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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

TYPE 1170-A F-M MONITOR FOR BROADCAST AND TELEVISION SERVICES

● **WHEN GENERAL RADIO ENGINEERS** set out to design the Type 1170-A F-M Monitor, their aim was to provide, for the f-m broadcast band and for television audio channels, a monitor that would have the same high quality of performance and simplicity of operation as the monitors for the a-m band that have so long been accepted as standard by the industry.

The problem of designing an instrument of this calibre was more difficult than that of designing a-m equipment, because of the more stringent requirements set by the FCC on distortion, noise, and audio frequency range. The first step was, therefore, to determine what circuits could be adapted directly from standard a-m practice, and the second to determine what circuits were new and critical.

To generate the standard frequency, the highly stable crystal oscillator developed for the a-m frequency monitor could be used. Similarly, the modulation indicating circuits could resemble those used in the a-m modulation monitor. The requirements for distortion and noise measurement, however, as well as for adequate stability of center-frequency indication, called for a discriminator better in both

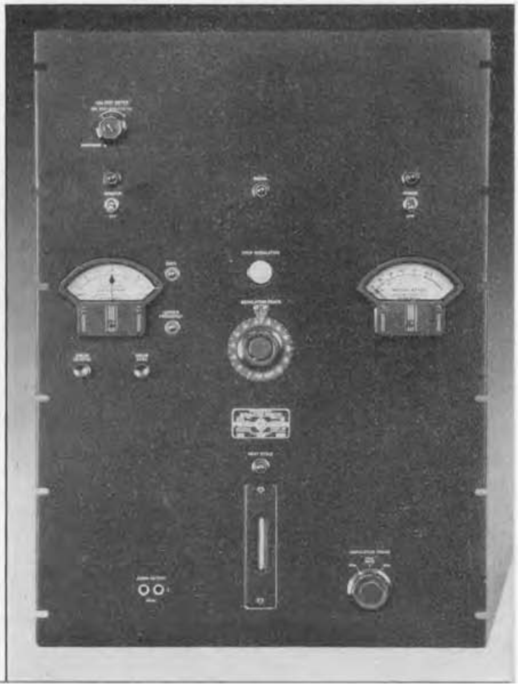


Figure 1. Panel view of the Type 1170-A F-M Monitor.

The standards of performance for f-m broadcasting are the highest that the industry has ever seen, owing primarily to the vision and unremitting effort of Major Edwin H. Armstrong. Only the use of equipment of the highest quality will insure the maintenance of these standards.

linearity and stability than the tuned-circuit type.

Tuned-circuit discriminators have been used in earlier types of monitors. They are highly sensitive and hence considerably simplify the monitor design. However, the tuned-circuit discriminator is not particularly satisfactory in either linearity or stability. It is basically a non-linear device. To approximate linearity over a 200-kc range, it must operate at an intermediate frequency of several megacycles. Slight drifts in circuit component values are troublesome, so that the center-frequency zero must be continually reset by comparison with a second crystal.

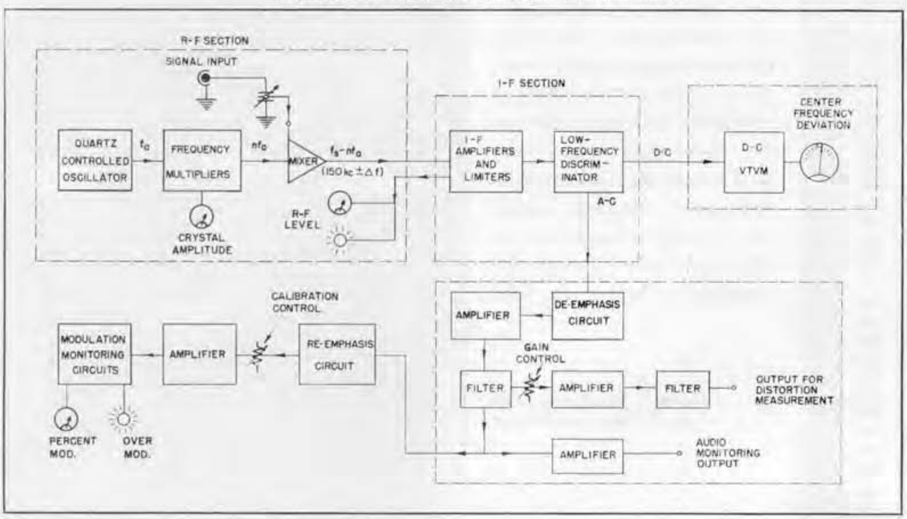
Pulse counters are inherently linear devices, and a discriminator employing this type of circuit can be made to operate linearly over a wide range with a minimum of critical circuit components and adjustments. The intermediate frequency can be low enough to achieve the stability necessary to eliminate secondary calibration adjustments.

A characteristic of the counter-type discriminator is its low sensitivity, so that it must operate at a high signal level to give a high signal-to-noise ratio. This need not be a serious limitation, however, for the desired result can be achieved quite simply, and the added circuits are notably free of critical adjustments.

Consequently, the pulse-counter type of discriminator was selected for use in the General Radio monitor. Using this discriminator, it is possible to obtain an over-all monitoring stability approaching that of the crystal oscillator, or a few parts per million.

As a result, the original design aim has been completely achieved. The new monitor gives (1) a continuous indication of center frequency without the necessity of frequency calibration checks; (2) an indication of percentage modulation (positive, negative, and full-wave) and a flashing lamp indication of overmodulation; (3) a high-fidelity output for distortion measurements—less than 0.2% distortion introduced by monitor; (4) a 600-ohm circuit for audio moni-

Figure 2. Functional block diagram of the monitor.



toring. Finally, the monitor is designed for television audio service as well as for f-m broadcasting.

The functional arrangement of the monitor is shown in Figure 2. A harmonic of a crystal oscillator beats with the incoming signal to produce an intermediate-frequency of 150 kilocycles. This beat passes through amplifiers and limiters to a counter-type discriminator. The d-c output of the discriminator provides the center-frequency indication, while the a-c output, after suitable filtering, operates the modulation indicators and furnishes a signal for distortion and noise measurements, as well as for audio monitoring.

The monitor is arranged mechanically so that the various circuits are segregated through the use of individual chassis assemblies. This makes all parts accessible and facilitates maintenance and tube replacements.

With one exception, vacuum-tube diodes are used throughout the monitor rather than crystal rectifiers. Crystals are not yet commercially available with characteristics as uniform as those of tubes. In particular, crystals exhibit a fluctuation with time in the ratio of front-to-back resistance, which precludes their use in circuits where long-period stability is desired.

The single crystal rectifier used in the monitor operates the r-f level indicator and the warning circuits, and supplies the bias on a control tube. For these functions, variations in characteristics have little effect.

CIRCUIT DETAILS OF THE MONITOR

R-F Section — The crystal oscillator circuit is one developed at the General Radio Company specifically for use in frequency monitors. It is highly stable; variations of 4% in the circuit capacitance, for instance, change the frequency by less than one part per million. The crystal has a temperature coefficient of less than two parts per million, and its temperature is maintained at 60° C. within ±0.15 degree.

The fundamental frequency of the crystal is between 1.4 and 2.2 Mc, and is so chosen that one of its harmonics, when heterodyned with the transmitter channel frequency, will produce a difference frequency of 150 kc.

The crystal oscillator is followed by an aperiodic buffer amplifier and three multiplier stages.

The tuned circuits in the multiplier stages have low Q and are operated at a high level to minimize the generation of f-m noise by phase modulation in the successive multiplier stages. A figure of 80 db below 100% modulation was chosen as a design objective for residual f-m noise. This is equivalent to a fluctuation of 7.5 cycles at the carrier frequency, or 7.5 parts in 100 million.

The 150 kc beat between crystal harmonic and transmitter frequency is produced in a pentagrid converter and is amplified by a single output stage.

For proper operation of the succeeding circuits, it is important that a specified minimum voltage be maintained, at the output of the mixer. An indicating meter is provided to measure this level. Since the voltage at this point depends on the r-f input, this device is also used as an indicator of r-f input level.

DISCRIMINATOR AND IF SECTION

Limiter Amplifier — To operate the discriminator it is necessary to generate a square-wave of constant amplitude. The 150-kc output from the r-f section passes through a diode clipper, a voltage amplifier, a second clipper, and finally drives two power tubes as limiting amplifiers.

The amplitude at the output of this amplifier is sufficient to assure a high signal-to-noise ratio and to eliminate all effects of contact potential in the discriminator diodes.

The voltage level is stabilized by regulating the plate and screen supplies of this final output stage. At this point in the circuit the signal is a square-wave of constant amplitude. The wave shape and the amplitude must be independent of frequency over a range of 150 plus and minus 100 kc in order to provide for wide modulation swings.

A control tube cuts off the gain of the amplifier tubes until sufficient input voltage has been reached to permit complete saturation of the input clipper stage. This prevents erratic indications on the meter with no input signal.

Discriminator Operation — The discriminator is shown in elementary form in Figure 3. The two diodes are connected in parallel but in opposite sense, so that the condenser is charged through the left-hand diode and discharged through the right-hand one. The time constants of the R-C circuits are made small compared to the time of one-half cycle of the intermediate frequency, so that the condenser is charged to the peak value of the square-wave and then completely discharged during alternate half cycles. The output of the discriminator, which appears across the resistor R_2 in series with the right-hand diode, consists of unidirectional pulses of constant shape and amplitude.

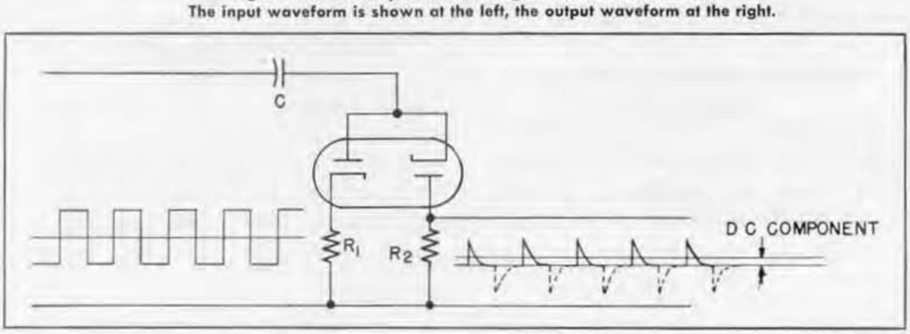
When the transmitter is unmodulated, the discriminator output has a d-c component equal to the average value of the voltage across R_2 and a series of a-c components at the pulse repetition frequency and its harmonics. The d-c component varies linearly with the transmitter frequency and consequently can be used to actuate the center-frequency indicator.

When the transmitter is frequency modulated, the pulses are "bunched up" or "spread out" when referred to a time base. The d-c component is not affected by the modulation except to the degree by which the average, or center, frequency changes under modulation.

Modulation also produces in the discriminator output a component of the modulation frequency, which is used to operate the modulation indicators and to feed the audio output circuits of the monitor.

Center Frequency Indicator — The d-c component of the discriminator output voltage is applied to a vacuum-tube voltmeter, with a bucking voltage that is independent of frequency, to operate a zero-center meter. A center-frequency shift will cause the differential voltage to change in magnitude and sign, and the

Figure 3. Elementary schematic diagram of the discriminator. The input waveform is shown at the left, the output waveform at the right.



d-c indicating meter will swing in one direction or the other by an amount proportional to the change in carrier frequency. The bucking voltage is derived from the square-wave that drives the discriminator and is proportional only to amplitude. Hence, minor variations in square-wave amplitude will affect the output of both the discriminator and the bucking circuit equally. The use of this amplitude stabilizing circuit eliminates the need for extreme regulation of the plate supply voltages as well as for precise control of all factors influencing the square-wave amplitude over its complete range of carrier swing.

AUDIO-OUTPUT SYSTEM

In order to recover the original modulation signal, the high-frequency components present in the pulse waveform are removed by means of low-pass filters.

Since the de-emphasis circuit normally employed in the audio-output channels constitutes an R-C filter with low-pass characteristics, this network can advantageously be used to couple the discriminator to the audio channels. The high series resistance helps to minimize the reactive loading effects of the external circuits upon the discriminator, and at the same time reduces the high-frequency components of the original pulse.

The resulting de-emphasized signal passes to a cathode-coupled amplifier and thence to one section of a low-pass filter. This filter section must pass without attenuation all audio frequencies up to 30 kc, the upper limit of audio measurements required by the FCC.

The second section of the filter is placed directly in the output of an amplifier, whose sole function is to drive the external distortion and noise meter. This filter section eliminates any remaining r-f components including pickup in the amplifier itself. To insure a minimum of residual distortion, the amplifier is operated at a constant low level. The input gain control can be set to give a constant output for any value of transmitter frequency swing between 6 and 100 kilocycles.

A second output, intended for local program monitoring, is obtained from a cathode-coupled amplifier with an effective output impedance of 600 ohms, unbalanced.

Modulation Metering Section

A standard pre-emphasis circuit restores the original audio-frequency characteristic for modulation measurements. This apparently roundabout method of producing the modulation signal by first de-emphasizing and then re-emphasizing has one very considerable advantage. As pointed out above, the de-emphasis circuit helps materially to eliminate the radio-frequency components of the pulse waveform. This reduces by the same degree the shielding necessary in the modulation monitoring circuits. The standard pre-emphasis circuit restores the audio-frequency components to a much greater degree than the r-f components.

An adjustable gain control is provided in the pre-amplifier circuit. This gain control permits the monitor to be calibrated for 100% modulation, with any value between the limits of 25 and 75 kc swing.

The modulation metering circuits and the overmodulation indicator circuit are nearly identical with those used in General Radio a-m monitors. The meter characteristics meet all FCC specifications. An important feature of this monitor, however, is the inclusion of a peak-to-peak, or total swing, indication, in addition to the usual positive and negative peak indications.

PERFORMANCE CHARACTERISTICS

Center-Frequency Indication — Monitoring practice in the standard a-m broadcast band has accustomed the transmitter engineer to stable center-frequency indicators. A glance at the monitor gives him a frequency indication that can be relied upon without calibration checks.

Many existing f-m monitors, however, do not have this degree of stability. Consequently, the zero reading must be checked against another crystal standard before a center-frequency reading is taken. It is customary to provide a push button on the panel for this calibration check. Such a procedure is inconvenient and time-consuming and is nearly impossible when remote indicators are used.

The TYPE 1170-A F-M Monitor is designed to give the same degree of stability as is customary in a-m monitors. Its over-all stability is ±4 parts per million, or about 400 cycles. A zero set is provided, which checks the electrical zero of the meter, but this need be used only once a day.

When this check is made, the accuracy of indication is bettered by a factor of two and is good to ±2 parts per million.

A glance at the meter gives the center frequency of the transmitter, even on a remote meter, and, in addition, a recorder can be operated to give a continuous record of center frequency.

To prevent erroneous on-frequency indications when the transmitter signal fails or drops below an adequate level, two warning signals are provided. The illumination of the center-frequency meter drops nearly to zero, and a pilot lamp on the panel is extinguished.

Distortion and Noise Measurements

The FCC has required the use of the standard 75 microsecond de-emphasis network in the measuring instruments. This results in a flat frequency response for the entire system between the transmitter audio input and the measuring device, and so duplicates the conditions actually obtained between studio and home receiver output. Measurements of noise and distortion are, however, referred to a given modulation percentage and frequency. The output voltage available for operation of the distortion and noise meter is thus reduced at the

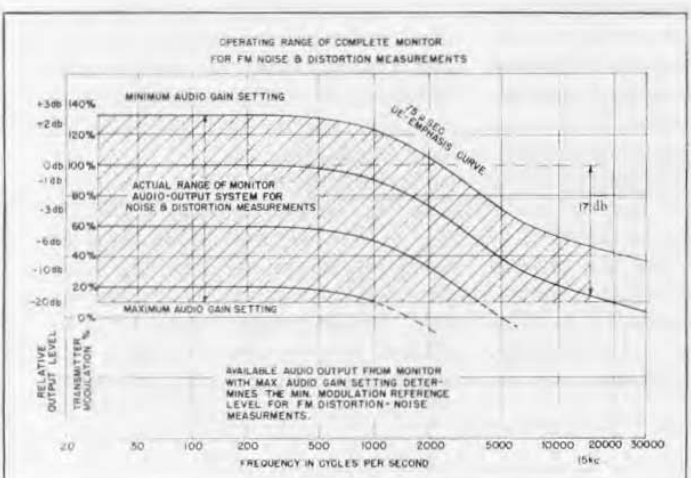


Figure 4. Operating range of the monitor for distortion and noise measurements.

high audio frequencies, and this limits the minimum percentage modulation at which distortion measurements can be made. Figure 4 shows this characteristic.

The very low distortion levels that will normally be measured in f-m transmitters impose rigid requirements on all units of the measuring system, and these include (1) the test oscillator, (2) the f-m monitor, and (3) the distortion meter. For this reason it is highly important to keep the residual distortion in any one unit as low as possible, since the minimum indicated level may equal the sum of all components in the system. Cancellation effects may reduce the indicated level below this amount, but, by the same token, readings of the transmitter distortion may be incorrect, should the level be so low as to approach the residual level of the measuring instruments.

Considerable effort was devoted toward keeping the residual audio distortion in the monitor extremely low and a figure of better than 0.2% has been achieved. When the monitor is used in conjunction with a Type 1301-A Low-Distortion Oscillator and Type 1932-A Distortion and Noise Meter, measurements can be made of f-m transmitter audio modulation distortion at values in the order of 0.5% rms distortion with a reasonable degree of accuracy.

Noise measurements in f-m systems will ordinarily be made at levels below -65 db. The residual noise level in both the f-m monitor and the noise meter is therefore of considerable importance. The combination of the Type 1170-A F-M Monitor with the Type 1932-A Distortion and Noise Meter will permit measurements to be made at levels of -75 db with accuracy.

In addition to its use in the transmitting station, this monitor is suitable for the production testing of f-m transmitters. The combination of the Type 1301-A Low-Distortion Oscillator, Type 1932-A Distortion and Noise Meter, and Type 1170-A F-M Monitor will permit transmitter type tests to be made as specified in the FCC's *Standards of Good Engineering Practice Concerning F-M Broadcast Stations*. Because of the wide range of frequencies over which this instrument will operate, and the ease of calibration adjustments, the monitor can easily be used with television aural transmitters. This flexibility of operation permits transmitter design engineers to perform type tests upon f-m transmitters of all types with a minimum of equipment.

— C. A. Cady

SPECIFICATIONS

Transmitter Frequency Range: 30 to 162 Mc with Type 1170-P1 R-F Tuning Unit; 160 to 220 Mc with Type 1170-P2 R-F Tuning Unit.

R-F Input Impedance: High impedance, with Type 774 Coaxial Connector. A capacitance attenuator is provided for adjusting the input level. The monitor can be used with standard R.M.A. transmitter monitoring output.

Input Sensitivity: 1 volt r-f, or better.

Input Level Indicators: A meter for indicating r-f input level is provided at the rear of the chassis. Signal pilot lamp and center-frequency meter pilot are illuminated when input level is adequate and are extinguished when level drops below the usable minimum.

Intermediate Frequency: 150 kc.

Discriminator: Pulse-counter type linear to better than 0.05% over a range of ±100 kc (133% modulation).

Center Frequency:

Indication: Meter is calibrated in 100-cycle divisions from -3000 to +3000 cycles per second. No zero set is necessary for each reading and no second crystal is provided.

Accuracy: Crystal frequency, when monitor is received, is within ±10 parts per million of specified channel frequency. Zero reading is adjustable over ±3000-cycle range to bring monitor into agreement with frequency-measuring service. Center frequency indication is then accurate to ±200 cycles per second.

Over-all Stability: ±400 cycles, or better, for long periods.

Percentage Modulation:

Indication: Meter is calibrated from 0 to 133%. Additional db scale is provided. Switch selects positive or negative peaks, or full-wave (peak-to-peak) indication. 100% modulation corresponds to 75 kc deviation for f-m bands. Single internal adjustment of meter circuit changes calibration to read 100% at 25 kc deviation, for television audio monitoring. Meter ballistics meet FCC requirements.

Accuracy: ±5% modulation.

Overmodulation Indicator: Lamp flashes when predetermined modulation level, as set on a dial, is exceeded. Range of dial is 0 to 120% modulation.

Output Circuits:

1. **Distortion and Noise Measurements:**

Terminals are provided for connecting a Type 1932-A Distortion and Noise Meter, and a gain control is provided.

Residual Distortion: Less than 0.2% at 100 kc swing (±133% modulation).

Response: 50 to 30,000 cycles per second ±½ db. Standard 75 microsecond de-emphasis circuit is included.

Maximum Output: 1.5 volts into 100,000 ohms.

Residual Noise Level: −75 db or better referred to 75 kc deviation; −65 db or better for 25 kc deviation.

Sensitivity: Full output can be obtained down to 8% of 75 kc deviation. Sensitivity varies with modulation frequency in accordance with standard de-emphasis characteristic.

2. **Audio Monitoring Output:**

Impedance: 600 ohms, unbalanced.

Output: Zero dbm at 75 kc deviation (100% modulation).

Response: 50 to 15,000 cycles per second ±¼ db.

Crystal Oscillator: General Radio high-stability circuit. Crystal is temperature-controlled at (60 ±0.15) C. Temperature coefficient of crystal is 2 parts per million per degree C, or less. Crystal oscillator output level can be read on panel meter by pressing a push-button switch. A jack is mounted at the rear of the chassis for connecting a milliammeter to check crystal oscillator plate current.

Remote Indicators: Circuits and terminals are provided for connecting the following indicators externally:

Center-frequency indicator
Percentage-modulation meter
Over-modulation lamp
600-ohm unbalanced aural monitor

Vacuum Tubes: The following tubes are used and are supplied with the monitor:

1—6AK6	2—6AG7	2—6C4
1—6AB7	2—6SN7-GT	1—815
1—6BE6	1—6AG5	2—OD3/VR150
2—2050	1—6SJ7	1—6J6
6—6AL5	4—6SL7-GT	1—991
1—6SK7	1—6AS7-G	1—OC3/VR105
2—3-4		

Accessories Supplied: All tubes, coaxial connector for r-f input, power line connection cord, power supply plug.

Power Supply: 105 to 125 volts, 50 to 60 cycles. Power-transformer-primary-connections can be changed to permit operation on 210 to 250 volts.

Power Input: 300 watts.

Mounting: 19-inch relay-rack panel with dust cover.

Panel Finish: Standard General Radio black crackle lacquer. Certain standard grays that can be processed in quantity can be furnished at an extra charge of $20.00.

Dimensions: Panel, 19 x 26¼ inches; depth behind panel, 13¼ inches, over-all.

Net Weight: 88 pounds.

Type	*Description*	*Code Word*	*Price*
1170-A	**F-M Monitor**	AHEAD	**$1625.00**

(Licensed under patents of the American Telephone and Telegraph Company.)

The Type 1170-A F-M Monitor was developed by a group consisting of A. P. G. Peterson, C. A. Woodward, W. F. Byers, and C. A. Cady, author of the foregoing article.

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