Recovery Effect in the Field Intensity of Atmospherics

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Integrated field intensity of atmospherics at 10, 20 and 30 kHz observed over Calcutta for a 3-yr period is analyzed to explore the recovery effect. The results exhibit a significant seasonal change in the amplitude of the recovery effect as well as the time difference between the occurrences of the peak value of this effect and the start of the sunrise fall. The duration of the effect and its frequency spectrum are also considered. The results are interpreted by considering the existing knowledge of source activity and propagation effect.

The pressing need for worldwide frequency standard and long range navigational aids initiated interest in the study of propagation of VLF signals. However, the major limitation for a proper VLF communication link is the atmospheric radio noise background in this frequency band. In fact, the VLF atmospherics, which impose a fundamental limitation to the efficiency of a link, are the VLF radio effects due to the presence of atmospheric radio noise background in the VLF band. These effects, which are useful for the future designs of radio communication systems. Marked changes in the level of integrated field intensity of atmospherics (IFIA) occur at a place during the early morning hours. After the sunrise, fall in the record of IFIA, a single peak referred to as recovery effect is often noted. Although the effects at high and medium frequencies are satisfactorily explained in terms of the changes in a single ionospherically reflected ray, the VLF effect is somewhat obscured. Lack of data of VLF atmospherics in the eastern part of India prompted us to make a detailed study of its characteristics in order to meet the needs of the communication service. The present study has, therefore, been made critically with a view to exploring the seasonal variations and the frequency spectrum of the recovery effect.

In this study the integrated field intensity of atmospherics at 10, 20 and 30 kHz in the VLF band over Calcutta (lat. 22°34′N; long. 88°24′E) for a period of 3 yr (Oct. 1976 to Sep. 1979) have been analyzed statistically. It has been observed that in the early morning hours the local meteorological activity is rather weak making the effect clearly discernible on most of the days.

Typical records of the recovery effect of IFIA after its sunrise fall are presented in Fig. 1. The upper one represents the general pattern of the diurnal variation of IFIA at 10 kHz. The samples on the lower left, middle and the right have been chosen to show the recovery effect at 10, 20 and 30 kHz on the same date.

It is seen that the effect starts simultaneously at all the three frequencies but with different magnitudes. During the period Oct. 1976 to Sep. 1979 altogether 798 recovery effects were noticed. Each was similar to any one of those reproduced in Fig. 1.

In this analysis a mean curve has been drawn through the initial level of the sunrise effect (A) of IFIA and points B and D for each of the days having the recovery effect in the record. The nearly horizontal line thus running between B and D forms the base level and is used to calculate the amplitude of recovery effect at 10, 20 and 30 kHz is presented in Table 1.

The frequency dependence of the effect in the amplitude is clearly noticeable (Table 1), showing maximum at 10 kHz and least at 30 kHz.

In Fig. 3 the average monthly variation of the time difference between the occurrence of recovery effect and the starting time of the sunrise effect (A) is plotted. The time difference exhibits a remarkable and systematic seasonal variation showing a pronounced minimum in December. Fig. 3 also shows a plot of the mean duration of the recovery effect. It is seen that the curve is almost a mirror image of the former one, with a minimum value during the cloudy monsoon season and a maximum during the clear months.
Fig. 1—Typical records of the field intensity of atmospherics (A—sunrise effect; B—first minimum; C—recovery effect; D—morning minimum; E—afternoon maximum; F—late minimum and G—night maximum)

Fig. 2—Curves showing the average monthly values of the recovery effect, i.e. \( (C_{\text{peak}} - \text{base level}) \) and those of the difference in amplitudes between the initial level at the start of the sunrise effect (A) and the morning minimum (D)

Fig. 3—Curves showing the average monthly variation of the time difference between \( C_{\text{peak}} \) and starting time of the sunrise effect (A) (The mean duration of the recovery effect has also been superimposed.)

Table 1—Mean Amplitude of \( (C_{\text{peak}} - \text{base level}) \) and \( (A - D) \) at 10, 20 and 30 kHz

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>Mean amplitude in dB (above 1 nV m) of</th>
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<tbody>
<tr>
<td></td>
<td>( (C_{\text{peak}} - \text{base level}) )</td>
</tr>
<tr>
<td>10</td>
<td>12.0</td>
</tr>
<tr>
<td>20</td>
<td>10.1</td>
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<tr>
<td>30</td>
<td>8.2</td>
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To explain the observed diminution in the intensity at sunrise one may consider that with the advance of the day more and more distant sources of atmospherics are switched off. After a certain time, sources which are still effective lie within a close range of the observatory. Reception from such nearer sources is due to the E-region and is absorbed by the D-region, which is under the control of solar ultraviolet radiation. The recovery effect appears to be due to a transient improvement of propagation from such nearer sources for which the reflection from E-region is still effective. Solar rays grazing the ozonosphere on striking the night E-layer, in fact, increase its ionization causing the improvement by reducing the deviative absorption. With the advance of time the solar rays reach the D-region producing ionization there. As a result the non-derivative absorption of the ray in the D-region starts and goes on increasing till the absorption becomes predominant. The D-region, at present, is believed to consist of two layers. The ionization of the lower of the two layers, the so called C-layer remains constant throughout the day.\(^3\)\(^4\). It appears, therefore, that in daytime and at short distances where the C-layer is penetrable, the ionization only above the C-layer contributes towards the variation of the field intensity of VLF atmospherics in addition to the atmospherics arising from the source.

The observed frequency dependence may be suitably explained from a consideration of the spectrum of the sources as well as the frequency dependence of the radiowave propagation. An analysis of a waveform\(^5\)\(^6\) has indicated that the discharges in the final 1 msec of the leader has a greater contribution than the return strokes at frequencies above 30 kHz but only about 1\(\%\) of the total energy at 10 kHz. Our results of the frequency dependence of the IFIA also indicate that the magnitudes for both (\(C_{\text{peak}}\) − base level) or (A − D) are maximum at 10 kHz and decrease with increasing frequency.

The above studies on VLF atmospherics indicate that the recovery effect is due to a single ray reflected from the ionosphere from sources for which the C-layer is just penetrable. Such studies if supplemented by observations of VLF signals transmitted from similar ranges might prove to be useful providing us with a deeper insight into the mechanism of recovery effect as well as that of the complex changes in the lower ionosphere around sunrise.

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References