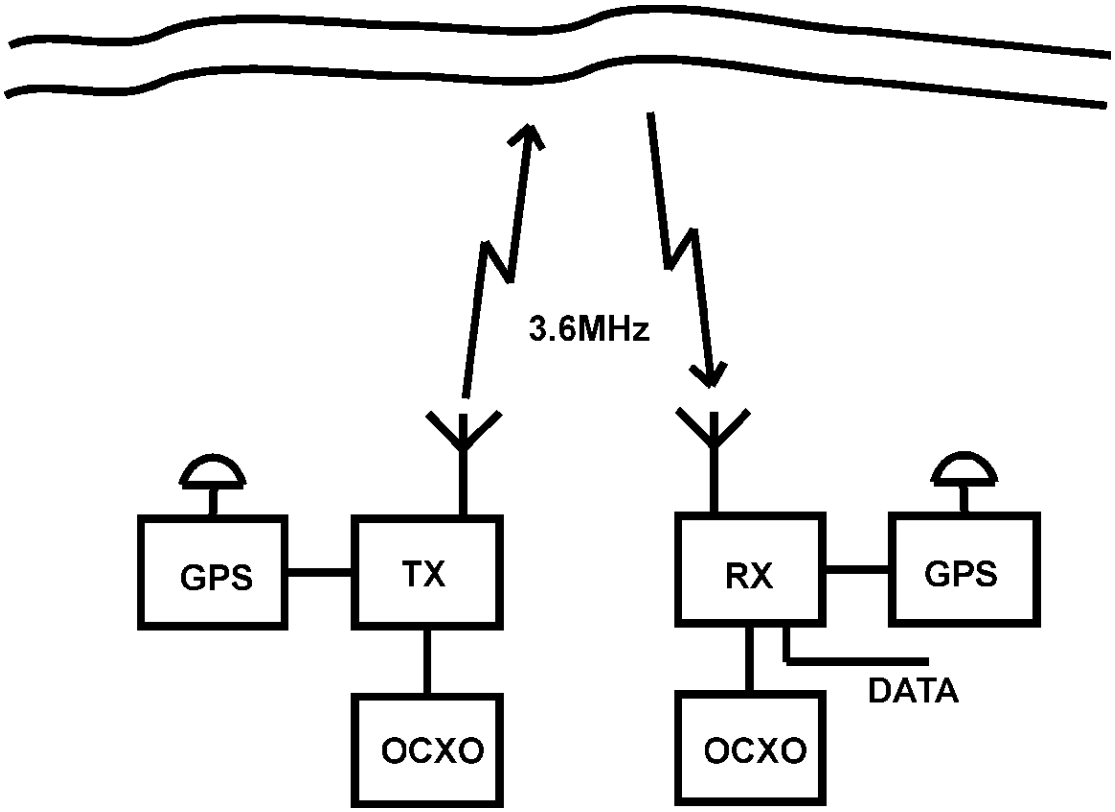
Description of the multi-point Doppler sounding system

A multi-point continuous Doppler sounding portable system is based on the measurements of the Doppler shift experienced by waves reflected from the ionosphere. The measurements are simultaneously performed on 3 to 5 frequencies with 4Hz separation around the centre frequency of 3594.5 kHz. Multipoint measurement makes it possible to investigate propagation of Acoustic Gravity Waves (AGW), infrasonic waves or ionospheric oscillations caused by fluctuations of geomagnetic field etc.
A precise frequency which is needed for Doppler shift measurements is generated by the direct digital synthesis derived from the high stability 10 MHz oscillators and controlled by the GPS clock. The overall stability of the order of $2x10^{-10}$ is achieved. The output power of each transmitter of is only 1 or 2 W. The recommended antenna is a dipole elevated to 5-10m above the ground. A maximum radiation is in the vertical direction. The Receiver can use the same dipole antenna or optionally, two crossed dipoles or magnetic loop antennas, which makes it possible to distinguish between ordinary and extraordinary waves.



Technical data

Transmitter:

frequency range	one frequency 3.594MHz (amateur band)
frequency stability	$2x10^{-10}$
power of transmitter	1W (30dBm)
type of modulation	CW + Morse code identification of ~5s duration every minute
type of sounding	vertical
transmitting antenna	horizontal dipole (2x 20m, approx. 5m high)

power consumption	4W/12 V DC
dimensions	200x100x50mm
weight	1kg

Receiver:

frequency range	one frequency 3.594MHz (amateur band)
bandwidth	100Hz
output	digital data, approx. 94MB/24h/channel
data interface	Fast Ethernet, RJ45 Connector
receiving antenna	horizontal dipole (2x 20m, approx. 5m high)
power consumption	approx. 10W/220V AC, battery operation as option
dimensions	250x150x75mm
weight	1kg

For dual-channel reception two units and two crossed dipoles or magnetic antennas are used.
The equipment can be tuned to other frequency if required.

For multipoint measurement (investigation of horizontal propagation) 4 to 5 transmitters are optimal.

An example of a Doppler shift spectrogram presenting signals from five transmitters after their reflections from the ionosphere is in Figure 2

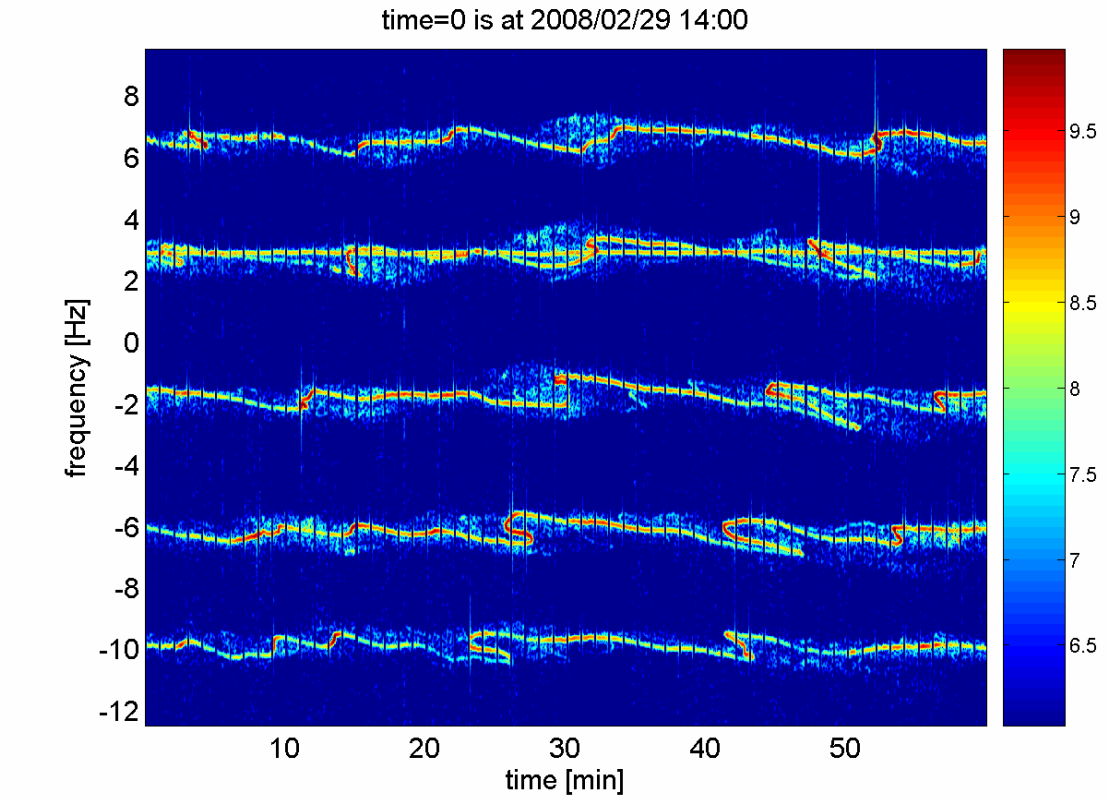


Fig. 2: Doppler shift spectrogram recorded from 14:00 to 13:00 UT on 29-2-2008.

Topology and other notes

The reflection points lie approximately in the midpoint between the transmitters and receiver (vertical projection to the Earth's surface).
The preferred distances between the transmitters and receiver are from ~60 to ~180 km. At higher distances, the individual signals seize to be correlated. At lower distances, the ground wave may partially disturb the measurement (it is seen on the second trace from the top in Fig. 1). The ground wave can be removed in frequency domain, if necessary; nevertheless, the signal with low Doppler shift is lost in such a case. The influence of the ground wave can also be minimized by proper orientation of the antennas (a minimum of antenna diagrams). The ground wave interference is negligible for distances larger than ~50 km. It also disappears if the receiver is shielded from the transmitter by a mountain. (Nevertheless, it could be advantageous to locate one transmitter relatively close to the receiver and to the ionosonde, obtaining in such a way a common volume measurement - ionosonde with one Doppler sounder). Generally, the transmitters should not lie in one line, they should form a rectangle or a rhomboid. The receiver should be more or less in the centre of the transmitters.

The frequency of transmitter can be changed to any desired. The so far used frequencies lie in the amateur band where transmitters serve simultaneously as beacons and help amateur assess the current condition of the ionosphere. So it is relatively easy to get a licence for the operation of transmitters. In this case an identification – call sign is transmitted each minute.