Recording Cochannel Broadcast Interference

Continuous field-intensity recording of an interfering standard broadcast station is possible using only one recorder. Extremely selective receiver having 13.5-cycle i-f accepts the interfering sky-wave signal while rejecting the stronger desired signal

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SKY-WAVE INTERFERENCE from a cochannel standard-broadcast station may be measured directly using a narrow-band recorder with a 13.5-cps intermediate frequency even before the desired station leaves the air.

The narrow-band recorder consists of a crystal-controlled superheterodyne receiver that incorporates four stages of tuned r-f. A selective i-f amplifier with two parallel-T feedback networks rejects to a high degree any signal differing appreciably from 13.5 cps. Further rejection of the desired signal is achieved by choosing frequencies such that strong unwanted signals are near zero beat with the local oscillator.

Since a standard field-intensity meter will measure some function of the vector sum of both desired and interfering stations, it is otherwise impossible to measure the interfering station's field intensity until the desired station leaves the air.

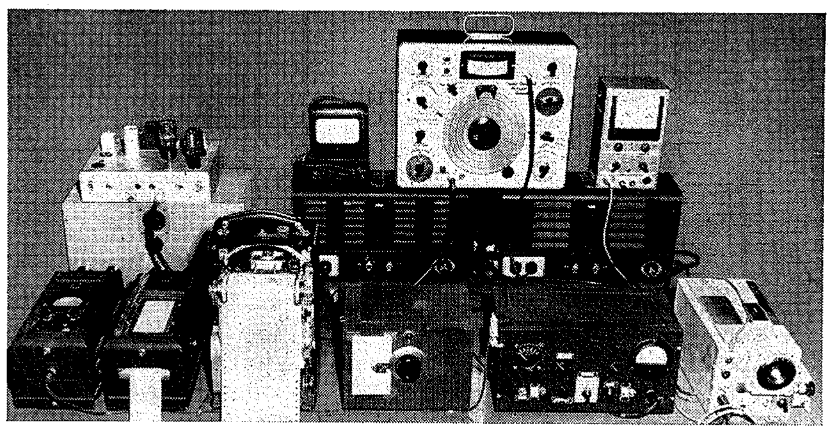
Standard Practice

Standard practice[1] is to measure a monitor station from sunset through the evening hours, obtaining its curve of skywave field intensity with respect to time. The monitor station should be close to the station under study, in frequency and location, and should preferably be a clear-channel station with known antenna characteristics.

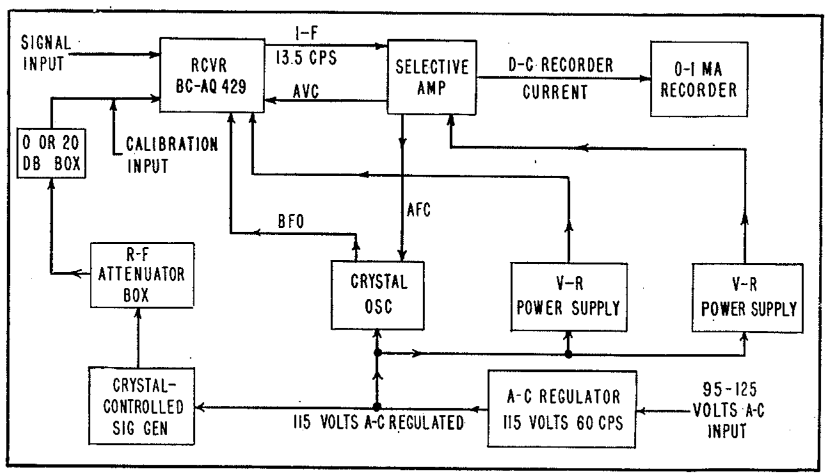
After the desired station signs off, the undesired station is measured directly and a ratio obtained between its measured field intensity and that of the monitor station. Using the curve of field intensity versus time for the monitor station and the above-mentioned ratio, the field intensity of the undesired station is extrapolated for earlier hours.

The FCC recognizes the second hour after sunset, ss + 2, as the standard hour for calculating or measuring interference. Having already established a field ratio between the undesired station and the monitor station's skywave curve, it is possible to determine the undesired station's field intensity at the standard hour, ss + 2, making any corrections for transmission conditions.

An earlier system for measuring interference directly[2,3] utilized a field-intensity recorder that made two graphical records. The first of these was a chart of the field intensity of the strongest signal on the channel and the second was a chart of the heterodyne voltage between



Narrow-band field-intensity recorder and associated calibrating equipment



Block diagram of complete setup for measuring and recording cochannel interference the strongest and weaker signals.

During summer 1948, measurements were made wherein all signals involved were skywaves. From time to time the desired or strongest signal on the channel varied widely in intensity, upsetting the reference voltage ratio of desired versus undesired signals. Under these circumstances, the equipment provided very little useful information.

Narrow-Band Recorder

The narrow-band recorder, which was developed in the fall of 1948, is shown with its associated calibration gear in the photograph and the block diagram. The receiver consists of four stages of tuned r-f, a diode detector, and an audio stage tuned to 13.5 cycles that actually constitutes the first stage of the i-f system. The selective amplifier follows the receiver. The output of the selective amplifier is connected to a diode detector and also to a cathode follower, which supplies the i-f to a frequency-discriminator circuit. The discriminator provides an afc voltage that is applied to a reactance tube in the crystal oscillator, thereby maintaining the output frequency in such a manner as to sustain the i-f at 13.5 cycles. Figure 1 is the overall i-f selectivity curve.

The crystal oscillator also introduces a voltage ahead of the detector for stabilizing the avc voltage produced by the desired signal. The output of the second detector supplies avc voltage to the first two r-f stages in the receiver and excites a d-c amplifier and graphic recorder. The narrow-band recorder incorporates both primary a-c power regulation and regulated d-c power supplies.

Calibration of the narrow-band recorder is accomplished by using a crystal-controlled signal generator to feed increments of power into the receiver antenna input terminals while maintaining a frequency difference of 13.5 cycles with respect to the receiver oscillator.

Figure 2 shows the response curve of signal input voltage versus recorder output in chart ma. This receiver response curve is corrected for the effective height of the receiving antenna to obtain an output response in millivolts per meter versus chart ma.

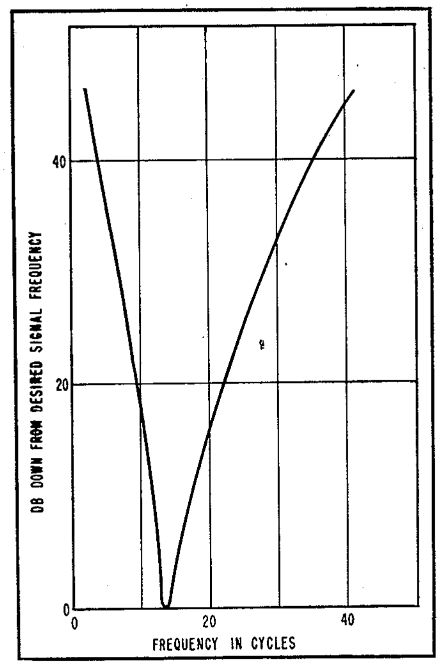


FIG. 1—Overall i-f selectivity curve shows high degree of rejection of signals differing from 13.5 cycles

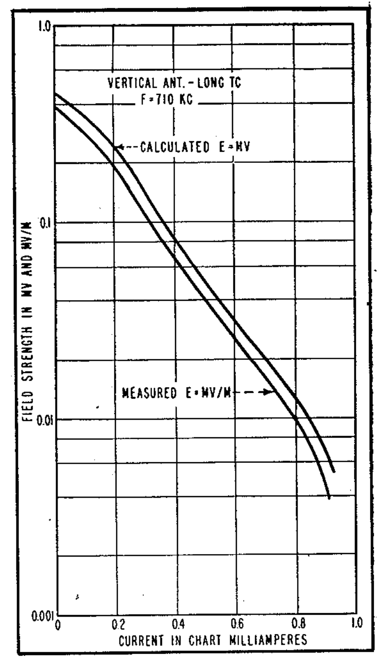


FIG. 2—Basic recorder response curve (right) and the same curve corrected for antenna effective height

After calibration of the narrow-band recorder, the antenna is connected and the signal to be measured is tuned in by adjustment of the local oscillator.

During operation of the recorder, the intermediate frequency is constantly monitored by a frequency meter that operates from the discriminator circuit. A Brush high-speed oscillograph is connected into the i-f system for frequent graphic checks of the intermediate frequency. A vacuum-tube voltmeter reads diode detector voltage, indicating the magnitude of oscillator injection voltage and the beat frequency between the local oscillator and any unwanted signals.

Field Tests

During 1949, the narrow-band recorder was field tested, making skywave studies of clear channel interference problems. Figure 4 shows three charts in terms of sunset hour. The narrow-band chart, Fig. 3A shows the drop in the undesired station's field intensity as operation is switched from nondirectional. Also shown are charts of desired signal, Fig. 3B, and the monitor signal, Fig. 3C.

Figure 4 shows three charts at ss + 4 and ss + 5. Figure 4B is the standard field-intensity recording of the desired station leaving the air with the undesired station remaining on. Figure 4A is the narrow-band recording of the undesired station. The monitor station field-intensity recording is shown in Fig. 4C. Also shown is the frequency check chart, Fig. 4D.

Supplementary Recordings

Cochannel skywave measurements made with the narrow-band recorder were supplemented by recordings of monitor and desired signals on separate recorders since the narrow-band recorder recorded only the undesired signal.

The monitor and desired stations were recorded using converted Command receivers. These receivers operated from regulated power supplies, with avc added for logarithmic recording, and d-c amplifiers driving Esterline-Angus recorders. Vertical antennas were used on all recorders. A Federal field-intensity meter calibrated by the Bureau of Standards was used to correct for effective antenna height of receiving antennas thus correcting the recorders' output response curves to read directly in mv per meter versus chart ma.

One-minute time constants were

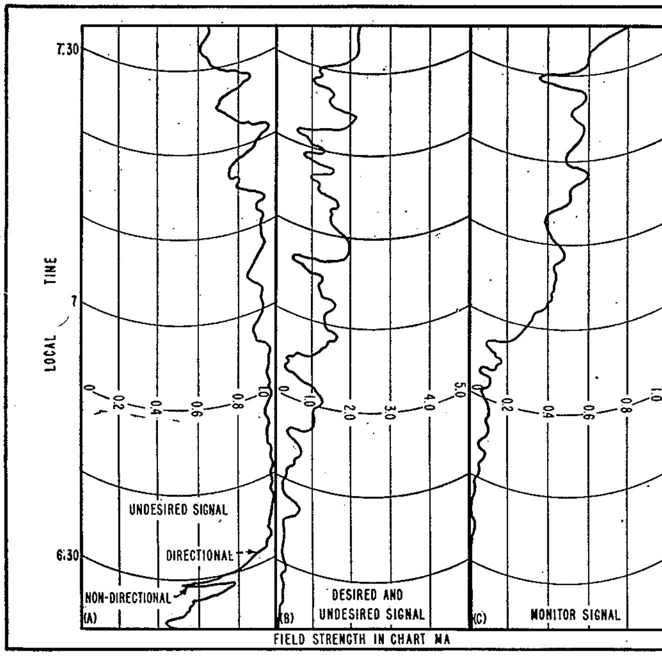


FIG. 3—Field intensity recordings made during sunset hour. Undesired signal (A) shows effects of changeover from nondirectional to directional antenna operation

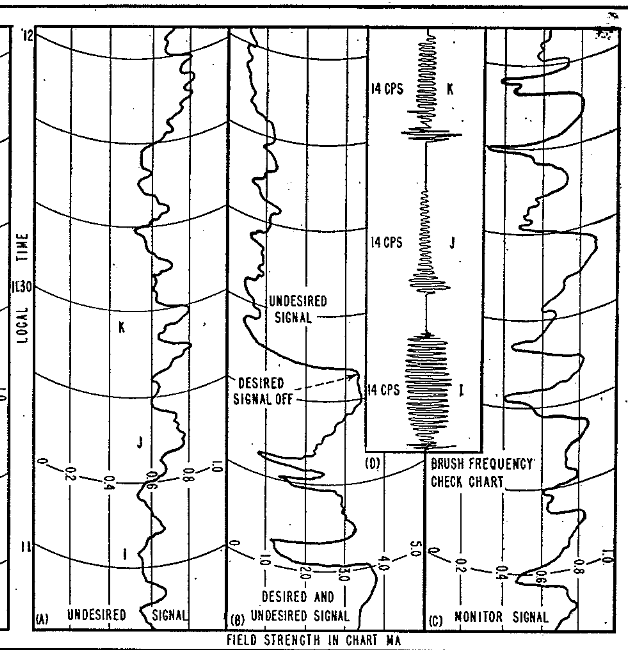


FIG. 4—Field-intensity recordings made at desired station's signoff time. Trace (B) shows interfering station's field-intensity after desired station signs off

used on all three recorders as this value is generally used in skywave studies. Measurements were usually limited to a certain bearing, centered around the desired station's 0.5 mv per meter contour.

Analysis of Data

In an analysis of skywave measurements between two stations, field-strength or interference ratios are determined with respect to sunset time. This is the time of sunset at midpoint of the transmission path between the station measured and the point of measurement. This time is obtained from FCC or Naval Observatory charts showing sunset time with respect to location. Analysis of skywave charts is made, determining the field strength exceeded for either 10 percent or 50 percent of sunset hour and each hour following.

Since skywave transmission varies from night to night, measurements are normally made over a thirty-day period. At the conclusion of the month's recording, the field intensities exceeded for either 10 percent or 50 percent of every hour during each night's operation are plotted against midpath sunset time, resulting in an average skywave curve during the thirty-day test. From this curve, it is possible to determine the average field intensity for ss + 2 or any other time.

Figure 5 shows a thirty-day summary curve of fifty-percent values for the undesired station, desired station, and the monitor station.

In conclusion, it may be of interest to note that nondirectional-to-directional antenna skywave ratio tests showed very poor correlation with calculated and ground-plane measurements. FCC nondirectional-to-directional antenna skywave ratio tests, involving approximately twenty-five radio stations showed similar results.

It appears that many existing directional systems, adjusted by ground-plane measurements, are not giving adequate skywave protection. Improved engineering standards are needed if the growth of cochannel skywave interference is to be kept to the same order of magnitude as that intended.

Credits

The narrow-band cochannel recorder is based upon the ideas of G. F. Leydorf, vice president and chief engineer of WJR. R. K. Clark, C. W. Jones, and G. L. Mills of WJR and R. A. Fox, and W. G. Hutton, of WGAR, developed the equipment under Mr. Leydorf's direction. Field testing was done by Mal Mobley. Mr. Leydorf assisted in the preparation of this paper.

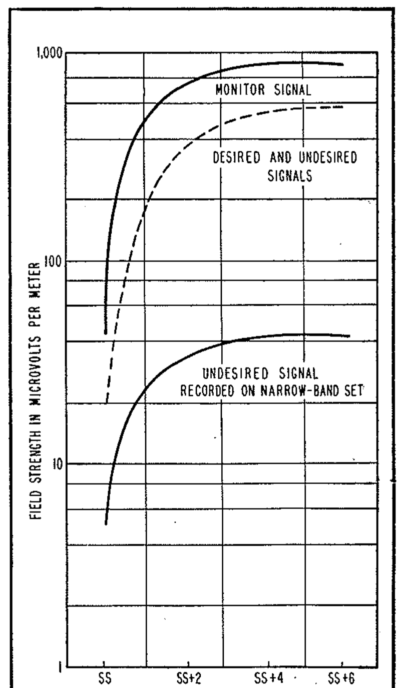


FIG. 5—Thirty-day summary of 50-percent hourly median values recorded both on narrow-band set and by conventional techniques

REFERENCES

(1) Federal Communications Commission, "Standards of Good Engineering Practice Concerning Standard Broadcast Stations", p 11, Washington, D. C., 1947.
(2) Glenn D. Gillett, U. S. Patent 2,079,265, May 4, 1937.
(3) R. A. Fox, A System for Continuously Recording Co-Channel Interference, NAB Convention, Los Angeles, 1948.

Constant-Current

Design reduces power-supply requirements because amplifier does not present varying load as do conventional circuits. Costs are cut by using only one high-voltage winding, one rectifier tube and minimum of filtering components in power supply

ONLY a simple, light power supply is required for the direct-current amplifier to be described. It does not present a variable load to the B supply, therefore the supply needs regulation only for line variations. Since line variations require a much smaller percentage of regulation control, a resulting overall system simplification is achieved.

The circuit of the newly developed amplifier shown in Fig. 1 differs from conventional d-c amplifier circuits only in the final push-pull stage. One-half of this stage serves as the output stage delivering power to the load. The other half delivers out-of-phase current to ground through an equivalent load, neutralizing both the flow of load current to ground and the accompanying drain on the B power supply.

The double-ended output stage acts like a single-ended output without the usual load current change in B-supply current. Consequently, the supply shown in Fig. 1 for the amplifier is considerably simpler than a conventional one for a d-c amplifier.

In particular, the simplified supply of Fig. 1 requires only one high-voltage winding and one rectifier tube instead of the two high-voltage windings and two rectifier tubes of the conventional supply. Because the load current does not change, neither voltage amplifier nor power amplifier tubes are required for voltage regulation and a resistor may be used in the place of a choke for filtering.

The divider formed by the two regulator tubes provides a satisfactory ground return because no load current flows to the mid-point of this divider.

Although the quiescent current from the B supply of Fig. 1 is twice the quiescent current of a conventional supply the maximum capacity of a conventional supply must be the same as that of Fig. 1 because at full load it delivers just as much current as does the supply shown in Fig. 1.

Drift of the amplifier of Fig. 1 is comparable to that of conventional, stable d-c amplifiers and averages one mv referred to the input grid. Over its rated operating range this amplifier is linear to $\pm\frac{1}{2}$ percent. Although no choke is used in the B-supply filter, the 60-cycle hum appearing across the output terminals is less than one mv referred to the input grid. Response of the amplifier is flat from zero to 20 kc for gains from 1 to 15.

The operating range of the output for which the amplifier of Fig. 1 retains its linearity of $\pm\frac{1}{2}$ percent is $\pm$ 10 ma into a load of 50 to 1,000 ohms. By changing the cathode resistor in the output stage, the amplifier can be made to develop $\pm$50 volts into loads greater than 50,000 ohms with a linearity of $\pm\frac{1}{2}$ percent.

Adjustment

There are only three points of adjustment; R_a, R_b, and R_n in the amplifier of Fig. 1 and two of these are used infrequently. Potentiom-

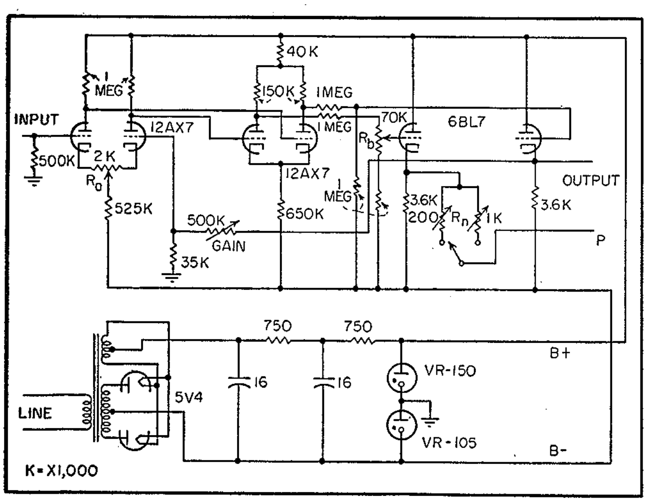
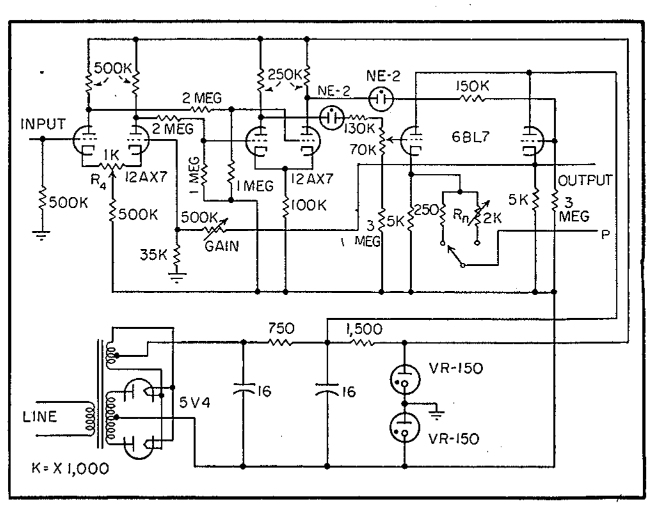


FIG. 1—Schematic diagram of the d-c amplifier. Double-ended output stage acts like single-ended output without the usual load current change



Modified version of the amplifier and power supply shown in Fig. 1. This circuit is designed for driving both photographic recorders and direct-writing recorders