VLF/ELF Noise Bursts Observed at MAITRI (Indian Antarctic Station)

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Abstract

Observation of VLF/ELF emissions at high latitude is attributed to the lightning, thunderstorm activities and power line radiations solar flares. At high latitudes contribution due to solar particle fluxes becomes important for VLF/ELF burst which are observed just after Solar Spike and Solar Noise Storm. The electrodynamics state of the high-latitude ionosphere is controlled by several geophysical processes The ELF/VLF bursts are observed starting from just above the 1300 Hz up to 8 kHz, this burst starts in ELF region and disappears in VLF band. These burst are observed geographically at the locations that are geomagnetically conjugate points e.g. burst recorded at South Pole is generated due to solar wind interaction and the precipitating particles geomagnetically conjugate in the Northern Pole Ionosphere-Magnetosphere.

Introduction

Very low frequency (VLF) (ionospheric noise) and Extremely low frequency (ELF) emissions, a class of naturally emitting radio phenomena very important diagnostic tool for probing the plasmasphere and beyond. VLF emissions are appear in wide variety of spectral forms and it may appear to be relatively steady for several minutes or even hours, or it may be occur in discrete burst as short as fraction of second. These emissions acquire importance because of its ability to allow to understand the electron density variation derived from the dispersion characteristics at simultaneously observation at different suitable stations as well as the effect of solar wind – magnetospheric interaction on the propagation along the field aligned irregularities. [Helliwell R.A., 1965] Very Low Frequency (VLF) are electromagnetic waves generated by lightning discharges which propagates along the magnetic field lines of the earth, get dispersed due to field aligned irregularities [Pathak et. Al. 1982; Prasad and Singh, 1982]. VLF/ELF emissions are localized geographically at the locations that are geomagnetically conjugate to one another. [Helliwell R.A., 1965 and Bespalov et. al. 1980].

The VLF emissions are characterized by their trigger source Observation of VLF/ELF emissions at high latitude is attributed to the lightning, thunderstorm activities and power line radiations solar flares. VLF/ELF noise burst of varying amplitudes and durations, are observed which are usually attributed to local and global source such as lightning and thunderstorm activities, sferics, power line radiations, wave particle interaction and solar flares etc. Sudden ionospheric disturbances (SID) are caused by solar flares which have been identified [Hayakawa and Sato, 1994]. Van Bise and Rausher (1994) observed ELF solar flares in addition to other environmental signals and [Hato et. al., 1994] observed ELF sudden enhancement of atmospheric (SEA) triggered by solar flares using magnetic antenna. Simultaneous observation of SEA at multiple stations confirmed their origin in Solar Flares.

Emission activity generally decreases with magnetic activity at high latitude and increases at low latitudes and a close association exist between auroral phenomena [Hattori et. al., 1989]. The relation between VLF emissions and aurora were explored by [Morozumi, 1962], a close association between auroral arcs and band were found. The VLF intensity decrease because of the absorption of VLF energy in D region of the ionosphere [Helliwell, 1965]. The two proposed models of the emissions at high latitudes, could explains the nature of VLF emissions (Sazhin and Hayakawa, 1994). In the first model the emission period was related to the bounce period of the charged particles bouncing between conjugate hemispheres. In the second model, the emission period was related to the two-hop whistler-transit time (Dowden and Helliwell, 1962).

Process of Solar Wind – Magnetosphere-Ionosphere Interaction at High Latitude

Significant progress has been made in elucidating the solar wind magnetosphere – ionosphere coupling processes at high latitude between (50 – 70) degrees geomagnetic. As the solar wind, magnetosphere, and ionosphere are intrinsically coupled through magnetic field lines latitudes) using propagation path. The magnetopause, the magnetosphere and the ionosphere are threaded by the same magnetic field lines; momentum and energy are exchanged among them.

Solar wind – magnetosphere – ionosphere coupling system or the interaction between the magnetosphere and the polar ionosphere play a vital role in the propagation mechanism. The two important energy input mechanism at high latitudes one is the large scale convection of the magnetic field lines due to solar wind interaction that result in building up
potential difference across the polar caps depending on the level of disturbance [Kamide and Baumjohann, 1993], other from the precipitating particles which comes from the collision retardation of magnetosphere energetic particles as they enter the lower atmosphere. It is not yet clear if most of these particles are from solar wind or terrestrial particles accelerated by solar wind energy. Some of the energy entering the dayside magnetosphere is directly transferred to high latitude ionospheres via field aligned currents and dissipated and the remaining part is transferred to magnetotail. Another part of energy stored in the magnetotail is transferred to auroral ionosphere via a particle precipitation and field aligned current.

The energy coupling processes at the magnetosphere can be divided into two categories (1) those processes called magnetic reconnection or field aligned merging, which imply interaction between solar wind magnetic field, i.e. interplanetary magnetic field (IMF) and the terrestrial magnetic field at the day side magnetopause [Dungey, 1961]; (2) other “non-magnetic” mechanisms which one usually refers to as a viscous – like interactions since they imply that tangential momentum is transferred from magnetosheath plasma through magnetopause via some kind of viscosity generated by micro – or macro instabilities [Axford and Hines ,1961]. Dungey (1958, 1961, and 1968) “magnetic reconnection” could cause the Earth’s magnetosphere to become “open”; reconnection is the dominant coupling process between the interplanetary and terrestrial magnetic fields. Magnetic reconnection will drive a tail ward plasmas flow on open field across the polar caps and magnetospheric lobes , while magnetic storms are intervals of enhanced geomagnetic activity that are caused by intense interaction between solar wind and the magnetosphere. The electrodynamics state of the high-latitude ionosphere is controlled by several geophysical processes [G.Lua et.al.,2001] Amongst the most observed ionospheric manifestation of solar wind-magnetospheric processes are the convection bursts associated with the so-called flux transfer events (FTEs), magnetic impulse events (MIEs), and traveling convection vortices (TCVs). Furthermore, the large-scale ionospheric convection configuration has also demonstrated a strong correspondence to variations in the interplanetary medium and substorm activity. The large-scale ionospheric convection as influenced by the solar wind– magnetosphere interaction and substorm activity.

When the IMF has a component anti-parallel with field lines threading the magnetopause they can become interconnected and plasma from the magnetosheath can gain access to the magnetosphere and vice versa, allowing the transfer of mass, energy and momentum from one to the other. Reconnected “open” magnetic field lines are carried antisunward by the solar wind flow, form the magnetotail lobes to the north and south of the tail neutral sheet and are eventually “closed” again through reconnection processes occurring in the tail—either near-Earth during sub storms or at a more distant neutral line—after which they return to the dayside to complete the “convection cycle” (Dungey, 1968).

Experimental Setup and Data Selection:

To have more acquaintance of the propagation characteristics of high latitude VLF/ELF emissions, recordings were carried out at Indian Antarctica Base Station Maitri, (70°46’S, 11°44’E, L ~ 4.6) with Orthogonal Crossed (Triangular) Loop Antenna (TLA). In which one loop in North-South Direction and other on in East-West Direction. Area of each loop is 144m² This TLA is Thin Wire Loop antenna designed to receive from the VLF range (30 kHz). Output impedance of both loops is matched and frequency above 30 kHz was filtered out remaining signal were suitably amplified by transistorized pre and main-amplifiers. Signal recording is carried out in digital format at the sampling rate 48 kHz by Digital Recorder and online on computer system. Data is stored in amplitude versus time file format and these file are converted in visible gray scale plot by Spectrum analyzer. For the present study, we have chosen VLF signals recorded at high latitude Indian base station at Maitri, Antarctica during day and night time during last week of Jan’03 to Feb’03. A large number of VLF emissions were observed in the day time during both magnetically quiet and disturbed periods.
Results and Discussion

The VLF/ELF emissions are widely used for investigating the magnetospheric processes of wave generation and propagation, wave-particle interactions, wave-induced particle precipitation and for probing of magnetospheric plasma structures and motions (Carpenter, 1978).

The VLF/ELF bursts are observed starting from just above the 1300 Hz up to 8 kHz, this burst starts in ELF region and disappears in VLF band. These burst are observed just after the Solar Spike and in between the period of Solar noise storm of Jan 2003 at Southern High Latitude Region (Indian Antarctic Station, Maitri 70° 46’ S, 11° 44’ E).

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processes at the magnetopause is magnetic reconnection or field aligned merging, which imply interaction between the solar wind magnetic field, i.e. interplanetary magnetic field (IMF) and the terrestrial magnetic field at the day side magnetopause. The maximum Solar Flux Density is around $130 \times 10^{-22}$ watt per square meter-hertz. Average Proton Density of Solar Wind Plasma is above $10^{-3}$ cm$^{-3}$ and average proton speed is just above 400 km sec$^{-1}$ at the time of generation. Possible generation starts from 1-2 R$_E$, as the generation of the burst is from the ELF frequency band. As the magnetopause may originate minimum magnetic field strength that occurs off the magnetic equator as a result of solar wind compression of the dayside magnetosphere and subsequently propagate in the Polar Regions.

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References:
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