ELSEVIER

Journal of Atmospheric and Solar-Terrestrial Physics 69 (2007) 1366–1376

Journal of ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS

www.elsevier.com/locate/jastp

Whistlers observed at low-latitude ground-based VLF facility in Fiji

Sushil Kumar*, D. Anil, A. Kishore, V. Ramachandran

Electrical Communication Research Group, School of Engineering and Physics, The University of the South Pacific, Suva, Fiji

Received 27 December 2006; received in revised form 20 March 2007; accepted 1 May 2007
Available online 10 May 2007

Abstract

The propagation features of nighttime whistlers to low-latitude station, Suva (−18.2°, 178.3°, geomag. lat. −22.1°, geomag. long. 253.5°, $L = 1.15$), Fiji, from preliminary observations made during the period from September 2003–2005, are reported. The observations of ELF–VLF signals commenced in September 2003 using the VLF set-up of World Wide Lightning Location Network at our station. The whistlers were observed during the severe magnetic storm of 20–22 November 2003 and moderate magnetic storm of 17–19 July 2005. A whistler with dispersion $D = 12.7\,s^{1/2}$ occurred on 22 November at 00:11 h LT. On 20 July at 01:00 h LT, a short whistler with dispersion $D = 20.9\,s^{1/2}$ and two whistler events having two-component whistlers with $D = 15.8$, $16.7\,s^{1/2}$ and 16.7, $17.3\,s^{1/2}$ were observed. Non-ducted pro-longitudinal mode of the whistler propagation supported by negative latitudinal electron density gradients in the ionosphere that are enhanced by magnetic storms, seems most likely mode of propagation for the whistlers with dispersion of 12.7–17.3 $s^{1/2}$ to this low-latitude station.

Keywords: Lightning discharge; Whistlers; Magnetic storms; PL mode of propagation

1. Introduction

It is well known that the return strokes of lightning discharges generate electromagnetic waves in a wide frequency range with peak spectral power at around 5–10 kHz (Prasad and Singh, 1982). Major part of the extremely low-frequency (ELF) and the very low-frequency (VLF) radiation propagates in the earth/sea-ionosphere waveguide as impulsive signals (sferics or tweeks) and a small part of the ELF–VLF radiation travels into the dispersive regions of the ionosphere and the magnetosphere as tones of descending and ascending frequencies called whistlers (Helliwell, 1965). A breakthrough in the whistler research started with the pioneer work of Storey (1953), who explained the whistler spectra in terms of the magneto-ionic theory and predicted that the path of whistler propagation was more or less aligned with the earth's magnetic field and extended between the hemispheres. Helliwell (1965) presented an excellent review of the early work on whistlers and related ionospheric phenomena. Several researchers have studied the dispersion and the propagation characteristics of whistlers and have used whistler as diagnostic tool for the magnetosphere (e.g., Carpenter and Smith, 1964; Helliwell, 1965; Hayakawa and

*Corresponding author. Tel.: +679 323 2144;
fax: +679 323 1511.
E-mail address: kumar_su@usp.ac.fj (S. Kumar).

1364-6826/$ - see front matter
doi:10.1016/j.jastp.2007.05.001

Tanaka, 1978; Park, 1982; Carpenter, 1988; Sazhin et al., 1992; Singh et al., 1998, 2004; Singh and Hayakawa, 2001; Pasmanik and Trakhtengertz, 2005; Carpenter, 2007).

Initially, the whistlers were thought essentially as high- and mid-latitude phenomena. However, wide varieties of whistlers have been recorded at low-latitude stations mainly in India, China, and Japan during the last three decades. Some of the new types of whistlers such as short, multiflesh, multipath, sharp, diffuse, risers, twin, low, and high dispersion has been observed. At low-latitude ground stations, whistlers with dispersion ranging from small value of $10\,s^{1/2}$ to large value of about $70\,s^{1/2}$ have been observed (Singh and Hayakawa, 2001). Whistlers at low latitudes are markedly different from those at the middle and high latitudes. Unlike the mid- and high-latitude whistlers, the propagation characteristics of low-latitude whistlers are not yet properly understood. Many researchers have reported a good number of whistlers at low latitudes from their nighttime observations (e.g., Singh et al., 1972, 1998, 2004; Hayakawa and Ohtsu, 1973; Hayakawa et al., 1973, 1990, 1995; Ondoh et al., 1979; Singh and Hayakawa, 2001).

In this communication, we present initial nighttime observations of whistlers and their dispersion characteristics at Suva, a low-latitude station (geomag. lat. -22.1, $L = 1.15$), Fiji, in the South Pacific region. We have also critically analyzed the origin of these whistlers using the lightning occurrence data from World Wide Lightning Location Network (WWLLN) and present arguments on the propagation mechanism of these whistlers. Due to increasing importance and veracity of the whistler technique, it has become essential to understand whistler propagation at the low latitudes.

2. Experimental set-up and data

We use WWLLN VLF set-up for global lightning detection at The University of the South Pacific, Suva, Fiji, to record lightning generated ELF–VLF radio signals. It consists of a short (1.5 m) whip antenna that receives the vertical electric field of transverse magnetic (TM) mode. The pre-amplifier fixed at the bottom of the whip antenna is coupled with ELF–VLF service unit (SU). A GPS antenna connected to the GPS receiver in the SU records the time of arrival of the sferics. The output of SU unit is fed to the two sound cards (48 kHz) in a PC connected with internet. Using one of the sound cards, the sferics packets are transmitted to the central processing units at LM-EM Research Ltd., Dunedin, New Zealand and at University of Washington, Seattle, USA, where they are analyzed for the global lightning detection. Dowden et al. (2002) have described the details of instrumentation and measurement technique of time of group arrival (TOGA) of sferics at multiple sites. Using the second sound card and the lightning software installed in the PC, ELF–VLF data are recorded in files of 11 MB/min. The data files are analyzed using MATLAB code, which gives one spectrogram (frequency f-time t plot) per second.

3. Results and discussion

We present here occurrence and dispersion characteristics of whistlers observed at a low-latitude station, Suva, Fiji, during the severe geomagnetic storm of 20–22 November 2003 and moderate geomagnetic storm of 17–19 July 2005 and discuss possible propagation mechanism of these whistlers to this station. During September–December 2003, ELF–VLF data were recorded for 30 min everyday at 00:00 h LT and only one whistler was detected on 22 November at 00:11 h LT. To study the diurnal occurrence of whistlers, data were recorded for 2 min at every hour in the year 2004 but no whistlers were detected. In the year 2005 up to September, we recorded the data for 30 min everyday at 01:00 h LT. A short whistler with dispersion $D = 20.9\,s^{1/2}$ and two whistlers having two components each with D of 16.5, 17.3 and 15.8, $16.7\,s^{1/2}$ were observed on 20 July at 01:00 h LT. Fourteen moderate storms ($-50\,nT \geqslant D_{st} \geqslant -100\,nT$) and 19 intense storms ($D_{st} \leqslant -100\,nT$) occurred during the period from September 2003 to 2005. Thus analysis of ELF–VLF data recorded during September 2003–2005 shows that the whistler activity at this station is limited to few intense/moderate geomagnetic storms. No whistlers were found in the daytime data. This result may be attributed to heavy absorption in the D-region of the ionosphere. The conjugate point of Suva lies in ocean where thunderstorm activity is relatively low as compared to that in the land. This may be one of the reasons for such rare observation of whistlers at Suva. It is generally believed that whistler activity at any station depends largely on lightning activity at its conjugate point in the opposite hemisphere, but Ohta and Hayakawa (1990) did not find any