Use of television broadcasting signals for mesosphere/lower thermosphere wind measurements by the meteor radiolocation method

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Summary

Terrestrial television broadcast signals (TVBS) as sounding signals for mesosphere/lower thermosphere (MLT) wind measurements by the radio meteor method are used. Observations of TVBS reflected from meteor trails (transmitter Kyiv, carrier frequency 59.25 MHz and their Doppler carrier frequency shift (Δf) have been obtained in April 2010 at Kharkiv (50°01'N 36°14'E), Ukraine. Mean hourly Δf (Δf_{mean}) has diurnal and semidiurnal components typical for MLT winds. Validation of the obtained results has been performed using TIMED/TIDI satellite wind profiles. It shows that Δf_{mean} is proportional to the MLT wind, thus TVBS can be used for the MLT wind measurements by the radio meteor method.

Theoretical considerations

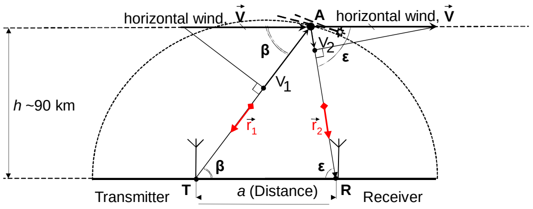

Fig. 1: Two projections of the meteor trail velocity for determination of the Doppler frequency shift of a sounding signal in bistatic radars.

Doppler frequency shift:

$$\Delta f = \frac{1}{\lambda} \cdot \vec{V} \cdot (\vec{r_1} + \vec{r_2}) = \frac{1}{\lambda} \cdot \left(\vec{V} \cdot \vec{r_1} + \vec{V} \cdot \vec{r_2}\right)$$

Δf = Doppler shift of the sounding signal carrier frequency, $\boldsymbol{V}$ = meteor trail drift vector; $\lambda = c/f_0$ =wavelength; f_0 = carrier frequency and c is the speed of light.

Doppler shift relative to wind speed:

$$D = \Delta f / |\vec{V}|$$

a) Parallel (||) drift of the meteor trail: (plot for $D_{||}$ in Fig. 2 , left).
b) Perpendicular (⊥) drift of the meteor trail (plot for $D_{\perp}$ in Fig. 2 , right).

If the transmitter is located westward or eastward of the receiver, the parallel /perpendicular drift equals the zonal /meridional wind component.

Parallel drift selection coefficient:

$$S_{||} = \frac{|D_{||}|}{|D_{||}| + |D_{\perp}|}$$

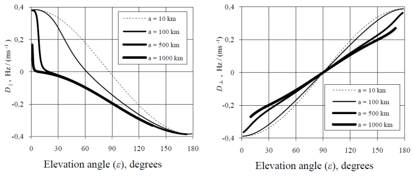

Fig. 2: Relative Doppler shift for different distances transmitter - receiver (a) and elevation angles (ε) of the meteor trail in the receiver position. Left panel (a) for $D_{||}$, right panel (b) for $D_{\perp}$.

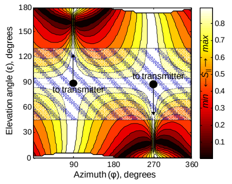

Fig. 3: Relation between $S_{||}$ and the angular coordinates (ε, φ) of the meteor trail for a = 500 km.

For ε close to 90° (reflections over the receiver, marked area) $S_{||}$ approaches unity, i.e. the Doppler shift (Δf) is mainly determined by the parallel wind component.

Conclusions

Use of TVBS allows to use external transmitters and consequently to reduce costs of MLT wind measurements. Validation has been performed using TIMED/TIDI satellite wind profiles over Kharkiv at the time of the radio measurements. The hypothesis that the experimental results and TIMED/TIDI winds are uncorrelated was discarded with a confidence of 95% (t-test). The mean diurnal variation of hourly average values of Δf is proportional to the MLT wind. This confirms that TVBS can be used for MLT wind measurements by the radio meteor method and that the developed technique can be used for MLT wind monitoring on the base of the existing TV broadcasting network. MLT vector wind monitoring is also possible by simultaneous using of several TV transmitters.

Acknowledgements:

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Experiment

Fig. 4: left: Kyiv transmitter (source of sounding signal); middle: receiver antenna for control of TVBS carrier frequency stability (top), for TVBS reflected from meteor trails and their spatial selection (bottom); right: receiver and reference frequency source (top); Analog/Digital Converter (ADC) (bottom)

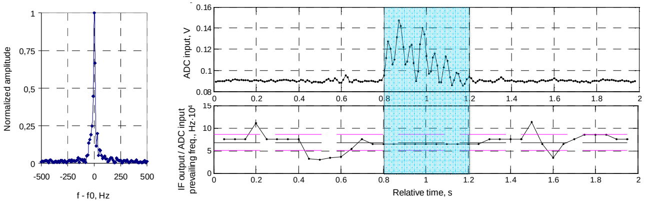


Fig. 5: left: 0.1s FFT-carrier frequency spectrum; right: example of meteor registration.

Validation

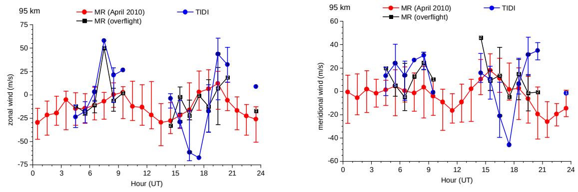
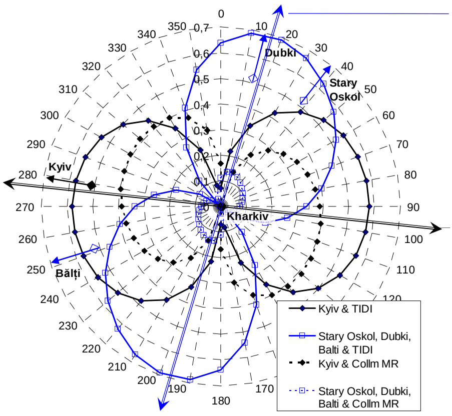


Fig.6: Monthly median hourly averaged Collm MR and TIDI zonal (left) and meridional (right) winds for 95 km height (at 51.3°N; 13°E).

Tab. 1: Location and working frequencies of used television transmitters within the second TV channel for Kharkiv, Ukraine.

Transmitter	Azimuth (φ); distance (a) (relative to Kharkiv)	Carrier frequency, MHz	Power, kW
Kyiv	279°; 414 km	59.25	340
Stary Oskol	38°; 173 km	59.239583	20
Dubki	14°; 865 km	59.239583	113
Bălți	251°; 656 km	59.239583	109



Δf_{mean} for TV transmitters Stary Oskol, Dubki, Bălți nearly corresponds to the MLT meridional wind (maximum correlation with TIDI wind projection to 15°-195° azimuth)

Δf_{mean} for TV transmitter Kyiv nearly corresponds to the MLT zonal wind (maximum correlation with TIDI wind projection to 95°-275° azimuth)

Fig. 7: Correlation coefficients between Δf_{mean} and projection of TIDI (solid lines) and Collm MR (dotted lines) MLT wind to different directions. Arrows indicate directions to the corresponding TV sources. Solid symbols denote Δf_{mean} for the TV transmitter Kyiv (f_0 = 59.25 MHz); open symbols (blue) to TV transmitters Stary Oskol, Dubki, and Bălți (f_0 = 59.239583 MHz).

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