Twenty Sixth Indian Antarctic Expedition 2006-2008
Ministry of Earth Sciences, Technical Publication No. 24, pp 63-72

Diurnal and Seasonal Variation of 30 MHz Cosmic Radio Signal observed at Maitri, Antarctica

K. Jeeva, Ajay Dhar, Anand K. Singh, A. L. Gudade and B. M. Pathan

Indian Institute of Geomagnetism, New Panvel, Navi Mumbai – 410 218

ABSTRACT

Observation of the cosmic radio noise using riometer is a reliable technique for monitoring the space weather. The cosmic radio noise will undergo absorption with enhancement of the solar originated corpuscular particles and electromagnetic waves into the Earth's atmosphere. The absorption is estimated based on the Quiet Day Curve (QDC) generated periodically from the unperturbed riometer signal. The present work deals about the behaviour of the diurnal and seasonal variation of the riometer signal with respect to the solar time and the influence of sidereal time and seasonal dependency.

Keywords: *Cosmic radio noise, Sidereal time, D-region absorption, Quiet Day Curve*

INTRODUCTION

Relative Ionospheric Opacity meter (Riometer) is a system to receive the cosmic radio noise from galactic radio sources to investigate the ionosphere (*Little,* 1954*; Little and Leinbach* 1958*; Little and Leinbach*, 1959). The stars and galaxies emit a broad spectrum of radio noise, virtually invariant in time and the noise is strong enough to be picked up using sensitive radio receivers, like Riometer. The Riometer usually operates at any fixed frequency between 25 MHz to 50 MHz. It is intended to measure the ionospheric absorption of cosmic radio noise directly above its location. At the ionospheric height nearly 60 to 110 km where significant numbers of free electrons are present, radio signals passing through the ionosphere may suffer losses (or become weaker) in a process called absorption.

The Riometer makes continuous observations of the noise level and thus are used to observe decrease in the noise relative to the quiet day level, when high energy particles precipitate and cause increased ionization

(*Stunning*, 1996; *Barabash et al*., 2002). The advantage of using the cosmic originated radio signal is that it is a continuous transmission available for observation without any artificial technical requirements. The trans-ionospheric propagation of radio signal is expected to have the impacts caused by the change of medium when it passes through the atmosphere with different composition of electron densities and molecule densities. This will cause, when there is no abrupt change in the ionisation, a smooth signal attenuation. On occasions there is sudden enhancement of ionisation, usually caused by the entry of galactic cosmic ray, precipitation of highly energetic electrons and protons into the atmosphere (in polar regions) and solar originated electromagnetic waves like X- rays and U-V rays. The Riometer absorption parameter is extensively used to study the behaviour of galactic originated Radio signal and ionospheric characteristics (*Grote Rebr,* 1956; *M. Fredrich and Shila Kirkwood,* 2000), Solar proton events influence over ionosphere (*Rakesh Parwar,* 2002*; Peter Stunning* 1996*; C.G.M Burn*, 2006*)* to calibrate antennas to test their directivity *(Jacob*, 2007*).* Though the absorption is of prime importance in understanding the space weather input into the Earth's near environment, the Quiet Day Curve (QDC) is also equally important as the absorption is determined from the quiet day curve. There are many techniques to estimate the QDC. Sky noise map (*Cane*, 1978) is one of the methods to determine the QDC. In reality the QDC is determined at regular intervals (weekly) by superimposing diurnal variations of the received signal flux and establishing the high-signal envelope (*Krishnasamy*, 1985). Matrix method (*Dreven*, 2003) is another technique to determine the QDC. QDC is generally generated from the mean unperturbed diurnal variation of the riometer signal over a small period. Thus the quiet time riometer signal is playing major role in the riometer studies. Hence, in the present work, emphasis is given to the quiet day riometer signal to understand the diurnal and seasonal variation of the riometer signal strength with 30 MHz observed at Maitri (70^{o} 30' 45" S 11^{o} 30' 45" E), Antarctica over the period January, 1st to December 31st 2007.

OBSERVATION

Solid state riometer from La Jolla Sciences has been installed at Maitri to monitor the 30 MHz galactic originated radio noise. The data is being sampled at 1 second sampling interval. The Data Acquisition

(DAQ) system generates one minute average file and hourly mean file from the raw data. In the present work we used the hourly mean data sets for analysis. The diurnal variation of the signal strength was plotted for each day and from that a monthly mean curve was obtained. This monthly diurnal curve was compared with the individual day of that particular month. The days which were deviating significantly from the monthly mean curve were removed and the days having good agreement with the monthly mean curves were considered to get the final monthly quiet time curve. The percentage of quiet days in each month is shown in Figure 1. Aiming towards understanding the diurnal characteristics of the quiet day curve, the data sets were averaged into two different groups; one for the complete year (curve with square marks in Figure 2 the) and the other one for the equinox months (solid curve in Figure 2).

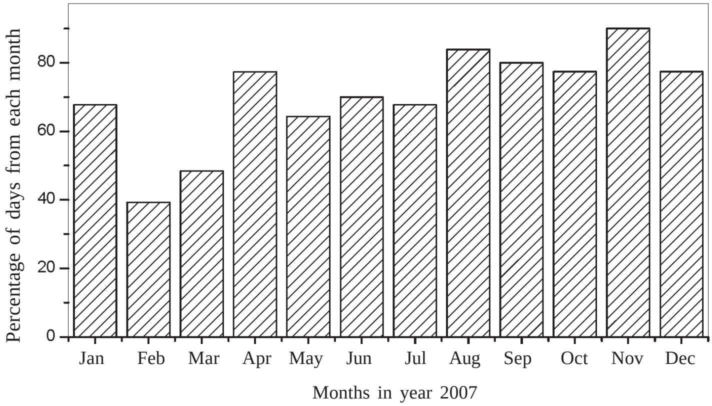

Fig. 1: Percentage of days considered from each month during 2007

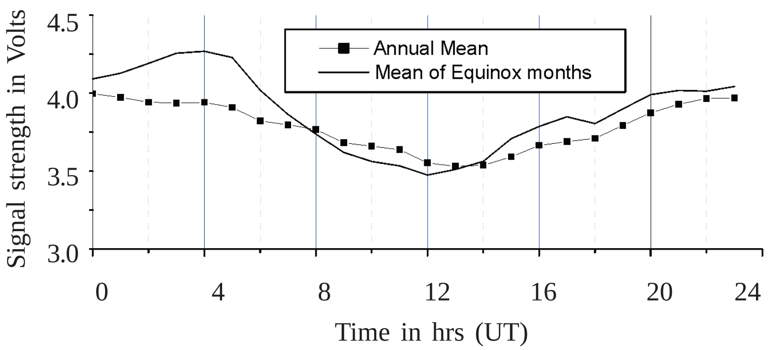

Fig. 2:Annual Mean Diurnal variation of the Signal strength for the year 2007

The annual minimum observed in this analysis was between 1300 hrs and 1500 hrs UT. In another curve, which was pertaining to the equinox months, the minimum was close to 1200 UT. Figure 3 shows the monthly mean quiet day curve for each month. The x-axis denotes time in UT hours and the y-axis, the Riometer signal in volts. The range of y-axis for each month was modified in such a way that the diurnal characteristics are clearly displayed. In the diurnal pattern we focussed our attention on the occurrence of the minimum, because the minimum is the indication of the maximum signal absorption for a given day. The sequence of the monthly mean curve is arranged starting from the month of March.

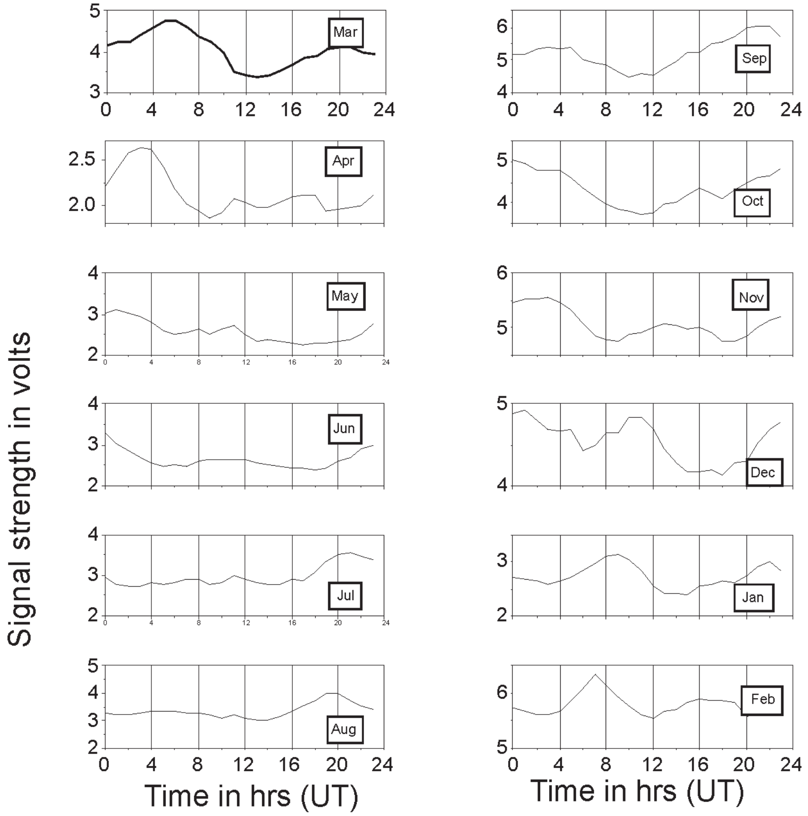

Fig. 3: Seasonal Variation of Riometer signal for the year 2007

The minimum signal occurred at about 1200 UT during the month of March is advanced by about two hours for the month of April. This advancement continues in a systematic manner. The time difference observed in the advancement is given in Table 1. From this table we infer that the time advancement is about 2 hours/month, excluding the abnormality seen during the months of September, October and November, and this works out to be about 4 minutes/day, i.e., for every one day the occurrence of the minimum is advanced by 4 minutes compared to the solar time. To confirm the repeatability of the diurnal curve we compared the data for the months September – December with the same months for the year 2006 (Figure 4). Figure 5 represents the monthly mean of the signal strength for the whole year. There is a biannual oscillation with two prominent peaks at the equinox months and one minimum around the June solstice month (Fig. 4).

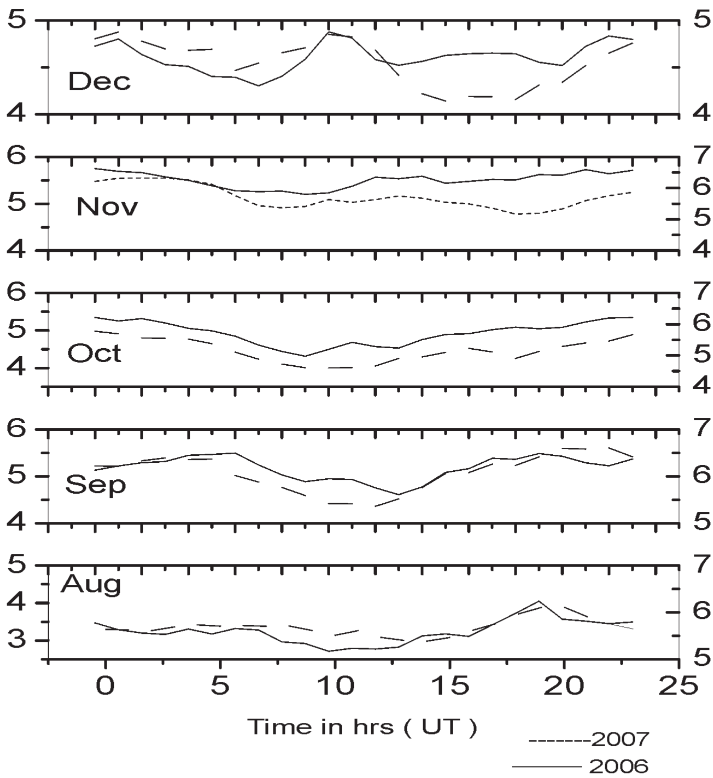

Fig. 4: Comparison of Riometer signal for the period August to December 2006 and 2007

Table 1

Month	Time of Maxima in UT	Difference in hours	Time of Maxima in UT	Difference in hours
March	13.5			
April	8.9	4.6		
May	5.8	3.1		
June	4.9	0.9		
Jul	2.7	2.2		
Aug	0	2.7		
Sep			11.46	1.4
Oct			10.0	2
Nov			8.0	2
Dec			6.0	3
Jan			3.0	1
Feb			2.0	-

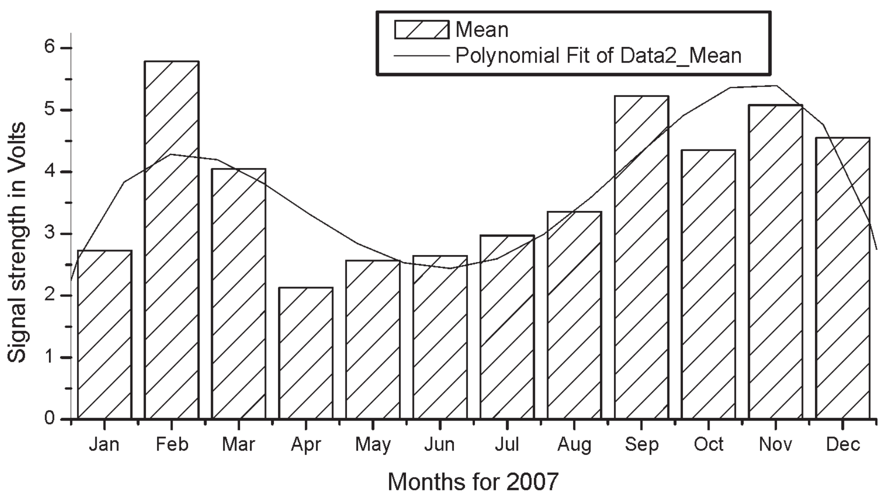

Fig. 5: Monthly mean value of Riometer signal strength for the year 2007

DISCUSSION

We could get considerable number of quiet days as the year 2007 happened to be the solar minimum year and it is expected that the number of quiet days is more than that of solar maximum. The amplitude of a radio wave expanding outward through space varies inversely with distance, weakening with increased distance. The decrease of the strength is called attenuation. The trans ionospheric signal from the galactic source first penetrates the F region followed by E and D region. The interaction of radio signal in F and E regions are predominantly with the free electrons rather than the gas molecules. These free electrons are excited by radio signals and make them to vibrate, and far fewer collisions occur. When the signal propagates in this condition there develops refraction of the signal. Since the frequency is at the fringe of the VHF it is able to penetrate those layers followed by them and they also penetrate the D layer. In D region the gas molecules density is more than the E and F regions. Each time a collision occurs with the gas molecule, a small amount of energy is dissipated and this is manifested as loss in the signal strength which is called absorption. The radio signal absorption is varied in the plasma dominated ionosphere. They may be listed as Quiet day absorption, F region absorption, Sudden Cosmic Noise Absorption (SCNA), Sudden Commencement Absorption (SCA), Polar Cap Absorption (PCA), Auroral Substorm Absorption (ASA), Dayside absorption, Electron Heating Absorption, Poleward Progressing Absorption, and Fluctuating Day Time absorption (FDA). A detailed description of the above listed absorption has been well documented by *Peter Stunning* (1996).

Since we are considering only the quiet day events for analysis it is appropriate to describe the cause for the diurnal pattern under the event of Quiet Day Absorption. The depression of the signal strength appears to be due to the normal solar UV and X-ray emissions an appreciable ionization is generated during daytime at altitudes of 60 and 100 km in the D- and lower E-regions where the electron-neutral collisions are important. The contribution from this ionization to the absorption of cosmic noise varies rather smoothly with solar zenith angle to reach a few tenths of a dB at 30 MHz and at local noon in the summer season (Peter Stunning, 1996). The minimum observed in this analysis is between 1300 and 1500 hrs UT for the annual curve. However the local time for this coordinates is around 1115 UT. There is difference in the expected minimum about a couple of hours. The curve is obtained from the monthly mean quiet curve over the entire season of the year. During this cycle about 3 months there was night hours and about 3 months there was day hours. They were May, June and July and November, December and January, respectively. During this period the ionospheric condition is entirely different and so there is no definite termination of day and night. The diurnal variation for the equinox months clearly displays the expected trend with minimum around local noon.

Sidereal Time Effect over the Signal Strength

The 30 MHz cosmic noise beam is reaching the antenna from a celestial body whose beam is not distributed over the celestial sphere uniformly. Hence the rotation of the Earth with respect to the celestial sphere is expected to make a time difference when Earth‘s rotation is considered. Thus when the Earth takes 24 hours to complete one rotation the celestial sphere takes about 23 hours and 56 minutes, i.e., 4 minutes shorter than the Earth rotation time which is called sidereal time. And thus there develops 4 minutes advancement per day. From our observation it is clearly seen that the received signal is sensitive to the sidereal time rather than the solar time. The minimum of the signal strength for the month of March alone matches with the local noon. This is because in the celestial equatorial coordinate system, the vernal equinox has right ascension and declination equal to zero and so the time difference between the sidereal time and solar time is expected to match with each other during the month of March. Thereafter the difference increases as the right ascension and declination increases gradually.

The monthly mean signal strength display its variability in a systematic manner with the lower signal strength during the June solstice months and maximum around the equinox months (March, April and September, October). As per the explanation given for the diurnal minimum in section 3 the June solstice month is expected to give maximum signal intensity as the observation location experiences darkness for about two months. Whereas we get a minimum signal strength suggesting a severe loss in the signal strength. The probable reason for this could be the distance between the receiver and the transmitter. There exists a relationship in the distance between the source and receiver. It can be explained from the equation given below:

Free space loss = 32.4 + 20xLog F(MHz) + 20xLog R(Km)

(*ECC REPORT 113, May* 2009)

(*F is the RF frequency expressed in MHz, and R is the distance between the transmitting and receiving antennas).*

From this it is possible to conclude that the R could be minimum for equinox period and maximum for solstice period particularly June solstice.

CONCLUSIONS

The diurnal variation of the galactic cosmic radio noise, for a given solar day, undergoes a systematic variation with a minimum at local noon owing to the zenith angle. The advancement in the occurrence of the minimum 2 hours/month clearly indicates that there is super imposed sidereal time effect besides the solar time effect. The annual minimum of the received signal found to be during the months of June and July and maximum during the autumn equinox. This gives a fairly good idea on the distance between the source and the receiver.

ACKNOWLEDGEMENTS

The work is supported by Department of Science & Technology, Government of India. The authors express their gratitude to the Director, Indian Institute of Geomagnetism and the Director, National Centre for Antarctic & Ocean Research for their continued support in conducting the experiment at Maitri, Antarctica. The authors sincerely thank all the team members of the XXVI Indian Scientific Expedition to Antarctica for their support in fulfilling various requirements during the expedition period.

REFERENCES

Barabash V, S. Kirkwood1, and P. B. Chilson., Annales Geophysicae, 20: 539–545, 2002.

C.G.M.Brum, M.A.Abdu, I.S.Batista,A.J.Karrasco, P.M. Terra., Numerical simulation of nighttime electron precipitation in the lower ionosphere over a sub-auroral region. Adv. Space. Res vol 37, 1051-1057, 2006.

Cane, H.V., A 30 MHz Map of the Whole Sky, *Aust. J. Phys.*, Vol. 31, pp. 561–565, 1978.

Drevin, G. R., and P. H. Stoker., Riometer quiet day curves determined by the maximum density method, *Radio Sci.*, *25*(6), 1159–1166, 1990.

Drevin G. R., Determining riometer quiet day curves. Radio Science Vol 38, No 2, 1024, 2003.

Fredrich M. and Shila Kirkwood., The D-region background at High latitudes Adv. Space. Res Vol 25, No1, pp15-23, 2000,

Jacob Lamblin., Radiodetection of astronomical phenomena in the cosmic ray dedicated CODALEMA experiment, 30TH INTERNATIONAL COSMIC RAY CONFERENCE, ICRC 07 Proceedings, pre conference edition. Page 1-30, 2007.

Little C.G., High latitude ionospheric observations using extraterrestrial radio waves. *Proc. IRE 42,* 1700, 1954.

Little C.G., Some measurements of high-latitude ionospheric absorption using extraterrestrial radio waves. *Proc. IRE 46, 33 & 348, 1958.*

Little C.G. and H. Leinbach., The Riometer - A Device for the Continuous Measurement of Ionospheric Absorption. Proc. IRE, vol. 47, pp 315 - 320, February 1959

Krishnaswamy S., D.L. Detrick and T.J. Rosenberg., The inflection point method of determining riometer quiet day curves," Radio Science, vol. 20, no. 1, pp 123-136, January- February 1985.

Peter Stauning., Investigations of ionospheric radio wave absorption processes using imaging riometer techniques. *Journal of Atmospheric and Terrestrial Physics, Vol. 58, No. 6, pp. 753-764, 1996*

Rakesh Panwar, John Caruana, Phil Wilkinson., Application of Riometers in Space Weather. WARS02 Proceedings, Workshop on the Applications of Radio Science) Leura, NSW Australia (20 - 22 February 2002)

Sven G. Bilén, C. Russell Philbrick, Adam C. Escobar, Brian C. Schratz, Eivind V. Thrane, Michael Gausa, Kolbjørn Dahle, Farideh Honary, Steven Marple, Roger Smith, Martin Friedrich, and Thomas Zilaji., NITTANYSAT— A student satellite mission for *d*-region study and calibration of riometers. 18th ESA Symposium on European Rocket and Balloon Programmes and related research vol 647,p407-412, 2007.

IPS Radio and Space Services, Sydney NSW 2000, Australia

Compatibility studies between multiple gigabit wireless systems in frequency range 57-66 GHz and other services and systems (except its in 63-64 GHz), Budapest, September 2007

Revised Hvar, May 2009 Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT),Or Broadcast Engineers Handbook, ABE Elettronica, Oct 1999.