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Ionospheric Observation of VLF Electrostatic Noise related to Harmonics of the Proton Gyrofrequency

BANDS of very-low-frequency (VLF) electrostatic noise related to harmonics of the proton gyrofrequency have been observed in the ionosphere with the Javelin 8·46 sounding rocket. The rocket payload, which was launched from Fort Churchill, Canada, at 0518 : 48 UT on May 25, 1968 (2318 : 48 local time, 70·1° invariant latitude), carried a VLF electric and magnetic field experiment consisting of eight antennas and six receivers and an electrostatic analyser for the measurement of electron and proton fluxes in the energy range from 5 eV to 50,000 eV. Two x-axis electric dipole antennas were used, each consisting of two conducting spheres and having centre-to-centre separations of 3·16 m and 42 cm. The two x-axis antennas were commutated, the short antenna being switched in place of the long antenna for 8 s in every 32 s; in these circumstances the characteristic wavelengths of the electric fields could be inferred. The payload reached a peak altitude of 801 km at 512 s after launch, and impacted 511 km from the launch site after a flight lasting 962 s.

Fig. 1 shows the wide-band data from the x-axis electric receiver in the form of a frequency–time spectrogram from 262 to 290 s after launch, with the observed noise bands occurring from 271·5 to 274·2 s and again from 279·8 to 281·6 s after launch. The upper and lower cut-off frequencies (defined as the frequencies at which the noise intensity is reduced by about 10 dB from the adjacent noise band) of each attenuation band have been measured from the spectrograms and are given in Tables 1 and 2. The error limits reflect the estimated uncertainty in determining the cut-off frequencies from the spectrograms. Also given in Tables 1 and 2 are the corresponding proton gyrofrequency harmonics, computed from an expansion for the geomagnetic field at the payload. Comparing the

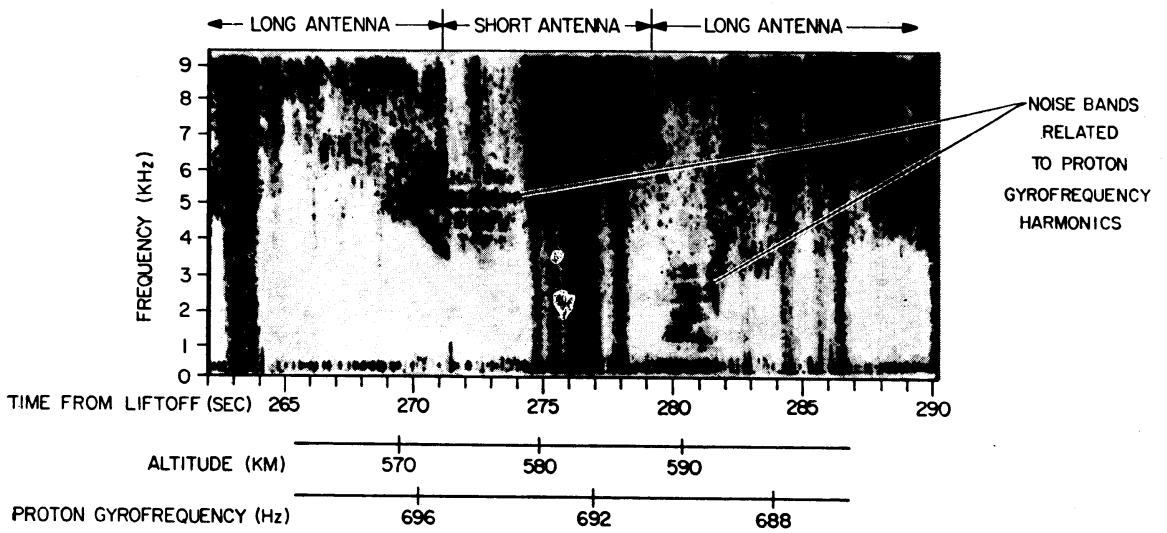

Fig. 1. Spectrogram showing the noise band emission related to the harmonics of the proton gyrofrequency.

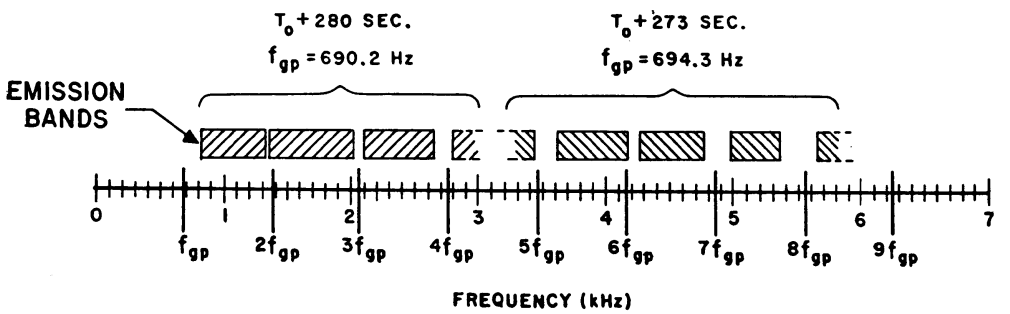

Fig. 2. The relation between the emission and attenuation bands and the harmonics of the proton gyrofrequency.

observed cut-off frequencies with the harmonics of the proton gyrofrequency, as given in Tables 1 and 2, we see that the proton gyrofrequency harmonics are generally within the attenuation bands of the observed emission, as shown in Fig. 2.

The noise intensities from the long and short electric antennas are very nearly equal (about 1·0 mV potential difference between the antenna elements), strongly suggesting that the wavelength of the observed noise is short

Table 1. FREQUENCIES OF ATTENUATION BANDS OBSERVED AT T_0+273 S AND FREQUENCIES OF CORRESPONDING PROTON GYROFREQUENCY HARMONICS ($f_{gp}=694{\cdot}3$ Hz ± 1 PER CENT)

Band-edge frequency (Hz) Lower	Band-edge frequency (Hz) Upper	Harmonic of proton gyrofrequency (Hz)
3,448 ± 25	3,619 ± 16	$5f_{gp}=3,471\pm34$
4,173 ± 25	4,258 ± 25	$6f_{gp}=4,165\pm41$
4,883 ± 30	4,987 ± 25	$7f_{gp}=4,860\pm48$
5,356 ± 40	5,650 ± 35	$8f_{gp}=5,554\pm55$

compared with the antenna length (3·16 m). This wavelength is consistent with the characteristic length expected for gyrofrequency harmonic interactions, on the order of the mean gyroradius, or about 2 m for thermal protons in the ionosphere. No comparable noise was observed with magnetic loop antennas flown on the same payload, indicating that the noise is electrostatic to within the sensitivity of the magnetic receiver (about 3×10^{-4} gammas in the frequency range from 650 Hz to 10 kHz).

Table 2. FREQUENCIES OF ATTENUATION BANDS OBSERVED AT T_0+280 S AND FREQUENCIES OF CORRESPONDING PROTON GYROFREQUENCY HARMONICS ($f_{gp}=690{\cdot}2$ Hz ± 1 PER CENT)

Band-edge frequency (Hz) Lower	Band-edge frequency (Hz) Upper	Harmonic of proton gyrofrequency (Hz)
*	827 ± 42	$f_{gp}=690\pm7$
1,326 ± 20	1,360 ± 13	$2f_{gp}=1,380\pm14$
2,022 ± 25	2,099 ± 35	$3f_{gp}=2,070\pm21$
2,647 ± 37	2,800 ± 37	$4f_{gp}=2,760\pm28$

* Could not be determined from data.

Effects at gyrofrequency harmonics are well known for a hot plasma in a static magnetic field[1,2]. Radiation at harmonics of the electron and ion gyrofrequency from laboratory plasmas has been reported and studied by several investigators[3-6]. The effects observed at harmonics of the proton gyrofrequency during this flight are believed to be the first confirmed observation of ion gyrofrequency harmonic effects in the ionosphere. A theoretical discussion of these data is in preparation and will be published with a detailed summary of the Javelin 8·46 flight.

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