

QUANTITATIVE MEASUREMENTS AT WASHINGTON ON THE SIGNALS FROM THE GERMAN RADIO STATIONS AT NAUEN AND EILVESE.*

BY

L. W. AUSTIN, Ph.D.

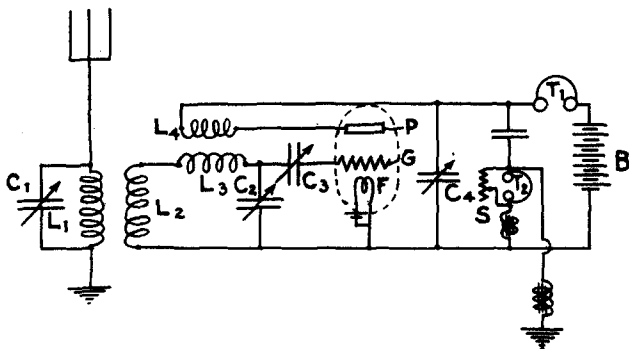
U. S. Naval Radio-Telegraphic Laboratory, Washington, D. C.

SINCE September, 1914, the strength of the signals received from Nauen and Eilvese has been measured almost daily at the U. S. Naval Radio Laboratory at the Bureau of Standards.

The antenna at the laboratory has an effective height of thirty metres. It is a flat top, 450 feet long, having two wires about two metres apart, 59 metres high at one end and 17 metres at the other. Its resistance at the longer wave-lengths is considerably lower than the one formerly used.

The circuits used for reception are shown in Fig. 1. The

FIG. 1.



detector is the de Forest audion, with an extra coupling, L_3L_4 , for producing local oscillations. The current-flow in the audion is naturally unstable, as in the Poulsen arc. This instability tends to produce oscillations, the period of which is determined by the circuit $L_2L_3C_2$. These oscillations are strengthened in the circuit PC_4F , and this increased energy is returned to the circuit $L_2L_3C_2$ through the coupling L_3L_4 , thus sustaining the original oscillations, which otherwise tend to break.

* Communicated by the Author.

In the reception of signals from stations sending out continuous oscillations from a high-frequency machine or arc, the receiving audion circuit is so adjusted that the local audion oscillations are slightly out of tune with the incoming oscillations. The combination of the two sets of oscillations produces beats of a frequency which can be heard in the receiving telephones. The pitch of the beats can be adjusted at will by regulating the amount of detuning.

The strength of signal is measured by the shunted telephone method, in which a non-inductive shunt s is placed across the telephones T_2 of the audion and reduced until the signals just remain audible. If I is the value of the current-pulses in the unshunted telephones, and I_0 the current which is just audible,

$$\frac{I}{I_0} = \frac{t+s}{s}$$

where t is the effective telephone resistance for the given beat frequency and s the resistance of the shunt which just permits

signals to be heard. The ratio $\frac{I}{I_0}$ is called the audibility of the signal. In an experiment described elsewhere¹ it has been shown that the audibility in the oscillating audion is proportional to the current in the receiving antenna, instead of to the square of the current, as in the electrolytic, the crystal contact detector, and the non-oscillating audion.

The oscillating audion is calibrated for quantitative measurements by comparing the audibility of a given signal with the deflection produced on a galvanometer attached to a silicon detector by the same signal.² The audion and silicon can be alternately connected to the secondary circuit by a double-throw switch, the circuit and coupling being adjusted in each case for maximum effect. Just before each experiment the silicon detector is calibrated by comparison with a thermo-element in the artificial antenna. It has been found that when the circuits are properly adjusted for each individual bulb practically all de Forest bulbs which are not evidently imperfect give about the

¹ *Journal Washn. Acad.*, 6, p. 81, 1916.

² On account of atmospheric disturbances this calibration is made on an artificial antenna having the same constants as the real antenna, the signals being produced by a second oscillating audion in the laboratory.

same sensitiveness. The sensitiveness, however, varies very greatly for slight changes of adjustment, so for measurement purposes it is of the greatest importance that the adjustment be made in exactly the same way. One of the most reliable methods is to tune the antenna and closed circuits with loose coupling and then, leaving the antenna unchanged, bring up the secondary and retune it at the best coupling. Using Baldwin telephones of 2000 ohms direct-current resistance and a sensitiveness of 5×10^{-10} ampères at 1000 cycles for normal ears, the least audible signal represents about 1.5×10^{-15} watts in the receiving system. The audibility increases as the square-root of the received energy. The proper adjustment of the main coupling appears to make the sensibility within wide limits practically independent of the resistance of the secondary and of the wave-length.

The results of the observations on Nauen and Eilvese from January 1, 1916, to July 1, 1916, are shown in the curves of Fig. 2. The earlier observations are not given, since, on account of changes in the methods of observation, they are not considered properly comparable with the later ones.

The most striking thing about these curves is their remarkable variability, the received current varying from 1×10^{-7} ampères to 80×10^{-7} ampères; that is, from about 25 audibility to more than 2000 audibility, with the method of adjustment used. The cause of these variations is not entirely clear. In some earlier experiments³ it was thought that probably the variations were, to a considerable extent at least, due to observational errors, but it seems now fairly certain that under normal conditions of atmospheric disturbances the limits of observational error are 20 to 30 per cent., while in extreme cases the limit may be two to one, which will not go far toward explaining these large changes in observed current.

It is now believed that the variation in intensity is due, for the most part, to an irregular reflection or possibly refraction in the upper atmosphere, which brings to the receiving station energy in addition to that which travels along close to the surface of the earth. It is also probable that there is a certain amount of absorption due to the ionization of the atmosphere. Marconi has stated that between Glace Bay and Clifden, Ireland, the signals are weaker during the presence of marked low barom-

³ *Bulletin Bureau of Standards*, 7, p. 315, 1911.

eter areas between the stations, and the present work seems to support his statements to some extent. There seems to be some reason to believe that regions where atmospheric disturbances are pronounced may be also regions of absorption.

Professor Sommerfeld and his students have developed a theory of the transmission of waves over a good conducting surface like salt water, which may be approximately expressed by the following formula: ⁴

$$(1) \quad I_R = 377 \frac{h_1 h_2 I_s}{\lambda d R} \cdot e^{-\frac{0.0019 \cdot d}{\sqrt{\lambda}}}$$

where I_r is the current in the receiving antenna, I_s the current in the sending antenna, h_1 and h_2 the respective heights of the centres of capacity of the sending and receiving antennas, λ the wave-length, d the distance, and R the resistance of the receiving system. The currents are expressed in ampères and the lengths in kilometres. The first term of this expression is derived from the Hertzian theory. The exponential term represents the falling off in intensity due to the failure of the waves to follow the curvature of the earth. Equation (1) takes no account of the possible return of some of this lost energy from the upper atmosphere, and it seems probable that this equation is fairly correct for the signals on the worst days. The formula for received current used by the Navy Department makes use of the same Hertzian term as Equation (1), but employs an exponential term which was derived empirically from the observations made during the long-distance tests between Brant Rock and the cruisers *Salem* and *Birmingham* in 1909 and 1910.⁵

$$(2) \text{ Navy formula} \quad I_R = 377 \frac{h_1 h_2 I_s}{\lambda d R} \cdot e^{-\frac{0.0015 \cdot d}{\sqrt{\lambda}}}$$

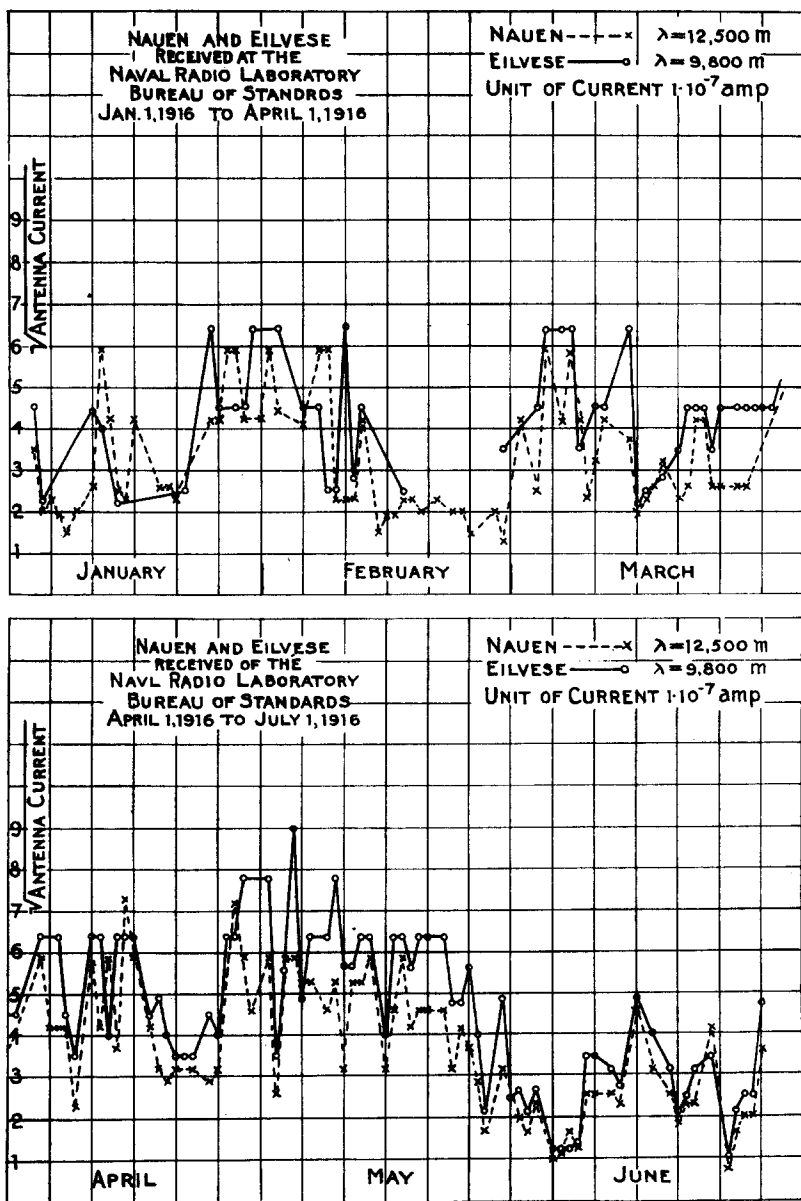
This formula was intended to represent the average value of received current over salt water in the day time, and appears, so far as can be certainly determined, to give results which are correct within the limits of observational error, at least up to 3600 nautical miles.

The observations shown in the curves of Fig. 2 were taken

⁴ A. Sommerfeld, *Ann. der Phys.*, **28**, p. 665, 1900; also H. March, *Ibid.*, **37**, p. 29, 1912; W. von Rybczynski, *Ibid.*, **41**, p. 191, 193; and J. Zenneck, "Lehrbuch der drahtlosen Telegraphie," p. 294.

⁵ *Bulletin Bureau of Standards*, **7**, p. 35, 1911, Reprint 159, and *Bulletin Bureau of Standards*, **11**, p. 69, 1914, Reprint 226.

FIG. 2.



in general between the hours of 9 and 11 A.M., Washington time, and therefore represent the signals transmitted from Germany to America when daylight covers the whole path of transmission. After sunset in Germany,—that is, when the path of the signals lies partly in darkness and partly in daylight,—the intensity of reception is often very much weakened, as though there were a backward reflection from the shadow wall.

Very few observations have been taken during the hours when the whole path of the signals lies in darkness, but these indicate that the variation between day and night at these wave-lengths is not greater than that noted on different days.⁶

The average observed received current for each month is given in the table, as well as the values calculated from the Sommerfeld theoretical formula and from the Navy formula.

The currents as calculated from the theoretical formula are seen to be less than one-tenth of the average observed values, but if the square-roots of the theoretical values of current be compared with the observed curves it is found that some of the minimum points are in fairly good agreement. The formula developed by H. M. Macdonald⁷ would apparently give even smaller values than Equation (1).

The table shows that the signals during April and May were stronger even than during the winter, and that this period of strong signals was followed by a very decided drop in June. These seasonal variations, as well as the daily variations shown in Fig. 2, are almost certainly connected with atmospheric changes, but these may to a considerable extent take place at heights above the ordinary range of meteorological observations. It is possible that the decrease in intensity in early summer may be connected with the southward movement of the low-pressure area of the North Atlantic. It is known that the seasonal changes at great heights lag behind the corresponding surface changes.⁸ The

⁶ The well-known increase in strength of night signals is a function both of the wave-length and of the distance. Wave-lengths of 10,000 and 12,000 metres will probably begin to show distinct strengthening at night at a distance of about 5000 miles.

⁷ See Eccles's "Wireless Telegraphy," p. 161, 1916.

⁸ See W. R. Blair, *Bulletin of the Mt. Weather Observatory*, U. S. Weather Bureau, vol. 6, part 4, p. 179, 1914.

study of these relationships, while it is of great interest, must wait until more observations are available.

MONTHLY AVERAGES OF OBSERVED RECEIVED CURRENT.

1916	From Nauen, ampères	From Eilvese, ampères
January.....	13.2.10 ⁻⁷	19.5.10 ⁻⁷
February.....	10.4	18.2
March.....	12.6	20.8
April.....	22.4	29.0
May.....	21.6	33.8
June.....	6.2	8.5
General Average.	14.4	21.6

CALCULATED.

From equation (1)....	0.95	1.91
From equation (2)....	14.3	22.2

DATA FOR CALCULATION.

	I_s Amperes	h_1 Metres	h_2 Metres	d Kilo- metres	λ Metres	R Ohms	$e^{-\frac{0.0019d}{\sqrt{\lambda}}}$	$e^{-\frac{0.0015d}{\sqrt{\lambda}}}$
Nauen.....	150*	150	30	6650	12500	124	0.0039	0.058
Eilvese.....	140*	150	30	6100	9800	93	0.0045	0.052

* As given in 1914.

U. S. Naval Radiotelegraphic Laboratory,
August, 1916.

Heat Losses Through Galvanized Roofing. ANON. (*The Iron Age*, vol. 98, No. 8, August 24, 1916.)—Loss of heat through a roof of galvanized steel sheets is less than through roofing consisting of cement and fibrous material compressed to sheets about $\frac{1}{4}$ inch in thickness, according to experiments made last year by the National Physical Laboratory at Teddington, England. A model hut was built up of walls of cork slabs, 2 inches thick, and a roof of the new material or of galvanized sheet iron. The air inside was heated by electrical resistance, which was not allowed to get sufficiently hot to set up appreciable radiation, and the air was agitated by a fan. The air temperature inside differed by 30° F. contrary to expectation, the heat losses through the cement, measured per square foot, were 20 per cent. greater than through metal, the reason being that the emissivity loss from the surface and not from the thermal conductivity of the material, is the decisive factor. When the iron was painted black the heat transmission increased, becoming equal to that of the cement; when the cement slabs were painted with aluminum they behaved like the iron.