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Climatic variance and its effects on decametric Jovian signal reception at a high altitude station Darjeeling

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In this paper precipitation, firing related to extraterrestrial bodies and other ionospheric effects on decametric Jovian radio signal reception at high altitude has been discussed. Jovian signal is observed at 20.1 MHz in the observatory installed at Darjeeling. As Jovian signal is studied under light of Jupiter-Io coupling, it is found that rainfall, out of different atmospheric components, has highest potential to influence reception of Jovian non-Io emission. The observations show that rainfall density plays crucial role in screening extra-terrestrial signal reception from Earth based observatories. The primitive study also suggests that cumulonimbus cloud may have effect on radio signal reception at high altitude. Some interesting findings regarding climatic influence on Jovian signal reception are reported in this paper.

Keywords: Rainfall, Jupiter-Io coupling; Decametric radio signal, Jovian signal reception, Extra-terrestrial signal reception, Cumulonimbus cloud

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1 Introduction

The magnetosphere of Jupiter and its radio emission exhibits a countable response in the decametric range. The decametric radio waves, generated by interaction between strong electric field by the heated ring of charged particles with intrinsic magnetic field, have frequencies in the range 1 - 40 MHz with a peak around 10 MHz[1]. Although due to opacity of F-layer of Earth's ionosphere, signals below 10 MHz are unable to reach to the earth based telescope and also the intensity of the emissions drops off rapidly at higher frequencies. Consequently, 20 MHz is taken as an optimal frequency for receiving Jovian emissions through ground based observatories[2]. Three specific Jovian longitudinal positioning (known as A-, B-, C-) with respect to observatory site enhances the chances of receiving Jovian burst from earth based telescope[3]. Among four Galilean satellites of Jupiter, Io's positioning is most influential in Jovian signal reception. Severe gravitational force of Jupiter causes shape distortion of Io and several eruption of lava occurs eventually. Io's volcanic activity by tidal heating, which in turn influences probability of detecting radio emissions largely by highly complex electro-dynamical coupling between Jovian magnetosphere with plasma torus and the atmospheres of Io[3-5]. An attempt is made to analyze received signal from both the Sun and the Jupiter by using radio telescope installed for 20.1 MHz, at a high altitude observatory, Darjeeling (latitude 27°3'11.5"N, longitude 88°15'31"E), West Bengal[2].

2 Climatology at the observational site

Different weather components modulate radio wave propagation and therefore, atmosphere acts as a filter for Earth based observatories like the present one at Darjeeling. A considerable amount of noise during sunset or sunrise indicates opacity of ionosphere (Fig. 1). That is why, generally, Jovian observation is made at night, from a few hours after sunset until sunrise while Jupiter is above horizon and Sun is below [Figs 2(a and b)]. Other than diurnal variation, ionospheric structure can be affected by seasonal change, geographic variations, and changes due to solar UV radiation[6,7]. The Sun's eleven-year cycle of activity has a great influence on the ionosphere and especially, solar flares can have a dramatic effect on decametric radio wave propagation by changing charge particle density[8].

In Darjeeling, fog/mist is an almost regular event. Rainfall at Darjeeling also does not limit itself to so called Indian rainy season, from June to August, whereas it pours throughout April to September[10] (Fig. 3). Rainfall affects the reception of an electromagnetic signal in three ways: (i) attenuates the signal; (ii) increases the system noise temperature; and (iii) changes the polarization. Attenuation occurs through poor dielectric precipitation like water droplets that absorb power from the radio wave and dissipates through heat loss or by scattering. The attenuation is determined by the volumetric distribution of the droplets. At frequencies of the order of 10 GHz and above, attenuation, either by absorption or scattering, because of fog with liquid water density denser than 0.5 g m^{-3}, is of minor importance[11].

Observations revealed that the considered bandwidth has perceptible degradation in signal strength and link quality in the presence of fire at GHz frequency range[12]. Intensely ionized and materialized trails of comets or large meteors present in between Jupiter and Earth can scatter the Jovian signal. The strength and duration of comet scatter signals decreases with increasing frequency. At 20.1 MHz frequency, noises were heard several times while comet ISON was in the proximity of Earth[13]. Duration of noise burst due to meteor shower lasted from second to minutes depending upon glancing angle of the meteor shower and it was more audible at night (Fig. 4).

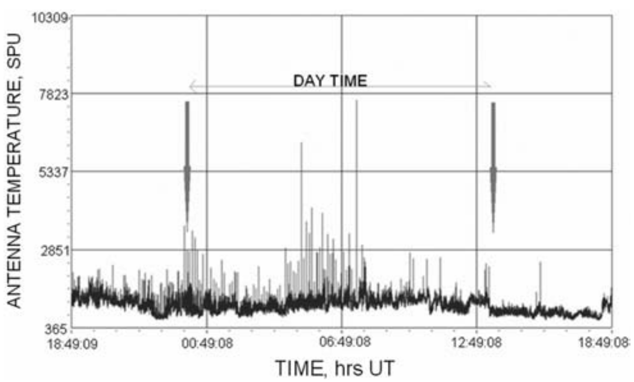

Fig. 1 — Fluctuation in signal profile at dawn and dusk [a demarcation indicates interval when the Sun was above the horizon at the observatory]

3 Observations

The calendar year 2012 has been chosen for presenting the preliminary observation at Darjeeling. Due to high altitude and radio quiet location, the observatory even provided freedom not to use any noise filter. In order to observe and record radio emission, a dual dipole antenna, a coaxial cable, and a receiver (RJ1.1) tuned at 20.1 MHz are used as primary equipments. Two half-wave dipole antennas

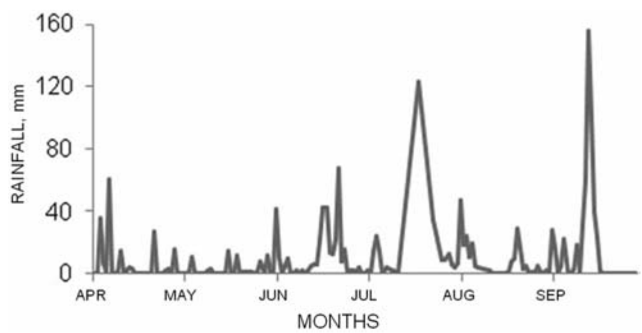

Fig. 3 — Rainfall variation from April to September in 2012 at Darjeeling

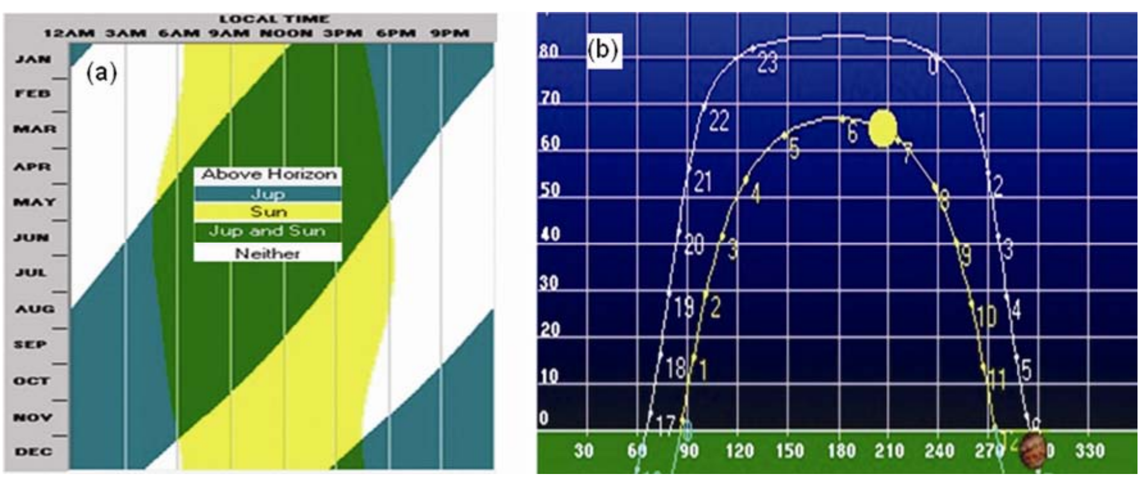

Fig. 2 — Position of Jupiter and Sun over the observatory at Darjeeling during 2012: a) Visibility of Jupiter (Blue-Green) and the Sun (Yellow); b) Altitude and azimuth of Jupiter and Sun on 14 September 2012 at Darjeeling [labels on the arcs are hours in UT] [*Source*: Bhattacharya & Mondal, *Int J Electron Commun Technol* (*India*), 4 (2013) pp 104-108]

placed in a phased array configuration connected by a power combiner and the combiner's output signal is fed into the Radio JOVE receiver for filtration and amplification. The output signal is then sent to a computer where it is stored in ASCII format. Radio-SkyPipe software is used to display the signal intensity with respect to time[14]. A schematic diagram of experimental setup is shown in Fig. 5. Jupiter is observed by 100 samples per millisecond at night when it is brightest source above horizon and the events lasted more than 5 ms are listed and the sample is averaged by 5, *i.e.* effectively data points are saved and displayed in every 0.5 s. The spikes, which sustained for more than 0.5 s and had amplitudes at least 5 times from baseline noise, are treated as Jovian bursts. To filter out true events during noise storm, methodology of nonlinear dynamics approach, like Fast Fourier Transform (FFT) and wavelet analysis[15] is employed. The observation time is subdivided into sub intervals and is Fourier transformed to represent them into normalized spectral distribution function to check its non-stationary nature. FFT projects signal to orthogonal basis for decomposition and reconstruction. In wavelet analysis, characteristics of positive wavelet coefficients indicate radio bursts distinguishably when signal is decomposed into two bi-orthogonal bases. Many regular bursts are eliminated as radio-frequency interference (RFI) from shortwave radio channel used for broadcast. To eliminate interference from brightest extraterrestrial radio sources, the present Jovian observation is limited to night time when Sun is below the horizon and Jupiter is above as shown in a typical day transit of Sun and Jupiter [Fig. 2(b)]. For some period in June and July, Jupiter and Sun remains above the horizon at almost same time [Fig. 2(a)], so this period of observation does not help to draw any reference without normalization.

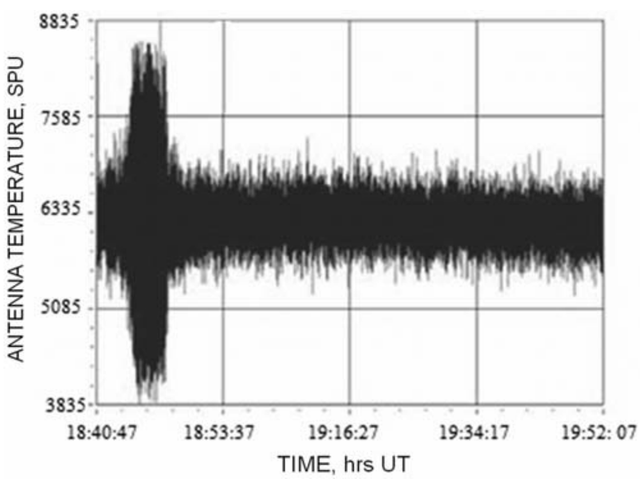

Fig. 4 — Effect of Comet ISON on Jovian Signal as observed on 28 November 2013 at 18:44 hrs UT [*Source*: Bhattacharya & Raha, *Int J Electron Commun Technol* (*India*), 5 (2014) pp 37-40]

4 Results and Discussion

Tropospheric scattering occurs when path of radio signals are altered by slight changes in the lower atmospheric refractive index caused by air turbulence and small changes in temperature and barometric pressure[16]. At high altitude, like Darjeeling (altitude 6545 ft), the temperature, pressure and particle density are found to decrease up to some significant values but tropospheric scattering is expected less at the present observed frequency. Though attenuation of 20 MHz signal by rain is very less but the present observation shows that only during heavy rainfall signal, reception quality can degrade slightly; whereas medium rainfall does not screen antenna at all (Fig. 6).

In Fig. 6, vertical axis is defined as relative count of rainfall quantity and number of received Jovian bursts for that day. It may be pointed out that the present study does not intend to measure exact amount of attenuation but look for any qualitative effect of attenuation on signal quality.

Though drop size distribution of rainfall[17] shows that it is not adequate for any attenuation in HF (high frequency, 3–30 MHz). Rainfall is measured by Automated Weather Station (AWS), Indian

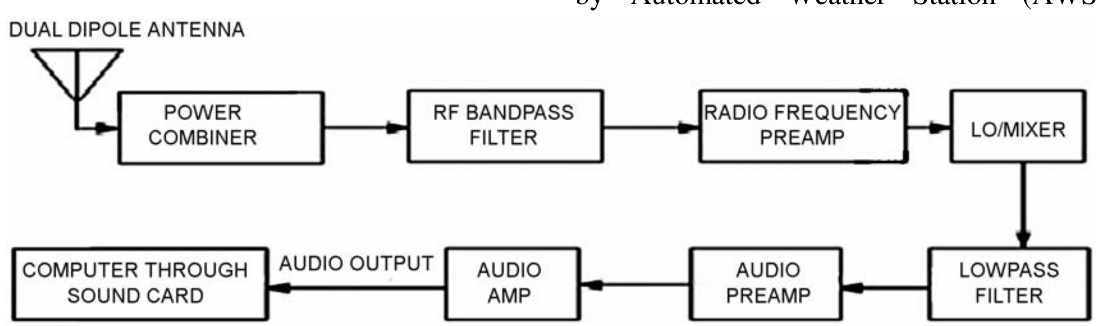

Fig. 5 — Block diagram of the experimental setup [*Source*: Bhattacharya *et al.*, *Int J Engn Sci Technol* (*India*), 4 (2012) pp 3029-3038]

Meteorological Department using rainfall sensor (tipping bucket) placed under open sky at Darjeeling, within 600 m areal distance from our observatory. This sensor has 2% accuracy at 240 mm h^{-1} rainfall for recording with 0.5 mm resolution and rainfall data is grouped by hour to integrate for a day. At the time of analysis, care is taken for difference of burst reception probability between Io phase and the central meridian longitude (CML). In general, probability of Jovian burst reception in Io phase is almost double to any CML region contribution[9] but here it is shown that probability of Jovian burst reception is not only governed by relative position of Jupiter-Io-Earth but terrestrial atmospherics have influence on it.

Since time of observation for Io phase is very less than general CML region contribution during the observation time at night, hence, in order to compare them, burst number is normalized on the basis of average number of bursts listened per hour. It is shown for many favorable Io positions *w.r.t.* superior geocentric conjunction (SGC), counting of significant burst was very less due to heavy rainfall (Fig. 7). For a clear day on an average, 2 to 6 Io influenced Jovian bursts per hour are received but the number falls dramatically when heavy rainfall with dense cloudy environment occurs. It shows that for light and medium shower, there are possibilities of Io Jovian burst reception but for non-Io or CML regions, number of Jovian bursts are rare to detect during medium shower (Fig. 8). Jovian burst mainly originates from CML region but there are few days when Io also adds up to Jovian storm for a limited time slot within the period of A-, B- or C- CML position. For those lucky days, it is observed that the ratio between Io and CML influenced Jovian bursts received at the observatory is 2:1 but on heavy rainy day, it rises up to 6:1. Figure 9 qualitatively shows that when rainfall becomes heavier, probability of receiving CML influenced Jovian burst decreases with respect to Io influenced ones. This higher possibility of receiving Io influenced Jovian burst may be due to large amount of heavy charged particle doping from Io's volcanic atmosphere to Jupiter's magnetosphere, which automatically

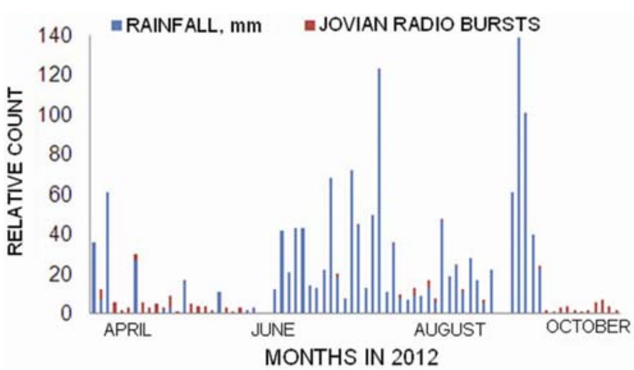

Fig. 6 — Comparative chart for rainfall and number of observed Jovian radio bursts [horizontal axis is not regular as only those days are listed when Jovian signal reception was possible]

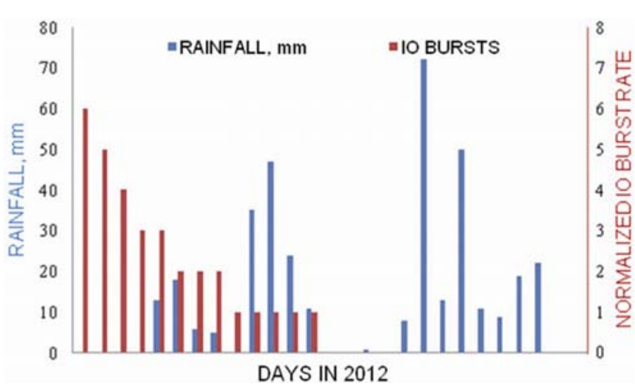

Fig. 7 — Comparative chart of rainfall vs normalized observed Io burst rate [horizontal axis representing day in discontinuous progression as Io phase observation is rare event]

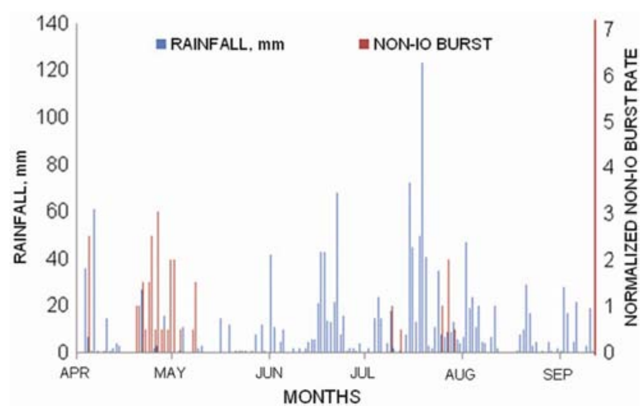

Fig. 8 — Comparative chart of rainfall vs normalized observed non-Io burst rate

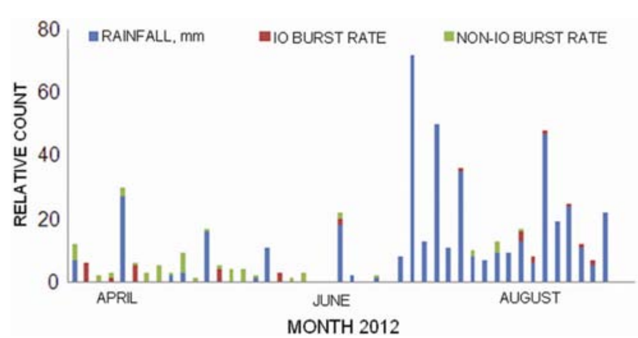

Fig. 9 — Relative count on Io and non-Io Jovian bursts based on daily rainfall [horizontal axis is not drawn to scale; data is presented for only those days when Io and non-Io bursts were available simultaneously]

increases probability of signal reception. This observation concludes that possibility of receiving HF radio signal is decreased to one third for low intensity signal than strong one.

As the antenna used in this study is also capable of observing low frequency solar burst along with Jovian signal at day time, less number of solar radio bursts are observed during heavy rainfall than clear sky day (Fig. 10). During the monsoon months when there are few days' bands of continuous downpour, the number of received solar radio bursts decreases dramatically though rainfall amount and intensity varies from one day to another. In Fig. 8, one can find some of those patches during mid monsoon (late June 2012) or at the time of depression (September 2012). This may be due to rapid and continuous elongation of E_s layer of ionosphere from rigorous lightning that reflects signal[18].

At the Darjeeling observatory, snowfall is very rare and so it was not possible to make any conclusion about its effect on Jovian radio signal reception. However, it is generally believed that attenuation from snow is less than that from rain falling at an equal rate[19], which was mainly based on the fact that the rain is physically much denser than snow. The SkyPipe records presented in this paper represent signals from Jupiter. In these records, the horizontal axes are time while the vertical axes are in SkyPipe Units (SPU) which uses a numeric scale to set at the time of using the sound card input. On the SkyPipe screen, the signal trace can be adjusted with the Jove receiver volume control and also the software volume control in Windows. With a variation of these gains, the trace can be moved up or down and expanded or compressed. No absolute reference point is there and in fact, the vertical scale units are relative, unit less and numbers. As a matter of fact, if the chart

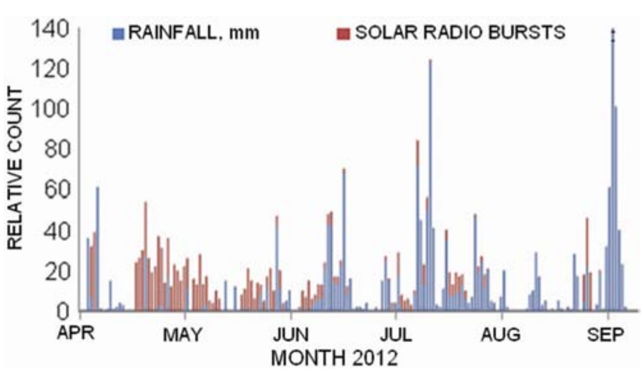

Fig. 10 — Comparative chart for rainfall and number of observed solar radio burst

exhibits signals getting stronger or weaker, it is hard to compare with records from other observers, if different gain settings are used.

5 Conclusion

Climatic variance in Darjeeling and its influences on decametric Jovian signal reception at the high altitude radio station are observed to analyze the signal reception dependencies over different climatic variables, mostly during rainfall. Intensity of decametric Jovian signal received at Earth based observatories are very low[20], ~ 10^4 Jy (where 1 Jy or Jansky $=10^{-26}$ $Wm^{-2}Hz^{-1}$), so dense precipitation has ability to screen it. Since intensity of Jovian signal increases during favorable Io positioning than ordinary CML, probability of receiving bust also increases. Further, during rainfall Jovian bursts originating exclusively from CML region are masked relatively more than Io contribution. Since Sun is more active and nearer to the Earth, so intensity of solar radio emission reaching Earth based observatories is also high with respect to Jovian signal. That is why solar bursts are received at 20.1 MHz even during heavy rainfall. In September 2012, during a very low pressure accompanied with cyclone Aila, even no solar bursts were registered due to few days patch of heavy rainfall and dense cloud. Additionally, it may be noted that as the solar radio bursts are dependent largely upon sunspot activity, it demands further study by solar observers to draw a conclusion over cloud effect.

The study has been conducted for one season of received Jovian signal. The study is concentrated on extended monsoon season in hilly Darjeeling so that effect of high altitude rainfall can be examined. The received unadulterated signal information suggests that the gross nature of weather dependency remains same. The same methodology can be used for reception of other extra-terrestrial feeble signals from earth based observatories. This observation will help to maneuver instrumental settings for better reception of signal.

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