ITU/WMO SEMINAR

Meteorological Radars

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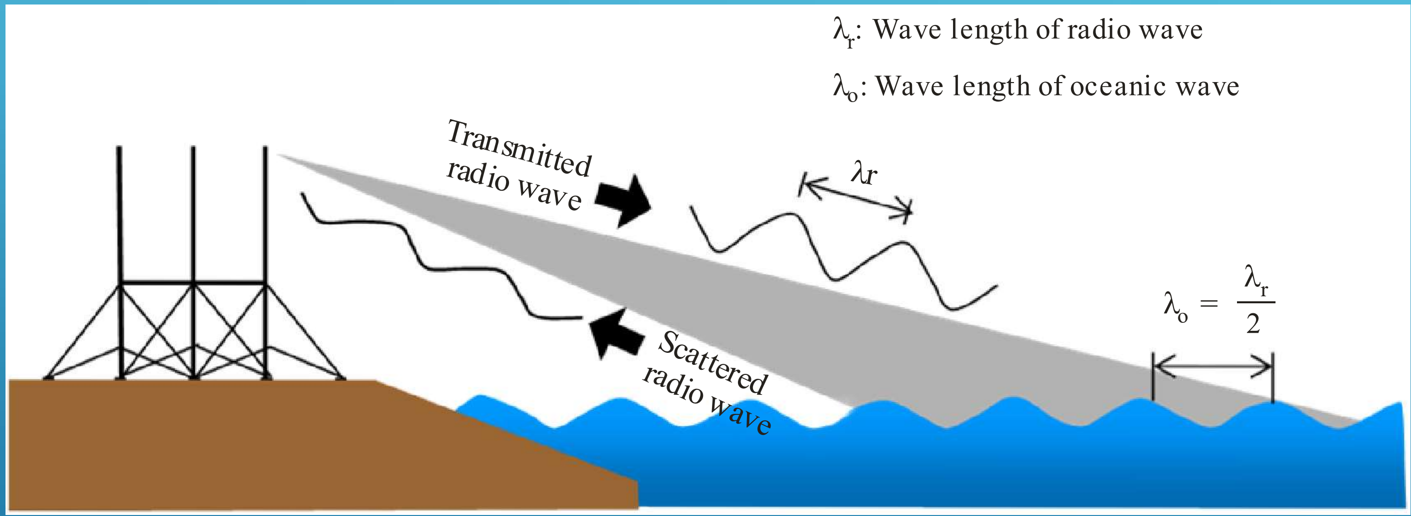
Summary

1. Oceanographic radars
2. Wind profiler radars
3. Weather radars
4. Some references/Publications

1. Oceanographic radars

What is an Oceanographic Radar?

Coastal radar that measures in the frequency range 3 to 50 MHz, currents and sea state in coastal waters and bays



M.1874-04

Provide a better understanding of issues like coastal pollution, fisheries management, search and rescue, beach erosion, maritime navigation, sediment transport and tsunami response

Spectrum history for oceanographic radars

- Prior to 2012 oceanographic radars were operated without regulatory status, under Radio Regulations Footnote No. **4.4**.
  - Systems were operated across a wide range of frequency bands between 3 and 50 MHz, potentially interfering with many systems that operated under allocated radio services.
- WRC-12 considered the need for allocations to operate oceanographic radars on a global basis
  - Allocations were created in multiple frequency bands with regulatory constraints.
  - Reduced the RF footprint of oceanographic radars from more than 10 MHz of bandwidth between 3 and 50 MHz to less than 3.475 MHz.

Applicable Radio Regulations footnotes

5.132A Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed or mobile services. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution **612 (Rev.WRC-12)**.

5.145A Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed service. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution **612 (Rev.WRC-12)**.

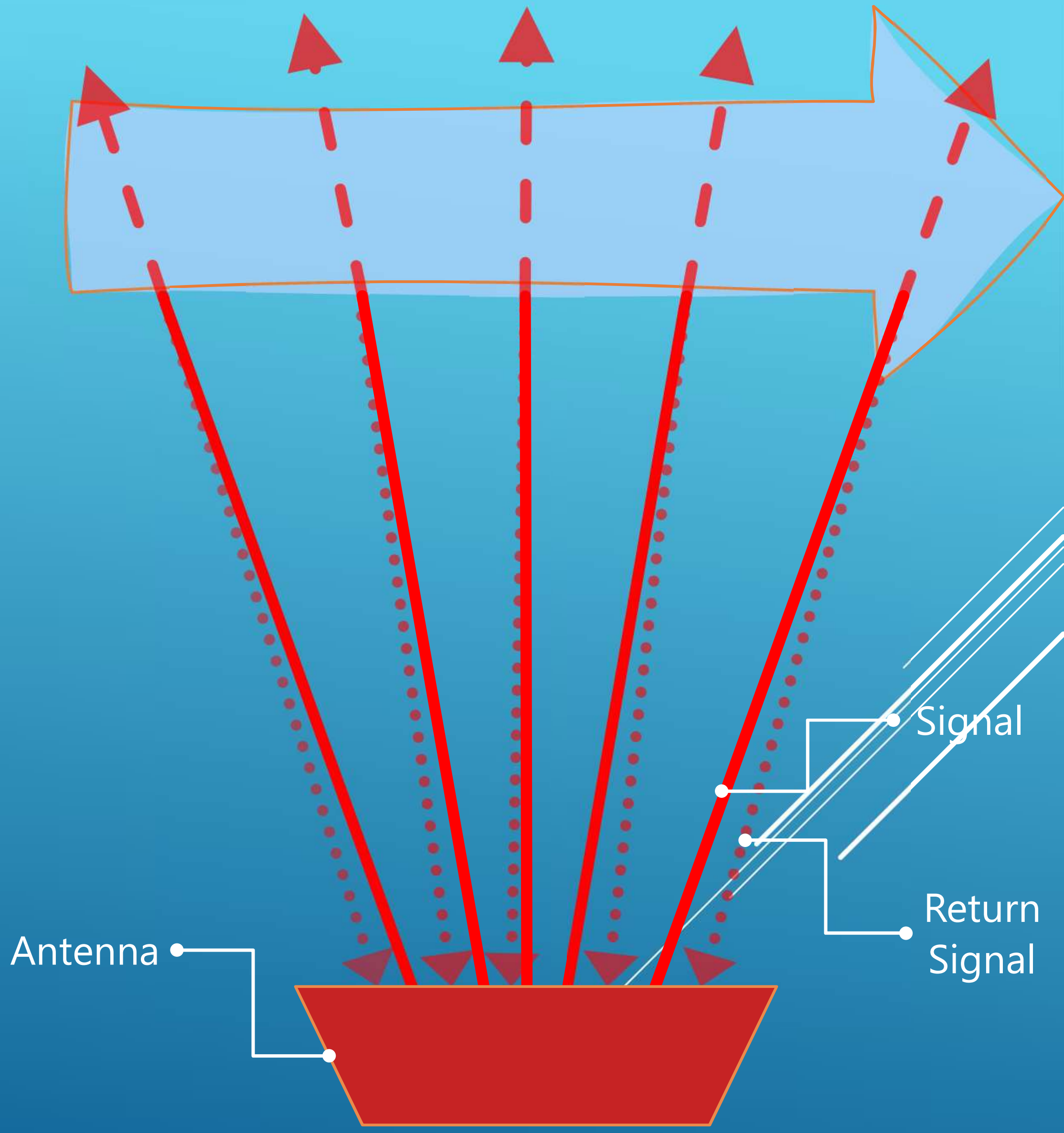
5.161A *Additional allocation:* in Korea (Rep. of), the United States and Mexico, the frequency bands 41.015- 41.665 MHz and 43.35-44 MHz are also allocated to the radiolocation service on a primary basis. Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed or mobile services. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution **612 (Rev.WRC-12)**.

2. Wind profiler radars

For what?

Detect the **tiny fraction** of emitted power backscattered from turbulence in the clear atmosphere.

- Used to obtain vertical profiles of wind over unattended and/or remote areas and can provide **continuous monitoring of the wind field in a specific location.**
- Can also be used to detect precipitation, measure major features in the vertical velocity field (e.g. gravity waves and convective updrafts), estimate the intensity of turbulence and measure atmospheric stability.



Frequency bands

Measurement characteristics depend on power, frequency and antenna size.

46-68 MHz

- *Stratosphere-troposphere measurements*
- Peak power of 250 kW, mean power of around 12.5 kW
- Large antenna: about 10,000 m^2
- Provide measurements between 3-30 km altitude

440-450 MHz

and 470-494 MHz

- Mean powers of 500 W for low altitude measurements and 2000 W for high altitude measurements.
- Provide measurements between 0.5-16 km altitude

904-928 MHz, 1270-1295 MHz

and 1300-1375 MHz

- *Boundary layer measurements*
- Mean power around 50 W
- Vertical resolution about 100m
- Provide measurements between 100-3000 m altitude

Interference and protection

Fixed location and upward viewpoint of wind profilers makes them **less vulnerable to interference** from other wind profilers or terrestrial services (e.g. mobile networks).

Space-based services could cause more of an issue, as these pass over the wind profiler.

Image: NERC

Image: NOAA

Operate in **frequency bands allocated to Radiolocation Service** through:

- **Resolution 217 (rev.WRC-23) in Radiolocation** service allocation **on a PRIMARY** basis
  - **440-450 MHz**
  - **904-928 MHz in Region 2 only**
  - **1 270-1 295 MHz**
  - **1 300-1 375 MHz**
- **RR footnotes** for specific countries on a ***secondary*** basis:
  - **46-68 MHz** allocated to **Radiolocation** service for wind profiler radars in various countries (**5.162A**).
  - **470-494 MHz** allocated to **Radiolocation** service for wind profiler radars in various countries (**5.291A**).

3. Weather radars

The importance of meteorological radar (1)

Weather radar is a **vital tool** for **meteorology, public safety, and disaster management**.

🌍 **Real-Time Weather Tracking**

•Detects **precipitation** (rain, snow, hail) and its **intensity**.
•Monitors the **movement and development** of storms, cyclones, and other weather systems.

⚡ **Early Warning for Extreme Weather**

•Provides **life-saving alerts** such as : s**evere thunderstorms**, f**lash floods** t**ornadoes**
•Helps **reduce casualties and economic losses** by enabling quick response.

🌩 **Improved Weather Forecasting**

•Enhances **short-term forecasts** (1–6 hours ahead).
•Supports meteorologists in predicting **storm paths, intensity, and timing**.

✈ **Aviation & Maritime Safety**

•**Aviation**: Helps pilots avoid **turbulence, icing, and wind shear**.
•**Maritime**: Warns ships of **storms, high waves, and hurricanes**.

The importance of meteorological radar (2)

Resource & Infrastructure Management

- **Agriculture**: Protects crops from **hail, droughts, or excessive rain**.
- **Energy Sector**: Optimizes **hydroelectric and wind power generation**.
- **Transportation**: Adjusts **road, rail, and air traffic** during extreme weather.

Scientific Research

- Studies **cloud formation, precipitation patterns, and atmospheric behavior**.
- Validates and improves **climate models and forecasting algorithms**.

Urban Planning & Emergency Response

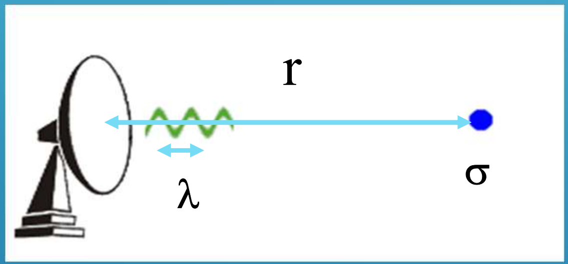
- Assists **city planners** in designing **drainage systems and flood defenses**.
- Supports **emergency services** (firefighters, rescue teams) in disaster preparedness.

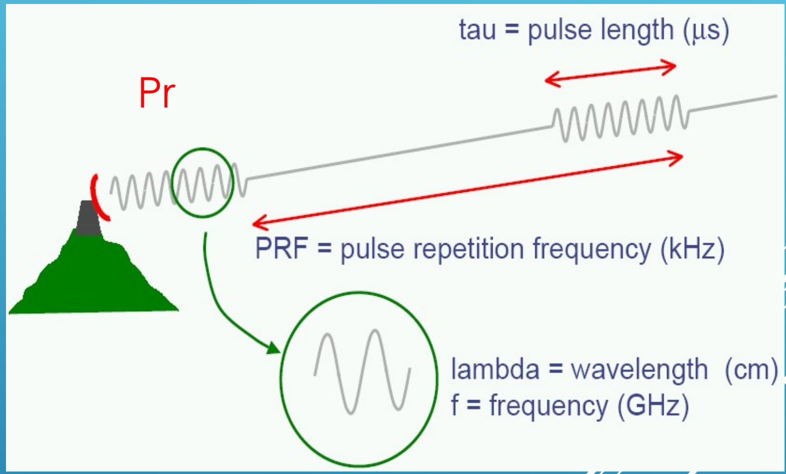
Why It Matters

- ✓ **Saves lives** by providing **early warnings**.
- ✓ **Protects property** from **storms, floods, and hail**.
- ✓ **Boosts economic efficiency** in **agriculture, energy, and transportation**.
- ✓ **Advances climate science** with **precise data collection**.

Definition and how it works?

Radar (**RA**dio **D**etection **A**nd **R**anging) is a **detection system** that uses **radio waves** to determine the **range (distance), angle, and velocity** of objects, such as aircraft, ships or weather formations.





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.

The importance of the wavelength

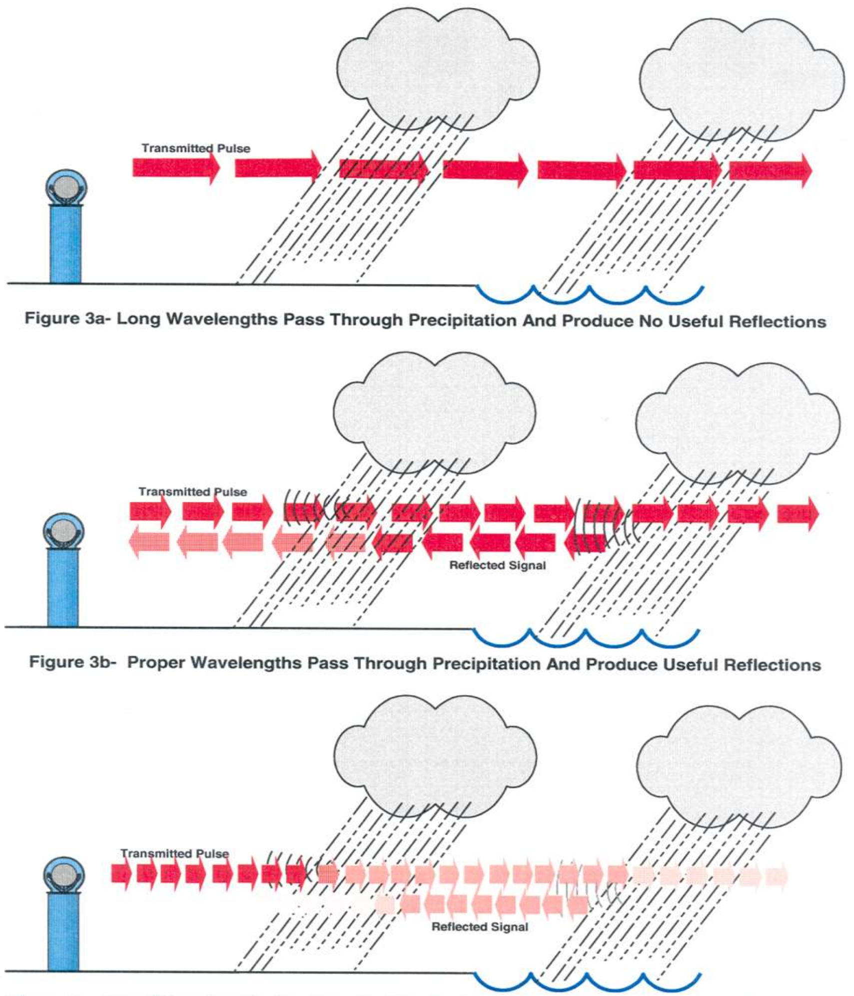


Figure 3a- Long Wavelengths Pass Through Precipitation And Produce No Useful Reflections

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

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

The wavelength of a radar system is a critical factor that determines its range, resolution, penetration, and sensitivity to different targets.

Choosing the right wavelength is essential for optimizing performance based on the radar's purpose (e.g., weather, aviation, military, or maritime).

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

Frequency bands

Meteorological radars operate under the **radiolocation service**

Be deployed in all radiolocation bands but are mainly found in three frequency bands

S-band
2700-2900 MHz
(see RR N° 4.423)

- **Best for: Long-range weather surveillance**
- **Pros:**
  - ✓ **Low attenuation:** Works well in **heavy rain or hail.**
  - ✓ **Covers large areas** (up to **400 km**).
- **Cons:**
  - ✓ **Lower resolution:** May miss **small hail or weak storms.**
  - ✓ **Expensive and large** (requires big antennas).

C-band
5250-5725 MHz
(focusing on 5600-5650 MHz, see RR N° 4.452)

- **Best for: Balanced performance** (range + resolution).
- **Pros:**
  - ✓ **Better resolution** than S-band (detects **smaller storms**).
  - ✓ **More compact** than S-band radars.
- **Cons:**
  - ✓ **Attenuated by heavy rain:** Signal weakens in **intense downpours.**
  - ✓ **Shorter range** (~200–300 km).

X-band
9300-9500 MHz
(see RR N° 4.475B)

- **Best for: High-resolution, short-range weather monitoring.**
- **Pros:**
  - ✓ **Detects small particles:** Ideal for **hail, tornado debris, or insect swarms.**
- **Cons:**
  - ✓ **High attenuation: Rain can block signals** (~100 km).
  - ✓ **Requires frequent calibration** due to sensitivity.

Meteorological radars specificities

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

The weather radar protection criteria is I/N=-10 dB (see ITU-R Rec. M.1849-3)

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

Scanning strategies

A **radar strategy** in meteorology is a **set of technical and operational choices** to:

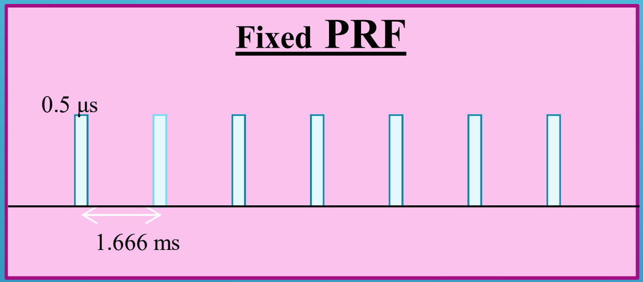
- ✓ **Optimize detection** (scanning, PRF, polarization).
- ✓ **Improve accuracy** (calibration, attenuation correction, data fusion).
- ✓ **Adapt to conditions** (clear air, precipitation, severe storms).
- ✓ **Integrate data into forecasting systems** (NWP, nowcasting).

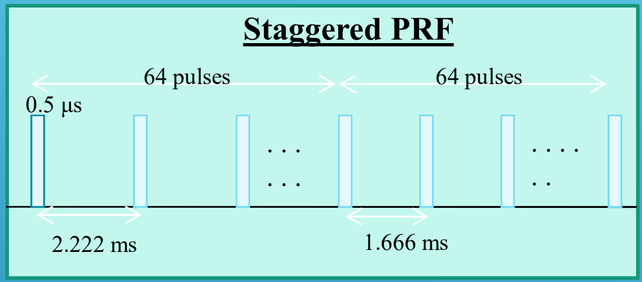
For a given radar, “scanning strategies” (typically of 10/15 minutes) make use of a variety of different emission schemes at different elevations, using sets of different pulse width, PRF and rotation speeds

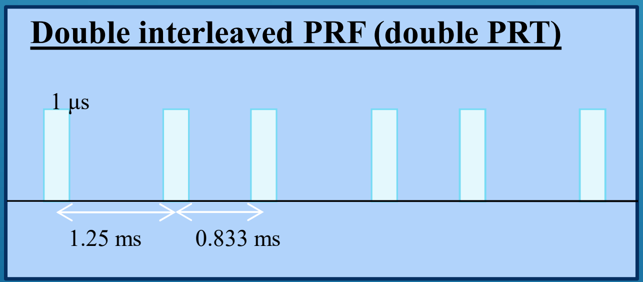
No typical schemes but large ranges of parameters:

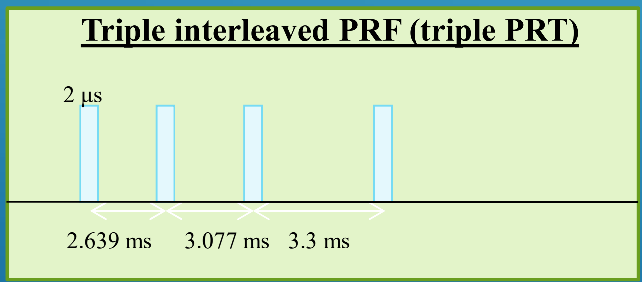
-Operational elevation ranging from 0° to 90°
-Pulse width ranging from 0.5 to 2.5 μs
-Pulse repetition Frequency (PRF) ranging from 250 to 1200 Hz
-Fixed and staggered / interleaved PRF
-Rotation speed ranging from 1 to 6 rpm

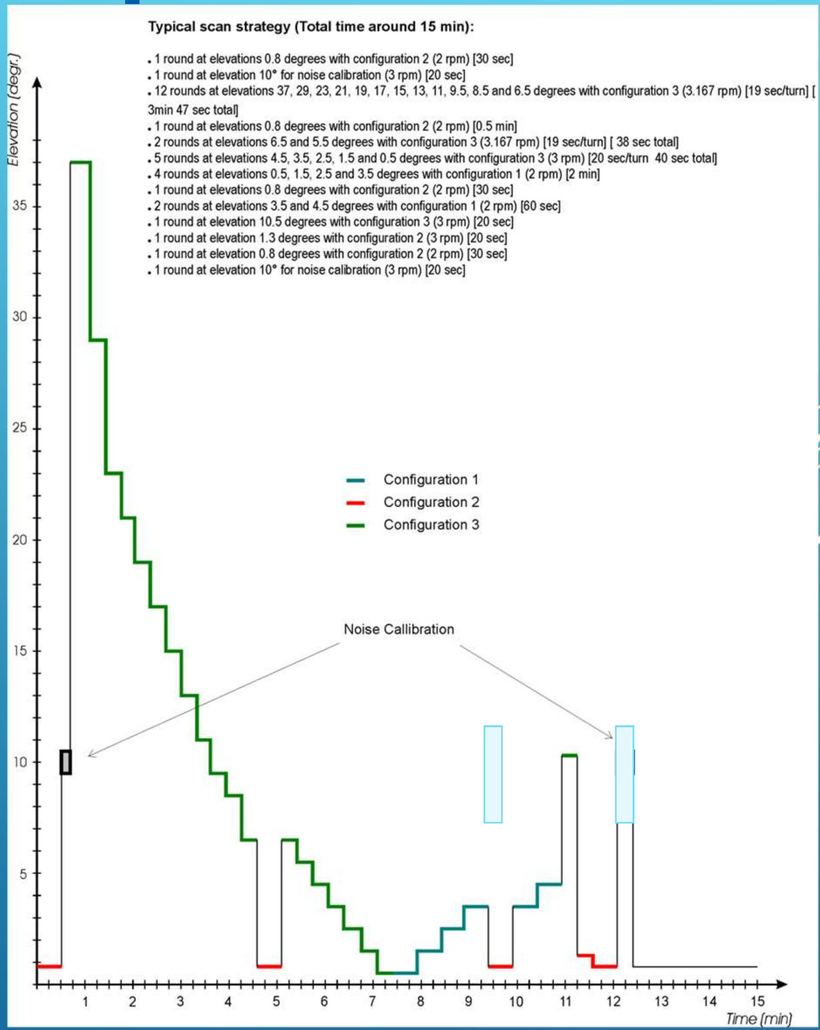
Emission schemes examples











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.

2700-2900 MHz:

- No end story: targeted by the Mobile community for IMT usage, denied at 3 WRCs …
- Subject to interference from out of band emission of IMT usage in the 2500-2690 MHz adjacent band.

5250-5725 MHz:

- Following WRC-03 decision for new mobile allocation in the 5 GHz frequency band, numerous interference cases experiences worldwide, especially in Europe, in particular due to non-compliant WAS/RLAN deployment.
- Envisioned by UWB applications.

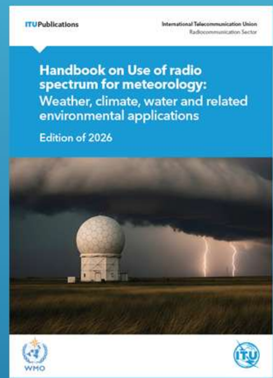
9300-9500 MHz:

- Targeted by mobile community for IMT usage. Denied at WRC-23
- Also envisioned by UWB applications
- Some interference cases from onboard meteorological radars

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*"



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

THANK YOU.