ON WHISTLING METEORS

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ABSTRACT. Very weak whistles, usually of rapidly decreasing pitch were observed at the Delhi receiving centre of the All India Radio, located at a distance of 10 miles from the transmitters, when the receiver was tuned to the carrier waves from one of the transmitters. These were explained by the A.I.R. investigators as due to a Döppler change in the frequency of the carrier waves scattered from a rapidly moving ionized mass of air at the head of a meteor entering the earth's atmosphere, and to consequent heterodyning of these waves with the ground waves of unmodified frequency. A review of the experimental results in connection with these whistles is given in the paper. The Döppler effect theory to explain these whistles is also critically examined. The striking similarity of these whistles with the whistling tones observed by Barkhausen, Eckersley, and Burton & Boardman in audio-frequency amplifiers with large aerials, is pointed out, as suggesting a common origin for both. Accepting Eckersley's theory of the 'whistler,' the possibility of the carrier waves scattered from the ionosphere being modulated by the Fourier components of such an electrical impulse is suggested. The components of the higher frequencies travel faster in the ionospheric medium, so that the modulation frequency is a function of time. The receiver tuned to the carrier would therefore reproduce a note, the pitch of which would also be a function of time. Accordingly the whistling tones, unconnected with meteors, would also be heard by the scattered waves. It is just possible that at least some of the whistles observed at Delhi were of this origin.

In view of the observed coincidence between the appearance of meteors and the so-called Döppler whistles, it is tentatively supposed that an electrical impulse can be produced by the stoppage of meteor in the ionosphere. The modulation of the scattered waves by the various components of this impulse would then be able to produce a whistle.

The observed dependence of the pitch of the whistle on the frequency of the carrier waves is also expected according to this view.

A few test experiments are suggested.

A DÖPPLER EFFECT PRODUCED BY METEORS

Recently certain interesting observations were made by Chamanlal and Venkataraman (1941) at the Delhi receiving centre of the All-India Radio, located at a distance of 10 miles from the Delhi short wave transmitters. During these observations, when a receiver was tuned to the carrier waves from one of the transmitters, weak whistles of an unusual character were audible under certain circumstances. The whistles appeared as high-pitched notes which rapidly descended in pitch. They were of short duration, varying from about one-fifth of a second to several seconds and occurred at random time intervals. They were most frequent in the early hours of the morning and were infrequently heard during the day time. During the early morning they were found to increase greatly in number and intensity.

The observed whistles were explained by the A.I.R. investigators as due to a Döppler change in the frequency of the weak carrier waves scattered from a rapidly moving ionized mass of air at the head of a meteor entering the earth's atmosphere and to consequent heterodyning of these waves with those reaching the receiving centre as ground waves of unmodified frequency. As the meteor rushing with some high speed through the upper atmosphere gradually slows down, there would evidently be a gradual decrease in the frequency change of the waves scattered from the head of the meteor. The scattered waves on interfering with the ground waves would then give rise to a heterodyne whistle of gradually descending pitch. From a knowledge of the initial beat-frequency due to this interference, the velocity of the meteor can be calculated from

$$\Delta f = \frac{2v}{c} \cdot f, \text{ where } \Delta f \text{ is the beat-frequency,}$$

f the carrier frequency, v the velocity of the ionized mass of air at the head of the meteor and c the velocity of light. Assuming a beat-frequency of 3Kc/s for a carrier frequency of 7 Mc/s, the calculated velocity would be 64 Km./s. This could be taken as of the same order as the maximum velocity of the meteors directly observed.

EVIDENCES IN SUPPORT OF THE DÖPPLER EFFECT THEORY

In support of the Döpplereffect theory the following facts can be adduced :

(1) The appearance of a meteor in the sky coincided with a whistle produced in the receiver.

(2) The number of whistles observed was at a maximum in the early morning, when the number and velocity of meteors entering the earth's atmosphere are greatest.

(3) No such whistle was heard with medium radio-frequency carrier waves. With such low frequency, the intensity of the scattered waves is feeble and the Döppler change is also considerably small.

The following two experimental results of the A.I.R. investigators can also be cited :

(1) The whistle heard on a carrier of 7.5 Mc/s commenced with an initial frequency about half that of the whistle heard on 15 Mc/s. The experiment was carried out by operating one transmitter near 15 Mc/s and a second transmitter near 7 Mc/s and connecting the output of the two receivers tuned separately to these frequencies to two loudspeakers or headphones, each being connected to each receiver. It was found that the whistles were first heard on the loudspeaker connected to the receiver tuned to the lower frequency and as these whistles descended in pitch, a whistle of higher pitch was heard on the other loudspeaker connected to the receiver tuned to the higher frequency. The observation of a higher pitch on the receiver tuned to the higher frequency was expected from the Döppler effect hypothesis.

(2) One of the Delhi transmitters was tuned to approximately 7 Mc/s radiating the carrier wave and a second transmitter was operated as a pulse transmitter on a slightly different frequency. In the majority of cases it was found that the entry of a meteor into the earth's upper atmosphere, as made evident by the whistle, was followed by a return from the ionosphere, as observed on a cathode-ray oscillograph.

Some special cases were also noted by the observers. While in the majority of cases the whistle was of descending pitch, in some cases, whistles were obtained with an ascending pitch. In a limited number of observations again, the whistle commenced with a descending pitch, passed through zero frequency and rose again in pitch. These special cases were explained as due to the relative velocity of the meteor at the receiving point having a component towards or away from the receiver.

REMARKS ON THE POSSIBILITY OF DETECTING DÖPPLER EFFECT UNDER THE CIRCUMSTANCES

It is well known that there are 'patchy' ionized regions in the ionosphere which cause scattering of the electromagnetic waves when they are incident on them. The whistle which was observed beyond the range of the ground wave by the A.I.R. investigators was considered by them to be an effect of interference between scattered waves from the ionosphere and the waves returned from the ionized mass of air at the head of a meteor. If a perceptible amount of ionospheric scattering is recognised, it is evident that the waves returned from the head of the meteor would only be a small fraction of the total scattered radiation reaching the receiver. The scattered waves from the ionosphere and also the ground wave have the same frequency as the carrier waves from the transmitter. These waves on interfering with relatively feeble radiation of modified frequency, scattered from the ionized mass of air at the head of a moving meteor, would hardly be able to produce a discernible beat-note. The heterodyne whistle may not therefore be heard under the circumstances. This is indeed a strong argument against the view that the observed whistles are due to Döppler effect. For a definite assertion on the point, it is however necessary to calculate, if possible, the amount of scattered radiation from the ionized mass of air which is formed at the head of a shooting star, relative to the radiation scattered from the ionosphere.

SIMILARITY OF THE OBSERVED WHISTLES WITH SOME AUDIO-FREQUENCY MUSICAL ATMOSPHERICS

It has been known for many years now that when a telephone or any audio-frequency amplifying device is placed directly in series with a large aerial, disturbances of a musical nature can be heard. It was Barkhausen (1919) who first described observations made during the last world war on whistling tones in a low frequency amplifier, the frequency of which decreased very rapidly from a high to a low value. Later T. L. Eckersley (1926-1927 and 1928) made some investigations on these musical atmospherics. He divided them into two classes, the short and the long whistlers. Both these whistlers were characterised by the fact that the disturbance started with a high pitch which dropped rapidly in the first class and slowly in the second class to a note of low pitch. The duration of a short whistler was sometimes one-fifth of a second. The long whistler was as long as 3 seconds.

In Burton and Boardman's (1933) investigations on audio-frequency atmospherics there were two distinct varieties of musical atmospherics which were given the onomatopoeic names, 'tweek' and 'swish.' A tweek consisted of a damped oscillation trailing a static impulse. It started above 2000 cycles and reduced very rapidly towards a lower limiting frequency. Its audible duration was less than one-eighth of a second. The tweeks were not usually observed during the day time, except near sunrise and sunset. Some data of tweek counts showed a very high value, some minutes before the ground sunrise. It was also found that the tweek number was considerably high during the summer and low during the winter. The swishes were also musical sounds—the frequency sometimes going downward and at other times upward. At times upward and downward progressions were observed simultaneously. The swishes were audible from ½ sec. to 4 sec., covering a frequency range from well below 800 to above 4000 cycles. The swishes appeared to have no connection with the time of the day and the time of the year or with local weather conditions. They were found to persist steadily through the early morning, bridging the transition period when the more common forms of atmospherics were found to fall off rapidly in number and intensity. According to Burton and Boardman, Eckerslsy observed both tweeks and swishes which were not however recognised by him as distinct varieties.

Whatever be the mechanism of production of these whistling tones, the similarity of these whistles with the whistles observed by the A. I. R. investigators is indeed striking. The latter observed a considerably large number of whistles in the early morning. The tweeks were also observed in large number during that period. One wonders whether the two phenomena are fundamentally the same or similar! One suggestion would be that the carrier waves were modulated in some way by the audio-frequency atmospherics which could then be heard in the receiver tuned to the frequency of the carrier waves.

ELECTRICAL IMPULSE PRODUCED BY A METEOR IN THE IONOSPHERE—A TENTATIVE SUGGESTION

Chamanlal and Venkataraman observed coincidence between the appearance of meteors and their observed whistles. If these whistles have any connection with the musical atmospherics, we would expect a correlation between the appearance of meteors and these musical atmospherics. In the few observations made by Burton and Boardman during two nights, there was no such correlation.

It can however be reasonably conjectured that an electrical impulse can be produced by the stoppage of meteors in the ionosphere. In that case, it is possible to explain the so-called Döppler whistles in a manner which is described in the next section. It should be noted that there is no experimental evidence of any electrical impulse being produced by meteors in the upper atmosphere. This suggestion means that there can be a kind of audio-frequency atmospherics which is distinct from the usual variety in its mode of production.

MODULATION OF THE CARRIER WAVES BY THE ELECTRICAL IMPULSE PRODUCED BY A METEOR IN THE IONOSPHERE

Eckersley formulated a theory based on ionospheric dispersion to explain the whistlers. Barkhausen (1930) offered two explanations—one based on multiple reflection between the earth and the ionosphere, and the other somewhat similar to Eckersley's view. Since the dispersive action of the ionosphere has the effect of transmitting different frequencies with different velocities, the various Fourier components into which an impulse is broken up, will then be drawn out into a musical note of rapidly decreasing frequency. The rate of variation with frequency would evidently depend on the amount of dispersion in the ionosphere.

The lowest pitch of the whistle, as shown by Eckersley, would be determined by

$$n_0^2 = \frac{Ne^2}{\pi m}$$

where N = number of electrons per c.c. and e and m are charge and mass of an electron.

Supposing now that an electrical impulse is produced by a meteor when it stops in the ionosphere, it is evident that its various frequency components would reach the lower fringe of the layer, one after another, in quick succession, the short wave-lengths arriving earlier than the long wave-lengths. Thus the carrier waves which are scattered from the ionosphere in the same region would be modulated by the audio-frequency oscillations—the modulation frequency being a function of time. The receiver tuned to the carrier would then reproduce a note of rapidly descending pitch.

If this view is correct, we would also expect audio-frequency atmospherics *unconnected with meteors* to produce a similar modulation of the carrier waves. Tweeks and swishes can therefore be heard by the scattered waves as modulated by these impulses in the manner already described. It is just possible that at least some of the whistles observed at Delhi were of this origin. Tweeks and some of the swishes are known to be of the descending pitch; some swishes again, are of the ascending pitch ; while a few swishes are of a mixed type. It is interesting that all these types of whistles were reported by the A.I.R. investigators. It seems probable that the whistles of the *ascending* pitch observed by these investigators are definitely unconnected with meteors. It is not, however, possible to explain these whistles as due to modulation of the carrier by the electrical impulse produced by the stoppage of meteors in the ionosphere.

It may be argued here that according to the suggested modulation theory, we would expect cross-modulation between different transmitting stations. The possibility of such 'Luxembourg effect' is however very remote. For a particular receiving centre, it is evident that the received sky-waves originally coming from the different transmitters would, in general, be reflected from widely separated regions of the ionosphere.

The dependence of the pitch of the whistle on the frequency of the carrier waves is also to be expected according to the modulation theory. We are concerned here with frequencies higher than the critical frequency for ionospheric reflection. Within this limit, the higher frequencies would penetrate the ionized layer without much refraction, whereas the lower frequencies would do the same suffering a relatively larger refraction. Consequently, corresponding to any angle of incidence, the track of the transmitted wave in the ionosphere would be at a higher level for a carrier wave of higher frequency than the corresponding track for a lower frequency. For the lower strata of the ionized layer, the electron concentration is higher at a higher level and since according to Eckersley, the lowest pitch of the whistle is proportional to the square root of the electron concentration, it is only reasonable to expect that the pitch of the whistle heard with higher frequency would be higher than that obtained with lower frequency carrier.

It should be noted that according to the modulation theory suggested in the paper, there would be side-bands on *both* sides of the carrier, for any electrical impulse modulating the latter. On the other hand, according to Chamanlal and Venkataraman's Döppler effect theory, the observed whistle would be *either* on the higher frequency side of the carrier in the case of an approaching meteor, *or* on the lower frequency side in the case of a receding meteor. For any particular variety of the whistle, it is indeed difficult to test whether or not another side-band exists simultaneously on the other side of the carrier. Taking the frequency of the whistle to be 3 Kc/s or of that order, it appears also doubtful whether such small frequency changes would be discernible in the region of such high frequency, even with a receiver of high selectivity.

SUGGESTIONS OF SOME TEST EXPERIMENTS

(*a*) Along with the receiver, if we have an audio-frequency amplifying system of high gain and high fidelity connected to a large aerial, it would be interesting to see whether both apparatus would give whistles of the same type. According to the suggested modulation theory, when the carrier waves of suitable frequency are sent up, the whistles, when produced, would be heard in both the cases. When the transmitter is off, the receiving set would fail to respond, whereas the audio-frequency amplifier would respond to the audio-frequency atmospherics.

(*b*) The return of the waves, as evidenced visually in the pulse experiments on the oscillographic screen, merely shows an increase in the electron concentration, when a meteor enters the ionosphere. Even when there are no meteors, and there is no indication of any return of the pulse, the audio-frequency amplifying system mentioned in (*a*) would respond to the audio-frequency atmospherics. When the tweeks and swishes are heard, it would be interesting to see whether these are also heard in the radio receiver, when a carrier wave of suitable frequency is sent up.

(*c*) Two receivers, one connected with a loop aerial or any suitable aerial and the other worked with a ground wave suppression aerial system and both tuned to the frequency of the carrier waves can be employed for listening to the whistles. If the whistle is really a heterodyne whistle due to interference between the ground wave and the waves of modified frequency scattered from the ionized mass of air at the head of a meteor, the receiver connected with the ground wave suppression aerial system would give no whistle, even though the meteors are visible. With the other receiver, however, the whistles would be heard. There is of course the possibility of a heterodyne whistle being produced by the interference between the waves scattered from the ionosphere and the waves returned from the head of a meteor, even when the ground waves are absent.

(*d*) Simultaneous appearance of a meteor and a whistle needs however a more convincing evidence.

It is desirable that a fuller investigation on the subject along the lines suggested in this paper should be carried out. If the Döppler effect explanation of the whistles observed by the A.I.R. investigators, is fully substantiated, this would indeed be the *first* evidence of a Döppler change of frequency in the case of wireless waves. Such experimental evidence has, however, been recently obtained by Sir Edward Appleton (1943) in connection with his simple method of demonstrating the circular polarization of ionospherically reflected radio waves. During the sunrise period (or the sunset period), when the height of ionospheric reflection is slowly decreasing (or increasing), the frequency of the ionospherically reflected waves would be slightly higher (or lower) than that of the ground waves due to Döppler effect. The ionospherically reflected waves and the ground waves, when received simultaneously in a loop aerial, would thus produce beats, causing variation in the output from the aerial. Regular fading has actually been observed during the sunrise and sunset periods,

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