PROPAGATION OF SOUND IN AN IRREGULAR ATMOSPHERE.

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SYNOPSIS.

Under poor atmospheric conditions, lower frequencies in aëroplane engine sounds become relatively enhanced; under good conditions, frequencies of order of 1,000 d.v. are heard at greatest distances. The former is explained by irregularities in the atmosphere and the latter by characteristics of audition.

Intensity of the sound varies much more rapidly than as the inverse square, crude observations giving much more nearly inverse sixth and fourth powers for maximum ranges under fair and good listening conditions, respectively.

LORD RAYLEIGH'S[1] reference to and explanation of the "highly uneven character of the sound" from aëroplanes in flight, leads the writer to make a record of three additional facts.

During experiments in connection with aëroplane detection and location the observers noticed that under what might be termed "poor listening" atmospheric conditions the sound from the aëroplane when at the greatest hearing distance was limited to the lowest frequencies in the emitted complex sound. These frequencies were for these particular aëroplanes approximately 90, 180, 270, etc., and the most prominent component was the one of lowest pitch. The sound from the same aëroplanes heard at the greatest possible distance under excellent night conditions was distinctly different. The lowest frequencies just named were not noticeable and the sharp cracking sounds of the engine explosions, with prominent components, probably of the order of 1,000, were most distinctly in evidence. The difference in the character of the sound in the two cases may be described as the cutting off of the higher frequencies in the former and of the lower frequencies in the latter. That there may be a more rapid decay of intensity of the higher frequencies is readily understood by a consideration of differences in wave-length. The irregularities in the planity of the strata, for example, would be more effective in scattering, by reflection and refraction, the frequencies having the shortest wave-lengths. In general, the irregularities of the atmosphere would affect the shorter wave-lengths the more.

[1] Nature, Vol. 101, 1918, p. 284.

The apparent better transmission for the higher frequencies in the second instance is not to be explained by any influence of the medium but rather by the characteristics of audition. The sense of loudness for the different frequencies is not the same, whether the intensities are measured in mechanical units or in terms of minimum audibility. It is the latter unit of measurement that is of interest in the present case, for the nature of the sound heard at a great distance from the source depends upon audibility.

Professor Sabine[1] has proved that a frequency of 64 and of 1,024 appear of equal loudness when the former is 7×10^4 times and the latter 15×10^6 times its own minimum audible intensity. This means that the observer might be situated near a source emitting these two sounds and consider them of equal loudness, and yet with a homogeneous atmosphere and the decrease of intensity of sound according to the inverse square law, he could find that as he recedes from the source he would cease to hear the lower frequency first because its intensity has passed below the minimum audible limit. Thus the explanation of the above-mentioned change of quality with distance from the aëroplane under good listening conditions is to be explained on the varying relative intensities required for equal loudness and minimum audibility. According to Sabine's values, given sounds of equal loudness at a given distance, the one of frequency approximately 1,024 will "carry" the farthest in an ideal medium if the ear is used as the receiving instrument, and the frequencies 64 and 2,048 on either side of this "maximum" will be heard approximately the same distance.

The other experimental fact worthy of record is the rapidity with which the intensity falls off with distance in the atmosphere. The experiments here to be mentioned are crude, but are sufficiently accurate inasmuch as the exact conditions of the atmosphere could not be recorded. Occasions were selected when the temperature gradient at the ground was practically zero and a comparison was made of the maximum distance from the unaided ear and from the listening device, respectively, that a complex sound could be heard. This experiment was repeated many times and in every case the maximum distance with the instrument was approximately ten times that with the unaided ear. Conditions were such that the selectivity of the instrument was believed negligible. Inasmuch as the experiments were performed on a heavily grassed prairie the decrease of intensity with distance must have been even more rapid than as the inverse square. Similar listening experiments were made using the same device and with aëroplanes in flight. On fair sunny days,

[1] Contributions, Phys. Laboratory, Harvard Univ., No. 8, 1910.

cumulus clouds forming, with aëroplanes at elevation of one thousand yards, the aëroplanes could be heard only twice as far as with the unaided ear. On days when the atmosphere was obviously more irregular, the decay of intensity was much more rapid. Under good night observing conditions with the aëroplane at an elevation of two thousand yards this maximum distance was increased to three times the distance possible with the unaided ear.

It thus appears that even when the atmosphere is favorable to sound transmission, there is sufficient irregularity to cause a surprisingly rapid decay of sound from an elevated source.

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