Communications

Analysis of Fading of Signals from Spread-F Irregularities Observed Simultaneously at different Heights

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Simultaneous fading of 2.4 MHz and 5.6 MHz pulsed radio signals from different heights is studied. Analysis of over 150 such records reveals that (i) the characteristic length and the line-of-sight velocity of the irregularities observed on these two frequencies increase with height to a certain extent and thereafter decrease, indicating the presence of vertical wind shear; and (ii) the irregularities observed on 2.4 MHz are larger in size and travel faster than those observed on 5.6 MHz, indicating that probably large size irregularities have greater prevailing drift velocities.

Fading observed in the pulsed radio waves reflected from the ionosphere may be caused by the random motion or the steady drift of the irregularities in the ionosphere or by a combination of both these effects. Several investigators3-6 studied the fading of these signals theoretically and also experimentally. Some interesting features of these signals under spread-F conditions have been studied by Rao and Rao7 and Krishnamurty and Rao.8 In the present study, we have employed the method9 of simultaneous recording of fading of signals transmitted vertically upwards and received after reflection from irregularities at different but specific heights.

The frequencies employed in our experiment are 5.6 and 2.4 MHz. The CRO is set to A, scope display and the signal is fed to the X-plates of the CRO, to which plates the time-base is applied. The time-base intensity is controlled to have only the height markers visible. As the signal is applied to the X-plates, the portion of the signal corresponding to each height marker moves the height marker to and fro along the X-direction as per the amplitude strength. When spread-F echoes are present as continuous or separate patches, the height range of the diffuse echoes is determined by noting the height range of extreme echoes whose amplitude is one-tenth of that of the strongest echo in the patch, thus avoiding any possible dependence of spread-F echorange on the gain setting and the power of the transmitter. Under this set condition, the movement of the 50-km height markers is recorded with an accuracy of ±5 km simultaneously by the vertical run of the film.

Over 150 such records are obtained with a minimum of three heights up to a maximum of six heights, depending upon the height and the extent of spread-F occurrence during post-sunset and pre-midnight period. One typical record is shown in Fig. 1, which is a trace of the original record after enlargement.

In the following analysis, two assumptions are made, viz. (i) the fading is due to horizontal movement of the irregularities and (ii) the temporal and spatial auto-correlation functions are similar.

The line-of-sight velocity $V$ is calculated by drawing the auto-correlation and noting the time $\tau$, for which the auto-correlation function falls to $e^{-1}$. Thus,

$$V = \frac{\lambda}{4\pi\tau} \quad \text{...(1)}$$

where $\lambda$ is the operating wavelength.

In case where fading is due to horizontal motion of the irregularities, Briggs10 showed a relation between the frequency $N$ of fading, the semi-angle $\theta$ of the cone of the scattered waves, the drift velocity $V_a$ and the operating wavelength $\lambda$ to be

$$\theta = \sin^{-1} \left(\frac{N\lambda}{2V_a}\right) \quad \text{...(2)}$$

When the temporal and spatial auto-correlation functions are assumed to be similar, Khastigar and Singh12 showed that

$$V_a = 14 V$$

The characteristic length $L$, the least distance for which fading details of a reflected wave are similar, is given by the equation13

**Fig. 1 — Typical record showing the fading at different heights**
\[ L = \frac{V_\alpha}{2N} \quad \text{...(3)} \]

The semi-cone angle refers to the scattered waves received from the ionosphere in different directions. This angle is found either to increase or to decrease with the height range in the present investigation. If the semi-cone angle were to remain constant with the increase of height, the characteristic length of the irregularities should increase with height. Increase of cone angle with height range could be caused either by the returning signals coming from layer heights or by the signals coming from points in the same horizontal level but from larger ranges. On the other hand, decrease of \( \theta \) with height range could only be caused by the signals coming from layer heights. Hence, the characteristic length and the line-of-sight velocity are studied only for the cases of \( \theta \) decreasing with height.

Using Eqs. (1)-(3) the fading characteristics, namely, \( V, \theta \) and \( L \) are calculated for each height and their behaviour with height are studied.

As an example of the several cases studied, the variations of \( L \) and \( V \) with virtual heights for the two operating frequencies 2.4 MHz and 5.6 MHz observed simultaneously (within an interval of 3 min) are shown in Fig. 2. It may be seen from Fig. 2 that both \( L \) and \( V \) increase with virtual height on 5.6 MHz, whereas they decrease to a certain height and later decrease for larger heights. As the true heights are different for the same virtual height observed on these two frequencies, the two observations may be taken as consistent indicating that both \( L \) and \( V \) increase first with height and then decrease at greater heights. As \( V \) indicates the vertical velocity, the picture is consistent with the presence of vertical wind shear.

It is also seen that the irregularities observed on 2.4 MHz are larger in size and travel faster than those observed for 5.6 MHz, indicating that probably large size irregularities have larger prevailing drift velocity. This may be due to the fact that the smaller size irregularities may have more random velocities and less prevailing drift velocities than those of larger size irregularities, the total energy of motion being the same for both.

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References

TEC from Group Delay Measurements near Magnetic Equator (Ootacamund)

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The results of total electron content (TEC), \( N_T \), derived from the group delay measurements made at Ootacamund during ATS-6 phase-II are presented. These results are also compared with the results of ionospheric TEC derived from the Faraday rotation measurements made simultaneously at the same station. The nighttime electron content values obtained from group delay measurements are found to be much higher than the corresponding values obtained from Faraday rotation measurements. The daytime values of \( N_T \) are also found to be higher on disturbed days than on quiet days.

Electron content measurements can be made using the Faraday rotation technique or the group

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