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HF DOPPLER OBSERVATION BETWEEN VOSTOK AND SYOWA, ANTARCTICA

Kenro NOZAKI[1], Takashi KIKUCHI[1] and Oleg A. TROSHICHEV[2]

[1]*Hiraiso Solar Terrestrial Research Center, Communications Research Laboratory, 3601, Isozaki, Nakaminato 311-12*
[2]*Arctic and Antarctic Research Institute, St. Petersburg 199226, Russia*

Abstract: Continuous short waves transmitted from Vostok Station (78°28′S, 106°48′E) were received at Syowa Station (69°00′S, 39°35′E) on monthly Regular World Days (RWDs). The transmitted frequencies were 14.985 MHz from 0700 to 0900 UT and 9.18 MHz from 1600 to 1800 UT. The cusp approached the midpoint of the circuit at the end of the UT morning transmission. Two kinds of Doppler structures were clearly recognized. Narrow band Doppler lines were consistently found during both morning and evening transmissions, whereas wide band Doppler structures dominated only in the morning. The wide band structures appeared and disappeared abruptly and sometimes had two spectrum peaks corresponding to velocities of separated irregularities around the midpoint. The narrow band structures still remained while the wide band structures changed spectrum shapes. Sawtooth-like Doppler structures were found in the narrow band lines in the morning transmissions.

1. Introduction

Charged particles which precipitate directly to the cusp region along an open magnetic field cause excessive ionization in the ionospheric *F*-region of the cusp region (*e.g.*, KELLEY, 1989). Plasma flow observed by many satellites indicates that the plasma convection through the cusp changes its pattern due to the interplanetary magnetic field.

To study the ionization and plasma transportation around the cusp, arrangements were made to perform multi-station HF Doppler measurements in Antarctica. In 1987, Russia started to transmit HF waves from Vostok Station (78°27′S, 106°51′E) and Leningradskaya Station (69°30′S, 159°24′E) using communication transmitters, and to receive signals at Molodezhnaya Station (67°40′S, 45°50′E). However, Leningradskaya Station was closed in April 1991. In September of that year, a Japanese receiving system was installed at Syowa Station (69°00′S, 39°35′E) by the 32nd Japanese Antarctic Research Expedition (JARE-32) wintering party. This system was expected to observe ionospheric plasma flow around the cusp by multipoint drift measurements.

In high latitude regions, medium- and large-scale traveling ionospheric disturbances (TIDs) are generated by atmospheric waves and by aurora activities. Waveforms of the TIDs become distorted while propagating from the source region to middle-latitude regions. OGAWA *et al.* (1987) observed medium-scale TIDs with satellite beacon signals and found seasonal and diurnal variations and *Kp* dependencies. HF Doppler measurement is one of the most popular means of detecting TIDs in use today. However, it was not used at Syowa Station until 1991 because of the lack of appropriate standard signals transmitted from stations in its vicinity.

HF Doppler traces obtained at high latitudes are quite different from those obtained at middle and low latitudes. Diffused traces with a band width of several Hz and rising/falling tone sawtooth-like structures were observed in northern Canada and Alaska (KITAMURA *et al.*, 1982; MINAMI *et al.*, 1991). The diffused traces sometimes appeared simultaneously with stable and narrow band Doppler lines, which are usually observed in mid latitudes.

In this report, we describe the HF Doppler receiving system at Syowa Station and preliminary results obtained by JARE-32.

2. Observation System

Non-modulated CW signals were transmitted from Vostok Station on monthly RWDs, 14.985 MHz signals from 0700 to 0900 and 9.18 MHz signals from 1600 to 1800 (UT). Transmitting power was 1 kW and transmitting antenna gain was 6–7 dBi.

The path along the great circle between Vostok Station and Syowa Station is 2170.3 km in length as shown in Fig. 1. Radio waves propagate along the geomagnetic meridian inside the polar cap. The cusp approached the midpoint of the path at the end of the morning transmission. The distance between the two midpoints of Vostok to Syowa and Vostok to Molodezhnaya is 150 km.

The Doppler shifts in the signals received at Syowa Station were analyzed in real

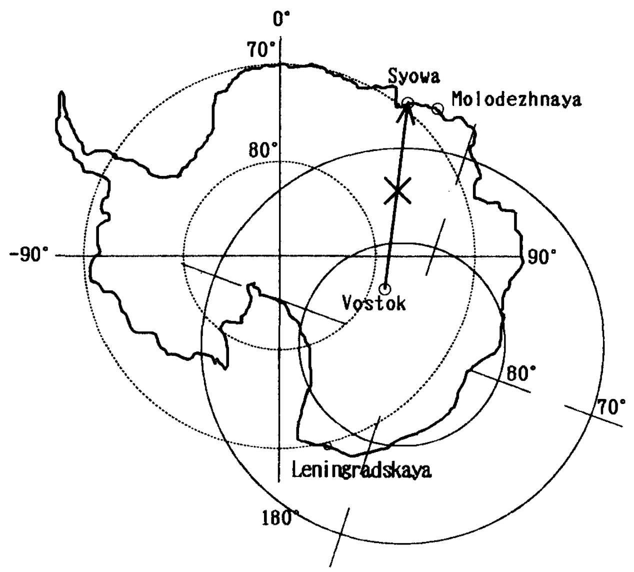

Fig. 1. HF Doppler observation circuits in Antarctica. "×" indicates the midpoint between Vostok Station and Syowa Station. Leningradskaya Station was closed in April 1991.

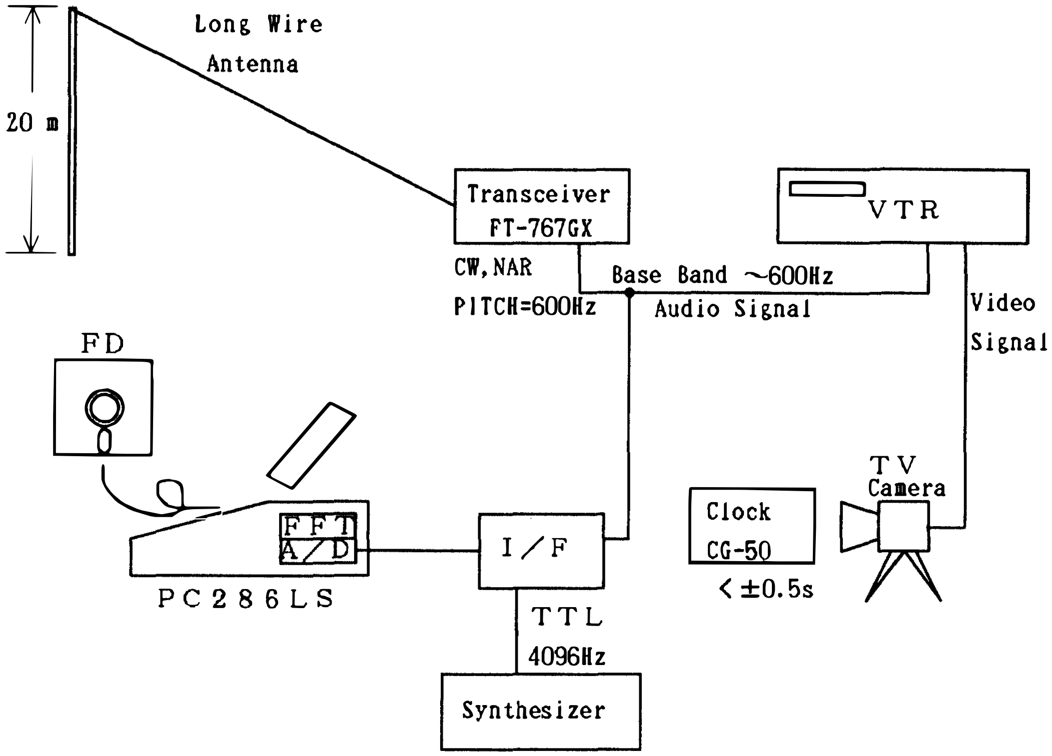

Fig. 2. Receiving system at Syowa Station. A TTL level 4096 Hz signal from a synthesizer is divided to be the clock signal for the A/D converter.

time. A block diagram of the receiving system is shown in Fig. 2. A 600 Hz band width HF transceiver in CW mode was connected to a long wire antenna. Baseband signals with a 600 Hz offset frequency were sampled with a 12 bits A/D converter and FFT analyzed with a pipeline array processor. Both the converter and the processor were incorporated into a laptop computer. The direct memory access (DMA) function in these peripherals enabled the computer to simultaneously perform A/D conversion, FFT analysis, and saving of data on floppy disks. Overall dynamic range in the Doppler analysis exceeded 40 dB. Frequency resolution was fixed at 1 Hz. The computer program was coded with C language to ensure real-time observation.

To facilitate further analysis, the baseband signals were recorded on the audio channels of a video tape and the clock display video signals were recorded on the video channels. The clock was adjusted to be within ±0.5 s of UT.

The receiving system was constructed in August 1991 and observations started the following month. Since crystal oscillators were used as frequency standards in both the transmitter and the receiver, the frequency resolution in this experiment was not expected to be as good as in usual HF Doppler experiments in Japan.

3. Observational Results

About 60 h of data were obtained during the JARE-32 wintering operation: each data set was about 2 h's. Geomagnetic activity during all of these observations was quiet to moderate, *i.e.*, $Kp < 4$.

Figure 3 shows a typical example of Doppler traces in UT evening along with signal intensity, geomagnetic H component and cosmic noise absorption (CNA) observed at Syowa Station. The width of the Doppler traces is half the power band of the power spectrum. A quiet line attributed to specular reflection at the midpoint of the path dominated throughout the observation period. The band width of this quiet line was maintained within a few Hz. Doppler shift of precisely zero cannot be pointed out because the frequency of the signal transmitted from Vostok Station was about 250 Hz lower than the nominal value. A weakly spread and irregular structure overlaid the narrow band stable line from 1703.

An example of the morning transmission with the same parameters is shown in Fig. 4. In this example, the transmission from Vostok Station was suspended from 0802 to 0809. A spread structure was predominant during the morning transmission. The center of the spread structure deviated about −40 Hz from the stable line at around 0733 corresponding to a line-of-sight phase velocity of 400 m/s. The half power bandwidth increased as much as 55 Hz in the January 14 observation.

A three-dimensional display for the period from 0738 to 0853 is illustrated in Fig. 5. Two spectral peaks were observed in the wide band structures. They appeared and disappeared abruptly as indicated by "A" and "B" in Figs. 4 and 5. A stable narrow band Doppler line can still be recognized while the spread structures have drifted to higher and/or lower frequencies as indicated by "C".

An enlarged *f-t* diagram is shown in Fig. 6 from 0820 to 0840 extracted from Fig.

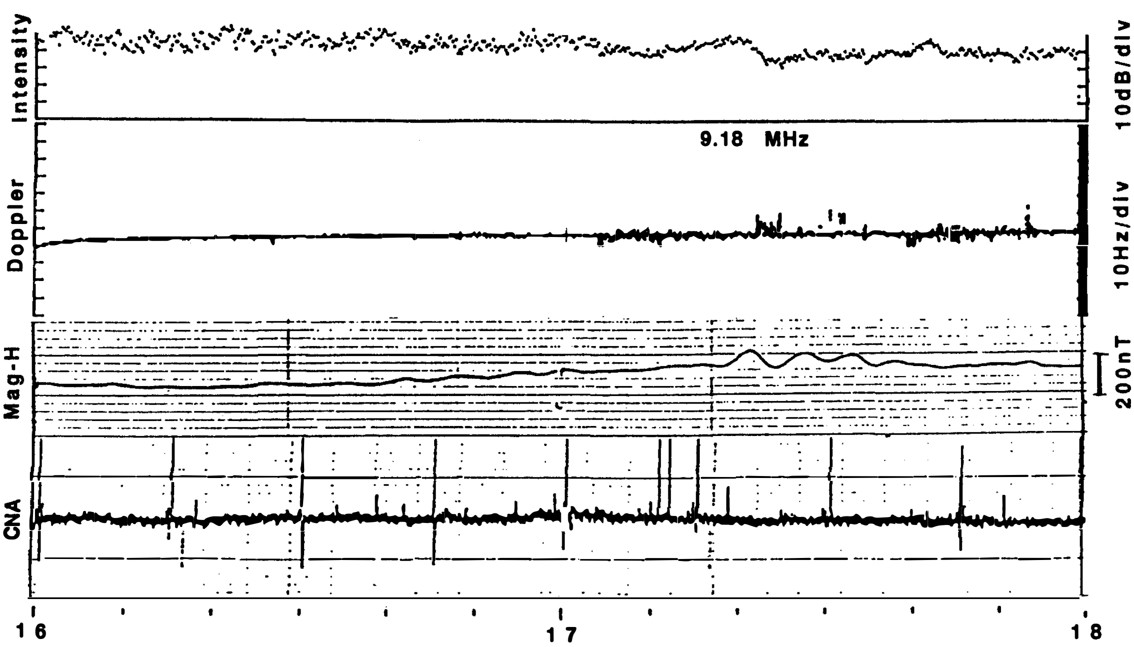

Fig. 3. Typical example of time variation in an evening Doppler spectrum. From the upper panel down: signal intensity, f-t diagram within −3 dB from spectrum peak, geomagnetic H-component, and CNA at Syowa Station.

4. Rising tone sawtooth-like structures appeared in the narrow band Doppler line. Periods of the sawtooth-like oscillations range between 20 s to 2.5 min in JARE-32 observations.

Intense irregular structures and sawtooth-like structures appeared in the stable line only in the morning transmissions. Only a rising tone was detected in the sawtooth-like structures during JARE-32 observations.

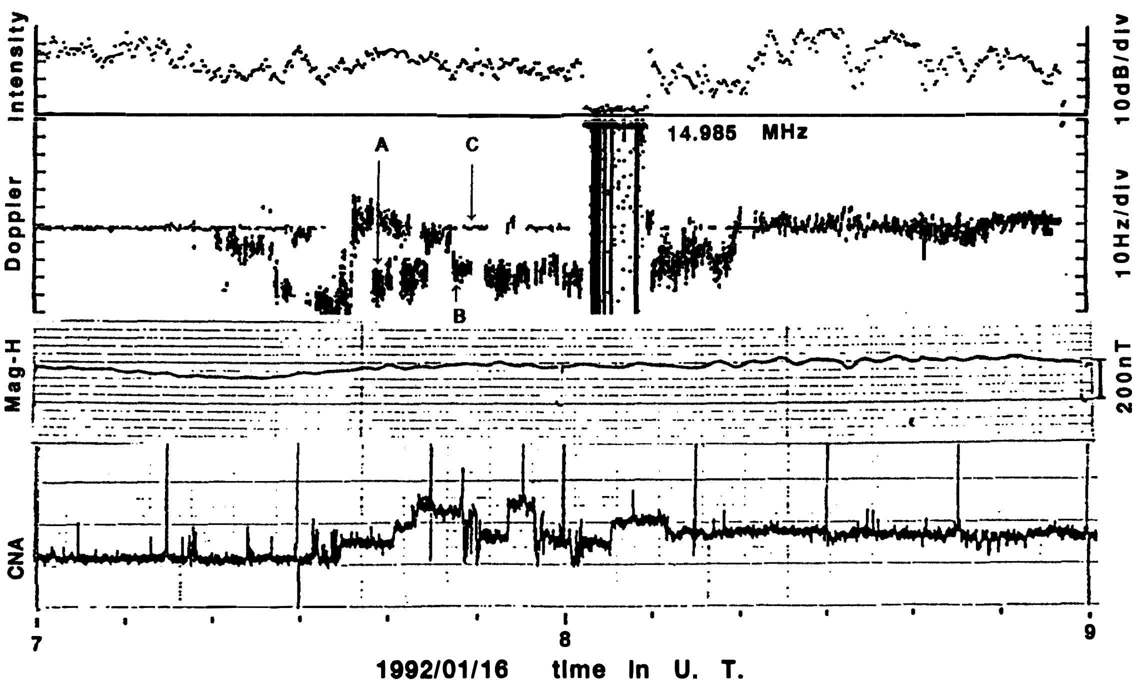

Fig. 4. Typical example of the morning Doppler spectrum shown in Fig. 3. Transmission was suspended from 0802 to 0809 UT. "A" and "B" indicate the sudden appearance of wide-band peaks. "C" indicates a narrow-band stable Doppler line.

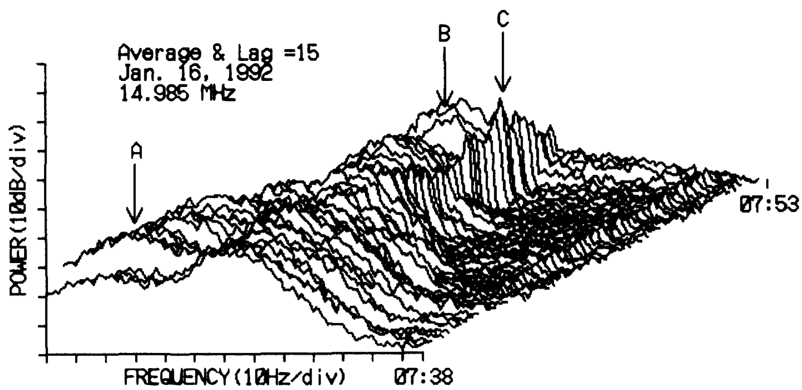

Fig. 5. A 3-dimensional display of the Doppler spectrum. "A", "B" and "C" indicate the same as in Fig. 4.

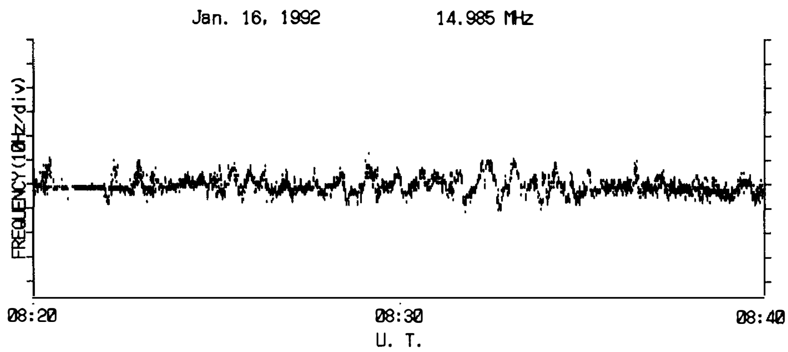

Fig. 6. F-t diagram from 0820 to 0840 UT on January 16, 1992. A rising tone sawtooth-like structure appeared in the narrow band spectrum.

4. Discussion

Because of the restricted observation time and frequency stability of both the transmitter and the receiver, long-term Doppler oscillation could not be detected. Doppler structures different from those seen in low- and middle-latitude regions have been observed in the aurora zone (KITAMURA *et al.*, 1982; MINAMI *et al.*, 1991). However, Doppler spectra inside the polar cap revealed structures more spread and more deviated than those obtained in the aurora zone.

The high Doppler activity observed in UT morning is consistent with an increased number of TIDs occurring in the afternoon observed by means of differential Doppler observation of satellite beacon signals at Syowa Station (OGAWA *et al.*, 1987). The spread and multi-peak structures in the morning observations are apparently due to the complicated plasma flow around the cusp. Cross correlation analysis with the Molodezhnaya Station data will make it possible to confirm plasma drift and waves in the ionosphere.

Sawtooth-like structures will make it possible to obtain much more information from one station's data. LYON (1979) showed that the amplitude, phase, arrival angle modulation, and shape of sawtooth-like structure reflect the amplitude, wavelength, and propagation direction of a corrugated reflector. TAKEFU and HIROSHIGE (1991) showed that electron density modulation in the ionosphere produces characteristic structures corresponding to the wavelength, amplitude, and velocity of TIDs. KITAMURA *et al.* (1982) obtained a drift velocity of 1 m/s to 50 m/s by analyzing falling tone discrete line structures observed in northern Canada. All sawtooth-like structures observed at Syowa Station were of the rising tone type, which suggests that the waves in the ionosphere propagated toward Syowa Station. More information about the ionosphere will be obtained by observing the arrival angle at Syowa Station.

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