Indian Journal of Radio & Space Physics
Vol. 24, August 1995, pp. 205-208

Interpretation of higher harmonic tweeks recorded at Agra*

Birbal Singh
Department of Physics, R B S College, Bichpuri, Agra 283 105

Received 19 December 1994; revised received 24 April 1995; accepted 15 May 1995

Higher harmonic tweeks (higher than the first harmonic) recorded for the first time at the low latitude station Agra (geomagn. lat., 17°N) are reported. The analysis of the data shows that higher harmonic tweeks are usually not associated with whistlers, and occur when the ionization in the lower ionosphere varies exponentially with height, giving the waveguide cut-off frequency $f_c = 1.6$ kHz. On the other hand, normal tweeks or those with first harmonic only, are often associated with whistlers and occur when $f_c = 1.8$ kHz. The higher harmonic tweeks have travelled distances between 4000 and 21000 km in the earth-ionosphere waveguide. The tweek activity is found to increase during periods of magnetic disturbances.

1 Introduction

Some of the electromagnetic energy at very low frequencies radiated by the return strokes of lightning discharges is propagated in the earth-ionosphere waveguide mode to large distances through multiple reflections from the earth and ionospheric boundaries. The dynamic spectrum of these signals appears as vertical line with a hook at lower frequencies. These are known as "tweeks" and sound like very short whistling tones. The tweeks are more common for propagation over sea-water paths during nighttime and they occasionally appear with harmonics. The studies of tweeks and their harmonics are useful in determining the location of the causative lightning discharges and the characteristics of the lower ionosphere.

The occurrence of tweeks was first reported during world war I when whistler studies were only elementary. Spectral analysis of the tweeks was carried out by Burton and Boardman[1]. Later on, Japanese workers also reported higher harmonic tweeks[2]. A detailed description of the early studies on tweeks and whistlers has been excellently presented by Helliwell[3]. Hayakawa *et al.*[4] have carried out direction finding studies on tweeks and have made a detailed interpretation of their occurrence and application in atmospheric studies.

Recently, we have recorded second and third harmonics of tweeks, for the first time, during whistler observations at Agra. In this paper, we study these tweeks and interpret their occurrence characteristics.

2 Observations

Tweeks have been recorded with the same set of equipment as employed for the observation of whistlers, namely, a vertical antenna, pre- and main amplifiers, and a tape recorder. The recorded data on magnetic tape are taken to a digital sonagraph machine for visual analysis and some transferred on to sonagram paper.

Tweeks with multiple harmonics were recorded during the campaign of whistler observations which started on 27 Dec. 1989 and continued till 24 Oct. 1992 on a routine basis.

3 Results and discussion

In Fig. 1 are shown some examples of higher harmonic tweeks recorded at Agra. While in Fig. 1 [(a) and (b)] the first and second harmonics are seen along with the fundamental, in Fig. 1(c), the third harmonics are seen in addition to the others. The fundamental frequency is found to be approximately 1.6 kHz (waveguide cut-off frequency); the higher harmonics are at 3.4, 5.3 and 7.0 kHz, which are close to the harmonics of the fundamental cut-off frequency. Similar higher harmonic tweeks have also been reported from observations at Varanasi[5]. Several spherics and whistlers have been recorded at Agra[6] and other low latitude stations in the country including Varnasi[7] with similar recording systems, which do not show harmonics. Even in the existing data, there are majority of tweeks without harmonics.

*This paper was presented at the National Space Science Symposium held at Vikram Sarabhai Space Centre, Trivandrum, during 20-24 Dec. 1994.

From the detailed analysis of the data up to date, we find that the tweeks observed with higher than the first harmonic are not associated with whistlers. Singh *et al.*[5] have also reported a similar result from observations at Varanasi. The majority of whistlers are recorded either with fundamental tweeks or with first harmonic only, and there is no case of whistlers recorded with tweeks having more than one harmonic. In Fig. 2 are shown two examples of whistlers recorded at Agra with tweeks exhibiting fundamentals (top) and first harmonics (bottom). An interesting result obtained from the detailed analysis of the data is that all the higher harmonic tweeks (not associat-

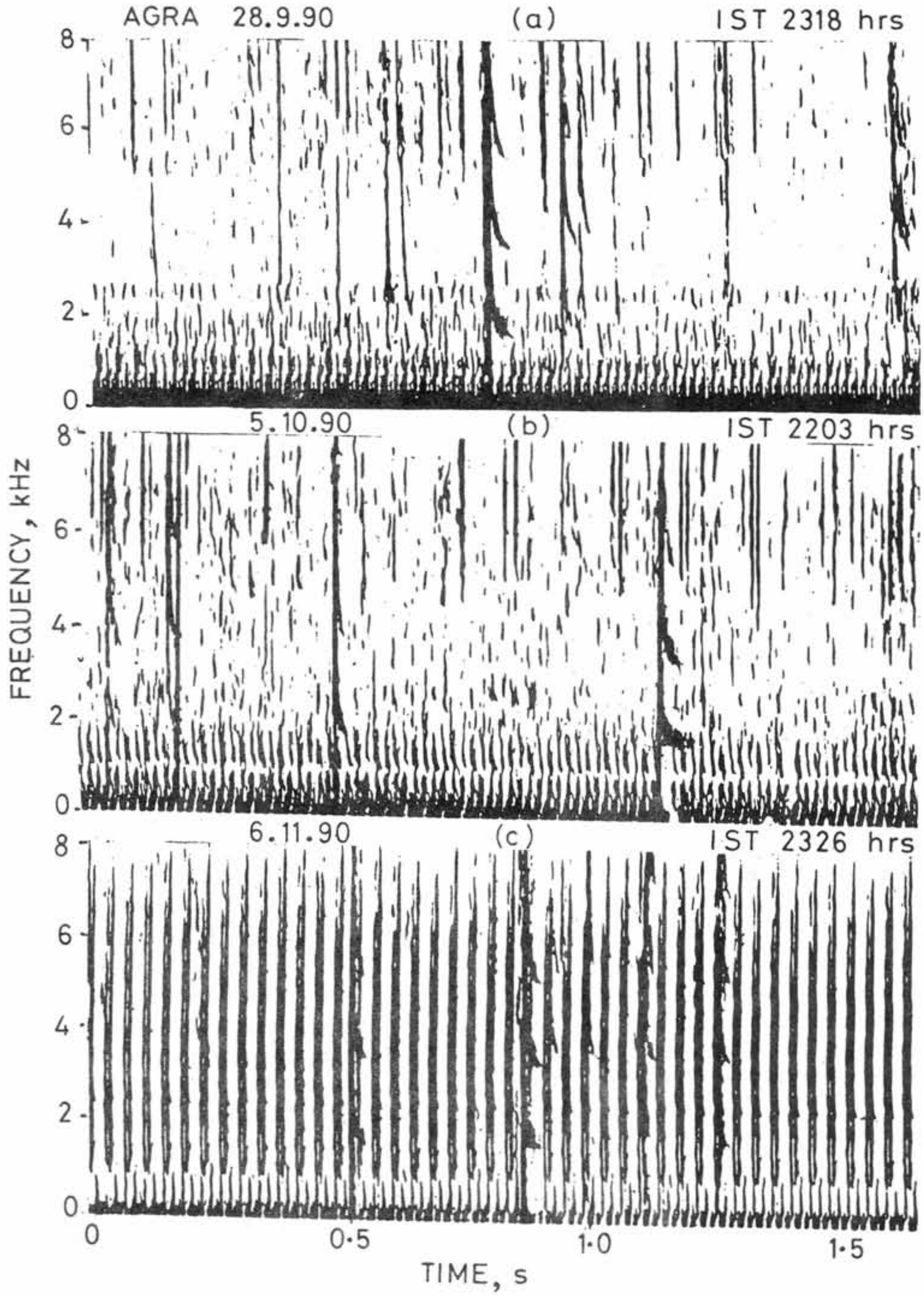

Fig. 1—Higher harmonic tweeks recorded at Agra: [(a) and (b), fundamental with two harmonics, and (c) fundamental with three harmonics.]

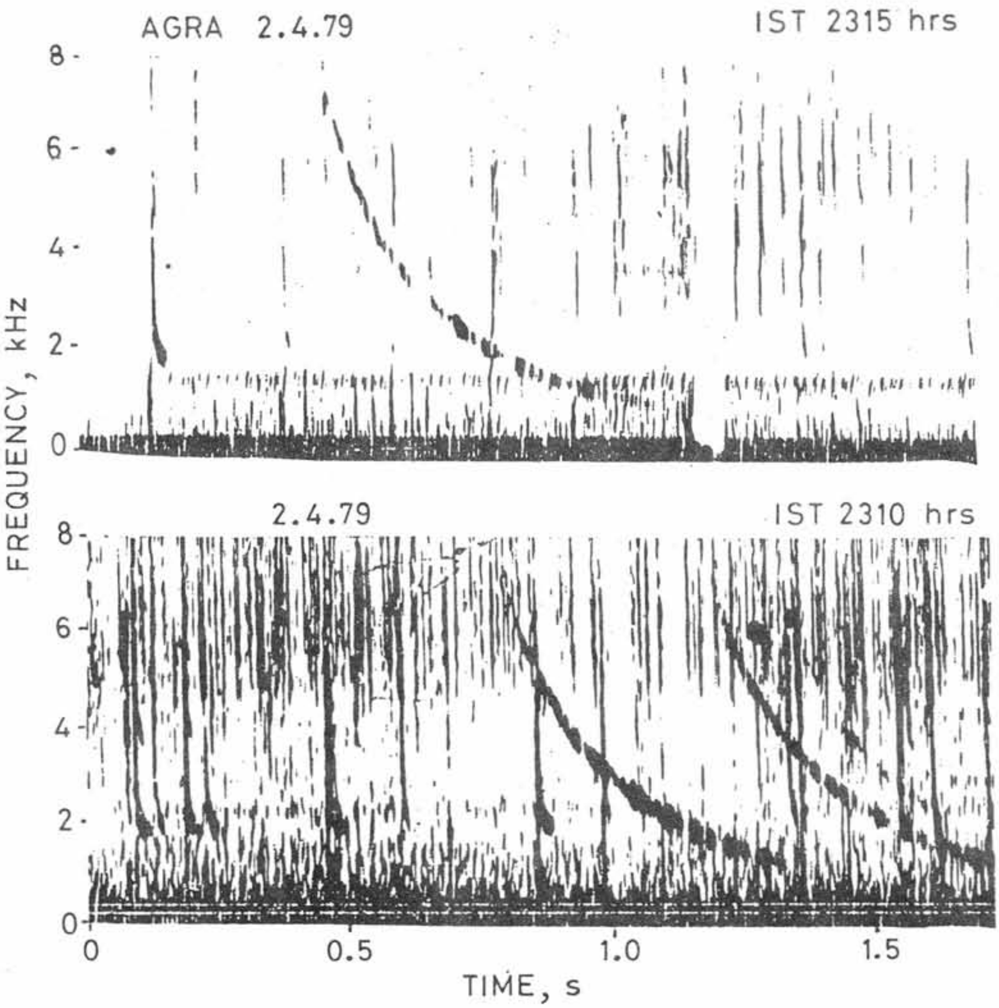

Fig. 2—Lower harmonic tweeks recorded at Agra associated with whistlers [top: whistler with fundamental tweek; and bottom: whistler with first harmonic.]

ed with whistlers) occurred at the waveguide cut-off frequency (fundamental tweek frequency) $f_c = 1.6$ kHz, whereas those associated with whistlers have occurred at $f_c = 1.8$ kHz. Following Helliwell[3] we have calculated the approximate distances travelled by these tweeks in the earth-ionosphere waveguide using the relation

$$D = c : \Delta t$$

where, c is the velocity of light in free space and Δt is the time separation between the leading edge of the tweek at f_c and 1.16 f_c. It is found that the higher harmonic tweeks shown in Fig. 1 have travelled distances in the range 4000-21000 km.

The occurrence of tweeks depends upon the earth-ionosphere waveguide parameters such as height of the ionosphere, conductivity of the earth, and electron density and collision frequency profiles of the lower ionosphere. Hayakawa *et al.*[4] have determined the attenuation of waves with frequencies between 1 and 3 kHz for a variety of electron density and collision frequency models with a perfectly conducting earth and an ionospheric height of 90 km. The electron density and collision frequency models are shown in Fig. 3 where E15, E24 and E35 represent the three exponential models with different gradients and R represents the experimental profile. The exponential profiles are often used for calculations in VLF band at frequencies above 10 kHz and are proved to be useful in explaining satisfactorily the observed phase and amplitude variations of VLF transmitter signals propagating large distances in the earth-ionosphere waveguide. Such electron density profiles are expressed by $N = N_0 \exp\{b(h-h_0)\}$, where $N_0 = 30.7$ cm^{-3}, $h_0 = 87$ km and b is assumed to take the values of 0.15, 0.24 and 0.35 km^{-1} for the three profiles, respectively. The profile indicated by R is suitable for accounting the phase and amplitude variations at ELF.

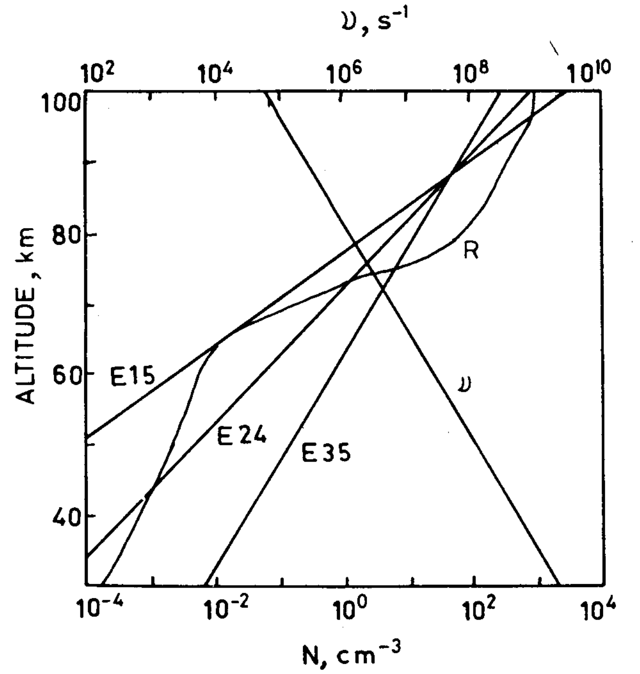

Fig. 3—Electron density and collision frequency models adopted in the study of tweeks (reproduced from Hayakawa *et al.*[4])

The collision frequency profile is reasonably assumed to be independent of latitude and longitude. The profiles E15-E35 yield f_c = 1.5-1.57 kHz for the first order mode, whereas the experimental profile R yields f_c = 1.75 kHz for the same mode. The attenuation computed at higher frequencies falls steeply in the exponential models but gradually in the experimental model.

Singh and Tantry[8] have also studied the attenuation and phase characteristics of ELF and VLF waves using exponential electron density and collision frequency profiles. They have found a peak attenuation rate of about 20 dB/1000 km at a frequency of ~1.6 kHz for nighttime conditions. These results suggest that the harmonics in the earth-ionosphere waveguide are controlled, particularly, by the profiles. The nonassociation of whistlers with higher harmonic tweeks may be interpreted in terms of unfavourable penetration conditions encountered by upward going wave-normals of the waves in the exponential electron density profiles. The association of whistlers with tweeks showing the fundamental and first harmonic only, is due to favourable lower ionospheric penetration conditions for whistler mode waves obtained in the experimental profile.

The occurrence rate of tweeks is found to increase greatly during periods of magnetic disturbance. An example of this positive correlation has been found during our observations between 27 and 29 Dec. 1989. It is worthwhile to mention here that whistler activity is also found to increase during periods of magnetic disturbances[9], but this is due to favourable propagation conditions in the magnetosphere. The increase in tweek activity could be due to the modification of the lower ionosphere caused by energetic particle precipitation favourable for earth-ionosphere waveguide mode propagation.

4 Summary and conclusion

The results can be summarized as follows:

(i) Second and third harmonic tweeks have been recorded for the first time at Agra, a low latitude ground station. Similar tweeks have also been reported from observations at Varanasi during same season of whistler observations.

(ii) The tweeks with higher harmonics occurred with the fundamental waveguide cut-off frequency (f_c) of 1.6 kHz. Such tweeks are usually not associated with whistlers.

(iii) The tweeks with a fundamental and first harmonic only are characterized by a waveguide cut-off frequency of 1.8 kHz, and are often associated with whistlers.

(iv) The tweek activity is found to increase during periods of magnetic disturbances.

(v) The higher harmonic tweeks have travelled distances ranging between 4000 and 21000 km in the earth-ionosphere waveguide.

Acknowledgement

The author is grateful to the University Grants Commission, New Delhi, for providing funds for this research.

References

1 Burton T & Boardman E M, *Proc IRE (Australia)*, 21 (1933) 1476.
2 Ohtsu J, *Proc Res Inst Atmos Nagoya Univ (Japan)*, 7 (1960) 58.
3 Helliwell R A, *Whistlers and related ionospheric phenomena* (Stanford Univ. Press, Stanford, California, USA) 1965.
4 Hayakawa M, Ohta K & Baba K, *J Geophys Res (USA)*, 99 (1994) 10733.
5 Singh R N, Singh R P, Singh U P & Singh A K, *Indian J Radio &Space Phys*, 21 (1992) 377.
6 Singh H, Prakash R & Singh B, *Indian J Radio & Space Phys*, 9 (1980) 130.
7 Somayajulu V V, Rao M & Tantry B A P, *Indian J Radio & Space Phys*, 1 (1972) 102.
8 Singh B & Tantry B A P, *Indian J Radio &Space Phys*, 1 (1972) 273.
9 Somayajulu V V & Tantry B A P, *J Geomagn & Geoelectr (Japan)*, 18 (1967) 81.