Proceedings of The Radio Club of America

Volume 37, No. 4
December, 1961

Founded 1909

A NEW METHOD OF ACCURATE FREQUENCY MEASUREMENT

by

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BOONTON, NEW JERSEY

THE RADIO CLUB OF AMERICA, INC.
11 West 42nd Street ★ ★ ★ New York City

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The Radio Club of America

ORGANIZED FOR INTERCHANGE OF KNOWLEDGE OF THE RADIO ART, THE PROMOTION OF GOOD FELLOWSHIP AMONG THE MEMBERS THEREOF, AND THE ADVANCEMENT OF PUBLIC INTEREST IN RADIO.

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The increase in the number of stations using the radio spectrum requires greater accuracy of frequency measurement. A practical frequency-measuring system, the Measurements Model 700, featuring rapid and continuous direct readout and an accuracy limited only by the reference frequency, is described.

Increasing use of the radio-frequency spectrum requires frequency-monitoring devices capable of high-accuracy measurements, yet simple in operation. The development of the Measurements Model 700 Standard Frequency Meter provides an instrument whose accuracy is limited only by the reference frequency. It features simple operation and rapid, continuous readout, without the use of headphones, transfer oscillator, or calibration curves.

A brief history of some of the early attempts to measure radio frequencies will not only be of historical interest but will emphasize the operating capabilities of present-day frequency measuring instruments such as the Measurements Model 700.

Figure 1 shows an early method of measuring half-wave length by means of stationary waves on parallel Lecher wires. The wires, whose distance apart was very small compared to their length, were terminated at one end by a fixed cross-strip AB. A second cross-strip, CD, and a sensitive Geissler tube, G, were movable along the wires. The condenser circuit, I, whose frequency was to be determined, was caused to act inductively on the parallel wires through very loose coupling. With G kept midway between AB and CD, CD and G were moved until G showed maximum illumination. This was the point at which the circuit ABCD was in resonance with the condenser circuit, I. At resonance, the current and voltage distribution was as shown by the curves I and V and the distance AD=BC was a half-wave length.

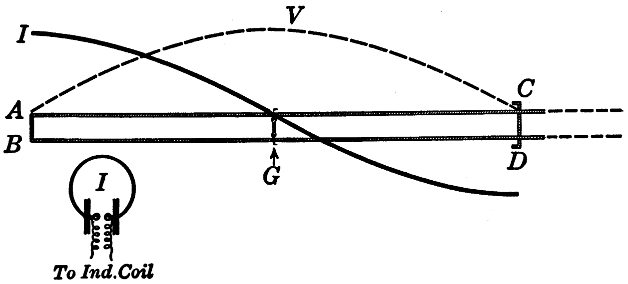

Figure 1. Measurement of Wave Length on Lecher Wires

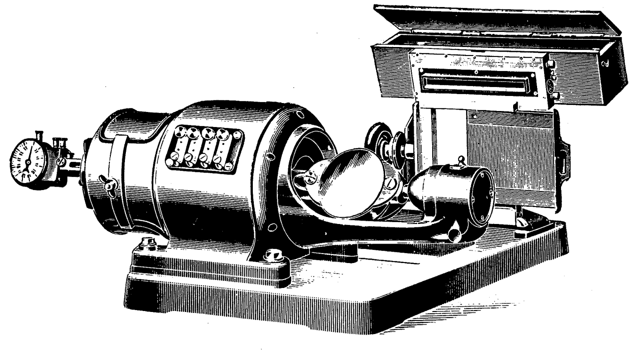

Figure 2. Oscillograph by H. Boas

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*Presented at the March 1960 meeting of the Radio Club of America, Inc., New York, New York.

One of the earliest frequency measuring instruments (Figure 2) was introduced by H. Boas in the late 'eighties. When used with spark-gap capacitor circuits, it photographed the spark in a rotating mirror. The device consisted of a glass tube with sheet-metal electrodes in a pure nitrogen atmosphere. A concave mirror, mounted on the shaft of a motor, reflected the image of the tube on a photographic plate. The distance between the light stripes (or the length of incandescence) served as the measure for the duration of a cycle.

Perhaps the first LC circuit to determine the high-frequency inductance of standard coils was shown in a Bureau of Standards circular issued in 1918.[1] Figure 3 is an illustration of this device. The smallest coil of a wave meter was compared at high frequencies with an inductance of simple form, such as a large single-turn square or rectangle whose value could be computed. The larger coil was then compared with the small coil, but certain corrections had to be considered, as outlined in the circular: "First, the condenser calibration takes account of the capacity only from the terminals A, B, the binding posts of the condenser. In addition to this there is the capacity between the leads to the square and between the leads, square, and the shield or case of the condenser. This correction may be determined experimentally by two methods. In one the square is cut, say at the points D and E, and some other coil connected to the terminals A, B, and coupled to a source of oscillations. Keeping the wave length of the source constant, the setting of the condenser C for resonance is obtained with the terminals of the square connected to the condenser terminals and then with them disconnected. The capacity of the condenser for resonance in the latter case will be greater than in the former by an amount very close to the required correction."

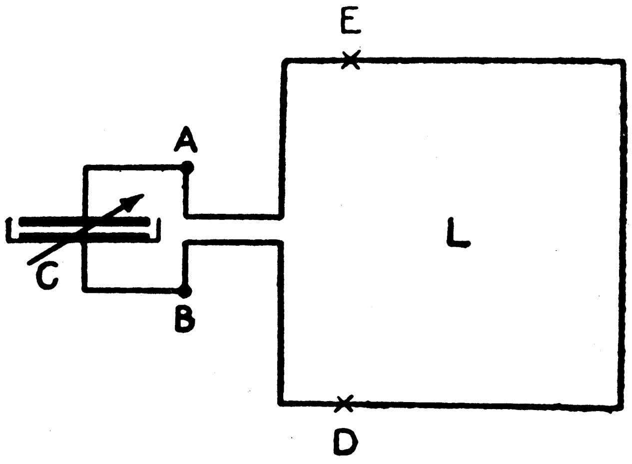

Figure 3. Circuit Consisting of a Calculable Inductance Standard and a Shielded Standard Capacitor

Also introduced in the early 1900's was a more elaborate LC circuit, shown in Figure 4. This instrument, the Franke-Donitz (Telefunken) wave meter, consisted of a variable capacitor, interchangeable coils for different ranges, and a hot-wire, air thermometer. Shortly thereafter, Marconi introduced the first truly portable instrument (Figures 5A and 5B) which featured a variable capacitor, a sensitive carborundum crystal detector, and a fixed self-inductance of rectangular shape, mounted in the cover of the case. Within the same period, the Bureau of Standards developed a method, shown in Figure 6, for connecting crystal detectors to LC circuits. When the source supplied only a small amount of power, a sensitive crystal detector and headphones were used for sharper tuning. Figure 7 illustrates another Telefunken circuit that not only provided for the measurement of wave lengths but was capable of generating controllable wave-length signals.

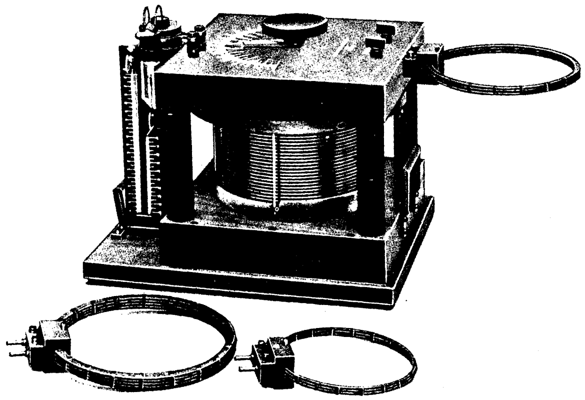

Figure 4. Franke-Donitz (Telefunken) Wave Meter

Perhaps the first direct-indicating frequency meter (Figure 8) was introduced in 1910 by G. Ferrie and T. Carpentier. This instrument compared a direct current through a resistance with one through an inductance. The voltage across

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[1] Radio Instruments and Measurements; Circular of the National Bureau of Standards C74; United States Government Printing Office; 1918, revised 1937.

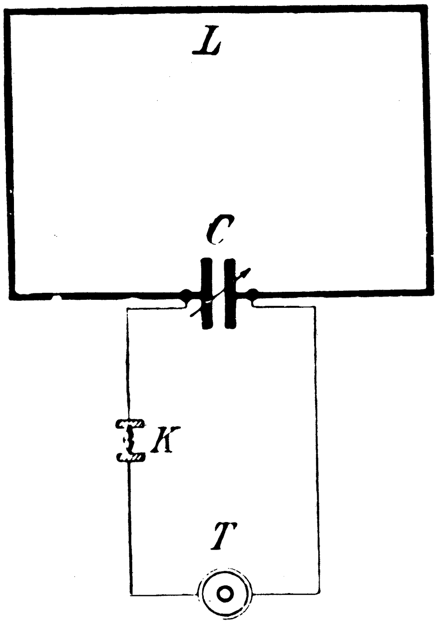

Figure 5A. Circuit of Marconi Portable Wave Meter

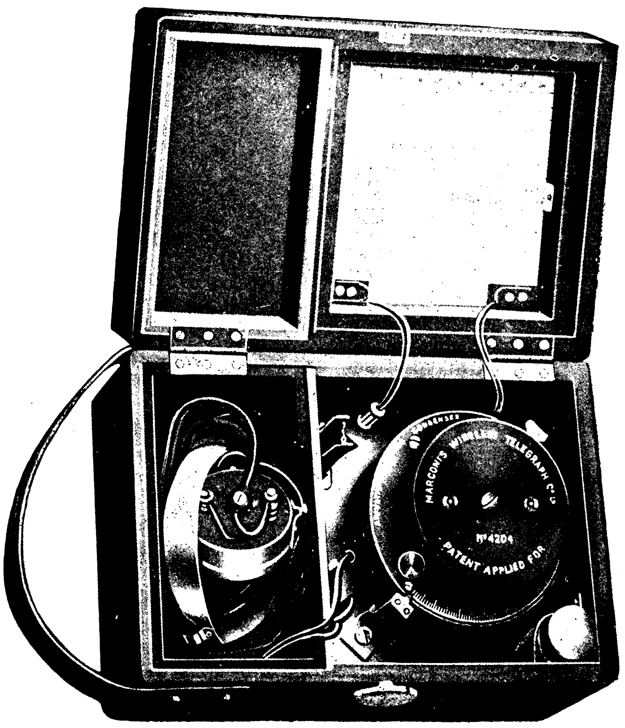

Figure 5B. Marconi Portable Wave Meter

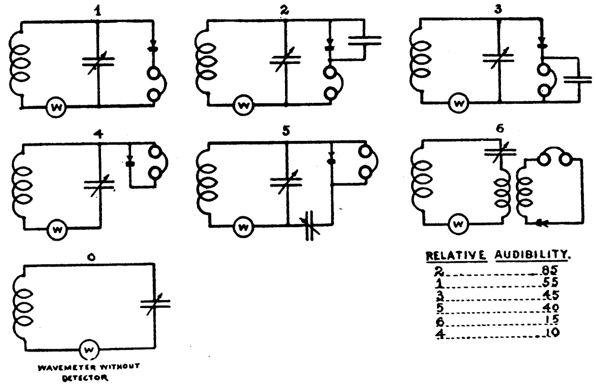

Figure 6. Wave-meter Circuits Using Detector and Phones

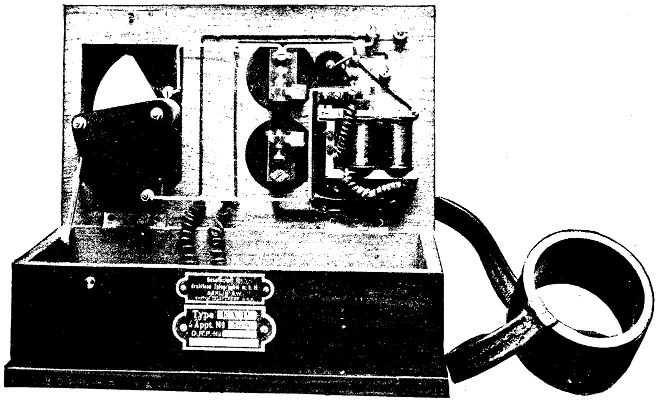

Figure 7. Improved Telefunken Wave Meter

the inductance was directly proportional to the frequency. The crossing of two pointers indicated the frequency on a dial. In 1916, a single-pointer, direct-indicating frequency meter, developed by G. Seibt and O. Scheller, was made by placing the coils at right angles as shown in Figure 9. The Weston Company used this principle in their direct-reading frequency meter for the lower-frequency range.

Following World War I, frequency measuring devices featured the use of the quartz crystal oscillator, as a fixed-frequency standard, the oscillating tube, and the heterodyne wave meter calibrated by a quartz crystal. Further improvements brought into use the oscillator circuit, known as the "Grid Dipper." Figures 10 and 11 show the original circuit of a high-frequency transmission line oscillator with a 1000-mc limit and the

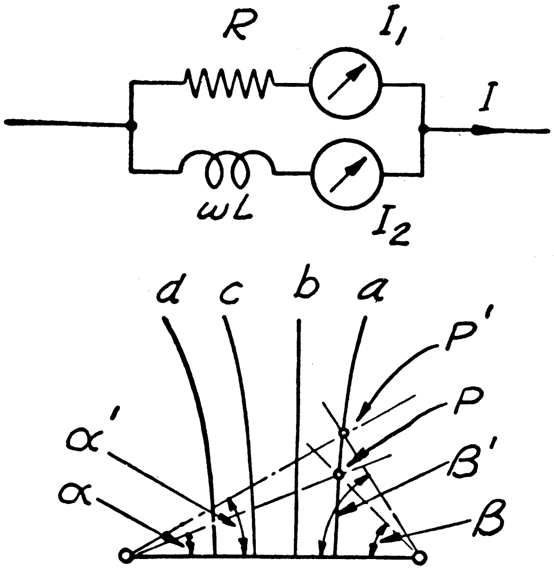

Figure 8. Direct-Indicating Frequency Meter by G. Ferrie and J. Carpentier

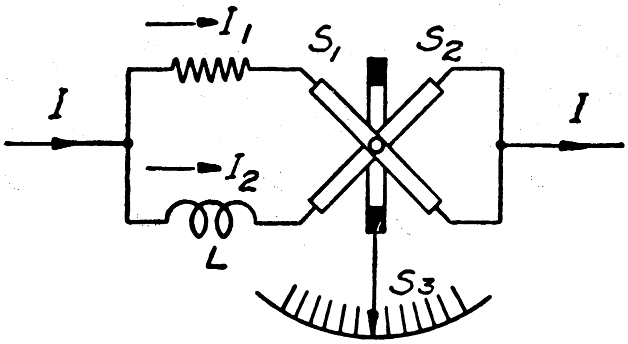

Figure 9. Dynamometric Direct-Indicating Frequency Meter

experimental instrument developed by Measurements from this circuit at the request of the Radiation Laboratories at MIT. Figure 12 shows the circuit of the first grid-dip meter available commercially with a range up to 1000 mc, and Figure 13 the meter as it is usually used today.

No brief history of developments in the frequency-measurement field would be complete without mentioning the U. S. Army Signal Corps Model BC-221 Frequency Meter, which was used throughout World War II. While time-consuming and difficult to use, it represented the best in practical mechanical-electrical design at that time. This meter used a

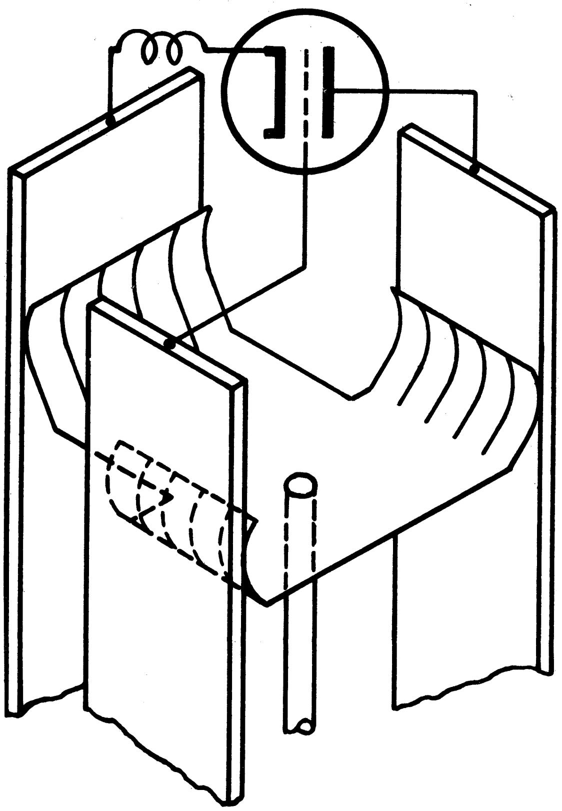

Figure 10. High-frequency Transmission Line Oscillator

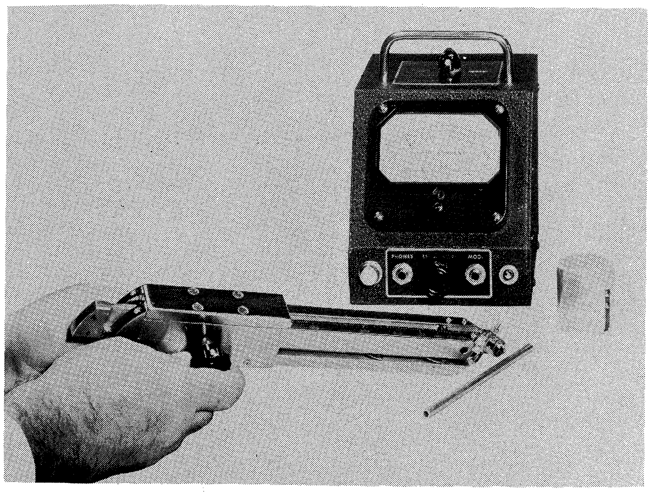

Figure 11. Experimental High-frequency Transmission Line Oscillator Developed by Measurements for MIT

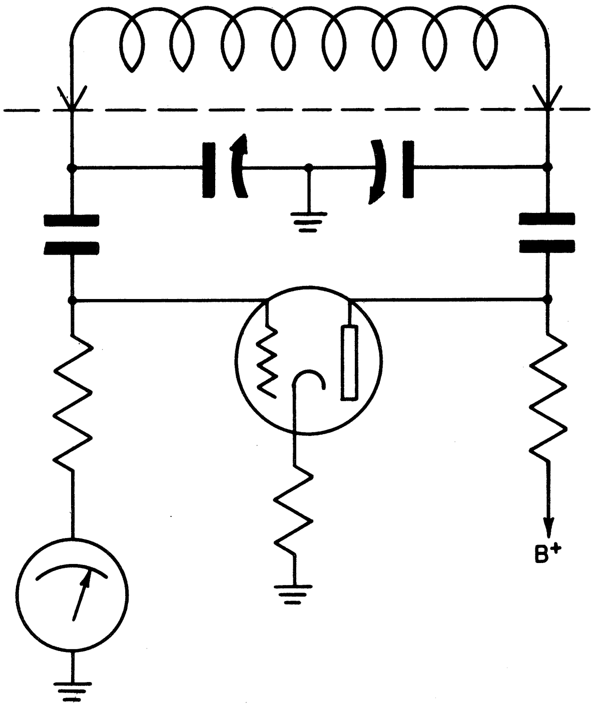

Figure 12. Circuit of First Commercial Grid-dip Meter

variable frequency oscillator with crystal check points and, except for the need to refer to approximately 100 pages of calibration tables, was simple to operate. With reasonable care and calibration, frequency-measurement accuracies of 0.005% were possible. Though the BC-221 was stable, sufficiently accurate, and relatively inexpensive, the possibility of extending the VFO measuring accuracy was not practical.

To meet the requirements for increased accuracy, a new instrument, the Measurements Model 700,[2] has been developed, which includes the following features:

1. Simplicity of operation.
2. Direct "in-line" readout.
3. Continuous frequency indication.
4. Freedom from spurious responses.
5. Accuracy limited only by crystal performance.

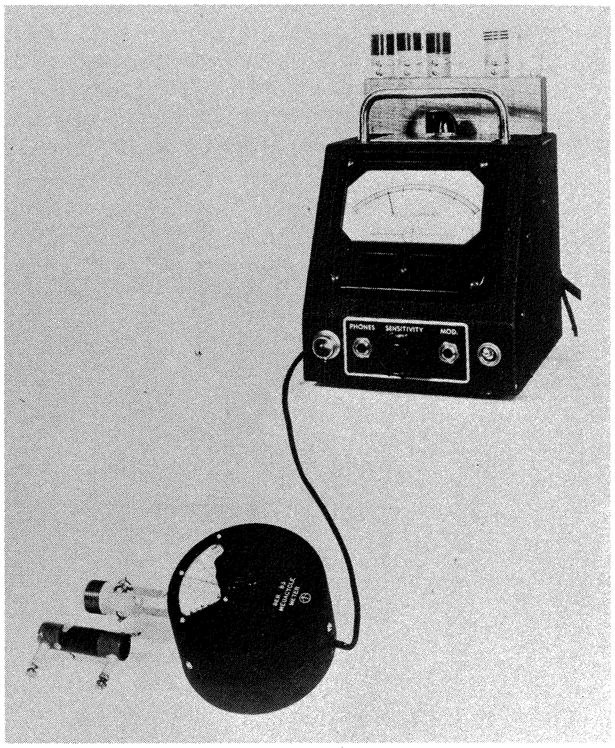

Figure 13. Model of Present-day Grid-dip Meter

The Model 700, unlike many instruments that preceded it, does not attempt to measure frequency in a single operation--it divides the measurement procedure into a series of simple, accurate steps.

Figure 14 shows the first Model 700 Standard Frequency Meter produced in Measurements lab-

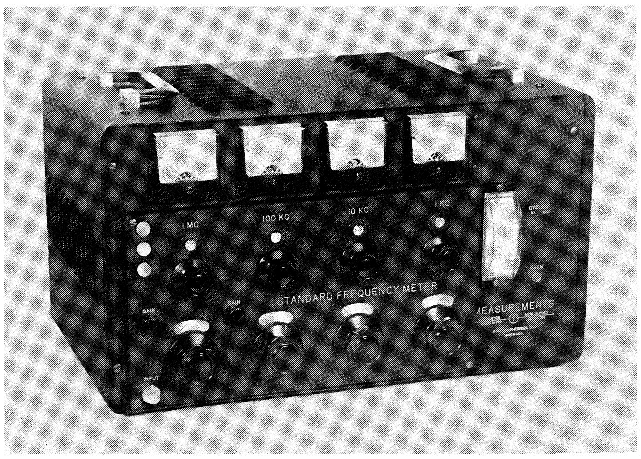

Figure 14. Measurements Model 700 Standard Frequency Meter

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[2] Since the presentation of this paper, a further improvement of the Model 700 has produced the Measurements Model 760 Standard Frequency Meter.

oratories. A simplified functional block diagram of the unit as originally conceived is shown in Figure 15. The knob, meter, and dial arrangements superimposed on the diagram closely represent the panel layout of a frequency meter and are similar to the actual unit shown in Figure 14.

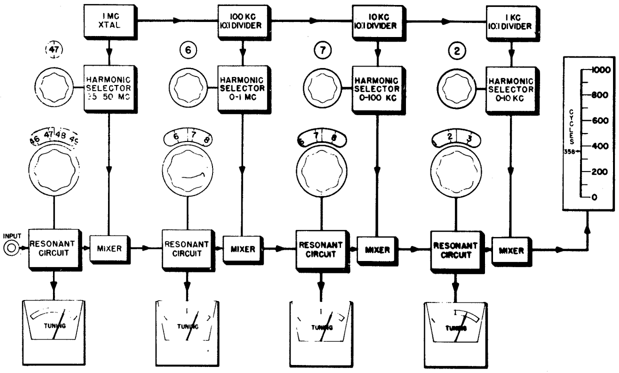


Figure 15. Simplified Functional Block Diagram of Frequency Meter

The principal component of the Model 700 is a 1-mc secondary-standard crystal oscillator capable of being adjusted against a primary standard such as WWV. The oscillator is stable enough to hold its calibration for extended periods and is oven-controlled so that its accuracy is limited only by the crystal accuracy.

The crystal oscillator frequency is divided through a series of 10:1 frequency dividers. For maximum reliability, this division uses a combination of 2:1 and 5:1 dividers. The divider outputs are fed to a series of sharply tuned LC harmonic selectors.

The unknown signal is identified to the closest megacycle by tuning the first resonant circuit for a peak reading on its associated meter. The megacycle harmonic selector is set to the harmonic indicated by the first resonant circuit and its output is mixed with the signal. The difference frequency is fed to the following tuned circuit and identified to the closest 100 kc. The 100-kc harmonic selector is set to the harmonic indicated by the second resonant circuit and its output is mixed with the signal. The process is repeated, continuing until the desired number of digits are identified. The remainder may be indicated on an audio frequency counter.

Table I illustrates a typical frequency measurement. Note that by displaying the order of the selected harmonics, the frequency is direct reading. The final three digits are displayed on a direct-reading audio counter.

TABLE I
TYPICAL FREQUENCY MEASUREMENTS

Readout	Frequency (cps)	Harmonic
-	47,672,358	-
47	-47,000,000	47th of 1 mc
-	672,358	-
6	-600,000	6th of 100 kc
-	72,358	-
7	-70,000	7th of 10 kc
-	2,358	-
2	-2,000	2nd of 1 kc
-	358	-
358	-358	Counter readout
	0	

Table II illustrates the system accuracy. Note that the measurement percentage-accuracy, excluding the audio counter, is equal to or slightly better than that of the reference crystal.

TABLE II
TYPICAL MEASUREMENT ACCURACY

	Frequency (cps)	Tolerance (cps) [1]
	47,672,358	-
	-47,000,000	47.000000
	672,358	-
	-600,000	0.600000
	72,358	-
	-70,000	0.070000
	2,358	-
	-2,000	0.002000
	358	47.672000
(counter)	-358	[2] 20.000000
	0	[3] 67.672000

[1] With crystal adjusted to within 0.0001% at 1 mc.

[2] Approximate counter accuracy equal to ±20 cycles. The system accuracy is limited only by the accuracy of the crystal and the counter circuit.

[3] Maximum error=0.000001f, ±20 cps, where f=measured frequency in cycles per second.

Almost all previous attempts to measure broad bands of frequency required extreme mechanical stability and precise calibration of oscillators or tank circuits. By grouping relatively standard computer-type blocks of stable, but not necessarily precise, circuits, it becomes practical to measure frequency to an accuracy previously impossible without a large amount of equipment.

The block diagram, Figure 15, and the typical frequency measurement of Table I are over-simplified representations of the frequency measurement technique. To make the system practical, a modification of the original concept was necessary (for reasons which will become evident).

Table III represents a measurement of the frequency of Tables I and II using the modified technique: the selection of higher-order harmonics. By assigning a number to each of the selected harmonics, the frequency is made direct reading.

TABLE III
MODIFIED TYPICAL FREQUENCY MEASUREMENT

Readout	Frequency (cps)	Harmonic
-	47,672,358	-
47	-45,000,000	45th of 1 mc
-	2,672,358	-
6	-2,400,000	24th of 100 kc
-	272,358	-
7	-250,000	25th of 10 kc
-	22,358	-
2	-20,000	20th of 1 kc
-	2,358	-
358	-2,358	Counter readout
	0	

The modified system has several advantages:

1. By working with higher-order harmonics, harmonic amplitudes are more nearly constant.

2. By raising the frequency in each stage, a 3:2 frequency or 9:4 tuning capacitance range may be used in both harmonic selector and signal identification circuits.

3. The heterodyne frequency is far removed from either of the mixed frequencies, simplifying mixer design.

4. As shown in Table IV, harmonic selector circuit Q requirements are made practical. Note that the only harmonics capable of supplying the 2- to 3-mc identification circuit of the 100-kc section are the desirable 45th and the relatively far-removed 50th harmonic of 1 mc. The beating of the unknown signals with the adjacent, difficult-to-suppress 44th and 46th harmonics of 1 mc produce frequencies outside the measuring band of the following 100-kc circuits. The result is that errors due to failure to suppress unwanted harmonics from the harmonic generators are eliminated. By purposely setting the harmonic selector five harmonics above the correct frequency indicated by the identification circuit, an unwanted reading could be obtained; however, by following the simple operating procedure, erroneous readings are impossible.

TABLE IV. HARMONIC SELECTION IN MODEL 700 SIGNAL GENERATOR

1-MC SECTION	47,672,358	-40,000,000 =	7,672,358		TO 2-3 MC TUNED AMPLIFIER
		-41,000,000 =	6,672,358		
		-42,000,000 =	5,672,358		
		-43,000,000 =	4,672,358		
		-44,000,000 =	3,672,358	Desirable Difference Frequency	
		-45,000,000 =	2,672,358		
		-46,000,000 =	1,672,358		
		-47,000,000 =	672,358		
		-48,000,000 =	327,642		
		-49,000,000 =	1,327,642	Unwanted Supplement	
		-50,000,000 =	2,327,642		
100-KC SECTION	2,672,358	-1,900,000 =	772,358		TO 200-300 KC TUNED AMPLIFIER
		-2,000,000 =	672,358		
		-2,100,000 =	572,358		
		-2,200,000 =	472,358		
		-2,300,000 =	372,358	Desirable Difference Frequency	
		-2,400,000 =	272,358		
		-2,500,000 =	172,358		
		-2,600,000 =	072,358		
		-2,700,000 =	027,642		
		-2,800,000 =	127,642	Unwanted Supplement	
		-2,900,000 =	227,642		

Table V shows that there is no decrease in the modified system accuracy and that the percentage accuracy, excluding the audio counter, remains equal to or better than that of the crystal.

TABLE V
TYPICAL MEASUREMENT ACCURACY

Frequency (cps)	Tolerance (cps) [1]
47,672,358	-
-45,000,000	45.000000
2,672,358	-
-2,400,000	2.400000
272,358	-
-250,000	0.250000
22,358	-
-20,000	0.020000
2,358	-
-2,000	0.002000
358	47.672000
-358	[2] 20.000000
0	[3] 67.672000

[1] With crystal adjusted to within 0.0001% at 1 mc.

[2] Approximate counter accuracy equal to ±20 cycles. The system accuracy is limited only by the accuracy of the crystal and the counter circuit.

[3] Maximum error=0.000001f ±20 cycles per second, where f=measured frequency in cycles per second.

In the Model 700 (Figure 13) produced in Measurements laboratories, the audio counter is a capacitor-integrator type. The audio sine wave is squared, differentiated, clipped, and used to charge a small capacitor. The energy is integrated and metered. Since, as shown in Table III, the 0- to 1-kc information is bootstrapped with an additional 2 kc, it is necessary to suppress the meter readout until the applied information exceeds 2 kc. To safeguard the accuracy of the audio counter, switched 2-kc and 3-kc harmonics from the dividers are made available for the calibration of the 0- and 1-kc meter points. The system is inherently linear, guaranteeing over-all accuracy of better than ±20 cycles.

Frequency division of 10:1 is accomplished through a 2:1 and 5:1 cathode-follower-isolated series of multivibrators, initially tested to provide stability over a ±20% change in heater potential and over elevated temperature conditions.

Figure 16 illustrates the differentiation and clipping required to generate relatively equal-amplitude harmonics when multivibrator-type dividers are used. Note that the half-cycle spikes must be removed to eliminate cancellation of certain harmonics by succeeding half-cycles of damped oscillations.

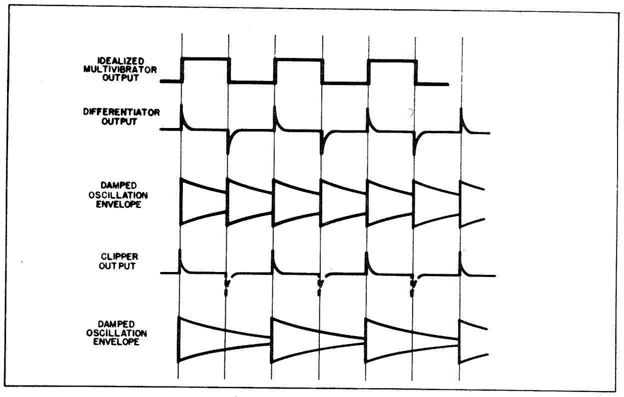


Figure 16. Differentiation and Clipping with Multivibrator-type Dividers

The identification circuits are high Q, LC amplifiers with germanium diode metering circuits. The harmonic selectors are fixed L, switched C, high Q tank circuits.

In providing frequency measurement accuracy and stability of 0.0002%, the Model 700 does not take full advantage of the inherent accuracy of the system. The system accuracy is limited basically by two factors: the absolute accuracy of the crystal and the accuracy of the final readout or counter circuit. For example, if the reference crystal is zero beat against WWV, and if consideration is given to greater audio-counter accuracy, many orders of magnitude of improvement are possible.

There are several desirable features included in the design and performance of the Model 700: A frequency can be measured in less than 1 minute by nontechnical personnel. The measuring process is straightforward and almost engineer-proof. The readout is direct and continuous. A recorder may be connected to the output of the counter circuit for continuous recording. The unit measures frequency without the use of a headset, interpolation oscillators, or calibration charts.

CORRESPONDENCE

"Your editorial in the recent Proceedings (Fall 1961) regarding projects that should be of interest to members in expanding their activities. Your ideas could, I believe, attract the younger element to our Club if we could contribute incentives and ideas when needed. I pass on an idea which has been tried out and proved effective. During the last couple of years I have encouraged several high school boys to do one different project each year relating to science in some aspect. By focusing their energies on one specific project they work harder at it and can better assess the results when the project is finished.

For example, a friend who was a pretty fair picture taker as a hobby lost interest until I suggested the possibility of aerial photography using large kites. He studied up on kites, and radio controls to trigger off the camera taken aloft. He redesigned a compact camera and devised means of bringing it back to ground safely. He had a pleasant summer with this new approach to his old hobby. The radio control got him interested in electronics and he is on his way toward other new fields, with something to show for his time and money. Another chap became very much engrossed in skin diving- and was very expert in the sport. Not being a "contest" sport its challenge soon wore off a bit, until last summer when I suggested that he "explore" the waters by electronics means; under-water sounds, echoes and similar effects. Having no previous knowledge, a little direction as to sources of information which he dug up on his own, started him off.

His fun with the various gadgets intrigued some of his pals, and now they are just as interested in under-water sounds as they are in rock-and-roll records, and are now learning how to pick up sounds and to classify them. This enthusiasm in unusual diversions involving science will possibly grow. It is a "fun" way of getting introduced to electronics. The CLUB could assist by suggestions, actual technical advice and perhaps even pieces of equipment. These youngsters are looking for something new and different to do. Here is our chance to benefit both them, ourselves, and the Club.

Sincerely yours,

Lloyd (Jacquet)"

Editor's Note: As we mentioned, these columns are open to all for an exchange of ideas, requests for sources of information relating to unusual problems, invitations to others when cooperation is needed, and above all -- the Proceedings is an excellent place where you can report results.

EDITORIAL

We have received several verbal comments on the recent editorial (Fall 1961) relating to the matter of picking out a hobby that combines both awarding interest, the chance of utilizing technical know-how that we may have in our specific fields, and the opportunity of doing something useful in a different field. We hope many of you will have time to get some of these follow-up ideas on paper so that we can publish them.

Comments have been received relating to the letter of Commander Watson on depositories for technical manuscripts (and possibly equipment items that may well be considered museum pieces). What the Club can do collectively remains to be seen, but one thing that is constructive is to have comments from many of you regarding present undertakings and suggested possibilities. Most of us have a few, at least, items that have historical interest.

DO YOU ATTEND MEETINGS?

A brash young designer you know, too
refused all his chances to go to
  the Club's technical talks
  and all night sessions balks
without getting both time off and dough, too.

Till the time that that company of his
on his project completed the biz
  sound he found, did this jerk
  that the change in his work
brought him down to a was from an is.

Then his calm and deliberate pace
Underwent a rightabout face
  in a field that was new
  lots of study was due
not to lag from the rest in the race.

EPILOGUE

He now knows the meetings he missed
would have brought him the needed assist
  As experiences of friends
  and their knowledge of trends
give rewards that make quite a list.

R. R. B.

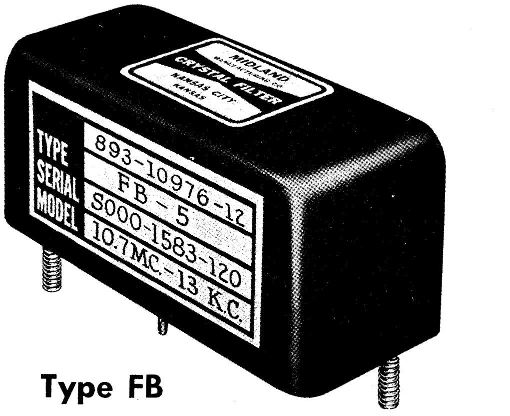
Is there anything anybody wants to add? Send it in.

Delivered In Quantity...

MINIATURE

Narrow Band-Pass Crystal Filters

The Midland Type FB Series is a group of hermetically sealed, eight-crystal, narrow-band filters that provide bandwidths in the range of 2 KC to 30 KC @ 6 db, with a center frequency of 10.7 MC. They are designed to operate in the environmental temperature range of −55°C to +90°C with an insertion loss of 4 db max. and an inband ripple of .8 db max. The Type FB narrow-band crystal filter is ideally suited for design in two-way communication systems, telemetry systems, electronic instrumentation equipment and other 10.7 megacycle applications where small fractional bandwidth filtering plus a high degree of selectivity and temperature stability is required. It can be used to best advantage in designing single-signal RF stages to give greater adjacent channel separation and performance reliability, in addition to conserving space and reducing material and manufacturing costs. Midland invites inquiries in assisting with any engineering problem where the use of crystals and crystal filters is proposed.



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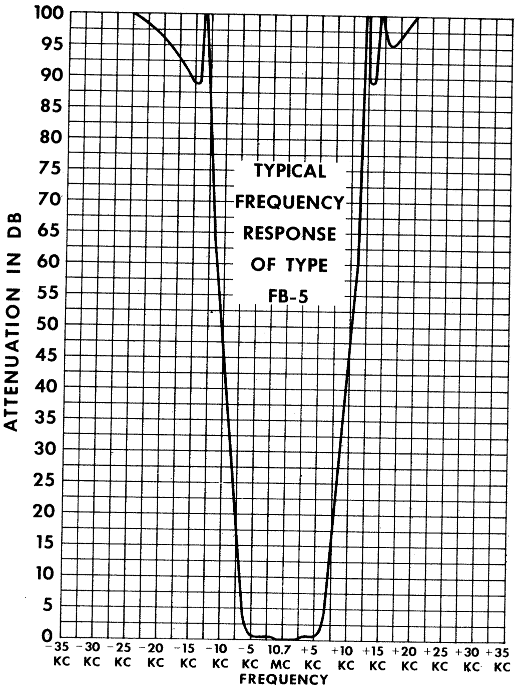


Specifications

	FB-2	FB-3	FB-5
Center Freq.*	10.7±200 CPS	10.7±225 CPS	10.7±375 CPS
BW @ 6 db Min.	2 KC	5 KC	13 KC
BW @ 60 db Max.	3.6 KC	9 KC	23 KC
60 db/6 db BWR Max.	1.8	1.8	1.8
BW @ 80 db Max.	4.5 KC	11.3 KC	26 KC
Ultimate Rejection Min.	105 db	105 db	105 db
Req. Source/Load Resistance (R_o)	130 ohms	330 ohms	1 K ohms
Inband Ripple Max.	.8 db	.8 db	.8 db
Insertion Loss Max.	4 db	4 db	4 db
BW @ 1 db Min.	1.5 KC	3.8 KC	10 KC

*Center freq is the arithmetic mean of the frequencies at 6 db.

Operating Temp. Range: −55°C to +90°C
Shock: 200 g
Vibration: 15 g to 2 KC
Max. Input Level: +10 dbm

Midland MANUFACTURING COMPANY, Kansas City 15, Kansas

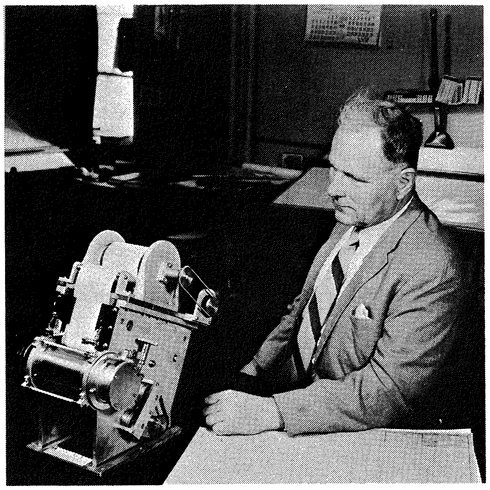
WORLD'S LARGEST PRODUCERS OF QUARTZ CRYSTALS

DIVISION PACIFIC INDUSTRIES INCORPORATED

Robert Finlay
SALES COMPANY
MANUFACTURERS REPRESENTATIVE
RIDGEWOOD NEW JERSEY

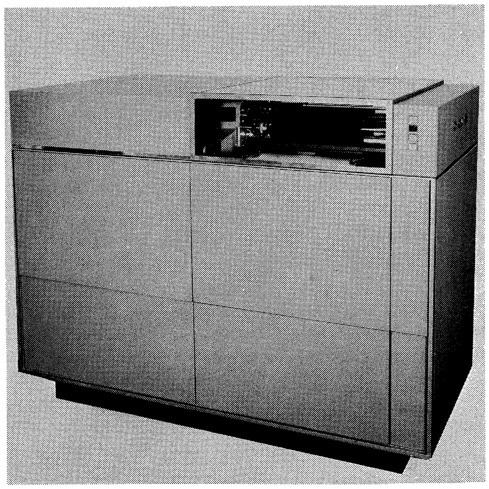
Shepard Laboratories High Speed

Input and Output Equipment



SHEPARD ELECTRONIC DECODERS receive and store coded information from Computer, Drum, Magnetic Tape, or communication link sources and emit pulses to each print column of the Typer in the manner prescribed by the logic of the customers' system. In instances where the customer uses a solid state buffer, register or counter as a part of the Computer itself, a simplified Decoder can be supplied to print on command the information residing in this buffer.

SHEPARD ELECTRONIC MINI-TYPER operates on the same principle as the Model 190. It provides the same choice of alpha-numeric characters (up to 64) and operates at speeds over 1,000 lines per minute. For numeric information only, speeds are in excess of 3,000 lines per minute. The 14-column unit measures 20" wide, 20" high and 26" deep. Models are offered with a capacity from 14 to 48 columns, with characters horizontally spaced 5 or 10 to the inch. Fully transistorized electronics available to enable printing information residing in customers' register, counter or memory.



SHEPARD ELECTRONIC HIGH SPEED TYPER, Model 380, operates on the rotary principle. Synchronized type wheels, each containing 64 alpha-numeric characters, spin continuously at 600, 900 or 1200 rpm. Timed hammers, propelled by solenoid magnets, select the desired character on each type wheel as it spins past the print line (175 inches per second). There is a separate type wheel with its own hammer and solenoid for each column. Typing rate is 600 to 1,000 lines per minute for alpha-numeric information and up to 4,500 lines per minute for numbers only. Line-per-minute speed is not affected by the number of columns. Models are available with up to 190 columns. A 120-column unit, running at 1,000 lines-per-minute, produces 120,000 characters per minute.

SHEPARD LABORATORIES, INC

480 MORRIS AVENUE
SUMMIT, NEW JERSEY

CRestview 3-5255
Literature Available

BALLANTINE True RMS VTVM model 350

Measures wide range of waveforms with 1/4% ACCURACY

For highly accurate voltage measurements, the uncertainty introduced by waveform distortion limits the use of average and peak-responding instruments. The Model 350 is a 0.25% accurate, true rms-responding instrument designed to overcome this limitation. It provides the engineer with a rugged, reliable and easy-to-use laboratory or production line instrument. It will measure a periodic waveform in which the ratio of peak voltage to rms is not over 2.

The method of measurement with the Model 350 is similar to balancing a bridge: four knobs are set for minimum indication and the unknown voltage is read directly from a 4 to 5 digit NIXIE® in-line readout. The precision exceeds the stated accuracy by 5 to 10 times. **Price: $720.**

SPECIFICATIONS

Voltage Range...... 0.1 V to 1199.9 V
Accuracy. 1/4%, 100 cps to 10 kc, 0.1 V to 300 V; 1/2% outside these limits
Frequency Range...... 50 cps to 20 kc
Max Crest Factor 2
Input Impedance .... 2 MΩ shunted by 15 pF to 45 pF

Write for brochure giving many more details

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Signal fires flaming across a network of some nine stations over a distance of sixty miles flashed the news of the fall of Troy to Agamemnon's palace at Mycenae. *Tele* in Greek means distance, and this—in 1194 B.C.—was *telecommunications.*

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"FAMOUS FIRSTS"

1939	MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.
	MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc.
1940	MODEL 58 UHF RADIO NOISE AND FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.
	MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator.
1941	MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.
1942	SPECIALIZED TEST EQUIPMENT FOR THE ARMED FORCES. WORLD WAR II.
1943	MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.
1944	MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.
1945	MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.
1946	MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type.
1947	MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wide-band, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.
1948	MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 420 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.
1949	MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.
1950	MODEL 111 CRYSTAL CALIBRATOR—A calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.
1951	MODEL 31 INTERMODULATION METER—With completely self-contained test signal generator, analyzer, voltmeter and power supply. Model 31 aids in obtaining peak performance from audio systems, AM and FM receivers and transmitters.
1952	MODEL 84 TV STANDARD SIGNAL GENERATOR—With a frequency range of 300-1000 Mc., this versatile new instrument is the first of its kind designed for the UHF television field.
1953	MODEL 59-UHF MEGACYCLE METER—With a frequency range of 420 to 940 megacycles, the first grid-dip meter to cover this range in a single band and to provide laboratory instrument performance.
1954	FM STANDARD SIGNAL GENERATOR. Designed originally for Military service. The commercial Model 95 is engineered to meet the rigid test requirements imposed on modern high quality electronic instruments. It provides frequency coverage between 50 Mc. and 400 Mc.
1955	RADIO INTERFERENCE MEASURING SET. An aperiodic noise meter useful to 1000 Mc.
1956	MODEL 505 STANDARD TEST SET FOR TRANSISTORS. A versatile transistor test set which facilitates the measurement of static and dynamic transistor parameters.
1957	RADIO FIELD STRENGTH AND INTERFERENCE MEASURING SET. A tuned radio interference and field strength set covering the frequency range of 150 Mc. to 1000 Mc.
1958	MODEL 560-FM STANDARD SIGNAL GENERATOR—First successful FM Signal Generator using solid state modulator.
1959	MODEL 700 FREQUENCY METER—A completely new concept of frequency measurement. An instrument capable of direct and continuous reading to one cycle in 25-1000 Mc range.
1960	MODEL 139 TEST OSCILLATOR—A compact, versatile, and portable instrument for rapid and accurate alignment of I.F. circuits in all types of radio receivers.
1961	MODEL 760 STANDARD FREQUENCY METER—An accurate, simple to operate, direct read-out, portable instrument designed for servicing two-way mobile radio equipment.

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