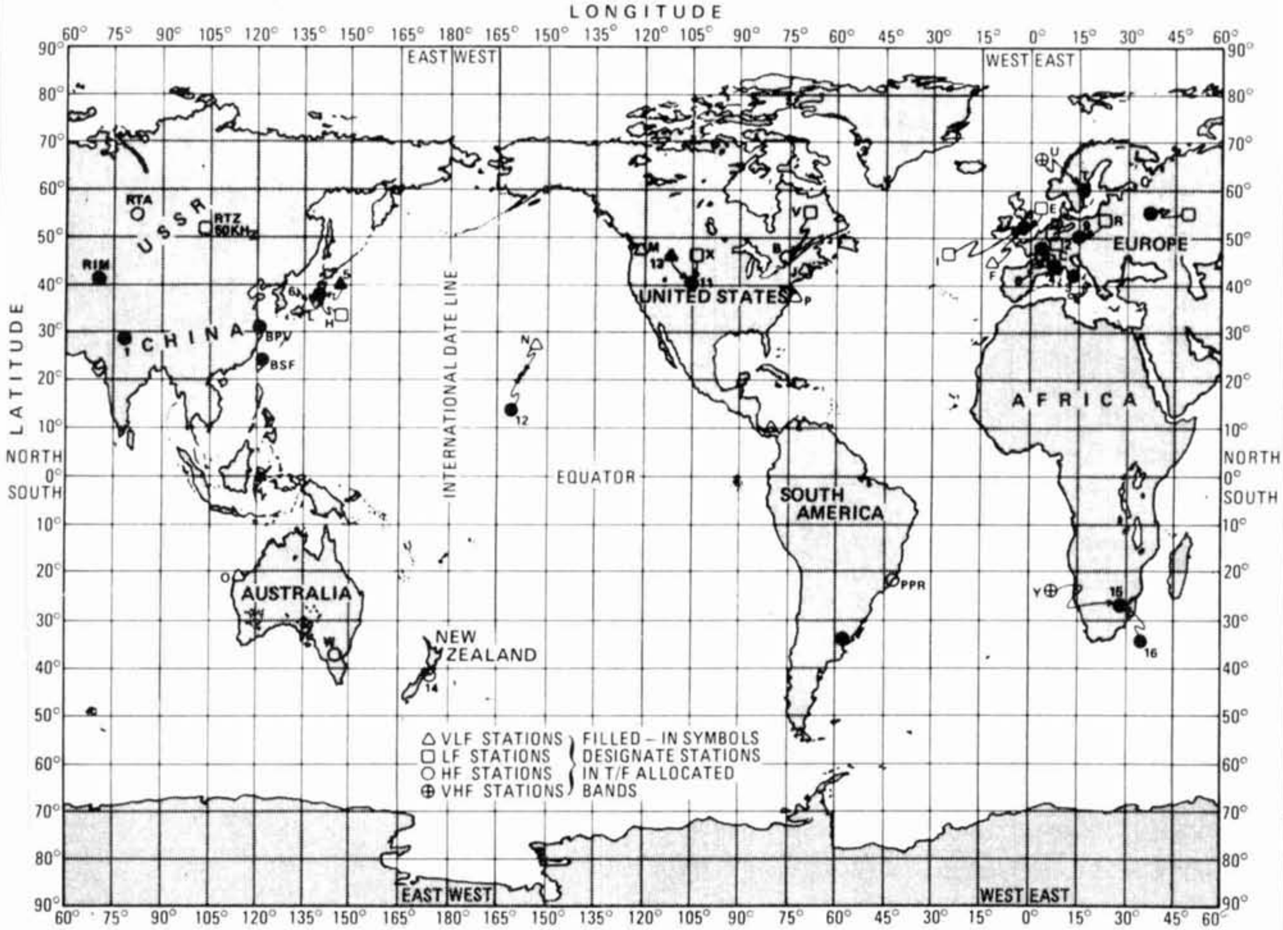

fig. 2. Worldwide location of broadcasting stations useful for TFD.

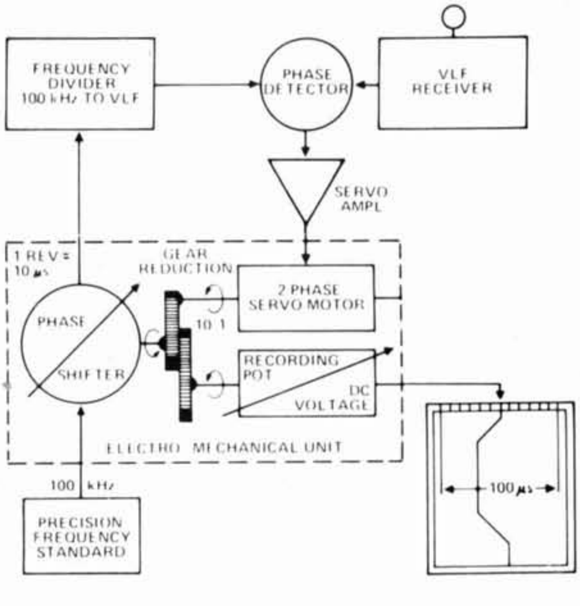

fig. 3. A typical electromechanical VLF single-frequency comparator.

fig. 4. The Fluke Model 207/205 VLF receiver/comparator.

new system was soon rewarded when Pierce, Winkler, and Corke demonstrated that a transatlantic phase comparison could be made on a 16-kHz carrier to within 2 microseconds. Today, most FTDs are made by atomic frequency standards and referenced to a coordinated international time base. This has seen the realization of economical and reliable dissemination of frequency to within several parts per 10^{11} in a 24-hour period.

VLF single frequency comparison

An older, electromechanical VLF method is shown in **fig. 3**. It uses the principle of a servo-driven phase shifter continuously phase locking a synthesized signal from the local standard to the received VLF signal. A linear potentiometer's output, connected to a constant voltage source, generates a voltage related to the phase shifter's position. The recorder shows the amount of phase shift experienced by the local synthesized signal and whether or not it agrees with the phase of the received signal. An early instrument that used this principle was the Fluke model 207/205 VLF receiver/comparator (see **fig. 4**). A more modern piece of equipment designed for the same purpose is the Tracor model 900A VLF/LF receiver shown in **fig. 5**, which operates in the VLF band from 20 to 25 kHz, and compares the phase of a local frequency standard with the received carrier of a frequency-stabilized transmitter. With this instrument, a local standard can be checked to within ten parts per billion.

A related instrument manufactured by Tracor is the model 527E frequency difference meter, shown in **fig. 6**. This solid-state instrument measures frequency differences instantly and has a built-in meter to provide signal-quality assessment regardless of whether the two signals (the reference and signal frequencies) are the same. Since this device is used in the calibration and determination of time and frequency, it is assumed that the two measured frequencies are relatively close to one another. The 527E has a scale that determines signal difference magnitude in the parts per 10^7 to 10^{11} range. An external recorder connector on the back of the instrument is available so that the internally generated dc voltage that is produced in proportion to frequency difference can be recorded. Consequently, this instrument can be used to adjust two oscillators to the same frequency, measure frequency differences between two oscillators, offset one oscillator from another by a given amount, and determine the short and long-term drift of an oscillator.

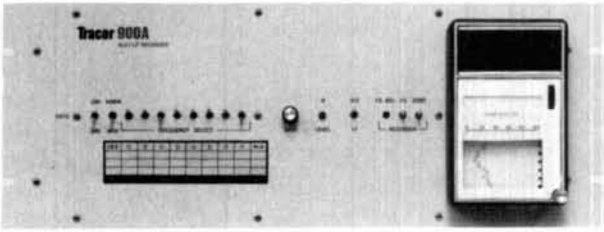

fig. 5. The Tracor VLF/LF receiver (Model 900A).

fig. 6. The Tracor frequency difference meter (Model 527E).

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fig. 7. The Tracor rubidium frequency standard, Model 308-A.

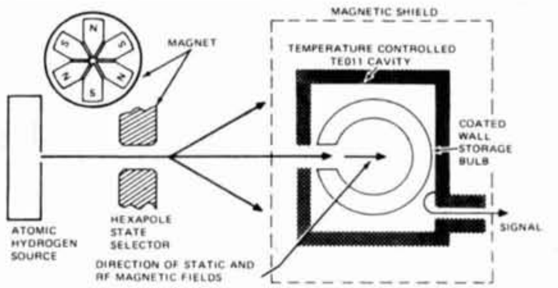

fig. 8. Diagram of the hydrogen maser.

Many labs in which extremely accurate and drift-free frequency standards are required use the Tracor 308-A to determine rubidium 87 frequency standards. This instrument, shown in **fig. 7**, is set at the factory for 10 parts per billion accuracy and has a month-long drift stability term of better than 30 parts per billion. Used in astronomy, navigation, metrology and communications, this instrument has an MTBF (mean time between failures) of better than 25,000 hours; compare this to many airborne military electronic pieces of equipment with MTBFs of less than 500 hours.

With the advent of solid-state electronics and mass production techniques these seemingly exotic pieces of equipment are not unduly expensive, considering the cost of comparable units ten years ago. The VLF/LF receiver with antenna is priced at approximately $2500; the frequency difference meter, $4800; and the rubidium 87 frequency standard, $14,500.

Why is the rubidium 87 standard so much more expensive than the others? First, let's take a look at atomic frequency standards in general.

atomic frequency standards

Atomic frequency standards employ an atomic resonance device with a frequency source such as a voltage-controlled oscillator phase-locked to it. These devices fall into two categories, active and passive. Cesium beam tubes and rubidium vapor gas cells are passive devices, whereas hydrogen masers are active devices, or resonators.

The hydrogen maser. This — the most stable of all known sources — provides a frequency that is well defined without any need for comparison with an external standard, as we have done previously. (For a quick visual explanation of the operation of the hydrogen maser, see **fig. 8**.) Unfortunately, this piece of equipment is large, expensive, power consuming, and at best suited only to laboratory use at this time. Its use is consequently limited to specialized applications requiring extreme accuracy as well as extraordinary stability. The hydrogen maser uses a beam of hydrogen atoms directed through a highly nonhomogeneous magnetic field that selects atoms in states of higher energy and allows them to proceed into a quartz bulb. Here, a tuned microwave cavity allows atoms to make random transits; the atoms reflected at each encounter within the bulb walls. While undergoing many collisions with the walls, the atoms' effective interaction times with the microwave field is lengthened to about 1 second. During this interaction process, the atoms tend to "relax" and release energy to the microwave field within the tuned cavity. This field also stimulates more atoms to radiate, and a steady-state maser reaction is achieved.

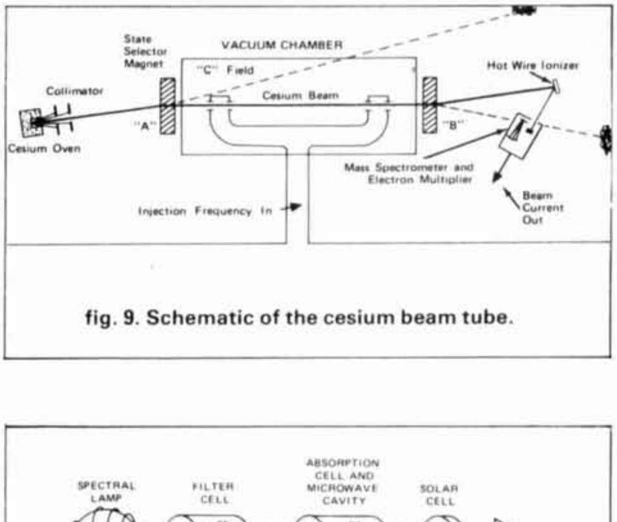

fig. 9. Schematic of the cesium beam tube.

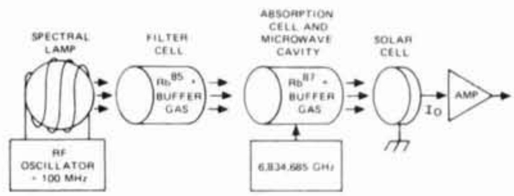

fig. 10. Rubidium vapor frequency standard assembly block diagram.

fig. 11. The Hewlett-Packard rubidium vapor frequency standard, Model 5065A.

Cesium beam standards. The basis for operation of the cesium beam standard is the Cesium 133 atom. This system yields an accurate frequency of 9,192,631,700.0000 Hz and is relatively impervious to external electric and magnetic field disturbances. (Refer to **fig. 9** for a visual explanation of the cesium beam standards.) As the Cesium 133 atoms leave the "oven," they are beamed into a vacuum chamber, where they are subjected to excitation by microwave energy. For frequency control, the atoms are made to perform a resonant absorption of energy from the microwave signal; after passing through a second magnetic field, they are deflected toward a hot-wire ionizer. The atoms are then passed through a mass spectrometer that detects and helps remove any contaminants that could otherwise cause random electrical noise bursts. Ion current is converted to electric current by the electron multiplier, and the amplified current is passed through signal processing electronics, which in turn regulates the frequency of a voltage-controlled oscillator. The oscillator's output frequency is multiplied and fed back again to the cesium beam through a waveguide that closes the loop and provides feedback control.

Rubidium vapor standards. Rubidium vapor standards, like cesium beam standards, employ a passive resonator to stabilize a quartz oscillator. Rubidium standards, however, are not self-calibrating and must therefore be checked against a cesium standard during construction. But once built, they are relatively small and are easily transported. Operation (see **fig. 10**,) is based on the principle of the containment of rubidium vapor and an inert buffer gas in a cell illuminated by a beam of precisely filtered light. A photodetector monitors changes, near resonance, in the amount of light absorbed as a function of applied microwave frequencies. The microwave signal is derived by multiplication of the quartz oscillator frequency. Resonance frequency is influenced by the inert buffer gas pressure. This is why rubidium must be calibrated against a cesium reference standard. The Hewlett-Packard model 5065A, shown in **fig. 11**, is one rubidium vapor frequency standard. It exhibits an extremely low drift-rate of less than 10 parts per billion per month and a short-term stability of better than 5 parts per billion averaged over a 1-second period.

time standards

As stated previously, time and frequency are reciprocal quantities; therefore, in order for one to be accurate, its counterpart must likewise be accurate. But how is time precisely defined? This discussion examines several methods and demonstrates the inherent inaccuracies of each.

In 1958, **Ephemeris Time (ET)** based on orbital motion of the earth about the sun at the beginning of the year 1900, was established. But this is a difficult method, and comparisons to ET are impractical. In 1964 the General Conference of Weights and Measures tentatively adopted the "atomic second" based on the number of transitions of the Cesium 133 atom. The standard was fully adopted in 1967.

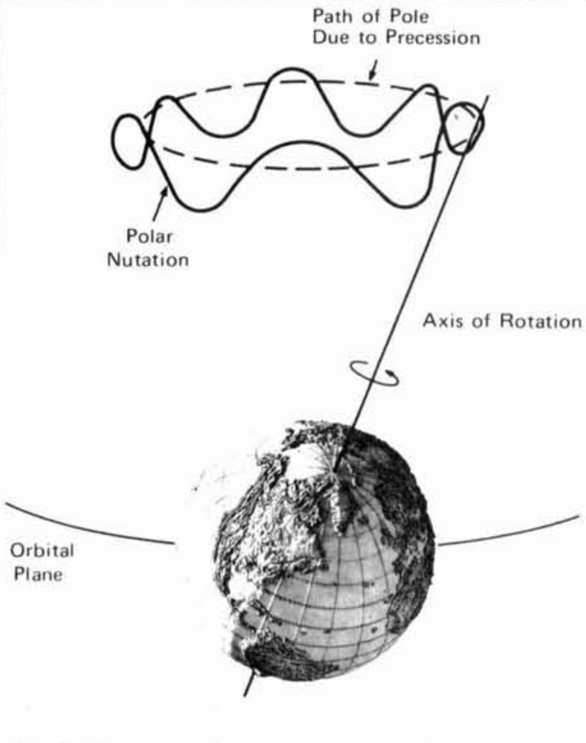

fig. 12. The seasonal wavy motion on the circular path of precession of the Earth's orbit.

table 3. National Laboratories collaborating with BIH.

abbreviation	laboratory	atomic standards qty.	mfr.	type
DHI	Deutsches Hydrographisches Institut, Hamburg, West Germany	1	HP	Cs Std
F	Commission National de l'Heure,	11	HP	CS Std
	Paris, France	1	HP	CS Tube with lab electronics
FOA	Research Institute of National Defence, Stockholm, Sweden	2	HP	Cs Std
IEN	Instituto Elettrotecnico Nazionale, Torino, Ittaly	4	HP	Cs Std
IGMA	Instituto Geographico Militar Buenos Aires, Argentina	1	E	Cs Std
ILOM	International Latitude Observatory, Mizusawa, Japan	1	HP	Cs Std
MSO	Mount Stromlo Observatory Canberra, Australia	1	HP	Cs Std
NBS	National Bureau of Standards,	8	HP	Cs Std
	Boulder, Colorado	1	LAB	Cs Std
NIS	National Institute for Standards, Cairo, U. A. R.	1	HP	Cs Std
NPL	National Physical Laboratory	4	HP	Cs Std
	Teddington, U. K.	1	Lab	Cs Std
		1	Hydrogen Maser	
NPRL	National Physical Research Laboratory, Pretoria, South Africa	1	HP	Cs Std
NRC	National Research Council of Canada,	3	HP	Cs Std
	Ottawa, Canada	1	Lab	Cs Std

Apparent solar time is based on the rotation of the earth about its axis with respect to the sun. There are problems with this system because its unit of time derived would be valid only if the sun were to reappear over a fixed point of observation at uniform intervals; of course, it does not. Additionally, there are irregular variations in the rotational speed of the earth and the earth's orbit is elliptical, not circular (see **fig. 12**). The orbital plane, therefore, does not coincide with the plane of the equator. (Then too, the orbital speed of an object whose path describes an ellipse is constantly changing.)

Mean solar time is simply apparent time averaged to eliminate variations due to orbital eccentricity and the tilt of the earth's axis. In a leap year, we should have 365.25 days per year. But actually, we have 365.2444 mean solar days.

Universal time, as with mean solar time, is based on the rotation of the earth about its axis; the units UT were chosen so that on the average, local noon would occur when the sun was on the local meridian. The problem with this system is again that the rotation of the earth is not constant.

Coordinated universal time is corrected universal time which involves the frequency of a precision universal oscillator such as a cesium or rubidium clock being offset from its nominal frequency by an amount which allowed for the clock rate to be nearly coincident with UT_2. (UT_2 is a type of universal time that uses correction factors for seasonal variations in the rotation of the earth.) On January 1, 1972, the UTC system was improved to allow UTC time to accumulate at the same rate as International Atomic Time and therefore eliminate the problem of operating systems adding offsets such as the so-called "leap second" that is added each year.

Laboratories that collaborate with the Bureau International de l'Heure (BIH), the French equivalent of our NBS (see **fig. 13**), are listed in **table 3**. In addition to the three hydrogen masers listed, it is likely that the U.S.S.R. has at least one maser, although this information is hard to obtain.

There are other systems, including apparent sidereal time, and mean sidereal time, but it is sufficient to say that these herculean attempts to establish accurate time intervals are made so that somebody can have an oscillator that is *truly* fine-tuned. Seriously though, if this area of time-keeping seems fascinating to you, as it does to me, then you may want to obtain map No. 76, depicting worldwide time zones, from the U. S. Navy Defense Mapping Agency.[1] You may also wish to be placed on the mailing list of the *NBS Time and Frequency Services Bulletin* issued monthly by the Time and Frequency Division of the National Bureau of Standards.[2]

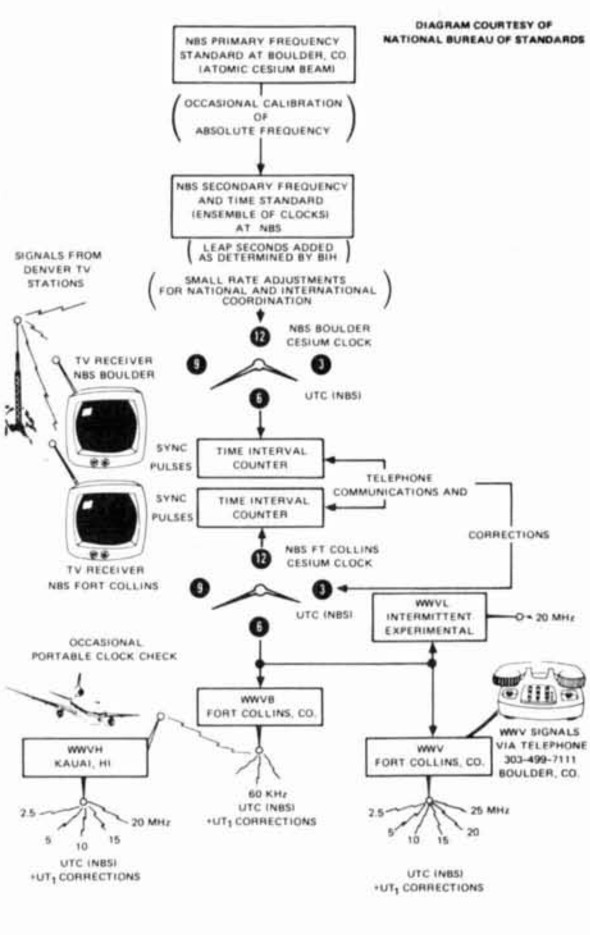

fig. 13. National Bureau of Standards frequency and time facilities.

acknowledgments

I would like to thank P. K. Weir of Hewlett-Packard and Lupe Lopez and Dick Rogers of John Fluke Mfg. and their respective companies as well as Tracor, Inc., for providing technical assistance and artwork for this article.

references

1. Address requests to MC2 Sales, U. S. Navy Defense Mapping Agency, Hydrographic Center, Washington, D. C. 20390. Enclose check or money order for $5.00.
2. Frequency-Time Broadcast Services Center, Time and Frequency Division, National Bureau of Standards, Boulder, Colorado 80302.

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Sprang, Steve, *Calibration-Philosophy in Practice*, Application Note, John Fluke Manufacturing Co., Inc.

Fundamentals of Time and Frequency Standards, Hewlett-Packard Application Note 52-1, October, 1974.

Timekeeping and Frequency Calibration, Hewlett-Packard Application Note 52-3, August, 1974.

ham radio

Clean up the computer clutter.

For less than $250 you can make your investment in yourself pay off!

Chances are you have spent a couple thousand dollars on setting up a computer system that gets a lot of your work done. But sometimes it gets to be work to work at it.

I know that when I have to move two program manuals and a pencil holder to boot up the disk drive, it is work. When there is an unlabeled floppy (that I am going to identify some day) on top of the monitor and the business checkbook is on top of the printer . . . and I will remember (I hope) before the next "report" comes through . . . that is work.

MICRO-OFFICE WORK CENTER

I found the annoyance of my own "computer clutter" was even worse than the extra work the disorder created. And that is when I started looking for some practical furniture for my computer set up. Since I had already spent a lot of money on the system itself, I was really dismayed when I found out how much it would cost to get a decent-looking desk or even a data table for my equipment. $400 . . . $500 . . . even more for a sleasy unit that looked like junk! In fact, it was junk! And it took a long time for me to find something that was really worth the money . . . and more.

A lot of my working day is spent with my computer, and I will bet a lot of your time is too. So I figure a "home" for my system—a housing that is good looking as well as efficient to work at—will pay off two ways:

1. Less work: an efficient and orderly layout will save me time and energy.
2. Personal satisfaction: good quality furnishings look better; they just plain feel better to work at too.

So imagine how good I felt to find the "Micro-Office" Work Center! These are fine pieces of computer system furniture that make my office-at-home as pleasant a place to work as it ought to be. And the biggest and best surprise is the low, low price for such good quality.

Here is what you get—all for only $249.50 plus shipping.

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Combine a scope and an NE555 multivibrator to build an important diagnostic tool

a time domain reflectometer

Before I describe how to build a TDR and discuss how it works, consider this simple example of the theory behind time domain reflectometry. Assume you're standing some distance away from the front of a large building. Yell, and you'll hear your echo. If you know the speed of sound and measure the time it takes between your initial call and the return of your echo, you can determine the distance between yourself and the building. Just multiply the speed of sound by the time it took for you to first hear your echo and divide by two. (You divide by two because the sound wave goes to *and* from the building; all you need to know is the distance in one direction.)

Suppose, now, that you get a call from the local repeater group saying the repeater cannot be heard. They believe the malfunction is in either the transmission line or the antenna, but they're not certain which it might be. With a time domain reflectometer, you can tell whether the problem is in the antenna or the line — and if the trouble is in the line, approximately where it is.

By sending a pulse or transition of levels down a transmission line, and then observing the reflected signal, you can determine whether the transmission line is open, shorted, or terminated by some value of resistance. If the termination resistance is different from the characteristic impedance of the line, its value can also be approximately determined.

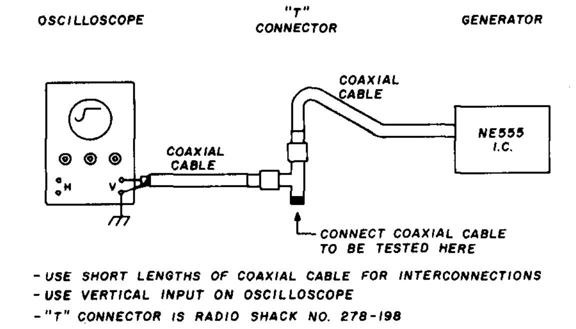

fig. 1. Equipment needed to develop a time domain reflectometer.

setting up

The test setup is illustrated in **fig. 1**.

The more accurately you measure the time, the more accurately you'll be able to locate the fault in the transmission line or antenna. Consequently, your oscilloscope should be capable of measuring time periods down to 0.1 μS and have a reasonably accurate time base. The bandwidth of the scope is not critical, but should be at least 5 MHz. Vertical sensitivity is relatively unimportant; any scope capable of measuring video signals should be adequate.

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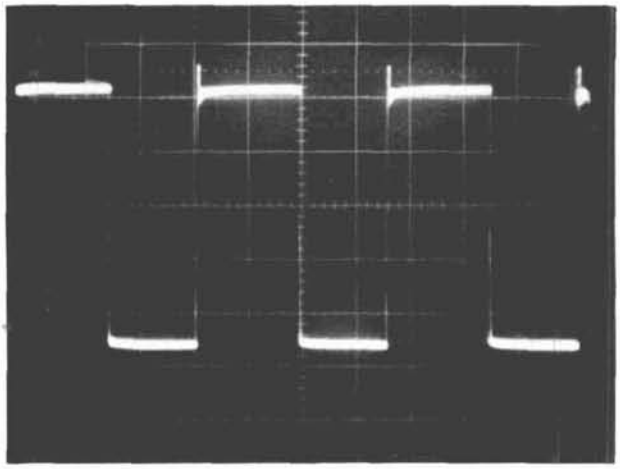


fig. 2. Output of an NE555 multivibrator. Horizontal deflection is 5 microseconds per centimeter.

Some scopes have a terminal marked "Gate Output," a pulse that coincides with the sweep time; this can also be used to provide the signal. It is important, however, that the scope output have the same impedance as the line you want to measure.

A 555 IC wired as an astable multivibrator provides the pulse train as it oscillates at a frequency of 60 kHz (see **fig. 2**). Frequency here is not critical; if yours is slightly different, that's fine. The value of R1 in the circuit should match the impedance of the line being tested — generally 50 or 75 ohms (**fig. 3**).

This entire assembly can be built on a Radio Shack project board (No. 276-024), with a switch added for selection of either 50 or 75 ohms output.

interpreting results

If the line is properly terminated in its characteristic impedance, the trace will appear as a straight line, indicating that all of the forward signal has been dissipated in the resistance and no reflection exists (see **fig. 4**). If, however, there is a reflection and the trace goes up, this would indicate that the end of the line is either open or of higher impedance than the cable (see **fig. 5**). If the trace goes down, the line is either shorted or of lower impedance than the cable (see **fig. 6**). As an aid to remembering which is which, consider this: when measuring voltage, a short (or low impedance) lowers the voltage and an open allows the voltage to rise.

To determine the location of the fault, you must measure the time between the initial pulse and the pulse caused by the problem. The speed of radio waves in free space is 983.5 feet per micro-second, so if you multiply the time it takes by the speed of light, the result will be the distance to the fault in feet. However, because the radio wave is slowed by the velocity factor of the coax, you must therefore multiply the previous distance by the velocity factor and then divide by two to determine location of the malfunction.

Perhaps the method will be clearer if we look at an example. Suppose we have a piece of RG-213, with a velocity factor of 0.66. A problem exists at a point that measures 0.3 μS down the line. The distance to the malfunction is the speed of radio waves multiplied by the time (983.5 × 0.3) = 295 feet. Correc-

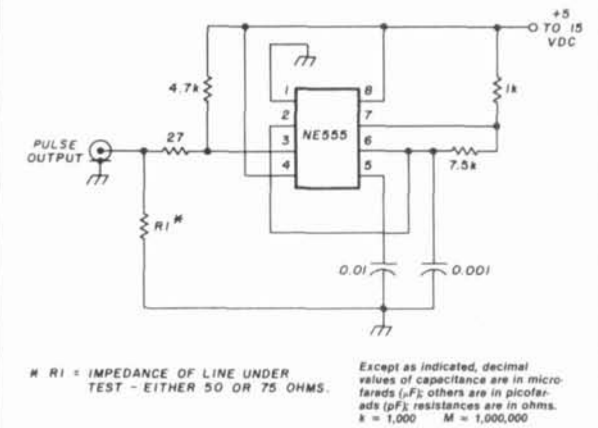


fig. 3. Schematic diagram of an NE555 astable multivibrator used in the time domain reflectometer.

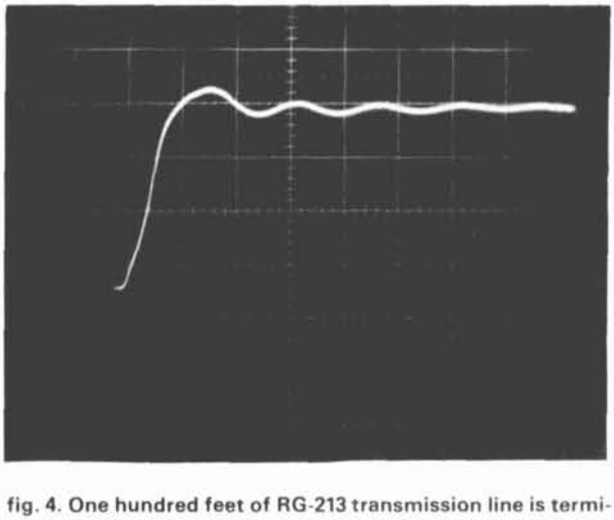


fig. 4. One hundred feet of RG-213 transmission line is terminated in 50 ohms. Note the basically flat response after the pulse arrives.

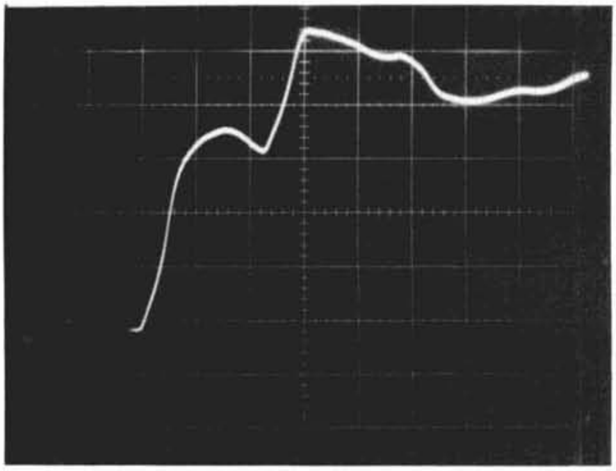


fig. 5. One hundred feet of RG-213 is now pulsed while an open exists at the far end (load end). The rapid rise in pulse height marks the location of the "fault" (open circuit). Horizontal deflection is 0.1 microseconds per centimeter.

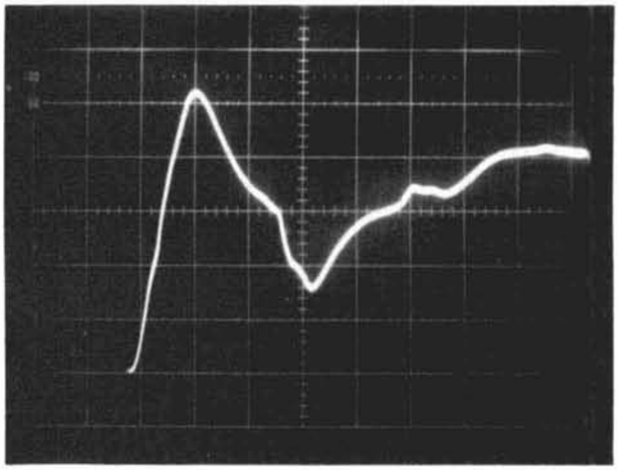


fig. 6. The same length of RG-213 is pulsed while a short exists at the free end. The rapid drop in pulse height marks the location of the "fault" (short circuit). Horizontal deflection is 0.1 microseconds per centimeter.

ting for the velocity factor, we multiply 295 feet by 0.66 to obtain 194 feet. Since this is the total distance the signal traveled, dividing 194 by two determines the distance from the measuring point to the fault. In this case the distance is 97 feet.

I have prepared a graph (**fig. 7**) showing the distance in feet versus the time to the problem, on which the result can be read directly in feet. There are two lines, each representing a different velocity factor; the top line represents transmission lines with a velocity factor of 0.80, which is typical of foam-filled lines, and the bottom one, a velocity factor of 0.66, which would include coax such as RG-8, RG-58, and RG-213.

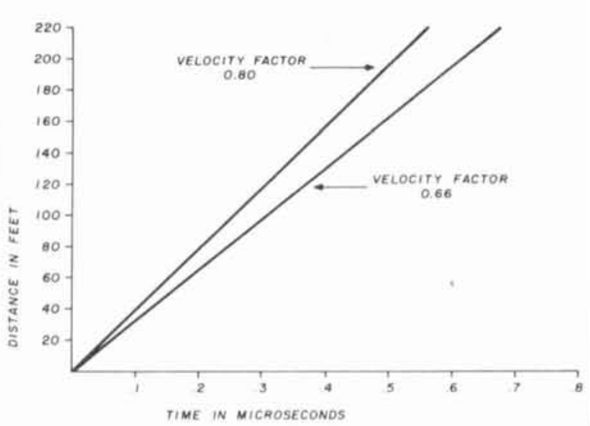


fig. 7. Chart enables rapid determination of the distance to a "fault" if elapsed time is known. Two cables with different velocity factors are considered.

conclusion

If your oscilloscope doesn't have a calibrated time base you may still be able to employ this method by using a section of cable of a known length and then expressing the unknown cable in lengths of the known one. If a 100-foot cable takes 0.3 μS to indicate a problem, then a measurement of 0.6 μS would indicate a cable 200-feet long. (Be sure the cables you use have the same velocity factor; if they don't, the comparison will not be valid.)*

If you want to measure cables that are less than 40 feet in length, the task becomes rather difficult because of the extremely short times involved. In this case it would be desirable to add a 100-foot section of coax and then subtract 100 feet when you are calculating the distance.

Now back to that phone call from the repeater group. By taking the TDR you've built from a scope and an NE555 multivibrator to the base of the tower — and keeping the principles of time domain reflectometry in mind — you'll be able to tell the climbers roughly where and what the problem is.

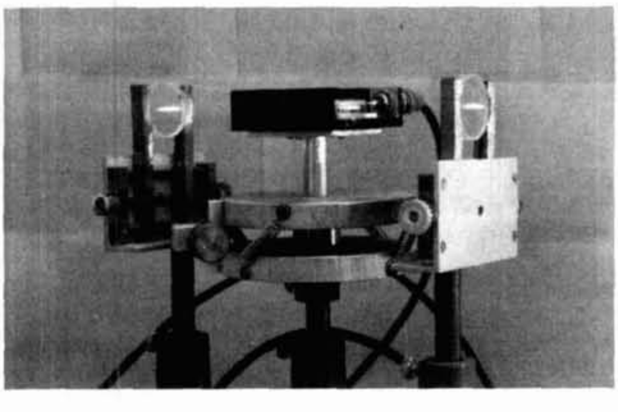
ham radio

*Even if the velocity factors differ, the fault can still be located as long as the ratio of velocity factors is known. While this method cannot be used to measure complex impedances, it is useful in determining problems along the line. Keep in mind that the antenna at the end of the line may be either open or shorted; this wouldn't be a fault on the line itself. **Editor**

construct an optical FM receiver

"See" the entire FM band and detect each station independently and simultaneously

The ability to see — instantaneously — and detect *a wide band of frequencies* is possible using an electro-optical technique known as Bragg cell operation.[1,2] A receiver providing this performance consists of an acoustic medium such as a slab of glass, a transducer bonded to the glass, a light source, optical elements and associated RF drive circuits.[3] What is achieved is a series of position-modulated light spots in the output (plane), each representing a separate station with its own information content. The practical result of this device is an FM receiver achieving 200 kHz resolution, sufficient to separate and detect all FM band stations.



Low-light photograph shows lateral width of light beam traversing Bragg cell.

Bragg cell operation can be understood in terms of a few physical concepts. An RF signal when applied across the terminals is transformed into a traveling acoustic (sound) wave in the cell. The pressure in the sound wave creates a traveling wave of rarefaction and compression in the glass medium which in turn causes analogous changes in the index of refraction. The Bragg cell, as shown in **fig. 1**, acts as a phase diffraction grating with an effective grating line separation equal to the wavelength of sound Λ (which is related to the wavelength of the RF-injected signal). The deflection angle ϕ_d (measured outside the cell) between the incident and the first order light term equals

$\frac{\lambda_o}{\lambda} = (\lambda_o \bullet f/V_s)$ where f is the frequency and V_s the sound velocity.

Incident light is most efficiently diffracted when the incident angle equals $1/2 \bullet \frac{\lambda_c}{\lambda}$ where λ_c refers to the center of the band. This angle, ϕ_B, known as the Bragg angle, may also be written as:

$$\phi_B = \lambda_o f_c / 2V_s \qquad \textbf{(1)}$$

where f_c is the center frequency, and
V_s is the sound velocity

This design uses a Bragg cell made of glass ($V_s = 4000$ m/second and the light source is a He-Ne laser [$\lambda_o = 6328\mathring{A}$ (Angstrom unit)]. Substituting these values in **eq. 1** shows that the Bragg angle is equal to:

$$\phi_B = 7.91 \times 10^{-5} f_c\,(MHz)\ radians,\ or$$

$$\phi_B = 4.53 \times 10^{-3} f_c\,(MHz)\ degrees \qquad \textbf{(2)}$$

Denoting the incident angle by ϕ_B, the Bragg cell operation can be represented as shown in **fig. 1**. All

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The University of Iowa, Department of Electrical & Computer Engineering, Iowa City, Iowa 52242

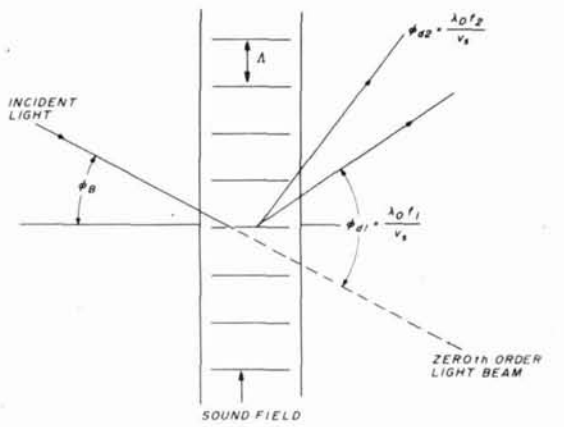


fig. 1. Bragg cell shows relationship between incident and diffracted light rays.

angles have been exaggerated for clarity. The Bragg cell diffracts light rays into angles controlled by spectrum of acoustic frequencies f_i, where $i = 1,2$, etc. This acoustic spectrum is identical to the frequency spectrum of the electrical signal. Though Bragg cells exhibit limited bandwidth, this design is sufficiently wide to accommodate the entire FM band.

system configuration

By definition, an electro-optical receiver contains both electronic circuits and optics (see **fig. 2**). The electronics are used as the input and output stages of the system with an optical medium in between. The input stages "condition" the received signal, providing compatibility with and driving the optics interface. The input stage electronics consists of an FM low-level amplifier, balanced mixer, local oscillator and RF power amplifier. Specifically an FM signal is amplified in the low-level stage (using a Radio Shack FM amplifier), mixed with a local oscillator in the HP 10514A mixer, and further amplified by the RF power amplifier (Intra-Action EE-40), achieving a power level of 1-2 watts necessary to drive the Bragg cell. Since the Bragg cell (Intra-Action ADM-40) is tuned for operation at 40 MHz, with an effective bandwidth of 40 MHz, it is necessary to translate the FM band (center frequency 97 MHz) down to this center frequency. This is accomplished by mixing with a 57 MHz local oscillator. In addition, the associated Bragg angle for 40 MHz, according to **eq. 2**, is 0.181 degrees.

The optics, shown in **fig. 2**, include four lenses, two of which are identical spherical converging lenses (L2 and L3, having a focal length of F2 ≅ 20 cm) and two are identical cylindrical lenses (L1 and L4, having a focal length of F1 ≅ 3 cm). The optical processing which precedes the Bragg cell is intended to spread the beam laterally (i.e., in the plane of the paper) which, for reasons to be explained later, en-

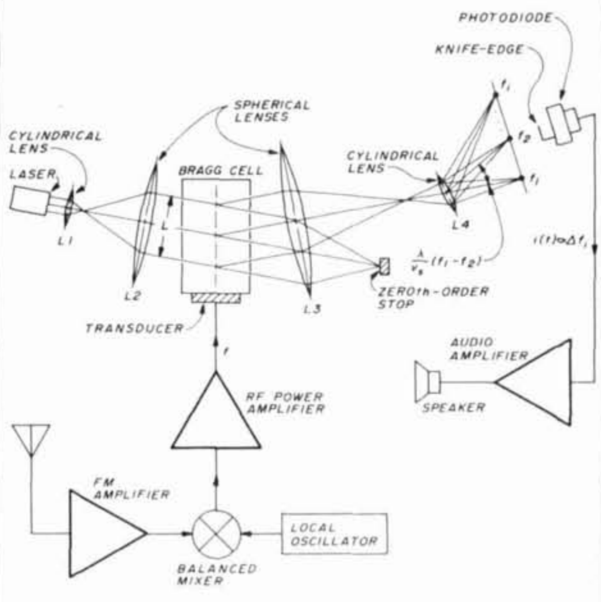
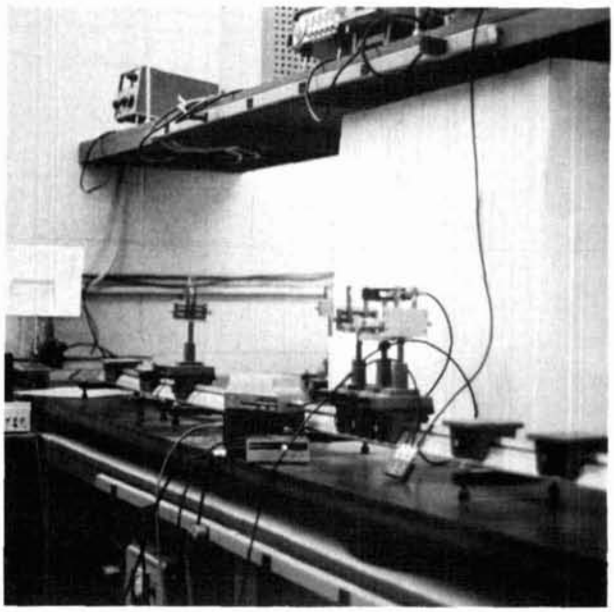
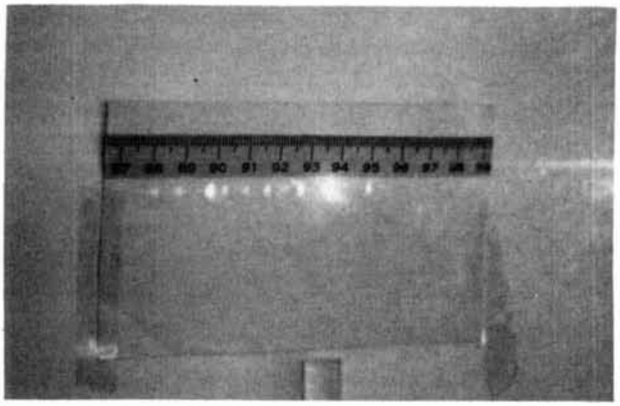


fig. 2. FM optical receiver block diagram.



Completed optical FM receiver.



Separated laser spots, each representing a different FM station. Large spot at right is zeroth order beam, schematically represented in *fig. 1*.

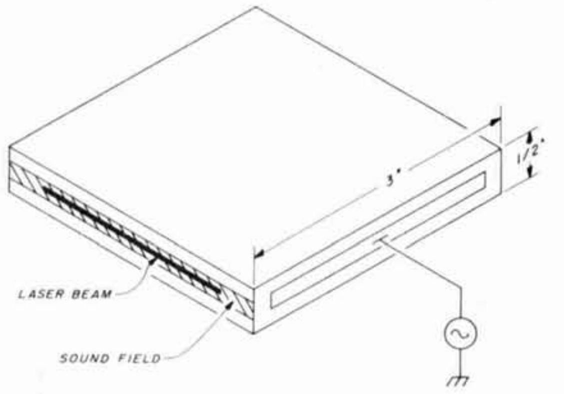


fig. 3. Acousto-optic Bragg cell with laser beam and sound field illustrated for clarity.

hances the frequency resolution. This situation is shown in **fig. 3**, and in the photograph above. The sound power is concentated in the cell along the center with a height of approximately 2 mm. Consequently, in order not to throw power away, the beam has been expanded in one direction only; this is accomplished by using a cylindrical lens for L1 instead of a spherical lens. The laterally diverging beam which follows L1 is collimated before entering the Bragg cell with a spherical lens L2. L2 is placed a distance equal to the sum of the focal lengths, F1 + F2, away from the cylindrical lens L1 so as to form a telescope configuration. A beam of fixed lateral width L, which is controlled by the ratio of F2/F1, is incident on the cell at the Bragg angle as shown in **fig. 2**.

Each FM carrier has an independent light beam diffracted in a direction determined by the carrier frequency. For clarity, only a few of the diffracted light beams are shown in **fig. 2**. The second spherical lens, L3, is intended to focus the emerging beams in its back focal (output) plane. The second converging cylindrical lens, L4, is placed in such a way that the back focal plane of L3 is imaged in the plane of the knife edge in front of the photodiode (see **figs. 2** and **4**).

theory of operation

For the i[th] FM station the signal's instantaneous frequency is represented by

$$f_{FM_i} = f^{o}{}_{FM_i} + \Delta f_i(t) \qquad \textbf{(3)}$$

which is the sum of a fixed carrier frequency $f^{o}_{FM_i}$ and a time varying frequency difference $\Delta f_i(t)$, the latter being proportional to the audio signal. The FM variation Δf_i is small compared to the carrier $f^{o}_{FM_i}$. Using **eq. 3** the i[th] FM station is beamed, on the average, in a direction given by

$$\phi_{di} = (\lambda f_i / V_s)$$
$$\cong 1.58 \times 10^{-4} [f^{o}_{FM_i}(MHz) - f_m (MHz)] \, radians,$$
$$or \qquad \textbf{(4)}$$
$$\cong 9.06 \times 10^{-3} [f^{o}_{FM_i}(MHz) - f_m (MHz)] \, degrees,$$

where f_m is the mixing frequency (57 MHz). This is illustrated in **fig. 5**. The actual instantaneous angle of deflection deviates slightly from the above angle due to the inclusion of $\Delta f_i(t)$ which causes a 'wobble,' $\Delta\phi_{di}$, in the deflected beam:

$$\Delta\phi_{di} = 1.58 \times 10^{-4} \Delta f_i (MHz) \, radians \; or$$
$$= 9.06 \times 10^{-3} \Delta f_i (MHz) \, degrees. \qquad \textbf{(5)}$$

This relationship between the audio signal (as encoded in Δf_i) and the variation in the deflected angle is used to generate an electrical signal with an *amplitude* proportional to the strength of the signal. By placing a knife edge screen in front of a photodiode (see **fig. 6**) in the detection plane, the integrated light

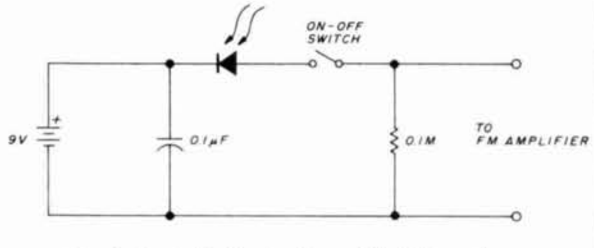


fig. 4. Photodiode circuit used in FM receiver.

intensity varies with the *wobble*, $\Delta\phi_{di}$, and hence provides a current proportional to Δf_i, i.e., proportional to the audio signal.

frequency resolution

Resolution is proportional to the lateral width of the light beam transversing the Bragg cell. The number of resolvable angles[2] for a total frequency change, Δf, is given by:

$$N = (d/V_s)\Delta f \qquad \textbf{(6)}$$

where d is the lateral width of the light beam. You may notice that (d/V_s) is the transit time of the sound as it transverses the light beam. In our case, the laser beam width is increased from 1 mm to 20 mm (2 cm), which is the lateral width L as shown in **fig. 2**. Since the full FM band (88-108 MHz) is used, Δf is then 20 MHz. Substituting the velocity of sound for glass, 4 $\times$ 10^3 m/sec in the equation, the calculated transit time, (0.02 m/4 $\times$ 10^3 m/sec), is 5 $\times$ 10^{-6} second. Direct substitution into **eq. 6** results in 100 resolvable points over the FM band or a frequency resolution of 200 kHz. Therefore all FM stations are resolvable. **Eq. 6** can be used to predict the resolution for any Bragg spectrum analyzer application.

In summary, the audio signal of the i^{th} FM station, Δf_i, results in a wobbling diffracted beam, $\Delta\phi_{di}$, which is then transferred to the electrical domain by using a photodiode positioned in the shadow of a knife edge.

where to get parts

Electronics obtainable from Radio Shack are:

Archer FM amplifier, Catalog No. 15-1122

Realistic stereo integrated-amplifier SA-102, Catalog No. 31-1963

FM antenna, Catalog No. 15-1639

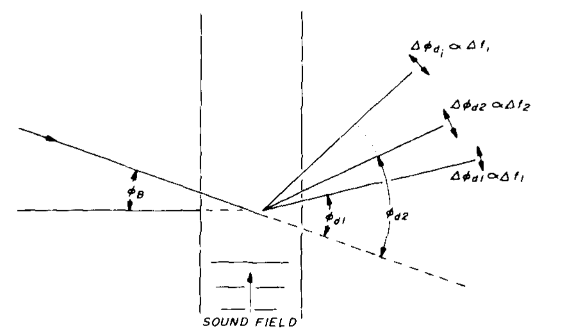


fig. 5. Diffracted beam paths that include audio signal modulation or "wobble."

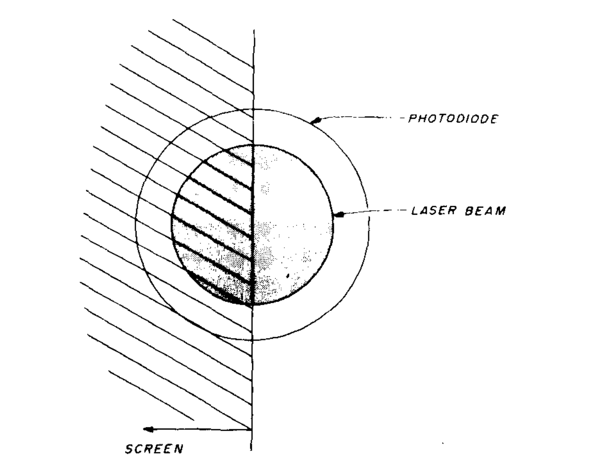


fig. 6. Knife-edge technique for the detection of wobble in diffracted light beam.

Archer color matching transformer, Catalog No. 15-1140

Realistic Minimus speaker, Catalog No. 40-1996

The following optics are available from Edmund Scientific Co., 101 E. Gloucester Pike, Barrington, New Jersey 08007:

He-Ne laser

Spherical converging lens (F $\cong$ 20)

Cylindrical converging lens (F $\cong$ 3)

The following are available from Intra-Action Co., 3719 Warren Avenue, Bellwood, Illinois 60104, telephone 312-595-3770:

RF amplifier — E-40

Bragg cell — ADM-40 or AOM-40

acknowledgments

We would like to thank Professor A. Korpel for his suggestions and critical review. The device discussed here represents an educational aspect of more fundamental research into acousto-optics supported by the National Science Foundation under grant #ECS-8121781.

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2. A. Korpel, "Acousto-Optics — A Review of Fundamentals," *Proceedings of the IEEE*, Vol. 69, #1, pages 48-53, January, 1981.
3. C. Drentea, WB3JZO, "The Bragg-Cell Receiver," *ham radio*, February, 1983, pages 42-44.

ham radio

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ham radio TECHNIQUES

Bill Orr W6SAI

I met Pat Hawker, G3VA, some years ago at an electronics trade show in New York, and since then, we've QSO'd from time to time. One of Pat's attributes is his ability to ferret out new ideas that otherwise could be lost in the noise of the day-to-day progress of the electronics world. I always enjoy reading Pat's column, "Technical Topics," in the magazine Radio Communication, *the flagship publication of the Radio Society of Great Britain.*

"absorbing yagi"

In his November, 1982, column, Pat described the "absorbing Yagi" antenna scheme of John Beech, G8SEQ. It appears that John has developed a new technique that improves the pattern of the conventional Yagi antenna, particularly in regard to the front-to-back ratio of this popular antenna (**fig. 1**). It's not difficult to achieve good gain with a Yagi; the antenna is most forgiving when it comes to adjustment and layout. The adjustment of front-to-back ratio, on the other hand, is both sensitive and crucial, and will vary greatly from one installation to the next. G8SEQ has achieved very high front-to-back ratios by the addition of a new element to the Yagi, which he calls an *absorber element*. He reports ratios as high as *75* dB for a 13-element VHF array!

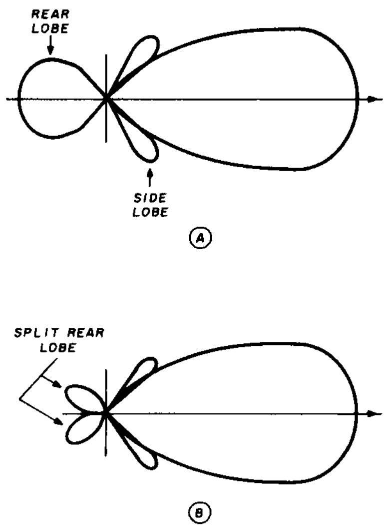

fig. 1. (*A*) Representation of field plot of a conventional Yagi showing side and rear lobes, and (*B*) Plot of "absorbing Yagi" showing reduction of unwanted lobes. The deep null to the rear of the array can be maximized by "fine tuning" the absorber element.

As the name suggests, the absorber element absorbs energy that would otherwise be radiated to the rear of the array. In its simplest form it is an extra dipole element, resonant at the operating frequency of the Yagi, with a resistor placed at its center. The resistance is approximately equal to the center impedance of the driven element (**fig. 2**).

The absorber adjustments consist of varying the spacing to the reflector and adjusting the value of the center resistor until optimum front-to-back ratio is observed. If the Yagi has a reasonable front-to-back ratio to begin with, an absorber resistor power rating of 25 watts will suffice even at full legal power.

According to Hawker, "G8SEQ suggests that one can regard the Yagi array as a directional bandpass filter, and that the absorber is the element that has been missing for years. With the same thinking now sometimes being applied to absorptive lowpass TVI filters, the unwanted RF is safely dissipated in a dummy load rather than attempting merely to 'short circuit' it with a reflector."[1]

While no specific dimensions are given, G8SEQ suggests that the absorber element be self-resonant at the operating frequency and placed about 0.23 wavelength behind the re-

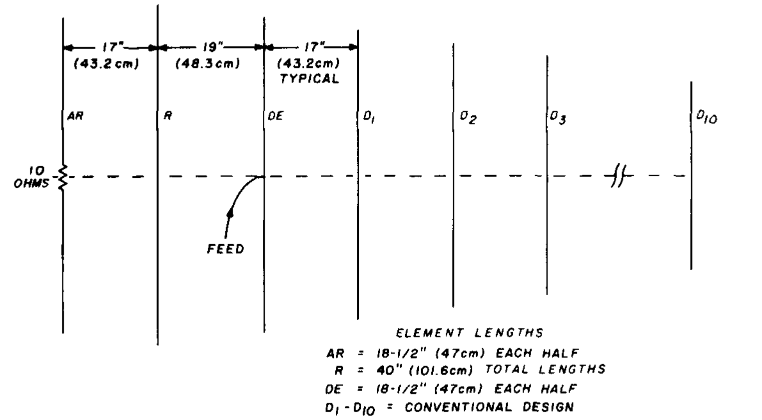

fig. 2. The G8SEQ absorbing Yagi for 144 MHz. The 12-element beam has conventional dimensions plus the addition of an absorber element 17 inches behind the normal reflector. Absorber has same dimensions as driven element. Elements are made of 3/8-inch diameter tubing.

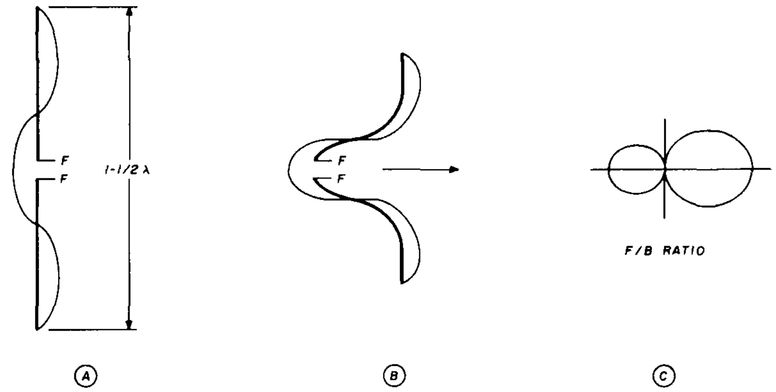

fig. 3. (*A*) Representation of current distribution on 3/2-wavelength dipole, and (*B*) optimum-shaped dipole. (*C*) Current distribution in modified dipole causes radiation to increase in forward direction.

flector and that the center resistor be about 10 ohms, noninductive. I would guess that less spacing could be used, provided absorber length and resistance were varied.

I think this is a good idea and I would be pleased to hear from any experimenters who try this novel technique. In today's world of heavy interference, antenna front-to-back ratio may be of more importance than antenna gain.

optimum-shaped antenna element

For some time I have heard about a new antenna element design that provided increased gain and improved operating characteristics. Again, Pat Hawker tracked it down and described it in his November column. The antenna, discussed at an International Conference on Antennas and Propagation in London in 1979, was developed by F. M. Landstorfer at the Technical University in Munich. Further work was done on the antenna by Cheng and Liang of Syracuse University in 1982.

For many years it was assumed that the "building block" of a beam antenna was a straight dipole element about a half-wavelength long. Landstorfer investigated the use of 3/2-wavelength element, curved in a specific manner, to provide forward gain and directivity (**fig. 3**). Landstorfer's element has a forward gain of about 5 dBi.

The main disadvantage of this idea is simply the larger size of the basic element. Even so, this is compensated for by the fact that far fewer elements are needed to obtain equivalent gain.

A three-element Yagi using this technique (**fig. 4**) was tested. The gain was measured at 11.5 dBi (about 9.4 dB over a dipole), with a front-to-back ratio of 26 dB. Sidelobe attenuation was better than 20 dB.

G3VA points out that the optimized shape of the elements is related to element diameter, and until more specific information is available, the cut-and-try technique is recommended for those wishing to experiment with this novel antenna.

the terminated, traveling-wave antenna

A final note before we leave Pat Hawker, G3VA. Pat wrote about an interesting antenna development originally described in the *IEEE Transactions on Antenna and Propagation*,[2] by Matsuzuka and Nagasawa of Nihon University (home of the famous Dr. Yagi of Yagi antenna fame), Tokusuda, Japan. Matsuzuka

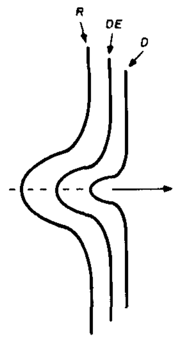

fig. 4. Top view of experimental Yagi using gain-optimized elements, each approximately 3/2-wavelengths long. VHF array of this design provided 11.5 dBi gain and a front-to-back ratio of about 26 dB.

and Nagasawa described a rectangular loop antenna, fed at the center of one side and terminated with a resistor placed in the opposite side (**fig. 5**). The loop provides a unidirectional pattern with the approximate dimensions shown. A very high (unspecified) front-to-back ratio is achieved over a significant bandwidth. Dimensions and resistor value are relatively non-critical.

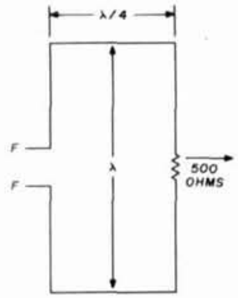

fig. 5. The terminated, traveling wave loop antenna provides good directivity, front-to-back ratio and bandwidth. Value of terminating resistor is not critical. RF energy reaching far end of antenna is dissipated in the resistor rather than being reflected back to the feedpoint. Wattage rating of resistor is equal to about one-half the power output of the transmitter.

VCR RFI: more problems for hams

I've heard that some Amateurs are experiencing RFI problems with their transmissions interfering with video cassette recorders (VCRs). I have a VCR myself, and have had no problems with it, perhaps because I'm not on the air when I'm watching it. However, I would appreciate hearing from any readers who have had VCR RFI and solved the problem (if they did). I have also heard that video disc recorders are RFI-prone, especially to signal in the region of the forthcoming 800 MHz Amateur band and the forthcoming mobile communication band.

As solid-state electronics invades our lives more and more, the RFI problem will become more severe. Unfortunately, even though Public Law 97-256 requires manufacturers to produce RFI free equipment, the FCC favors voluntary standards, rather than imposed standards. This leaves the door wide open to abuse and circumvention of the law, leaving the Radio Amateur to take the blame for RFI caused by poorly designed products.

the 4-1000A linear amplifier

There's a considerable amount of interest in using the 4-1000A tetrode as a cathode-driven, linear amplifier, and it is a popular tube for "home brew" equipment. In grounded grid service, the tube will operate well at plate potentials between 3 and 5 kV and can easily provide up to the legal 1.5 kW PEP output limit. Typical operation of this tube at 3 kV is as follows:

DC plate voltage	3 kV
zero-signal plate current	55 mA
single-tone plate current	700 mA
single-tone grid current	275 mA
single-tone driving power	120 watts
load impedance	2350 ohms
driving impedance	104 ohms
plate input power	2100 watts (PEP)
useful output power	1320 watts (PEP)
3rd order distortion	−34 dB
5th order distortion	−36 dB

Note: Single-tone grid current is sum of grid one and grid two currents. Useful power output is power delivered to the load. Plate power output is 1500 watts PEP.

For full information on the 4-1000A and other glass tubes suited for grounded grid service, write to me at EIMAC, 301 Industrial Way, San Carlos, California 94070. (Enclose two first-class stamps or two IRCs for postage.)

Circuit design and additional information on linear amplifiers may be found in the 22nd edition of *The Radio Handbook*, published by Howard W. Sams and available from Ham Radio's Bookstore, Greenville, New Hampshire 03048.

references

1. Pat Hawker, G3VA, "Technical Topics," *Radio Communication*, November, 1982, page 959.
2. *IEEE Transactions on Antennas and Propagation*, Vol. AP-30, No. 4, July, 1982.

ham radio

More Details? CHECK—OFF Page 118

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EMI/RFI test receivers

Specialized receivers demand tighter design requirements

This article was prepared from a paper originally delivered at Electro 82, an electronic show and convention held in Boston on May 25-27, 1982. **Editor**

Many electrical devices — *from computers to hair dryers* — generate electrical noise. This noise is either conducted along power cables to other electrical devices, or radiated through the unit's enclosure, keyboard, or screen to the world outside, thereby producing interference that affects still other electrical instruments.

A receiver able to detect and measure this interference and relate it to precise (accepted) international standards must necessarily be based upon a different design than that of a communications receiver. The latter type normally covers the 10 kHz to 1000 MHz frequency range and is primarily designed to receive and decode selected transmissions. Conversely, an EMI receiver must include the following design features:

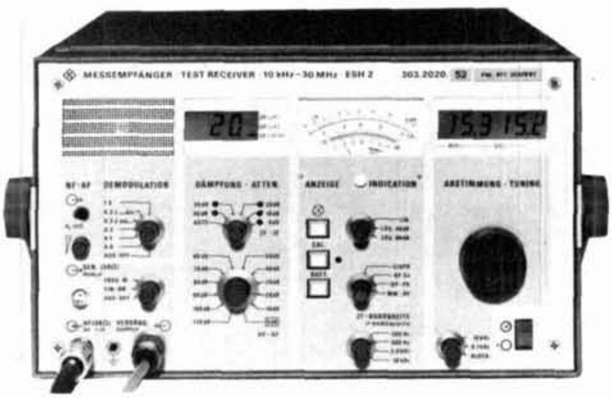


fig. 1. Manually operated EMI/RFI test receiver, type ESH. Frequency range, 10 kHz to 30 MHz.

A greater instantaneous dynamic range than that of a communications receiver, since the energy of incoming pulses can be higher than several intelligence-bearing signals or constant carriers

A circuit that monitors the maximum allowable voltage at different stages, to prevent short-term overload

Detector time constants that conform to internationally agreed-upon standards

Appropriate IF bandwidths

Precise amplitude calibration over the operating frequency range (Attainment of this normally requires the use of either a spectrum generator or tracking generator.)

If active antennas are used to measure the field in the low frequency range, they must have the *necessary dynamic range and proper antenna correction factor*.

The different requirements of test receivers and normal communications receivers will be discussed in this article, with special attention paid to the relative advantages or disadvantages of manual and automatic measuring capability.

dynamic requirements

Before specific EMI/RFI receivers — such as the Rohde & Schwartz ESH2 manually-operated

By Dr. Ulrich L. Rohde, DJ2LR, President, Communications Consulting Corp., 52 Hillcrest Drive, Upper Saddle River, New Jersey 07458

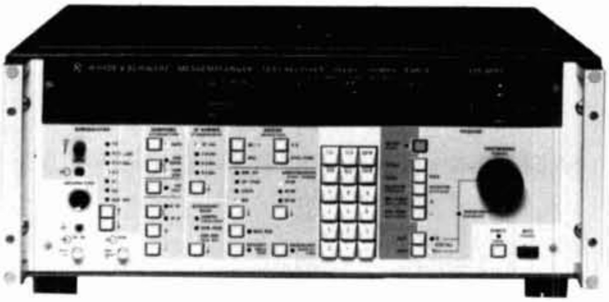


fig. 2. Microprocessor-controlled EMI/RFI test receiver, type ESH3, features built-in intelligence. Frequency range, 10 kHz to 30 MHz.

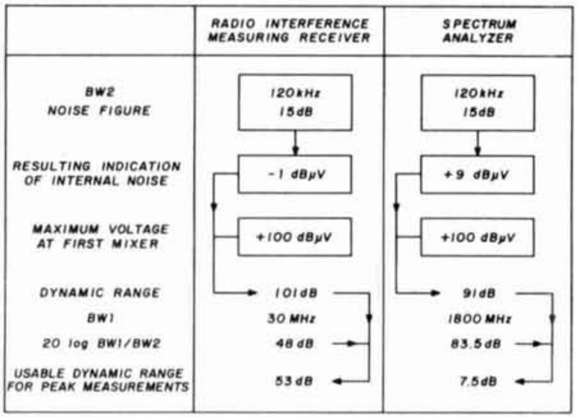


fig. 3. Comparison of EMI/RFI receiver and spectrum analyzer to evaluate usable dynamic range.

EMI/RFI 10 kHz to 30 MHz receiver (**fig. 1**) or the ESH3 computer-controllable EMI/RFI test receiver with built-in intelligence (**fig. 2**) — were introduced, spectrum analyzers were generally used to detect and characterize emitted noise spectrums. There has been some controversy as to whether spectrum analyzers that employ special "quasi-peak" detectors (CISPR/ANSI) can provide the necessary information. This is an important issue and should be clarified.[1]

The spectrum analyzer, while quite capable of rapidly providing data on CW and various sinusoidal signals, is not as suited to measure pulse spectrum parameters with the same facility. To understand why, a discussion on spectrum and bandwidth requirements is called for.

Electrical pulses of short duration possess considerable energy over a wide frequency range. When this signal is introduced into a bandpass filter, the output peak voltage (of the pulse) is proportional to the pulse bandwidth (which is approximately the 6 dB bandwidth of the filter).

$$E_{peak} \propto BW\,(6\,dB) \tag{1}$$

If a signal having a pulse spectrum is introduced into two cascaded bandpass filters with different bandwidths, $BW1$ and $BW2$ (with $BW1 > BW2$), the ratio of the output peak voltage is equal to the ratio of the filter bandwidths or:

$$\frac{E_{1peak}}{E_{2peak}} = \frac{BW1}{BW2} \text{ or,} \tag{2a}$$

$$\Delta E\,(dB) = 20 \log \frac{BW1}{BW2}\,dB \tag{2b}$$

significance of different bandwidths

Here, the question of RF preselection (input RF bandwidth) comes into play. If no preselection exists (as in the case with a spectrum analyzer), the measured output levels (analyzer and receiver) are different. Assume you are testing in the 30-1000 MHz range. Typical input filter bandwidths are

measuring receiver	$BW1 = 30\,MHz$
spectrum analyzer	$BW1 = 1800\,MHz$

Consequently, the voltage E1 presented to the first mixer of the device is 48 dB and 83.5 dB higher, respectively, than the output (indicated) voltage E2. Therefore, the narrower RF filter of the measuring receiver lowers the required mixer dynamic range by 35.5 dB (83.5 − 48 = 35.5).

Let us apply these facts to the measuring receiver and spectrum analyzer. We have assumed that each device uses the same mixer (with equal maximum input voltages), and the receiver has an approximately 10 dB lower noise figure. (This is typical, though the difference may even be greater, as in **fig. 3**.)

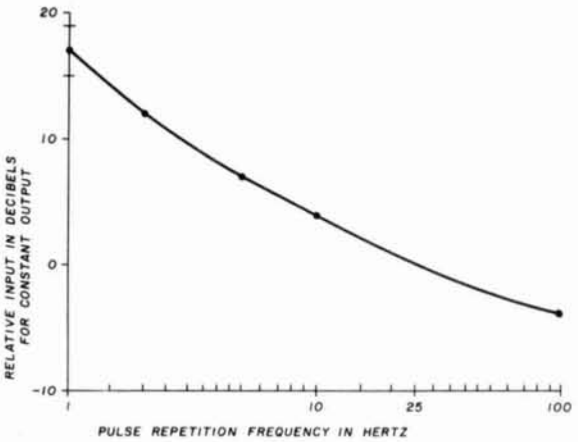


fig. 4. Pulse response curve for the frequency range 10 kHz to 150 kHz (per CISPR Publication No. 16, 1977).

Therefore, one can see that when making "peak" measurements with a spectrum analyzer the usable dynamic range is so limited that the measurement must be monitored carefully to assure the linear operation of the mixer. This can be accomplished by switching in a small amount of attenuation and comparing this value to the drop in measured output. However, this is time-consuming, and definitely not in line with the requirements for rapid automated testing.

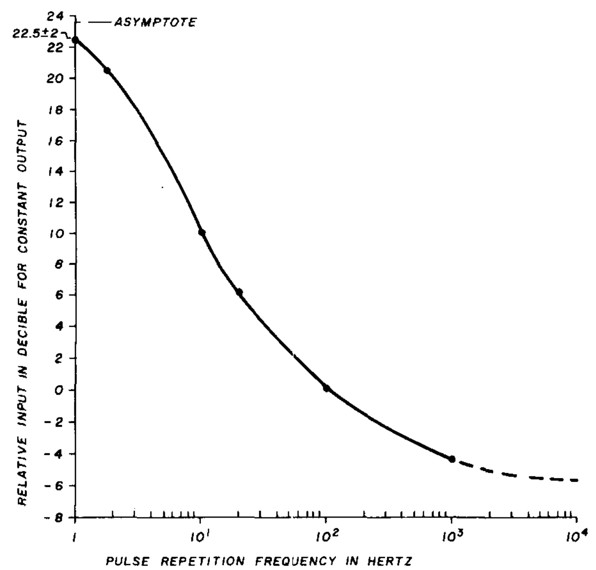


fig. 5. Pulse response curve for the frequency range 150 kHz to 30 MHz (per CISPR Publication No. 16, 1977).

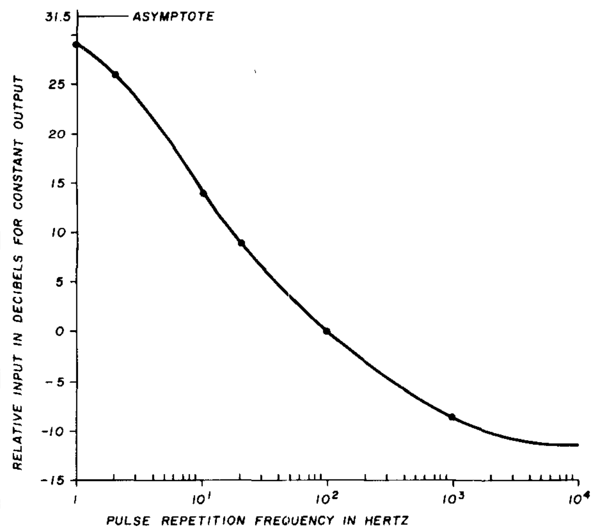


fig. 6. Pulse response curve for the frequency range 30 MHz to 1000 MHz (per CISPR Publication No. 16, 1977).

problem with quasi-peak detectors

The most serious flaw in the application of spectrum analyzers is in the use of a "quasi-peak" detector. A "quasi-peak" detector is simply a weighting network that gives a weighted indication based on the PRF (pulse repetition frequency) of the incoming pulse spectrum. (The curves for this weighting are shown in **figs. 4**, **5**, and **6**). The variation in weighting in the VHF/UHF range is 39.5 dB. It is impossible for a measuring device with a usable dynamic range of only 7.5 dB to give a correctly weighted output over a 39.5 dB range. (Remember, the weighting circuitry is at the IF, **after** the "damage" is done.)

The final conclusion is that, based on the simple physics of the measurement, it is difficult to measure pulse spectra peaks with a spectrum analyzer, and the use of "quasi-peak" circuitry at the IF of an analyzer is impossible without appropriate RF preselection. (**Fig. 7** shows overall selectivity as a function of frequency range required for the EMI/RFI test receiver to meet specifications.)

high-dynamic range required

Fig. 8 shows the block diagram of a modern RFI test receiver. It consists of an RF attenuator, a built-in calibrator, a tracking input filter, a mixer, IF stages, and the detector for demodulation, as well as the required weighting filter and rectifiers.

It becomes immediately apparent that the major difference between this block diagram and the block diagram of a typical communication receiver is the RF attenuator, the calibrator, and the lack of preamplification ahead of the mixer.

Assume that a high level double-balanced mixer is used, and that both the RF attenuator and the bandpass filter do not introduce any intermodulation distortion. In this case, the large signal performance of the receiver is determined by the mixer and the stage immediately following the mixer, most likely a termination amplifier with a crystal filter immediately following it.

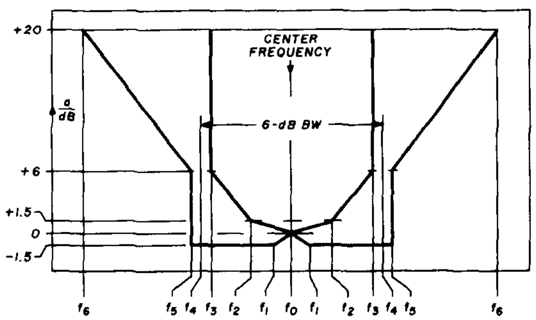
The mixer, typically a passive device, introduces 5.5 to 6 dB of loss to the next stage (an amplifier). Most likely, these two stages determine the overall *intermodulation distortion performance* of the receiver. The high level double balanced mixer and the post-amplifier probably have a +30 dBm intercept point.

The presence of the input filter not only reduces the number of signals but also improves the second order intermodulation distortion substantially, relative to a wide-open front end.

prevention of overload

The receiver can saturate if the combined signal level present at the output of the input tracking and IF crystal filters is excessive. While it may not be possible to prevent such an overload condition initially, it is important to detect the condition. The input RF attenuator can then be used to reduce the overload.

The automatic and computer controllable EMI/RFI receiver ESH3 automatically switches in the required attenuation to make sure that this overload condition does not occur while providing a 60 dB dynamic range at the IF.



RF RANGE MHz					
	MIN	0.010	0.15	30	MHz
	MAX	0.150	30	1000	MHz
$f_1 = f_0 \pm$		0.05	1	10	kHz
$f_2 = f_0 \pm$		0.05	2	20	kHz
$f_3 = f_0 \pm$		0.085	4	50	kHz
$f_4 = f_0 \pm$		0.1	4.5	60	kHz
$f_5 = f_0 \pm$		0.11	5	70	kHz
$f_6 = f_0 \pm$		0.22	10	140	kHz

fig. 7. Required selectivity of the EMI/RFI receiver as a function of frequency range.

The microprocessor-controlled receiver has its own intelligence and combines the proper RF and IF attenuation for optimum dynamic range. It is theoretically possible to increase the IF attenuation rather than the RF attenuation. As in the manually operated receiver, the two functions are not tied together, and the inexperienced operator may not be aware that the intermodulation distortion products can only be reduced by using the RF attenuator.

In order to monitor the actual overload, special detectors are placed after the mixers, because modern receivers use a first IF approximately twice the maximum receiving frequency, the first IF of the test receivers can be expected to be in the vicinity of 70 to 80 MHz. The second IF is then substantially lower (between 9 and 11 MHz), depending upon the receiver, and sometimes even a third IF (30 kHz) for the very narrow bandwidth requirements is used. This design requires two monitoring stages after the mixers to make sure no overload occurs.

time constants

EMI receivers are also distinguished by specific values of detector attack and decay time constants, with typical values being 1 and 160 milliseconds, respectively, in the 0.15-30 MHz frequency range. A good communications receiver uses totally different time constants. In the SSB/CW mode, the attack time would probably vary between 3 and 15 mS, depending upon the manufacturer, and the discharge time constant would be in the vicinity of 200 mS to 10 seconds selectable. The 1 mS attack time for the pulse receiver is too fast and will result in a "quasi-peak" reading, which for the EMI receiver is desirable

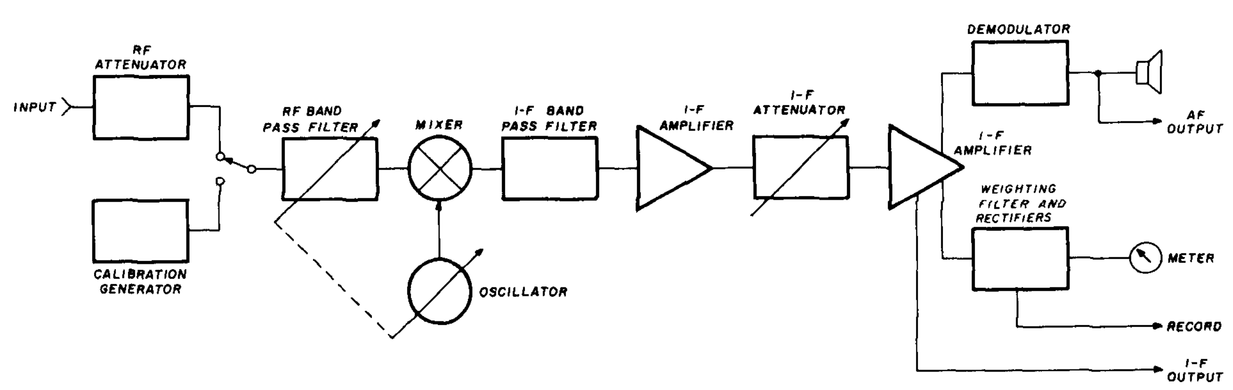


fig. 8. Block diagram of an EMI/RFI receiver.

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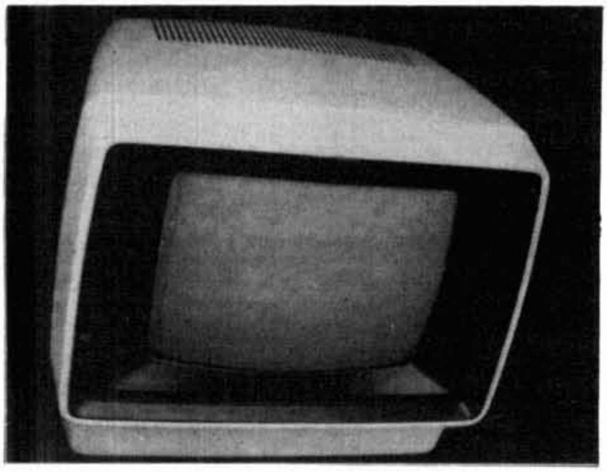

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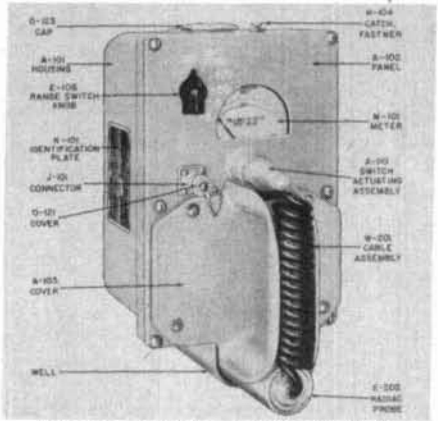

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but would lock up the AGC in a communication receiver each time an unwanted noise spike occurred.

Some manufacturers have chosen to make the EMI/RFI receivers more universal by adding built-in detectors for the communication mode as well. The ESH2 and ESH3 have this flexibility.

IF bandwidth

Special IF bandwidths are needed in EMI/RFI receivers; 200 Hz is chosen for the lowest frequency range (10 kHz-150 kHz) 9 kHz for 0.15-30 MHz and 120 kHz for 30-1000 MHz.

At 200 Hz, the bandwidth for the frequency range of 10 kHz to 150 kHz almost requires a triple conversion receiver in order to obtain narrow bandwidth with a good shape factor.

At 30 kHz, the 200 Hz bandwidth filter is more likely a mechanical filter than a crystal filter, as the cost otherwise would be prohibitive.

amplitude calibration

There are two ways to calibrate the receiver. One is to use a pulse generator, such as the ones manufactured by Schwarzbeck, (models IGM 2913, 10 kHz to 30 MHz, and IGU 2912, 25 MHz to 1000 MHz) which operate over a fairly wide pulse rate. With a calibrating pulse of 0.316 microvolts per second and a repetition frequency of 100 Hz, the frequency range of 150 kHz to 30 MHz can be covered. The particular calibration voltage should give a 0 dB reading on the meter.

Sine wave calibration is also possible. This requires a second generator which can be provided inside the instrument. The sine wave output is a good cross-reference for the calibration of the pulse generator.[2] As the calibration of the instrument depends upon these signal sources, it is important that these signal sources be built in such a way that aging effects, temperature, and voltage variations do not affect them. Modern special feedback circuits can solve this problem.

In the case of automated receivers, like Rohde & Schwarz ESH3, the built-in microprocessor, together with the random access memory, allows the development of a scanning program in which the receiver is calibrated over the entire frequency range, and the actual error is stored in memory. As measurements are made, the receiver uses a "look-up" table to add the correction factor. This is convenient because the operator does not have to worry about the accuracy of the receiver.

A manually operated receiver has to be calibrated for each major frequency change, which can be time-consuming since the values also have to be written down for future use. A word of caution: it should be remembered that the frequency synthesizer also is an

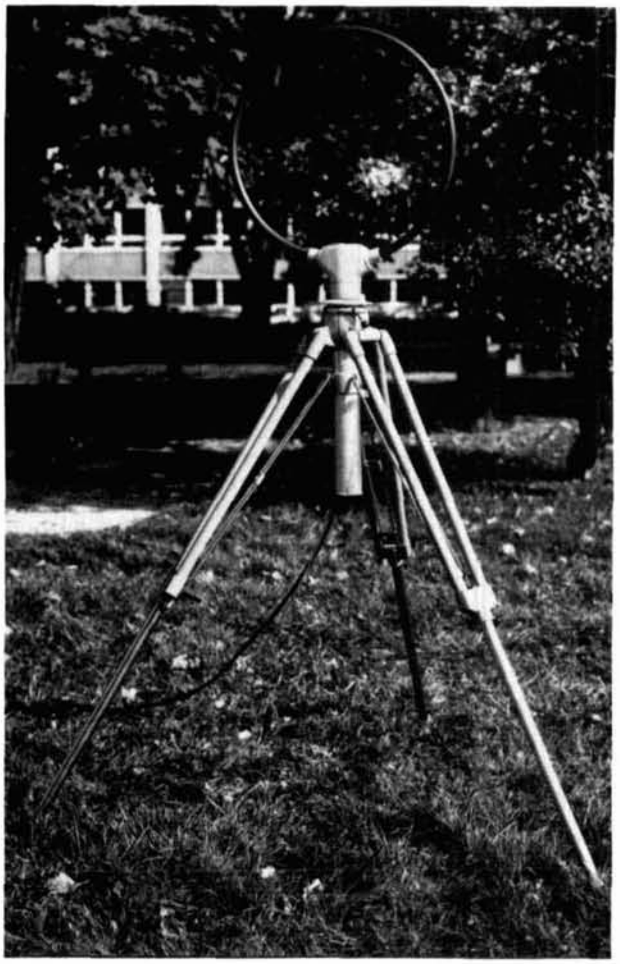

fig. 9. Loop antenna system recommended for EMI/RFI testing.

important factor in receiver performance. The noise sideband of the synthesizer and its inherent spurious performance have to be good enough to prevent any spurious frequencies or sidebands from appearing and giving erroneous readings. Therefore, the reference suppression and all mixing products have to be suppressed sufficiently.

antennas

The use of tuned antennas is rare at lower frequencies (between 10 kHz and 150 kHz). In this frequency range it is better to use loop antennas or active antennas. Again, it is important to make sure that the dynamic range of the active antennas are sufficient. While the test site has to be properly designed and reflections have to be avoided it should be mentioned here that if an active antenna is used, its dynamic range must be sufficient.

For frequencies above 20 or 30 MHz, reference dipoles or logarithmic periodic antennas may be used, depending upon the particular frequency. It would be best to look up the particular recommendations and

requirements by CISPR and VDE/FTZ. (To measure conducted interference, current probes and absorbing clamps can be connected to the receiver, but this will not be discussed here, since this article is limited to discussion of the receiver itself.)

Fig. 9 shows a loop antenna; **fig. 10** shows an active rod antenna; **fig. 11** shows a log-periodic antenna for VHF/UHF.

conclusion

The EMI/RFI receiver is a more sophisticated and, therefore, more expensive receiver than standard communication receivers. While it is possible to incorporate features to make the reception of communication transmission possible, which is useful for signal identification, then overall accuracy, special pulse response behavior, and the necessary preselector make the receiver more complicated and, thus more expensive. EMI/RFI receivers should be offered in both manual and automated versions to fit varying budgets. However, if large quantities of data must be handled, the automated version is the more logical choice.

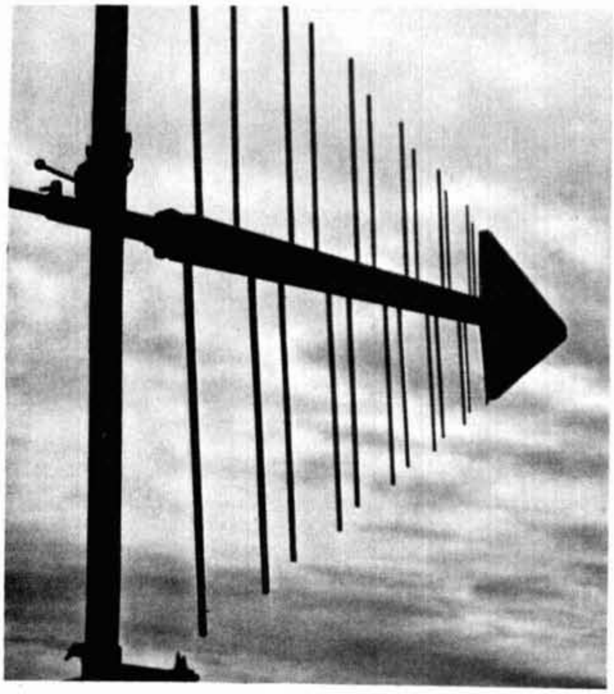

fig. 11. Logarithmic periodic antenna for EMI/RFI testing up to 1000 MHz.

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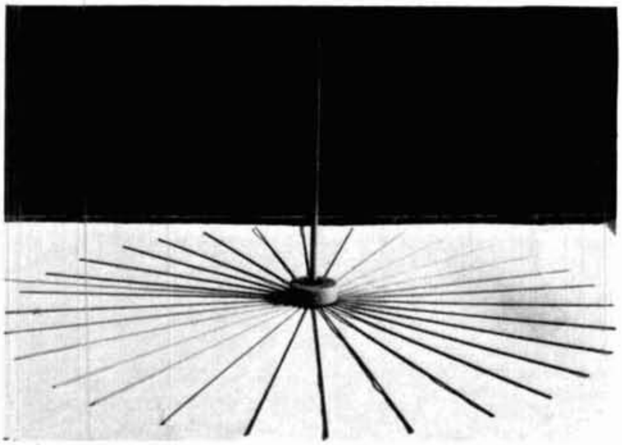

fig. 10. Rod antenna recommended for EMI/RFI testing for frequency range up to 30 MHz.

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Racal RA6790 Communication Receiver Operating & Service Manual.

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103	115	127	139	151	163	175	187	199	211	223	235	247	259	271	283	295	307	319	331	343
104	116	128	140	152	164	176	188	200	212	224	236	248	260	272	284	296	308	320	332	344
105	117	129	141	153	165	177	189	201	213	225	237	249	261	273	285	297	309	321	333	345
106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312	324	336	348
109	121	133	145	157	169	181	193	205	217	229	241	253	265	277	289	301	313	325	337	349
110	122	134	146	158	170	182	194	206	218	230	242	254	266	278	290	302	314	326	338	350
111	123	135	147	159	171	183	195	207	219	231	243	255	267	279	291	303	315	327	339	
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a simple shortwave broadcast receiver

Most Amateur transceivers just cover the ham bands. Because I wanted something with which I could listen to international shortwave newscasts, I constructed this simple shortwave broadcast receiver that tunes the 6 and 9 MHz SW bands and is inexpensive to build. Building it takes a little skill and you'll need a few test instruments to get it going, but I'm sure you'll enjoy listening to something you've built completely on your own.

To keep construction simple and costs down, I based the circuit on the J.W. Miller 8901-B and 8902-B IF amplifier and detector (mechanical assemblies are illustrated in **figs. 1A** and **1B**). This unit contains three stages of IF amplification and a diode detector inside the capsule. The output is more than enough to drive a 2N2222 audio stage, which in turn drives an LM380N audio chip at several watts output. This in turn drives a 12-inch loudspeaker.

In order to keep the circuit simple and eliminate self-oscillation problems which would require decoupling and shielding, no RF stage was used. The antenna just goes through a double-tuned circuit directly into the 40673 mixer. The large capacity 365-365 gang-tuning condenser eliminates the need for bandswitching for the input stage since it tunes the entire 6 to 9 MHz band. The only drawback is that it has very sharp tuning, and care must be used to make sure the input tuning is on the station you are listening to. With this broad tuning range, it is possible to tune on an image station 455 kHz away. If the panel is marked, there should be no trouble making the tuned circuits track and tune to the same frequency, once the two input slugs are adjusted as described in the following section.

All of the coils in the receiver are wound on National XR-50 coil forms; the number of turns indicated is only approximate, since lead length to the bandswitch can vary. I used a two-position tone control switch for bandchanging.

By Ed Marriner, W6XM, 528 Colima Street, La Jolla, California 92037

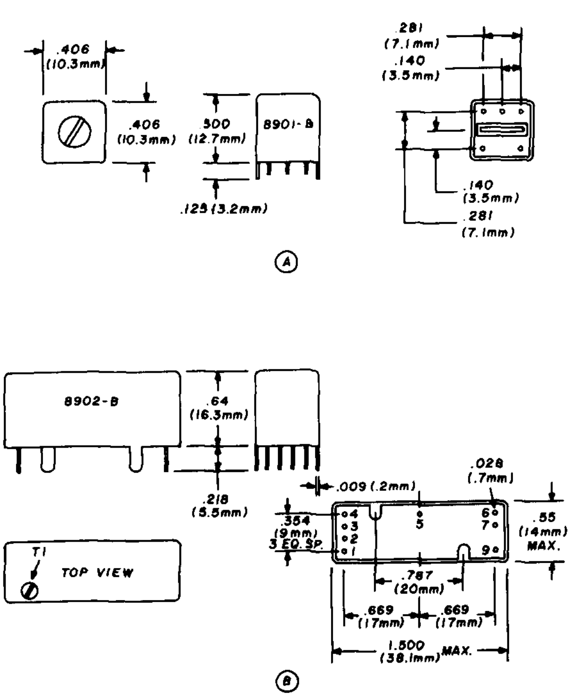

fig. 1. (A) 8901-B module mechanical assembly; (B) 8902-B module mechanical assembly.

The receiver was built on a California chassis (No. 122) that measures 4.5 × 8.5 inches (11.43 × 21.59 cm). Using etched boards, everything fits on the top of the chassis, making it easier to work on. Spacers are needed to keep the printed circuit board high enough to prevent the RG-174/U from being punctured by wires projecting from below.

The variable oscillator could probably be made without the emitter follower. However, experience suggests that the isolation between stages is necessary to prevent oscillator pulling. Finally, the oscillator is mechanically tuned using a Jackson Ball 5:1 drive. A schematic of the completed receiver is provided in **fig. 2**.

construction and alignment

The power supply was built first, followed by the audio section. Once I knew the audio section was working I added the IF and mixer stage. The antenna-tuned circuit was last and perhaps the most difficult to adjust. Here a grid dip oscillator is a must. I unsoldered the 7 pF coupling capacitor and tuned each coil separately on 6 MHz for best tracking. The 15 pF trimmer was primarily used to reduce any "mistracking" when different antennas were attached.

table 1. Abbreviated list of stations that transmit in the 6 and 9 MHz bands.

frequency (kHz)	station	frequency (kHz)	station
5955	Voice of Nicaragua	9360	Radio Madrid, Spain
5975	BBC — London	9410	BBC
5985	Radio China	9510	BBC Northern Ireland
6005	BBC	9540	Radio Nederland
6020	Habana, Cuba	9545	Radio Germany
6030	Voice of America	9565	Voice of America
6040	Voice of America	9580	Radio South Africa
6050	HCJB — Quito, Ecuador	9590	Radio Nederland
6060	Radio Haban, Cuba	9630	Radio Spain
6065	Radio Madrid, Spain	9635	Radio Moscow
6070	WYFR ("Family Radio")	9650	Voice of America
6075	WYFR ("Family Radio")	9670	Voice of America
6095	HCJB — Quito, Ecuador	9700	Voice of America
6115	Radio Moscow	9720	HCJB — Quito, Ecuador
6115	Voz de Llanos, Colombia	9735	BBC
6120	BBC	9745	HCJB — Quito, Ecuador
6125	BBC and Voice of America	9755	Voice of America
6140	*Radio Canada*	9780	Radio Moscow
6155	Voice of America	9810	Radio Moscow
6165	Radio Nederland	9825	BBC
6170	BBC	9835	Radio Budapest
6175	BBC	9915	BBC
6195	Radio Canada		

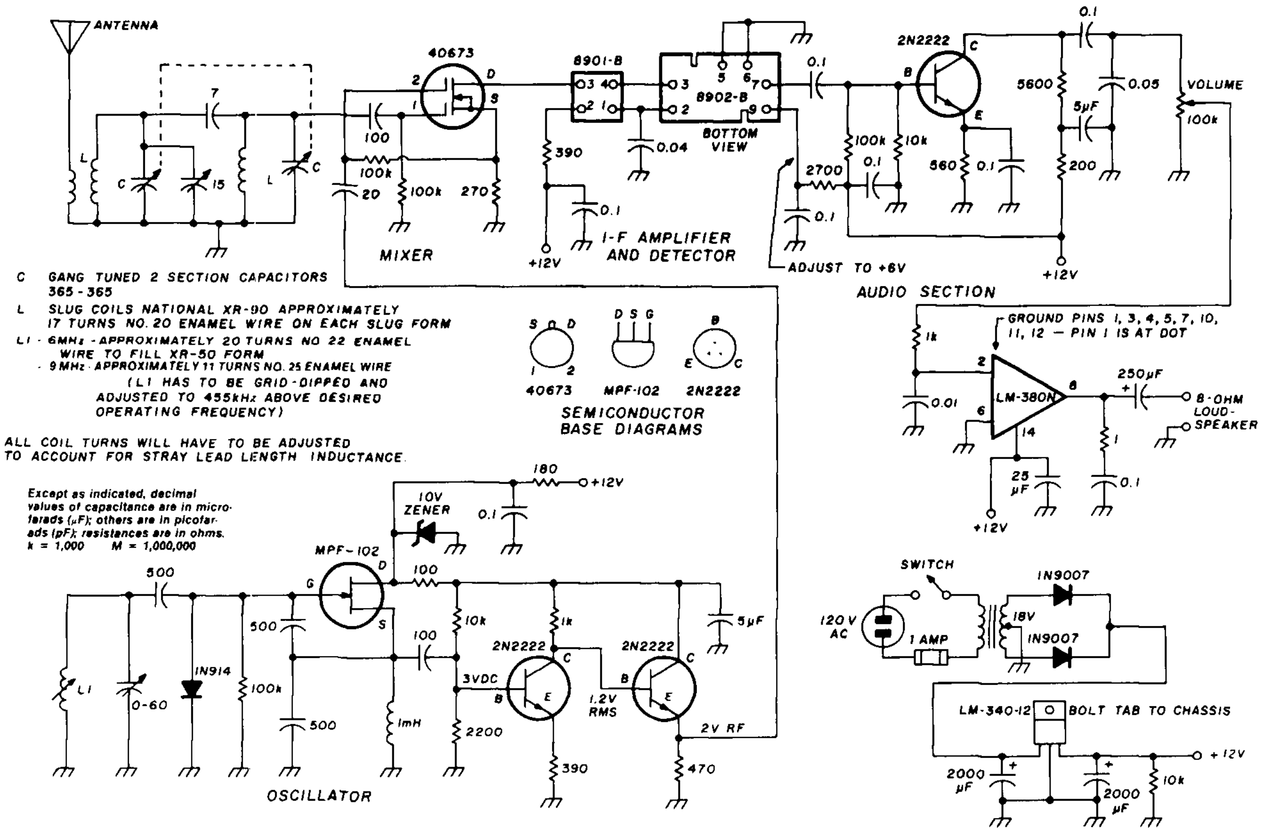

fig. 2. Two shortwave band receiver schematic diagram.

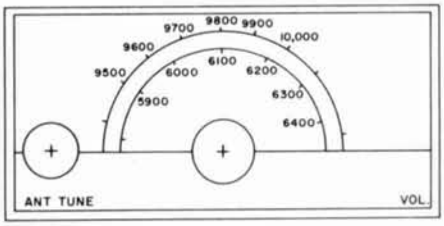

fig. 3. Frequency scale template for the broadcast receiver.

If you have a signal generator modulated by an audio tone it helps to align the 455 kHz IF and approximately calibrate the main frequency dials. If your signal generator is not accurate, then the dial should be checked against another receiver and recalibrated if necessary. (A frequency scale template is provided in **fig. 3**.)

Since only the 6 and 9 MHz bands are used, adjusting the receiver should not be much of a problem. For daytime listening, a coil could be wound for the 11 MHz band.

operation

This receiver is appropriate for language practice and for listening to the news, which most shortwave stations give on the hour. Several religious stations also come in strong: two are WYFR "the Family Radio station," and HCJB in Quito, Ecuador. In the early morning the Japanese stations are particularly strong. I have listed some of the stations active on the two bands and actually heard all those listed in **table 1**.

where to get parts

Be sure to include an SASE when writing for catalogs or information. Transistors and other parts may be obtained from:

Circuit Specialists
Box 3047
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Fort Myers, FL 33906-6017

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St. Petersburg, FL 33708

J.W. Miller/Bell Industries
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8205	3.45
8212	1.75
8214	3.80
8216	1.70
8224	2.20
8226	1.75
8228	3.45
8237	18.95
8237-5	20.95
8238	4.45
8243	4.40
8250	9.95
8251	4.45
8253	6.90
8253-5	7.90
8255	4.45
8255-5	5.20
8257	7.90
8257-5	8.90
8259	6.85
8259-5	7.45
8271	38.95
8272	38.95
8275	28.95
8279	8.90
8279-5	9.00
8272	6.45
8283	6.45
8284	5.45
8286	6.45
8287	6.45
8288	24.00
8289	48.95

Z-80

2.5 Mhz

Z80-CPU	3.90
Z80-CTC	4.45
Z80-DART	9.95
Z80-DMA	13.95
Z80-PIO	4.45
Z80-SIO/0	15.95
Z80-SIO/1	15.95
Z80-SIO/2	15.95
Z80-SIO/9	15.95

4.0 Mhz

Z80A-CPU	4.90
Z80A-CTC	4.90
Z80A-DART	10.95
Z80A-DMA	15.95
Z80A-PIO	4.90
Z80A-SIO/0	15.95
Z80A-SIO/1	15.95
Z80A-SIO/2	15.95
Z80A-SIO/9	15.95

6.0 Mhz

Z80B-CPU	12.95
Z80B-CTC	12.95
Z80B-PIO	12.95
Z80B-DART	18.95

ZILOG

Z6132	33.95
Z8671	38.95

DISC CONTROLLERS

1771	15.95
1791	23.95
1793	25.95
1795	48.95
1797	48.95
2791	53.95
2793	53.95
2795	58.95
2797	58.95
6843	33.95
8272	38.95
UPD765	38.95
MB8876	28.95
MB8877	33.95
1691	16.95
2143	17.95

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AY3-1014	6.90
AY5-1013	3.90
AY3-1015	6.90
PT-1472	9.90
TR1602	3.90
2350	9.90
2651	8.90
TMS6011	5.90
IM6402	7.90
IM6403	8.90
INS8250	9.95

INTERFACE

8T26	1.54
8T28	1.84
8T95	.88
8T96	.88
8T97	.88
8T98	.88
DM8131	2.90
DP8304	2.24
DS8835	1.94
DS8836	.98

VOLTAGE REGULATORS

7805T	.74	7905T	.84
78MO5C	.34	7908T	.84
7808T	.74	7912T	.84
7812T	.74	7915T	.84
7815T	.74	7924T	.84
7824T	.74	7905K	1.44
7805K	1.34	7912K	1.44
7812K	1.34	7915K	1.44
7815K	1.34	7924K	1.44
7824K	1.34	79L05	.78
78L05	.68	79L12	.78
78L12	.68	79L15	.78
78L15	.68	LM323K	4.90
78H05K	9.90	UA78S40	1.90
78H12K	9.90		

C,T = TO-220 K = TO-3 L = TO-92

DIP SWITCHES

4 POSITION	.84
5 POSITION	.89
6 POSITION	.89
7 POSITION	.94
8 POSITION	.94

IC SOCKETS

	1-99	100
8 pin ST	.12	.10
14 pin ST	.14	.11
16 pin ST	.16	.12
18 pin ST	.19	.17
20 pin ST	.28	.26
22 pin ST	.29	.26
24 pin ST	.29	.26
28 pin ST	.39	.31
40 pin ST	.48	.38
64 pin ST	4.20	call
ST = SOLDERTAIL		
8 pin WW	.58	.48
14 pin WW	.68	.51
16 pin WW	.68	.57
18 pin WW	.98	.89
20 pin WW	1.04	.97
22 pin WW	1.34	1.23
24 pin WW	1.44	1.30
28 pin WW	1.64	1.44
40 pin WW	1.94	1.75
WW = WIREWRAP		
16 pin ZIF	6.70	call
24 pin ZIF	9.90	call
28 pin ZIF	9.95	call

ZIF = TEXTOOL (Zero Insertion Force)

CRYSTALS

32.768khz	1.90
1.0 mhz	4.90
1.8432	4.90
2.0	3.90
2.097152	3.90
2.4576	3.90
3.2768	3.90
3.579535	3.90
4.0	3.90
5.0	3.90
5.0688	3.90
5.185	3.90
5.7143	3.90
6.0	3.90
6.144	3.90
6.5536	3.90
8.0	3.90
10.0	3.90
10.738635	3.90
14.31818	3.90
15.0	3.90
16.0	3.90
17.430	3.90
18.0	3.90
18.432	3.90
20.0	3.90
22.1184	3.90
32.0	3.90

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Paddle Adapple	24.95
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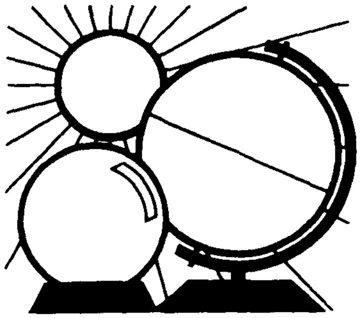


DX FORECASTER

Garth Stonehocker, KØRYW

The proximity of November to the winter solstice, a time when the geomagnetic field is quiet, normally means undisturbed conditions. But because this year is one of several in the sunspot decline, many disturbances can be expected this month. Therefore, we can expect unusual propagation conditions to occur, with the emphasis on the following days: November 7th through 12th, 17th through 20th, and on the 25th and 30th.

vhf-ers take note

Many days of meteor showers will occur between October 26th and November 22nd, with a shower maximum from the 3rd through the 10th at a rate of ten per hour. This shower is known as the *Taurids*. Lunar perigee is on the 1st and 26th, and the full moon on the 20th.

winter season DX

November through February constitutes the winter DX season. Because the D and E regions of the ionosphere receive less energy from the sun in the northern hemisphere during this time, less ionization occurs. Therefore the daytime attenuation of radio signals in winter is lower than during the rest of the year. At the same time, ion production each day is better able to drift and diffuse up into the F region of the ionosphere. The result is an increased range of operating frequencies between the lowest and the maximum usable frequencies (LUF-MUF). The maximum usable frequency rises rapidly as the sun rises each day, peaking just after noontime. The frequency diminishes in the late afternoon, evening, and through the night to a low value just before dawn the next day. The exception to this situation is for locations nearer to the equator, where the F region ionization continues to drift and diffuse up during the afternoon and evening to become the transequatorial maximums described in last month's column. The maximum usable frequency peak reached each day and the depth of the predawn minimum frequency of the next morning are related to the solar flux each day. The higher the flux during the day, the higher the frequency and the lower the dip the next morning.

Wintertime DX provides openings with these characteristics:

- Better daytime signal strengths on the lower frequencies
- Nighttime DX openings earlier each day in the evenings
- More frequent transequatorial paths toward the south
- Higher signal strengths on all bands most of the time.

band-by-band summary

Ten and fifteen meters will be open for F_2 long skip and transequatorial one-long-hop propagation. Worldwide DX is prevalent from after sunrise until well after sunset most days, especially during periods of high solar flux conditions and moderate geomagnetic field disturbances.

Twenty meters will be open most days and nearly throughout the night to some areas of the world. This mode follows the sun across the sky: east, south, then west with long skip of 1000-2500 miles.

Thirty meters is a day and night band. The day portion should be similar to 20 meters; signal strengths, however, may decrease during midday on some days of higher solar flux values. This band will also be usable well into the night and often through the night. Problem nights will probably follow high solar flux days and be related to the deep dip of MUF an hour or so before dawn. The distances covered on this band might exceed 80-meter nighttime paths while being less than 20-meter daytime paths.

Forty meters, like 30 meters, is a transition band with all-night propagation as well as some short-skip conditions during the daytime. Most areas of the world can be worked from darkness until just after sunrise. Hops shorten to about 2000 miles on this band, but the number of hops can increase since the signal attenuation is low at night.

Eighty meters, traditionally the ragchewing band, is also good for distant operation. The band operates much like 40 meters, except in that the hop distances shorten to around 1500 miles at night and even less during the daytime. Because the noise is so low, this band is a pleasure to work during this time of year. The path direction follows the darkness across the earth — east, south, then west. Lots of QRM can be expected, however. (Remember, the DX window is 3790-3800 kHz.)

One-sixty meters will be similar to 80 meters, with skip hops reduced to

NOVEMBER

WESTERN USA

GMT	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	
PST	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	
ASIA FAR EAST	20	20	30	30	30	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20	20	20	N
EUROPE	20	15	15	15	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	20	20	20	NE
S. AFRICA	15	10	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	15	15	15	E
S. AMERICA	10	10	10	15	15	15	15	20	20	20	20	20	20	20	20	20	20*	15	15	15	10	10	10	10	SE
ANTARCTICA	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	S
NEW ZEALAND	10	10	10	10	10	10	15	15	20	20	20	20	20	20	20	15	15	15	10	10	10	10	10	10	SW
OCEANIA AUSTRALIA	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	10	W
JAPAN	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	20	20	20	20	15	15	20*	20	NW

MID USA

MST	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	
ASIA FAR EAST	30	20	20	20	30	20	20	20	20	20	20	20	20	20	30	30	40	40	40	40*	30	30	30	30	N
EUROPE	20	20	20	20	20	20*	20*	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	20	20	NE
S. AFRICA	15	10	10	10	10	10	10	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	E
S. AMERICA	10	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	SE
ANTARCTICA	15	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	S
NEW ZEALAND	10	10	10	10	15	15	15	15	20	20	20	20	20	20	20	20	15	15	15	15	10	10	10	10	SW
OCEANIA AUSTRALIA	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	W
JAPAN	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	20	20	20	15	15	20*	20	20	NW
CST	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	

EASTERN USA

EST	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	
ASIA FAR EAST	30	30	30	20	20	20	20	20	20	20	20	20	20	20	30	30	40	40	40	40	30	30	30	30	N
EUROPE	20	20	20	20	20	20	20*	20*	20*	20	30	30	30	40	40	40	30	30	30	30	30	30	20	20	NE
S. AFRICA	15	10	10	10	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	E
CARIBBEAN S. AMERICA	10	10	10	10	10	15	15	15	15	20	20	20	20	20	20	20	15	15	15	15	10	10	10	10	SE
ANTARCTICA	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	S
NEW ZEALAND	10	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	20	20*	15	15	15	10	10	10	SW
OCEANIA AUSTRALIA	10	10	10	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	15	15	15*	10	10	W
JAPAN	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	30	30*	20	20	20	15	15	20	NW

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides the MUF during 'normal' hours.

*Look at next **higher** band for possible openings.

about 1000 miles. It will provide good DX for late night and early morning DXers. Stations in many areas of the country can now run higher power. (Once again, please keep the DX windows — 1825-1830 kHz and 1850-1855 kHz — free of local contacts.)

last-minute forecast

During November expect the higher frequency bands — 10 through 30 meters — to be best during the middle of the month; a solar radio flux maximum is expected during that time. Maximum flux is also possible on the 25th which would mean a good, long DX holiday weekend. (Monitor radio station WWV for geophysical data at 18 minutes after the hour on 2.5, 5, 10, 15 or 20 MHz to update this forecast.) The lower frequency bands are expected to be good throughout the month, but somewhat better during the predawn hours at the beginning and end of the month.

ham radio

short circuits

building blocks

In KB0CY's article, "Audio Filter Building Blocks" (July, 1983), **fig. 2** (page 76) should show all +12V connections going to pin 7 of the four LF356's. One LF356 (upper center) shows pin 1 as the +12V connection; this is incorrect.

briefcase bobtail

In the directions for a "Briefcase Bobtail" given by Paul M. Rich (Comments, July, 1983, page 12), the twelve turns of No. 14 wire should be spaced 1/4 inch apart, not one inch apart. The call sign HH2KR was incorrectly given as HH2DR.

Bobtail curtain

In part one of the Bobtail curtain series by W6BCX (February, 1983, page 82), an article on the Bobtail is referred to in the April, 1948, issue of *CQ*. The correct date of publication is March, 1948.

technical forum

Have a technical question? Ask your fellow Amateurs through Technical Forum. You'll reach knowledgeable readers ready to help you find the answer you're looking for. *Have an answer?* Send it in. Every month we'll award a specially selected book from Ham Radio's Bookstore to the writer of the best response to a question previously posed in this column. Address your questions and answers (typewritten, if possible) to Technical Forum, *ham radio magazine*, Greenville, New Hampshire 03048.

bunny hunt

In the May, 1983, Technical Forum, N3BEK raised the problem of RFI on 160 meters from a local broadcast station.

May I suggest he try using the station's field intensity meter to go on a low-frequency "bunny hunt." It is not unusual for the down guys on utility poles to unintentionally provide 60 Hz rectification at corroded joints and create fluorescent light-type noise in high-frequency receivers. Utility wires, down guys, grounds from pole-mounted transformers, and the like can all have partially corroded splices and connections that are good at power line voltages but act as semi-conductors when exposed to the 1-10 volts of RF (field intensity in V/M). This type of re-radiation is common in many AM antenna systems, and has to be tuned out at the source of re-radiation; that particular parasitic element has to be made non-resonant at the carrier frequency in order to make the antenna system of the station produce the desired radiation pattern.

It is entirely possible that a downguy, power drop messenger cable, or the ham antenna might have a discontinuity that would produce the "mystery station on 160 meters." The temperature/frequency relationship mentioned in the column would indicate a change in the resonant frequency as the element gets warm; it gets longer due to expansion, and the self-resonance lowers. The fact that the station uses asymmetrical modulation has no bearing on the situation other than developing 3 dB additional sideband power on modulation tips. Assuming mixing is taking place by the diode-type action mentioned above, at a non-linear portion of that diode, and the self-resonance of the antenna producing the carrier and higher sideband energy, this would account for the unintelligible audio mentioned in the letter. The cure can be as simple as cleaning the connection or adding a resonant circuit to detune it from the 160 meter band or 1500 kHz station. Judging by the report of the station's engineering people and the intensity at N3BEK's QTH, my guess is that it's close to the shack. But, since you have to find the source to cure it, that's where the field intensity meter is helpful. It should be able to detect signals to fractions of a microvolt. Hope this helps. Good luck. — **Ed Karl, KØKL**

mysterious spur solved

In response to my letter to Technical Forum (May, 1983), I received a telephone call from Robert Schantz, a Los Angeles broadcast radio consultant. After determining that the local 50 kW transmitter was manufactured by Continental, he said he was familiar with the design of that particular asymmetrically-modulated transmitter. He has experienced the generation of spurs from transmitters of that design — in one case, 250 kHz in the broadcast band. He said the Continental transmitter includes a complex feedback circuit in the modulator that is critical to adjustment. When the adjustment allows the generation of a spur, the frequency of that spur depends on the characteristics of the antenna system.

It is his conjecture that small changes in antenna characteristics, along with changes in temperature, are causing the frequency of the spur to shift.

My money is on Mr. Schantz's solution. — **Jack Geist, N3BEK**

too many turns

Like WB2NTQ (June, 1983), I have also tried to create high impedance (above 100 ohms) transformers with powdered iron toroids and failed. Here is why.

The problem in WB2NTQ's transformer is in his secondary winding, which at 29 MHz, is operating above its natural resonant frequency. The usable bandwidth for a transformer on the high end is determined by the self resonance of the windings. This resonance occurs when a winding is effectively 1/4-wavelength long. Due to the dielectric constants of wire insulation and core material, and the capacity between adjacent turns the total wire length in a resonant winding can be significantly less than 1/4 wavelength in air.

The low frequency limit of a transformer is determined by the inductive reactance of the transformer winding becoming lower than five or so times the source or load impedance. Small cores of high permeability material produce transformers with the greatest bandwidth.

The largest core I can find data on is a T200 size. Each turn is 1.85 inches on that core and could be longer on a larger toroid. Total length on WB2NTQ's high impedance winding is then about 135 inches (ignoring wire size and winding looseness). This is a quarter wave at 21.86 MHz, neglecting dielectric effects. Thus the capacitive reactive term is in parallel with the resistive component on the input side.

There are just too many turns on the transformer. The low permeability of the powdered iron core makes the design all the more difficult. I'd first cut the secondary length down to about 1/8-wavelength at the maximum desired frequency. That would

be about 49 inches and would wind twenty-six turns. I would wind these as thirteen turns bifilar connected series aiding. The center tap would be the ground side of the 50 ohm connection. This would be a simple 75 to 300 ohm transformer. To get 50 ohms I would tap one side of the bifilar winding at 10 or 11 turns out from the center tap. Ten turns would give a turns ratio of 10 to 26 or an impedance ratio of 50 to 338 ohms. Tapping at 11 turns would give a ratio of 50 to 279 ohms.

The low frequency end of this transformer would be at the frequency where the inductance of the 11-turn section has an inductive reactance of $5 \times 50 = 250$ ohms. On a T200-2 this winding inductance is about 1.3 microhenries. To the limit of the accuracy with which I can read my Shure reactance rule, this happens at 30 MHz!

A larger core would give more inductance per turn but at the same time would have more wire in a turn. High impedance, large size and low permeability together prevent this core from performing adequately. The powdered iron toroid just is not appropriate for such a high impedance winding, but might function if constructed within these limits for a single band.

A better core for this application might be either an F-240 or F-114 in Q1 (mix 61) or Q2 (mix 62) ferrite. The smaller core in Q1 would require five turns on the 50 ohm section and twelve turns total on the 300 ohm winding for a minimum operating frequency of 14 MHz. I would wind this as six bifilar turns connected series aiding with the primary tap at five turns. The windings should be spread uniformly around the whole core. The impedance ratio would be 50 to 288 ohms. On this core a winding would have a length of about one inch per turn. Twelve secondary turns would be about 12 inches long and should work well beyond 50 MHz.

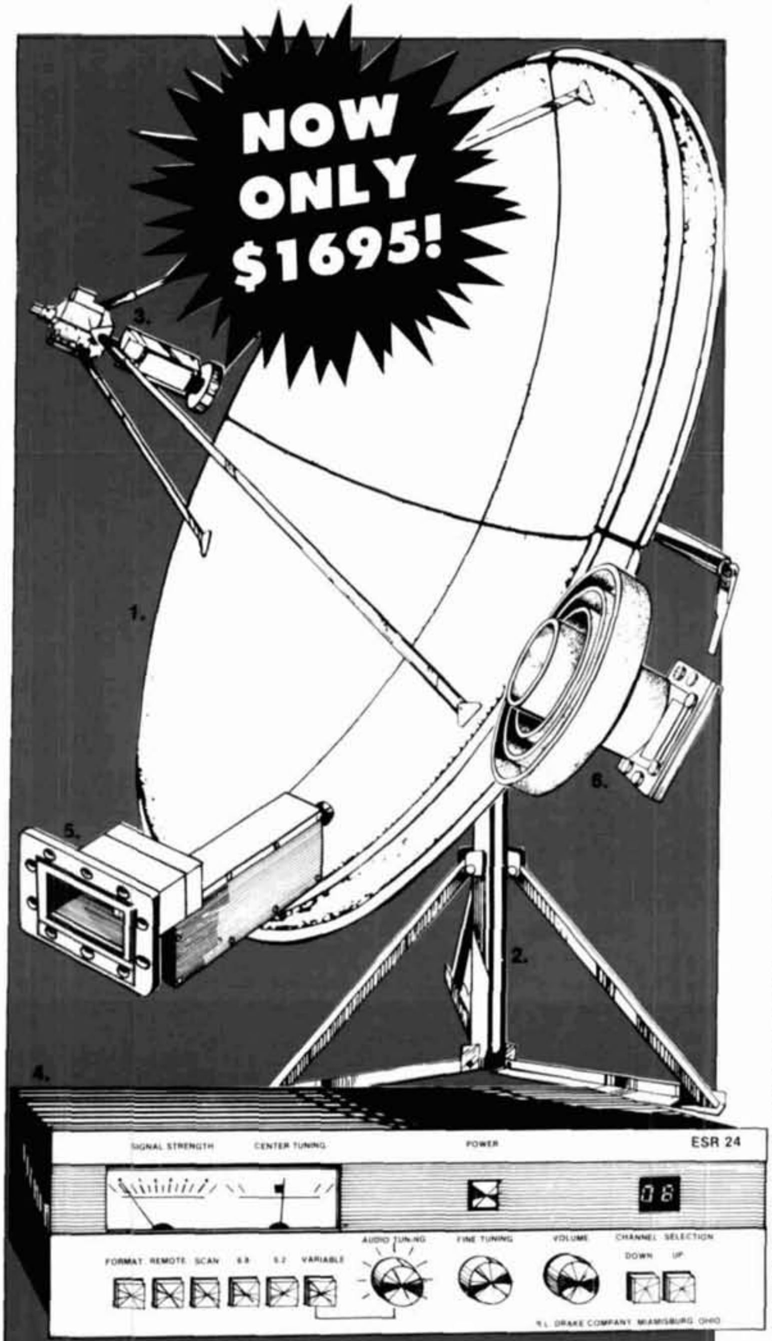
To achieve wide bandwidth it is necessary to use a high permeability core material to extend to low frequency end of the pass band with a minimum winding conductor length. At the high frequency limit the core is practically uncoupled from the winding and only the core's dielectric constant is significant. The dielectric constant for ferrite can be high, so isolating the winding from the core can help extend the high frequency end as long as the winding conductor length does not grow too much at the same time. Thick wire insulation reduces the inductive coupling between adjacent bifilar turns at the high frequency end of the pass band. A better winding would be made of enameled wires twisted together for the bifilar winding and then covered with a heavy walled Teflon™ insulating tubing. — **Gerald A. Johnson, K0CQ**

standing-wave indicator

I have just bought a standing-wave indicator, type B812A, manufactured by FXR, Inc., of Woodside, New York. The unit is not functioning at present and I wonder whether anyone might have a circuit diagram or other information which would help me get the unit working.

After reading the interesting article on this type of unit by Bob Stein, W6NBI, in the January, 1977, issue of *ham radio*, I feel the device would be a very useful addition to my workshop. — **Arthur Williams, GW8FKB**

Complete 10 ft. satellite TV system featuring Drake



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6. Scalor feed horn. Delivers 0.5 dB more gain than conventional types. Virtually eliminates system noise.
Note: A VCR's RF modulator will work with this system, otherwise one will be needed (approximate cost $59. Connecting cables between receiver and antenna not included.

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IN ALABAMA CALL 1-800-292-8668 9 AM TIL 5:30 PM CST, MONDAY THRU FRIDAY

More Details? CHECK—OFF Page 118

✓ 165

✓ 107

improved stability and dial calibration for the Heathkit HW-8

The HW-8 transceiver exhibits approximately 1500 Hz drift in transmit and receive frequency when the supply voltage varies over a range of 10 to 13.5 VDC. This results in CW chirp when using a poorly regulated supply, such as a weak, dry battery. Additionally, even with a well-regulated supply, the VFO dial calibration is in error on all but the 7 MHz band.

Most of the drift and chirp problem is caused by the Heterodyne Oscillator (Q6). The reverse-biased switching diodes in the tuned circuits of all but the selected band exhibit a capacitance which varies with supply voltage. This capacitance, essentially in parallel with the selected crystal, causes pulling of the oscillator frequency. The solution is to regulate the supply voltage to Q6. The small amount of shift which still remains after Q6 is stabilized is caused by the inability of the Zener diode (ZD-1) to fully stabilize the voltage for the Variable Frequency Oscillator (Q2). This can be corrected by replacing the Zener-diode regulator circuit with a Motorola MC7808CP three-terminal regulator integrated circuit.

The VFO dial calibration problem is a matter of fine tuning the VFO and HFO in accordance with the procedure described here. The Heathkit procedure does not calibrate the frequency of the HFO; it also does not switch in the offset capacitor (C55) during VFO calibration so that the dial will read transmit frequency.

modification procedure

Remove the following resistors: R78, R81, R82, R84, R85, R87, R88, and R91 (see **fig. 1**).

Install 7.5-volt, 1-watt (SK-3059) or equivalent, Zener diodes (anode lead to ground) in the positions formerly occupied by R81, R84, R87, and R91 (100k resistors).

Install 470 ohm, 1/4-watt resistors in the positions formerly occupied by R78, R82, R85 and R88 (1k resistors).

Install a 0.01 μF, 25 VDC ceramic capacitor on the foil side of the main PC board. Solder one lead to the junction of R36 and the yellow wire which attaches to point *B*. Solder the other lead of the capacitor to a nearby ground foil.

Remove ZD-1 and R33 (470 ohm). Drill a 1/32 inch hole midway between the two holes from which R33 was removed. Install the MC7808CP voltage regulator as follows:

Input *B* lead to R33 hole which ties to 13.4-volt line; insert common *C* lead through the drilled hole and output *E* lead to R33 hole which ties to C52 and R3 (47 ohm).

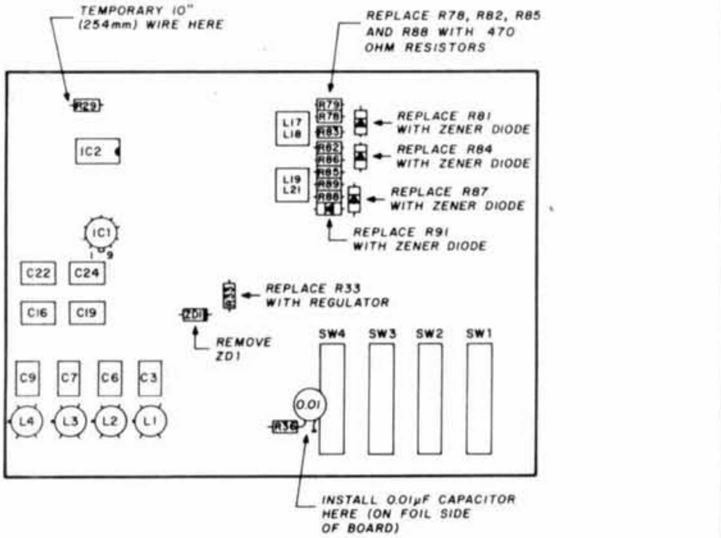


fig. 1. Component drawing indicates modifications to be made.

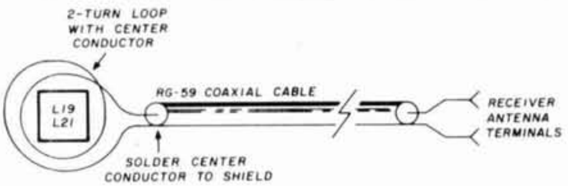


fig. 2. 2-turn pick up loop is used for fine alignment.

Solder and clip the excess from the *B* and *E* leads. Slip a piece of insulation over the *C* lead and solder the lead to a nearby ground foil. Be sure that it does not short to other foil leads.

fine alignment procedure

Make a pick-up loop as shown in **fig. 2** and place it around L19/21. Connect the opposite end to the antenna terminals of a calibrated receiver capable of tuning 12 to 30 MHz.*

Press the 3.5 MHz bandswitch.

Tune the calibrated receiver to 12.395 MHz.

Adjust L17 (bottom slug) for zero-beat.

Press the 7.0 MHz bandswitch.

Tune the calibrated receiver to 15.895 MHz.

Adjust L18 (top slug) for zero-beat.

Press the 14.0 MHz bandswitch.

Tune the calibrated receiver to 22.895 MHz.

Adjust L19 (bottom slug) for zero-beat.

Press the 21.0 MHz bandswitch.

Tune the calibrated receiver to 29.895 MHz.

Adjust L21 (top slug) for zero-beat.

Temporarily attach a 10-inch piece of wire to the end of R29 (22k) which connects to point WW. Connect the other end of the wire to one of the ON/OFF switch terminals. This will cause the antenna relay to close and the receiver to mute.

Realign the VFO as described in the Heathkit instruction manual, page 62.

Remove the temporary wire and reinstall the cabinet cover. This completes the modification and alignment.

Robert W. Lewis, W3HVK

*If a calibrated receiver for this frequency range is not available, a frequency counter can be used. The output of the heterodyne oscillator can be picked off at the emitter of Q7, preferably through a 0.001 to 0.01 μF coupling capacitor. The pick-up loop described for use with a receiver likely will not provide enough signal to drive a frequency counter. — Editor

product REVIEW

Soar model 5025 digital multimeter

A number of different multimeters have crossed my desk in recent months and I must admit it has been fascinating to see and use the latest state-of-the-art equipment. The newest unit on my desk for review, however, is quite different from the others.

The Soar Model 5025 is not just a nuts-and-bolts measuring device. It incorporates a unique comparator circuit that can be used in a number of different ways.

One of the greatest advantages of the "new breed" of multimeters is extensive use of specially designed chips. The Soar 5025 has a unique 80 pin LSI chip that keeps overall parts count down while ensuring long term stability and accuracy. Only by examining the schematic can one fully appreciate how LSI has changed the complexion of equipment design and utilization.

general specifications

The 5025 has an easy-to-read, low current consumption, LCD readout with a maximum reading of 1999. The readout also has annunciators to audibly alert for function, unit polarity, decimal, low battery, continuity and diode test. The unit is mounted in a rugged ABS plastic case with a U-bracket handle/tilt stand and is fully shielded from RFI/EMI. The probes are designed for safety to reduce the chance of an accidental shock when being used. One of the "neatest" innovations of this new breed of multimeters is the automatic ranging feature. When doing a number of different voltage or resistance readings, this feature is quite a time saver.

Battery life is estimated at >300 hours with alkaline batteries and >200 hours with regular zinc carbon batteries. Four size "C" batteries or a portable AC adapter may be used. The model 5025 also incorporates a built-in overload protection for all ranges with surge protection up to 6000 volts.

comparator circuit

Besides standard ohms, volts, and current measurements, the Soar Model 5025 also has a built-in comparator circuit. The comparator can be used on all measurement ranges and was designed with production and QC testing in mind.

To use the comparator circuit, you select the designed high and low figure on the thumbwheel switches above the LCD readout, punch in the proper range to be tested, and press the "compare" switch. The 5025 will then measure the parameter in question. If the value being measured is within the limit set, the beeper will sound and the value will appear in the LCD readout. If the value is either above or below the preset limits, the beeper will not sound.

use

I had occasion to use the Soar 5025 while troubleshooting a broken radio. I found the U-bracket to be invaluable in getting the multimeter into a position that was easy to see. I also found the 1/2 inch LCD readouts to be a nice feature. I also used it outside to make a number of continuity checks on a vertical antenna ground system. The LCD readouts are easy to read in the sun and the handy beeper assured that there was circuit continuity without the need of looking at the unit.

specifications

Size: 7.25" × 2.25" × 7.125" (186 × 57 × 180 mm)

Weight: 1.9 pounds (850 g) less batteries

Cp. Temp 0°C to 40°C

Accuracy guaranteed for 1 year
- DCV ±.25%
- ACV ±.5%
- Resistors 200-200 kilohms ±.25; 2000 K ±1%; 20 M ±2%
- DCA 200μ to 200 mA; 10A ±1.0%
- ACA 200μ – 20 mA ±1%; 200 mA – 10 A ±1.2%

For more information contact NA Soar, 1126 Cornell Avenue, Cherry Hill, New Jersey 08002. RS#313

N1ACH

NEW products

ICOM transceiver

ICOM's new IC-471A is a 20 MHz coverage base station transceiver for 430-450 MHz. It

NEW products

features 10 watt output, 32 full function memories, and built-in sub-audible tone selectable from the main tuning dial.

ICOM system accessories work with the IC-471A. This unit features ICOM's new two-color display, showing frequency digits in white and control functions in red, for easy visibility under all lighting conditions. With the IC-471A, it is possible to scan all frequencies, memories, or modes.

For information, contact ICOM America, Inc., 2112-116th Ave., NE, Bellevue, Washington 98004. RS#311

RTTY/CW interface

The ROM-116 is now distributed and sold exclusively by the Flesher Corporation. The ROM-116 interfaces the Radio Shack TRS-80* models I, III, and IV, and comes with features that include two serial ports, fourteen buffers, split-screen (formatted or unformatted) vertically displayed status, automatic CW/ID, PTT control, Sel-Cal, error correction, text editor, quick break with word mode, word wrapping, preload, two independent callsign buffers (one for user and one for station called), repeat transmission, right hand justification on transmit from the main buffer, time and date with automatic update, and adjustable line length. It also will support a computer printer for hard copy, receive and send RTTY at all standard Baudot and ASCII rates up to 1200 baud; it is TTL compatible, will receive and transmit CW with full break-in mode, CW preload (cassette or disk versions), and cassette or disk save messages or pictures. Several software packages, such as a MAILBOX program (1.4MBO or 3.4MBO) and LOAD HEX (for receiving/

sending disk files on RTTY), are also available. Two versions are marketed; prices will range from $225.00 for the older units to $325.00 for the newer units.

For information, contact Flesher Corporation, at P.O. Box 976, Topeka, Kansas 66601. RS#309

*A trademark of the Tandy Corp.

power center

Ultima Electronics announces the immediate availability of a new state-of-the-art electronic outlet power center designed for fail-safe industrial, residential, and commercial use.

Designated "Surgefree," the new unit features all solid-state electronic circuitry. Compact in size, it can be plugged into any 120 VAC outlet to instantly sense and suppress destructive effects of high-voltage transient spikes and surges to sensitive electronic equipment. It is rated at 15 amps (1875 watt), 125 VAC, with a resettable circuit breaker that protects against accidental power overloads.

Model SF-200, with two sockets, sells for $69.95; Model SF-600, with six sockets, $89.95; Model SF-1000, with ten sockets, $99.95.

For further information, contact Ultima Electronics Ltd., 59-7 Central Avenue, Farmingdale, New York. RS#308

compact mobile transceivers

Trio-Kenwood Communications has announced the addition of two new ultra-compact models to their line of mobile transceivers.

The 2-meter version, model TM-201A, incorporates microprocessor-controlled operating features in a new lightweight slim-line design. Features include 25 watts of RF output, dual-digit VFO's, five memories, priority alert scan, memory and band scans, lithium battery memory back-up (estimated 5-year life), high-visibility yellow LED display, external speaker, and a 16-key autopatch UP/DOWN microphone. An audible "beeper" confirms operation of selected functions. An optional FC-10 frequency

NEW products

controller allows remote control of frequency, VFO selection, memory recall, and memory channel selection. An optional TU-3 two-frequency tone encoder permits operation on repeaters having different sub-audible tones.

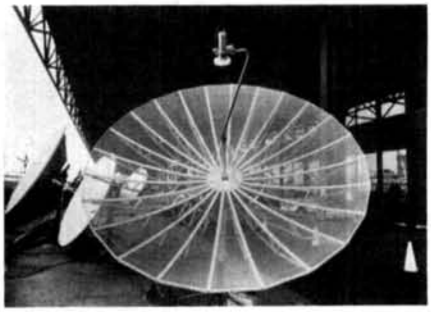
A 70 cm version, the TM-401A, is similar to the TM-201A in features and appearance, and is available with a maximum of 12 watts RF output.

For additional information, contact Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.

modular dish antenna

The new modular aluminum X-11 satellite TV antenna developed by KLM Electronics, Inc., was named one of the most innovative products for 1983 in the Design & Engineering Exhibition of the Summer Consumer Electronics Show at Chicago's McCormick Place.

The X-11 is the first satellite TV antenna to be selected for recognition at the Exhibition. Because of its size, it was displayed outside the exhibition hall.



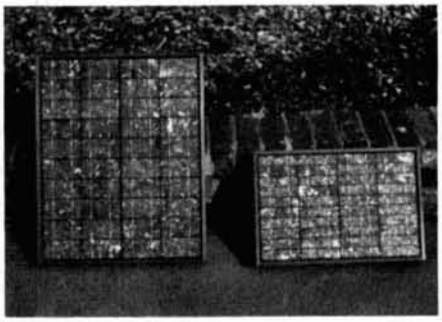
The X-11 is designed to reduce dealer setup time by 60 to 70 percent and to permit easy assembly by the consumer. It handles 100 mph winds and can be shipped by United Parcel Service.

For more information, contact KLM Electronics, Inc., 16890 Church Street, Morgan Hill, California 95037. RS#307

panel discussion

Two new photovoltaic panels, the SX-10 and SX-20, are available from ENCON. Rated at 10 watts; the SX-10 features different current/voltage selections (8 VDC at 1.05 amperes, 13.3 VDC at 0.52 amperes) the ham can wire himself. The SX-20, rated at 20 watts, offers a choice of 8.6 VDC at 2.09 amperes and 17.3 VDC at 1.05 amperes.

The SX-10 and SX-20 can be used for mobile QRP operations or can be permanently mounted for charging batteries. Their life expectancy is 30 years or more, and they're said to be able to withstand a wind load of over 160 MPH and golfball-size hailstones. They're both water- and moisture-proof.



For complete information, contact ENCON, 27600 Schoolcraft Road, Livonia, Michigan 48150. RS#306

precision tips

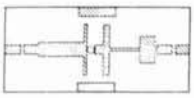
Six new precision soldering iron tips have been introduced for use with the recently introduced Ungar Series 9000 soldering iron and systems. The new tips are 1/16 and 0.090-inch spade, 1/32 and 3/64-inch screwdriver, 1/32-inch short spade and the 0.020 conical. The list price of each tip is $3.75. All are interchangeable with the modular Ungar System 9300 and System 9000 and 9100 variable-temperature systems.

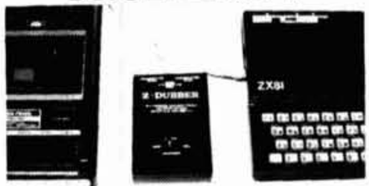
For further information, contact Ungar, P.O. Box 6005, Compton, California 90220. RS#305

elevation rotators

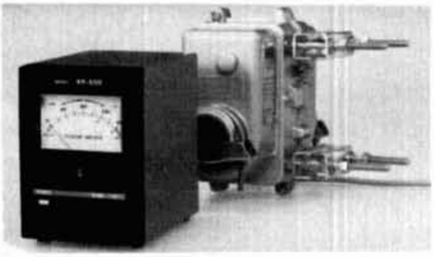
The entire Kenpro product line is again available to Amateurs in the United States. Distributed to local dealers by Spectrum West, the Kenpro line includes the KR 500 elevation rotor, said to be the only dedicated elevation rotator available to retail consumers. The line also includes the KR 2000 RC, described as the strongest azimuth rotator available, with over 10,000 kg/cm torque and the ability to hold over 30 square feet of wind load in a tower configuration.

For more modest applications, Kenpro





NEW products



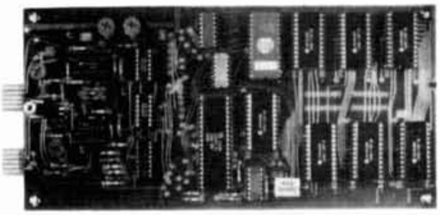
makes the smaller KR 400 and KR 600, which measure 12 and 14 square feet, respectively. A full line of accessories is also available.

The KR 2000 RC lists for $495.95; the KR 400, $149.95; the KR 600, $259.95.

For further information, contact Spectrum West, 5717 N.E. 56th Street, Seattle, Washington 98105. RS#304

packet radio TNC

The Model PK1 TNC from GLB Electronics has a self-contained MODEM and requires only a 12-volt power supply, a data terminal and a radio transceiver for packet operation. The data terminal can be a personal computer, a

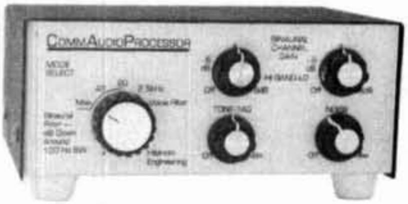


"dumb" terminal (keyboard and display), or even a mechanical teletype machine. The terminal interface is RS-232 compatible and self-adapts to ASCII or Baudot and at data rates ranging from 45 to 9600 baud. An adaptor is available for converting mechanical teletype machines to the RS-232 interface. Standard Bell 202 tones are used, with a data rate of 1200 baud, making it compatible with both Vancouver (VADC) and Tucson systems.

Utilizing a Z80A microprocessor, the Model PK1 has 8K of ROM and 4K of RAM as standard equipment. RAM can be readily expanded to 14K, using 2K "byte-wide" memory chips and to 56K via modification using 8K chips. The VADC protocol is available now, and AX.25 is to be released by the end of the year. Conversion to AX.25 is accomplished by means of exchanging ROM's at nominal cost.

The Model PK1 is a printed-circuit assembly, measuring 4.5 × 9.4 inches. It's priced at

CommAudioProcessor



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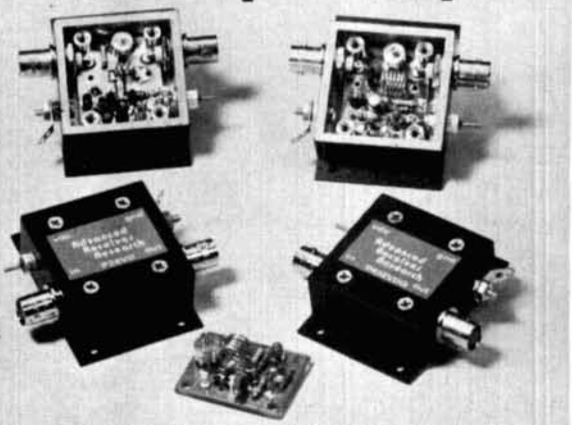

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P50VDG	50-54	‹0.5	24	+12	GaAsFET	$79.95
P144VD	144-148	‹1.5	15	0	DGFET	$29.95
P144VDA	144-148	‹1.0	15	0	DGFET	$37.95
P144VDG	144-148	‹0.5	24	+12	GaAsFET	$79.95
P220VD	220-225	‹1.8	15	0	DGFET	$29.95
P220VDA	220-225	‹1.2	15	0	DGFET	$37.95
P220VDG	220-225	‹0.5	20	+12	GaAsFET	$79.95
P432VD	420-450	‹1.8	15	−20	Bipolar	$32.95
P432VDA	420-450	‹1.1	17	−20	Bipolar	$49.95
P432VDG	420-450	‹0.5	16	+12	GaAsFET	$79.95

Advanced Receiver Research

Preamps are available without case and connectors: subtract $10. Other preamps available in the 1 - 800 MHz range. Prices shown are postpaid for U.S. and Canada. CT residents add 7-½% sales tax. C.O.D. orders add $2. Air mail to foreign countries add 10%.

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✓ 102

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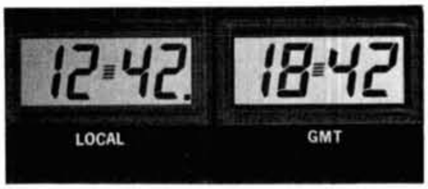
$149.95, wired and tested, with documentation and instructions. Power required is a single +12 volt supply at 1/4 amperes. Connecting cables are also available. Documentation is available for $5, refundable on purchase.

For complete information, contact GLB Electronics, 1952 Clinton Street, Buffalo, New York 14206. RS#310

ham clock

The BHC Big Ham Clock features two large 5/8 inch tall LCD modules, one for local time (12 or 24 hour type) and one for GMT. Each clock module can be programmed for the desired combination of month/day, hours/minutes, seconds, and set to WWV.



Each module will run from one to three years on the replaceable battery; the two modules are mounted in a black anodized desk top frame. The price is $29.95, plus $1.50 for shipping.

For more information, contact BHC, Inc., 1716 Woodhead, Houston, Texas 77019. RS#303

test mount adapter

The new Larsen Electronics test mount adapter simplifies tracing problems in antenna or radio. It can be used to check the antenna feedline VSWR and the radio power output simultaneously by simply screwing the adapter onto the mount and applying a dummy load. Other uses include use as a coax extension.

For further information, contact Larsen Electronics, P.O. Box 1799, Vancouver, Washington 98668. RS#312

NEW products

"maxi" baluns

The Unadilla/Reyco/Inline W2DU-(6) and W2DU-(2) baluns handle 3.5 kW power. Model W2DU-(6) is used for 160-6 meter applications while the W2DU-(2) handles those in the 6-1¼ meter range. Pull-apart tensile strength is rated at more than 600 pounds.

The baluns are adaptable to dipoles, inverted-vee, quads and Yagi antennas. Both are contained in weatherproof housing and have built-in lightning arrestors.

The price of each is $24.75. For more information, contact Microwave Filter Co., Inc., 6743 Kinne Street, East Syracuse, New York 13057. RS#302

easy-to-operate shortwave radio

The new Bearcat DX-1000 features direct access keyboard tuning and covers the 10 kHz to 30 MHz spectrum. Ten memory channels allow storage of favorite frequencies for instant recall or for faster "band scanning" during important openings. The digital display measures frequencies to 1 kHz and doubles as a two-time zone, 24-hour digital quartz clock. A built-in timer can be programmed to activate peripheral equipment. Other important features include independent selectivity selection, with 12, 6, and 2.7 kHz IF filters to help separate high-powered stations on adjacent frequencies, plus a two-position noise blanking system that stops Russian interference. It also features an RF attenuator, FM squelch control, tone control, battery backup system, LED indicators for modes and functions, front mounted speaker, "fast" and "slow" AGC, and separate push buttons for selecting AM, LSB, USB, CW, or FM modes. The unit comes with a built-in telescoping antenna for portable use, and includes an SO-239 antenna connector for 50 ohm leads, and a screw connector for "High Z."

The suggested retail price is $599.95. For further information, contact Electra Company, 300 East County Line Road, Cumberland, Indiana 46229. RS#301

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Coming Events

ACTIVITIES

"Places to go..."

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MASSACHUSETTS: The Honeywell 1200 Radio Club, sponsor of 147.72/12 repeater and the Waltham Amateur Radio Association, sponsor of 146.04/64 repeater, will hold their annual Amateur Radio and electronics auction, Saturday, November 19, Honeywell Plant, 300 Concord Road, Billerica. Exit 27 off Route 3. Doors open 10 AM. Free admission and parking. Snack bar and bargain parts store. Talk in on both repeaters. For information: Doug Purdy, N1BUB, 3 Visco Road, Burlington, MA 01803.

MICHIGAN: The Oak Park High School Electronics Club presents the 14th annual Swap 'N Shop, Sunday, November 27, Oak Park High School, Oak Park. 8 AM to 4 PM. Admission $2.00. 8 ft. tables $6.00. Refreshments available. For information/reservations: SASE to Herman Gardner, Oak Park High School, 13701 Oak Park Blvd., Oak Park, MI 48237. (313) 968-2675.

MINNESOTA: The annual Handi-Ham Winter Hamfest, Saturday, December 3, Eagles Club, Faribault. Registration 9 AM. There will be a Handi-Ham equipment auction, dinner at noon followed by a program. Talk in on 19/79. For information: Don Franz, WØFIT, 1114 Frank Avenue, Albert Lea, MN 56007.

NEW YORK: Radio Central ARC presents the 5th annual "Ham-Central" All Inside flea market and Hamfest, Sunday, November 27, Temple Isaiah's main social hall, 1404 Stony Brook Road, Stony Brook, Long Island. Doors open 7:30 AM for sellers/dealers; 9 AM general admission. Tickets $3.00 (OM or XYL and kids under 12 free). $7.00 for 8 ft. table space includes one free admission. Free parking. Nearby shopping. For information or reservations: Scotty Policastro, KA2EQW (516) 589-2557, 80 7th Street, Bohemia, NY 11716 or Bob Yarmus, K2RGZ (516) 981-2709, 3 Haven Ct., Lake Grove, NY 11755.

NORTH CAROLINA: The Guilford Amateur Radio Club's annual Hamfest/Computerfest, November 26 and 27, National Guard Armory, Greensboro. 9 AM each day. Admission $3.50 advance; $5.00 at gate. Tailgating allowed with price of admission. Food and free parking. Talk in on 144.65/145.25 and 146.52 simplex. An equipment check-out booth with test equipment and a technician available free for those wishing to check equipment prior to purchase. For information or advance tickets SASE to GARC, P.O. Box 7007, Greensboro, NC 27407. Please make checks payable to GARC.

OHIO: The Great Lakes/Ohio Valley Satellite Technical Show and Consumer Fair will be held November 19-20 at the University Hilton, Columbus, Ohio. Brought to you by Satellite Reception Systems, Athens, Ohio. Consumer Ticket Price $3.50. 1-800-592-1956 National, 1-800-592-1957 in Ohio.

OHIO: The Massillon Amateur Radio Club, W8NP, will present "Auctionfest '83" Sunday, November 13, 8 AM to 5 PM, Massillon K of C Hall, 988 Cherry Road N.W., Massillon. Flea market setup 7 AM; auction at 11 AM. Advance tickets $2.50, $3.00 at door. Tables $5.00 per 8 ft. space. Talk in on 147.78/.18. For information and reservations SASE to MARC, 920 Tremont Avenue S.W., Massillon, Ohio 44646.

PENNSYLVANIA: The Foothills ARC's 15th annual Hamfest, Saturday, November 5, St. Bruno's Church, South Greensburg. Tickets $2.00 or 3/$5.00. Indoor flea market tables $5.00. Mobile check-in on 146.07/67. For information, tickets or tables: WA3HOL or write FARC, P.O. Box 236, Greensburg, PA 15601.

OPERATING EVENTS
"Things to do..."

NOVEMBER 3 TO 6: The NBS-BRASS of Gaithersburg, Maryland, will operate K3AA to observe the dedication of the first active Amateur Radio Club station at the National Bureau of Standards. Multi-op activities on CW, Phone and RTTY near low end of 80 to 10 meter Novice and General class bands. Certificate available for SASE to BRASS, c/o National Bureau of Standards, Mailroom, Washington, DC 20234.

NOVEMBER 5 AND 6: Radio Central ARC, Rocky Point, New York, will operate WA2UEC from the former RCA HF Radio station called "Radio Central" to commemorate the 62nd year of the now silent station. 2-160 meters up 10 kHz from edge of General band and on 2 meters on 146.52 and 144.550/145.150 repeater. Novice band operation 7.110 kHz. For a special QSL card showing a photo of the former station send your QSL with large SASE to Radio Central ARC, P.O. Box 680, Miller Place, NY 11764 or QSL to Callbook address.

NOVEMBER 11, 12 AND 13: The Armored Force Amateur Radio Nationwide Emergency Team (A FAR NET) will help commemorate Veteran's Day by operating a special event station, 1200 UTC and 2400 UTC on all three days. 40 meters: 7280 to 7290 kHz. 20 meters: 14,320 to 14,330 kHz. 15 meters: 21,370 to 21,380 kHz. Those making contact with member stations can obtain a commemorative certificate by sending $1.00 to Harry B. Thomsen, W2PJH, 348 Jefferson Avenue, Apt. 15, Canadaigua, NY 14424. Indicate call letters of station contacted, the station's A FAR number, date, time and bands. Include call, name and address.

NOVEMBER 24: Thanksgiving Day. A special events station sponsored by the Whitman ARC and Plimoth Plantation will operate from the Plimoth Plantation's 1627 Pilgram Village museum. Call WA1NPO, 1300 GMT to 2000+ GMT. This event will be supported by members of the Plymouth (Devon, England) Radio Club operating G3PRC from a site overlooking Plymouth Sound from which the original "Mayflower" set sail in 1620. To receive a certificate, send proof of contact and $1.00 or 3 IRC's to: Whitman ARC, P.O. Box 48, Whitman, MA 02382. For additional information: KA1CZS (617) 826-4772; WB1CNM (617) 586-7524; Rosemary Carroll, Plimoth Plantation, P.O. Box 1620, Plymouth, MA 02360 (617) 746-1622; or Peter Jackson, G3ADV, 32 Brown Avenue, Parkfield, Nantwich, Chesshire, UK, Phone 0270-626149.

NOVEMBER 26 TO JANUARY 8: The Niagara Falls Radio Club will operate special event station W2QYV during the Festival of Lights from Niagara Falls, New York, 1500 UTC to 0300 UTC in the General portion of 20, 40 and 80. For a color photograph award send QSL and $2.00 donation along with 8½ × 11 SASE (55¢ postage) to Angelo Zino, WA2UJR, Awards Manager, 16 Council St., Niagara Falls, NY 14304.

DECEMBER 3: The Connecticut DX Association will operate KO1R, 1300 to 2000 Z, from the home of Mark Twain, Mark Twain Memorial, Hartford, CT. Frequencies for Phone and CW will be lower portion of General and upper portion of Advanced bands. For a full color QSL send your QSL and SASE to: Conn. DX Assn., P.O. Box 181, Columbia, CT 06237.

DECEMBER 3 TO 5: The Telephone Pioneer Radio Amateurs, John D. Burlie Chapter No. 89, 19th annual QSO Party. T.P.A.R. Operators in U.S. and Canada are invited to participate. Starting 1900 UTC, Saturday, December 3 to 0500 UTC, Monday, December 5. Suggested phone frequencies: 3.895-3.935; 7.255-7.295; 14.265-14.305; 21.355-21.395; 28.685-28.725; 50.10-554.00; 144.100-148.00. Contacts via repeater or simplex are valid. Suggested CW Frequencies: 3.555-3.595; 7.055-7.095; 14.055-14.095; 21.055-21.095; 28.055-28.095; 50.00-54.00 (Novice/Tech): 3.725, 7.125, 21.125, 28.125. RTTY use customary freq. Scoring: contact points times chapters contacted. Only one multiplier taken for each chapter worked. Maximum multiplier is 98 (TPA chapters 1-98) plus no more than 10 ITPA chapters. Exchange: Contact and chapter numbers. Return log sheets via your ARC Coordinator showing date, time, station worked, chapter name and number, contact number and claimed score. Post-marked no later than January 15, 1984. Send to: Ted Phelps, W8TP, John D. Burlie Chapter No. 89, Telephone Pioneers of America, c/o Western Electric, Dept. 45430, 6200 East Broad Street, Columbus, Ohio 43213.

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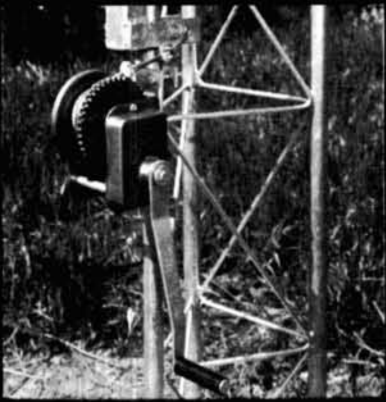

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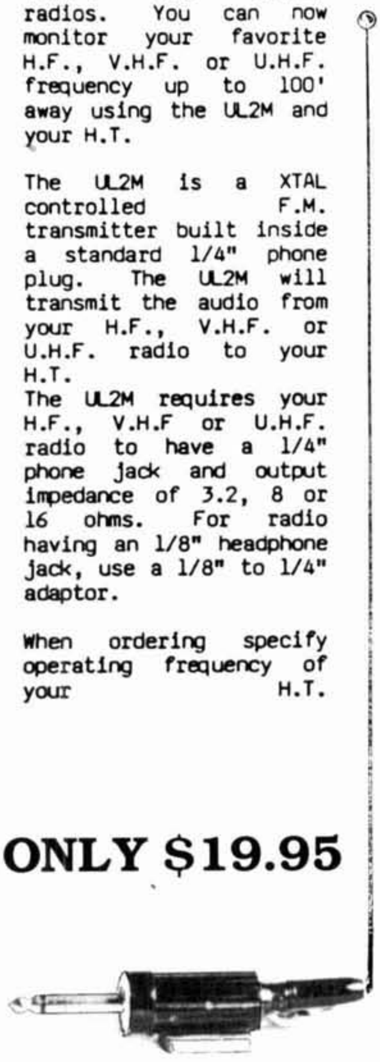

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The R-2000 is an innovative all-mode SSB, CW, AM, FM receiver that covers 150 kHz–30 MHz, with an optional VC-10 VHF converter unit to provide coverage of the 118-174 MHz frequency range. New microprocessor controlled operating features and an "UP" conversion PLL circuit assure maximum flexibility and ease of operation to enhance the excitement of listening to stations around the world.

R-2000 FEATURES:

- **Covers 150 kHz–30 MHz in 30 bands.** Uses innovative UP-conversion digitally controlled PLL circuit. UP/DOWN band switches (1-MHz step). VFO's continuously tuneable across the band and from band to band.
- **Optional 118-174 MHz coverage.** Through use of innovative microprocessor technology, frequency, band, and mode data of stations in the 118-174 MHz range may be tuned, displayed (full frequency, ie., 146.000.0), stored in memory, recalled, and scanned, using the R-2000 front panel controls and frequency display, allowing maximum convenience and ease of operation.
  The optional VC-10 VHF converter unit may be easily installed on the rear panel of the R-2000.
- **All mode: USB, LSB, CW, AM, FM.** Provides expanded flexibility in receiving various signal types. Front panel mode selector keys, with LED indicators.
- **Digital VFO's for best stability.** 50-Hz step, switchable to 500-Hz or 5-kHz. F. LOCK switch provided.
- **Ten memories store frequency, band, and mode data.** Complete information on frequency, band, and mode is stored in memory, assuring maximum ease of operation. Each memory may be tuned as a VFO. Original memory frequency may be recalled. AUTO. M switch for automatic storage of current operating data, or, when off, selective storage of data using M. IN switch.
- **Lithium battery memory back-up. (Est. 5 yr. life.)**
- **Programmable memory scan.** Scans all memories, or may be programmed to scan specific memories. HOLD switch interrupts scanning. Frequency, band, and mode are automatically selected in accordance with the memory channel being scanned. The scanning time is approximately 2 seconds per channel.
- **Programmable band scan.** Scans automatically within the programmed bandwidth. Memory channels 9 and 0 establish upper and lower scan limits. HOLD switch interrupts scanning. Frequency may be adjusted, using the tuning control, during scan HOLD.
- **Fluorescent tube digital display (100-Hz resolution).** Built-in 7 digit fluorescent tube digital display indicates frequency or time, plus memory channel number. DIM switch provided. The display may be switched to indicate CLOCK-2, FREQUENCY, CLOCK-1, and timer ON or OFF by the front panel FUNCTION switch.
- **Dual 24-hour quartz clocks, with timer.**
- **Three built-in IF filters with NARROW/WIDE selector switch. (CW filter opt.)** 6-kHz wide or 2.7-kHz narrow on AM. 2.7-kHz automatic on SSB. 2.7-kHz wide on CW, or, with optional YG-455C filter installed, 500-Hz narrow. 15-kHz automatic on FM.
- **Squelch circuit, all mode, built-in, with BUSY indicator.**
- **Noise blanker built-in.**
- **Large front mounted speaker.**
- **Tone control.**
- **RF step attenuator. (0-10-20-30 dB.)** Four step attenuator, plus antenna fuse.
- **AGC switch. (Slow-Fast.)**
- **"S" meter, with SINPO "S" scale.**
- **100/120/220/240 VAC, or 13.8 VDC operation** (with opt. DCK-1 cable kit).

Other features.

- RECORD output jack.
- Audible "beeper" (through speaker).
- Carrying handle.
- Headphone jack.
- External speaker jack.

Optional accessories:

- VC-10 118-174 MHz converter.
- HS-4, HS-5, HS-6, HS-7 headphones.
- DCK-1 DC cable kit.
- YG-455C 500-Hz CW filter.
- HC-10 World digital quartz clock.
- AL-2 Surge Shunt

More information on the R-2000 is available from all authorized dealers of Trio-Kenwood Communications 1111 West Walnut Street Compton, California 90220.

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