

RADIOTRANSMISSION AND WEATHER.

BY A. H. TAYLOR.

IN a previous paper on this subject¹ the writer submitted evidence which seemed to show that unusually good radio transmission across long overland distances at night is preceded the day before by generally cloudy conditions prevailing in the region across which the nocturnal good transmission takes place.

The evidence presented in that paper has been greatly strengthened by subsequent observations. In particular it may be mentioned, that out of some sixty cases of good transmission studied since September 24, 1913, forty-four have followed a generally cloudy condition over the area in case, while of the other sixteen, a majority have occurred during the shortest days of the year, when the hours of sunlight in the latitude of Grand Forks, N. D., are relatively few.

Before discussing the bearing of this evidence on the idea of the reflection and refraction² of electric waves by ionized layers of the earth's atmosphere, it will perhaps be well to examine some of the data collected at this station since September 24, 1913, for evidence of a somewhat different character.

In commenting upon the previous paper, the editor of the *Electrical World* suggested that the effects noted might have been indirectly due to general cloudiness, inasmuch as this would usually bring about some rainfall and would therefore probably reduce the ground absorption which is thought to be much larger in overland than oversea transmission. Fortunately the weather during the fall of 1913, especially during the months of October and November, was of such a nature in this part of the continent as to make it possible to settle this important question. The height of the aerial at this station is but 85 feet, so that the nearest of the Great Lakes stations do not usually make themselves heard until after dark. Nevertheless, during a period of over a month in which no moisture whatever fell in northern Minnesota the stations at Port Arthur, VBA, and Duluth, WDM, were heard as early as 4:30 P. M. on several occasions. Subsequent comparison of weather reports

¹ *Electrical World*, August 30, 1913.

² Dr. W. Eccles, in *The Electricians*, September 27, 1912, and September 19, 1913.

showed that in each instance the intervening region had been very cloudy. In spite of the fact that during this period no rain fell, or even snow until about December 1, there was a great deal of cloudy weather over northern Minnesota, and hence especially close attention was given to the transmissivity from VBA and WDM. In 80 per cent. of the cases of very good transmission from these stations to this one (9YN) the preceding day had been very cloudy in this region. The effect of moisture on ground absorption is here eliminated. I am therefore forced to conclude that the effect of alterations of earth absorption are entirely overshadowed by the larger favorable influence of preceding cloudiness. Incidentally these experiments showed that the normal day absorption on clear days in this region is very large. This is supported by the fact that our own signals sent on a 500 m. wave with 7 amperes aerial current were but fairly received just before dusk in Minneapolis at the North Central High School with a 100 ft. aerial, whereas less than an hour later they were repeatedly picked up by Mr. Keith Russell on a 70 ft. aerial in Toronto. The first distance is 300 and the last 1,000 miles.

It has occurred to the writer to analyze data at hand for the possible influence of barometric pressure on transmission. The weather maps corresponding to the days preceeding the evenings of observation were examined and 24 were found which indicated that rather low barometer readings had prevailed in or near the areas across which transmission had been studied. Of these only two were found to correspond with records of bad transmission, while the others all corresponded to records of good transmission. Inasmuch as the weather maps do not arrive here until the day after the transmission records are made, it is not possible for the observer to be prejudiced. Conclusions as to good or bad transmission were based on observations on Sayville, N. Y., call WSL; Arlington, Va., call NAA; Key West NAR (1,800 m.) Wellfleet, Mass., WCC; San Diego, NPL, and the Lakes stations at Milwaukee, WME; Port Arthur, VBA; Duluth, WDM; Sault Ste. Marie, VBB. For reasons not at once apparent many stations on the Gulf of Mexico or in the Mississippi valley are received here with extraordinary clearness. A good many observations were made on signals from battleships in the Gulf and upon Galveston, WGV; New Orleans, WHK; Ft. Sam Houston, WUJ; Michigan University, 8XA; Ft. Leavenworth, WUV, and others. From the west coast, observations were also made upon Mare Island, NPH; Point Arguello, NPK, and occasionally upon Victoria, VAK. A great many other stations might be mentioned as being heard here when transmission was unusually good. A good many vessels were reported at this station but it was not often possible to locate them very definitely.

Finally, shunted telephone readings have been made on our own signals at Memphis, Tenn., by Br. John Berchmanns, of Christian Brothers College; at St. Louis by Mr. A. S. Blattermann at Washington University; at Boulder Colorado, by Mr. Strock; and by Mr. H. S. Sheppard at Michigan University in connection with certain tests to be reported on jointly in a future paper. Several amateurs at points from 600 to 1,100 miles distant have been kind enough to make written reports on the relative strength of our signals, among these Mr. Stockman at Denver, Colorado, and Mr. Miller, at Bushnell, Ill.

In reference to the influence of barometric pressure, it must be noted that areas of low barometer are always more or less cloudy. In order to settle this point it is necessary to consider the cases where the barometer readings were generally rather high over the areas studied. Of 18 cases which could be put in this class, 11 showed good transmission and 7 poor. But of these 11 cases of good transmission, 4 were reported from the valley of the Mississippi, which the author has reason to believe permits phenomenally good transmission, and 6 were over generally cloudy areas. Of the 7 cases of bad transmission associated with rather high barometer, 5 were over very cloudy areas. The writer does not consider this evidence conclusive, but it might mean that high barometer is unfavorable to transmission. Clear-cut cases for long distances are not easy to find for either the high or the low barometer classes.

On the whole it seems as if the presence of clouds is the controlling factor, modified somewhat perhaps by barometric conditions. Bearing this in mind, it seemed worth while to attempt to find out whether cloudiness would be most beneficial at the sender or at the receiver. Accordingly the evenings of observation were divided as follows:

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| 1. Senders and receiver both in cloudy area. | Good transmission 19; bad 4. |
| 2. Senders and receiver both in clear area. | Good transmission 7; bad 6. |
| 3. Senders, cloudy; receiver, clear. | Good transmission 14; bad 3. |
| 4. Senders, clear; receiver, cloudy. | Good transmission 8; bad 7. |

From this analysis it seems that few cases of good transmission are reported when both stations have been in the clear area preceding the night of observation and about the same indifferent result is seen when the sender only has been in the clear. On the other hand, when the sender but not the receiver has been in the cloudy, the ratio of good to bad transmissions is about the same as when the cloudiness has been quite general. This ratio is 5:1 in favor of good transmission. Cloudiness in that portion of the area of transmission near the sender is evidently of the most importance in favoring transmission. This should have an important influence on the formation of any theory which will take

account of the variations of nocturnal transmission as a function of the weather of the preceding day.

It seems to the writer that the most serious attempt to correlate fact and theory in long distance transmission problems has been made by Dr. Eccles in the two papers previously mentioned. As he points out, the hypothesis of an upper layer of ionized air was suggested by Heaviside in 1900, and the idea of the production of such ionization by bombardment of cosmic dust has been advanced by Dr. W. J. Humphreys¹ to account for the fact that according to the researches of Newcomb, Yntema, Campbell and Abbott, there is received from the sky a total amount of light which exceeds the total light from the stars. Dr. Eccles seems to prefer however the hypothesis of Professor Schuster,² put forward to justify his theory of the diurnal variations of terrestrial magnetism. This would mean a gradual increase in ionization and hence in conductivity with the height, but on the whole a degree of ionization which would create a very great absorption. He points out that a very much smaller degree of ionization would suffice to explain some of the phenomena of long-distance radio transmission.

If the equations of the electromagnetic wave in free space be modified by the addition of a term representing the ionic convection current in the path of the wave, there results an expression for the wave velocity which exceeds that of light in free space. A better way of stating this is perhaps to say that the refractive index of ionized air would be less than unity, just as in the case of thin films of some metals whose refractive indices may be much less than unity for light rays. The effect of a refractive index diminishing with increasing altitude would be to tend to bend the waves back to earth, thus following more or less its curvature.

Dr. Eccles offers the very plausible suggestion in regard to the well-known facts of nocturnal long transmission, that the middle portion of the atmosphere is at night mainly unionized on account of the absence of sunlight, but that partial reflections occur at the very high permanently ionized layer. This reflection would not take place during the day, as there would be no very sharp transition from ionized to unionized atmosphere. His calculations on the amount of bending of long waves during the day time show that a distribution of ionization is possible such that these waves, at certain critical altitudes (ranging from 40 kilometers for a 2,000 m. wave to 100 kilometers for a 200 m. wave) would suffer a refraction so abrupt as to be equivalent to a reflection,

¹ W. J. Humphreys, *Astrophysical Journal*, May, 1912.

² *Phil. Trans., A*, 1907.

thus accounting for the possibility of long distance transmission being better in the daytime with long waves than at night. This has been occasionally reported by Marconi of trans-Atlantic transmission. The writer has taken many observations on the 1,800 m. wave of Key West, on Arlington at 2,500 m. and on Sayville at 2,800 m., but on three occasions only, in the month of December, were any of them heard in the daytime at this station. The exception was Arlington, distant about 1,400 miles. The signals were barely audible, and not to be compared in intensity with the 9:00 P. M. (central time) time signals. The signals of these stations have always been received here stronger as it became later in the evening. The aerial at this station is however not high enough to do long distance receiving in daylight.

The writer does not consider that the evidence which has been presented in this and the preceding paper is in conflict with the theory of Dr. Eccles. On the other hand it is in no wise to be explained by that theory, dealing as it does with refractions and reflections at relatively high altitudes. The author is inclined to accept the idea of a permanently ionized upper layer at great altitude; he is even willing to entertain the notion that the ionized middle region in daylight plays an important rôle in determining the generally large day absorption, but he considers that the evidence here submitted can only be accounted for by assuming a reflection at the cloud level brought about by a more or less abrupt alteration in the velocity of the wave above and below this level. It is not the clouds themselves that reflect, as good transmission between here and the Lake district has often been observed on very clear nights provided that the day has been cloudy. It is rather caused by an electrical discontinuity which persists after the clouds which caused it have perhaps long disappeared. It is difficult to believe that the probable degree of ionization by sunlight at the cloud level could be sufficient to be of influence, but so far no other more plausible suggestion has occurred to the writer. If this ionization is appreciable, then the clouds would in daylight produce a discontinuity layer which might persist for some hours after sunset. By the time this discontinuity fades away the ionization in the whole intermediate region of the atmosphere will be reduced so that waves may reach the permanently ionized upper layer and be reflected by it with little absorption. Thus good transmission will continue until the morning twilight. It naturally follows that general cloudiness would be beneficial in daylight. As far as observations taken at this station go, they fully agree with this. Unfortunately the day range of this station for reception of signals is not sufficiently great to settle this point definitely. The fact that cloudiness at the sender (where the

radiant energy would without reflection be highly divergent) is more beneficial that at the receiver, seems to lend support to this theory. The theory leaves us without any adequate explanation of the day absorption which Austin has shown to be very regular in oversea transmission at least. We must therefore either assume that the day time ionization under the cloud level averages much larger than is generally assumed, or that the radiation is divided as follows:

1. A portion reflected from the cloud level, and passing from sender to receiver as between two approximately parallel surfaces, and hence not following the inverse square law of divergence, and not heavily absorbed, since it travels in a feebly ionized medium.
2. A portion entering the middle ionized region and refracted back towards the earth according to the theory of Dr. Eccles. This portion would be absorbed during the day, but very feebly absorbed at night.
3. A portion passing through the middle region and partially reflected at the upper permanently ionized layer. This would be heavily absorbed during the day, and feebly absorbed at night.
4. A portion which passes out into space and is lost.

It is likely that the second portion is of the most importance in the daytime, while the vagaries of long distance nocturnal transmission are due to combinations at the receiver of the first and third portions. Those rapid variations in the strength of signals (swinging), and the slower fluctuations (fading) so familiar to operators in long range work may well be due to interference effects between these two portions.

The rapidity with which these effects often occur strongly suggests the idea of a violent commotion in the lower levels in the wave path.

Accordingly, daylight transmission over a clear area would be carried on mainly by the second portion, the third portion being heavily absorbed. Daylight transmission over a cloudy area (especially where cloudy at sender and its vicinity) would be reinforced by the first portion.

Nocturnal transmission following clear days would be carried on by the second portion reinforced by the third, both portions being feebly absorbed. Nocturnal transmission following cloudiness would in general be carried on by all three portions, but the evidence here presented suggests that the first portion, added to the third, both feebly absorbed, is of great importance.

Since completing this paper the writer has read an interesting account by Nipher, in the Proceedings of the Saint Louis Academy of Sciences, 1913, of local magnetic storms whose origin he believes to have traced to the influence of clouds. He finds also a period of magnetic disturbances coinciding with the well known twilight fluctuations in radiotrans-

mission. Prof. Nipher suggests a variation in the ionization of the *lower* levels caused by variations in the sunlight as the nature of this influence. There seems to be an intimate connection between these phenomena and the variations in radiotransmission.

RADIO STATION 9YN, UNIVERSITY, N. D.,

February 21, 1914.