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Behavior of VLF Atmospherics Around Morning Hours on the Coast of the Bay of Bengal

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Simultaneous observations of VLF atmospherics at 10, 20, and 30 kHz recorded in a low-latitude tropical station, Calcutta, on the coast of the Bay of Bengal, exhibit a 'stepped-fall' on the level of atmospherics activity around morning hours. As many as three steps have been observed in some of the cases. The phenomenon has been analyzed in relation to its occurrence, duration, starting time, and magnitude. The seasonal variations and frequency dependence also have been examined. Results reveal that both duration and magnitude of the main step are greater than those for the second and third steps. In general, there are seasonal characteristics. The probable explanation of the phenomenon has been made in terms of the distribution of effective noise sources at such times, mainly at the sea thunderstorms around the observing site.

INTRODUCTION

Continuous recordings of atmospheric radio noise have been made at a lot of stations for studying geophysical aspects, especially from the IGY period. The recordings provide valuable information on the radio noise related to the basic problems of lightning [*Lauter*, 1966; *Nakai*, 1977; *Taylor*, 1978; *Bhattacharya et al.*, 1979]. The intensity of atmospherics at a place under the influence of widely distributed sources and received through ionospheric propagation is known to exhibit some remarkable changes during the early morning hours [*WMO*, 1957]. Still, it seems inadequate to get a complete picture of the atmospheric noise particularly over the seashore stations, like Calcutta, where sources are usually based on topographical sea-land interaction. In fact, the activity and the location of the main storm areas distributed widely depending on the geographical situation of our station seems to be really responsible for the noise level at the measuring site. Observations of VLF atmospherics over the low-latitude station, Calcutta (22°34′N; 88°24′E), situated on the coast of the Bay of Bengal, show amplitude variations in the form of pronounced 'steps' in the early morning hours, hereinafter referred to as 'stepped-fall,' the properties of which have been examined in this paper.

ANALYSES AND RESULTS

The daily records of the integrated field intensity of atmospherics (IFIA) at 10, 20, and 30 kHz for a period of 2 years from October 1976 to September 1978 have been utilized in this analysis. Typical records of the stepped-fall are presented in Figure 1. In the figure the start and the end of a fall is marked by S_n and E_n, respectively, where n denotes the corresponding step. The record on the left side shows the three steps of fall at all the frequencies, while the two other samples, the middle one and the right, have been chosen to show, respectively, the two stepped-fall and one stepped-fall only. The first two steps, referred to as the third step and the second step, are relatively weak and are occasionally split up into substeps, while the last one, called the main step fall, always is clearly visible. The figure also shows that the start, S_n, and end, E_n, time of each of the steps at all the frequencies are equal, but their magnitudes are different.

During the period under consideration the annual occurrences of the number of steps observed at each of the frequencies are shown in Table 1.

The table indicates that the occurrences of the main step at all the three frequencies are equal, but they are different for the second and third steps. The duration of an individual stepped-fall at different frequencies was measured from the records. The monthly average value of the duration for different steps have been calculated, and these are plotted to get the seasonal variation in Figure 2. For the third and second steps, an overall monthly mean value of duration has been obtained by considering the three frequencies together. The figure clearly shows that the durations are higher in the local winter months. The variation is larger for the main step possessing higher duration than for the second or third step. The figure also shows that the monthly deviation from the mean value is greater for the main step, and it is systematic from year to year.

The scatter diagrams of the starting time of different steps and the end of the whole effect for one of the frequencies, namely, 10 kHz, are drawn in Figure 3. The figure reveals a tendency of the scattered points to cluster parallel to the line of ground sunrise. Summarily, the time sequence of the steps in relation to the ground sunrise for all the three frequencies have been shown by the histograms of Figure 4. It is seen that though the number of occurrences of the third and second steps are different at the three frequencies, they are almost similar in shape. For the main step, whose occurrences are equal at all the frequencies, the onset times are distributed on both sides of the local ground sunrise while their ends occur always after the ground sunrise.

The monthly mean values of the amplitude of the fall for the third, second, and main steps at 10, 20, and 30 kHz are then plotted in Figure 5. The figure shows that in summer (March–May) and monsoon (June–September) months when the sources are local and highly active, there is an especially pronounced sunrise effect of considerably higher magnitude of fall than in winter. It also is seen that the fall at 30 kHz is slightly greater than at 10 kHz.

DISCUSSION

Earlier authors explained the so-called 'sunrise effect,' a distinct drop at early morning hours, usually in terms of the changes of ionization in the propagation path, considering the

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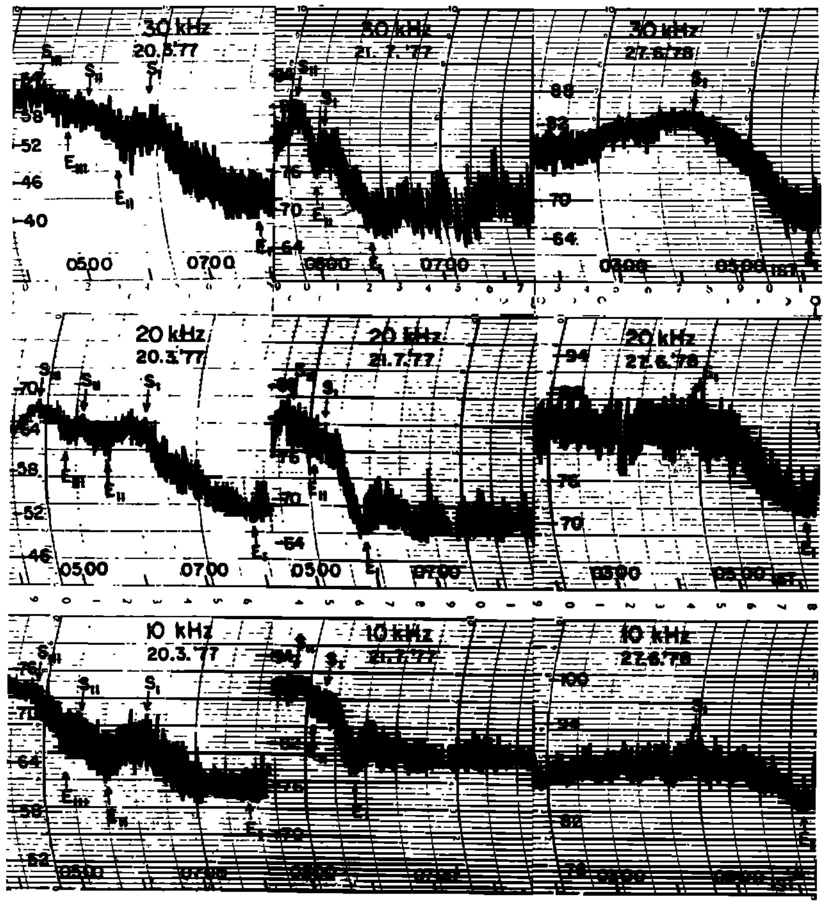

Fig. 1. Typical records of IFIA showing the stepped structure of the sunrise effect at 10, 20, and 30 kHz; ordinates are in decibels above 1 $\mu V/m$.

geometry of the east-west section through the station [*Thomas and Burgess*, 1947]. The attempt to explain in an almost analogous way the stepped structure in the atmospherics level during early morning, as was noted by *Chiplonkar and Marwadi* [1966], on the western coast of India, appears somewhat obscure and not completely justified. We would like to emphasize the distribution of the noise-generating areas around our observing station to explain the expected and the observed features of stepped-fall of atmospherics over Calcutta.

Calcutta is on the border of the tropics and the temperate zone and also is situated at the coast of the Bay of Bengal and thus is well influenced by the meteorological conditions. The location of major atmospheric sources lie in certain well-defined regions of 'definite meteorological disturbances' where thunderstorms are very frequent [*Mason*, 1972]. During nighttime, activity of sea thunderstorms increases vigorously with its peak around midnight, while over land the activity becomes very weak at such times [*Takeuchi and Nagatani*, 1974; *Sarkar and Bhattacharya*, 1979].

VLF propagation can be modeled by using a quasi-ray path concept [*Berry and Christman*, 1965]. It may be assumed that ionospheric reflection occurs for the nighttime ionosphere at 90 km altitudes. A simple calculation using a 30 km ozone screening layer for UV radiation gives the time of ionosphere sunrise at 90 km altitudes to be 31 min prior to ground sunrise. Over a complete year one would expect each of the above-cited source regions to encompass a large geographic area most likely extending 5°–15° longitude. This longitude spread would equate to a variation in onset times dependent upon the number of ionospheric reflections. The 15° upper bound in longitude extent would reduce to 7.5° for a 1 hop path, 3.75° for a 2 hop path, and 2.5° for a 3 hop path. Absorption time onset variations would be 30, 15, and 10 min, respectively.

The most probable thunderstorm centers in and around the Bay of Bengal with their respective distances and directions from Calcutta are listed in Table 2.

Considering the sources at different locations we may expect that the first grouping causing the main step would occur over a time range of 21 min before to 21 min after GSR with

TABLE 1. Annual Occurrences of Third Step, Second Step, and Main Step at 10, 20, and 30 kHz

Annual Period, October–September	10 kHz			20 kHz			30 kHz		
	Third Step	Second Step	Main Step	Third Step	Second Step	Main Step	Third Step	Second Step	Main Step
1976–1977	102	154	310	80	124	310	78	115	310
1977–1978	106	148	316	89	127	316	83	114	316

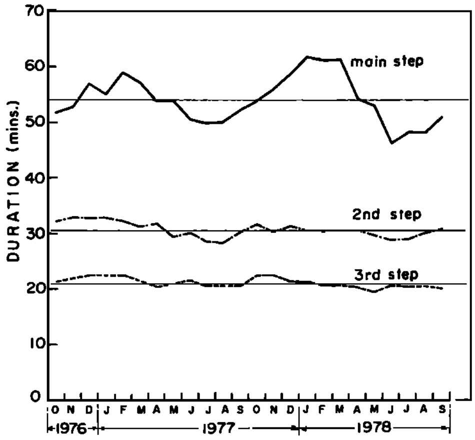

Fig. 2. Seasonal variation of the monthly average durations of the third, second, and main steps.

the spread being from 30 min for Ceylon sources to 10 min for the west sources, such as La Reunion and Zanzibar; the second grouping would occur about 51 min prior to GSR and have an onset spread from 15 to 30 min from the sources of Bangkok, Singapore, and Rangoon; the third grouping would occur from far distance sources approximately 83 min prior to GSR, having a spread of 10 min. An examination of our observed results (Figure 4), in fact, agrees well with that expected from the above consideration of geographically distributed storm centers.

Because the location of the effective sources are distributed at different distances from the recording station, they are expected to switch off one after another by sunlight. Therefore, it appears that the steps are produced by the successive elimination of the effective sources caused by the continually increasing *D* layer absorption of waves on their two-way path through the newly formed part of the *D* layer. Around sunrise the local noise-generating thunderstorm activity surrounding the observation site is minimum; thus a strong propagation loss appears to be the cause of the large magnitude of the mainfall.

The day-to-day occurrence or season-to-season variation of

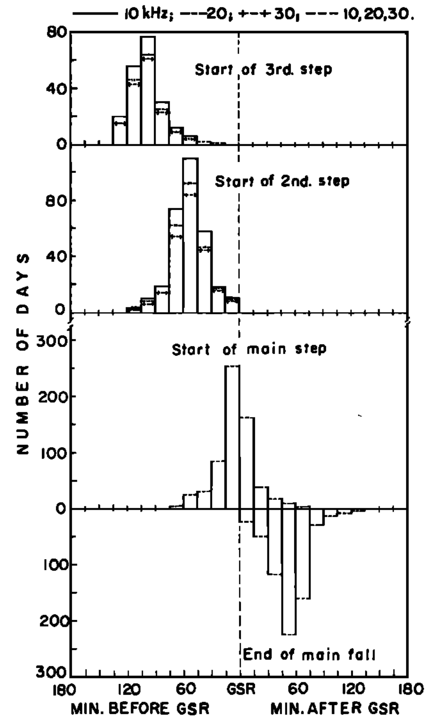

Fig. 4. Histograms of the time difference between local GSR and the start or end of sunrise fall.

the stepped-fall is mostly due to the variation in the number and the location of the sources of atmospherics. In the winter months, as the local sources are weaker, distant sources have a considerable influence on the records. Actually, in this season the strong storm centers have been shifted toward south on the Tropic of Capricorn with a wider lateral extent. Because of this the durations of the fall during the local winter season are higher than in summer when the steps caused by the distant sources tend to be masked by the stronger nearer sources [*Sarkar et al.*, 1980].

From the discussion made above the stepped-fall in VLF atmospherics observed over the tropical station, Calcutta, ap-

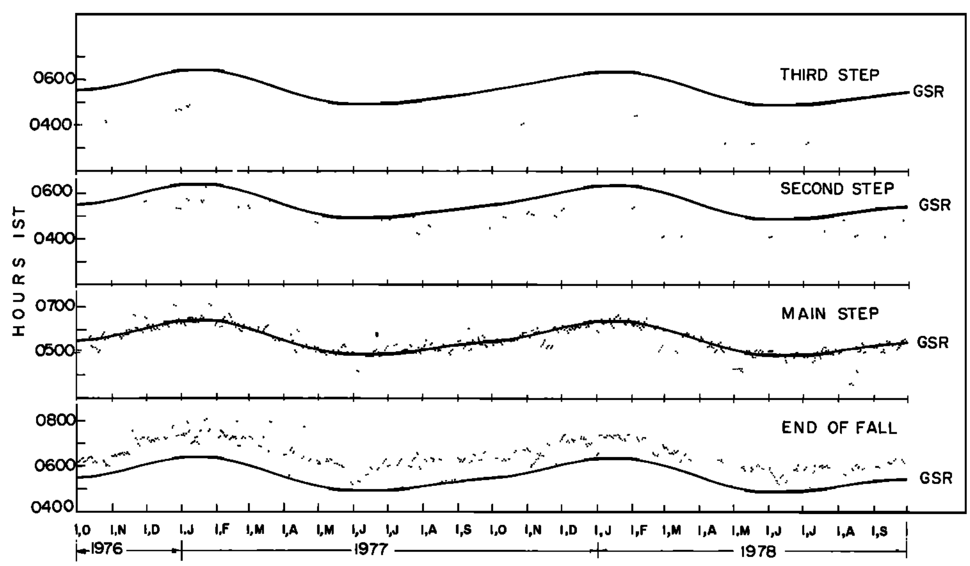

Fig. 3. Scatter diagrams of the time of start of each step and the time of end of the sunrise fall against the day observed at 10 kHz.

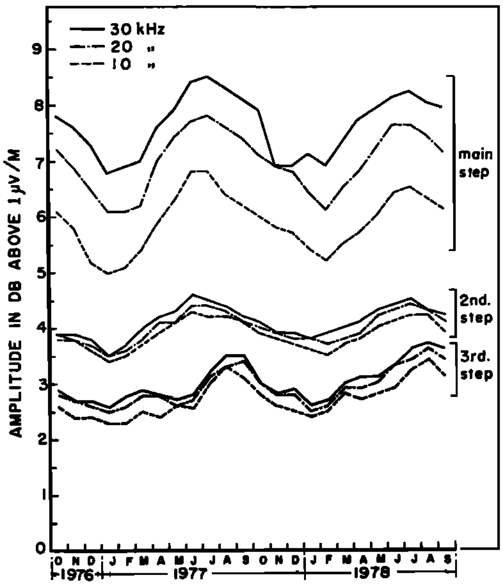

Fig. 5. Seasonal variation of the monthly mean amplitudes of the sunrise fall for each step at 10, 20, and 30 kHz.

pears to be caused by the thunderstorm activity around the observing site. However, it shows on few occasions that if the main step occurs early or late on a given day the other steps also occur, suggesting a probable influence of a single source for the whole phenomena. It will therefore be interesting to analyze the behavior of atmospherics at some other sea shore observatories sufficiently far east or west of Calcutta to examine the agreement with those expected from a concept of single or multiple sources discussed above.

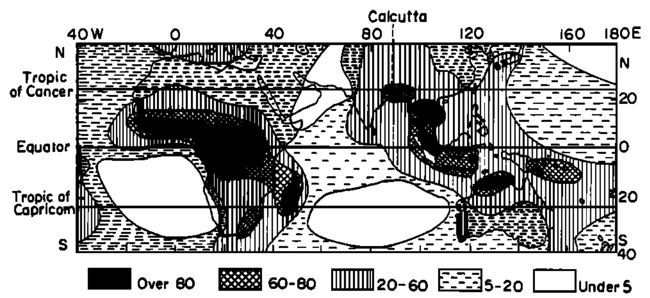

Fig. 6. Map showing annual occurrences of mean thunderstorms around Calcutta [*Nieuwolt*, 1977].

TABLE 2. Thunderstorm Centers In and Around the Bay of Bengal With Respective Distances and Directions From Calcutta

Storm Centers	Propagation Distance, kms	Direction from Calcutta
Rangoon	990	SE
Bangkok	1600	SE
Ceylon	1900	SW
Singapore	2800	SE
Tokyo	4900	NE
La Reunion	6080	W
New Guinea	6200	SE
Zanzibar	6320	SW

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