FREMODYNE F-M Receivers

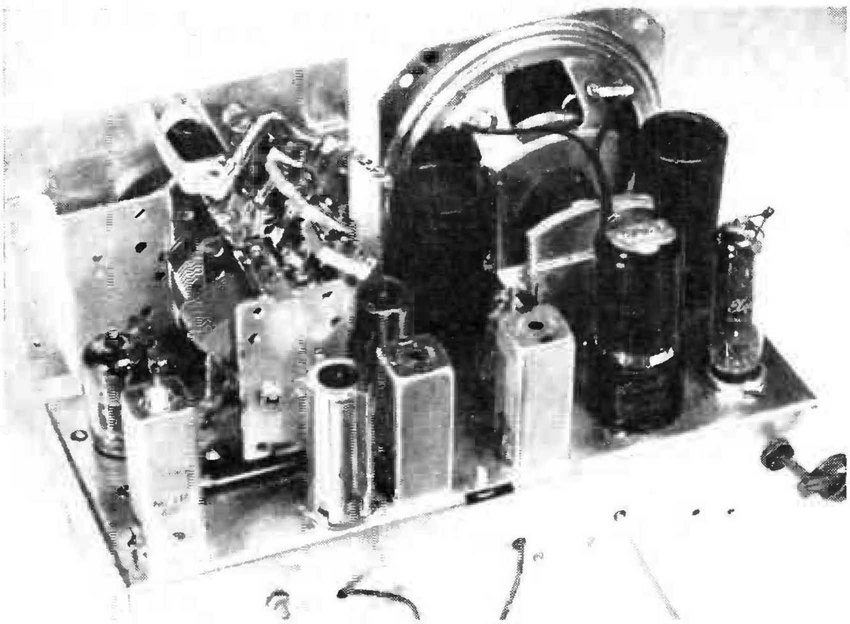
Description and evaluation of measurements made on a novel superregenerative superheterodyne circuit offered for low-cost mass-produced f-m receivers. Figures are given for sensitivity, quieting-sensitivity, distortion, audio response, selectivity, and radiation

THE MOST inexpensive approach, to date, to the production of an f-m broadcast receiver is the "Fremodyne" circuit, licensed by Hazeltine Electronics Corporation to some 125 manufacturers, 5 of whom are currently in production. Because of its potential impact upon every aspect of f-m broadcast listening, the editors of ELECTRONICS canvassed the manufacturing licensees and found that two of them already had receivers or converters. One a-c/d-c table model receiver for f-m and a-m was purchased, another of the same make was borrowed, f-m converter supplied gratis by another manufacturer.

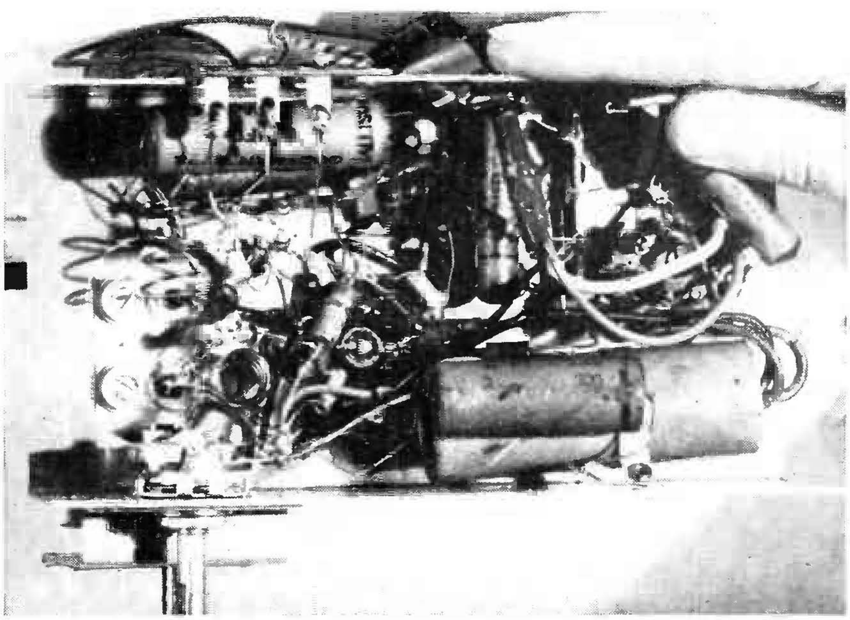
Using standard testing equipment as well as qualitative listening tests, the editors subjected two available versions of the Fremodyne circuit to a series of fundamental tests that will be of significant interest to designers in the f-m field. The tests conducted included sensitivity (signal-noise ratio), quieting-sensitivity (quieting of receiver noise by an unmodulated carrier), distortion, relative audio response, selectivity (response to adjacent and co-channel interference), and radiated interference, although the terms used are not synonymous with those definitions as applied in standard RMA receiver tests.

It should be emphasized that, for reasons to be given, certain arbitrary criteria of judgment were adopted. An extension of the testing method to two conventional types of f-m receivers is intended to aid in interpreting the test results.

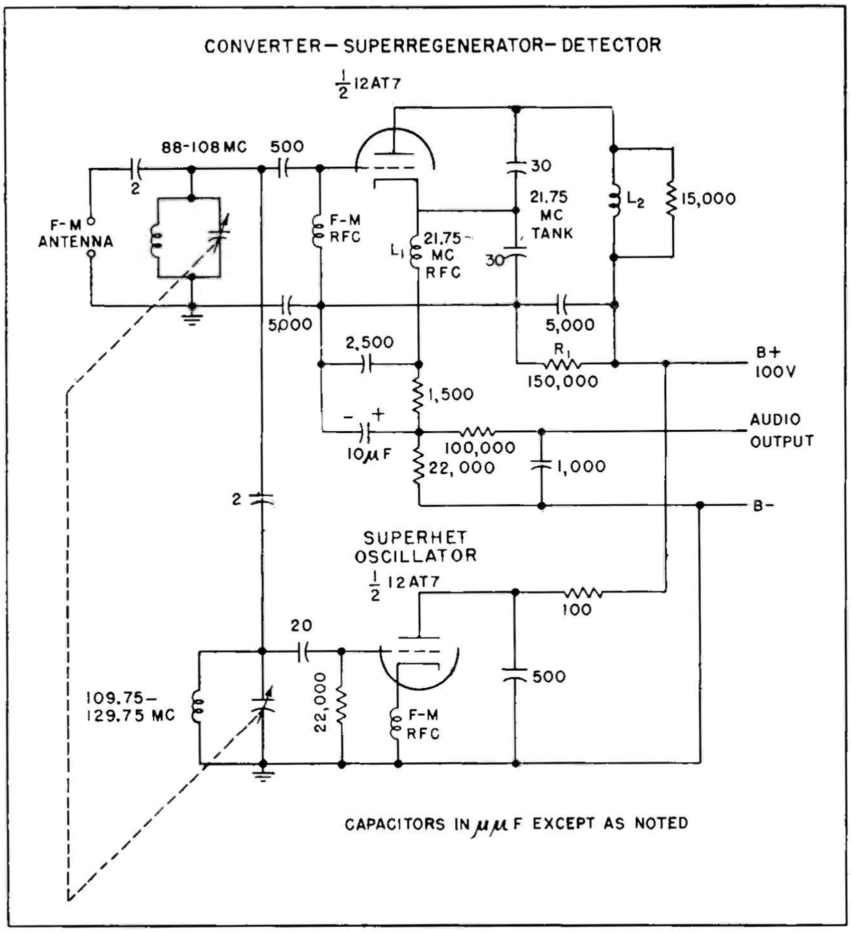
Described by Hazeltine as a superregenerative superheterodyne,



Combination a-m and f-m receiver using the superregenerative superheterodyne circuit. Local and signal tuning coils and padders can be seen above tuning gang at left



Under-chassis view of a Fremodyne f-m converter with r-f circuit at left. Later models use the same basic circuit but have an additional audio amplifier tube



Schematic diagram of the basic Fremodyne circuit

the basic Fremodyne circuit shown consists of a double triode tube, one section of which is used as a local oscillator of the Colpitts type displaced 21.75 megacycles above (or below) the incoming signal frequency.

The local oscillator (lower section in the diagram) output is fed onto the grid of the other triode section (upper section) along with the antenna input. This upper grid circuit is tuned to the signal frequency. The plate tank of the upper section forms a Colpitts oscillator using L_2 and the two 30 $\mu\mu$f capacitors tuned to 21.75 mc. The same triode section operates as a superheterodyne converter and i-f amplifier. It is also a self-quenching superregenerative detector with a quenching frequency in the region of 17 to 22 kc (Hazeltine recommends a quench frequency of 30 kc) by virtue of the 150,000-ohm resistor R_1 returned to B plus. By these means, the oscillator frequency which gives the strongest radiated signal, is displaced from the carrier frequency. Since the detector operates at one frequency, a fixed optimum amount of quench is easily obtained without a separate control. The quench waveshape is controlled by a 1,500-ohm resistor and 2,500 $\mu\mu$f capacitor.

Audio signal is recovered across a 22,000-ohm resistor in the lead from cathode to B minus.

Engineers will find that the circuit behaves in every respect like a simple single-tube self-quenched superregenerative receiver that they may have used at one time or another in receiving f-m signals. As with conventional a-m detectors, slope detection of f-m signals is possible if slight mistuning from the center of the carrier frequency can be satisfactorily achieved and the degradation of the audio quality can be tolerated.

It must be recognized that tests of a superregenerative circuit as an f-m receiver are to some extent arbitrary insofar as distortion, signal-noise ratio and quieting measurements are concerned. Tuning for maximum quieting of the receiver by an incoming carrier gives inacceptable audio output that is rich in second-harmonic distortion. As the receiver is tuned farther down one slope or the other of the detection curve in order to obviate distortion the noise increases. The practice adopted during the tests was always to tune the receiver on the high-frequency side of the incoming signal at the optimum point between distortion and noise.

Testing Equipment

Signal-noise and distortion measurements were made using equipment connected as indicated in the block diagram of Fig. 1.

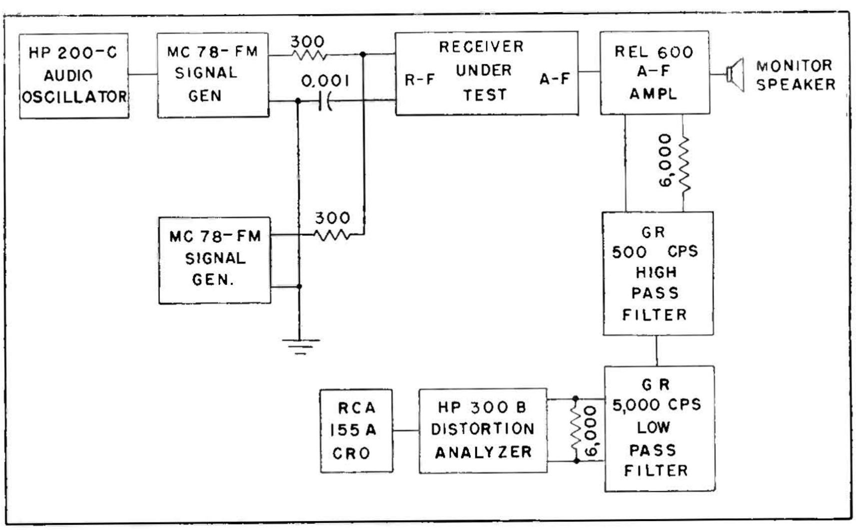


FIG. 1—Block diagram of the testing equipment used and the interconnections

The signal generators were Measurements Corp. model 78-FM for the frequency range covered by the f-m broadcast band, with provision for internal or external frequency modulation of the carrier. The audio oscillator was a Hewlett-Packard type 200-C. Audio output in every case was taken after the de-emphasis network included in the receiver but ahead of any audio amplifier so that the superregenerative circuit was measured alone. Suitable gain was provided by a Radio Engineering Labs. audio amplifier model 600. The loudspeaker was connected to a separate output from the amplifier for monitoring purposes. Owing to hum and quenching frequency noise only the pass band between 500 and 5,000 cycles was measured, except as later noted. Filtering was accomplished with General Radio 500-cycle high-pass and 5,000-cycle low-pass sections. The distortion analyzer was a Hewlett-Packard model 330B instrument and the oscilloscope an RCA type 155A.

Fremodyne sets 1 and 3, discussed hereafter, are a-m/f-m, a-c/d-c receivers of a type shown in the block diagram of Fig. 2. Set 2 as tested comprises only the Fremodyne circuit and power supply; it was designed for use as an f-m converter for existing a-m receivers. Both sets as now manufactured have a line-cord antenna and also make provision for connecting an external antenna, although the line-cord connection was omitted in set 2, in the particular sample tested.

Set 4 is a Zenith model 8H023 a-m/f-m, high-and-low-band receiver of conventional f-m design, that has been in use for some months without readjustments. It contains a stage of trf, converter, two i-f's, limiter and discriminator. Set 5 is a special receiver, Radio Engineering Laboratories model 646, designed for optimum f-m reception and is in no way comparable to a low-priced home receiver. It has a trf stage, converter, three i-f's, two limiters, discriminator.

Measurements were made of the signal-to-noise (actually signal-plus-noise to noise) ratio at 90 mc using, with one exception, 50 kc deviation with 1,000-cycle modulation. The higher audio frequency was necessary, rather than the more standard 400 cycles, because of the 500-to-5,000 cycle pass band used in the tests. A more considerable deviation than 22.5 kc was desirable in order to obtain a tuning point midway between distortion and noise that would have significance from a listener's point of view. It also served to facilitate duplication of tuning settings during the tests, because they occurred on a straight portion of the detection slope.

Initial tests of Fremodyne set 2 using 400 cycles at 75 kc deviation were essentially preliminary and seemed too severe. Time was not available to repeat them at 1,000 cycles using the lower deviation of 50 kc standardized for the other receivers. The figures as presented are corrected for attenuation of the 400-cycle signal by the 500-cycle high-pass filter. Fremodyne set 3 developed a bad hum after several hours of operation so that only the check points shown, measured before hum began, are felt to be representative.

F-M Receiver Characteristics

The results plotted in Fig. 3 make use of the phenomenon that the desirable characteristics of an f-m receiver include an avc action (the audio output must not change appreciably with changes in signal

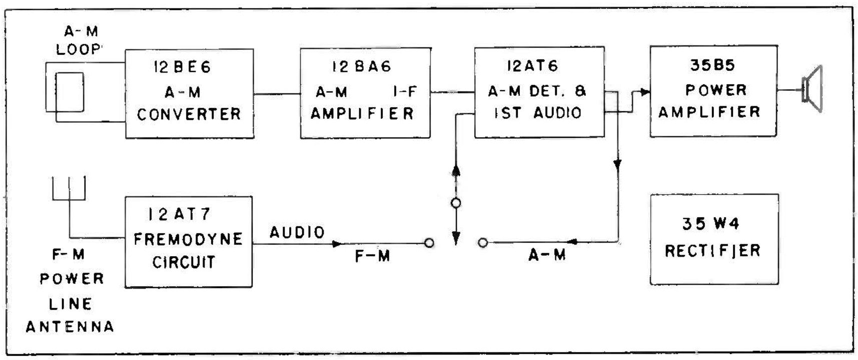


FIG. 2—Block diagram of an f-m/a-m receiver in which the audio system is common to both the Fremodyne and a conventional superheterodyne receiver circuit

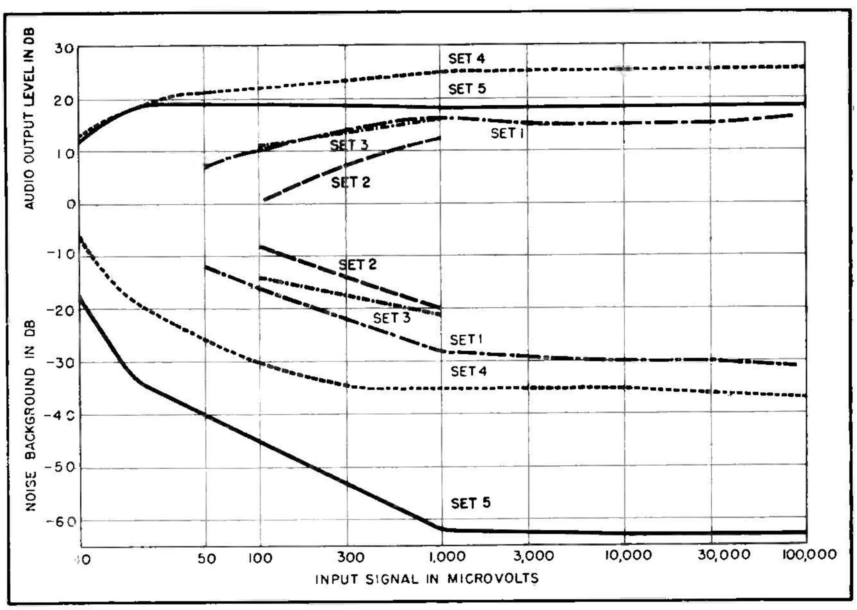


FIG. 3—Audio-output level and receiver noise background separately plotted against input signal strength. Signal-noise performance of an f-m receiver is more clearly indicated by the area enclosed between the curves than by the curves considered separately

strength) as well as an increasing quieting of set noise with increased signal. The horizontal zero axis represents the noise in the absence of signal and so serves merely as a reference, except at the zero-zero point. Quieting in db below the noise level is plotted against unmodulated input signal and can be considered the noise background as encountered by the listener.

The audio level curves (ideally straight horizontal lines with the exception of a short positive slope near the zero-zero point) are computed by subtracting the quieting figures in db from those representing the signal-to-noise ratio at the same signal input. The general shape of the curves is the same for all the receivers tested and the three Fremodynes group fairly closely. What is not immediately so apparent from this presentation is the rather wide difference in performance when we consider not only the separate displacements from the reference axis, but the sum or spread between the two characteristics, audio level and noise background. The average of the two best Fremodynes varies from 26 db at 100 μv to 47 db at 85,000 μv input, while the Zenith (set 4) varies between 52 and 62 db over the same signal input range.

Inspection of the signal generator connection (Fig. 1) will show that while the curves are comparable among the receivers for this test, the effective source actually has an impedance of about 150 ohms and voltages of half the values shown. In other words a receiver that gives 45 db of quieting (noise background scale) at 100 microvolts in this test can be expected to give the same quieting with only 50 microvolts from a single standard signal generator connected to the receiver through approximately 150 ohms.

Percentage distortion for varying signal inputs modulated at 1,000 cycles with 50 kc deviation is shown in Fig. 4. The initial negative slope of each curve represents the inclusion of a large amount of noise at low signal input (owing to lack of quieting) and is, therefore, not particularly significant. The extremely high distortion encountered in set 2 is, undoubtedly, owing to the use of 75 kc deviation (at 400 cycles) rather than the 50 kc later standardized for the other receivers. It is included as a matter of interest but should not be regarded as having comparison significance.

Table I—Adjacent and Cochannel Interference

(Modulated interference to unmodulated signal of 1,000 μv)

Interfering Signal	Interfering Signal Strength in μv (for 3db rise in background noise)				
	Set 1	Set 2	Set 3	Set 4	Set 5
Cochannel	50	35	25	25	130
200 kc low	5,000	20,000	10,000	4,000	900
400 kc low	60,000	100,000	85,000	30,000	—
200 kc high	150	180	100	2,500	5,000
400 kc high	40,000	40,000	30,000	15,000	—

(Unmodulated interference to modulated signal of 1,000 μv)

Interfering Signal	Interfering Signal Strength in μv (see text)				
Cochannel	15	20	20	600	200
200 kc low	2,000	5,000	4,000	10,000	40,000
400 kc low	50,000	>100,000	>100,000	100,000	>100,000
200 kc high	400	250	2,000	2,500	8,000
400 kc high	30,000	>100,000	>100,000	80,000	>100,000

Table II—Radiation Interference in Microvolts

(Receiver under test tuned to 100 mc. Interference frequency shown in left-hand column)

Freq.	Set 1	Set 2	Set 3	Set 4	Set 5
54	....	....	....	5,500	....
64.3	....	....	....	....	....
78.25	....	30,000	....	....	....
87	1,000	....	....	....	....
100	2,000	....	4,000	....	....
100.5	....	600	....	....	....
101	....	4,000	....	....	....
101.6	....	650	....	....	....
107.3	....	1,000	....	....	....
108	....	....	2,500	6,500	....
109.5	2,000	....	....	....	....
111.1	....	....	....	....	1,000
121.8	300	....	....	....	....
122	25,000	....	20,000	....	....

Interference Measurements

Adjacent and cochannel interference measurements centering about 90 mc are given in Table I. It should be noted that tuning of the Fremodyne receivers was fixed on the high-frequency side. Because of the off-center tuning the results of the high and low adjacent channel interference are not comparable. The test setup used is that of Fig. 1. The modulating signal was, with the exception of set 2, 1,000 cycles at 50 kc deviation. Set 2 was tested against 400-cycle modulation at 75-kc deviation. Despite this fact, there is a good correspondence in the order of magnitude of the results.

In the conventional receivers an interfering signal when increased beyond a certain point "captures" the receiver, whereas in the Fremodyne there is merely an increase in the interference. For instance, cochannel interference of a modulated signal was noticed in set 4 at 600 microvolts, but when the interfering signal was increased to 1,000 microvolts the desired signal was obliterated and the receiver was completely captured by the interfering signal.

When the desired signal was unmodulated and the interfering signal modulated, the criterion of interference was a 3 db rise in the background noise. This amount of rise is, of course, a more severe test to the receivers with low background. In the unmodulated interference to a modulated signal the standard was an arbitrary disturbance of the cathode-ray pattern of the audio. It was always judged by the same individual over the short period of the test.

Audio Response

Relative audio response, including the de-emphasis circuit, was measured on two receivers, modifying the measuring setup (Fig. 1) by substituting a General Radio 15,000-cycle low-pass filter for the band-pass filter.

The results, corrected for the de-emphasis characteristic, are shown in Fig. 5. The signal input to both sets was 1,000 microvolts using 1,000 cycle tone modulation with 50-kc deviation. Test was not made on set 3 because of hum trouble that developed. The tests show that although the sets have a flat audio output response from about 100 to 1,000 cycles, divergence from uniformity starts increasing rapidly on either side of these limits. Even more important, distortion due to beating with the quench frequency begins at about 4,000 cycles in set 1 and between 6,000 and 8,000 cycles in set 2, so that the flat portions of the curves are the only useful ones. The intermodulation effect probably results from the low quench frequency.

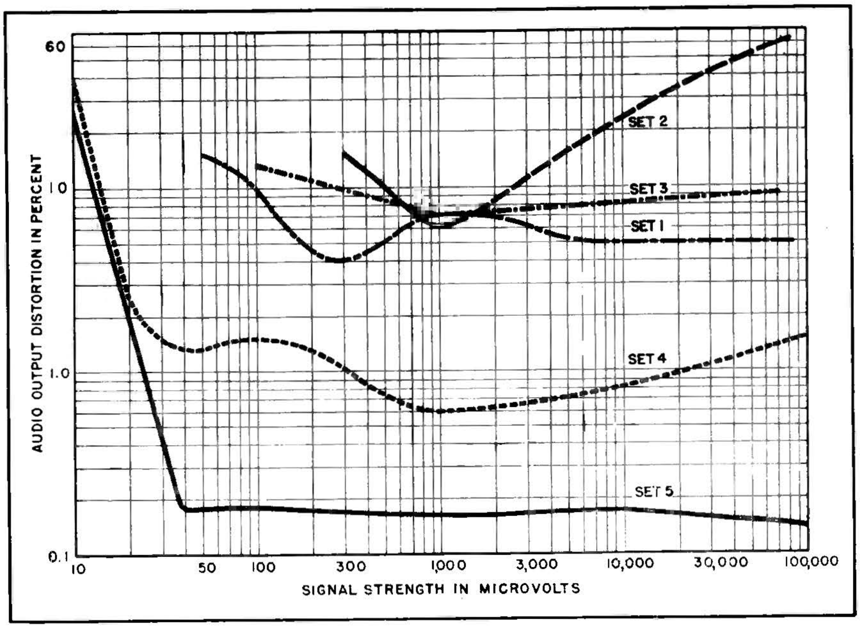


FIG. 4—Percentage audio output distortion plotted against input signal strength. (Curve for set 2 is not comparable to others. See text). Initial negative slope is caused by noise

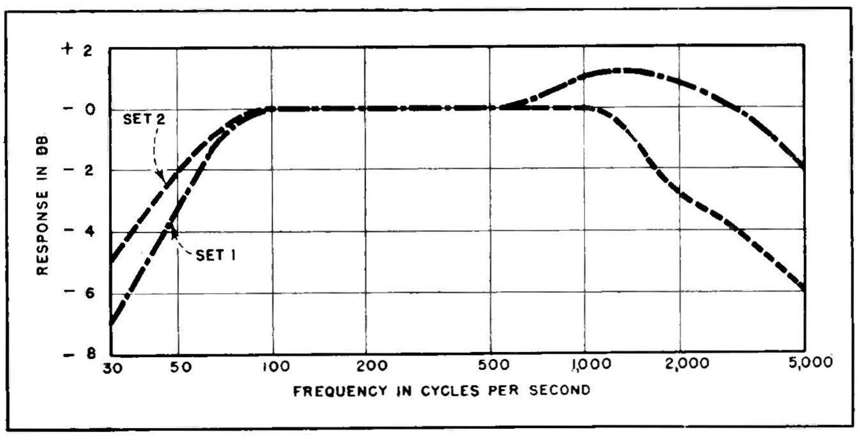


FIG. 5—Relative audio response for sets 1 and 2

Radiated Signals

Of significance both to the set owner and to those receiving signals in the same or adjacent bands is the amount of power radiated by a receiver. The antenna, or antenna and ground, terminals of the Fremodyne circuit were connected through a 10-foot length of 70-ohm coaxial cable to the antenna terminals of a Hallicrafters S-27 receiver and the dials set to 100 mc. Then the S-27 receiver was tuned for points of strongest signal emanating from the receiver under test and the signal strength calibrated with a Measurements Corp. generator. As might be expected, the greatest signal intensity occurred at the frequency of the local oscillator. Other wide-band interference was also found, peaking at the frequencies and with the strengths listed in Table II. Radiated signals of less than 300 microvolts intensity are not included. Strong noise signals peaking at 21.75 mc in a band over 3 mc wide could also be picked up on a Hallicrafters S-28 receiver about 10 feet away and not physically connected to the test receiver.

Qualitative Listening Tests

In the editorial offices of ELECTRONICS on the 30th floor of the McGraw-Hill Building near Times Square, it was found possible to pick up 16 f-m broadcast stations using only the line cord antenna used in Fremodyne sets 2 and 3.

Although the audio quality of the programs as received in the f-m position is inferior to that from a-m stations carrying the same material, the relative freedom from fluorescent lighting, elevator contactor and other noise makes the f-m section preferable for continued listening. Cochannel listening with two similar receivers spaced about 25 feet apart along corridors is impossible, and even at about 100 feet there is some squealing and hash across the dial of either receiver.—A. A. McK.