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C-band meteorological radars Threats related to RLAN 5 GHz

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Ground-based meteorological radars

- Described in Recommendation ITU-R M.1849-1 on "*Technical and operational aspects of ground-based meteorological radars*"
- Among meteorological radio applications, meteorological radars are specific and essential since they allow for in-situ and real time detection, quantification and monitoring of **rain** and **wind** conditions
- These data are input to Numerical Weather Prediction models for nowcasting, short-term and medium-term forecasting
- The rain accumulation data is used in hydrological process, e.g. flooding monitoring
- Meteorological radar networks represent the last line of defence against loss of life and property in flash flood or severe storms events,

Meteorological radars relate to Public Safety

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Meteorological radars bands

- Meteorological radars can be found in the :
  - S-band : 2700-2900 MHz
    - typical 750-1000 kW peak with around 45 dBi antenna (i.e. up to 105 dBW e.i.r.p.)
    - 300-350 km range
  - C-band : 5250-5725 MHz (mainly in the 5600-5650 MHz, see RR No **5.452**)
    - typical 250 kW peak with around 45 dBi antenna (i.e. up to around 100 dBW e.i.r.p.)
    - 200-250 km range
  - X-band : 9300-9500 MHz
    - typical 10-50 kW peak with around 40 dBi antenna (i.e. up to around 85 dBW e.i.r.p.)
    - 50-100 km range

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

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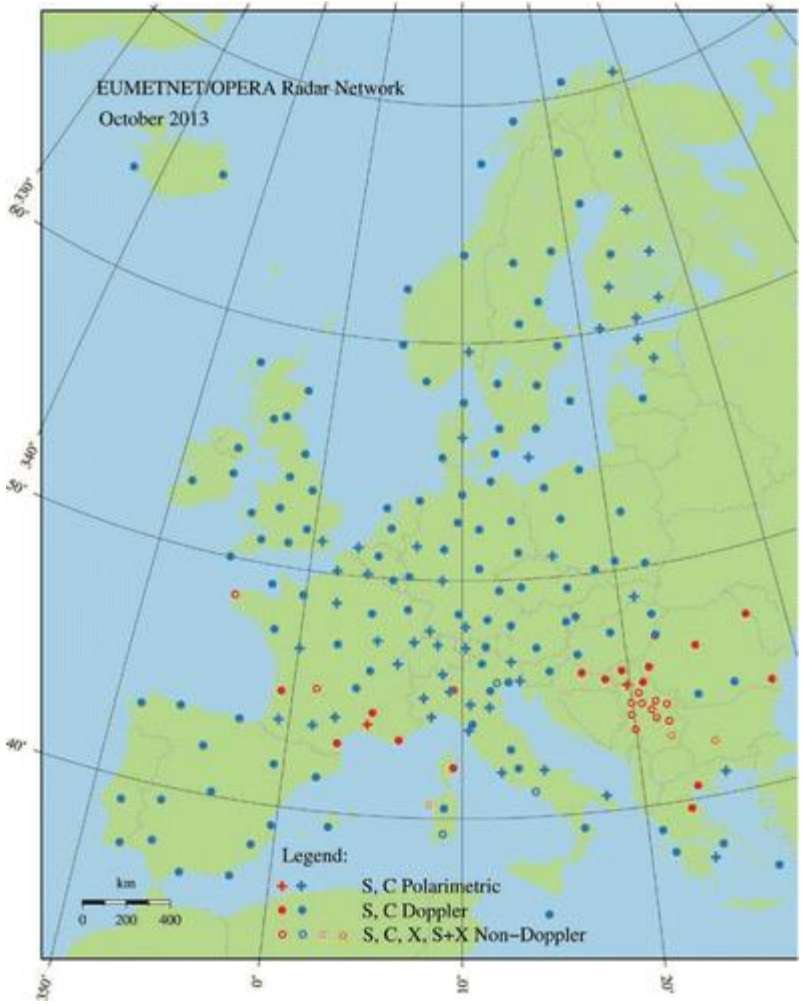
Meteorological radars network in Europe

- The best trade-off compromise is reached in the C-Band that forms the basis for the European network
- 178 meteorological radars in the band 5600-5650 MHz and 5 in the band 5350-5470 MHz (over 25 EUMETNET and associates members)
- 31 radars are implemented in the S-Band, mainly south Europe to overcome heavy rain conditions
- 16 radars are implemented in the X-Band, mainly for specific local coverage
- Data from most of these radars are nowadays used to compose the European OPERA composite image



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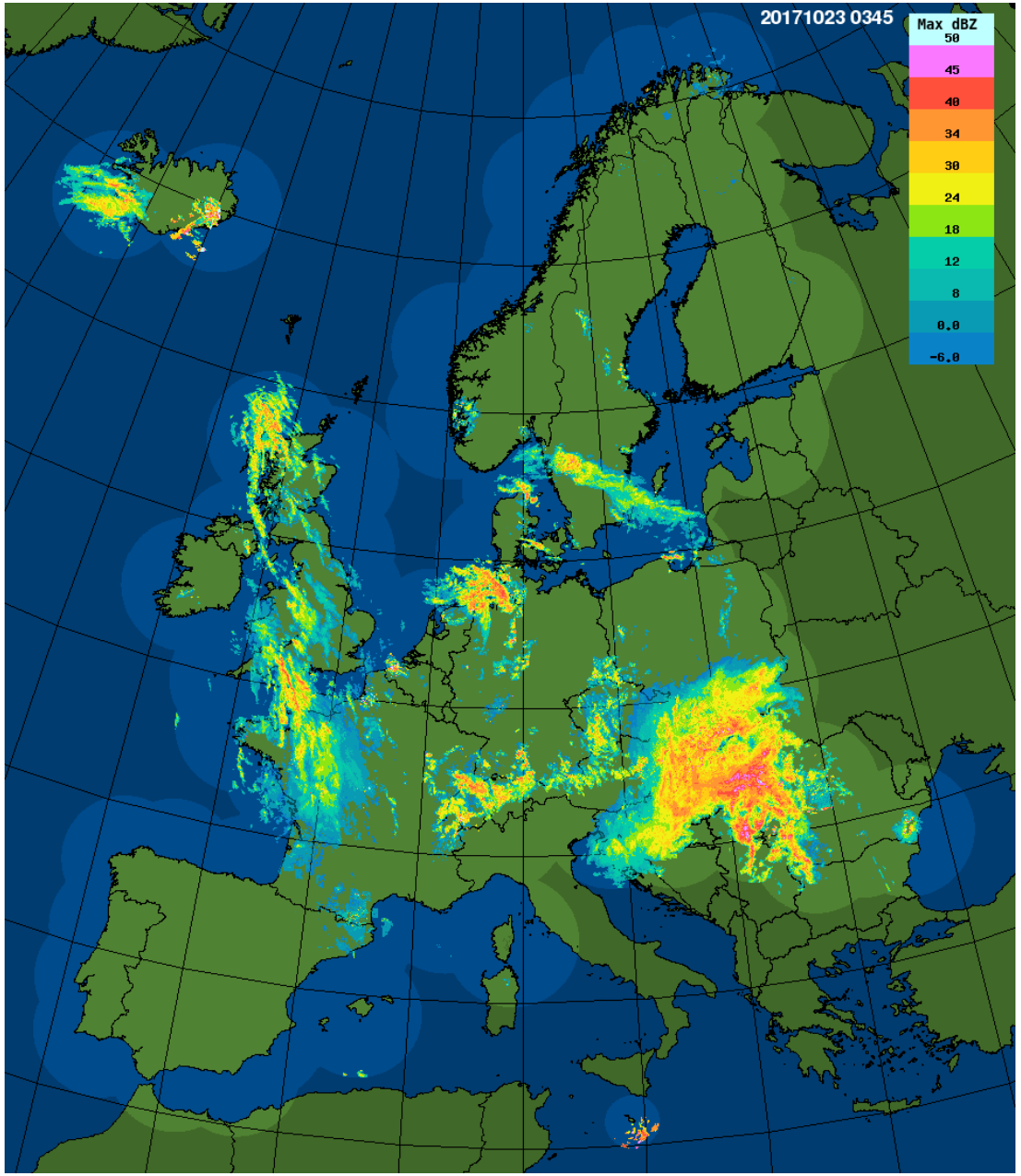
Recent enquiry among 23 EUMETNET members quoting the importance of meteorological radars products for various activities in their country (from 0= not used to 5 = very very important).

Number of respondents: 23

	0	1	2	3	4	5	Total	Average
Aviation weather service	0	0	0	1	7	15	23	4.61
Hydrological applications	1	2	2	4	6	8	23	3.57
Flooding of rivers	1	1	3	6	4	6	21	3.38
Hydropower	6	4	5	6	0	0	21	1.52
Flash floods	1	1	1	7	3	10	23	3.74
Warning of severe weather	0	0	0	0	3	20	23	4.87
Insurance claims (afterwards)	0	0	5	11	5	2	23	3.17
Television and web	0	1	0	8	10	4	23	3.7
Assimilation in NWP models	3	1	3	4	5	3	19	2.84

This is an idyllic situation

but, since 2006 …



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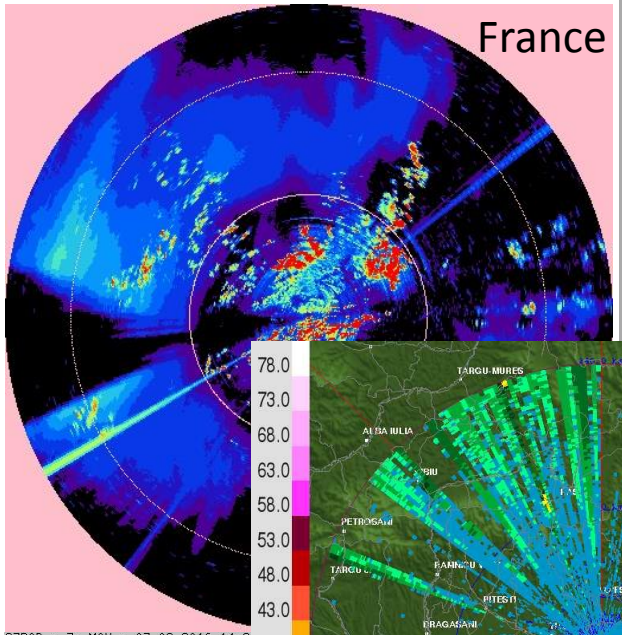

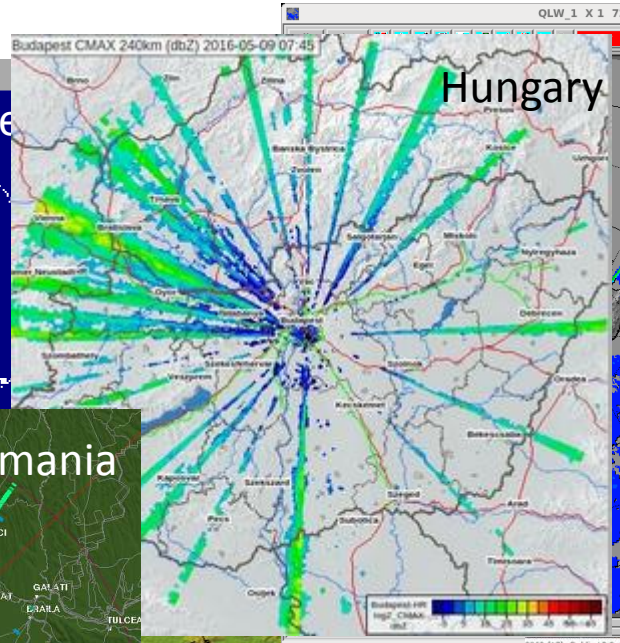

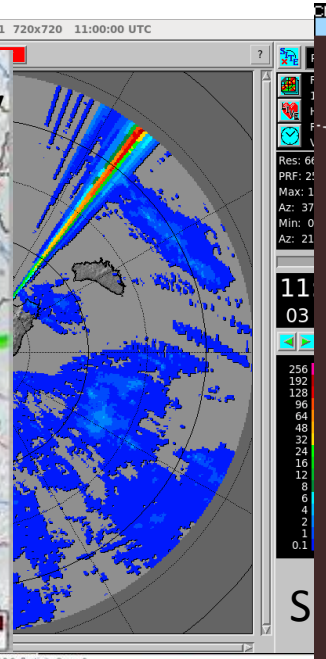

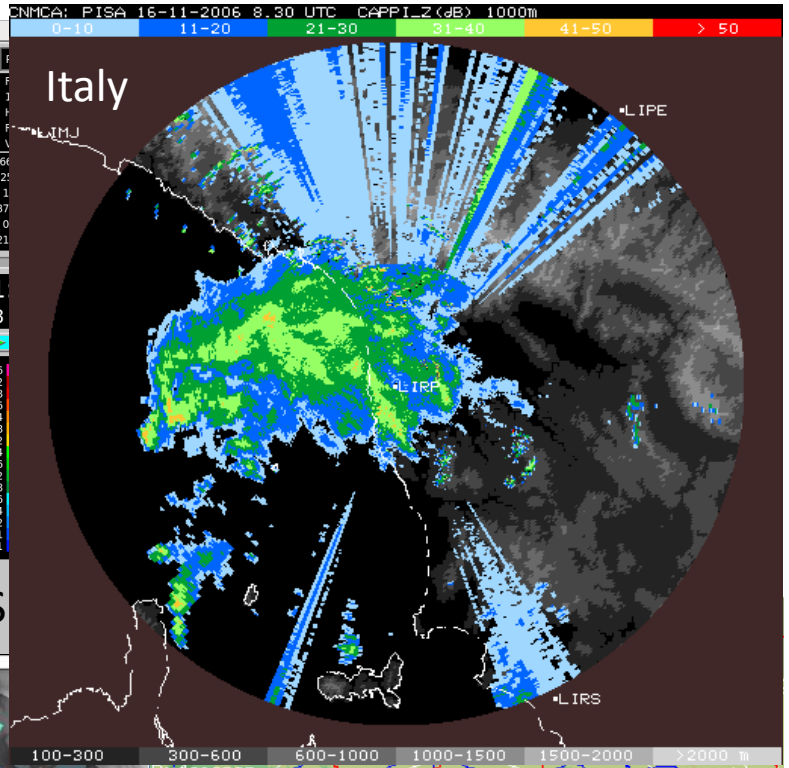

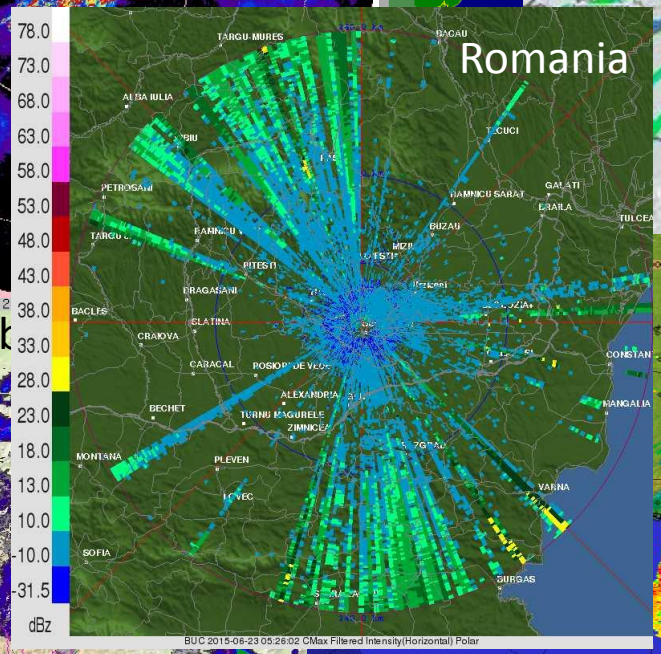

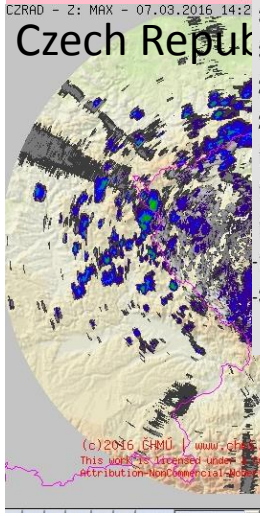

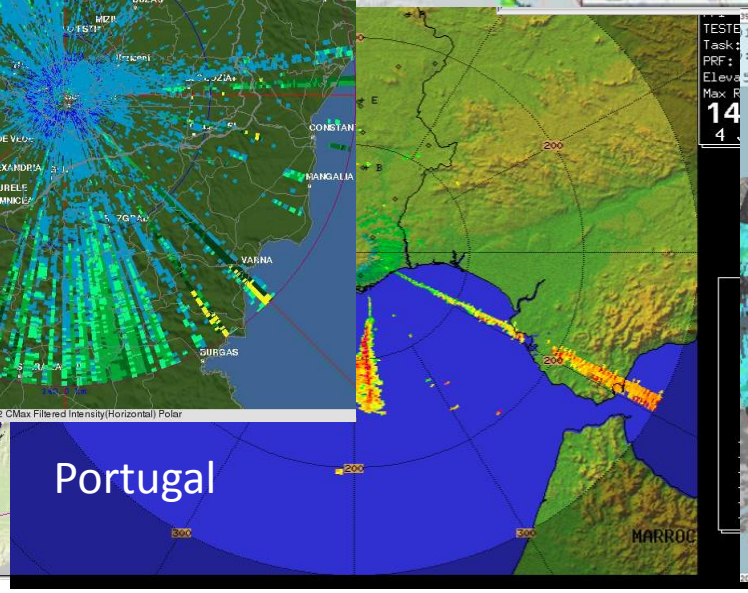

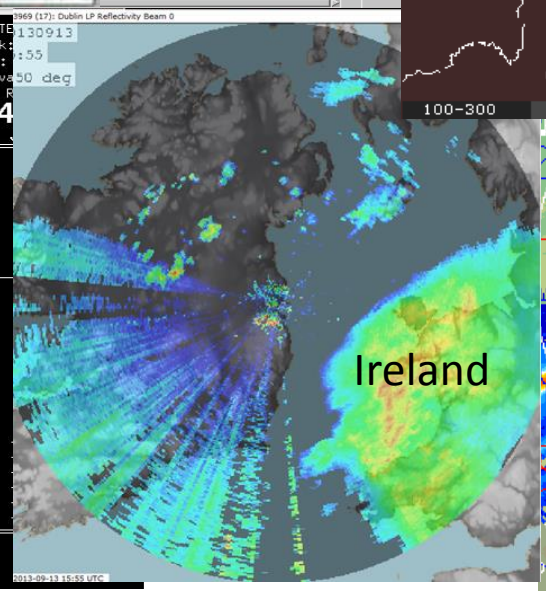

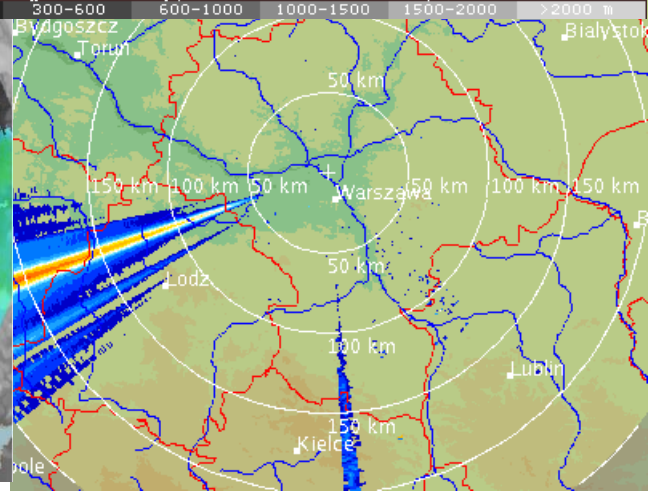

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Genesis of the problem

- The World Radiocommunications Conference 2003 (WRC-03) made the decision to authorise WAS/RLAN (e.g. WiFi) in the bands 5150-5350 MHz and 5470-5725 MHz
- This authorisation has been made under certain technical conditions set-up in WRC Resolution 229
- Among other conditions (eirp limits, ….), the protection of radars is expected to be enabled by the implementation by RLAN of the so-called DFS feature (Dynamic Frequency Selection), a kind of “listen before talk”
- Before using a certain channel, the RLAN DFS needs to check during a certain time (1 mn initially) whether it detects a radar signal on this channel. If a detection is made, then the RLAN has to find another channel.
- The DFS specifications include a number of parameters, in particular a minimum detection signal (-64 dBm) and a large variety of radar signals to detect (so-called “test signals”).
- The general specifications of DFS are given in Recommendation ITU-R M.1652
- Detailed specifications are given in ETSI standard EN 301 893

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The first interference cases

- The WRC-03 decisions on 5 GHz RLAN were transferred into European Regulations with the adoption of:
  - ECC Decision ECC/DEC/(04)08 (November 2004)
  - EC Decision 2005/513/EC (July 2005)
- The first interference cases occurred in 2006, mainly in Eastern Europe
- European authorities (in particular EU TCAM, responsible for market surveillance) were alerted
- It was rapidly demonstrated that the DFS detailed specifications given in ETSI standard EN 301 893 were not covering the specificities of meteorological radars.
- EU TCAM mandated ETSI to modify standard EN 301 893 to better take into account meteorological radars specificities and in particular representative “test signals”.
- EUMETNET was deeply involved in this work that led in 2008 to the new releases V1.5.1 and V1.6.1 of the RLAN standard.

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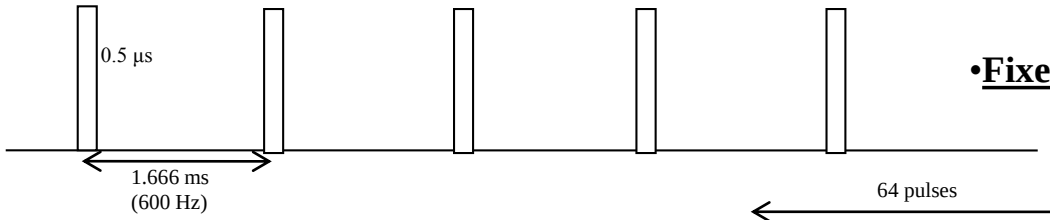
Meteorological radars specificities

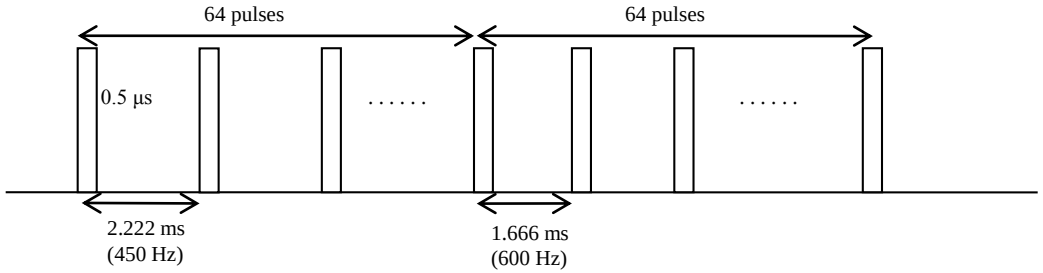
- Unlike other radars that have a radar equation (i.e. the receiving signal vs the EIRP) proportional to $1/r^4$, for meteorological radars it is $1/r^2$. This has an impact on the sensitivity to and acceptable level of interference
- Unlike other radars, meteorological radars perform volumetric scanning/cartography of the entire atmosphere within the radar range
- To elaborate the meteorological products (mainly reflectivity and Doppler) over the whole range, meteorological radars operations are based on “scanning strategies”
- For a given radar, “scanning strategies” (typically of 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 (for operational radars)
  - Pulse repetition Frequency (PRF) ranging from 250 to 1200 Hz (for operational radars)
  - Fixed and staggered / interleaved PRF
  - Rotation speed ranging from 1 to 6 rpm

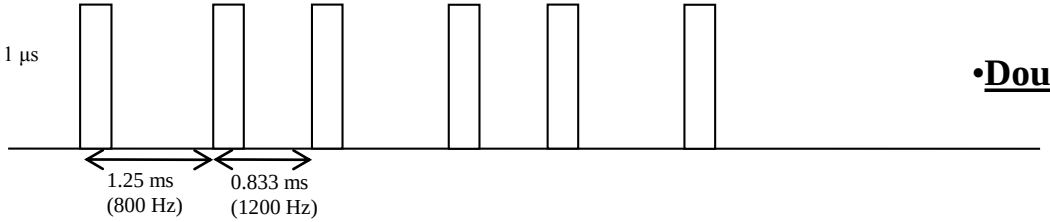
Meteorological radars emission schemes



•**Fixed PRF**

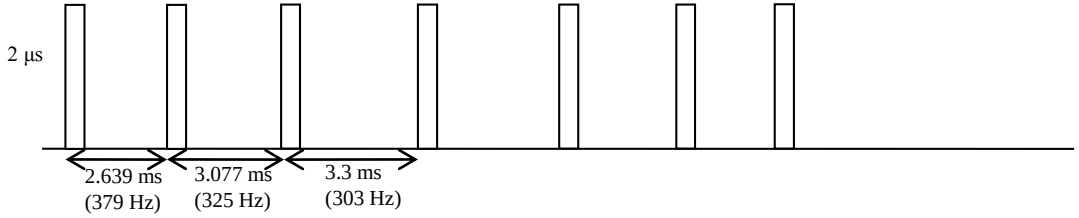
•**Staggered PRF**





•**Double interleaved PRF (double PRT)**

•**Triple interleaved PRF (triple PRT)**



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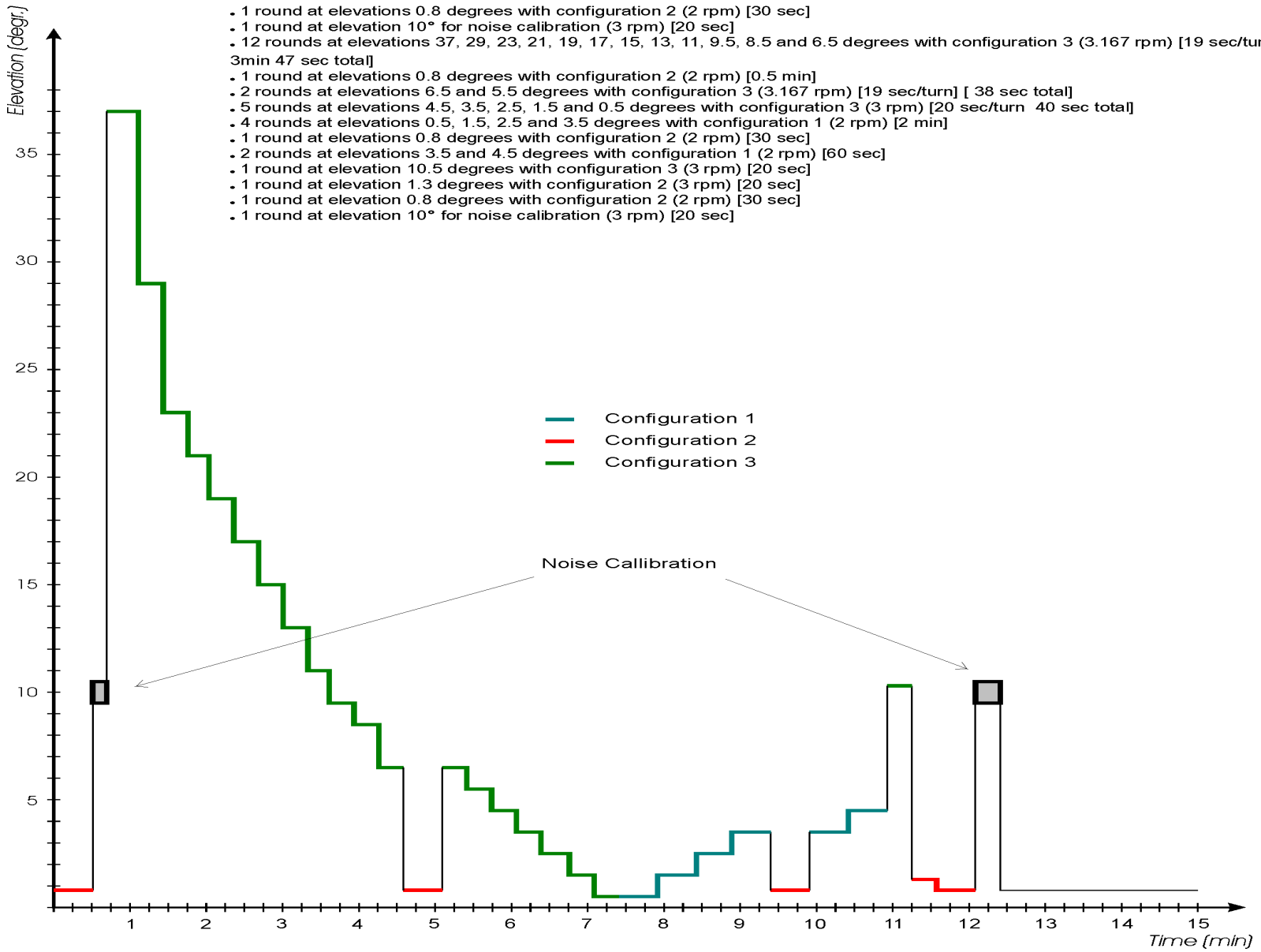
Example of scanning strategy

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]



Noise calibration ("Zero Check")

- Denoting *S* the useful signal (from which the radar is able to determine all meteorological products) and N the noise level:
  - for each gate/pixel, the radar measures the return signal hence corresponding to the useful signal (*S*) and the noise (*N*), i.e. *N+S*
  - to retrieve the *S*, the radar extract from *N+S*, the noise level *N*
- In order to get the more precise meteorological products, the signal S has to be as accurate as possible which means that the noise calibration of the radar is a crucial issue.
- This noise calibration, also called "Zero Check", is therefore performed on a regular basis, either during regular radar emissions (by statistical estimation) or during specific periods of time (typically 1 radar turn) during which the noise is measured, and will be used as reference for the "scanning strategy"
- In many cases, this noise measurement is performed without any radar emission
- Any interference during the noise calibration will pollute all products during a global "scanning strategy"

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Modifications of the DFS specifications

- These modifications were included, together with detailed description of new tests signals in ETSI EN 301 893
- They are also described in Report ITU-R M.2115-1

These specifications were and are still considered by EUMETNET satisfactory to ensure detection of meteorological radars

	V1.3.1/ V1.4.1	**V1.5.1**		**V.1.6.1**
Parameter	All Channels	**5600-5650 MHz**	Other channels	
Date of Withdraw (DOW)	**1 July 2010** (April 09 for 5600-5650 MHz band)	**1 January 2013**		N/A
Minimum pulse width (see detailed test signals in table below)	1 µs	**0.8 µs**		**0.5 µs**
PRF (see detailed test signals in table below)	Fixed	**Fixed, Staggered and Interleaved**		V1.5.1
Channel Availability Check (CAC) time	1 minute	**10 minutes**	1 minute	V1.5.1
Off-Channel CAC (Note 1)	No	**Yes**		V1.5.1
CAC and Off-Channel CAC detection probability (Note 2)	60%	**99.99%**	60%	V1.5.1
In-service monitoring detection probability	60%	60%		V1.5.1
CAC for slave devices with power above 200 mW (after initial detection by In-service)	No	**Yes**		V1.5.1
Detection Threshold	-64 dBm (>200 mW) -62 dBm (<200 mW)	-62 +10 -EIRP Spectral Density (dBm/MHz) + G (dBi), however the DFS threshold level shall not be lower than -64 dBm assuming a 0 dBi receive antenna gain		V1.5.1
Channel Move time	10s	10s		V1.5.1
Channel closing time	260 ms	**1s**		V1.5.1
Non-occupancy period	30 minutes	30 minutes		V1.5.1
Possibility to exclude 5600-5650 MHz band from the channel plan or to exclude these channels from the list of usable channels	No	**Yes**		V1.5.1

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EUMETNET commitments

- Associated with the modification of the ETSI standard EN 301 893, EUMETNET adopted in 2008 a Recommendation on "**C-Band Meteorological radars design to ensure global and long-term coexistence with 5 GHz RLAN"**
- This Recommendation includes in particular the following technical and operational guidelines to be considered with the highest care and priority by EUMETNET members:
  - only operate radars in the 5600-5650 MHz band (except for Switzerland which radars are operating outside RLAN bands)
  - transmit minimum number of detectable signals over scanning strategies
    - 1 detectable signal at low elevation at maximum every 10 minutes
    - Expected to ensure future development of meteorological radars
  - improve to the best extent and at minimum to the future regulated levels the out-of-band emissions of radars
  - improve to the best extent the out-of-band signal rejection of the radar receiver, with a particular focus on the image-frequency.

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Non-compliant RLAN

- When ETSI EN 301 893 V1.5.1/V1.6.1 was released in 2008, it was acknowledged that it would take time to see an improvement.
- In 2011, no improvement was noted and EUMETNET raised once again the issue to European Authorities
- An global enquiry was performed which results were:
  - that all investigated interference cases relate to outdoor WAS/RLAN fixed installations operating co-channel with the radar (long-term events)
  - short-term interference events were reported but the short duration of these cases does not give the opportunity for administrations to further investigate the situation and to identify the source of the interference
  - A considerable number of the reported interference cases were caused by equipment where the DFS mechanism was disabled by the user (non-compliant RLAN since DFS is mandatory)
  - In some cases, where DFS was disabled, re-enabling DFS did not cause the equipment to detect the radar. The DFS did not function as intended (non-compliant DFS)
  - Insufficient or no investigation at all on why DFS did not work as intended
  - No action against non-compliant or illegally used equipment

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Non-compliant RLAN

- These findings were confirmed by an ADCO/RTTE market surveillance campaign involving 21 European countries.
- 64 different products were investigated and the results were meaningful:
  - For 3 products (5 %), DFS was not implemented !
  - For 22 products (34 %), DFS could be deactivated by the user, either directly of by changing the firmware
  - For 7 products (11 %), the manufacturer provided information in the user manual on how to deactivate the DFS
  - For 44 products (69 %), this information was provided on the manufacturer's website !
  - For 38 products (59 %), the DFS function could be indirectly deactivated by changing the device's region or country of use
- **Overall, this campaign showed that more than 70% of the products on the market were not compliant !!**

ECC Report 192

- On this basis, ECC adopted ECC Report 192 (February 2014), summarising the situation and providing guidance to market surveillance and interference monitoring authorities to ensure incentive not to place anymore non-compliant equipment on the market
- In particular, it makes clear that in those cases where the WAS/RLAN is operating co-channel with the radar and is causing interference into the radar, market enforcement shall not allow such equipment to be operated or remain in use and no effort should be made to solve the interference case by:
  - 1. Re-configuring the WAS/RLAN equipment to a different channel, or
  - 2. Re-enabling DFS again (where it was disabled), or
  - 3. Reducing the Tx-output power.
- It encourages to undertake action that can end in a safeguard clause procedure to ban the considered equipment from the European market.
- It also mention the benefit to maintain and publish a list of non-compliant equipment for which Member States had initiated a safeguard clause

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And now ?

- ECC Report 192 was a very promising framework ….
- … but EUMETNET was naïve enough to believe that it would allow to cleaning the market and having sustainable effect on interference to meteorological radars
- We have realised that almost all European NRA have not changed their behaviour and are not applying at all the guidance from ECC Report 192
- The direct result being that interference to meteorological radars are continuously increasing
- In 2016, it was it was considered necessary to have a new and quantified picture of the situation within EUMETNET and an enquiry was performed among the 25 members operating C-Band radars.

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EUMETNET 2016 enquiry

- answers from 23 members and associates over 25 possible having C-Band radars (only Iceland and Italy did not provide their elements), involving 153 radars, among of which 148 operates in the 5600-5650 MHz band
- Overall, the enquiry results confirmed the high level of interference faced by EUMETNET members and associates:
  - All 23 respondents experienced interference with cases reported to 122 radars (80% of radars)
  - For 2015, this represent 21 respondents having experienced interference with cases reported to 110 radars (72% of radars)
  - 21 members (88%) have not seen an improvement of the interference situation (13 “increasing“ and 8 “stable“)
- In Austria, with an automatic interference detector, 1.4 Millions interference cases (most of them short-term) have been detected on their 5 radars in 2015 !!
- Last but not least, the questionnaire confirm the lack of relevant actions undertaken by NRA following interference cases (i.e. frequency shift, …) and the deficiency of the market surveillance with most interference cases due to non-compliant and illegal RLAN usage.

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EUMETNET 2017 enquiry

- The same exercise was reiterated in 2017 for interference in 2016 to radars operating in the 5600-5650 MHz band
- answers from 22 members and associates over 24 possible having C-Band radars (only Iceland and Italy did not provide their elements (Switzerland radars are in the 5350-5470 MHz band), involving 154 radars
- the enquiry results show a new increase of interference :
  - All 22 respondents experienced interference in 2016 with cases reported to 128 radars (83% of radars)
  - 21 members (95%) have not seen an improvement of the interference situation compared to 2015 (11 “increasing“ and 10 “stable“)
- Once again, the questionnaire confirm the lack of relevant actions undertaken by NRA following interference cases (i.e. frequency shift, …) and the deficiency of the market surveillance with most interference cases due to non-compliant and illegal RLAN usage.
- In Ireland, the NRA systematically refuses to intervene, the Dublin Airport radar is continuously interfered since 3 years. This radar has been excluded from composite images (UK Metoffice and OPERA) !!

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Current actions in Europe

- A high level EUMETNET letter has been sent in January 2017 to the European Commission, copy ECC, to provide a summary of the enquiries outcomes, to raise the lack of relevant actions from NRA and request for solving the problem within short notice,
- This letter makes it clear that rapid actions are necessary, that status quo is not an option and that in the absence of rapid results, there would be no other choice for EUMETNET than to request a ban of RLAN in the 5600-5650 MHz band, consistently with situation on a number of countries worldwide, such as in Canada and Australia
- At this stage, an action framework has been set-up by ECC:
  - Make sure that ECC Report 192 is from now fully applied by national enforcement authorities, with particular stress on the fact of not leaving any non-compliant equipment in use
  - Prepare awareness and information actions from National radio administrations as well as in the CEPT web-site
  - Consider the possibility to release a “Name and Blame” list of non-compliant 5 GHz RLAN equipment (at national level and/or CEPT level)
  - Recommend to the European Commission to activate Article 5 of the RE Directive for 5 GHz RLAN, under which manufacturers will have to register their radio equipment
- A recent ECC (FM22) questionnaire to European NRAs has confirmed the EUMETNET findings, with more than 550 interference cases in 2016 within 24 countries. The distance between interfering RLAN and radar has been reported in a range from few hundred meters to 181 km !!!!!!
- No action plan developed yet from the European Commission

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Lessons related to the RLAN 5 GHz issue

- The RLAN 5 GHz issue is a consequence of a bad decision at WRC-03 at which the meteorological community did not realise the importance of the item. Only Canada and Australia did, and subsequently banned the 5600-5650 MHz band for RLAN in their country.
- It therefore confirms and justifies the imperious need for the meteorological community to be involved in frequency management, in particular at WRC level
- Current growing feeling that **European Authorities are totally unable to solve the case and hence to control their own decision**
- If the trend is maintained = **Big risk of loosing the band** (e.g. South Africa)
- Growing feeling that the policy is to give spectrum to telecommunications, at all cost, in particular at all risk for incumbent services
- The scientific community is often considered as over-conservative, but RLAN 5 GHz issue is the best proof of the contrary

Before the current situation improves, EUMETNET will now oppose any proposal to identify a frequency band of interest for meteorological applications to mass-market unlicensed type radio application.

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General lessons

Facing the difficulties to solve current interference cases, consideration of future issues in the frequency management process should lead to raising a lot of “WHAT IF” ?

- **WHAT IF … the initial assumptions are too optimistic ?**
- **WHAT IF … the possible conditions cannot actually be controlled ?**
- **WHAT IF … a different application than expected makes use of the spectrum ?**
- **WHAT IF … non-compliant equipment can easily be put on the market ?**

This is **“Building upon experience”** and **“Risk Assessment”**

Making an error once is a **MISTAKE**, making it twice is a **FAULT**

We can only appeal for worldwide countries to ensure protection and availability of essential frequency bands used for meteorology and Earth observations

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Thank you for your attention

PS: do not hesitate to contact me if you need any clarifications or more detailed information on this issue