# A Correlation Study of VLF Sferics with Atmospheric Vertical Electric Field at Kolkata along with its Deviation from Global Character

[1]A. Guha, [1]S. S. De, [2]B. K. De and [1]P. K. Mandal

*[1]Centre of Advanced Study in Radiophysics and Electronics, 1, Girish Vidyaratna Lane, University of Calcutta, Kolkata 700 009, India*
*[2]Department of Physics, Tripura University, Suriyamaninagar, Tripura (W) 799 130, India*
*[1]E-mail: anirban1001@yahoo.com*

## INTRODUCTION

The relationship between atmospheric electric field and global thunderstorm activity has been studied by many workers. In many observations [1-3], the diurnal variation of electric field matches closely with the Carnegie curve which is the generally accepted global unitary variation of electric field on earth with maximum around 1900 UT and minimum around 0400 UT. Most of these observations were made at high latitudes at open oceans or at polar regions to avoid the effects of local generators which may significantly alter the variation of the observed parameter. But some recent studies in tropical region ($\pm 25^0$) [4] show large changes in the diurnal pattern of the electric field in which the 40-day average field curve shows a maximum at 1000 UT and a minimum at 0000 UT with a small secondary peak at 1900 UT.

The results of some more recent observations at the Indian Station Maitri, in Antarctica ($70^0 45' 52''$S, $11^0 44' 3''$ E) [5] are also in contrast to the generally observed unitary diurnal variation, where 20 fair-weather-day field curve shows a maximum at 1300 UT, a secondary maximum at 1900 UT and a minimum at 0100 UT. Since Antarctica is a region free of manmade pollution, the measurements at Maitri are quite significant in understanding the relationship between global thunderstorm activity and atmospheric electricity parameters.

Our measurements at Kolkata also indicate the departure from general picture. We are regularly measuring the atmospheric vertical electric field and VLF Sferics (<30 KHz) at frequencies 1, 3, 5, 7, 9, and 12 KHz. Sferics are electromagnetic pulses generated by lightning strokes which propagate in the atmospheric waveguide between earth's surface and the lower ionosphere and it can reach several thousand kilometers from its source [6]. So thunderstorm activities at large distances can be monitored by studying the intensity of Sferics power. In this paper, we have compared the diurnal variation of vertical electric field with the diurnal variation of amplitude spectrum of Sferics intensity. The possible reason of deviation of recent observations from the general one is also discussed briefly.

## EXPERIMENTAL SETUP

We are taking observations from the roof top at a height of 26 meter from ground. The vertical electric field is measured with an ac field-mill which has an aluminum rotor plate of 12 cm. in diameter. The output from the amplifier is recorded through computer sound card at a sample rate of 44,100 per second. The rms value of the recorded signal is used to find the required electric field from the calibration chart. The field-mill has been calibrated in a vertical field setup between two large aluminum cover plates, electrically isolated at a given potential through a fixed distance between them. The outer shield of the field-mill is grounded properly to ensure protection from possible field distortions. The sensitivity of the field-mill is $(0.33\pm0.03)$ $Vm^{-1}$.

For the observation of power spectrum of VLF Sferics at 1, 3, 5, 7, 9, and 12 KHz, an 8 SWG straight copper wire of 120 meter in horizontal length is used as the antenna. The antenna, which is installed 30 meters above the ground, is sensitive to the vertical electric field component of the electromagnetic noise. The signal processors are tuned to the desired frequencies. The overall Q-factor of the tuning circuit is around 300. The signal from the tuning stage is rectified and fed to a log amplifier. The time constant of the output from the signal processor is 10 seconds. The data are recorded simultaneously at six channels using a 12 bit ADC at a sample rate of 5 per second.

For a period of previous eight months (January 2004 to August 2004), the outputs from these two instruments have been found to be steady and consistent.

## OBSERVATRIONAL RESULTS

We have analyzed the vertical electric field data statistically following Deshpande and Kamra (2001). For the analysis, we have taken 20 fair weather days' data. We define a fair weather day when there is no precipitation at the site, high clouds are less than 3 octas throughout the day and wind speed is less than 10 ms $^{-1}$ . Hourly average values from records of vertical electric field for 20 fair weather days have been used to obtain the histogram (Fig. 1), mean value curve (Fig. 2) and amplitude ratio curve (maximum-minimum/mean) (Fig. 3). Our results also show considerable deviations from those of the Carnegie curve. The two primary maxima at our results are at 0500 UT and 0745 UT with a secondary maximum at 1415 UT respectively and a minimum at 0000 UT (Fig. 1) instead of a single maximum at 1800-1900 UT and a minimum at 0300-0400 UT of Carnegie curve. The mean value in our results (Fig. 2) is 179.3 Vm$^{-1}$ compared to 132 Vm$^{-1}$ in the Carnegie result. The mean amplitude ratio in our result (Fig. 3) is 0.89 with some values as large as 2.06, where the mean amplitude ratio in the Carnegie results is 0.47, with the observed value not exceeding beyond 1.0.

Fig. 4 is shown for comparison of diurnal variation of vertical electric field and average VLF Sferics intensity at Kolkata. The diurnal variation of Sferics intensity averaged for 30 minutes at all frequencies matches closely with the diurnal variation of electric field averaged for 30 minutes except around the local sunrise time 0000 UT (0530 LT).

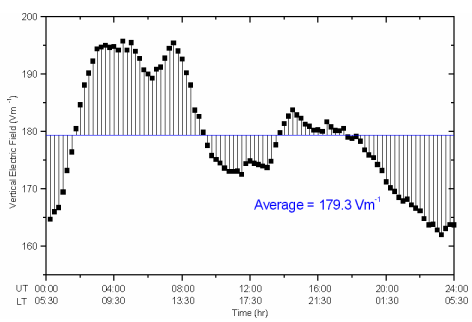


Fig. 1 Histogram Plot of Vertical Electric Field for Seven Months (Feb. 2004 to Aug. 2004)

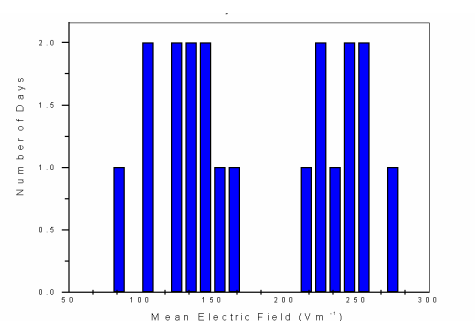


Fig.2 Mean Value vs. Number of Days Plot for the Vertical Electric Field

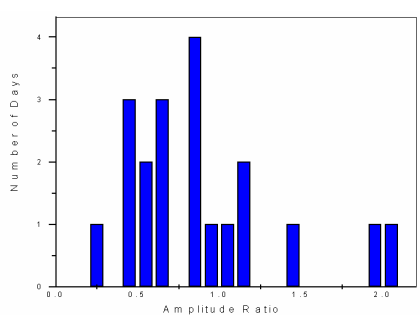


Fig. 3 Amplitude Ratio vs. Number of Days Plot for the Vertical Electric Field

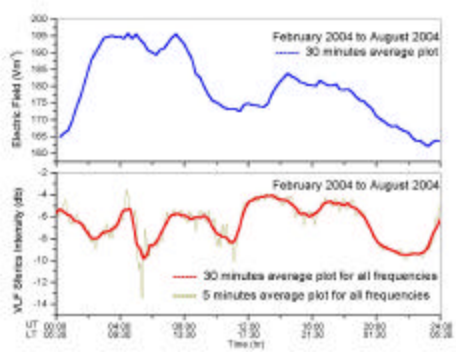


Fig. 4 Comparison between the Diurnal Variation of the Vertical Electric Field and Diurnal Variation of the Average Sferics Intensity for all Frequencies

The result of correlation study of our data is depicted in Fig. 5. The data of two hours have been taken to find out each correlation coefficient "r". From Fig. 6, it is clear that the values of "r" remain positive most of the time except from 0530 hr local time to 0730 hr local time and 1630hr local time to 1830 hr local time which coincide with the sunrise and sunset periods respectively at Kolkata.

## INTERPRETARIONS OF THE OBSERVED RESULTS

Since we are taking measurements from a ground station in tropical region (± $23^0$ ), the local pollution due to manmade activities are expected to influence the diurnal variation of vertical potential gradient due to global and regional thunderstorm activities. Following Ogawa [7], we have taken an hourly average in the calculations that greatly reduced the local fluctuations in the results. Since the relaxation time constant of the fair weather ô = $å_0$/ë is of the order of 20 to 25 minutes, any averaging period above ô would reduce the difference caused by local activities; $å_0$ is the permittivity of the free space and ë is the conductivity of the atmosphere near ground.

We obtained the average value of the vertical electric field at Kolkata to be 179.3 $Vm^{-1}$ which is higher than the values measured by others [1-3]. This is due to the reduction of the value of the conductivity of the air over Kolkata because of high concentration of airborne particles and aitken nuclei. Average concentration of airborne particles is given in table 1, where SPM and RPM concentrations are higher than the normal values (based on the available data of three months during 2004 from West Bengal Pollution Control Board, India).

In our analysis, we averaged our data for 20 fair weather days which greatly nullified the effects of local fluctuations due to man made pollution. The distinguished sunrise effect observed in VLF Sferics, which does not fit with electric field variation, clearly suggests that we are observing the effects of distant thunderstorm activities. If the increase of Sferics intensity were due to increase of locally generated thunderstorms, it should have a clear signature on the vertical electric field variation which is not present in the present case. The earlier works on power spectrum analysis of Sferics from lightning [6] show that the diurnal variation of Sferics rate observed at Roorkee ($29^0 31'$ N, $77^0 35'$ E) and Pretoria ($25^0 26'$ S, $28^0 7'$ E) exhibits similarity with the diurnal variation of vertical electric field at Kew and Potsdam [8]. This establishes the fact that by observing Sferics intensity, the relationship between vertical electric field and thunderstorm activities can be rigorously studied.

The main feature in our observation is the marked variation from Carnegie's oceanic field curve which is a statistical average of about 130 days spread over several years. Similar deviations have been reported by Kamra *et al*. [4], Deshpande and Kamra [5] and Anderson [9]. As pointed out by Takagi [10], columnar resistance, electrical conductivity, seasonal variation of ionospheric horizontal electric field and distance from active thunderstorm areas may also influence the universal vertical electric field on a regional scale. It must be remembered that the generally accepted thunderstorm occurrence frequency curve of Whipple and Scarce [11] with maximum around 1900 UT and minimum around 0400 UT is the average of three major continental thunderstorm activity centers namely Asia and Australia, Africa and Europe, and America (Orville and Henderson, 1986). Moreover each continental average is over 81 years [4]. Recent satellite observations [12] show that there exist a great variability in the longitudinal distribution of thunderstorm activity centre and it also shows seasonal variations. One interesting feature observed from the LIS satellite (http://thunder.nsstc.nasa.gov) lightning distribution is that the thunderstorm activity in the Himalayan region is more prominent than Asia-Australia region. The Asia-Australia has long been thought as one of the largest thunderstorm producing regions but recent record confirms that the thunderstorm from Himalayan regions is also strong enough to be one of the distinguished lightning centres all over the world.

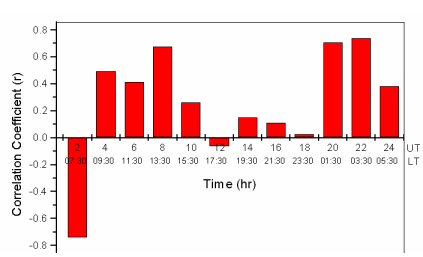


Fig. 5 Correlation Study of VLF Sferics and Vertical Electric Field

We feel that short time seasonal analysis extending not beyond a few months can reveal a lot about the relationship between the thunderstorm activity and atmospheric vertical electric field at a regional scale. The results of many short term analyses can then be integrated to discuss the validity of Wilson's hypothesis for the classical picture of a global electric circuit and to study the dependences of vertical electric field with global thunderstorm activities.

## DISCUSSIONS

In order to find out the degree of correlation between VLF Sferics intensity and vertical electric field, we have statistically analysed our data to find out the correlation coefficient between these two parameters. Positive and negative values of correlation coefficient signify positive and negative correlation between two. The average correlation coefficient for the 24 hr period is 0.264 which indicates the positive correlation in the diurnal variation of Sferics intensity and vertical electric field.

To explore regional thunderstorm activities and their effects on global electric circuit, the data of atmospheric conductivity, Maxwell current and Schumann resonance phenomenon would be helpful along with vertical electric field and VLF Sferics. Simultaneous measurements of the above mentioned parameters at different latitudes would definitely help us understanding global as well as regional thunderstorm activities. It will allow us to reexamine critically certain parameters of atmospheric electricity which have long served as de facto standards of global electric circuit [13].

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