The Real-time Diagnostics of HF Radio Channel on the Base of Ionospheric Backscatter Sounding Data

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We present such method.

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- group path $P(f)$ and angle of arrival $G(f)$ of oblique sounding on the normalized grid of frequencies $\beta = f/f_m$, where f_m is the maximum usable frequency for the considered distance, $(P(\beta))$;

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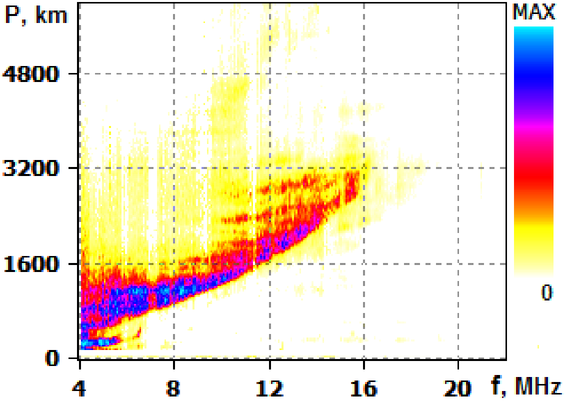
- group path $P_m(f)$ of a backscatter signal by the leading edge on the normalized frequency grid $\nu = f/f_m$, where f_m is the maximum usable frequency for the maximum propagation distance of a BS signal, $(P(\nu))$.

Method of direct diagnostics for radio channel

These ratios allow us to provide

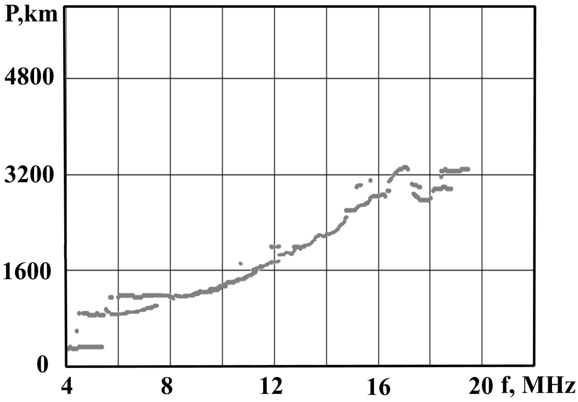
- automatic interpretation of the registered signals on BS experimental ionograms and constructing the backscatter leading edge;
- real-time determination of MUFs, $P(f)$, and $G(f)$ for the given radio path on BS data.

To check the method, we use a chirp ionosonde located in ISTP SB RAS to obtain BS data. It allows us to get ionograms like



Real-time diagnostics

We use simple data filtration by a cellular automaton to extract points with significant amplitudes corresponded to leading edge of a BS signal.



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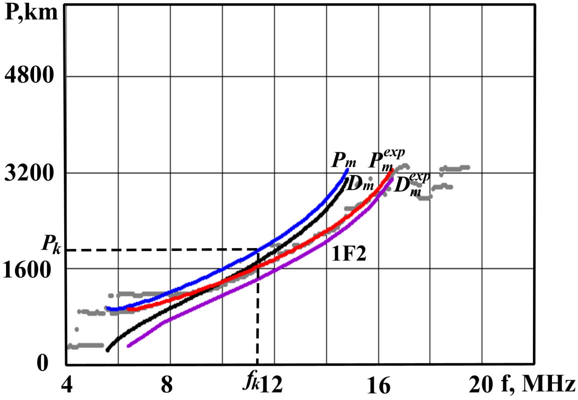
Further, the presented ratios allow us to scale simulated P_m and D_m to get best similarity with experimental gray points. It can be made various methods. Our choice is the mask around P_m. The value of the scale parameter ν is selected so as to provide best coverage of gray points by the mask. It gives us P_m^{exp}. The D_m^{exp} can be calculate with D_m and ν.

Here, you can see the result of such data processing. The simulated P_m (blue line) and D_m (black line) don't match for experimental data (gray points). Scaling solves this problem and allow us to match for gray points relatively well.



The calculation of MUF for a OS signal with fixed distance is based on an adiabatic ratio P_m/D_m. At the first stage for forecasting ionosphere parameters we calculate the leading edge of the BS signal $P_m(f)$ and the distance of the skip zone border $D_m(f)$. For radio path with distance D_0, the ratio $\eta = P_m/D_0$ is calculated.

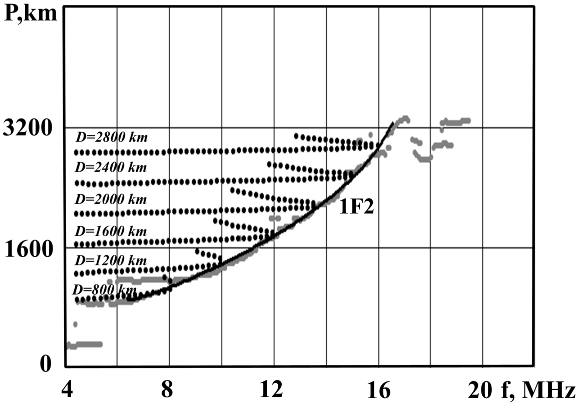
Further we use P_m^{exp} to determine the frequency f_m that corresponds the group path $P_m^{exp} = \eta D_0$. The frequency f_m is the real maximum usable frequency for the distance D_0.

After definition of MUF f_m for given distances with a help of BS data, one can restore real group path $P_r(f)$ and angle of arrival $G_r(f)$ of oblique sounding by the results of the long-term forecast.

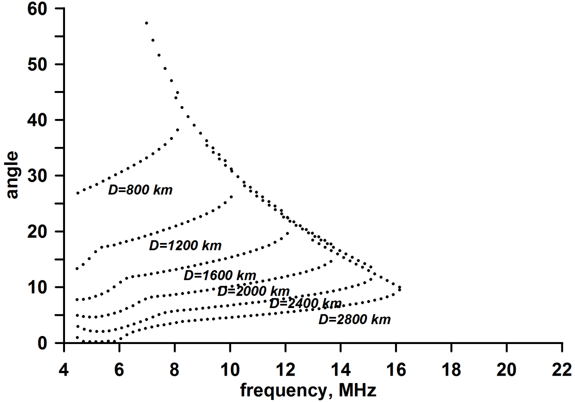
Oblique sounding characteristics, $P(f)$ and $G(f)$ are calculated for distance D_0. Then this characteristics recalculated to the relative grid of frequencies $\beta = f/f_m^d$. Here, f_m^d is maximal usable frequency for simulating OS.

The real OS sounding characteristics, $P_r(f)$ and $G_r(f)$, at current time moment is restored from $P(\beta)$ and $G(\beta)$ by multiplying β on f_m from the previous slide.

Here, you can see the result of restoration of group path P_r using BS data on the grid of distances.



Here, you can see the result of restoration of arrival angle G_r using BS data on the grid of distances.



BS ionogram inversion

Obtained P_m^{exp} allow us to determine the ionospheric parameters such as a critical frequency f_{cr} and a maximum height h_m of the 1F2 layer.

The following steps allow one to get this parameters

1. On a frequency grid $f_k, k = \overline{1, N}$, functions $D_m^k(f_{cr}, h_m)$ and $P^k(f_{cr}, h_m)$ are calculated for different admissible pairs of ionospheric parameters (f_{cr}, h_m) with quasi-parabolic dependence of profile $N_e(r)$. Parameters of quasi-parabolas, h_b and h_0 , are derived from h_m:

$$h_b = h_m \frac{c_b - 1}{c_b}$$

$$h_0 = h_m \frac{c_0 - 1}{c_0}$$

We set $c_b = 1.5$ and$c_0 = 8$.

2. From given frequency f_k we determine group path P_k using $P_m^{exp}(f)$, and distance D_k to the skip zone border using $D_m^{exp}(f)$. It will be correspond to set of parameters (f_{cr}, h_m).

3. A single pair of the ionospheric parameters (f_{cr}, h_m) is determined from equations

$$D_k = D_m^k(f_{cr}, h_m),$$

$$P_k = P_m^k(f_{cr}, h_m),$$

as a cross point of two curves representing solutions of these equations.

The skip zone border corresponding to distance D_k is formed by the ionospheric region at distance $D_k/2$ from the transmitter. This assumption are based on geometry of caustic curve in the waveguide for descending trajectories of one hop mode of propagation. The determined parameters allow us to plot the two-dimensional distribution of electron density along backscatter sounding.

Conclusion

- We present the methods of real-time diagnostics HF radio channel by the results of automatic processing and interpretation of backscatter ionosphere sounding received by the chirp ionosonde developed in ISTP SB RAS.
- The inversion scheme of the backscatter signal leading edge into parameters of the quasi-parabolic profile of electron concentration is presented on the basis of comparison of experimental and calculated minimum delays of scattered signals and corresponding distances to the skip zone border.