Multipoint Continuous Doppler sounding system

(Basic description of the system developed at the Institute of Atmospheric Physics, Academy of Sciences, Czech Republic, Prague,

Principle of measurement and recommended topology

The principle of Doppler sounding can be in a simplified way described as follows: A vertically-propagating radio wave reflects at the height where its frequency matches the local plasma frequency, which is determined by the electron density. It can be used for an investigation of infrasound, acoustic gravity waves (AGWs), geomagnetic fluctuations etc. An infrasound wave or AGW causes, via collisions between neutral and charged particles, fluctuations (movement) of the reflecting level, and hence the Doppler shift of the reflected radio wave.

The recommended system consists of 3 transmitters and 1 receiver (plus one transmitter and one receiver as spare pieces; the minimum configuration to study horizontal propagation of GWs is 3 transmitters and 1 receiver). **The recommended topology** is that the transmitters form approximately equilateral triangle, the receiver is located in the middle if possible. **The precise configuration is not critical, but the transmitters should not be on one straight line.** The recommended distance of transmitters is approximately 100 km. For the distances larger than ~150 km, the cross-correlations of signals usually decrease. On the other hand, for the distances shorter than ~ 50 km, the time differences between corresponding signatures on different signal paths are relatively small, hence the precision of determination of horizontal velocities decreases; in addition, the ground wave might be also strong for very short distances.

Range of frequencies and potential limitations

The system can detect ionospheric fluctuations of periods ~10 s and larger. The system is most suitable for studying of waves of periods from ~20 s to ~100 minutes (For larger periods the system works too, but the ionosonde might be more advantageous since it provides information from the whole range of altitudes.) The height of reflections depends on the electron density in the ionosphere, and can be determined from a nearby ionosonde. The best Doppler shift is usually observed when the reflection is from the F2 layer (~180 km-300 km). If the reflection is from altitudes lower than ~150 km (E layer), the Doppler shift is usually very small, and often difficult to analyze. In addition, during summer days, if the D layer is well developed, the sounding radio signal might experience a strong attenuation (very weak signal is received) around noon. If a so called spread F develops during the night, the spectrum of the received signal is also spread (wide), so it is not possible to characterize the received signal by a single Doppler shift frequency, and to determine time delays between corresponding signatures (waves) on different signals accurately (to compute propagation velocities).

Technical information

The Doppler system operates at fixed frequency, which can be selected depending on the local conditions (e.g. ~3.59, 4.65, and 7.04 MHz is used in the Czech Republic to obtain also the vertical component of propagation; 4.63 MHz is used in Argentina; 6.57 (4.66) MHz is used in Taiwan). The transmitted power is ~1W. Only carrier frequency is transmitted. An identification (call mark in Morse code) is transmitted each minute for ~6 s. GPS receivers are used for the time synchronization of the transmitters and receiver.

For the transmitters, dipole wire antennas (just few meters above ground) are sufficient. Just an access to power supply is enough for the transmitters.

For the receiver (Figure 1) dipole wire antenna can be used as well, but magnetic loop antenna is recommended for the receiver since they require less space, provide usually better signal to noise ration and minimize the potential damage by lightning. The internet connection is advantageous, but not necessary for the receiver. It is possible to download the data to a notebook via USB as well. The inner memory in the receiver is sufficient for about 11 days, but downloading 11 days of data (1GByte of data) takes relatively long time, the baud rate is ~0.9 Mbit/s via Ethernet or about 2 Mbit/s via USB. The memory can be enlarged.

The specific frequencies of the individual transmitters (Figure 2) are shifted by 4 Hz so that the signals of all transmitters could be displayed in one common Doppler shift spectrogram (Figure 3). The received signal is first mixed with the signal from the local oscillator. That allows a down-conversion to lower frequencies to reduce the volume of recorded data (IQ conversion scheme is used). All the oscillators in the transmitters and receivers are of high stability (on the order of $\sim 10^{-10}$). The low frequency signal is digitized and archived (both I and Q components). Next, the data processing, namely, a spectral analysis follows.

Data structure

The data are stored in binary files. Each file contains 15 minutes of record. The name of the file has the following notation:
YYMMDDHH.FXX,
Where YY= year, MM =month, DD=day, HH=hour, and XX=initial minute (00,15, 30, 45).

Each file consists of 15 data packets. Each data packet begins by a header, followed by a data block. The header, (64 Bytes), contains identification string, time stamp, coordinates of the receiver, and technological information (parameters set). The data block consists of 16384 samples. The sampling frequency is 305.1758 Hz, which actually corresponds to ~ 54 s of data. The data are not stored, when the calling mark is transmitted (~6 s). The data (16384 samples) are stored in 2 channels shifted by 90 degrees in phase (I, Q components), with 16 bit resolution. That means they are stored in 4*16384 = 65536 Bytes altogether.

Specific software was developed to control remotely the receiver and to perform primary data processing – visualization in the form of Doppler shift spectrograms.

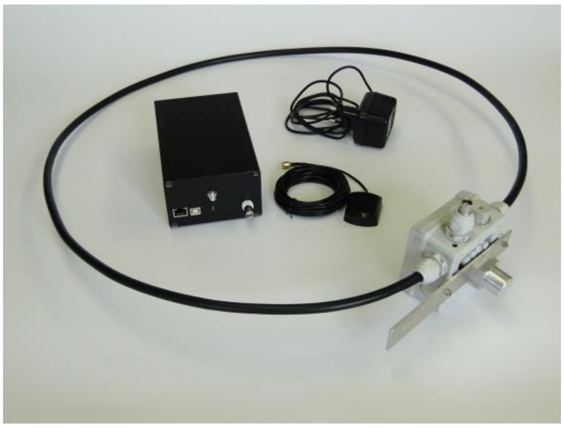

Fig. 1: Receiver set

Fig. 2: Transmitter set

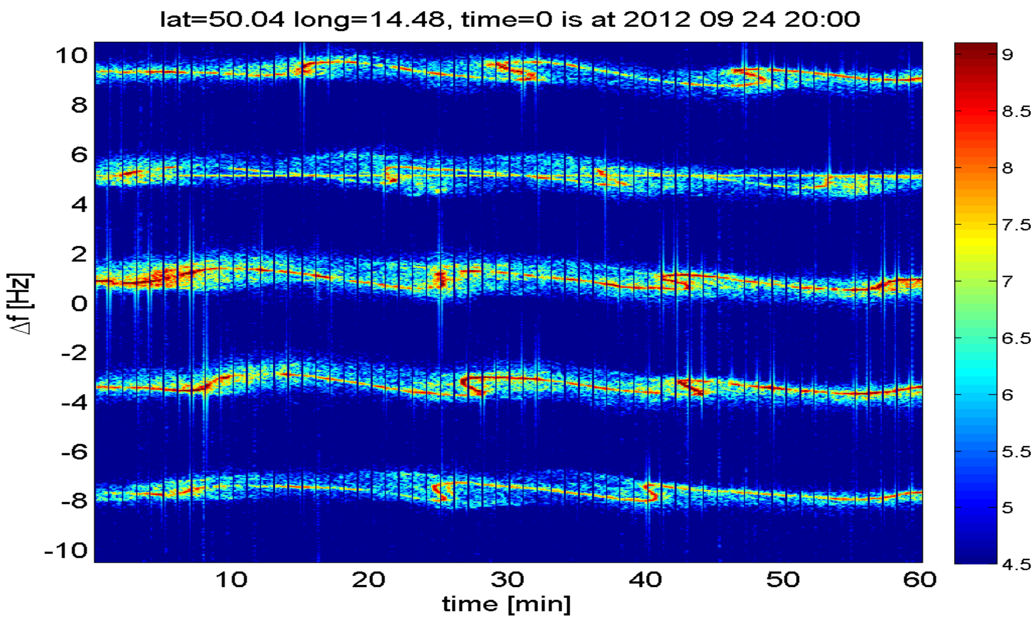

Fig. 3: An example of Doppler shift spectrogram showing Atmospheric Gravity Waves observation in the Czech Republic (signals from 5 transmitters).

Summary of technical specifications

Transmitters
3 pieces at three different locations
transmitted power - 1 W,
only power supply is needed,
recommended antenna: half wavelength dipole, e.g., simple wire antenna about 3 m above the ground

Receiver
Power supply and internet connection required
Assumed antenna: magnetic loop - around 1 m of diamter

Recommended distance between transmitters and receiver around 100 km (approximately from ~50 to ~120 km). In ideal case the transmitters should form roughly equilateral triangle.

Selected references:

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