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A Study on the Terminator Times for the Signal of 52.10 Khz Transmitted From Crimrod, UK Received at Kiel Lonwave Monitor, Germany

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***Abstract*- We analysed the signal of 52.10 KHz of 2015, transmitted by a VLF station at Crimond, Fraserburgh, England and received at Kiel Longwave Monitor, Germany for terminator time shifts. We found that average VLF day length was few hours longer than average day length of normal days. Average day length of each month gradually increased from the month of January to June and gradually decreased from the month of June to December. D layer formation time was found to fluctuate from 10 minutes to 40 minutes throughout the year and D Layer Dissipation time was found to fluctuate from 30 minutes to 60 minutes throughout the year.**

***Keywords*- VLF, sunrise/sunset terminator time, D-layer, VLF day, D-layer formation/disappearance time.**

I. INTRODUCTION

Very low frequency/ Low frequency (VLF/LF) is radio wave which frequency ranges from to 3 KHz to 300 KHz and wave length ranges from 1 km to 100 km. VLF/LF waves can be guided by both earth and the ionosphere so signals can be sent [1]. Lightening has radio signature as a result location of lightening strokes can be determined using VLF/LF waves [2, 3]. D region in the ionosphere reflects VLF/LF wave as a result D layer formation time (DLDT) and D layer dissipation time (DLDT) can be determined [4]. Any signal transmitted between satellite and a station in earth must pass through ionosphere [5], and since the ionosphere is rapidly changing [6] the only means we have to monitor the ionosphere is VLF/LF waves.VLF/LF waves can be used in a subterranean mapping [7,8,9] and communication with submarines [10, 11] as VLF/LF waves can penetrate into the ground and sea water [12]. Some studies have hinted at the possibility of using VLF waves for the study of precursors of terrestrial events such as earthquakes and volcanoes [13-17]. The D layer formation time (DLFT) is the time taken for the formation of D region and D layer dissipation time (DLDT) is the time taken for the dissipation of D region. Sunrise termination time (SRTT) is the moment in VLF day at which D layer formation is complete. Sunset termination time (SSTT) is the moment in VLF day at which D region completely dissipates.

II. METHODOLOGY

The data was in ASCII form received at Kiel Longwave Monitor [18], Germany.

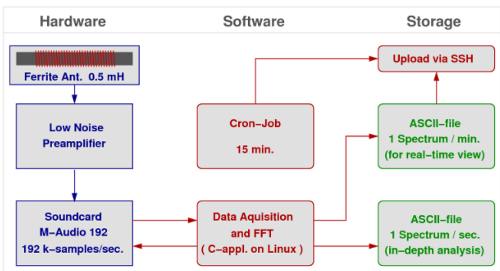

Fig. 1 Block diagram of the Kiel Longwave Monitor

By drawing the graphs of raw data obtained from the system of Kiel Longwave Monitor (Fig. 1), we determined sunrise time, sunset time, SRTT and SSTT. We found DLFT by subtracting sunrise time from SRTT and DLDT by subtracting sunset time from

SSTT. Then, we plotted graph of SRTT, SSTT, DLFT and DLDT of each month. We also drew $\pm 2\sigma$ line in the same graphs to check for anomalies. Sunrise termination time (SRTT) is the moment in VLF day at which D layer formation is complete. Sunset termination time (SSTT) is the moment in VLF day at which D region completely dissipates. VLF day is the period between SRTT and SSTT. The system was shut down in July as a result data of July was missing.

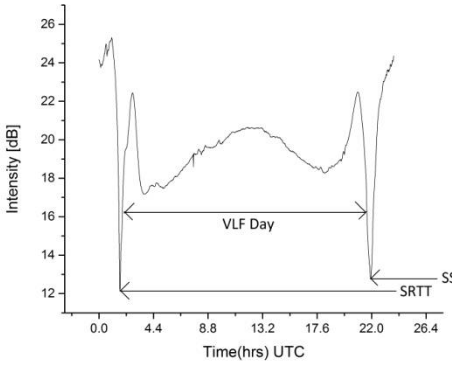

Fig. 2 Sunrise Terminator time (SRTT), sunset terminator time (SSTT) and the length of VLF day

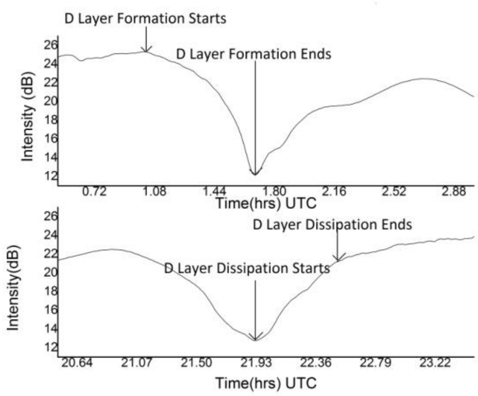

Fig. 3 Zoomedgraph for D layer formation time and D layer dissipation time of averaged graph of June

The two crests shown in the fig 2 is due to destructive interference between the ground wave and the sky wave due to change in path difference between ground wave and sky wave because of D layer formation and D layer dissipation.

III. RESULTS AND DISCUSSIONS

A. Sunrise Termination Time (SRTT)

The general pattern of SRTT throughout the year in each month is show in the fig 4,5 and 6.

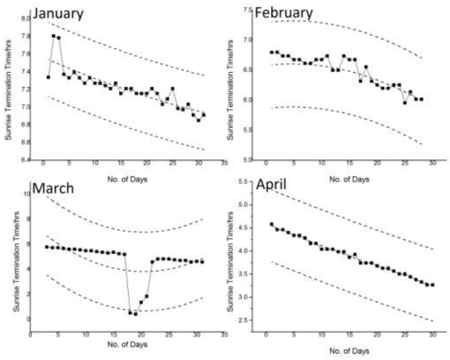

Fig. 4 Graph of Sunrise termination time of January, February, March and April

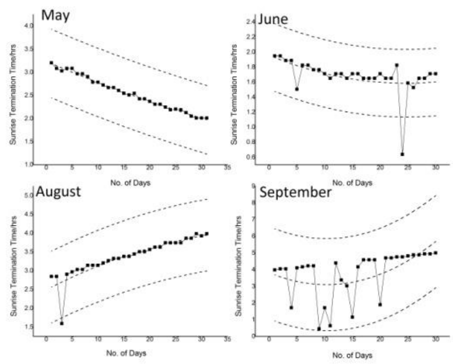

Fig. 5 Graph of Sunrise termination time of the May, June, August and September

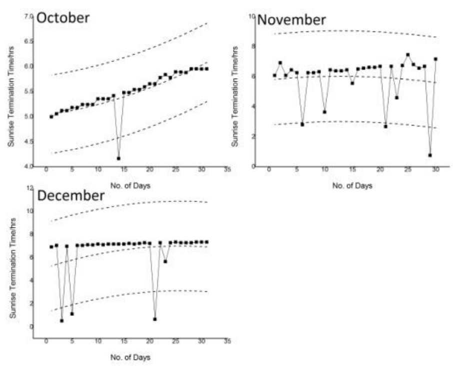

Fig. 6 Graph of Sunrise termination time of October, November and December

In the month of July the system was shut due to which data is not available. In some cases there are anomalies; for example in the month of December. The anomalies might not be due to terrestrial activities like earthquake and volcanoes since the UK is not located on a plate margin and is therefore not currently tectonically active [19].

B. Sunset Termination Time (SSTT)

The general pattern of SSTT throughout the year is shown in the fig 7, 8 and 9.

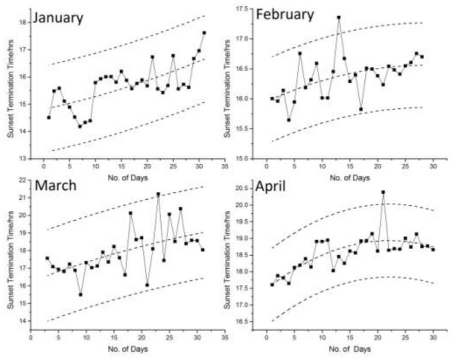

Fig. 7 Graph of Sunset termination time of January, February, March and April

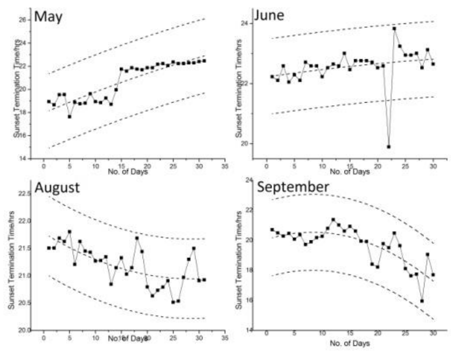

Fig. 8 Graph of Sunset termination time of May, June, August and September

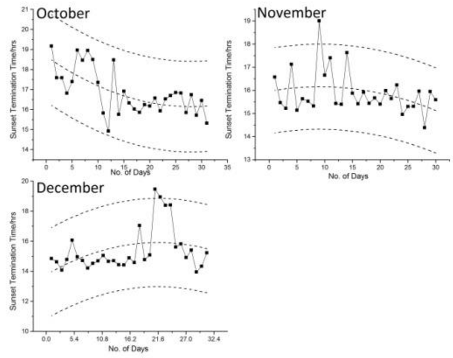

Fig. 9 Sunset termination time of October, November and December

In some months, SSTTs have crossed $\pm 2\sigma$ line, the cause might be CG flashes or other ionospheric disturbances. Since a path of the ground waves from England (the country from which the signal is transmitted) to Germany (the country in which the signal is received) is almost exclusively oceanic, the salinity effect might have altered the ground waved to behave anomalously, which might have in turn affected the sunset terminator time.

C. D layer Formation Time (DLFT)

The general pattern of DLFT throughout the year is shown in fig 10, 11 and 12.

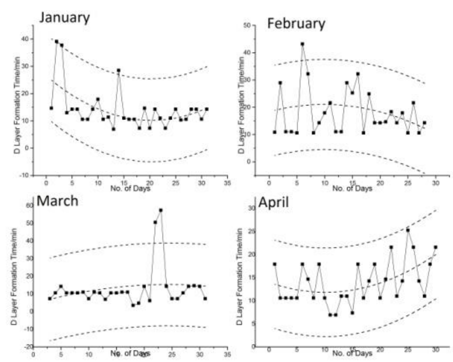

Fig. 10 Graph of D layer formation time of January, February, March and April

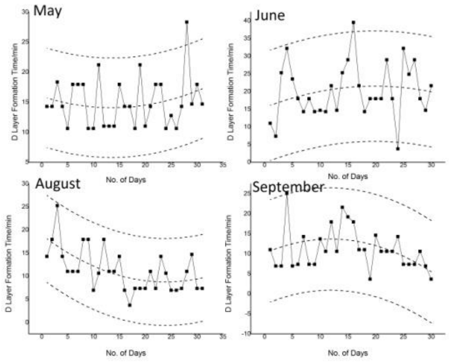

Fig. 11 Graph of D layer formation time of May, June, August and September

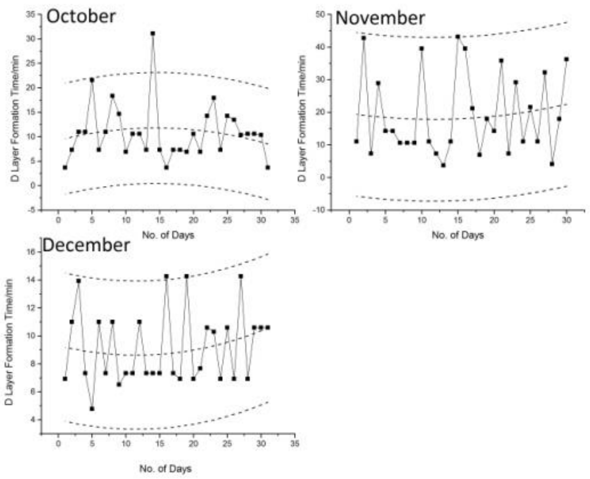

Fig. 12 Graph of D layer formation time of October, November and December

DLFT time reached its lowest in summer and autumn season where it averaged around14 minutes and it's highest in winters-17 minutes.

D. D layer Dissipation Time (DLDT)

The general pattern of DLDT through the year is shown in fig 13, 14 and 15.

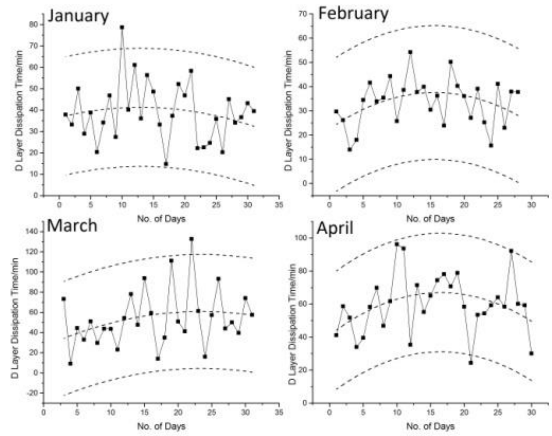

Fig. 13 Graph of D layer dissipation time of January, February, March and April

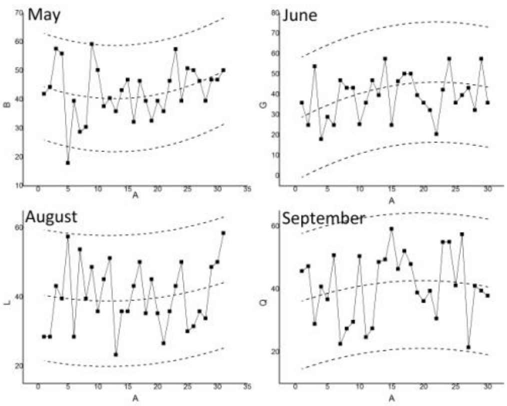

Fig. 14 Graph of D layer dissipation time of May, June, August and September

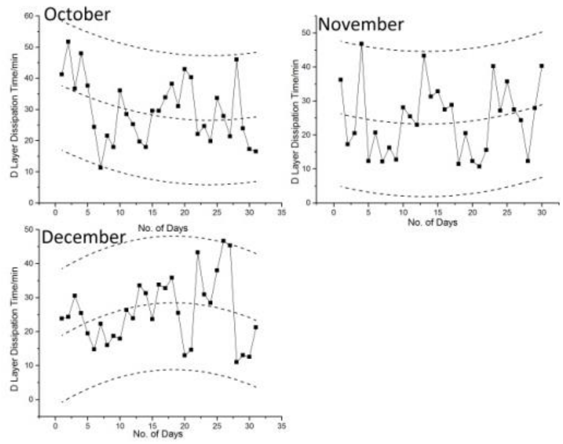

Fig. 15 Graph of D layer dissipation time of October, November and December

Average DLDT reached it's maximum in spring 48 minutes and descended to its lowest in autumn and winter season where it averaged around 33 minutes.

E. VLF day/ Normal day

The general pattern of average VLF day length and average actual day length in each month is shown in fig 16.The graph is symmetrical- does not break its pattern- and retains its symmetry which shows that no terrestrial events have taken place to topple it. The bars for each month in the fig. 16 gradually increase from January to June, and gradually decrease from June to December because days are longer in summer than in winter.

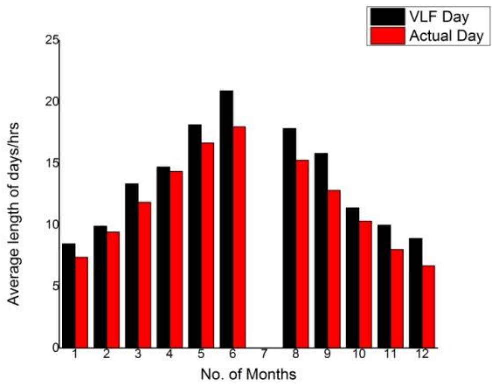

Fig 16: Comparison between VLF day and Actual Day

IV. CONCLUSION

The average DLFT and DLDT is less than 60 minutes throughout the year which is consistent with the theory. Therefore, we can study approximate sunrise time, sunset time, D layer formation, and D layer dissipation time using VLF. In case there are events like earthquake or volcanoes SRTT, SSTT, DLFT and DLDT cross $\pm 2\sigma$ line otherwise they don't. That's why the method of terminator time shift can be used to study anomalies.

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