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A Technique to Evaluate Meteoric Contribution to lf Propagation*

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A technique to evaluate contribution to the D- and E- layer ionization by low level meteors using an optical, vhf radar, and highly directive lf field strength measurements, combined in a single system is discussed. This reveals a correlation between the radio and optical meteor measurements and change in the ionization. A radio echo usually precedes the optical pulse and both are followed later by an enhanced lf signal. It is concluded that an ionization dumping process occurs as the meteor vaporizes in and above or below the D-and E-layers. This takes place slowly, and the measurement of the delay between the radio located meteor and the enhanced lf signal strength shows good agreement with the vertical and horizontal diffusion rates.

1. Introduction

Studies on meteor influx and interaction with the atmosphere are already very well documented.[1-21] Being extraterrestrial in origin, meteor is one of the most scientifically accessible and valuable objects for study by earth-based observers, and this in turn can reveal more about the nature of the earth's atmosphere. It reveals itself to the observer in many ways, primarily generating intense ionization plumes along its track, apart from a thermally generated acoustic pressure wave and is also accompanied sometimes by a radiation output in the visible region. Depending on its mass, volume, velocity and angle of entry, it generates an ionization and thermal shockfront whose effects on the surrounding atmosphere are considerable.[22,23]

The meteor products contribute to the atmosphere in many ways. The ionization products add to the reflectivity of the ionosphere, particularly at the lower levels. Wherever they are small, the effect may not be significant, but when large they can produce noticeable effects on radio communication particularly at lf (Ref. 22). The meteoric dust also produces significant changes in the dynamics of the weather, contributing nuclei for cloud seeding, though this process is still not completely understood.

This study reports some of the results of an effort initiated to investigate the correlation between various meteor-generated phenomena. The aim was to study the records obtained from the meteor radio location and optical outputs and to extend this to lf radiation paths via the E-layer region at which level meteors mostly ionize. For this purpose a complete experimental system[24-26] was designed, fabricated and measurements carried out at different periods of time but especially during predicted meteoric shower dates. Based upon the results, certain observations have been made regarding the nature of the correlation. In spite of the experimental difficulties encountered, this study reveals and confirms the link that exists between the meteors and lf propagation. Further improvements to the apparatus are being visualized to improve the data collection and analysis. A night airglow system is also being evaluated together with this system to measure any increase in airglow intensities due to specific large meteor ionization inputs.

2. Experimental System

The system as shown in Fig. 1 was constructed for the above purpose and it used three specific methods of studying the meteor. The first was a low power pulsed transmitter-receiver system utilizing pulsed peak output of 1 kW at 60 MHz and serving as a simple radar. This system was pulsed with the help of a stable crystal controlled pulse generator operating at prf ranging between 1-400 Hz. The

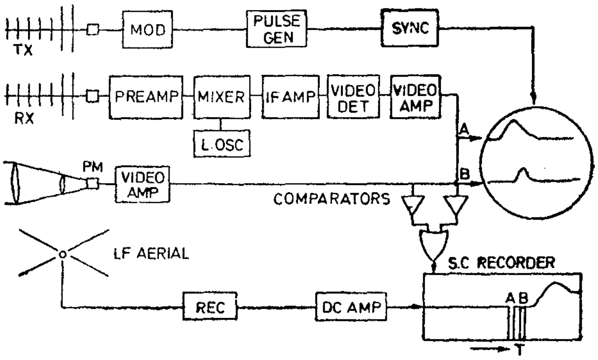

Fig. 1 – Experimental system

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pulses were suitably amplified and modulated on to the transmitting tube which is a vhf triode (type 4 CX 200) whose output is coupled to a directional Yagi array beaming the signal in the direction of an expected meteor. The received signal is picked up by the same aerial system through a duplexor and then fed to a sensitive pre-amplifier. It is later passed on to a modified Philips tuner (ELC 2000 S) which converts it to an lf of 30·7 MHz. A five stage lf amplifier is used to selectively amplify the signal and feed it to a video amplifier detector and finally to one beam of a double beam oscilloscope. The display utilizes a double beam oscilloscope (type OS 769) and normally the lower beam represents the range along the *X*-axis and amplitude of the echo along *Y*-axis. The system is capable of providing more than 140 dB receiving gain.

The second method utilizes an 80 mm aperture wide-angled lens coupled to a photomultiplier (type 931 A). This photomultiplier is coupled to a high gain video amplifier and then to the other beam of the oscilloscope. The meteor track which might appear in the field of view of the optical system usually generates an output which can be displayed along the *Y*-axis of the other beam. This beam is usually triggered by the radio transmitter pulse.

A third method involves the study of lf propagation of signals, obtained from lf beacon stations around the experimental site of ranges exceeding 200 km. As there are many of these, located at all the points of the azimuth, it involved the use of a sensitive lf receiver using integrated circuits and phase locked loops. The detected dc output (which is proportional to the square of the carrier amplitude) was fed to a strip chart recorder to enable correlation to be obtained. An innovation built into this arrangement was the use of two comparators working from the video outputs from systems A and B, to feed a pulse to the strip chart input through an OR gate so that the position in time of the meteor influx could be precisely fixed on the strip chart. In this manner it is possible to find out the approximate delay between the meteor influx, optical location and the change in the lf propagation. The system was run continuously, usually at nighttimes when long range lf circuits were possible. Since, essentially all the three modes of detection were primarily looking at different aspects of the same phenomenon, the system was arranged as shown in Fig. 2. The E-layer reflection point was approximately computed and the antenna angle was calculated to within a degree. The entire system was then aligned in the direction of the beacon station. Many such beacon stations were utilized for these studies but preferentially along the north-south axis and to the north of the site. This was because it was found that signals obtained from stations to the north of the site gave rise to very strong and steady outputs while those to east and west generated very erratic outputs. No explanation has been found for this observation.

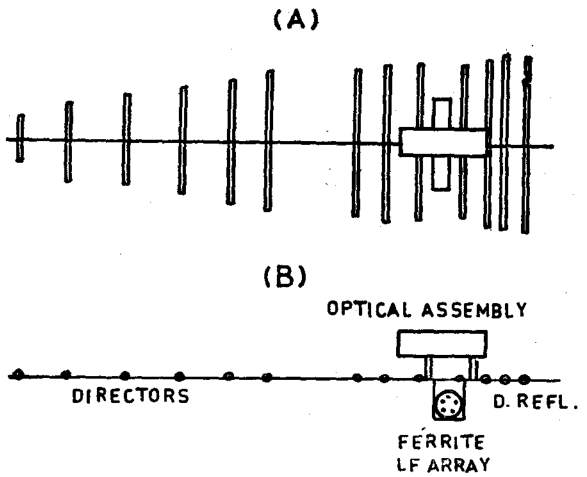

Fig. 2—Yagi antenna system: (A) plan view; and (B) side view

The experimental difficulties were considerable as the photomultiplier system tended to overload due to the ambient light from the city sky. Due to the difficulties of obtaining power, it was not possible to shift the station to a less troublesome site. The vhf radar, built around an old tube, behaved erratically and a certain amount of frequency modulation was also produced.

3. Results

Typical records are shown in Fig. 3 to illustrate some of the observations made here. The observations based on the results are as follows:

(i) At this operating frequency a very large number of radio-echo envelopes were obtained. However, very few (less than 1%) of the echo envelopes were accompanied by a visible output. This confirms the already observed feature of meteor influx, that a high percentage of meteors are of very small size and only a few of them have sizes and masses large enough to generate a strong ionization trail and become visible both by optical and radio means.[14]

(ii) The onset of the radio-echo envelope and the optical signal do not coincide, but the radio-echo envelope usually precedes the optical pulse by as much as 50 msec but at times as low as 1 msec.

(iii) The decay of the radio-echo envelope is very much delayed beyond the optical signal by about as much time as the radio-echo envelope preceded it.

(iv) The optical signal (which has not been correlated for oblique flight paths) shows a behaviour which

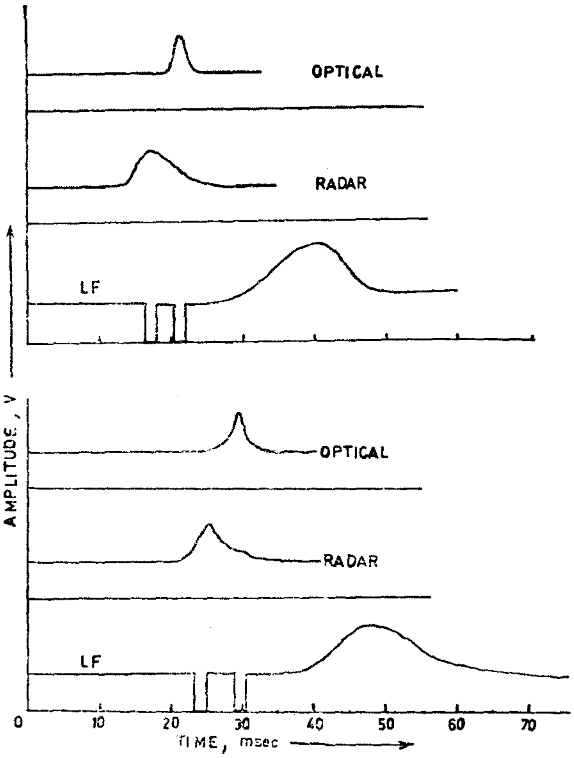

Fig. 3 – Typical records taken during experiment

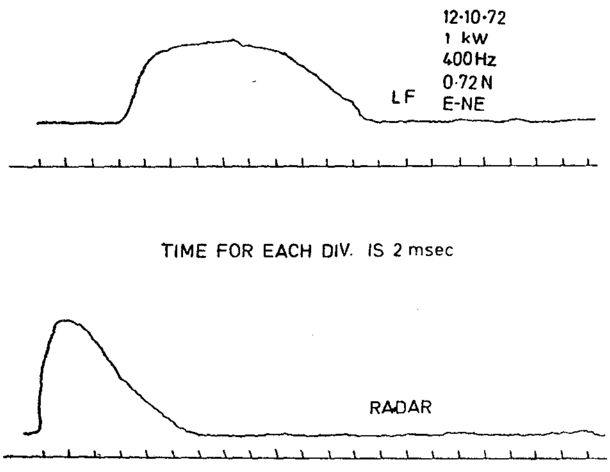

Fig. 4—A typical record of the lf signal accompanied by a vhf radio-echo envelope

is characteristic for most of the meteors observed. It was noticed that in most cases the intensity reached a maximum and then decayed rapidly to zero.

(v) The low frequency propagation is significantly affected during nighttime studies in the frequency range 200-400 kHz. An enhancement is usually noted soon after the meteor influx which is many orders of magnitude higher than the mean signal strength at the input. The correlation that exists between the optical and oblique radio signal envelope is fair enough within the limits of experimental error of the system. In some cases, instead of an enhancement a characteristic dip in the signal strength has been observed. This has occurred only in two cases and more observations will be needed before any explanation can be given for these sporadic results.

(vi) The lf enhancement is always preceded by optical and radio-echo envelopes and sometimes appears many hundreds of milliseconds later and persists for as long a time.

(vii) At times, an enhancement has been observed without any corresponding optical and radio-echo envelopes. This is yet to be explained.

(viii) Fig. 4 shows a typical record in which an enhancement has been noticed for lf signal strength while accompanied by a vhf radio-echo envelope, but no optical input is seen.

4. Discussion

The probability of locating a meteor, capable of activating all the three modes of study along the field of view of the system is extremely low. The observations utilized in arriving at these results, are based upon 22 consistent measurements out of more than 47 records spread over a period of two years from Oct. 1971 to Dec. 1973. These observations do indicate in a broad manner the existence of a possible correlation between the meteor ionization, high altitude diffusion and drift effects and their effect on the lower ionosphere. Three points emerge from the above studies which are as follows:

(i) The radio-echo signal envelope is obviously obtained from the ionization shockfront which precedes the optical signal.

(ii) The optical output is generated due to thermal destruction of the meteoric material and reaches a peak at almost two-thirds of its optical track (this is based upon the records and visual observations). Probably, the increase in atmospheric density along its penetration track causes the meteor to heat up more the deeper it goes, resulting in a gradual increase in optical output.

(iii) The low frequency enhancement is probably brought about by the contribution of the ionization component to the D- and E-layers. This is characteristic of the recorded meteors and no other mechanism of coupling seems to be possible. The meteor ionization does not immediately contribute to these layers, but vertical and horizontal drift processes transfer this ionization to these layers after a slight delay.

A preliminary calculation carried out on meteors whose range could be located accurately and whose height could be triangulated, reveals that there is sufficient support for the above conclusions that ionization from low level meteors is dumped into the

E-layer, as the measured and calculated delays show good agreement.

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