A CONTINUOUS RECORDER OF RADIO FIELD INTENSITIES

By K. A. Norton and S. E. Reymer.

ABSTRACT

A recorder of received radio field intensities is described which is used for making continuous records with no attention from operating personnel during periods of at least 24 hours. A bridge arrangement is described which makes feasible the operation of the recorder from a commercial alternating voltage supply. Sample records of received field intensities from several American broadcasting stations are also shown, to illustrate the flexibility of the recording method used and also to illustrate some interesting properties of broadcast transmissions which have been shown by the use of this recorder.

The recorder described in this paper was developed at the Bureau of Standards for the purpose of making continuous records of received field intensities of radio stations. Several of these recorders have been constructed and are in continuous use for recording the received intensities of broadcasting and other stations.

The apparatus has the following characteristics: (a) It has a wide frequency range, 540 to 20,000 kilocycles per second; (b) all operating voltages are obtained from the 110-volt 60-cycle power supply; (c) the scale of the recorder can be made to accommodate the radio-frequency voltage range from 1 to 300,000 microvolts, or any reasonable portion of that range, e.g., 300 to 1,000; (d) the scale of the recorder is very nearly logarithmic over the entire intensity range, making possible a uniform percentage accuracy for all portions of the range measured (this feature is of the greatest importance in field intensity measurements since the diurnal variation of radio field intensities may be as much as 100,000 to 1 for a distant station); (e) indications are independent of small variations in line voltage and temperature; (f) the cost is small, since the parts used are commercially available, having been designed and constructed for other purposes; (g) it requires a minimum of attention from the operating personnel, calibrations being required, for a large part of the frequency range, only once in 48 hours; (h) it is portable, as shown by transportation of two of the recorders in a truck more than 3,000 miles, and use during and after the trip.

The method used in recording is as follows. A potentiometer recorder 2 (such as is used for recording temperature, humidity, etc.)

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1 Read at U.R.S.I. meeting at Washington, April 27, 1933.
2 The Brown potentiometer recorder was used, although the Leeds and Northrup potentiometer recorders have been used successfully also.
was used to record the plate resistance of a vacuum tube used as the first intermediate-frequency amplifier in a superheterodyne receiving set. A broadcast receiving set was employed which incorporated an automatic volume control. To cover the frequency band from 1,500 to 20,000 kc, a high-frequency converter was used in conjunction with the broadcast receiving set. The circuit arrangement of the potentiometer recorder is shown in figure 1. It may be seen that it is a wheatstone bridge, the recorder operating in such a manner as to automatically adjust the slide wire \( S \) (having a maximum resistance of 50 ohms) for zero current in the galvanometer \( G \). The 250-v. direct current is obtained from the power supply of the receiving set, and \( R_3 \) is made large enough (about 250,000 ohms) so that the voltage across the slide wire in the recorder is about 50 mv. \( R_p \) is the plate resistance of the vacuum tube used for measurement. In order to change the intensity range of the recorder it is only necessary to vary \( R_1 \) and \( R_2 \). These resistors are variable between the limits 0 to 50 ohms and 0 to 175 ohms, respectively. An approximate relation between \( R_p \) and the radio-frequency voltage \( E \) impressed across the input terminals of the receiving set was found experimentally to be:

\[
R_p \approx C \log E
\]  

(1)

It was found that \( R_p \) was very sensitive to small changes in the power-supply voltage, a 5 percent variation causing an apparent 100 percent change in the recorded value of \( E \). These variations were effectively eliminated by replacing \( R_3 \) by the plate resistance of a tube similar to that used for \( R_p ^* \). Since the ratio \( R_p / R_3 \) is independent of line voltage, the recorder no longer responds to power-supply voltage variations. This independence of line voltage for this ratio of plate resistances does not require an exact match of tube characteristics.  

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3 A Fada KW superheterodyne receiver was used, primarily because it was well shielded and had an appropriate automatic volume control.

4 This modification was suggested by L. V. Berkner of the radio section.
The sensitivity of the receiving set did not change appreciably with 5 percent variations in the supply voltage so that the function as given in (1) is independent of such variations. The final circuit arrangement of the receiving set and recorder is given in figure 2.

The recorder is calibrated by removing the antenna and applying a local voltage from a standard radio-frequency generator across the antenna and ground terminals of the receiving set (or converter in the case of the higher frequencies). A measurement is occasionally made of the ratio of the voltage across the input terminals introduced by the standard generator and that produced by a known field intensity acting on the antenna; the absolute value of this field intensity is measured by a field-intensity set. In ordinary calibrations of the recorders, it is only necessary to have the standard radio-frequency generator accurate for relative values, the absolute value of the field intensity being checked occasionally as mentioned. One precaution may be mentioned in using this method. It is necessary that the internal impedance of the standard generator be small compared to the input impedance of the receiving set; if this is not the case it will be necessary to make corrections for this shunting impedance in order to keep the relative values of the local voltage correct.

In figure 3 are given several different calibrations of the recorder in terms of microvolts applied to the receiving set. All of these different voltage ranges were obtained simply by varying the resistances $R_1$ and $R_2$. In general, it was found necessary to increase the range for the higher frequencies for two reasons: First, because the intensities on those frequencies vary over a wide range, and, second, the fading is so rapid that the recorder (which changes its balance point only once every 3 seconds) could not follow the variations when the intensity range was decreased. The maximum amount of balancing each 3 seconds amounts to about 8 percent of the total scale value. In this connection it may be mentioned that the recorder is usually run at the rate of 2 inches of record paper per hour but may be run at rates of from 1 to 6 in. per hour; on the frequencies above 2,000 kc it has been found desirable to run the recorder at a rate of 6 in. per hour in order to resolve the rapid fading characteristic of such frequencies.

A temperature variation of $\pm 3^\circ$ C. was found to have a slight effect on the accuracy of the records, especially on the higher broadcast frequencies (1,100 to 1,500 kc), this effect being due primarily to a drift of the heterodyne oscillator. In order to keep this effect at a minimum, the intermediate-frequency band-pass may be broadened, provided the overall selectivity of the receiving set will allow this for the particular existing conditions of interference on neighboring frequencies. On the lower broadcast frequencies (540 to 1,100 kc) it was found that a $6^\circ$ C. temperature change did not appreciably affect the records. By using a frequency of 575 kc for the intermediate frequency for the converter, the high frequencies also are free from effects of temperature variations. The temperature of the building in which the apparatus is housed is thermostatically controlled to about $\pm 3^\circ$ C. The effect of temperature variation is thus eliminated.

Figure 4 is a photograph of the receiving set and recorder as used for the frequencies between 1,500 and 20,000 kc. Figure 5 is a photograph of several recorders as used for various frequencies in the broad-
Figure 2.—Circuit diagram of recording appar
Figure 4.—Field intensity recorder used for frequencies from 1,500 to 20,000 kc.

Figure 5.—Field intensity recorders used for broadcast frequencies, 550 to 1,500 kc.
CALIBRATION IN MICROVOLTS R.F. METER

NIGHT RECORD OF WLA.E 850 kG.
6:00 P.M. TO 4:00 P.M. FEB. 22, 1933.

53 km.
Figure 6.—Field intensity records of station WEAF, New York, N.Y., frequency 660 ke, power 50 kw, distance 323 km.
970 kc, power 5 kw, distance 3,750 km; and WSM, Nashville, Tenn., frequency 650 kc,
cast frequency band. Lead-cable transmission lines are used to connect the receiving sets to vertical antennas.

Some examples of the records obtained are given in figures 6 and 7. The field-intensity scales are given by the numbers at the left and by the horizontal lines. Time is given in eastern standard time for hourly intervals along the middle of the records. Table 1 gives the location, frequency, power, and distance (from the receiving station) of the broadcasting stations recorded.

![Sample calibrations of the field intensity recorder.](image)

**Figure 3.**

**Table 1**

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Frequency</th>
<th>Power</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEAF</td>
<td>Bellmore, Long Island, N.Y.</td>
<td>660</td>
<td>50</td>
<td>353</td>
</tr>
<tr>
<td>WCFL</td>
<td>Chicago, Ill.</td>
<td>970</td>
<td>134</td>
<td>988</td>
</tr>
<tr>
<td>KJR</td>
<td>Seattle, Wash.</td>
<td>970</td>
<td>5</td>
<td>3,750</td>
</tr>
<tr>
<td>WSM</td>
<td>Nashville, Tenn.</td>
<td>650</td>
<td>50</td>
<td>925</td>
</tr>
</tbody>
</table>

Figure 6 shows two 24-hour records of station WEAF, located on Long Island. In the upper record the relative steadiness of the day field intensity indicates that it consists primarily of a ground wave.
Field intensity records of stations WCFL, Chicago, Ill., frequency 970 ke, power 1.5 kw, distance 888 km; KJR, Seattle, Wash., frequency 970 ke, power 5 kw, distance 3,750 km; and WSM, Nashville, Tenn., frequency 650 ke, power 50 kw, distance 828 km.
The fact that the apparatus used recorded the ground wave as a substantially straight line indicates its freedom from line voltage and temperature fluctuations. It will be noticed that the scale of the recorder is approximately logarithmic, making possible an equal percentage accuracy for all parts of the range. Over a period of several months no field intensities have been received for this station greater than 10 mv per meter. At 7:30 p.m. there is a decrease in the field intensity following the rise shown. The dip appears on most of the records of this station, which extend over a period of about 6 months. Severe fading at night is characteristic of this particular distance and frequency.

In figure 7 the upper record is of WCFL, Chicago, Ill., and KJR, Seattle, Wash. These stations operate simultaneously on a frequency of 970 kc. The record of KJR may only be seen when WCFL is not broadcasting. The daytime fields are from another station on a neighboring frequency, and are recorded because the receiving set is not sufficiently selective to eliminate them. Atmospheric disturbances are the source of the received field intensities shown between 3 and 6:45 a.m.

The lower record on figure 7 is of WSM, Nashville, Tenn., on a frequency of 650 kc. The received intensity is due to the sky wave, not only at night but throughout the daytime, the variations being in a ratio of 20 to 1 at noon. For this frequency and distance, about 930 km, the fading is very much less objectionable than for nearer distances. On this record also the effects of atmospherics may be seen in the early morning hours.

Washington, May 15, 1933.