

REPORT ITU-R M.2013

WIND PROFILER RADARS

(1997)

1 General subject matter

1.1 Introduction

Wind profiler radars are radio systems which can be very helpful in weather forecasting applications. To be able to make use of the benefits of wind profiler radars, suitable radio frequency bands need to be identified for the accommodation of this type of system.

One must note the existence of acoustic wind profilers (Doppler SODARs). They can be used to complement certain wind profiler radar measurements at very low altitudes. However, we stress that Doppler SODARs cannot be used as a substitute for wind profiler radars.

On the one hand, radar systems for weather forecasting purposes are to be accommodated in the frequency allocations of the radiolocation service and/or the meteorological aids service. Existing uses in these bands need to be protected and compatibility with the services in the adjacent bands has to be assured. On the other hand, accommodation in the frequency bands of other radio services could be considered, if this is acceptable from a frequency-sharing point of view.

For the identification of the various compatibility and/or sharing options, a clear understanding of the concept of wind profiler radar systems and their behaviour in the electromagnetic environment is needed.

In the following paragraphs the need for wind profiler radars will be touched upon and a general system description will be given including the typical electromagnetic behaviour.

1.2 User requirements for wind profiler radar data

The development of weather forecasting presently requires frequent, closely spaced and high quality wind data with improved accuracy from near the Earth's surface to high in the atmosphere. Wind data based principally on balloon borne instruments, satellite measurements and automated aircraft reporting systems are insufficient to satisfy the needs of the increasingly high resolution atmospheric computer models as well as those on man-machine interactive forecasting systems. Without substantial increases in high resolution wind data, the capacity of these new models and interactive systems being deployed later this decade to improve weather forecasts and severe weather warnings will be greatly limited.

Planetary numerical models of the atmosphere which produce three to ten day forecasts require upper air data from extensive areas of the globe. Especially in remote areas, wind profiler radars operating unattended may offer a means of obtaining essential high altitude data for these models from data sparse areas.

Numerical models for forecasts from 3 to 48 h covering a continent or smaller area require data from a large vertical extent of the atmosphere, typically from 200 m to 18 km, with vertical resolution of approximately 250 m depending on the application. The time resolution presently needed is for hourly data.

For very short-term weather forecasting, air pollution monitoring, wind field analyses and forecasts of toxic plume trajectories resulting from chemical or nuclear incidents, severe weather warnings for aviation, meteorological observations, airport operations and public protection, meteorologists need wind information with a very high temporal and spatial resolution, mainly in the lower atmosphere. The requirements are for continuous data acquisition, between the ground and 5 km, with a desirable resolution sometimes as low as 30 m. Measurements will usually be made in populated areas.

Wind profiler radars also play an important role in experimental atmospheric research. Their ability to measure wind with a high temporal and spatial resolution makes them very well suited for the experimental verification of models, for boundary layer research and for the investigation of processes that are important for understanding the atmosphere, including climate evolution.

At present meteorological organizations use balloon borne systems to measure profiles of wind, temperature and humidity from the ground to high in the atmosphere. While current wind profiler radars do not operationally measure all of these parameters, they do have several advantages in comparison to the balloon based systems in meeting the above-mentioned requirements:

- they sample winds nearly continuously;
- the winds are measured almost directly above the site;
- the vertical air velocity can be measured;
- they provide the temporal and spatial density soundings needed to compute derived fields in a much more timely manner;
- the cost per observation is lower;
- they operate unattended in nearly all weather conditions.

In addition, it has been demonstrated that wind profiler radars can be adapted to measure temperature profiles when they are used in conjunction with a radio-acoustic sounding system (RASS). This opens the possibility to obtain denser and higher quality temperature profiles compared to present measurement techniques such as balloon tracking. No other measurement technique will present comparable advantages in the near future, including satellite borne sensors.

The World Meteorological Organization has expressed the need to operate such radars as a matter of urgency, due to the necessity of better monitoring and forecasting of the Earth's atmosphere. A standardization of operating frequency bands is most important for the weather services in order to build an operational network in a practical and cost-effective manner.

1.3 System concept of wind profiler radars

Wind profiler radars are vertically directed pulsed Doppler radars capable of analysing the back-scattered signals to determine the velocity of air along the beams. By steering the beams typically 15° from zenith, the horizontal and vertical components of the air motion can be obtained.

Wind profiler radars depend on signals scattered from gradients in the radio refractive index associated with turbulent eddies with scales of one-half the radar wavelength (Bragg resonance). Hydrometeor scattering may also contribute or even dominate the returned signals, depending on the radar operating frequency. The goal of detecting the very weak clear air signals dictates the use of long coherent dwell times, low-noise system design, low antenna side lobes, and careful attention to siting, and potential interference.

A related development, the RASS provides profiles of temperature, typically with no alteration of the radio emission characteristics of the wind profiler radar. The propagation velocity of a Bragg-matched acoustic signal, which is related to the air temperature, is measured by the wind profiler radar using slightly different Doppler processing.

The nature of the scattering mechanism requires wind profiler radars to function between 40 and 1 400 MHz. As frequency increases over 1 300 MHz, performance of the wind profiler radar decreases significantly. The choice of operating frequency is influenced by the required altitude coverage and resolution.

1.4 Radiation aspects of wind profiler radar systems

In practice, systems are built for three frequency bands, i.e. around 50 MHz, 400 MHz, and 1 000 MHz, and these systems typically operate in two modes (see Note 1) which trade height coverage for resolution. Table 1 lists the range of characteristics of wind profiler radars in these three bands:

NOTE 1 – Low mode means shorter pulse, lower altitude; high mode means longer pulse, higher altitude.

TABLE 1

Range of operational wind profiler radars characteristics

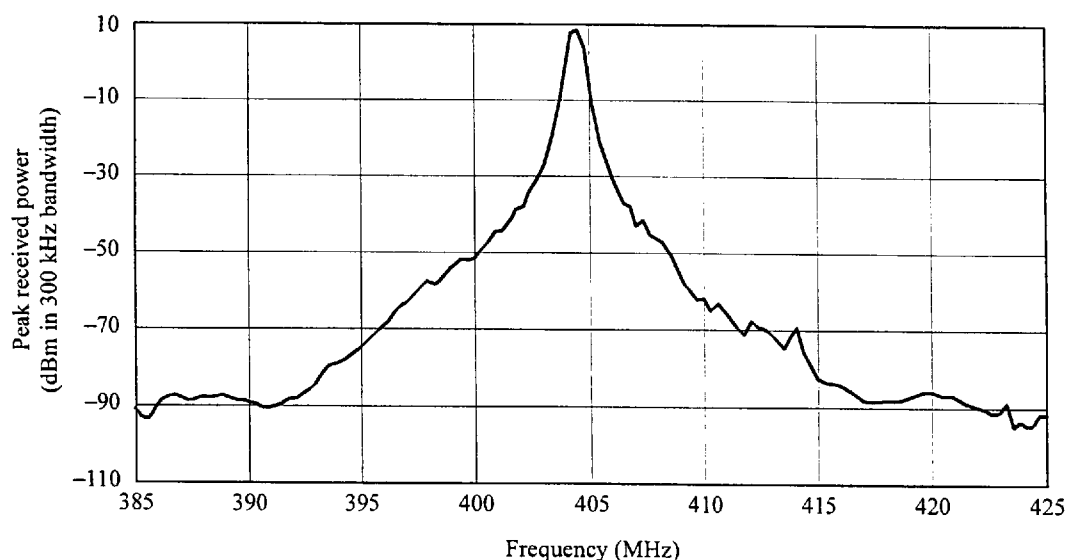
	50 MHz	400 MHz	1 000 MHz
Height range (km)	1-24	0.5-16	0.5-3
Height resolution (m)	150-1 500	150-1 200	30-150
Antenna type	Yagi, coaxial, co-linear	Yagi, coaxial, co-linear, co-linear	dish, patch co-linear
Antenna size (m ²)	2 500-10 000	30-150	3-15
Peak power (kW)	5-60	5-50	0.5-5
Mean power (kW)	0.5-5	0.2-2.0	0.05-0.5
Necessary bandwidth (MHz)	0.2-2.2	0.3-2.2	0.7-7.3

1.4.1 Harmonization of operating frequencies

Global harmonization of wind profiler radar operational frequencies and identification of spectrum by a world radiocommunication conference is most important. This will enable cost-effective development and exploitation of wind profiler radars. Wind profiler radars are operated as pulse-modulated Doppler radars or in frequency modulated-CW-mode. FM CW-mode radars were not considered further in this report because of lack of technical standard. Examples of spectrum produced by a pulse-modulated Doppler radar is shown in Fig. 1.

FIGURE 1

Spectrum characteristic of a pulse-modulated Doppler radar



Pulse width: 1.67 μ s
Pulse repetition frequency: 10 kHz

Rap 2013-01

Based on discussions with manufacturers, wind profiler radars (see Note 1) can be designed to operate on assigned frequencies in a range up to ± 1 per cent.

NOTE 1 – For example, the National Telecommunications and Information Administration (NTIA/USA) – “Manual of Regulations and Procedures for Federal Radio Frequency Management”.

To accomplish this, small compromises would have to be made in the design of the RF power transmitter, antenna, circulator, and receiver noise figure. These would not be expected to degrade performance by more than 1 dB, an amount which could easily be compensated by a small increase in radiated power.

1.4.2 Antenna pattern

The desired signal being a reflection from clear air is very weak. This requires both extreme sensitivity in the wind profiler radar receiver and a vertically directed antenna with low amplitude side lobes. The antenna pattern, especially at large off-axis angles from main beam, is important in analysing potential interference.

As measurements for a 400 MHz wind profiler radar in Switzerland have shown, siting the profiler antenna in a sufficiently deep topographical depression can reduce most low-elevation side lobes by up to 20 dB. Terrain shielding is also effective for 50 MHz wind profiler radars as experience in Japan and Germany has shown. Investigations in Germany show that a specially designed fence around a profiler antenna can improve the low-angle side-lobe suppression by 10 dB to 15 dB.

1.4.3 Polarization

The polarization of signals received near the ground from a wind profiler radar changes randomly as a result of the scattering process. Similarly, the polarization of signals received directly from a side lobe is also likely to be random. The mean contribution of polarization decoupling to an improvement of sharing conditions is, therefore, only minimal (e.g. 3 dB).

1.4.4 Occupied bandwidth

For the efficient use of the limited radio spectrum resource, all efforts must be made to reduce the occupied bandwidth as well as unwanted emissions to a minimum.

The spectrum produced by pulse-modulated emissions is mainly determined by the shape of the pulses, the choice of the transmitter chain and the output filtering employed. Control of the spectrum can be achieved by appropriate pulse shaping, phase modulation and amplifier linearity.

Measurements accomplished in Germany with a 50 MHz wind profiler radar in this respect have shown that pulse shaping reduces the occupied bandwidth by a factor up to five compared to the bandwidth of rectangular pulses.

It should be noted that pulse shaping produces, as a side effect, a reduction of average transmitter power and a reduction of the effective range.

With reference to the 99% bandwidth (see Radio Regulations (RR) No. S1.153) of the radars in Fig. 1, the spectrum represents good technical achievement at this time.

Due to the fact that the bandwidth of a frequency modulated emission largely depends on the frequency deviation, it should be reduced as far as possible with regard to technical and operational/functional aspects of the spectrum.

In this study it is assumed that the occupied bandwidth of a wind profiler radar completely falls within a proposed candidate band.

1.5 Sharing considerations between wind profiler radars and other systems in various services

It may be possible to use bands other than those as identified in this report but such use must be preceded by studies which show compatibility.

1.5.1 Land mobile service

Sharing between wind profiler radars and the land mobile service is possible with proper frequency/distance (F/D) separation. Land mobile operations are mostly concentrated in urban areas. In some countries wind profiler radars may be located in remote areas. This will enhance sharing possibilities except in densely populated countries. Two cases must be considered concerning sharing with wind profiler radars. The two cases are sharing with base stations and sharing with vehicular and portable stations. Sharing with base stations is easier since they operate at known specific locations, thus proper distance separation can be maintained. Vehicular and portable stations, however, operate intermittently throughout the entire area covered by the base station.

1.5.2 Aeronautical services

In general, sharing with airborne systems requires large F/D separation and as a result sharing may be difficult. In addition, harmful interference to aircraft must be avoided in bands which provide critical communication such as aeronautical radionavigation.

An aircraft flying close to the wind profiler radar may suffer harmful interference and may also cause strong reflections back to the wind profiler radar that will disrupt wind data for that length of time. Thus, the location of wind profiler radars intended for strictly meteorological use, should avoid the flight paths of aircraft. On the other hand, 1 000 MHz wind profiler radars might be used in airport areas for measuring winds. In this case, the benefit of the observation may outweigh the temporary disturbance by aircraft.

1.5.3 Satellite and space services

Sharing with satellite and space services requires large angular and frequency separation, and as a result sharing may be difficult. Usually satellite and space services receivers are very sensitive and may experience interference and overload from wind profiler radars depending on the position and antenna pattern. Wind profiler radars are also very sensitive, and may experience interference from satellite and space services. Harmful interference to safety-of-life satellite operation must be avoided.

1.5.4 Fixed service

Sharing between wind profiler radars and the fixed service is possible with proper F/D separation.

Fixed systems typically transmit point-to-point or point-to-multipoint over tropospheric propagation paths (including line-of-sight). Some fixed systems employ highly directional antennas. The transmission paths are well defined. Some fixed systems are transportable.

1.5.5 Radio astronomy service

Radio astronomy stations are receiving stations that listen for radio waves of cosmic origin. Radio astronomy bands are used internationally for various activities such as very long baseline interferometry and spectral line observations. Receivers used for radio astronomy are extremely sensitive and this service requires large frequency and/or distance separations from other services to preclude interference.

Furthermore, wind profiler radar users operating in bands adjacent to radio astronomy bands must ensure that harmful interference is not caused to radio astronomy. These bands should be avoided.

1.5.6 Meteorological aids service

This service is used worldwide for gathering meteorological data for weather prediction, severe storm warning and research. Data gathering systems include satellite imagery and radiosondes.

Tracking of balloons and telemetry from radiosondes may be accomplished in several ways. Therefore, the sharing criteria must be in accordance with the method used to receive wind data.