Possible use of television broadcasting signals for wind measurements by the meteor radiolocation method – main theoretical aspects and results of first experiments

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Summary

The possibility of using terrestrial television (TV) broadcast signals (TVBS) as sounding signals for mesosphere-lower thermosphere (MLT) wind measurements by the radio meteor method is investigated. Such approach allows to use external TV transmitters as sounding signal sources and consequently to reduce costs of measurements. It is shown that meteor trails in the area above the receiver should be selected to eliminate MLT wind measurement ambiguity. Results of experimental observations are presented. Validation of the results has been performed using datasets from the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite and a SKiYMET meteor radar (Collm Observatory, Germany). It is shown that the obtained experimental results and TIMED mean winds are correlated with a correlation coefficient of 0.58 (significance level 0.95 according to a t-test). The measurements show for the first time that terrestrial television broadcast signals can be used for MLT wind measurements and that the developed technique may be used for MLT wind monitoring on the base of the existing terrestrial TV broadcasting network.

Zusammenfassung

Es wird untersucht, inwieweit terrestrischer Fernsehsignale zur Sondierung des Windes in der Mesosphäre und unteren Thermosphäre genutzt werden können. Ein solcher Ansatz erlaubt es, externe Sender als Quelle zu verwenden und damit Kosten zu sparen. Es wird gezeigt, dass Meteorsignale im Raum über dem Empfänger genutzt werden können, welches die Uneindeutigkeit der Windsignale verringert. Ergebnisse eines Experiments werden gezeigt und anhand von TIMED-Satellitendaten und VHF-Radarmessungen validiert. Die Messungen zeigen zum ersten Mal die Möglichkeit einer Windmessung in der unteren Thermosphäre auf der Basis terrestrischer Fernsehsignale.

1 Introduction

The meteor radiolocation method is one of the main techniques for wind measurements in the mesosphere/lower thermosphere region (MLT, 75-110 km) (Manning et al., 1954; Kashcheyev et al., 1967). The wind measurement principle is the detection of the Doppler shift of the reflected very high frequency (VHF) radio waves from ionized meteor trails, which delivers radial wind velocities along the line of sight of the radio wave. For the realization of such measurements special meteor radars (MRs) are used. These radars are actively transmitting and radiate a special sounding signal with a peak power ranging from few kilowatts to several megawatts and allow to determine the coordinates of meteor trails (elevation ε, azimuth angle φ, altitude h) and its drift velocity along the sounding direction (Hocking et al., 2001; Kashcheyev et al, 2002).

Oleynikov et al. (2010) showed that terrestrial television (TV) broadcast signals (TVBS) can be used as sounding signals for the radiolocation of meteor trails (estimation of meteor daily flux). The use of TVBS allows excluding the transmitter unit from the measurement equipment, because such kind of sounding signals have been already radiated by the existing transmitters of the terrestrial TV broadcasting network. Consequently the equipment for meteor radiolocation with TVBS as sounding signals enables one:

- to reduce operating costs of such by significant reduction of energy consumption, which is essentially determined by the transmitter unit,
- to carry out the measurements without registration of measurement equipment in the State Centres of Radio Frequencies,
- to carry out the measurements also within an urban environment. The use of active VHF MRs is usually allowed only far from urban areas and only in with the vertical direction of the sounding signal radiation. This requirement is caused by the high radiated power of active MR in a frequency band occupied by other users,
- to carry out the measurements without payment of the radio frequency registration fees, which in some countries as, e.g., Ukraine, are collected,
- to save energy (additional using of the energy of the TV transmitters).

The aim of this work is a further development of the work by Oleynikov et al. (2010), including the theoretical and experimental investigation of the possibility to use TVBS for MLT wind measurements by the meteor radiolocation method. Such an approach of TVBS use is, to our knowledge, investigated for the first time.

2 Theoretical aspects

In the case of using TVBS for radiolocation, the distance a between the receiver and the source of the transmitted signal (TV transmitter position) is comparable to or exceeds the range to the target (the meteor trail). Consequently, such kind of a radar-system may be classified as a bistatic radar. The Doppler frequency shift (F_d) can be calculated as (Skolnik, 1970; Chernjak, 1993):

$$F_d = \frac{1}{\lambda} \cdot \vec{V} \cdot (\vec{r_1} + \vec{r_2}) = \frac{1}{\lambda} \cdot \left(\vec{V} \cdot \vec{r_1} + \vec{V} \cdot \vec{r_2}\right), \quad (1)$$

where F_d is the Doppler shift of the sounding signal carrier frequency, $\vec{V}$ is the meteor trail velocity vector; $\vec{r_1}$ are $\vec{r_2}$ the vectors in the directions from the meteor trail to transmitter and receiver; $\lambda = c/f_0$ is the wavelength of the sounding signal carrier frequency f_0, and c is the speed of light. The geometry of the problem is shown in Fig. 1.

Eq. (1) and Fig. 1 show that the Doppler shift of the sounding signal carrier frequency is a sum of two terms, essentially the scalar products $\vec{V} \cdot \vec{r_1}$ and $\vec{V} \cdot \vec{r_2}$, which are proportional to the meteor trail velocity projection on the sounding signal propagation path between transmitter/receiver and trail. Hence the Doppler shift depends on the geometry of the sounding signal propagation path or, in other words, on the meteor trail location relative to the receiver and transmitter. Thus, for a constant wind velocity vector the Doppler shift can have different values for various locations of the trail (e.g. its *h*, and angular coordinates ε, φ relative to receiver position).

Fig. 2 shows the dependence of the value $D = F_d / |\vec{V}|$ on the elevation of the meteor trail in the receiver position (ε, Fig. 1). The *D* value characterizes the Doppler shift of the reflected signal relative to the magnitude of the trail velocity vector. The curves in Fig. 2 were calculated by Eq. (1) for the following special cases:

- parallel (||) drift of the meteor trail in the parallel plane, which contains the transmitter and receiver positions and which is orthogonal to the Earth's surface. The drift of the meteor trail is directed from the transmitter to the receiver (plot for $D_{||}$ in Fig. 2 a). Note that in the case the transmitter is located westward or eastward of the receiver, the parallel drift equals the zonal wind component,
- perpendicular (⊥) drift of the meteor trail in the perpendicular plane, which contains the receiver position (plot for $D_{\perp}$ in Fig. 2 b). The perpendicular plane is orthogonal to the Earth's surface and to the parallel plane. In the case the transmitter is located westward or eastward of the receiver, the perpendicular drift equals the meridional wind component.

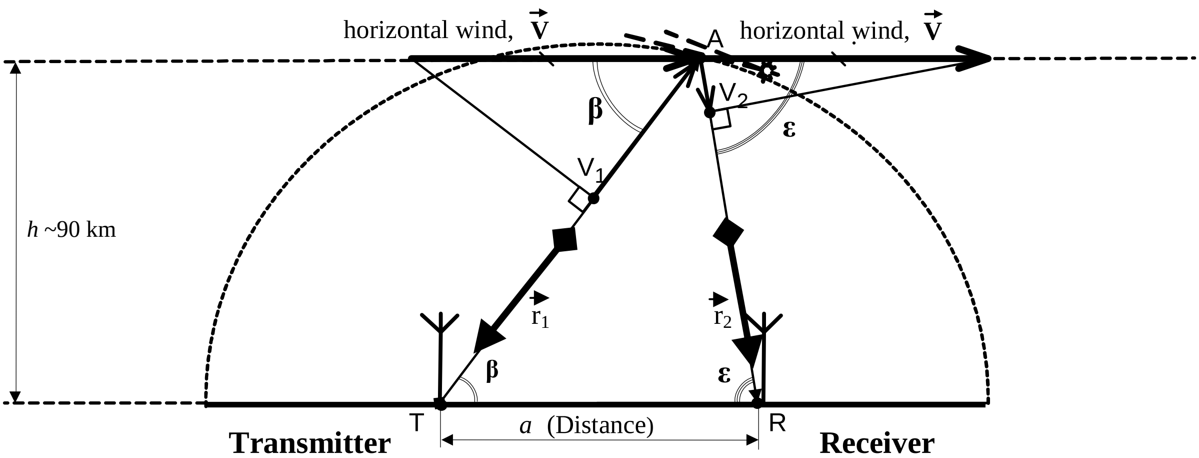

Fig. 1: Two projections of the meteor trail velocity for determination of the Doppler shift of a sounding signal in bistatic radars.

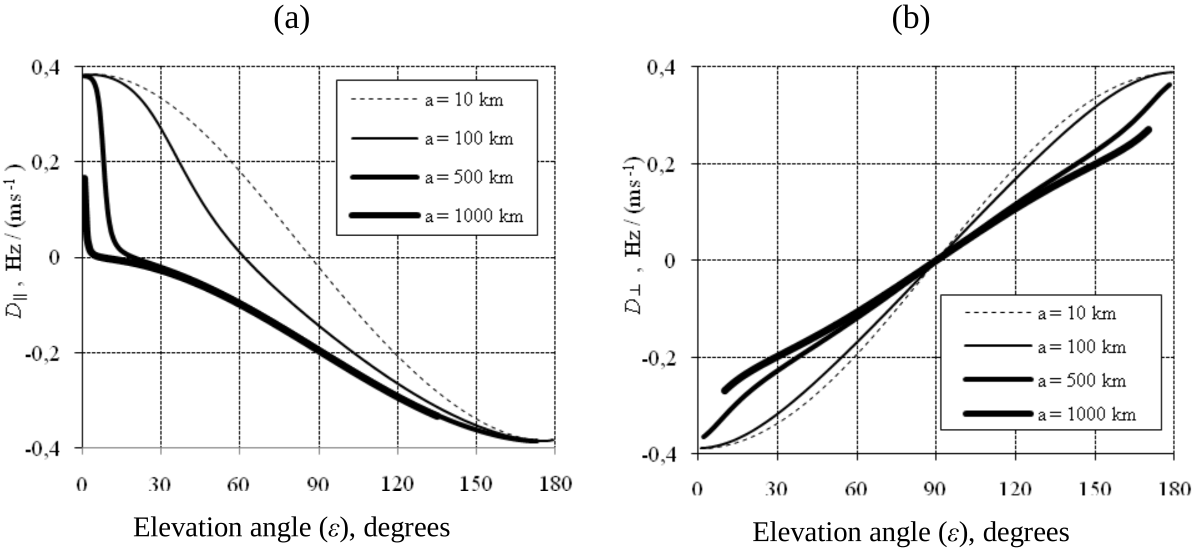

Fig. 2: Relative Doppler shift of reflected signals for different elevation angles ε of the meteor trail in the receiver position. Left panel (a) for $D_{||}$, right panel (b) for $D_{\perp}$.

The calculations for both cases were performed under the assumption that vertical winds are small (Hocking et al., 2001), taking into account the curvature of the Earth's surface, for a constant magnitude of the meteor trail drift velocity vector (1 m/s) at 90 km altitude, and for different *a*. The carrier frequency of the sounding signal corresponds to the nominal value of the second TV channel carrier frequency f_0 = 59.25 MHz, GOST 7845-92 (1992).

Fig. 2 also shows that Doppler shift of the same order of magnitude may be caused by either parallel or perpendicular drift of the meteor trail. Likewise, the same component of the drift vector (parallel or perpendicular) can produce different Doppler shift, even with a different sign, since the sign of the Doppler shift depends on ε. There are also ε values, for which one of the drift components causes no Doppler effect, when $D_{||}$ or $D_{\perp}$, respectively, is equal to zero. In conclusion, the influence of ε and the combination of parallel and perpendicular wind component lead to ambiguity of the meteor trail drift measurements.

To analyse the meteor trail drift velocity measurement ambiguity the selection coefficient of the parallel drift ($S_{||}$) component is used:

$$S_{\|} = \frac{|D_{\|}|}{|D_{\|}| + |D_{\perp}|} \ , \qquad (2)$$

which quantifies the contribution of the Doppler shift due to the parallel drift component to the overall Doppler shift. Values of $S_{||}$ close to unity/zero mean that the Doppler shift is essentially determined by the parallel/perpendicular drift component. Fig. 3 presents the relation between $S_{||}$ and the angular coordinates (ε,φ) of the meteor trail relative to the receiver position. The transmitter position (point T in Fig. 2) is chosen $a = 500$ km westward from the receiver (the transmitter is below the horizon relative to the receiver, $\varphi = 270°$, $\varepsilon \approx -2.2°$ or for the same point $\varphi = 90°$, $\varepsilon \approx 182.2°$). The meteor height is taken as $h = 90$ km. Fig. 3 shows that maximum $S_{||}$ corresponds to meteor trails with ε close to 90° and those in a direction away from the transmitter.

With increasing a the area with $S_{||}$ close to unity increases and the area of minimum $S_{||}$ is shifted to lower ε. However, at very large a the spherical Earth's surface shields the sounding signal propagation path. This effect is negligible for $a < 700$ km. For example, for $a = 500$ km receiving of the signals reflected from meteor trails can be impossible for $\varepsilon > 170°$ (<10° in the direction opposite to the transmitter, see Fig. 3). For selecting and measuring of the parallel component of the meteor trail drift velocity (and thus the parallel component of MLT wind) only those signals should be used that are reflected from meteor trails within the area with $S_{||}$ close to unity (dashed area in Fig. 3). For $a > 100$ km the condition $S_{||} \geq 0.5$ corresponds to $\varepsilon = 90 \pm 45°$. Such a spatial selection of meteor trails can be realized using a vertically pointing antenna with a beamwidth that should not exceed ~60-90° (Kukush et al., 2011a).

We may conclude that the Doppler shift due to $D_{||}$ has a constant sign in the region above the receiver position ($\varepsilon = 90 \pm 45°$, see Fig. 2 for $a > 100$ km). In contrast to $D_{||}$, $D_{\perp}$ has negative values for ε less than 90° and positive values for ε more than 90°. If the distribution of ε is symmetric about 90°, the average value of $D_{\perp}$ will tend to zero in contrast to the average value of $D_{||}$. Consequently, the mean selection coefficient $S_{||}$ for averaged values of $D_{||}$ and $D_{\perp}$ will exceed $S_{||}$ for single values of $D_{||}$ and $D_{\perp}$. Hence the average Doppler shift for signals from meteors above the receiver are expected to correspond to the average parallel MLT wind component more closely than individual values.

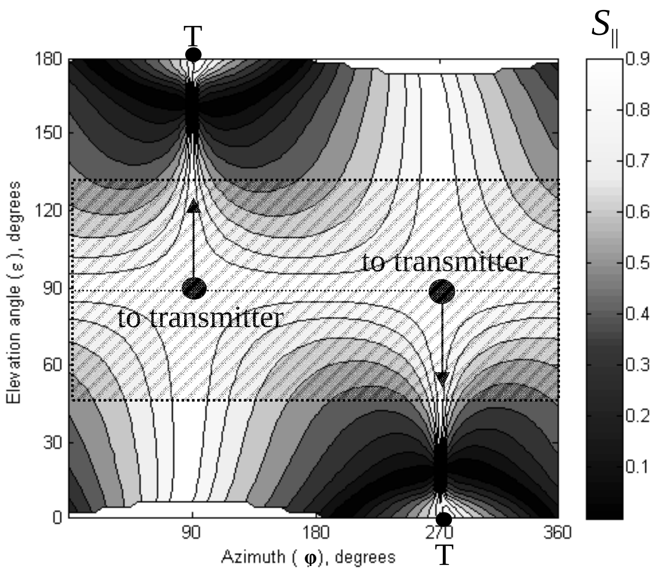

Fig. 3: Relation between the selection coefficient of the meteor trail drift parallel component ($S_{||}$) and the angular coordinates (ε, φ) of the meteor trail.

Tab. 1: Location and working frequencies of sources of TVBS within the second TV channel for Kharkiv, Ukraine.

Transmitter	φ; *a* (relative to Kharkiv)	carrier frequency, MHz; and CO (rounded to 0.1kHz)	Power, kW
Kyiv	279°; 414 km	59.25; (0 kHz)	340
Stary Oskol	38°; 173 km	59.239583; (–10.4 kHz)	20
Dubki	14°; 865 km	59.239583; (–10.4 kHz)	113
Borisoglebsk	40°; 436 km	59.260417; (+10.4 kHz)	40
Bălți	251°; 656 km	59.239583; (–10.4 kHz)	109
Bryansk	36°; 380 km	59.260417; (+10.4 kHz)	36
Vilnus	309°; 907 km	59.253906; (+ 3.9 kHz)	177
Krasnodar	159°; 593 km	59.244792; (– 5.2 kHz)	27

Receiving signals along the vertical direction has advantages also from a practical point of view: because of the vertically oriented maximum of the directional diagram, the receiver antenna has large attenuation for "terrestrial" signals. These signals can come directly from the transmitter or from other transmitters, which have similar working frequencies (within one octave) and which are located in a similar direction than the receiver. Such signals, owing to their large possible power, could mask the signals reflected from meteor trails or cause nonlinear distortion in the receiver.

A vertically oriented receiver antenna offers equal conditions for receiving of TVBS reflected from meteor trails, which are radiated by different TV transmitters at different φ. For each signal it is then possible to estimate the MLT wind component parallel to the azimuth of the corresponding TV transmitter. Hence various components of the MLT wind can be measured in the same region and the horizontal MLT wind vector can be estimated.

3 Usable transmitters of second TV channel for MLT wind measurements at Kharkiv, Ukraine

There are no TV transmitters of the second TV channel directly in Kharkiv. This enables one to receive signals from remote TV transmitter of the second TV channel (see Tab. 1) by reflection from meteor trails (Oleynikov et. al., 2010). However, receiving TVBS reflected from meteor trails is not always possible in a real environment with substantial noise sources.

Measurements of the meteor trail velocity using reflected TVBS requires the knowledge of φ of a signal source to determine the azimuth of a measured wind component. Initially such kind of information is not defined, because each of the TV transmitters in Tab. 1 can be the source of received TVBS. The signal source, however, can be identified by the carrier frequency (f_0), being the sum of the nominal frequency of the TV channel (constant for all TV transmitters of the same channel) and the carrier offset (CO), which is individually defined for each TV transmitter in the national standards (e.g., GOST 7845-92, 1992) and has an order of magnitude of 10 kHz. Therefore, the carrier frequency estimation of TVBS reflected from meteor trails allows to obtain the following information:

- a coarse estimation of the frequency (to the order of magnitude of kHz) allows to identify the source of TVBS (TV transmitter). Unambiguous identification is not always possible, because some TV transmitters have the same working frequency/CO, see Tab. 1. However, this estimation can significantly reduce the list of possible transmitters of the received signal,
- an accurate estimation of the frequency (to the order of magnitude of Hz) and its shift from the working frequency of corresponding TV transmitter allows to estimate the Doppler shift, which was caused by the meteor trail drift parallel to the direction from receiver to a defined TV transmitter.

The average duration of a meteor is ~0.1 s and may reach up to 2 s (McKinley, 1961; Hocking et al., 2001). The stability of the TVBS carrier frequencies during such a short time interval is not regulated in the corresponding normative documents such as GOST 7845-92 (1992). However, this parameter is critical for the measurement of meteor trail drift velocity. Kukush and Oleynikov (2010) experimentally estimated the standard deviation δ_{rad} of the TVBS vision carrier frequency. The structure of their instrumentation was similar to the one used here (see section 4 below). For the stability measurements the ground waves of TV transmitters at Stary Oskol (second TV channel) and Kharkiv (third TV channel) were used. The measurement time (τ_{meas}) was chosen equal to the average duration of the meteor trail signal (0.1 s) and more. It was found that $\delta_{rad} = 2$ Hz for $\tau_{meas} = 0.1$ s, $\delta_{rad} = 0.3$ Hz for $\tau_{meas} = 10$ s, and $\delta_{rad} = 1$ Hz for $\tau_{meas} = 24$ h. Thus, δ_{rad} does not exceed the typical values of the Doppler shift (several tens of Hz) owing to meteor trail drift. Hence the vision carrier frequency of TVBS is sufficiently stable for the Doppler shift estimation, being the difference between the working frequency of a TV transmitter and the frequency of its signal, which was reflected from a meteor trail.

4 Description of the test equipment

The test equipment consists of a three-element Yagi receiver antenna, a specialized receiver, standard analog-digital converter (ADC), a reference frequency source and a computer for digital signal processing (Kukush et al., 2011b). The antenna points vertically. The 3 dB beamwidth is 90° (by simulation results from the program MMANA, (Mori, 2000)). The antenna is used for receiving and spatial selection of TVBS reflected from meteor trails above the receiving position. It agrees with the requirements of the measurements of the meteor trail parallel drift velocity component or parallel component of MLT wind (see above).

The receiver is of single superheterodyne type. It has an amplitude detector and amplitude limiter outputs, which are used for the power and carrier frequency estimation of the received signal. The intermediate frequency (IF) of the receiver is 6.5 MHz. The IF channel bandwidth is 160 kHz. The adjacent-channel selectivity in the IF path is 40 dB. Adjacent and image channel selectivity in the radio path is at least 60 dB. The receiver sensitivity in the antenna input is better than 1 mV (with the output signal-to-noise ratio (SNR) equal to 2). The high adjacent and image channel selectivity makes it possible to receive the meteor trails signals in urban conditions with noisy environment. The reference frequency source is used for the local oscillator and A/D clocking voltage synchronization. The instability of the reference frequency source (type Ч6-31, russ.) is $5 \cdot 10^{-10}$ for τ_{meas} = 10 s, $5 \cdot 10^{-8}$ for τ_{meas} = 24 h, and $5 \cdot 10^{-7}$ for τ_{meas} = 6 months. The on/off frequency setting error is $5 \cdot 10^{-8}$.

A series of test measurements had shown that this test equipment allows to estimate the frequency of a radio signal with few μV amplitude during a measurement time of 0.1 s with a standard deviation error in the order of magnitude of few Hz. The precise error value depends, among others, on the input SNR, and the envelop type of the signal. The expected TVBS carrier frequency Doppler shift due to reflection from meteor trails is much greater than this error and can take values up to several tens of Hz for meteor trails with a drift velocity up to 150 m/s (McKinley, 1961) and $\varepsilon = 90 \pm 45°$. Hence the specifications of the test equipment are sufficient for receiving TVBS reflected from meteor trails and to reveal its carrier frequency Doppler shift.

5 Experimental results

At the Kharkiv National University of Radio Electronics, Kharkiv (50°N; 36.2° E), Ukraine, four series of continuous measurements using the above described test equipment were carried out during April 2010. The dates of the measurements are: 1.-3., 12.-14., 16.-19., 21.-23. April 2010. In total, more than 7,500 meteor echoes from TVBS were recorded. The distribution of the received signal carrier frequencies has a clear peak at 59.25 MHz within 120 kHz bandwidth (the nominal value of the second TV channel vision carrier frequency). The maximums of the distribution correspond to working frequencies of TV transmitters that can be received in Kharkov by reflection from meteor trails (see Tab. 1). The total number of received signals is different for each radio frequency and depends on the power and distance of the respective transmitter. The diurnal variation of the hourly number of signals agrees well with literature (McKinley, 1961; Kashcheyev et al, 1967; Arras et al., 2009).

The width of the received carrier signal frequency distribution in the vicinity of the working frequency for specific TV transmitters (Tab. 1) exceeds more than three times the standard deviation of TVBS carrier frequency variation before reflection. The deviation of the carrier frequency of the TVBS reflected from meteor trails (Δf) reaches 40 Hz, while the standard deviation of the TVBS carrier frequency before the reflection from the meteor trail (the stability of the TV transmitter working frequency) is smaller than 2 Hz for τ_{meas} = 0.1 s (Kukush and Oleynikov, 2010).

The mean diurnal variations for all experimental data of the carrier frequency shift (Δf_{mean}) are shown in Fig. 4. The values are calculated separately by TVBS, which are radiated by transmitters with two different working frequencies. It should be noted that before the Δf_{mean} calculation the series of Δf was limited within a 10 Hz band centered in the respective TV transmitter working frequency to bring them to a single-mode distribution law. The amount of single Δf for the Δf_{mean} calculation ranges between 32 and 100 values per hour (referred to the mean diurnal variations) for the TV transmitter at Kyiv and from 15 to 80 values per hour for the TV transmitters at Stary Oskol, Dubki, and Bălți.

If the observed Δf and Δf_{mean} are caused by the Doppler effect due to reflection from meteor trails, then these variations should be correlated with the variation of the parallel component of mean meteor zone wind speed. The direction of the parallel component of the wind speed is determined by the azimuth of the source of the received TVBS. Winds from the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite and the Collm MR are used to reveal the correlation between the experimental Δf_{mean} and variations of the MLT wind.

TIMED is a low-Earth orbiting (625 km) NASA satellite that started its measurements in 2001 (http://www.timed.jhuapl.edu). One of the four experiments on board TIMED is the TIMED Doppler Interferometer (TIDI, Killeen et al., 1999, 2006). It measures horizontal winds and temperatures at 60 – 300 km with a vertical resolution of ~2 km at the lower altitudes and with accuracies that approach ~3 m/s and ~2K, respectively. Each profile takes 100-200 seconds to complete. This results is a nominal horizontal spacing of approximately 750 km between profiles along the orbit. The precession rate of TIMED is such that it will take 60 days to precess 12 hours in local time. Hence, a one-month TIDI dataset is not sufficient to construct a mean diurnal wind variation that covers all local times. During April 2010, TIDI measured up to three wind profiles per day in an area of 10x10 degrees centered around Kharkiv.

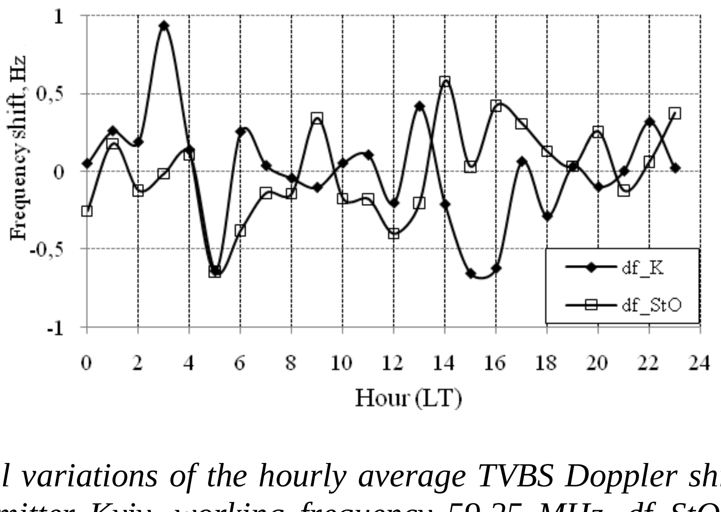

*Fig. 4: Mean diurnal variations of the hourly average TVBS Doppler shifts. The curves show: df_K – transmitter Kyiv, working frequency 59.25 MHz, df_StO – transmitters Stary Oskol, Dubki, and Bălți, 59.239583 MHz (*CO *≈ –10.4 kHz).*

The low statistical reliability (compared to, e.g., a radar) of the TIDI dataset for a local area is compensated by the following advantages:

- it is possible to reconstruct the horizontal wind vector,
- the TIDI wind profiles were obtained simultaneously in the same volume than the experimental measurements.

The SKiYMET MR at Collm Observatory (51.3°N; 13°E), Germany has been operated nearly continuously since summer 2004 (Jacobi et al., 2005; Jacobi, 2011). The latitude is close to the one of Kharkiv, while the longitude differs by 23.2°. However, the main diurnal variation at higher midlatitudes is owing to the semidiurnal tide, which is known to be essentially migrating. Monthly mean amplitudes and phases (the latter in local time) are similar at different longitudes (e.g., Jacobi et al., 1999). Hence, it is also possible to use the Collm MR winds for comparison with the Kharkiv experimental data. First, however, we use the MR data to validate the TIDI winds. Fig. 5 shows that Collm MR and TIDI mean diurnal wind variations during April 2010 correspond to altitudes above ~90 km. We conclude from that for the altitude of maximum meteor detection rate we may use TIDI winds for comparison with the radio-meteor winds. The distribution of meteor heights has a near Gaussian envelope with a maximum between 85 and 95 km; very often the centroid altitude is near 90 km (Kashcheyev et al., 2002; Stober et al., 2008).

Fig. 6 presents the correlation coefficients between the mean diurnal variation of hourly averaged frequency shift values Δf_{mean} and hourly averaged TIDI vector wind $\vec{V}_{TIDI}$ projections for different azimuths of this projection. Two separate sets of Δf_{mean} are used for TVBS emitted by transmitters with different working frequencies, similar to Fig. 4. $\vec{V}_{TIDI}$ values are averaged between the height range 87.5-92.5 km. Corresponding correlation coefficients using Δf_{mean} and vector wind values of the Collm MR ($\vec{V}_{COLLM}$) are also shown. These are obtained for the same time and altitude range, but refer to the MLT region over Collm. The correlation analysis between the variations Δf_{mean} and projections of $\vec{V}_{TIDI}$ and $\vec{V}_{COLLM}$ at different directions (Fig. 6) shows the following:

- maximum correlation between Δf_{mean} and $\vec{V}_{TIDI}$ or $\vec{V}_{COLLM}$ projection is found for a direction pointing to (or away from) the respective TVBS sources. If the working frequency is used by several transmitters (e.g., for $f_0 = 59.239583$ *MHz*, CO ≈ *-10.4 kHz*; TV transmitters in Stary Oskol, Dubki, and Bălți), the direction for maximum correlation lies "between" the directions to these TV transmitters according to their respective power and distance,
- maximum correlation coefficients exceed 0.58 (significance > 0.95, according to a t-test),
- minimum correlation is found for a direction orthogonal to one to the transmitter,
- the maximum correlation between Δf_{mean} and projections of $\vec{V}_{TIDI}$ is stronger than the corresponding correlation between Δf_{mean} and $\vec{V}_{COLLM}$, owing to the spatial difference of 23.2° in longitude and 1.3° in latitude, giving rise to mean diurnal wind differences at time scales below the semidiurnal tidal one.

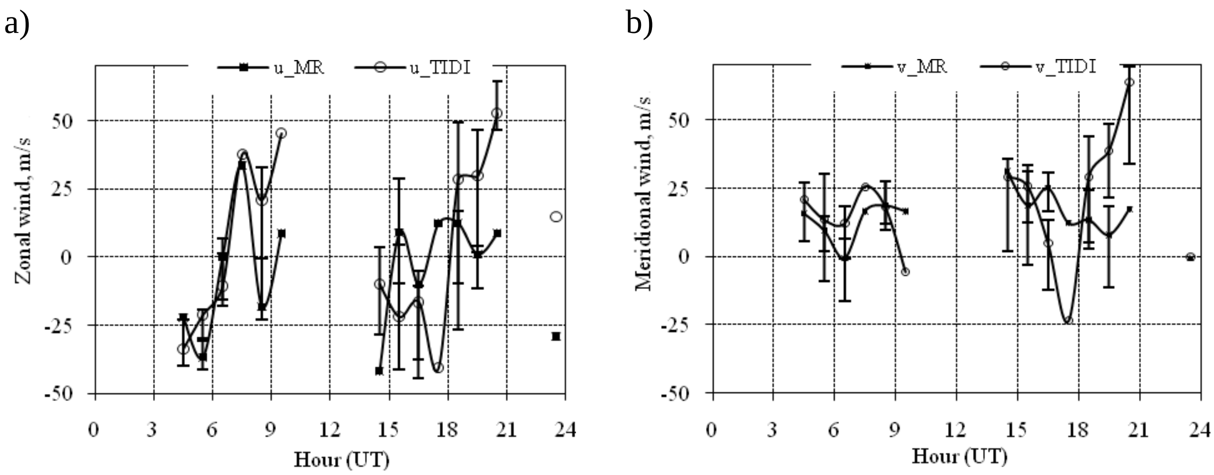

Fig. 5: Monthly mean hourly averaged Collm MR and TIDI zonal (a) and meridional (b) winds for 90 km height. Data are from April 2010 including all profiles when the TIDI profile matches the Collm one.

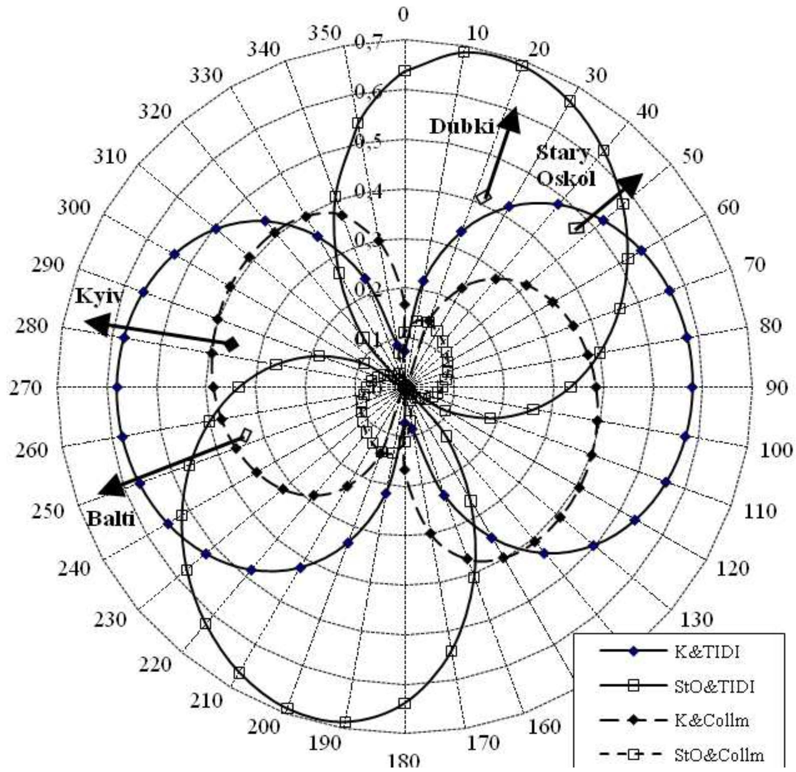

Fig. 6: Correlation coefficients between TVBS frequency shift (Δf_{mean}) and projection of TIDI (solid lines) and Collm MR (dotted lines) MLT wind to different directions. Arrows indicate directions to the corresponding TVBS sources. Solid symbols denote Δf_{mean} for the TV transmitter Kyiv (f_0 = 59.25 MHz); open symbols to TV transmitters Stary Oskol, Dubki, and Bălți (f_0 = 59.239583 MHz, CO ≈ *–10.4 kHz).*

The experimental results confirm that the measured carrier frequency shifts are caused by the Doppler effect due to meteor trail drift through the MLT wind, because they are proportional to the parallel MLT wind component. Such parallel components nearly correspond to the zonal wind by using signals from the TV transmitter Kyiv and the meridional wind by using a signals from TV transmitters Stary Oskol, Dubki, and Bălți. Hence the TVBS can be used for MLT wind measurements by the MR method.

Conclusions

The possibility of using terrestrial TV broadcast signals (TVBS) as sounding signals for MLT wind measurements by the radio meteor method is investigated for the first time. Use of TVBS allows to use external transmitters and consequently to reduce costs of such measurements. Using a specially developed receiver und digital signal processing tool, observations of TVBS reflected from meteor trails (second TV channel, nominal carrier frequency 59.25 MHz, SECAM colour TV system) and their Doppler shift have been obtained in April 2010 at Kharkiv, Ukraine. Validation of the obtained results has been performed using TIMED/TIDI satellite wind profiles over Kharkiv at the time of the radio measurements and Collm MR data. The hypothesis that the experimental results and TIMED/TIDI winds are uncorrelated can be discarded with a confidence of 0.95 (according to a t-test).

The measurements show that the mean diurnal variation of hourly average values of Δf is proportional to the MLT wind. It confirms that the 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 terrestrial TV broadcasting network. MLT vector wind monitoring is also possible by simultaneous using of several TV transmitters.

But this kind of TVBS usage is still to be further investigated due to relatively short time interval of the experiment TIMED satellite dataset used for validation does not have full time coverage. Validation of the results using a MR in the same area would lead to more reliable results. Further, during the experiment the angular coordinates of corresponding meteor trails are not known. There parameters, however, are necessary to increase the accuracy of MLT wind measurements and for possible wind profile estimation, and could be obtained using multi-channel receiver with spatially distributed antennas, which can be configured to act as an interferometer.

Acknowledgements

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