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Vertical velocity from HF Doppler measurements over Ahmedabad

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ABSTRACT
HF Doppler radar operating at 2.5 MHz was developed and operated at Ahmedabad for a number of nights during 1986-87. The system made use of the existing ionosonde, C-4 model, as transmitter and a crystal controlled frequency synthesiser provided the RF excitation. Quadrature outputs of the phase coherent receiver were recorded both in analogue form on paper charts and in digital form at a sampling rate of 50 Hz. The velocity could be determined with a resolution of 1 m/s. Measurements show vertical velocity ranging between 0 and 25 m/s with a mean value of 9.2 m/s. A comparison with the vertical velocity obtained from the time variation of the minimum virtual height of F-layer, h'F, from a co-located ionosonde shows good agreement.

INTRODUCTION

Vertical drift velocity is an important ionospheric parameter and a measure of the zonal electric field in equatorial region. Vertical drifts in the post sunset period in the equatorial region play a major role in the onset of equatorial spread-F. Vertical velocities have been estimated from ionosonde data using the rate of change of the base height of F-layer (h'F), peak height (h_{max})or from true height analysis (Mitra et al. 1964, Balsley 1969, Abdu et al. 1981). The limitations in estimating vertical velocity from ionosonde data arise due to limitation in the group height measurements. Incoherent scatter radar (Woodman and Hagfors 1969) is best suited for measuring vertical drift velocities but is very expensive to operate on a continuous basis. Rastogi et al. (1991) compared the vertical velocity obtained from the rate of change of virtual height of F-layer (h'F) at Huancayo during night hours with the vertical velocity obtained from incoherent scatter radar at Jicamarca and found very good correlation. The equatorial F-region shows rapid changes in height in the post-sunset period therefore one can obtain fairly reliable estimates of the vertical velocity. However, at other low latitudes the ionosonde derived vertical velocity will have limitations due to limitations in the group height measurements. HF Doppler technique is a well-established method to study vertical drift velocity in the ionospheric F-region during night-time with better accuracy.

Phase path changes due to vertical movement of F-layer are a sensitive indicator of vertical velocity. Phase path or HF Doppler method is simple and inexpensive and has been used extensively for vertical velocity measurements. The technique was first developed by Findlay (1951) and modified by Reddi and Rao (1971). This method was further modified by Balan et al. (1982) to record data on analogue chart paper. In India, measurements using this technique have been made from Kodaikanal, 10.2° N (Sastri et al. 1991) and Trivandrum, 8.4° N (Namboothiri et al. 1989, Balan et al. 1992) close to the magnetic equator and from Waltair, 17.7° N (Satya Ramesh et al. 1984, Sriramrao et al. 1991) situated northward from the magnetic equator. Measurements were also made from Varanasi, 25.3° N (Srivastava et al. 1970) and from Nagpur, 21.1° N, Dhopte et al. (1996). The measurements close to dip equator, namely at Trivandrum and Kodaikanal, in the post-sunset period were found to be related to the zonal electric fields but at other locations away from the magnetic equator contribution due to meridional winds is also present. HF Doppler radar operating at 2.5 MHz was developed at the Physical Research Laboratory, Ahmedabad, using the transmitter unit of the C-4 model ionosonde and measurements were made on a number of nights during the period 1986-87. The vertical velocities thus obtained and a comparison with the vertical velocities obtained from collocated ionosonde data (which is in regular operation since last five decades) are described in the present paper.

HF DOPPLER SYSTEM

Block diagram of the HF Doppler system developed and operated at PRL is shown in Fig.1. A crystal

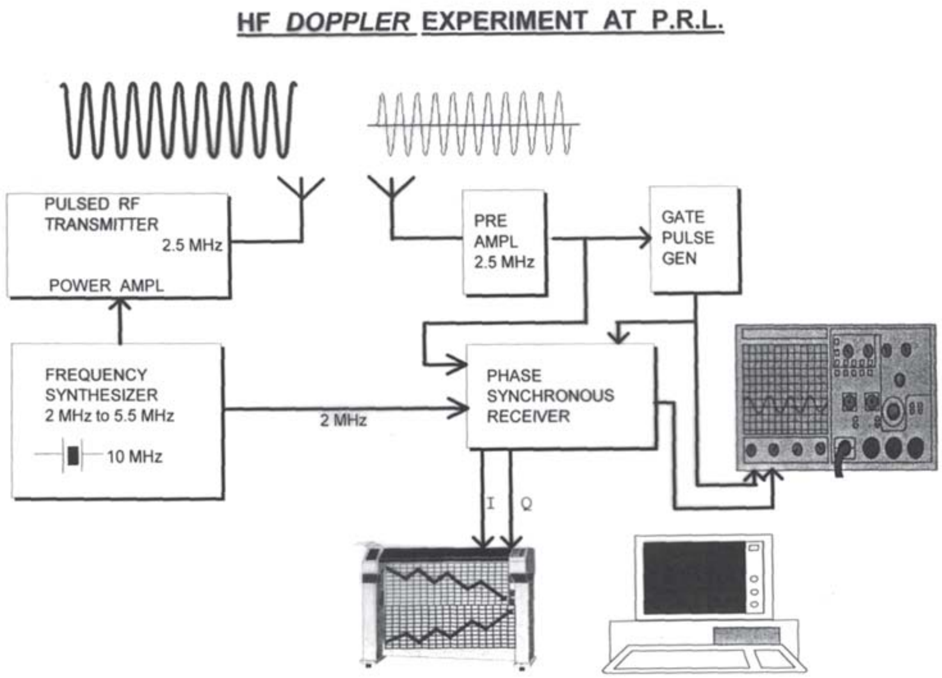

Figure 1. Block diagram of the HF Doppler experiment developed at PRL.

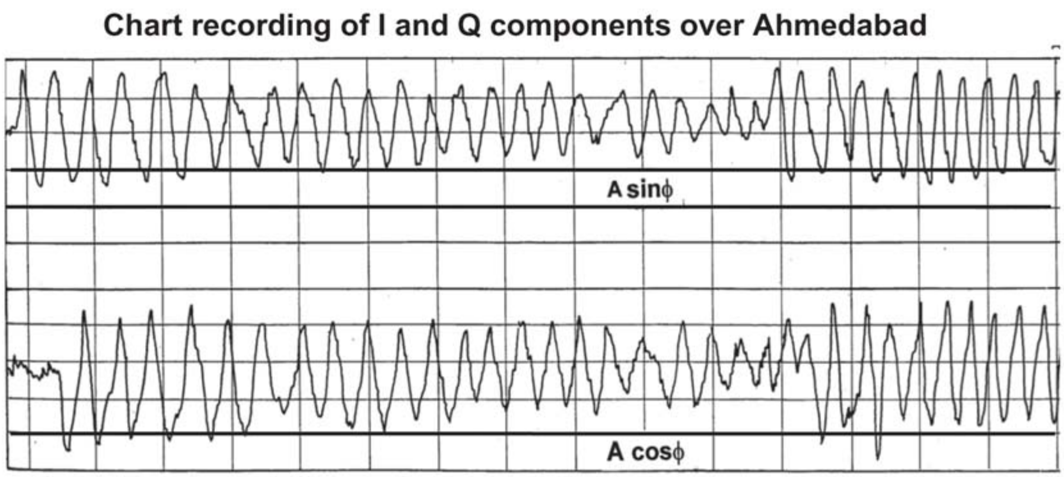

Figure 2. Sample of paper chart recordings of the quadrature outputs of the phase measurements made over Ahmedabad.

controlled (10 MHz) frequency synthesiser (in the range 2.5 MHz to 5.5 MHz) was fabricated to provide RF excitation to the driver amplifier, which was subsequently amplified in voltage and power and transmitted using the ionosonde antenna. The echo received by the antenna was pre-amplified and fed to the phase synchronous receiver. Crystal-controlled frequency synthesiser also provided the phase-reference for measuring the phase. The preamplifier electronics also generated the time-shifted pulse for gating the F-region echo.

Quadrature outputs of the phase coherent receiver were recorded both in analogue form on paper chart and in digital form at a sampling frequency of 50 Hz. An example of the chart paper recording of the quadrature components is shown in Fig. 2. The Doppler frequency could be ascertained graphically using a cursor and a menu-driven program. In addition to this, FFT analysis was done to obtain high-resolution vertical velocity measurements. Vertical velocity could be determined with an accuracy of 1 m/s.

DATA AND RESULTS

The system was operated on many nights during 18-01 hours of years 1986-87 in time-sharing mode between quarter hourly radio soundings of the ionosphere using ionosonde. In these measurements, a radio frequency of 2.5 MHz was used. The distribution of the vertical velocity obtained from recordings made in 1986-87 is shown as a histogram of percentage occurrence of velocity in Fig. 3. The vertical velocity ranged from 1 m/s to 25 m/s with a mean value of 9.2 m/s. The mass scatter plots describing the variation with time of the vertical velocity during different seasons and for the entire period (annual) are shown in Fig. 4. Five point simple average values are also shown by filled black circles in the figure 4. There are fewer data points during summer and covering the time from 20h to midnight. There is a large day-to-day variability in the vertical velocity. Most of the times vertical velocities are found to lie between 20 m/s to –8 m/s during winter, 24 m/s to –10 m/s during equinoxes and between 20 m/s to – 20 m/s during summer. Though there is no consistent variation of the vertical velocity with time, instead there are more points showing upward velocity during winter and equinoxes but in summer almost equal number of points show downward velocity. The full circles denote the average values for every 10 minutes. The mean values, averaged over 10 minutes, range from zero to ~16 m/s during winter, zero to 20 m/s during equinoxes and between 18 m/s to –20 m/s during summer.

A comparison of the vertical velocity obtained from HF Doppler measurements with the velocity derived from the time rate of the h′F variations from ionosonde, for the night of 6 February 1986 is shown in Fig. 5. The vertical velocities obtained from HF Doppler method are averaged over 10 minutes. The vertical velocities from ionosonde are derived from the quarter hourly ionograms and a three point running mean is used for smoothing. The HF Doppler velocities show consistent variation with vertical velocity increasing steadily from about 2 m/s at 1900 h to 15 m/s at 2100 h and beyond. The maximum velocity is about 20 m/s at 0100h and afterward there is rapid decrease in the vertical velocity and reaches to –13 m/s at 0210h. The velocities obtained from h′F variations, though show some fluctuations but are in fair agreement with the velocities from the HF Doppler method. This further demonstrates the suitability of HF Doppler technique to estimate vertical velocity.

DISCUSSION

The mean vertical velocity of 9 m/s during night time for Ahmedabad is close to the values of 8 m/s reported for Varanasi (Srivastava et al. 1970) and 8 m/s for equinoxes and 6 m/s during solstices for Nagpur

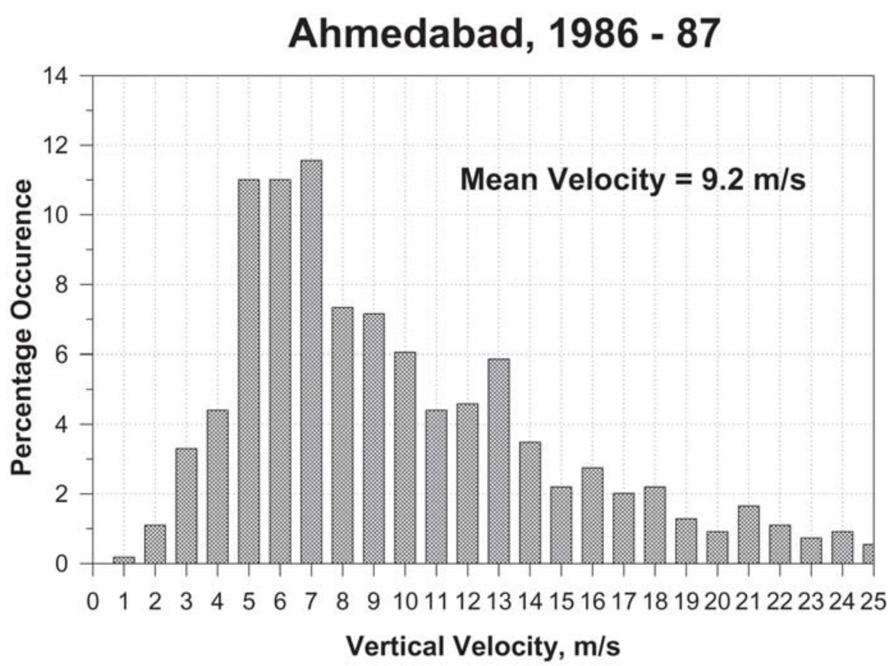

Figure 3. Histogram of percentage occurrence of F-region vertical velocity measured during selected nights of 1986-87 over Ahmedabad.

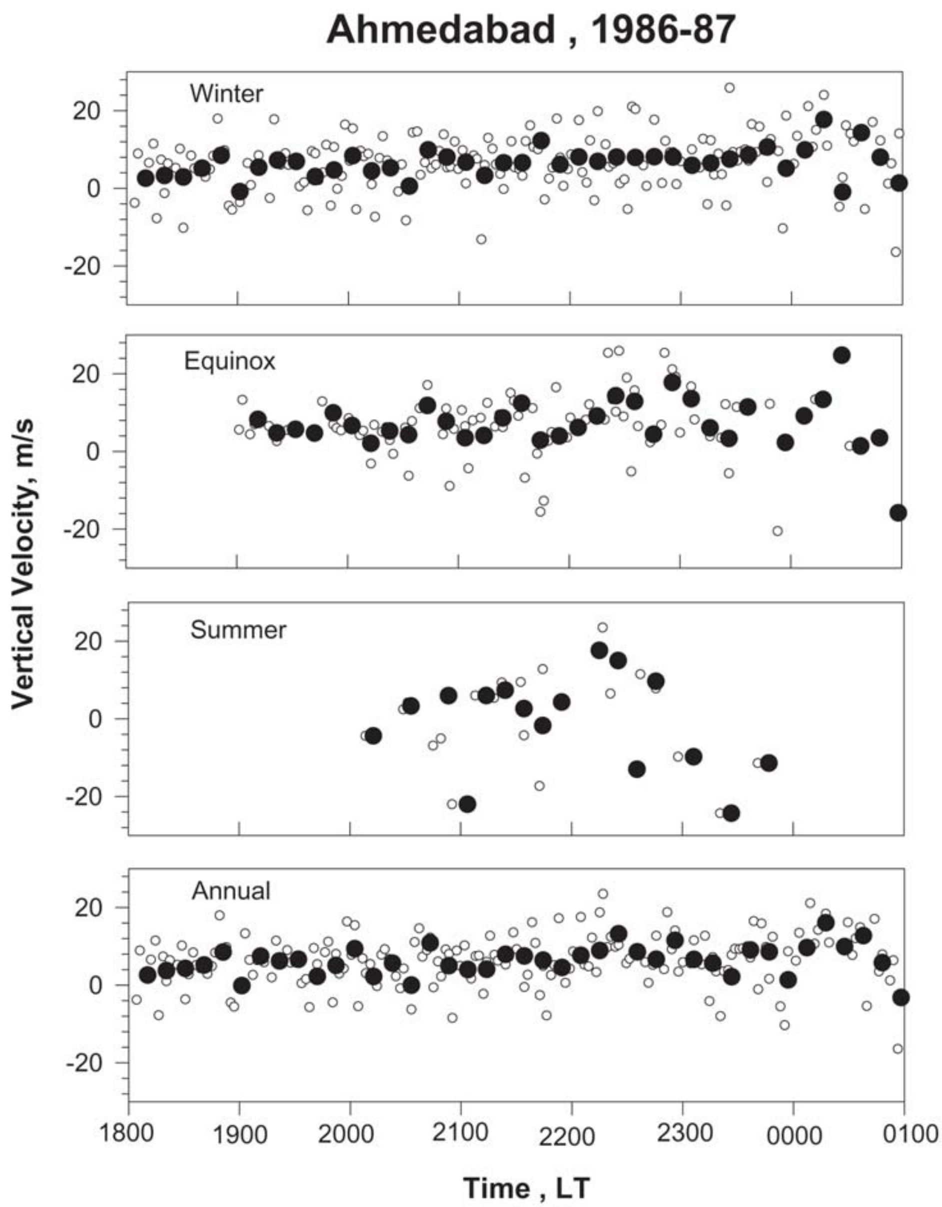

Figure 4. Temporal variations of the F-region vertical velocity measured over Ahmedabad grouped separately for the three seasons and for annual during 1986-87. Small hollow circles are the data points and filled black circles are five points mean values.

(Dhopte et al. 1996). The measurements at equatorial station Trivandrum (Namboothiri et al. 1989) show large vertical velocities in the post-sunset period with values up to 40 m/s during equinoxes and 10 m/s during summer. The high values of the vertical velocities near the dip equator are due to the strong pre-reversal enhancement of the electric field in the post-sunset period. Away from the dip equator the measurements at Waltair (Sriramarao et al. 1991) showed vertical velocity of about 15 m/s in the post-sunset period associated primarily with the electrodynamic drift while the vertical drifts later in the night are primarily due to the neutral wind effects. A comparison of the annual mean vertical velocity at Varanasi, Nagpur and Waltair by Dhopte et al. (1996) showed that the post-sunset vertical velocity was higher at Waltair (more than 15 m/s) than the vertical velocities of ~ 5 m/s at Nagpur and Varanasi. Another peak of about 5-10 m/s occurring around 21-22h at the three stations was associated with the equatorward neutral winds. The vertical movements of the F-layer during night are important for triggering of equatorial

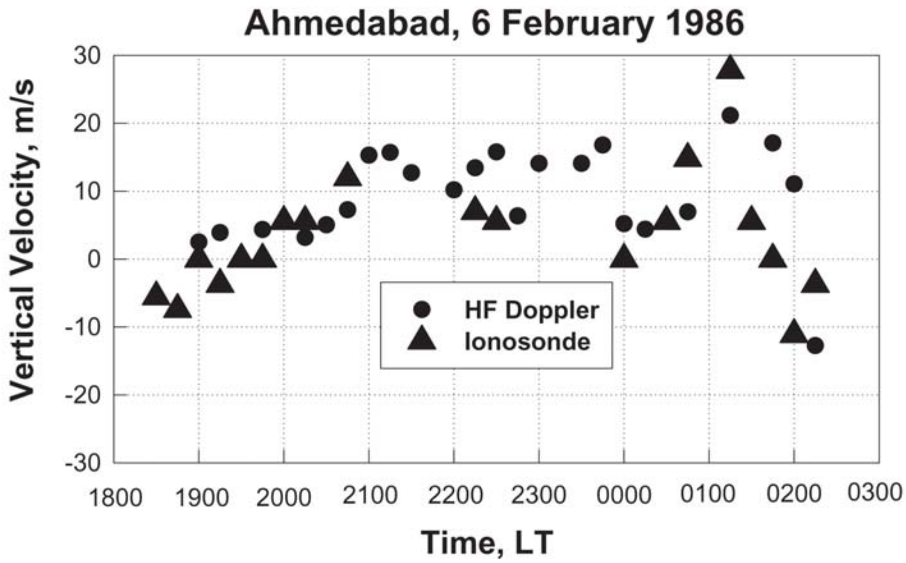

Figure 5. Comparison of the F-region vertical velocity measured by the HF Doppler method and derived from ionosonde during the night of 6 February 1986.

spread-F and also in controlling the peak electron density and height of F-layer. Co-ordianted vertical drift measurements at a chain of stations in India using HF Doppler technique is therefore important to understand the ionosphere-thermosphere system at low latitudes.

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