DIURNAL AND ANNUAL VARIATIONS IN OVERLAND RADIO-TRANSMISSION.

By A. H. Taylor.

IT is a fact well known among radio operators that the winter range of a wireless station greatly exceeds its mid-summer range.

This is partly due to the prevalence of "strays" during the summer season, especially on the long wave-lengths, and partly due to a real difference in transmission, which may perhaps be ascribed to a difference in absorption brought about by different conditions of earth and atmosphere during summer and winter.

Most quantitative experiments so far in long distance work have, for obvious reasons, been with oversea transmission, since a ship station at definite adjustment may be sent out to great distance from a land station sending at constant power, thus making possible, as in the experiments of Austin,[1] a series of measurements under similar conditions at the receiving station, varying only the distance between the two. This method of procedure is obviously impossible for long distance overland transmission, although it is possible in shorter distance field tests. Austin represents the oversea transmission as being quite constant in the daytime, and following the law

$$i_2 = \frac{Ki_1\epsilon^{-\frac{KD}{\sqrt{\lambda}}}}{\lambda D},$$

when i_2 is the received current, to the square of which the audibility may be taken as proportional. The constant K depends on the heights to center of capacity of sending and receiving antenna, the type of antenna used, and the equivalent resistance of the receiver, while i is the sending current and λ the wave length in kilometers. D is the distance between stations, also in K.M. Application of this formula to the 3,500 m. wave so frequently used this spring by Arlington (NAA) in correspondence with Key West (NAR) indicates that it should suffer a thirty-six fold loss in audibility due to absorption in traversing an oversea distance equal to the overland distance between Grand Forks and Washington. Some roughly quantitative results calculated from observations taken here on this wave indicated that it was received nearly 120 times stronger

[1] Bull. Bur. Standards, Vol. 7, No. 3.

at midnight than at noon. This estimate is based on shunted telephone readings, using a single 800 foot aerial wire of seven strands of No. 22 phosphor bronze, far end 120 feet in height, near end 65 feet. An audion detector was used and a 3,200Ω New Navy type telephone receiver. The signals were barely distinctly audible at noon, but the best midnight (or thereabouts) readings showed shunts of as low as 14Ω. Bearing in mind Braun's[1] recent criticism of shunted telephone readings, the writer can hardly give these results weight enough to attempt to calculate the absorption coefficient for this wave, especially since it is far from safe to assume the midnight transmission to be unabsorbed. They do indicate, however, that the average daylight transmission was fully four to five times as much absorbed as it should have been in an equal oversea distance, according to the Austin formula. Furthermore, as anticipated in a previous paper,[2] the daylight transmission overland is most certainly affected by the weather and the time of year, and is by no means as constant as oversea transmission.

In this connection it is of interest to note that the noon time signal from N A A at 2,500 m., $i. = 87A$, $p = 52$ K.W. could not be received here on the single-wire aerial without the use of a second audion used to amplify the first, while the 3,500 m., $i = 104A$, $P = 58$ K.W., an hour later was distinctly audible, with one audion. This shows that the shorter wave suffers even greater absorption.

I am greatly indebted to Captain Bullard, U. S. N., for data on the 3,500 m. wave.

At the present time, June 20, in order to get the 11:00 A.M. (Central time) or noon time signal at 2,500 m., we are obliged to use a 3-wire 800 foot aerial, although in midwinter a small 150 foot aerial sufficed.

I have no hesitation, therefore, in asserting that the daylight transmission between here and Washington is many times stronger in winter than in summer, this statement being based on comparative shunted telephone readings on the two aerials, long and short, indicating that for Sayville, N. Y., 2,800 meters, the long aerial is seven times as effective as the short one. The long aerial having been recently installed, to cope with summer conditions, no winter observations have yet been taken on it. This long aerial points S. E. and is, therefore, unfavorably directive, else it would be even more efficient.

From observations on Arlington, Va., 1,400 miles, and Key West, Fla., 1,840 miles, it would seem that annual variations are dependent on the character of the country traversed. In midwinter the 2,500 m. wave $i = 57A$, $P = 52$ K.W. of Arlington, received on the smaller aerial,

[1] F. Braun, Yahrbuch d. drahtlosen Teleg. und Telephonie, April, 1914.

[2] Taylor, PHYS. REV., May, 1914.

equivalent resistance 40Ω, was very little stronger, and indeed frequently not as strong as the 1,800 m. $i = 37\,A$, $P = 23$ K.W. wave of Key West. (The equivalent aerial resistance for 1,800 m. wave 27Ω) I am indebted to Captain J. L. Jayne, U. S. N., for the data on these waves. I am not informed as to the height to the center of capacity at Key West, but for the purpose of argument, assuming it to be the same, the relative intensities of these two waves should be as

$$\frac{i^2}{\lambda^2 D^2 \cdot R} = 2.7 \times 10^{-6}$$

for N A A (Arlington), and $n = 1.8 \times 10^{-6}$ for N A R, Key West, neglecting absorption. With absorption at 1,800 meters in all probability greater than at 2,500 m. N A A should have been heard much louder than N A R. These observations were taken between 9:00 and 9:45 P. M., Central time. As the spring came on, a marked change in this relation came about. Both stations averaged weaker and weaker, finally frequently necesstating the use of the double audion detector or amplifier, but N A R faded much faster than N A A, becoming at that hour seldom audible after April 1, so that from approximate equality in intensity, the signals of Key West were in the course of three months reduced to less than one tenth the intensity of those of Arlington. The writer can scarcely believe that this difference can be attributed entirely to difference in wave-lengths, unless at the same time we assume that the absorption in the Mississippi Valley, which offers a remarkably preferential highway for radio-transmission in winter, increased much more rapidly than that over the more northerly path between here and Washington.

It has occurred to the writer that the loosening up of the ground by plant growth in the spring, and even the growth itself, may be accompanied by a certain amount of ionization from radioactive sources, thus accounting for the almost sudden increase of absorption of electromagnetic waves which occurs in the spring. This effect would be more noticeable over a southerly route.

The preferential winter transmission in the direction of the Gulf of Mexico to Grand Forks, may be due to high soil conductivity in the lower half of the Mississippi Valley, brought on by abundant rainfall. The generally level nature of the country is also unquestionably an aid.

Several investigators mention in recent papers the fact that river valleys, such as the Rhine and Rhone, offer preferential paths. Among these might be mentioned M. Reich,[1] who mentions a distinct difference in transmission between Göttingen and Köln, and Göttingen and Strass-

[1] M. Reich, Phys. Zeitschrift, 14, 1913.

burg, while he attributes to the fact that a valley favors, for a great part of the distance, the transmission from Strassburg to Göttingen. The writer does not, therefore, advance the idea of the preferential Mississippi Valley path as anything new, but wishes rather to call attention to the fact that, judging from the Key West signals, this preference, so striking in the winter, disappears quite completely in the spring.

Since it usually happens that the transmission rises rapidly after sunset, it might be urged that the whole matter might be accounted for by the difference in time of sunset between Washington and Key West.

This difference is, however, only about one fourth the total difference between Washington and Grand Forks, and seems insufficient to cause any great difference. In order to be sure of this point, the Key West signals were usually followed, when possible, to nearly 10:30, Central time, with marked increase in intensity, although not nearly enough increase even then to compare favorably in the spring with the 9:00 Arlington signals.

It must be noted, in reference to the inconstancy of daylight transmission, that Austin distinctly states that for oversea transmission the daylight transmission is exceedingly constant.

His experiments over long distances would seem to prove this quite conclusively, but his experiments have not, to the knowledge of the writer, been repeated across equally long distances entirely overland. The investigations of H. Mosler,[1] on the annual and daily variations in the intensity of signals from Nordeich and the Eiffel tower led him to conclude that the intensity in the daytime was essentially constant, and varied little if any during the year. This absolutely erroneous conclusion is due to the short distance of only a few hundred kilometers, over which his signals were received. If the absorption is, as seems to be generally accepted, a logarithmic function of the distance, which holds also for Sommerfeld's surface wave, then variations scarcely perceptible at 300 K.M. will be very great at 3,000 K.M. As for the daily variation at Grand Forks of the Arlington 11:00 A.M. Central signal, while it is by no means as great as the variation from summer to winter, yet variations of threefold in the intensity are now being observed, and an attempt is being made to correlate these diurnal variations with weather conditions.

During the month of April Arlington was not only heard frequently on 3,500 m. at 1:00 P.M. but also at 6:00 P.M., and almost invariably with greater intensity, in the ratio of two or three to one. This may be due to the fact that twilight had already begun at Arlington.

[1] H. Mosler, Electrot. Ztschr., 35, 1913.

Summary.

1. Overland daylight absorption of electromagnetic waves is several times greater than oversea absorption calculated from the Austin formula.

2. Overland daylight absorption is, unlike oversea absorption, not constant.

3. Overland daylight transmission on long waves is much stronger between Grand Forks and Washington (1,400 miles) in winter than in summer.

4. Overland nocturnal transmission varies with the time of year to a different degree, depending on the nature of the country traversed.

5. The Mississippi Valley shows a very wide variation in summer and winter transmission.

Radio Station 9YN,
University, N. D.
July 15, 1914.