“Mobile System for Remote Sensing of Wind, Humidity, Temperature and Precipitation Microstructure Profiles during Special Events and Sport Competitions”

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Introduction

Meteorological support of the special events became more and more desirable, because the now casting at the definite place in definite time is often more important than very accurate weather forecasts for the region with 24 hours scenario. One of the bright example of such event is Olympic Games. More and more improved sports records are much more dependant from the weather now then even 20-30 years ago. And it is especially true for the winter Olympic Games – practically all kind of open air competitions are depended on the wind, precipitations and current snow surface conditions.

It is well known, that the accuracy of the weather forecasts as on the long scale as for now casting is in the forward correlation with the space density of the observational net. The utilization of the area observations as weather radar is very much appreciated, as they allow improving 1-2 hour forecasts. Upper air soundings can provide local small range NWP models with the fresh data flow, which makes the results of NWP much more valuable.

However, construction of the developed meteorological infrastructure is very expensive operation. And making decision, what kind of instruments use to be implemented at the site on the permanent base, and what kind of instruments can be used on the temporary base is always result of very difficult compromise. The two main questions in such compromise are: who and how will operate with these facilities after the event. If there is not positive answer on any of these questions for each definite system, thus the systems use to be accepted as “temporary”.

On the base of the above consideration, the system for remote radar wind profiling and remote microwave radiometer temperature and humidity profiling during Sochi 2014 Winter Olympic Games were decided as “temporary”. The remote sensing tools (except weather radars) are steel requires personal with high qualification at site. Local weather services don’t have such personal. Utilization of the “real time” wind profiles and temperature\humidity profiles are not in duty obligations for the routine measurements at local weather services.

Due to these reasons, it was decided to construct mobile facility for wind and temperature\humidity remote sensing with the ability to provide atmosphere parameters profiles up to the height 3km above the installation height. The mobile installation can be easy exploit after the Sochi 2014 for weather service of the other special events. From the other hand, the possibility to move the observational point even during the Olympic Games in Sochi provides special flexibility to the scientists, who will take care about now casting. Taking into account the synoptic situation, it is always possible to move and install the system on the position in front of general atmosphere motion. So the air mass, which is expected to be at the Olympic object, will pass over the sounding place 1-2 hours earlier, which will give great benefit for the forecasters.

But, such a strategy creates additional difficulties in obtaining of the information with satisfactory quality. The problems are that mountain environment has a strong impact on the wind profiler side lobes and horizontal homogeneity of the air temperature and humidity. These problems and possible ways of overlapping are discussed in the report.

System construction

The system of vertical profiling of wind direction and speed in parallel with the temperature and humidity was constructed on the base of ordinary trailer platform for evacuation of a cars and was named Mobile System for Atmosphere Remote Sensing (MS ARS). In addition to the remote sensors of standard aero logical parameters, due to the special request of Main Meteorologist of the Olympic Games 2014, we have implemented in our system the vertically pointed Micro Rain Radar MRR-2. General view of the system in the "working position" is presented on the Fig.1

Figure 1. The general view of Mobile System for Atmosphere Remote Sensing

The system was composed with the next remote sensing instruments:

-Radar wind profiler (manufactured by company "Scintec" Germany)

-Microwave temperature\humidity profiler (manufactured by company "RPG" Germany)

- Micro Rain Radar MRR-2 (manufactured by company "Metek" Germany)

MS ARS was equipped with the all necessary additional devices for providing of the autonomous operation of the system within a few days. Among them are:

-Two (2) electric power engines (gasoline operated) for 4 KW each;

-thermo isolated and electromagnetic protected “operator cabin“ for “in door” electronic units of the remote sensing devices and for duty personal during adjustment operations;

-vibration protected 19’ rack inside the “operator cabin“ for the electronic units, notebook and data transmitting equipment;

-industrial dust\shock protected notebook for operation with all three remote sensing instruments and for processing of the automatic data transmitting algorithm;

-router for real time GSM data transmission;

-GPS for positioning of the current location;

-heater\ventilator for providing of the comfort conditions inside the “operator cabin“;

-two external intense light lamps on light diodes base;

-four side lobes protection screens to prevent horizontal side lobes of the radar wind profiler;

-azimuth rotating assembly to permit azimuth adjustment of the wind profiler antenna;

-set of spare parts and instruments.

General views of the main remote sensing instruments are presented on the Fig.2 and Fig.3. The “inside” view of the “operator cabin“ is presented on the Fig.4

Figure 2 General view of the radar wind profiler with side lobes suppression screens

Figure 3 General view of the microwave temperature\humidity profiler (right) and Micro Rain Radar (left)

Figure 4 Inside view of the operator cabin.

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The main problem with the construction of the MS ARS was the space restrictions problem. Restrictions for platform width and height are consequent from the current Road Rules applicable in Russian Federation. So all industrially produced trailer are corresponding to that Rules. But the length of the platform was the matter of choice. However, the specific road feature in Sochi area (very narrow streets with critical inclinations and wild turns) push us to choose just the shortest trailer- 4m long only.

This circumstance was the main reason for all consequent engineering solutions. For instance, the “operator cabin“ was installed perpendicular to the direction of motion, and its width was compressed up to 1.2m – minimum ergonomic size. Height of the “operator cabin“ was also minimum from the ergonomic point of view- 2m. And just length of the “operator cabin“ was equal to the trailer width and equal to 2m also.

Compression of the cabin size was necessary to support normal operation of the radar wind profiler. The point is that “Scintec” wind profiler is radar system operating with the phase array flat antenna with minimum dimensions 1.8m x 1.8m. For this reason the frame for antenna supporting should has minimum dimensions 2m by 2m. Thus, if we would put the “operator cabin“ to the very front of trailer and the antenna frame on very end of it, we will have the distance in between not more than 0.8m. The principle of operation of the wind profiler is in electronic scanning of the radar beam in 4 orthogonal directions and strait forward in zenith. These 4 orthogonal directions corresponds to South, West, North, and East and inclined from the vertical direction on 20 degree.

It is easy to see from the geometry of our trailer, that the wind profiler antenna, mounted on the floor of the trailer, would not operate properly because of the rear wall of the “operator cabin“. Walls of the “operator cabin“ made from the “sandwich panel” with aluminium plates outside. For this reason, the radar beam inclined to the cabin will be reflected from it and the data processing will give us wrong results.

To avoid this effect, we have lifted the radar antenna on about 1m above the trailer floor. This solution requires the construction of the additional frame, but, as a benefit, we have had an extra space beneath of the radar antenna for power supply engines. Lifting of the radar antenna gives us a little bit more space on the top part of the “operator cabin“. We have had a possibility to install MRR-2 and microwave radiometer on the rear wall of the cabin. Initially we were thinking to put these two instruments on the front wall, but the service of this devises is much more comfortable without stairs if it would be mounted over the platform floor.

One more feature of the MS ARS construction is in very light “easy to install” screens for wind radar side lobes suppression. In the original construction these screens were very rigid, and thus heavy. The main functional requirements to these screens were just to reflect electromagnetic waves with wavelength about 20 centimetres. It is well known, that for ideal reflection of electromagnetic waves, the roughness (non uniformity) of the surface should be less then wavelength divided by 16. In our case it is about 1.3cm. Taking this into account we have used 12mm thick polycarbonate plates covered by aluminium foil and have mounted it around the radar wind profiler antenna sides with inclination about 45 degree. The bottom perimeter of the screens is fixed by the antenna frame, and the top perimeter is fixed by the steel wire. The construction is not rigid at all, but it is very light. This last behaviour allows to assemble\disassemble the screens very fast and easy, which permit to reduce transforming time from transport to working position. The flexible screens could play negative role also, if it would be vibrating during the hard near the ground wind. This effect will be discussed in the next section.

Technical parameters of the remote sensing instruments, as it is declared by the manufacturers (1),(2),(3), are presented in the Tab.1, Tab.2 and Tab.3 respectively

Operating Frequency	800 to 1400 MHz, typically 915, 924, 1280, 1290, 1299, or 1357.5 MHz.
Transmitted Pulse Bandwidth	@400 ns pulse 2.60 MHz (-3 dB) @700 ns pulse 1.45 MHz (-3 dB) @1400 ns pulse 730 kHz (-3 dB) @2800 ns pulse 370 kHz (-3 dB)
Peak RF Power (measured at final amp/preamp unit Ant port)	≥ 450 W pk. and < 1000 W pk.
Maximum Average RF Power (measured at final amp/preamp unit Ant port)	100 W avg.
Receiver Characteristics	
Noise Figure	≤ 0.6 dB
Linear dynamic range	≥ 84 dB
+3 dB Input Sensitivity	< -140 dBm
Phased Array Antenna Characteristics (1290 MHz, 4-panel)	
Type	Electrically steerable micropatch phased array
formed by	four 0.82-0.87m x 0.82-0.87m antenna panels
Aperture	Nominally 3.0 m2
Direction	Zenith and ± 15.5° from zenith in four orthogonal directions
Gain	~26 dBi
Beam width	~9°
Profiler Operating Conditions	
Temperature	40º C to +50º C
Relative Humidity	10 to 100%
Wind Speed	≤ 50 m/s
Snow Depth	≤ 50 cm
Ice Thickness	≤ 5 cm
Typical Performance Specifications	
Minimum measurement height(1)	120 m
Maximum measurement height(2)	2 to 5 km
Wind speed accuracy	< 1 m/s
Wind direction accuracy	< 10º
-1) Dependent upon transmit pulse duration and surrounding clutter environment	2) Dependent upon transmit pulse duration, atmospheric scattering conditions, profiler configuration, installation location, and surrounding environment

Table 1 Technical parameters of Radar Wind Profiler.

Topic	RPG-HATPRO
Sampling Rate	1 second
Antenna beam resolution	3.5° (Hum. Profiler), 1.8° (Temp. Profiler)
Boundary Layer Temperature resolution	50 m
Boundary Layer Temperature accuracy	0.25 K RMS
Time for absolute calibration	2 minutes
Absolute calibration interval	6 month
Dicke switch calibration standard	Yes
Long term TB drift	0.2 K / year
Receiver Technology	DDFA
Channels	9, fixed, parallel scanning
Channels for profiling	2 (Hum. Prof), 7(Temp. Prof)
Time resolution	1 second
Radiometric Noise [10 sec. integration time]	0.06 K RMS
Thermal receiver stability	0.03 K
Dew Blower Heater system (prevents formation of liquid water on microwave window under fog conditions)	Yes
Channel centre frequency accuracy	0.5 MHz
Internal file backup system (1 GByte capacity flash)	Yes
Data cable, max. length	fiber optics, 1400 m
Serial data speed	115.000 Baud

Table 2 Technical parameters of temperature/humidity microwave profiler.

Topic	MRR-2
Working frequency	24 GHz
Modulation type	FM-CW
Transmitted power	50 mW
Antenna diameter	ø 60 cm
Doppler spectra	0 ... 9 m/s (ø 0.2 ... 6 mm
Outputs	rain rate
Indication	“Bright Band” height
Height range	30 ... 6000 m,
Number of height intervals	30

Table 3 Technical parameters of Micro Rain Radar MRR-2.

System operation

It is expected, that the first operational tests of the constructed system will be done during the winter 2012-2013. There are a few visible limitations for operation of the system in mountain environment. Moreover, all the remote sensing instruments, involved in MS ARS, have specific limitations from the point of view of electromagnetic interference. Below we will present the short analysis of these limitations for each individual instrument.

Radar wind profiler: Wind profiler is operating at the frequencies which are very near the cell phone operation. For this reason the "quiet", in electromagnetic sense, place is the best one for operation. This requirements means that the site for observation should be far enough from cell phone towers, power electric lines, military radars, and electric transportation as train, tram and trolley bus. As the sources of interference noise are usually located at very definite directions, it seems to be that for each location is possible to minimize the influence of the noise by adjusting of the azimuth direction of the radar antenna.

For this purpose, the antenna was supplied with the azimuth rotating assembly (see Fig.6). The operation for the adjustment is very simple. After choosing of the measurement site and running the power engines, the wind radar is switched on in "receiver" mode. Then the radar antenna lifted up from the frame with the special spare tools and then rotated in azimuth with the rotating assembly. The output video signal is indicated on the special monitor. The azimuth position with the minimum signal is decided as optimal one. If the site for measurements allows turning the trailer as a whole to get coalescence of the found optimal direction with the trailer main direction, it should be done.

Then the side lobes suppression screens should be installed and the signal level should be controlled once again. If it will exceed the former level, the screens should be removed. The screens itself, due to vibration, can give the Doppler shift in the side lobes. But the average value of this shift should be around zero because the time with positive (to radar) and negative (from radar) Doppler velocity will be the same.

The main purpose for application of the screens is in suppression of the reflection from the "near the ground" side lobes. These side lobes are mostly confusing because near the ground there are a lot of moving objects with the backscattering cross-section much higher than air turbulence. Operating in the mountain environment is probably most complicated from this point of view: if one "near the ground" side lobe is looking to the hill, other one is looking in the space at the sufficient height.

Due to this reasons, it is probably impossible to elaborate any final rule, how to operate in this conditions. Thus, only experimental adjustment with inter comparisons of radar wind profiler with radiozond data will provide reliable respond.

Microwave temperature\humidity profiler: Microwave temperature\humidity profiler is operating at the wide range of frequencies. Parts of them are near the absorption line of the atmosphere oxygen, and for this reason are very safe from the electromagnetic interference. Other part is near absorption line of water vapour. But this line is not too strong as 60GHz oxygen line, so electromagnetic interference is possible. But the number of radio transmitters, operating at these frequencies, is very small, and mostly located nearby airports.

But for microwave profiler there is other principal limitation. The physical principle of temperature and humidity profile retrieval is based on the assumption about "layer uniform" atmosphere. Such an assumption is working well at the flat area- atmosphere is really layer stratified. And it is clear that in the mountain environment, when coming airflow lifted up along the mountain shape, we cannot expect the same air temperature at the same height level near the mountain and far from it. Only one can be recommended here use for the measurements kind of flat fields between hills, with sufficient horizontal dimensions (more than 5 km).

One more important, but not critical remark is connected with the height of sounding above the sea level. As far the retrieving algorithm is using calculation of the absorption in the oxygen depending on the pressure, thus it is necessary not forgotten to implement the correction of the height of real measurements.

Micro Rain Radar MRR-2: Micro Rain Radar MRR-2 is looking striate in zenith direction, and thus does not have any specific problems operating in the mountain environment. The electromagnetic interference at the operating frequency is also not too often, and if it happens, just necessary to wait for a while, because such an interference are very short in time.

Summaries

- The Mobile System for Atmosphere Remote Sensing (MS ARS) was developed and constructed. The system is ready for measurements of Wind, Humidity, Temperature and Precipitation Microstructure Profiles in field conditions.

-The main limitations for field operation of MS ARS were discussed, and preliminary recommendations to overlap these limitations were elaborated.

- The final instructions for proper operation of the system in mountain environment can be done after inter comparisons of the data with radizond profiles.

References

1. User Guide "**Radar Wind Profiler** " (http://www.scintec.com)
2. Technical Manual (standard radiometers) "HATPRO" (http://www.radiometer-physics.de)
3. "Micro Rain Radar 24 GHz" (**http://www.metek.de**)