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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

MEASURING NOISE LEVELS ON FREQUENCY-MODULATED TRANSMITTERS

Also IN THIS ISSUE

●THE "Standards of Good Engineering Practice Concerning F-M Broadcast Stations" impose certain minimum noise-level requirements on frequency-modulated transmitters. Both f-m and a-m noise levels must be held below specified limits. Moreover, it is now required that these tests be made on an annual basis, at least once during the four months' period preceding the station license renewal.

In the past, the evaluation of noise level might be limited to a single set of measurements made when the transmitter was first installed and operated. The practicability of repeat measurements was largely a matter of balancing the cost of a distortion and noise meter against the desire for superior quality. New FCC requirements, however, make it desirable to have the necessary measuring equipment available in the station for the routine inspection of the transmitter characteristics.

F-M NOISE LEVEL

Measurements of the f-m noise level are usually made by applying

Figure 1. View of the Type 1932-P1 A-M Detector Unit plugged into the panel jacks of a Type 1932-A Distortion and Noise Meter. Below the Distortion and Noise Meter is a Type 1301-A Low-Distortion Oscillator.

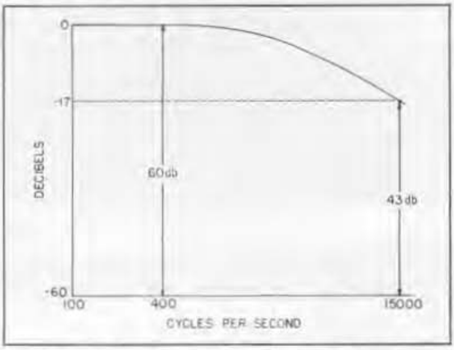


Figure 2. Effect of the de-emphasis characteristic on noise and distortion measurements with constant modulation percentage.

the audio output derived from an F-M modulation monitor to a conventional distortion and noise meter. The TYPES 1170-A F-M Monitor[1] and TYPE 1932-A Distortion and Noise Meter[2] have been previously described for this purpose.

The F-M Monitor provides a very linear f-m detector and de-emphasized audio output circuit. The Distortion and Noise Meter is an audio-frequency device exclusively and measures the distortion and noise characteristics of an audio signal. Measurements are made at a reference of 400 cycles, 100 per cent modulation.

It is important to recognize that the reference frequency must also be given, because of the de-emphasis circuit within the measuring equipment, which results in a decrease in audio output at high modulation frequencies for a constant percentage of modulation. The over-all transmission system from microphone to receiver output is flat, because of the canceling effects of pre-emphasis in the transmitter and de-emphasis within the receiver. However, when the transmitter percentage modulation is held constant, rather than its audio input level, the de-emphasis results in less audio output at the higher audio frequencies.

As an example, consider a typical case in which the power line hum components are the major source of noise. If the reference frequency is 400 cycles, the results might be, say, −60 db. Should the measurement be referred to 15,000 cycles, the same conditions would give an indication of only −43 db, as shown in Figure 2.

It is also interesting to note that this same effect will influence the results obtained in distortion measurements. Take for example, the case of a 60 db noise level below the stated reference of 400 cycles, 100% modulation. Most distortion and noise meters currently used operate upon the principle of removing the fundamental audio component only and indicating the remaining components above and below the fundamental, as distortion. Thus the 60 db noise level at 400 cycles would produce an effective minimum distortion reading of 0.1% on the meter, since 60 db corresponds to a voltage ratio of 1:0.001. Likewise, the same system noise level would result in a minimum distortion reading of 0.7% at 15,000 cycles, since 43 db corresponds to a voltage ratio of 1:0.007.

A-M NOISE LEVEL

The amplitude-modulation noise level has largely been the concern of the transmitter design engineer in the past, but it is now necessary for the transmitter operating engineer to become familiar with its measurement. The demodulation system, shown in Figure 3, uses a conventional linear rectifier and r-f filter as is usual in a-m practice, but there are two important differences — (1) there is no longer an available reference modulation to calibrate the system,

[1] C. A. Cady, "Type 1170-A F-M Monitor for Broadcast and Television Services," *Experimenter*, XXII, 5, October, 1947.
[2] Frank D. Lewis, "Distortion Measurement in the Broadcasting Station," *Experimenter*, XXIV, 1, June, 1949.

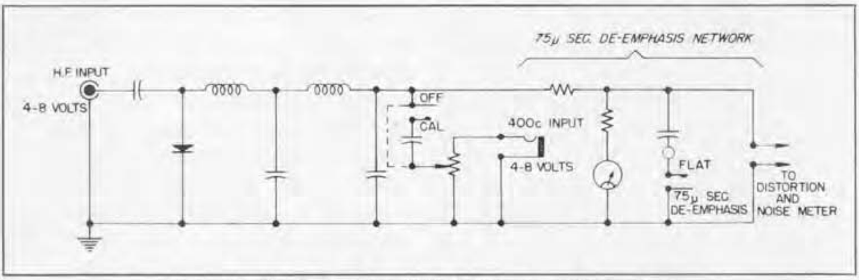


Figure 3. Circuit of the Type 1932-A Distortion and Noise Meter.

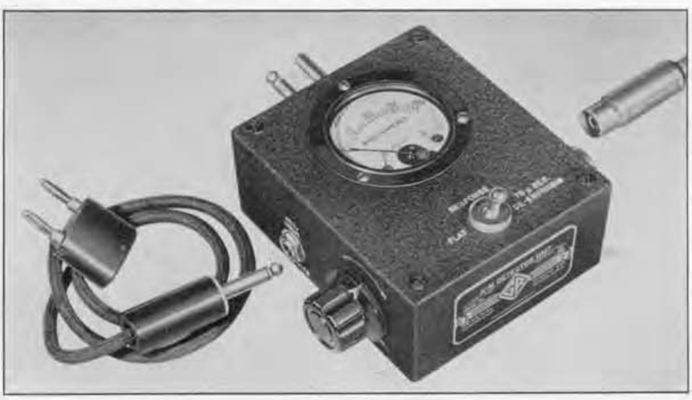
and (2) a 75 μ-second, de-emphasis network is specified by the FCC in the audio measurement device (to match the receiver characteristic).

Since the noise modulation is inherently a very low modulation percentage, certain of the problems associated with linear detector design are removed, such as negative peak clipping at high modulation frequencies. We do, however, have to provide for an external audio calibrating voltage which can be established at a level equivalent to 100% amplitude modulation. This is accomplished by using the d-c output of the rectifier as a standard of comparison. Connecting an external audio signal to the detector and establishing an arbitrary reference level as noted by the rectified dc, and at the same time setting up the noise meter to read full scale, establishes the first reference point. When the inserted audio signal is removed and replaced by the transmitter carrier frequency and the r-f level is adjusted to give the same d-c rectified current as before, the noise meter will then read the noise level directly. The change in rectifier efficiency between the audio test frequency and the transmitter carrier frequency is compensated for, since the average rectifier dc is maintained constant in each case.

An r-f filter, following the detector, isolates r-f components from the noise meter. The 75 μ-second de-emphasis network is added to give the desired response characteristics.

The r-f input circuit can be coupled directly into a low impedance transmission line, thus avoiding the limitations of tuned circuits upon the r-f bandwidth and the need for adjustments. Most transmitter monitoring outputs are adequate to provide 4 to 8 volts for operating the crystal rectifier. This voltage

Figure 4. Close-up view of the A-M Detector Unit. The coaxial connector at the right is supplied with the unit; the cord, plug and jack at the left are not.



range is a compromise between detector linearity and over-all sensitivity.

TYPE 1932-P1 A-M DETECTOR UNIT

The detector unit, arranged in a convenient plug-in form, is shown in Figure 4. It plugs directly into jacks on the panel of the TYPE 1932-A Distortion and Noise Meter. Direct connection to the r-f monitoring line is provided by means of a coaxial jack on the right side. An audio input jack and a convenient amplitude control and disconnect switch are provided on the left side. The diode-current microammeter is mounted in an easily viewed position at the top of the unit, together with a switch for removing the 75 μ-second de-emphasis network when it is not desired. No r-f gain control is provided because it is not needed. It is merely necessary to accept any reference r-f signal within the operating range of the meter, then to establish the audio level equal to this value by means of the control provided, and finally to reinsert the r-f connection and measure the noise level directly.

The plug-in construction is convenient and avoids unnecessary duplication of facilities, particularly when the distortion and noise meter is to be used with several transmitters, as in stations operating A-M, F-M, and TV transmitters.

— C. A. CADY

SPECIFICATIONS

R-F Input:
50 — 220 Mc.
4 to 8 volts required, from low-impedance line.
Type 774-G Connector.

Audio Input:
400 cycles.
4 to 8 volts required; internal potentiometer is provided.
Input impedance = 1000 Ω.
Standard single-contact telephone-jack connector.

Audio Output:
30 — 30,000 cycles ± 1 db; or 75 μsec de-emphasis characteristic.
1 to 1.5 volts, into 100 kΩ load.
Plugs to fit standard W. E. panel jacks, on Type 1932-A Distortion and Noise Meter are provided.

Accessories:
1 Type 774-M Cable Jack.

Mounting:
Black wrinkle-finish case.

Dimensions:
5¼ x 6 x 2½ inches, overall.

Net Weight:
1½ pounds.

Type		*Code Word*	*Price*
1932-P1	A-M Detector Unit	AMDET	$55.00

THE VERSATILE VOLTAGE DIVIDER

PART III

EXAMPLES IN GENERAL RADIO INSTRUMENTS

Many specialized voltage dividers have been designed and manufactured for use in various of our instruments.

1. **CRL Dials for Bridges, etc.** One of the most widely used items is a TYPE 433-LC Voltage Divider (L for logarithmic, C for compensating mechanism) used as a rheostat in several alternating-current bridges, including TYPES 625-A, 650-A, 740-B, 740-BG, and 1611-A. The 20-db logarithmic feature is not used as such, since there is no extension resistor. The mandrel is used only to spread the scale at the low end in order to make percentage accuracy more nearly the same throughout the dial.

The dials are etched to a curve which

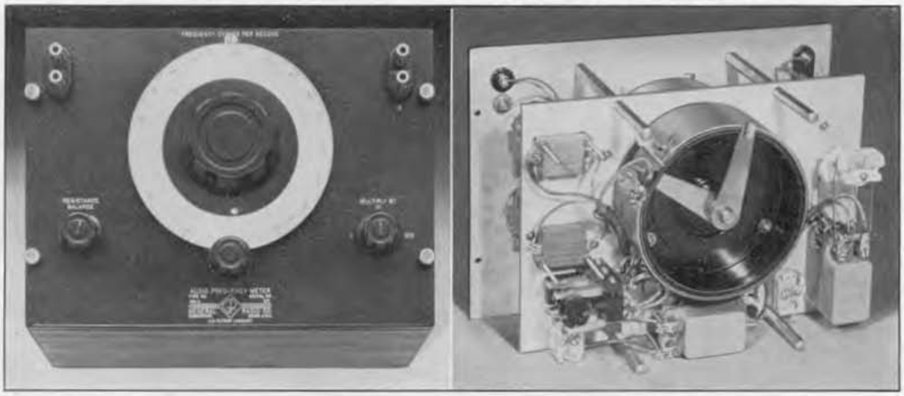
represents the average of a number of voltage dividers in production. It is a fairly simple matter to track the voltage divider to the scale by using a screw driver on the adjusting screws of the compensating mechanism. A d-c Wheatstone bridge is simply set for a resistance value corresponding to the then dial setting and the compensating mechanism adjusted until the bridge balances.

2. **Wien Bridge.** Two voltage dividers very similar to that described under "1" but having a different resistance value and being ganged together back-to-back are employed in our TYPE 1141-A Frequency Meter (Wien-bridge type) for continuous frequency adjustment, while the bridge capacitors are switched to provide decade steps. For various reasons the compensating mechanism is not included, and so each instrument is hand-calibrated. Techniques have been worked out for engraving a complete set of marks on the frequency scale distributed according to a smooth curve but starting from a minimum number of actually calibrated and marked points on the scales. In this instrument, extension resistors are employed, the dial covers a range a little over ten to one and does not go up to infinity, and the accuracy of setting is practically uniform throughout the dial.

Figure 11. Panel view of the Type 650-A Impedance Bridge. The logarithmic rheostat controlled by the large dial was shown in Figure 2, Part I, of this article.

3. **Twin-T R-C Networks.** Our TYPES 760-A and 762-A Sound and Vibration Analyzers use R-C twin-T networks for frequency determination. Capacitors are shifted for stepping multipliers of three and ten, while the continuous adjustment therebetween is afforded by three ganged voltage dividers operating as rheostats. One of these voltage dividers is one-half the resistance of the other

Figure 12. Panel (left) and interior (right) views of the Type 1141-A Audio Frequency Meter.



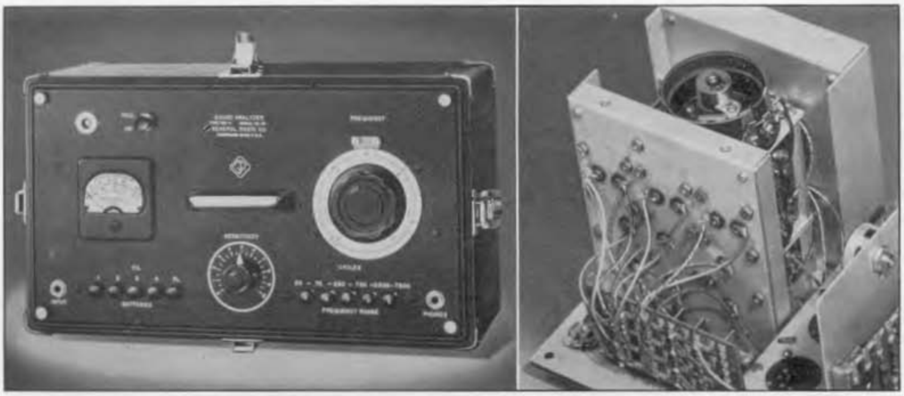


Figure 13. Panel view (left) and portion of interior of Type 760-A Sound Analyzer. In the interior view at the right, one unit of the four-gang voltage divider can be seen.

two. Close tracking is important if the instruments are to function properly. It has been found that the desired closeness of tracking is not easy to obtain if the third or one-half-resistance unit is wound using a different size of wire from the other two. Experience has shown that it costs less in the end to make the half-resistance unit by connecting in parallel two full-resistance units. Accordingly, four voltage dividers are ganged and driven by a single steel-cored phenolic shaft.

The trapezoidal mandrels have a straight taper with a ratio of about 2½ between extreme widths. The curve shape is, accordingly, a portion of a parabola. In manufacturing these four-gang voltage dividers, the mandrel shapes and thicknesses are closely controlled, the concentricity and dimensions of the bases are assured, the winding is carefully controlled, and each group of four associated units is carefully selected from among a large production quantity for tracking uniformity.

EXAMPLES OF SPECIAL UNITS FOR CUSTOMERS

With the factors mentioned earlier under the heading of ECONOMICS taken into account, there have been many

Figure 14. Panel view (left) of a Western Electric detector used in checking coils. The four-gang rheostat controlled by the TUNING dial is shown at the right.

special voltage dividers manufactured for our customers. A few examples may prove interesting:

1. **Twin-T R-C Networks.** In the manufacture of coils of many sorts for use in the nation-wide telephone system, measuring equipment is used for which hyper-accurate ganged rheostats are needed. These are similar to the ones just described for use in our analyzers, but are held to closer tracking tolerances and have some special features desired by the customer, such as pigtails in parallel with the sliding center contacts, for instance. Pigtails have not been necessary on the ganged resistors for our analyzers, and could not be used anyhow, since as a convenience feature there are no stops provided and the shaft can be rotated continuously.

2. **Vacuum-Tube Checker.** The Hickok Electrical Instrument Company desired a precision rheostat which should have a resistance-rotation curve in which the resistance would be proportional to the five-thirds power of the rotation. If the rheostat were so made, the dial would have numbers, representing "C" bias of the tube, evenly spaced. If the rheostats could be made accurately like one another, this dial could be electrochemically etched with consequent saving in calibration time.

Figure 15. Mandrel shape used for the "C"-bias rheostat in the tube checker of Figure 16.

To meet the five-thirds power curve, the lengths of the turns of wire on the rheostat should vary according to the two-thirds power of the rotation. This, unfortunately, would mean that the width of a mandrel of a finite thickness would be negative at zero rotation. Accordingly, the shape had to depart from the theoretical for about the first fifth of the rotation. This departure was accounted for in the etched scale, making it somewhat crowded near zero. Cuts of a modified instrument and of the special voltage divider with the shaped mandrel are shown. Figure 15 shows the actual mandrel shape employed, the dotted line showing what the shape would have been if nothing governed it but the mathematics.

3. **Air-Brake Test Set.** The problem of braking a modern high-speed passenger train is not a simple one. It should be possible to apply the brakes to any desired degree, having a servo-mechanism to assist in that application, and there should be safety features to assure that an emergency braking system will take over if the servo system fails.

Figure 16. Panel view (left) and interior (right) of the vacuum-tube checker. The "C"-bias rheostat is near the lower right-hand corner in the interior view.

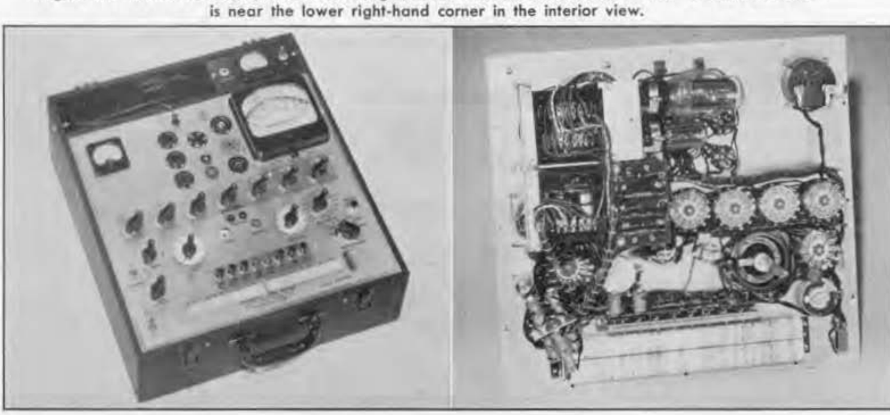


Figure 17. Panel and interior views of the air-brake test set. The dials control identical rheostats, one of which can be seen at the right in the interior view, ganged with another, smaller, rheostat.

As part of this complete braking system, Westinghouse Air Brake Company of Wilmerding, Pennsylvania, designed a Wheatstone-bridge-type device which periodically checks to see whether the brakes on all of the cars are working. This system has been described in the technical literature.[1, 2]

Each car contains a solenoid associated with the braking mechanism. In a long train these solenoids are connected in parallel and form one (the unknown) arm of the bridge. The other, or variable, arm is the special rheostat manufactured here. Its etched metal scale is approximately evenly divided, with the divisions numbered to correspond to the number of cars in the train. The resistance must vary inversely with the rotation, then.

It was soon discovered that the slope at the wide end was too large and the width at the narrow end too small to be manufacturable. However, a suitable compromise was reached in which the rheostat mandrel was curved for about 80% of the rotation and parallel-sided for the remaining 20%. On this straight portion, two different wire sizes were used, giving a dog-leg approximation to a mathematical curve. Figure 18 shows the shape of the mandrel employed. The rheostat is shown in the interior view of the circuit-checking equipment. The two dials are associated with two like rheostats, since each equipment actually contains two operating Wheatstone bridges as well as a number of relays and other circuit elements.

—P. K. McElroy

1 C. M. Hines, "A Unique Application of the Wheatstone Bridge to High-Speed Train Braking," A.I.E.E. Technical Paper 48-53, December, 1947.

2 Fuller description of this type brake in previous paper.

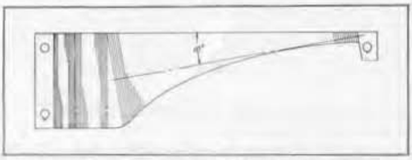


Figure 18. Mandrel used for the rheostats in the air-brake test set.