Radars

Training Workshop on Radio Frequency matters
for the Asia-Pacific Region

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The importance of meteorological radar

A high quality of data collected by meteorological radar is essential for:

- in-situ and real time detection, quantification and monitoring of **rain** and **wind** conditions
- input to Numerical Weather Prediction models for nowcasting, short-term and medium-term forecasting
- aeronautical and maritime navigation,
- monitoring Chemical or Nuclear disasters,
- hydrological rain, floods, severe storms or ouragan alert processes

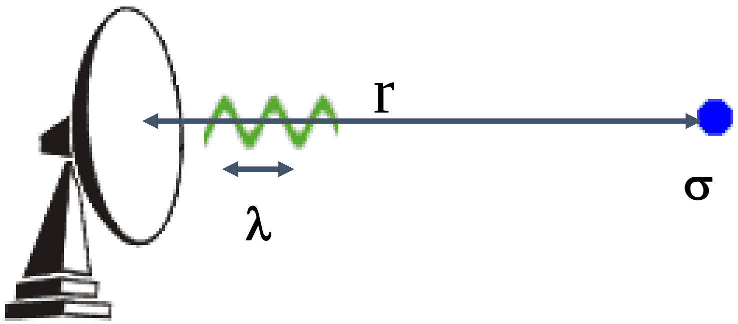
=> Meteorological radars relate to Public Safety

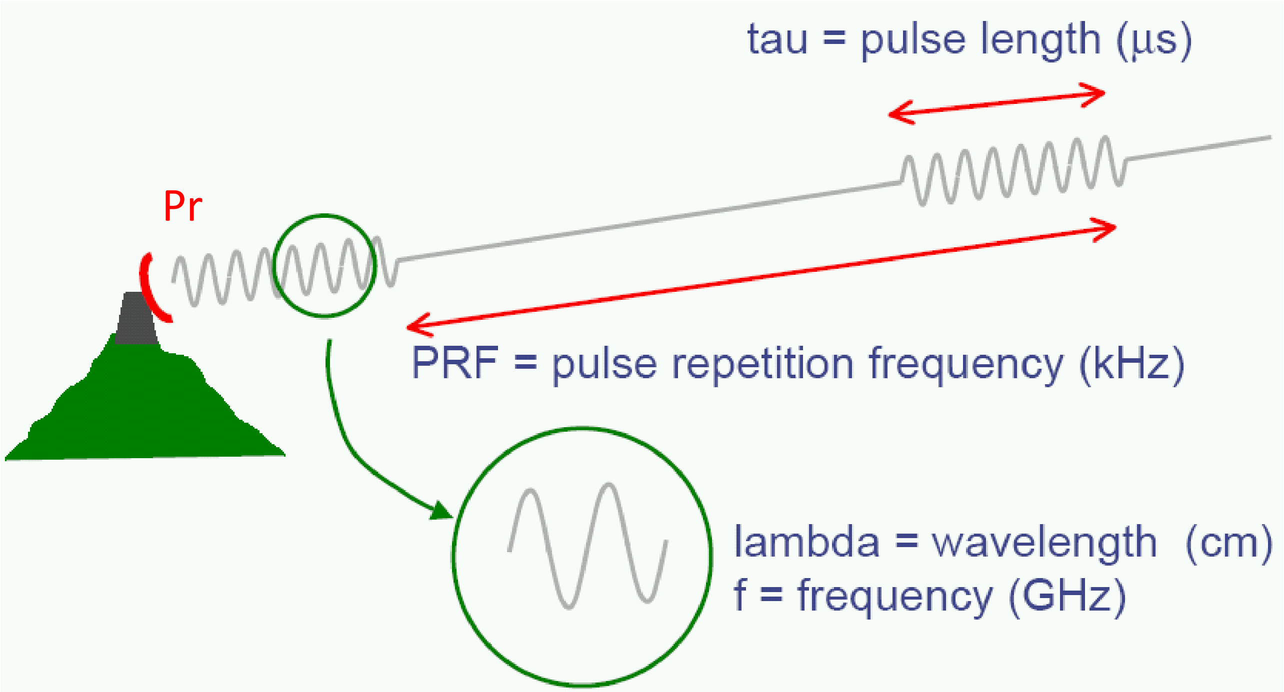
Definition

RADAR = RAdio Detection And Ranging.

Dictionary: Device for determining the position and distance of an obstacle by emitting radio waves and detecting the waves reflected from its surface.

How it works?





Emission into the atmosphere, at regular intervals (PRF), of very short, powerful electromagnetic pulses (τ) at high frequency (f,λ). The targets (σ) absorb part of the energy of the beam and radiate in all directions. The very small fraction returned to the radar (Pr) is the useful signal.

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The importance of the wavelength

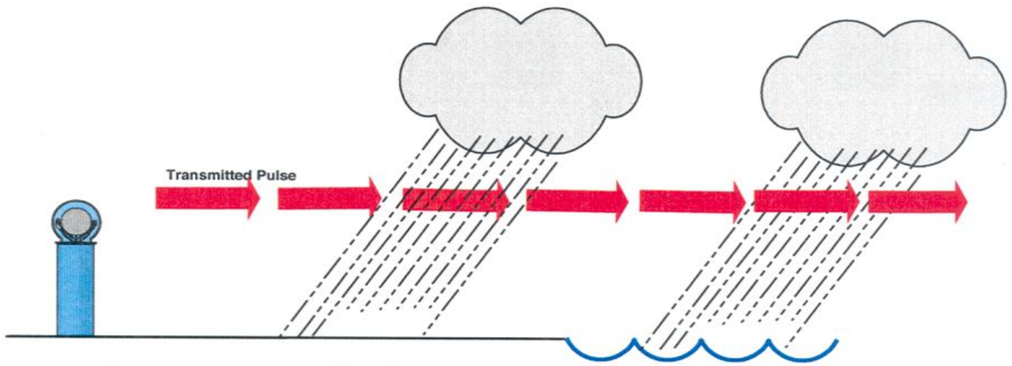


Figure 3a- Long Wavelengths Pass Through Precipitation And Produce No Useful Reflections

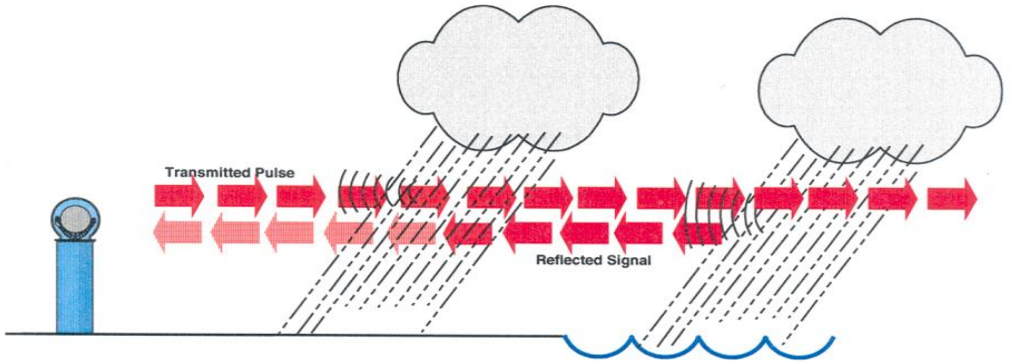


Figure 3b- Proper Wavelengths Pass Through Precipitation And Produce Useful Reflections

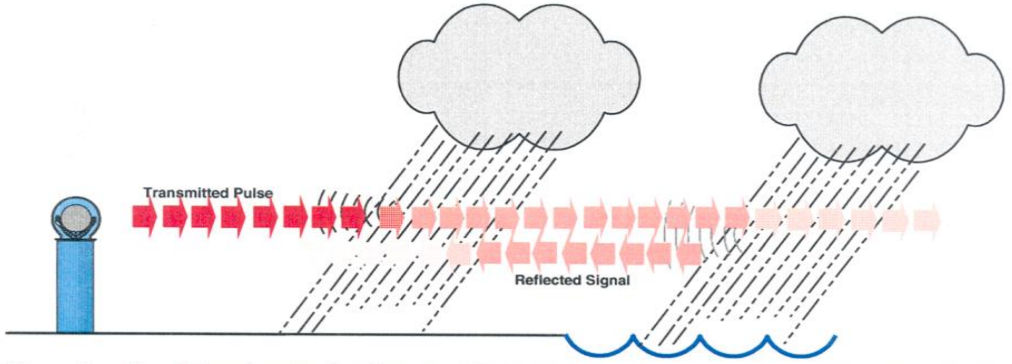


Figure 3c- Short Wavelengths Are Absorbed By Precipitation And Produce No Useful Reflections

=>

For meteorological use the operational frequency band is of prime importance and cannot be easily replaced

Meteorological radars: frequency bands

Meteorological radars operate under the **radiolocation service**

They can in theory be deployed in all radiolocation bands but are mainly found in three frequency bands

The choice of the band is a trade-off between mainly range, rain attenuation and data accuracy

Radar networks worldwide are in general using S-Band and C-Band whereas X-Band radars are used in specific environments or to complete global coverage

S-band
2700-2900 MHz
(see RR N° **5.423**)

C-band
5350-5725 MHz
(focusing on 5600-5650 MHz, see RR N° **5.452**)

X-band
9300-9500 MHz
(see RR N° **5.475B**)

5.423 In the band 2 700-2 900 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the aeronautical radionavigation service.

5.452 Between 5 600 MHz and 5 650 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the maritime radionavigation service.

5.475B In the band 9 300-9 500 MHz, stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from, radars operating in the radionavigation service in conformity with the Radio Regulations. Ground-based radars used for meteorological purposes have priority over other radiolocation uses. (WRC-07)

Meteorological radars specificities

Unlike other radars that have a radar equation (i.e. the receiving signal vs the EIRP) proportional to $1/r^4$, **for meteorological radars it is $1/r^2$.** This has an impact on the sensitivity to and acceptable level of interference

Other radars are used for detection and tracking of discrete targets whereas, ***meteorological radars perform volumetric scanning/cartography of the entire atmosphere within the radar range***.

In order to get more precise meteorological products, the **noise calibration "Zero Check", of radars is crucial**. Performed on a regular basis, either during regular radar emissions (by statistical estimation) or during specific periods of time (typically 1 radar turn), it will be used as reference for the "scanning strategy".

Any interference during the noise calibration process will pollute radar products

To elaborate the meteorological products (mainly reflectivity and Doppler) over the whole range, meteorological radars operations are based on "**scanning strategies**"

Scanning strategies

For a given radar, “scanning strategies” (typically of 10-15 minutes) make use of a variety of different emission schemes at different **elevations**, using sets of different **pulse width**, **Pulse repetition Frequency (PRF)** and **rotation speeds**

No typical schemes but large ranges of parameters.

Elevation ranging from **0° to 90°**

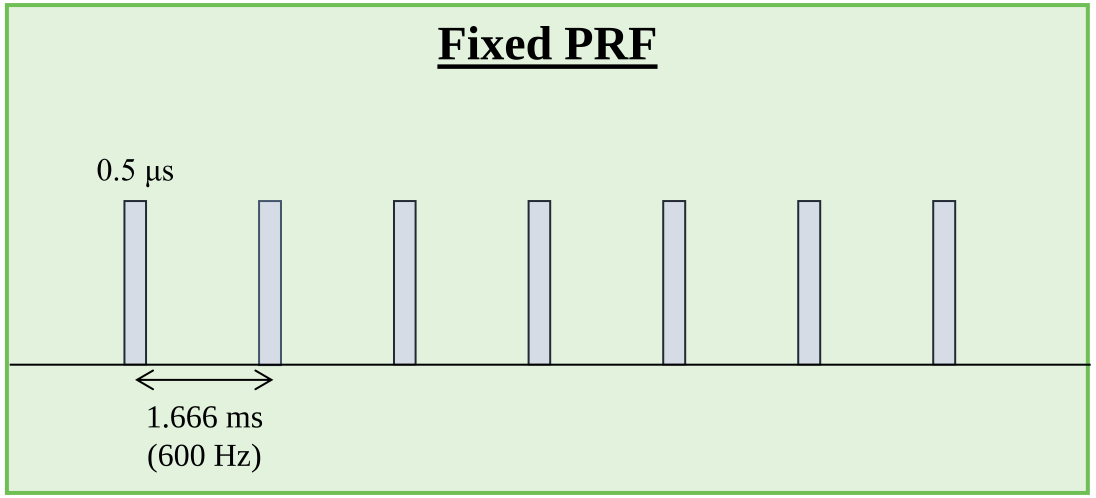
Pulse width ranging from **0.5 to 2.5 µs** (for operational radars)

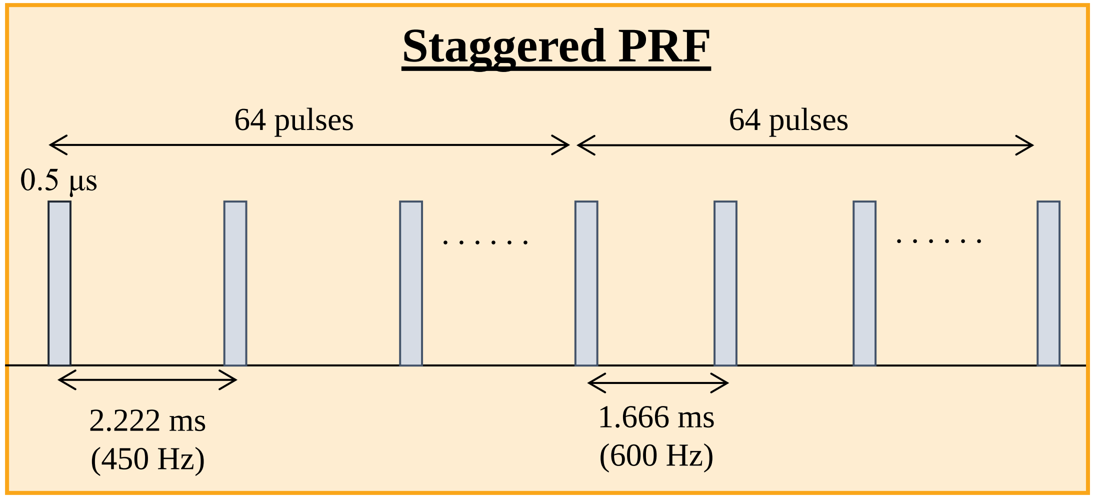
Pulse repetition Frequency (PRF) ranging from **250 to 1200 Hz** (for operational radars)

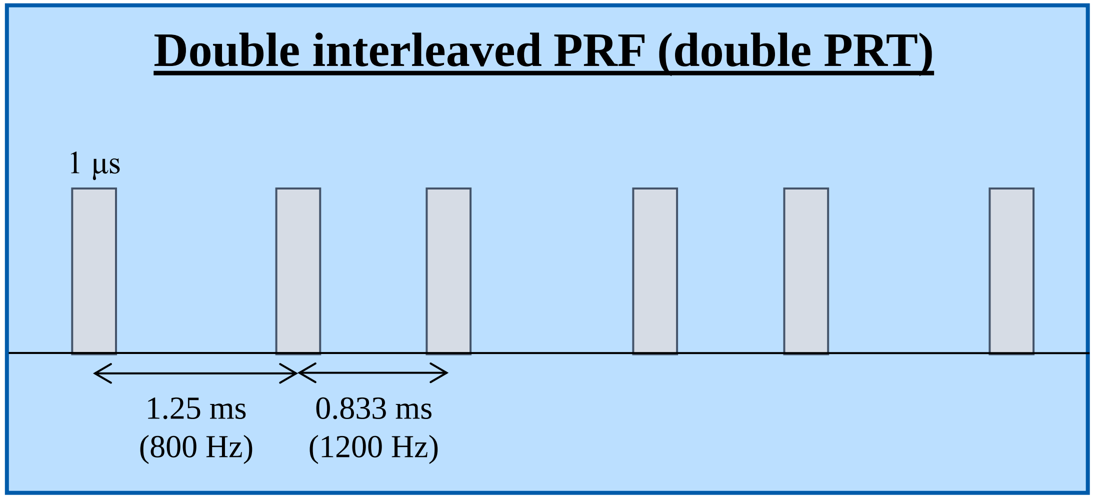
PRF Fixed and staggered or **interleaved**

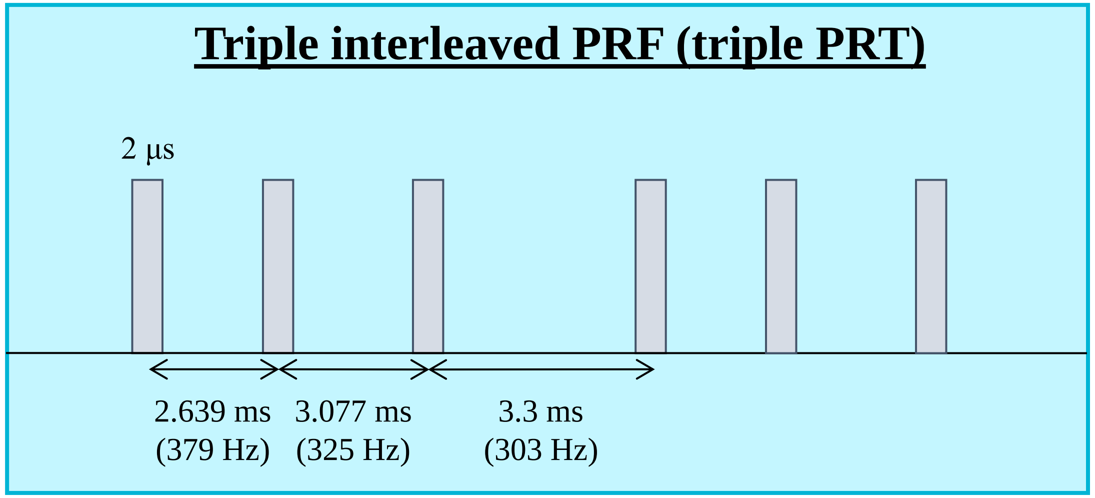
Rotation speed ranging from **1 to 6 rpm**

Emission schemes examples





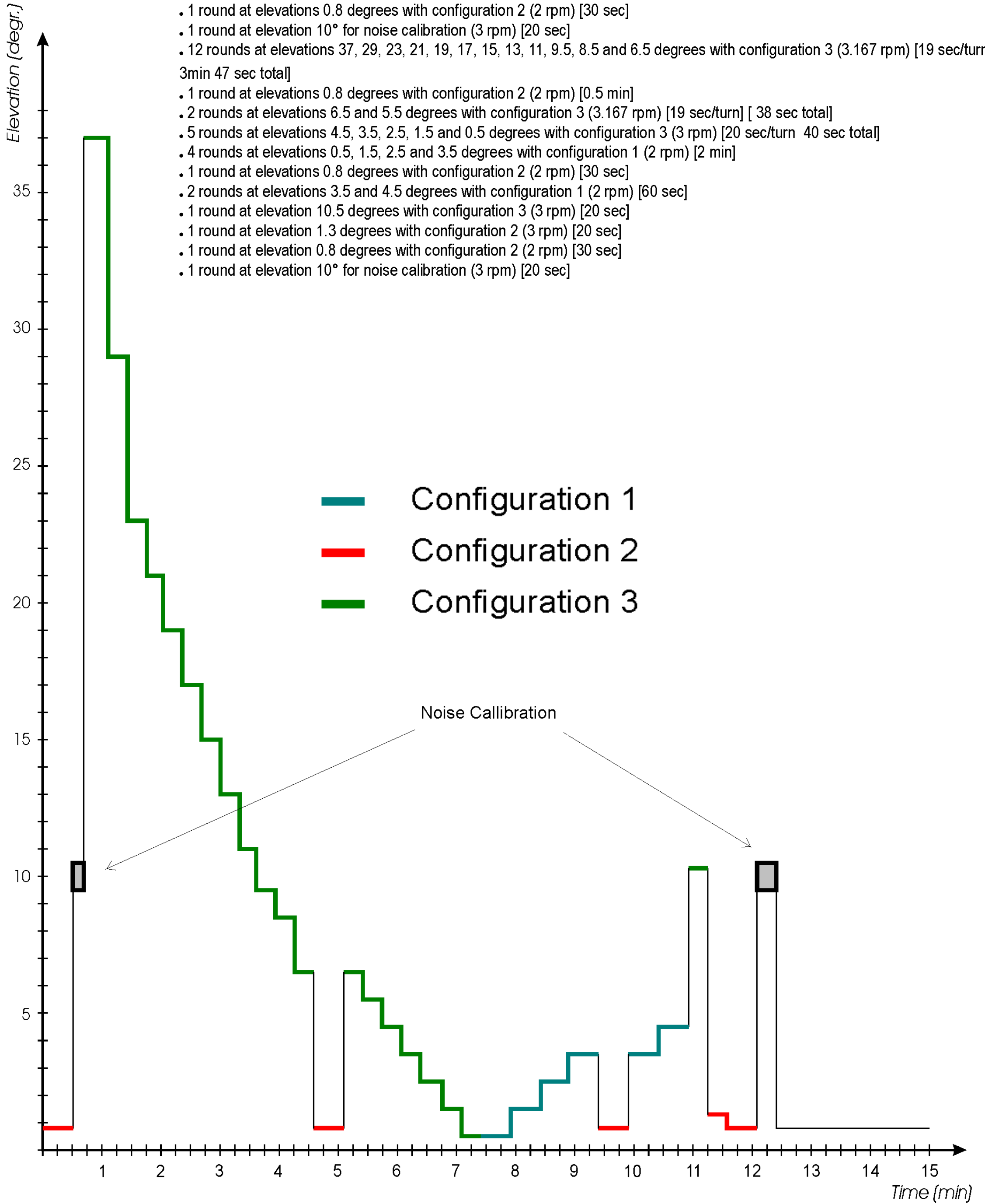




Example of scanning strategy

Typical scan strategy (Total time around 15 min):

- 1 round at elevations 0.8 degrees with configuration 2 (2 rpm) [30 sec]
- 1 round at elevation 10° for noise calibration (3 rpm) [20 sec]
- 12 rounds at elevations 37, 29, 23, 21, 19, 17, 15, 13, 11, 9.5, 8.5 and 6.5 degrees with configuration 3 (3.167 rpm) [19 sec/turn] [3min 47 sec total]
- 1 round at elevations 0.8 degrees with configuration 2 (2 rpm) [0.5 min]
- 2 rounds at elevations 6.5 and 5.5 degrees with configuration 3 (3.167 rpm) [19 sec/turn] [38 sec total]
- 5 rounds at elevations 4.5, 3.5, 2.5, 1.5 and 0.5 degrees with configuration 3 (3 rpm) [20 sec/turn 40 sec total]
- 4 rounds at elevations 0.5, 1.5, 2.5 and 3.5 degrees with configuration 1 (2 rpm) [2 min]
- 1 round at elevations 0.8 degrees with configuration 2 (2 rpm) [30 sec]
- 2 rounds at elevations 3.5 and 4.5 degrees with configuration 1 (2 rpm) [60 sec]
- 1 round at elevation 10.5 degrees with configuration 3 (3 rpm) [20 sec]
- 1 round at elevation 1.3 degrees with configuration 2 (3 rpm) [20 sec]
- 1 round at elevation 0.8 degrees with configuration 2 (2 rpm) [30 sec]
- 1 round at elevation 10° for noise calibration (3 rpm) [20 sec]



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Past, current and future threats

A number of threats are facing weather radars in all bands and the interference situation may become a threshold for change.

S-Band:

- Has been targeted many times by the Mobile community for IMT usage. Denied at 3 WRC but it may come back …
- Under threat of IMT usage in the adjacent band 2500-2690 MHz (current interference, e.g. Canada,…)

C-Band:

- For about 20 years, it is under threat of WAS/RLAN 5 GHz with numerous interference cases experiences worldwide, especially in Europe. This is due to a massive deployment of non-compliant WAS/RLAN
- It is envisioned by UWB applications

X-Band:

- Targeted by Mobile community for IMT usage. It was denied at WRC-23 but may come at later stage ….
- It is also envisioned by UWB applications

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Future developments

Among others, it is important to highlight a major step that relates to **solid state meteorological radars**

- For decades, **vacuum tubes (Magnetron, Klystron)** were the only solution to allow for very high power peak transmissions (several hundred kW)
- Solid State Power Amplifiers (SSPA) based on **semiconductor** technology now also allow for high power peak transmissions (several kW).
- It presents a number of advantages (Pulse agility and higher resolution and sensitivity, robustness, compactness, improved efficiency, …)
- However impact on compatibility with other services (e.g. WAS/RLAN) still need to be assessed (work ongoing in ITU under the umbrella of WMO)

Another development relates to the possible **move of some C-band meteorological radars from 5.6 GHz to 5.4 GHz band** in order to potentially avoid interference from WAS/RLAN 5GHz.

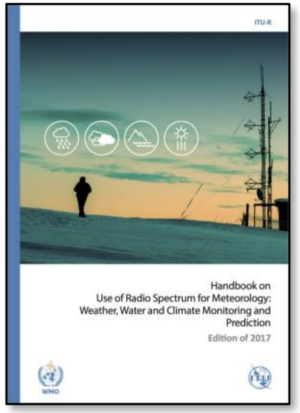
- Although only representing a quite small frequency shift, this may represent a number of technical and regulatory challenges that need to be studied.
- Compatibility with EESS (active) needs to be taken into account.

Some references/Publications

ITU-R Recommendation M.1849-3 on "*Technical and operational aspects of ground-based meteorological radars*"

Chapter 4 of the WMO-ITU Handbook on "*Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction*"

- Note that this chapter also includes some elements on other types of meteorological radars, in particular Wind Profilers Radars (WPR)
- Chapter under revision



In order to have an overview of what global meteorological radars network may look like, the WMO database webpage is relevant

https://wrd.mgm.gov.tr/Home/Wrd

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Thank you.

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