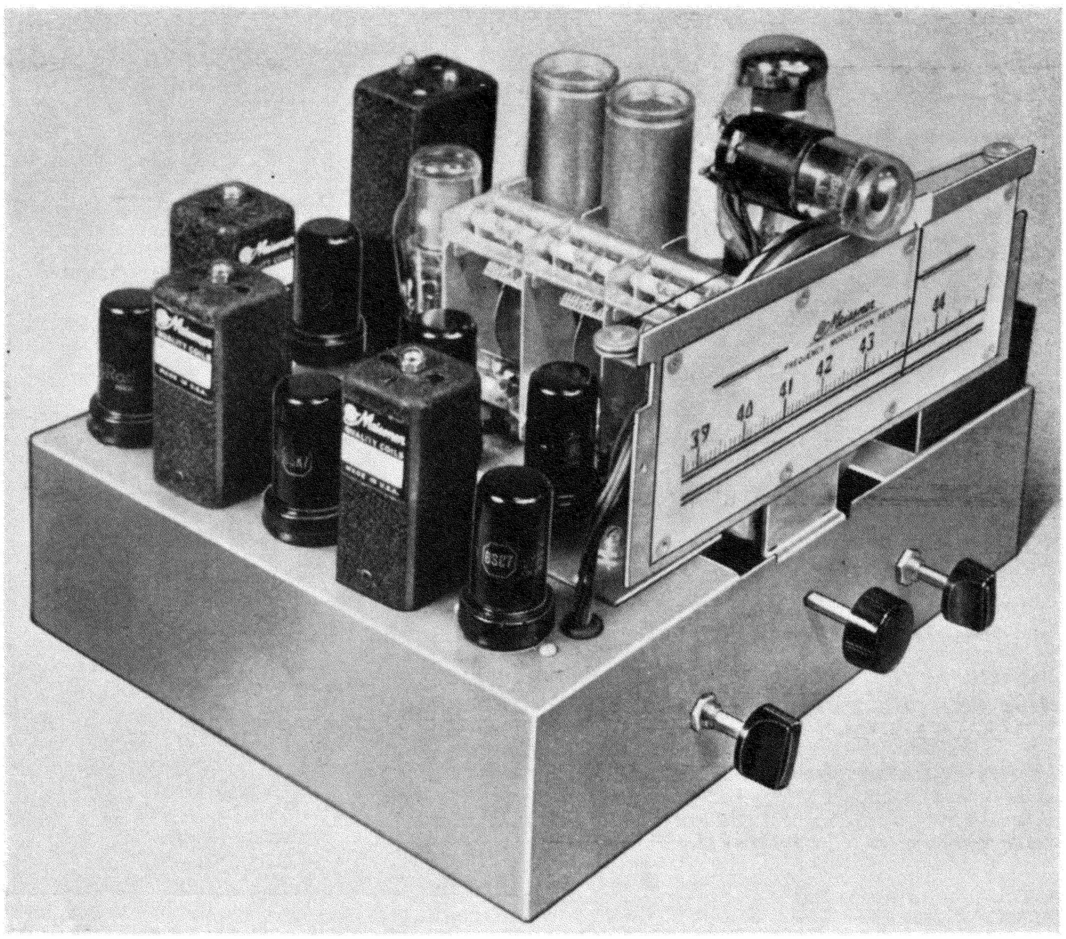


As compact as a modern "ordinary" receiver, the F. M. receptor is simple to operate and build.

Design Notes on a
FREQUENCY MODULATION RECEPTOR

by F. W. WALTER
Mt. Carmel, Illinois

Frequency Modulation seems here to stay and so we present a very fine receptor for those who are located within the range of these stations

A SYSTEM of radio broadcasting and reception that practically eliminates all natural and man-made interference has been known to radio engineers for several years. Only lately has the news of this new system reached the public through the medium of newspaper and news magazine articles. Few people, even well-informed Servicemen, Amateurs or Experimenters, have a sufficiently clear idea of the operation of the system to be able to explain wherein the new and the old systems of broadcasting differ and what eliminates the static and interference in the new system.*

The purpose of this article is to bring out the fundamental differences in the two systems of transmission and reception and to explain how the static is truly eliminated, a feat "proven impossible" by several noted and capable engineers.

The results achieved by the use of *Frequency Modulated* transmission (the new system) are so marvelous that they must be witnessed to be believed and fully appreciated. For example, in the densely populated sections of New York City where there is every conceivable type of elevator control, and many other types of electrical equipment producing a regular barrage of electrical noise, programs transmitted by the new system are received with perfect satisfaction in places where the older type of set was useless.

Unlike regular broadcasting, frequency-modulated broadcasting is now being done on frequencies around 40 megacycles. It is notably free from interference of all kinds and has, with a few watts of transmitter power, delivered a cleaner signal than hundreds, or in some cases even thousands, of watts at broadcast frequencies over equal distances. In addition, the fidelity obtained with the new system has been exceptional.

There are two basic characteristics of a receiver for frequency-modulated signals that enable the receiver to re-

* Strictly speaking, F.M. is not new. See Morecroft. "Principles of Radio Communication," 3rd Ed. Pages 824-828. Ed.

produce program material without static. First, the receiver is so designed that it will not respond to *amplitude* variations in the received signal; therefore, static impulses are not reproduced because a static discharge appears as a voltage (or amplitude) variation. Secondly, the program is transmitted by means possessing none of the amplitude modulated characteristics which are similar to static or other electrical interferences of the usual type.

Of course, a man-made interfering signal can be produced intentionally, but no man-made interference of the type resulting from sparking electrical equipment, or from automobile ignition systems can generate that characteristic of a Frequency-Modulated transmission.

Since the explanation of the performance of a receiver for Frequency-Modulated signals requires a circuit diagram, the *Meissner Frequency Modulation Receptor* was chosen as a typical example for discussion, and its particular suitability for illustrating the various points in the explanation.

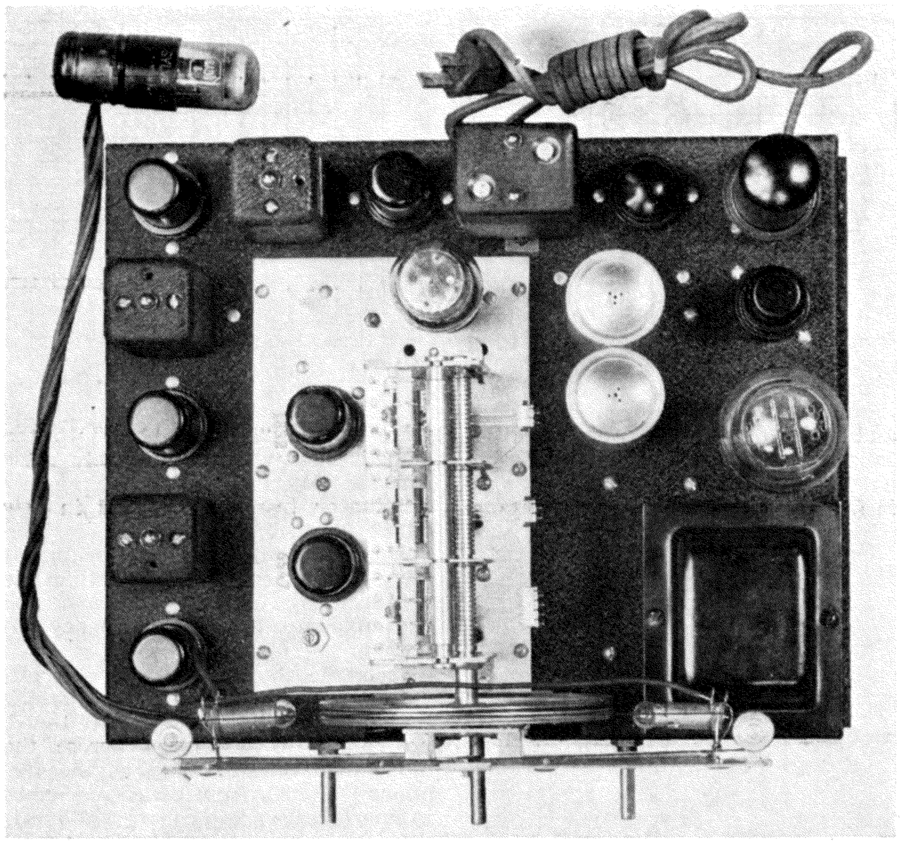
Since, as stated above, the first requirement for the elimination of interference is that the receiver should not respond to amplitude variations, a portion of the receiver must be designed to reproduce every signal at the same level.

Referring to Fig. 2, a portion of the diagram is labeled "Limiter." It is the function of this tube to deliver all signals (above a certain minimum level) to the detector *at the same level.* It is this tube that "cuts off" (so to speak) all static, or similar impulses.

Those experimenters who have used Automatic Noise Suppressors will have some idea of how this tube works, but in the case of the A.N.S., the problem was to cut off only those interference peaks that *exceeded* the modulation peaks. When the interference was of the ignition noise type, considerable improvement could be made by the use of the A.N.S., but when this was of a continual grinding type of noise, only a little louder than the desired signal, the A.N.S. would hardly begin to suppress the noise before it would seriously distort the signal.

In the Frequency Modulation Receptor, the Limiter tube does not have to distinguish between the difference in signal strength of the desired program and an undesired interfering noise; its function is to deliver everything, signal and noise, to the detector at the same level. Harmonic distortion of the signal is of no consequence.

In order to be most positive about delivering all signals at the same level, the d.c. voltages applied to the *Limiter* tube are such that the tube overloads easily, and an AVC circuit operated by this tube is designed to *keep it overloaded* as long as the signal is above a certain low level. Since very few AVC circuits hold the output of an amplifier to a sufficiently uniform level to suppress all amplitude modulation and static pulses (even amplified AVC systems), the overload condition is selected for the Limiter tube. When once the tube reaches its *full* output it can not give more output regardless of how much more signal is applied to its grid. The one point that must be guarded against in the design of the Limiter is to see that the output of the overloaded tube does not *decrease* as the input signal is *increased.*

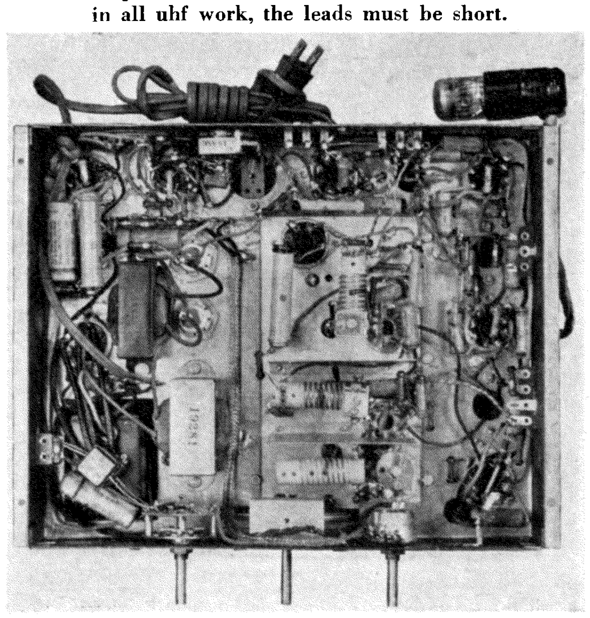


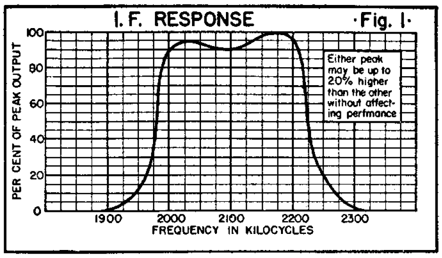
Top view of the frequency modulation receptor of commercial make. Note that it is not very much different from the ordinary radio superheterodyne receiver.

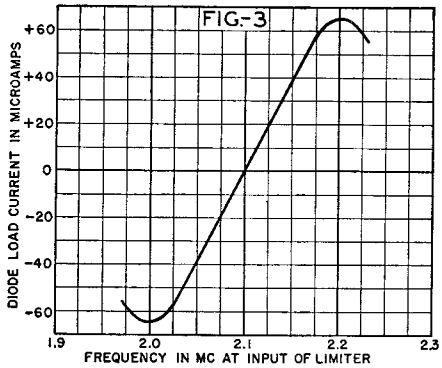
By means of this overload characteristic, all signals come out of the Limiter tube at the same level. Consequently, if a broadcast signal using the conventional (Amplitude) type of modulation is tuned in on a receiver designed for Frequency Modulation, the "Limiter Tube" completely and thoroughly spoils the program. The problem then to find means for passing a signal through the "Limiter Tube" without having it garbled and distorted. If the conventional (Amplitude) type of modulation is ruined by the "Limiter Tube" it is obvious that some other type of modulation must be employed.

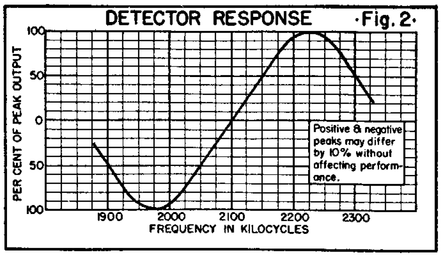
Since the frequency of the signal is not changed by passing through the "Limiter Tube," a type of signal is transmitted in which sound-pressure variations in front of the microphone are translated into *frequency variations* in the transmitted carrier. After hearing of crystal control for the frequency of transmitters for so many years, and hearing boasts about frequency stability within one or two cycles per million, the idea of working with a signal whose frequency is intentionally made to shift as much as 75 kc. (75,000 cycles) to either side of its nominal frequency is nothing short of revolutionary, but it is the basic

The underchassis view indicates that as in all uhf work, the leads must be short.



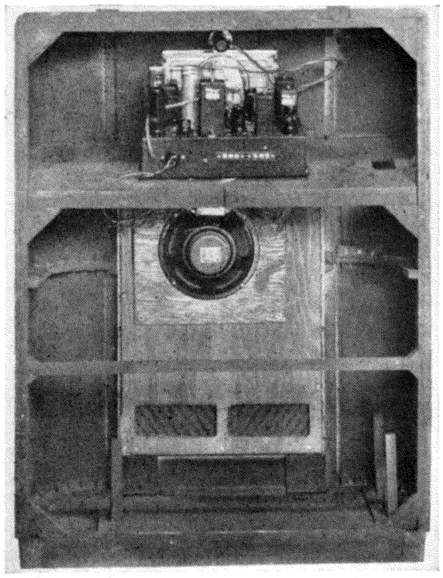






idea of a frequency-modulated signal, and is the characteristic of the signal from which this type of broadcasting takes its name.

In the receiver, the signal *fed into* the Limiter tube varies in frequency and may vary also in amplitude because of fading. The signal coming out of the "Limiter Tube" *varies only in frequency* but has constant voltage.



The frequency modulation receptor installed in a fine large console.

Since all detectors converting i.f. signals into audio signals are devices that work solely through voltage variations, some device is necessary to *convert the frequency variation* of the signal back to *voltage variations* so that the detector may have a voltage variation to rectify.

The transformer connecting the plate of the "Limiter Tube" to the diode is the device which performs this function. In fact, it is like the discriminator transformer used in sets employing A.F.C. (Automatic Frequency Control), but it is working at a higher frequency (2100 kc.) than the conventional A.F.C. transformer and accommodates a wider frequency variation.

It is the characteristic of this circuit that, at the frequency to which both primary and secondary are tuned, no voltage is developed across the diode load resistors but, as the frequency departs from exact resonance in one direction, a positive voltage is developed across the load resistors while, if the frequency departs from exact resonance in the opposite direction, a negative voltage increases. This transformer, together with the double-diode detector, converts frequency variations back into audio voltage variations, which are amplified in the normal manner and reproduced by a conventional loudspeaker.

Limiter AVC

An examination of the circuit feeding the grid of the "Limiter Tube" will show a striking similarity to the conventional diode AVC circuit with the exception that, in place of a diode at the *high-potential* end of the i.f. transformer secondary, the grid of the 1852 tube is used.

Those familiar with diode AVC action will realize that this grid must draw grid current in order for the AVC voltage to be developed. At first glance it might seem peculiar to allow this grid to draw current since such action in a normal receiver would result in considerable distortion, but it must be remembered that amplitude variations do not accompany the carrier in a frequency-modulated signal, and therefore, amplitude distortion in this part of the receiver is entirely permissible. From the low-potential end of this transformer secondary, a conventional circuit of AVC resistors and condensers connects to the preceding amplifier tubes to regulate the gain of the i.f. amplifier to an amount that will keep the "Limiter Tube" overloaded as described in a preceding section.

Characteristics of the Signal

It has been said in many places in the preceding part of this article that the principal difference between this signal and the conventional broadcasting signal is that the program material is transmitted by *variations in frequency* instead of by *variations in amplitude.* It has not been brought out in so many words until now, however, that the loudness of any particular tone in the program is proportional to the *amount of the frequency shift.*

In other words, during a pause in the program, that is, a moment of silence, the carrier is fixed in frequency, and as modulation is applied, increasing from a whisper up to full volume, the amount of *carrier shift* increases from zero up to a maximum of 75 kc. (according to present standards of operation.) The frequency of the audio note corresponds to the number of

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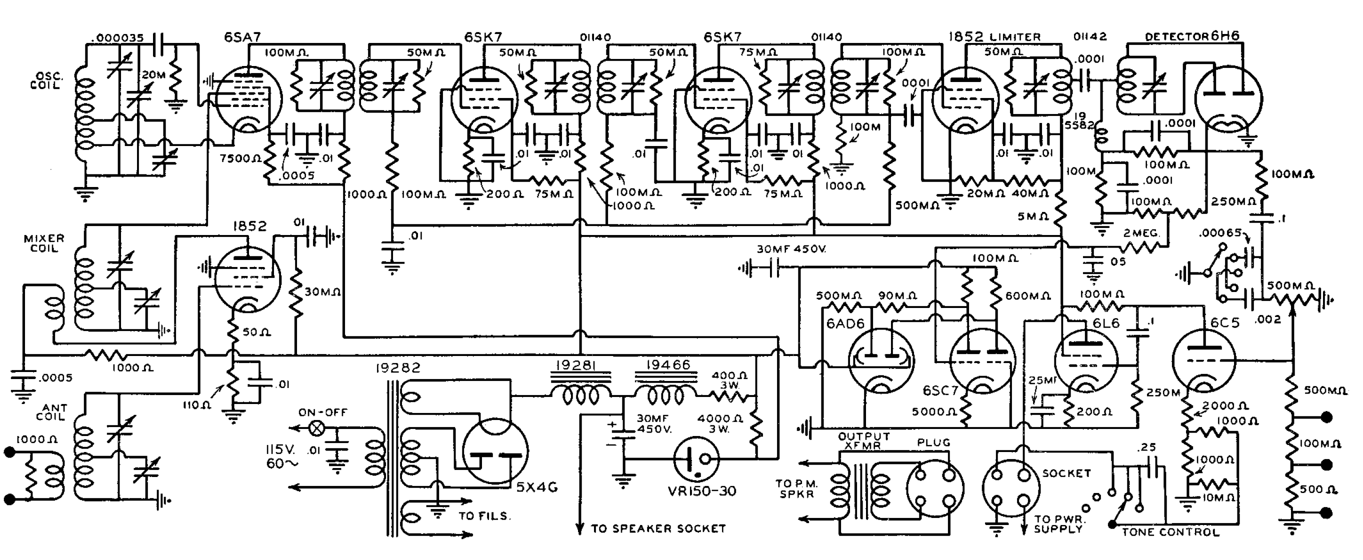

F. M. Receptor

(*Concluded from page 12*)

times per second that the carrier shifts from its lowest frequency to its highest frequency and back.

The frequencies utilized at the present time for this type of program lie between 39 megacycles and 44 megacycles. Those familiar with television performance will recognize that these frequencies give reliable performance only slightly beyond the optical horizon but in certain cases travel very long distances. These long-distance transmissions can not be relied upon to be consistent, however.

In the Frequency Modulated Receiver, a stage of r.f. amplification, easily identified in the circuit diagram, has been employed to give high sensitivity and signal-to-noise-ratio and to provide a much better image-ratio than could be obtained without its use. As in television receivers, the r.f. amplifier tube employed is an 1852 giving very high gain, but because the pass band, 150 kc., is much narrower than the 2 to 3 megacycle pass band of a television receiver, it is not necessary to broaden the r.f. circuits by connecting resistances across them as in the case of television r.f. circuits.

There is an interesting point in the circuit diagram to observe in the cathode circuit of the r.f. amplifier. There are two resistances in series, one of which is 110 ohms, bypassed to ground in the normal manner, but the other resistor is *not* bypassed. This un-bypassed resistor introduces some degeneration into this stage and stabilizes the action of the tube. It also reduces the effect of the plate on the grid circuit and reduces the loading of the grid. If the tube had its entire cathode resistor bypassed, it would act as a resistance shunted across the tuned circuit, a phenomenon associated only with operation at very high frequencies.

The circuit of the i.f. amplifier looks very much like a television amplifier circuit, inasmuch, as all transformers have resistors connected across both windings. This is done to smooth out the humps in the tuning curve after the transformers have been "overcoupled" to give the width of band pass necessary for proper operation.

Because of the number of stages used to obtain the selectivity characteristics desired, it is not necessary to use tubes with extremely high gain. The tubes used are therefore, not television amplifier tubes, but tubes more commonly used in normal receiver design, type 6SK7. These tubes perform much like the more common 6K7 but have a little more gain, and have the convenience of the single-ended construction with no grid cap on top. As explained in a preceding section, the gain of the amplifier is controlled automatically by voltage fed back from the "Limiter Tube" for that purpose.

The translator tube (combined oscillator and first detector) is a type 6SA7, noted for its freedom from oscillator frequency shift. The feedback necessary to make the tube oscillate is obtained by connecting the cathode to a tap on the tuned circuit. It is a peculiarity of this tube that the lead from the cathode of the tube to the tap on the coil must be *very* short when working at high frequencies.

Since the proper functioning of the detector circuit requires the mid-frequency of the i.f. system to remain tuned to the center of the i.f. response curve, every effort has been made to prevent drift in any of the important circuits.

Although it is most convenient to align the receiver with a frequency-modulated oscillator, a satisfactory job can also be done with an accurately-calibrated signal generator or oscillator covering a range in the vicinity of 2.1 mc. The object of alignment is to adjust the i.f. trimmers so that the i.f. system has a pass band from 2.0 to 2.2 mc., and then to adjust the detector coil to cover exactly the same band.

Proceed as follows:

1. Disconnect the mixer coil, the center coil on the r.f. assembly from terminal No. 8, control grid, of the 6SA7 tube. This is point "C" on the circuit diagram.

2. Connect the "hot" output terminal of the generator or oscillator to this grid, and the ground terminal to the chassis.

3. Connect a 0-50 or 0-200 microammeter in series with the ground end of the 100,000 ohm resistor R1 which connects the black wire from the 3rd i.f. coil to ground. This will measure the grid current of the 1852 "Limiter Tube." Thirty to 100 microammeters is all that should be expected at this point. If an Analyst or electronic voltmeter is available, it can be connected directly to the grid return lead (black wire) of the same transformer without disconnecting the resistor. This measures the Limiter grid bias voltage. A reading of 3 to 10 volts should be considered normal.

4. Set the oscillator at 2,175 kc. and align the i.f. trimmers for maximum response. Then go over all trimmers and tighten (turn clock-wise) them very closely until, on each trimmer, a barely perceptible decrease in Limiter grid current or bias voltage is noted. Then adjust the oscillator dial to 2,025 kc. The grid current (or voltage) should be approximately the same as at 2,175 kc. If it is not, adjust the i.f. trimmers for maximum response, leaving them in the *loosest* position which will give this response. Then repeat the previous adjustment at 2,175 kc. The output should remain nearly the same when tuning between the two frequencies, and should begin to decrease on each side of the two frequencies. The approximate i.f. response curve is shown in Fig. 1.

5. Remove the microammeter and re-connect the 100,000-ohm resistor as it was before.

6. Connect the microammeter in series with the ground end of the 100,000-ohm resistor, R2, which joins the 2-megohm resistor in the detector load circuit to ground. A high impedance electronic voltmeter, such as that in the Analyst or similar device, can be connected between the junction of the 100,000-ohm and the 2-megohm resistor and ground. (Point B.) This measures the detector output current or voltage.

7. Adjust the test oscillator to 2,200 kc. Adjust both trimmers on the detector coil (01142) for a peak. Readjust the oscillator to 2,000 kc. Reverse the connections to the microammeter or electronic voltmeter or read reversed voltages. Again adjust the two trimmers for a peak, turning them only a small amount one way or the other. Then slowly tune the oscillator to 2,100 kc.; the detector-output current or voltage should decrease. Carefully re-adjust the trimmer nearest the 6H6 tube until the current or voltage is zero. An insulated screwdriver is essential; this is an extremely important operation. Turning the oscillator dial one way should make the voltage positive and the other way negative. Again set the oscillator to 2,200 kc. and adjust the trimmer nearest the 1852 tube for a peak. Repeat the previous operation of centering the zero reading on 2,100 kc. as was done with the other trimmer. This completes the alignment of the i.f. channel. Re-connect the 100,-00-ohm load resistor R2 to restore the circuit to its original condition. An approximate detector response curve is shown in Fig. 2.

8. Re-connect the control grid of the 6SA7 to the mixer coil and disconnect the generator from this point. (Point C.)

9. Connect an antenna to the Receptor and again prepare to measure the Limiter grid current or voltage.

10. Set the dial of the Receptor to the frequency of any F-M transmitter that is within receiving range. The oscillator trimmer is the small variable condenser, provided with a screwdriver adjustment, on the sub-chassis near the dial. This should be adjusted so that the received signal produces a current or voltage reading on the Limiter grid. Then adjust the trimmers on the mixer and antenna coils for maximum reading at the Limiter grid.

These trimmers should align rather loosely. If they are tightened so that the frequency of the r.f. circuit equals the oscillator frequency, spurious oscillations and responses are produced. The oscillator frequency is normally 2,100 kc. lower than the signal frequency. When the above adjustments are completed and the 100,000-ohm Limiter grid load resistor is again grounded, the Receptor has been aligned. Do not attempt to operate the Receptor without an antenna.

Inverse Feedback Amplifier

Some receivers, like the one shown, are manufactured as a self-powered tuner to be used with an external amplifier. Such an amplifier may be a regular public-address unit. —30—