Radar Detection and DFS on MikroTik

MikroTik User Meeting
London 2016

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Experience?

- 25 years working with RF from 9kHz to 100GHz with UK Gov, Radiocommunications Agency RIS and Ofcom.
- Training certifications from companies such as Marconi, Hewlett-Packard, Rohde & Schwarz, Microsoft, Ruckus, Meru, MikroTik and Ubiquiti.
- A user of MikroTik since 2006
- Certified Consultant and Trainer since 2009 and holder of all MikroTik certifications MTCNA, MTCRE, MTCTCE, MTCUME, MTCWE and MTCINE.

Who are LinITX?

- Largest MikroTik Distributor in the UK
- Largest number of MikroTik Certified Consultants and Trainers in a single UK Company
- Certified MikroTik Training Centre since 2011
- Provide Consultancy and Third Line Support to ISPs and WISPs using MikroTik and troubleshoot issues affecting Small to Enterprise clients using Ruckus and Ubiquiti

DFS - What is it?

- “Dynamic Frequency Selection” - not the infamous furniture company (although, it could be said **this** particular DFS “bargain sale” **has** finally ended with MikroTik!)

DFS - Why?

- Legacy (i.e. pre existing) users of 5GHz would only allow WiFi on “their” band **if** and **only if**, they were protected from interference from these new services
- Dynamic Frequency Selection was chosen to:
  1. Look for any active Radar signals and immediately change channel if detected
  2. Randomly pick a channel to spread the energy across the band

DFS - So why now?

- Nothing has **recently** changed with DFS legislation.
- DFS was there, right from the start in 1999 when 5GHz was released **17 years ago**!
- Some vendors chose to ignore it
- Some vendors allowed DFS to be disabled
- Some vendors designed their system in such a way that allowed it easy to “hack”

DFS - So why now?

- End result?
  - Those legacy users, the organisations who originally agreed to this secondary usage of this spectrum got fed up of the interference
  - They started to complain to regulators
  - Therefore, regulators started chasing down the sources of the interference

DFS - So why now?

- Regulators after spending many years tracing interference to legacy users and accumulating a mass of evidence showing wide spread and endemic mis-use by end users decided to act:
  - By notifying the Commission under Article 9 of the Directive 1999/5/EC
    - requesting the ETSI standards be updated
    - consider restricting the WiFi equipment from being sold / moved within the EU

History of 5GHz in Europe

- All started in 1991 with CEPT (European Conference of Postal and Telecommunications Administration) publishing “Recommendation T/R 10-01” stating that new spectrum was required at 5GHz (and 17GHz) for WiFi and also recognised ETSI would be responsible for the technical specification

History of 5GHz in Europe

- 1992 - After consulting with ETSI, CEPT publishes Recommendation TR 22-06

- 1996 ERC (European Radiocommunications Committee) published ERC/DEC/(96)03 and permits 5150-5250MHz for indoors use only and at low power (to protect existing Satellite Uplinks)

History of 5GHz in Europe

- 1998 - at the request of ETSI, ERC agrees further spectrum is required at 5GHz

- 1999 - Decision ERC/DEC/(99)23 adds 5250-5350MHz and 5470-5725MHz with more Tx power but with the added caveat that DFS was required to protect legacy users (Military Radar and Satellite uplinks)

History of 5GHz in Europe

- ERC/DEC/(99)/23 stated:
  - "*that in many countries there is an essential military need for the operation of land, airborne and maritime radars in the bands between 5250 and 5850 MHz. In those countries priority is given to military radars and therefore protection from interference cannot be requested by HIPERLANs*"
- **(Note: No mention of weather radars!)**

History of 5GHz in Europe

- ERC/DEC/(99)/23 also stated that DFS was mandatory between 5470-5725MHz to enforce random channel selection
- I.e. DFS is not just about Radar detection, but also about spreading the energy of multiple Wireless LANs devices evenly and randomly across the band to reduce potential for interference to legacy users (mainly satellite uplinks)

History of 5GHz in Europe

- ETSI standard EN 301 893 is sent for national vote in Europe in June 2003, just in time for the ITU World Radio Conference in 2003 (WRC(03))
- WRC(03) was the opportunity for the 5GHz band to be fully harmonised across the world
- Resolution 229 at the WRC(03) meeting enabled the 5GHz band with DFS according to ITU-R Recommendation M.1652

History of 5GHz in Europe

- ITU Resolution 229 stated :
  - "…*that there is a need to protect the existing primary services in the 5150-5350 MHz and 5470-5725 MHz bands*" and that
  - "…*studies have shown that sharing between the radiodetermination and mobile services in the bands 5250-5350 MHz and 5470-5725 MHz is only possible with the application of mitigation techniques such as* ***dynamic frequency selection***"

History of 5GHz in Europe

- As a result of WRC(03), CEPT issued a new decision “ECC/DEC/(04)/08” in July 2004 which stated:
  - “*WAS/RLANs operating in the bands 5250-5350 MHz and 5470-5725 MHz shall use dynamic frequency selection (DFS) as described in Recommendation ITU-R M. 1652 to ensure compatible operation with radiodetermination systems*” (aka Radar)

DFS Radar Detection

- ITU Recommendation “ITU-R M. 1652” was adopted as the standard for defining what a Radar signature looked like
- However it was already out of date with operational radar technology used even at the time when the standard was ratified!

5GHz future proofing

- Luckily for the ITU, it was also invited to:
  - "… *continue studies on suitable test methods and procedures for the implementation of dynamic frequency selection, taking into account practical experience*"
- Which is one reason why the DFS standards have constantly evolved **and tightened** over the years following on from WRC(03)

Weather Radar users

- The European Meteorological community (and a major radar occupant of 5GHz in Europe) were never consulted!
- It was mainly just, the USA, Canada and Australia that took part in early discussions about DFS when drafting the WRC(03) Decision

Weather Radar users

- One result was that Australia and Canada completely banned use of WLANs between 5600-5650MHz, others followed suit, except the EU
- Many 5GHz Meteorological Radar users in countries around the world started getting more and more interference as 5GHz WiFi equipment was installed

Is Weather radar important?

- Using 5GHz Radar, the Met Office can detect potential future rain fall more accurately, which in turn:
  - Saves lives by allowing warnings to be broadcast
  - Allows Emergency responders organisations, Transport and Travel services to plan ahead
  - Allow Utilities to plan when and how to restore damaged Gas, Electric, Water, Telecommunications services
  - Warn of potential damage to buildings and land

Is Weather radar important?

- Weather radar is a “Safety of Life” system!
- The Met Office provides data for (amongst many others organisations):
  - CAA/NATS and MoD about weather that may affect safety of Aircraft flights
  - Highways Agency and Maritime & Coastguard Agency to ensure safety of Maritime and road transportation
  - Environment Agency for Flood warnings

EUMETNET Enquiry

- EUMETNET (a body representing all the EU Meteorological departments) complained to the EU Commission around 2006 and requested an urgent enquiry between hardware vendors and the Meteorological community to resolve problems
- Around the same time FCC, NTIA and WLAN vendors collaborated to develop a revised DFS algorithm - released in July 2006

EUMETNET Enquiry

- Outcome of enquiry (around 2007):
  - vendors were found to be allowing DFS to be disabled (however DFS is **mandatory**)
  - vendors' radar detection algorithms in ETSI standard were not consistent with modern and **real** radar signatures
  - Vendors who did have DFS enabled were therefore **not** detecting real Radar signals

EUMETNET Enquiry

- Radar Signatures:
  - Min. of 1µS pulse width was defined in technical standard, however many weather radars used a 0.5µS pulse width
  - some radars operated with flexible, variable and staggered PRF (Pulse Repetition Frequency) schemes (original 2003 DFS standard only defined a **static** PRF)

EUMETNET Enquiry

- Recommendations (2006/2007):
  - Request to update the ETSI standard to:
    - increase the CAC time in the band 5600-5650MHz from 60s to **10 minutes**
    - increase probability of detection from 60% to 99.99% within 5600-5650MHz

EUMETNET Enquiry

- Outcome of enquiry (2006/2007):
  - Also agreed that Weather Radars will ensure they transmit test pulses at least every 10-15 minutes during their normally quiet “receive only noise-calibration” phase to increase the opportunity for detection by WLAN hardware
    (Noise calibration usually carried out with antenna at an elevation of 45-60 degrees after 2 active scans (i.e every 30mins)

ETSI DFS Standards

- For the majority of the 5GHz band (Ofcom Bands A and B) DFS requirements are contained in ETSI EN 301 893
  - **Latest is v1.8.1**

- For the 5.8GHz band 5725MHz - 5875MHz (Ofcom Band C) DFS requirements are defined in ETSI EN 302 502
  - **Latest is v1.2.1**

ETSI Standard Updates?

- Soon after the EUMETNET recommendations, ETSI revised EN301893
  - v1.4.1 (2007) DFS made **mandatory**
  - v1.5.1 (2008) Made Radar pulse detection more reliable, increased CAC time to **10 minutes** for the 5600-5650 weather radar band and made “uniform spreading” **mandatory**

ETSI Standard Updates?

- Further updates were made until March 2015
- Each update added more accurate radar signatures and increased the probability of protecting existing legacy radar users

- However… did it make much difference?
  - not really!

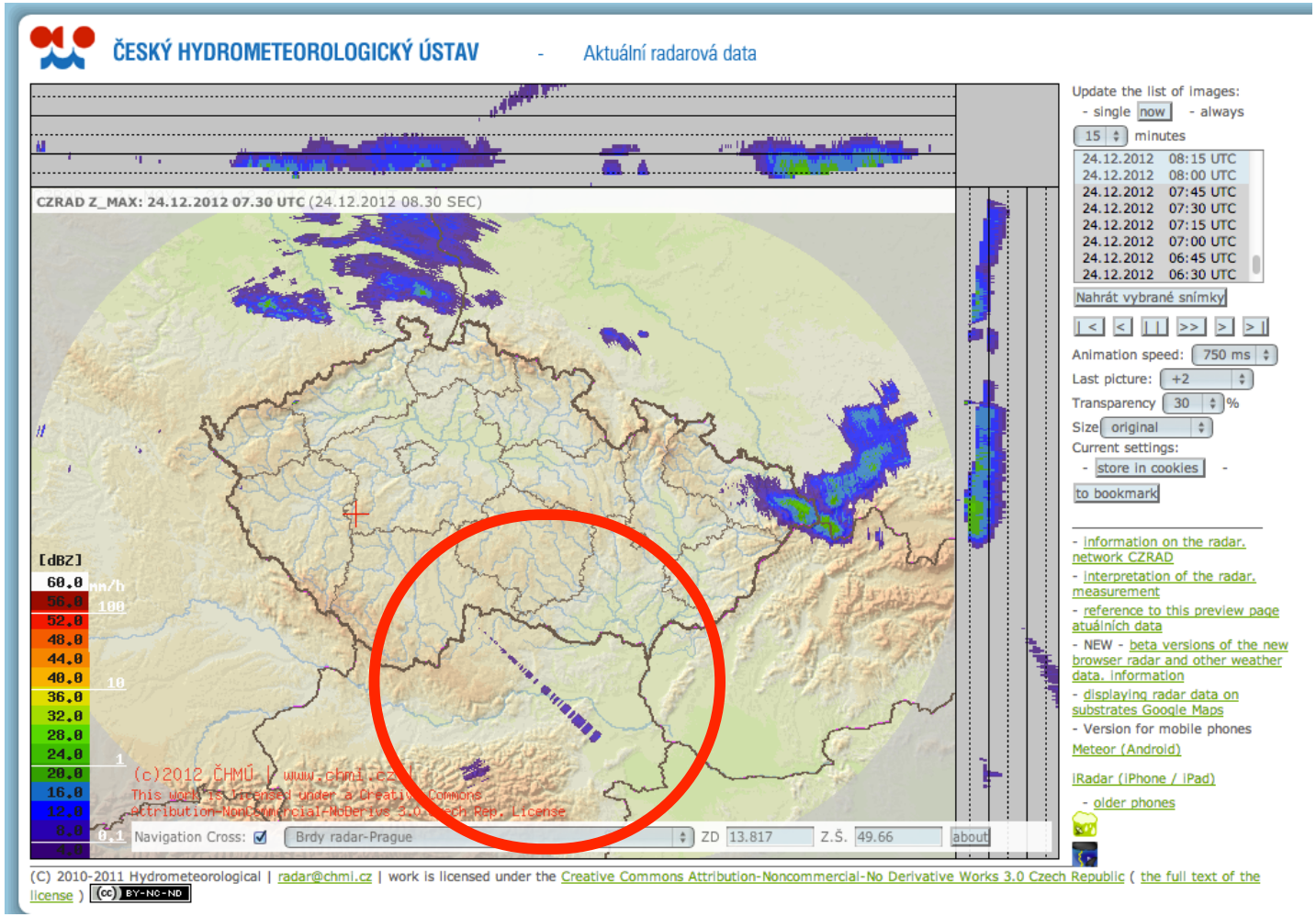
Radar Interference

- More than 12 Countries in EU regularly report interference problems to their Regulatory Authorities (in the UK, to Ofcom)
- Many other regulatory authorities around the world are still receiving regular complaints of interference to Weather Radar

Hungary Radar Interference

- Hungary reported that for **one whole month**, their weather radar systems on 5GHz was **completely un-operational**

Czech Radar Interference

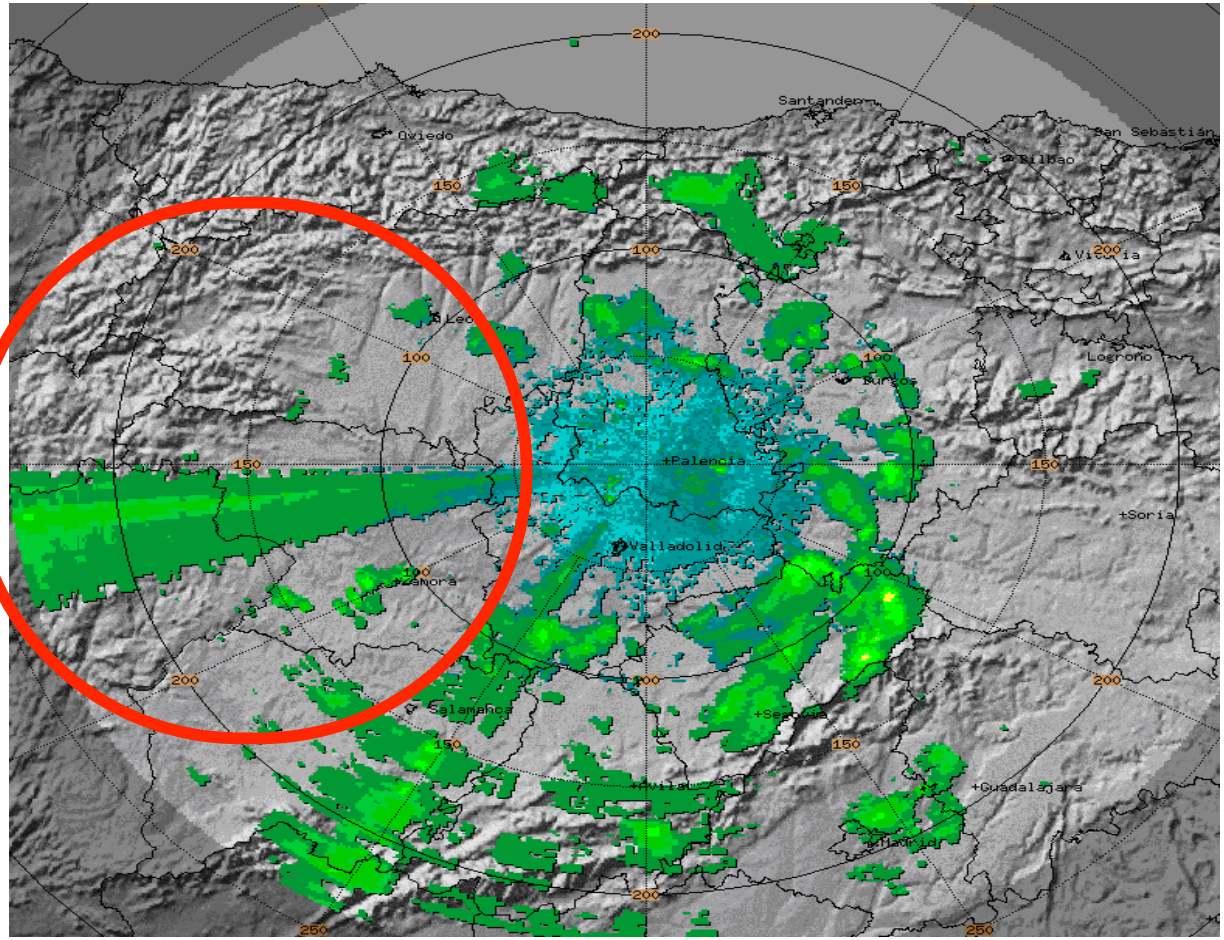


- http://portal.chmi.cz/files/portal/docs/meteo/rad/data_jsradview.html

Czech Radar Interference

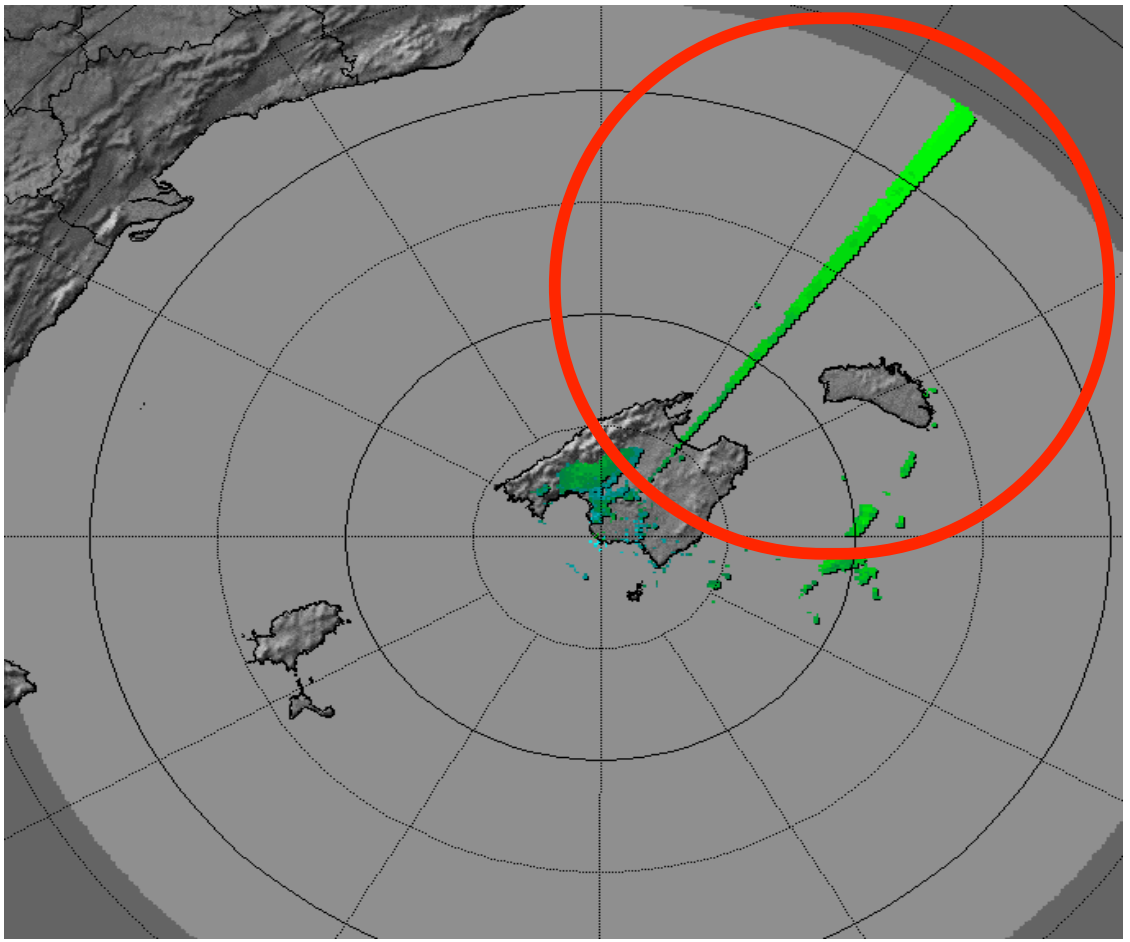
- Interference has become so bad, they list the offenders detected every day by MAC address, SSID and RadioName on their website!
- E.g. nearly 40 for 10th November 2016
- See http://radar4ctu.bourky.cz/Ruseni.html

Interference to Spanish Radar



Source: http://www.cept.org/Documents/wg-se/4579/SE(12)034_Extract-of-the-response-to-the-WGFM-questionnaire-on-the-current-status-of-DFS-in-the-5GHZ-frequency-band

Interference to Spanish Radar



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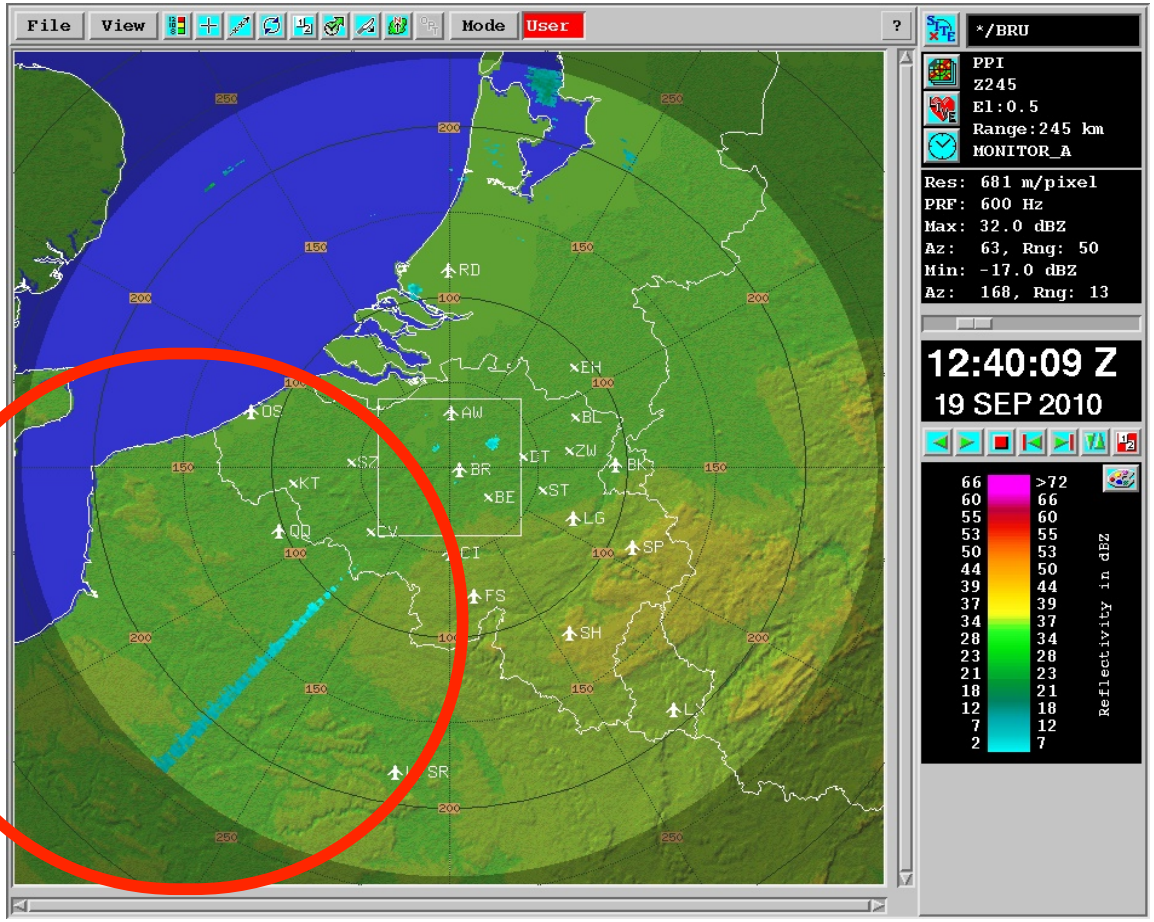
Interference to Belgian Radar



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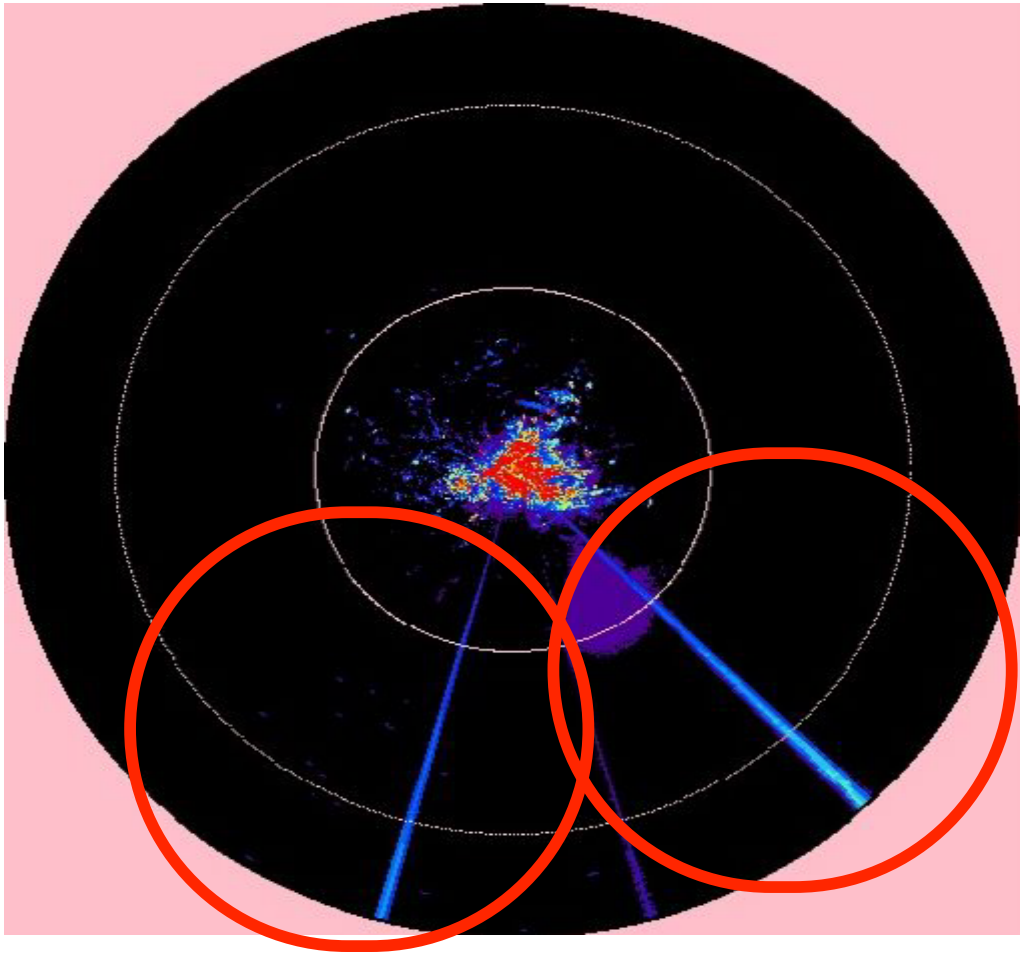
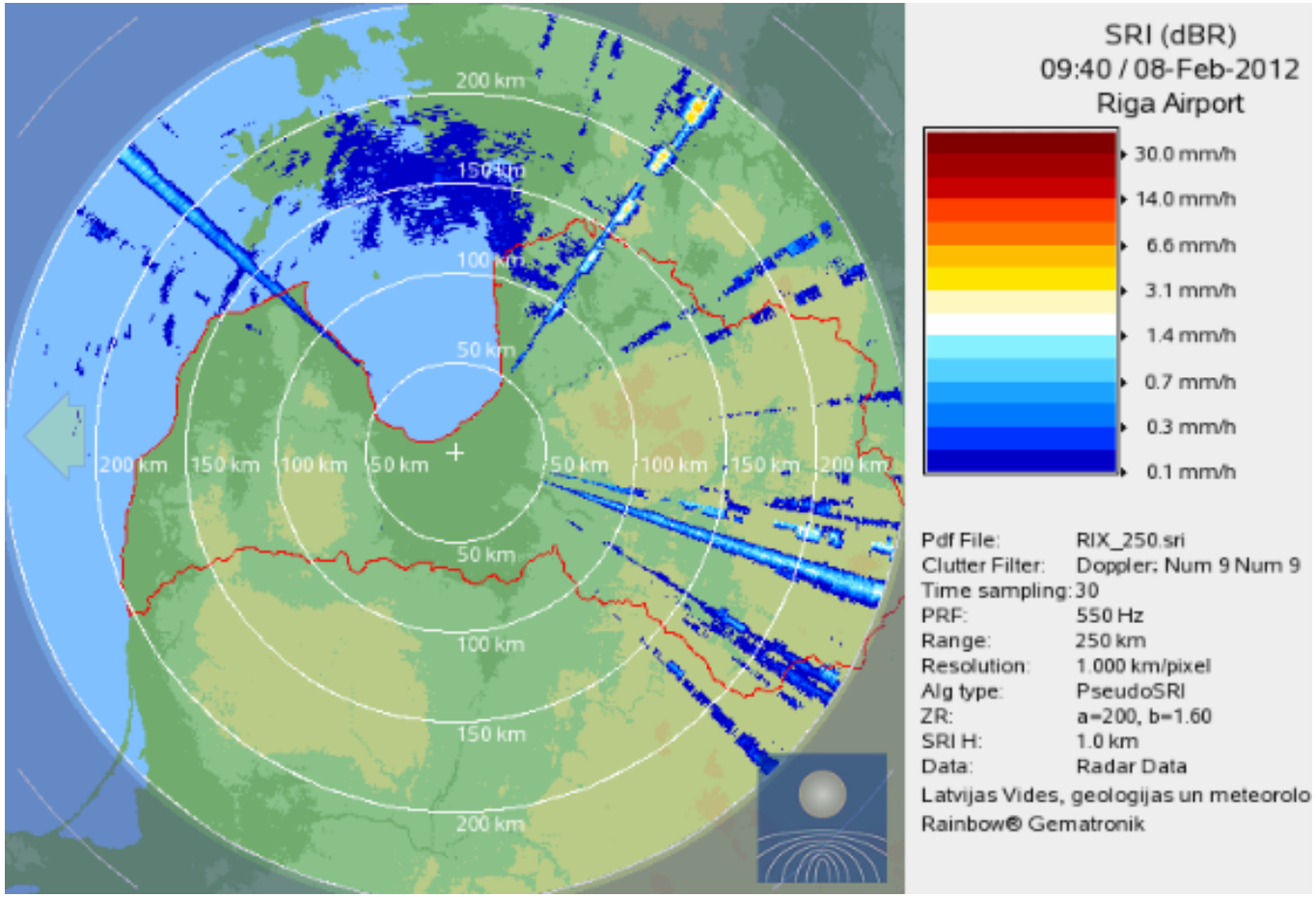
Interference to French Radar



Source: http://www.cept.org/Documents/wg-se/4579/SE(12)034_Extract-of-the-response-to-the-WGFM-questionnaire-on-the-current-status-of-DFS-in-the-5GHZ-frequency-band

Interference to Latvia Radar



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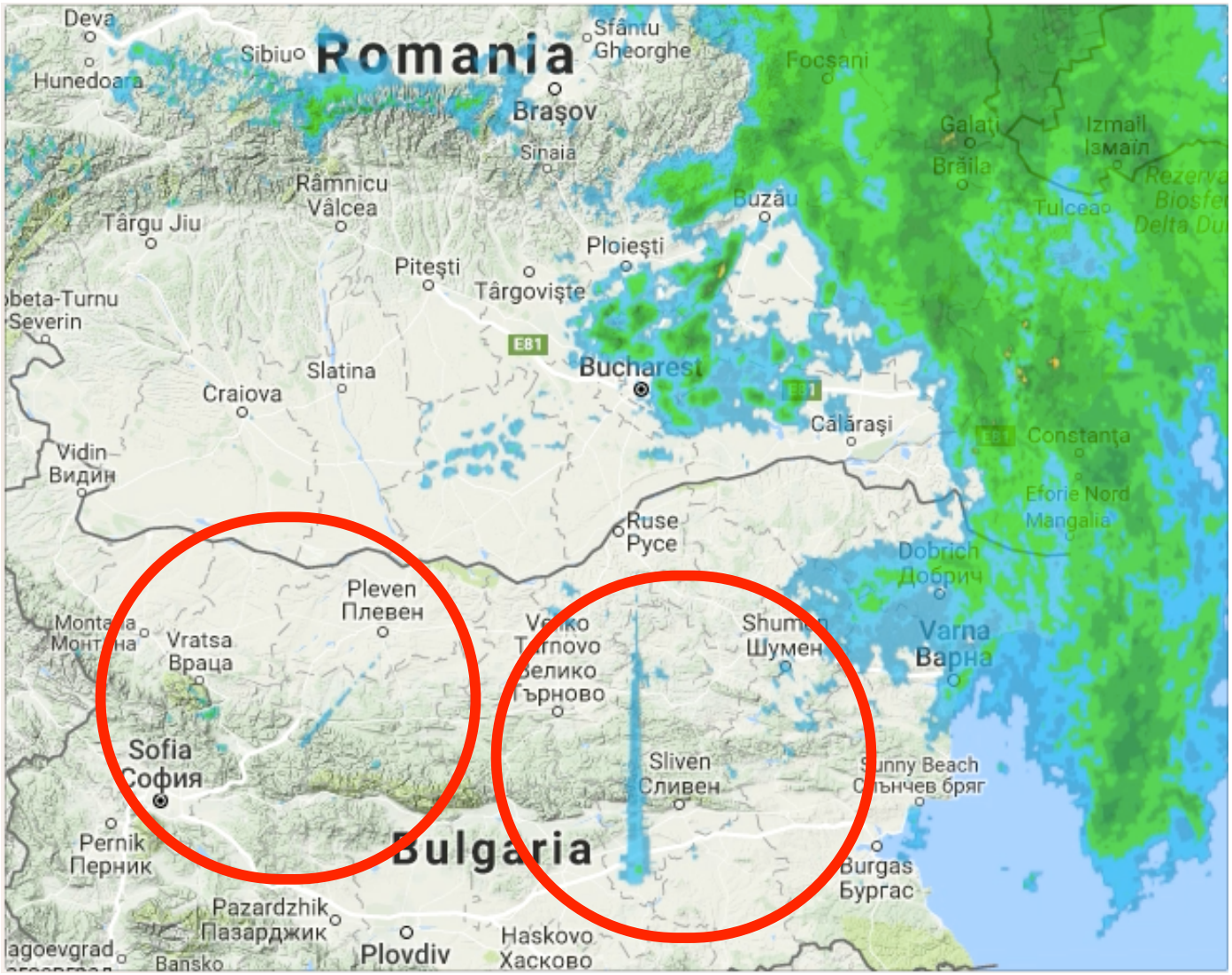
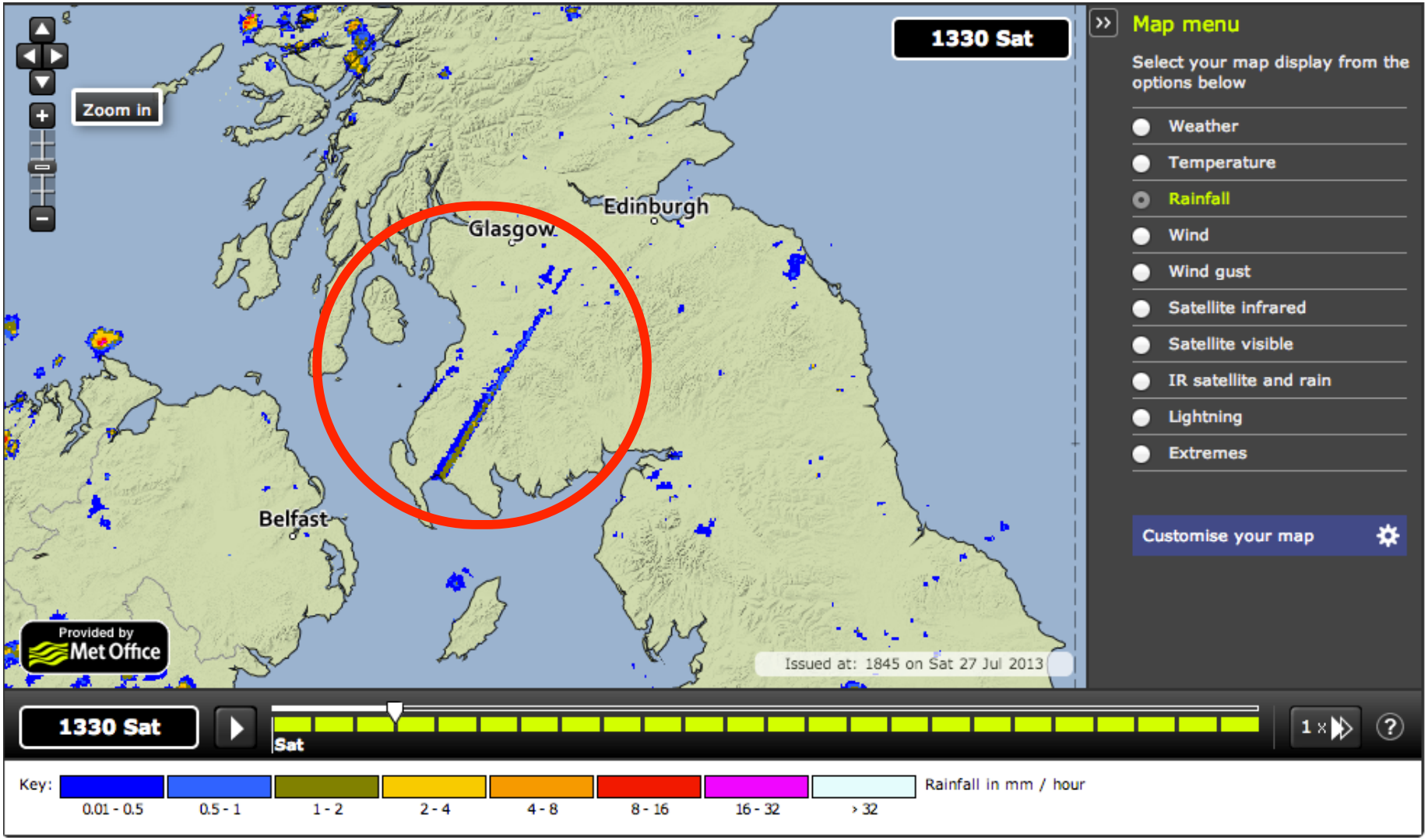
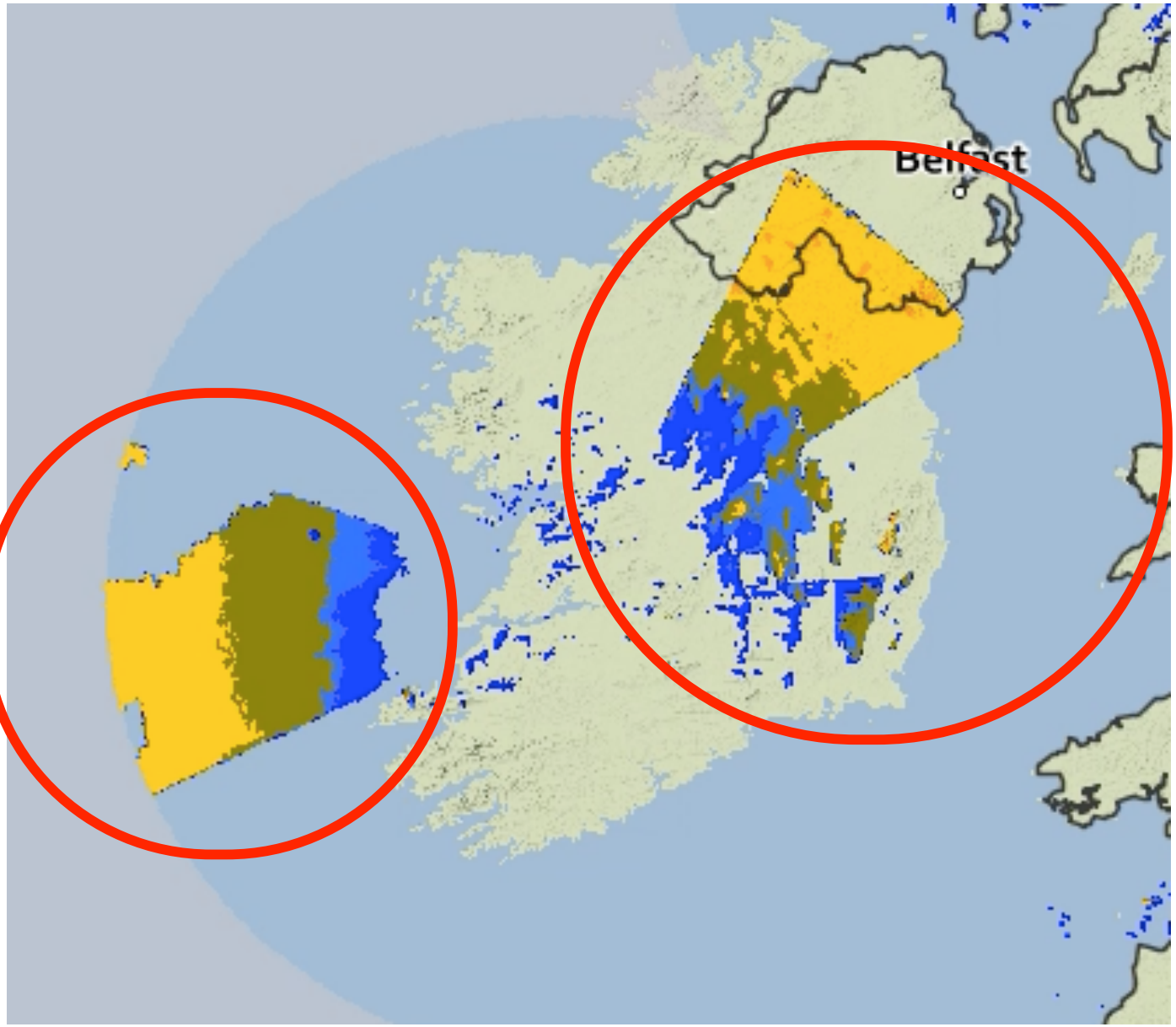
Interference to Romania Radar



Interference to UK Radar



Interference to Irish Radar



CEPT ECC Working Group FM Questionnaire sent out March 2012

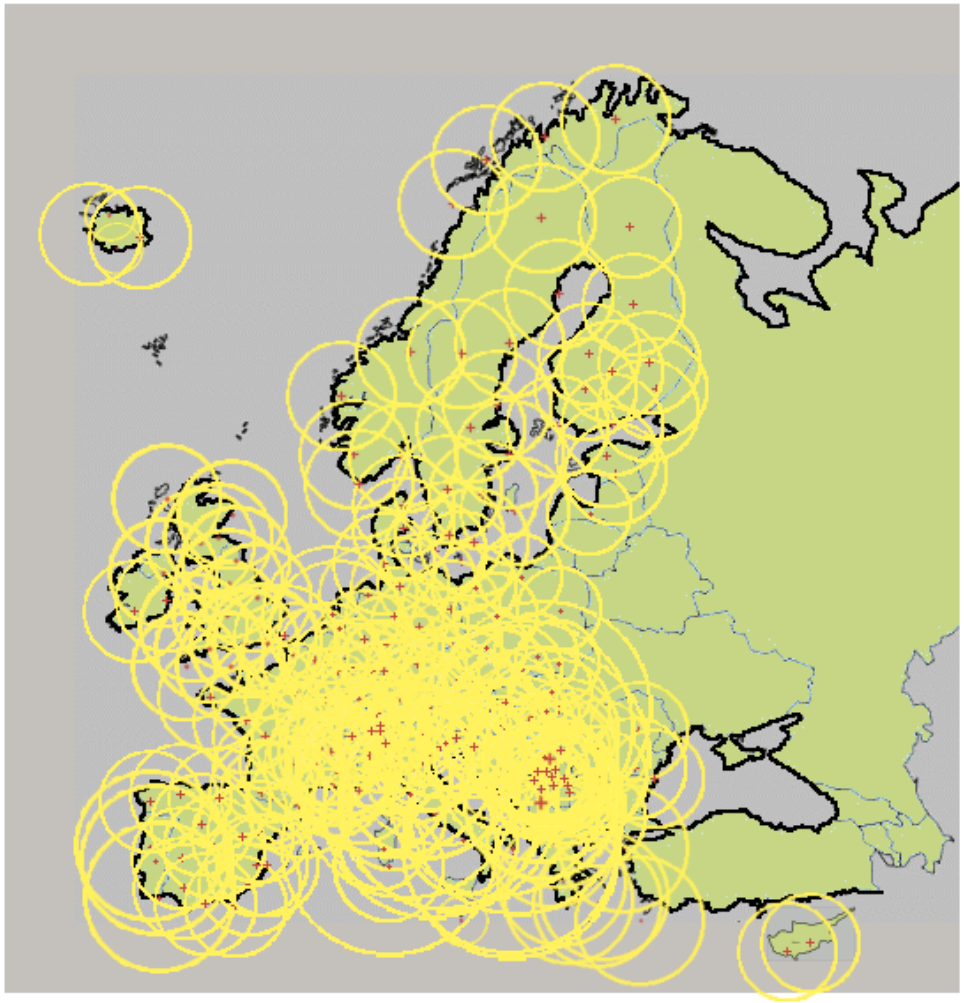
Reports	Country	Max Distance
11	Austria	23 km
1	Belgium	10 km
50	Czech Republic	100 km
1	Estonia	6 km
1	Finland	6 km
11	France	28 km
10	Germany	N/A
45	Hungary	45 km
3	Italy	30 km
23	Latvia	20 km
N/A	Poland	20 km
1	Slovak Republic	N/A
3	Spain	8 km
15	The Netherlands	30 km
Thousands*	United Kingdom	100km

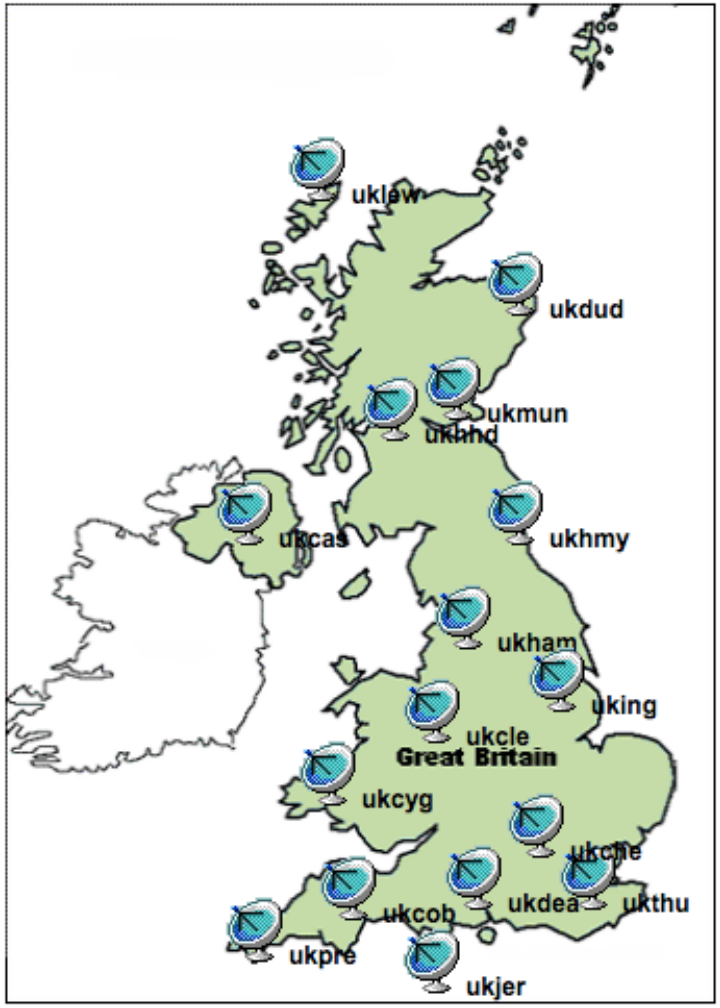
* Ofcom had 1000's of reports, but only 24 were on long enough to trace source

Ofcom Results in 2012

24 cases investigated - what was outcome?	
2 x Wireless cameras	Re-tuned to a different frequency
8 x Point to Point Links	5 of 8 re-tuned to a different frequency 3 had DFS re-enabled
1 x Cell Phone Enhancer	Removed by Enforcement Team
1 x Mast Head Amplifier	Turned off or removed by Enforcement Team
1 x Military Radar	Turned off or removed by Enforcement Team as 'non-standard'
1 x Military (Unknown)	Turned off or removed by Enforcement Team as 'non-standard'
10 x unresolved / unknown	Interference source never traced

Where are they?





Source: http://www.eumetnet.eu/opera092013/a_start.html

UK Weather Radar

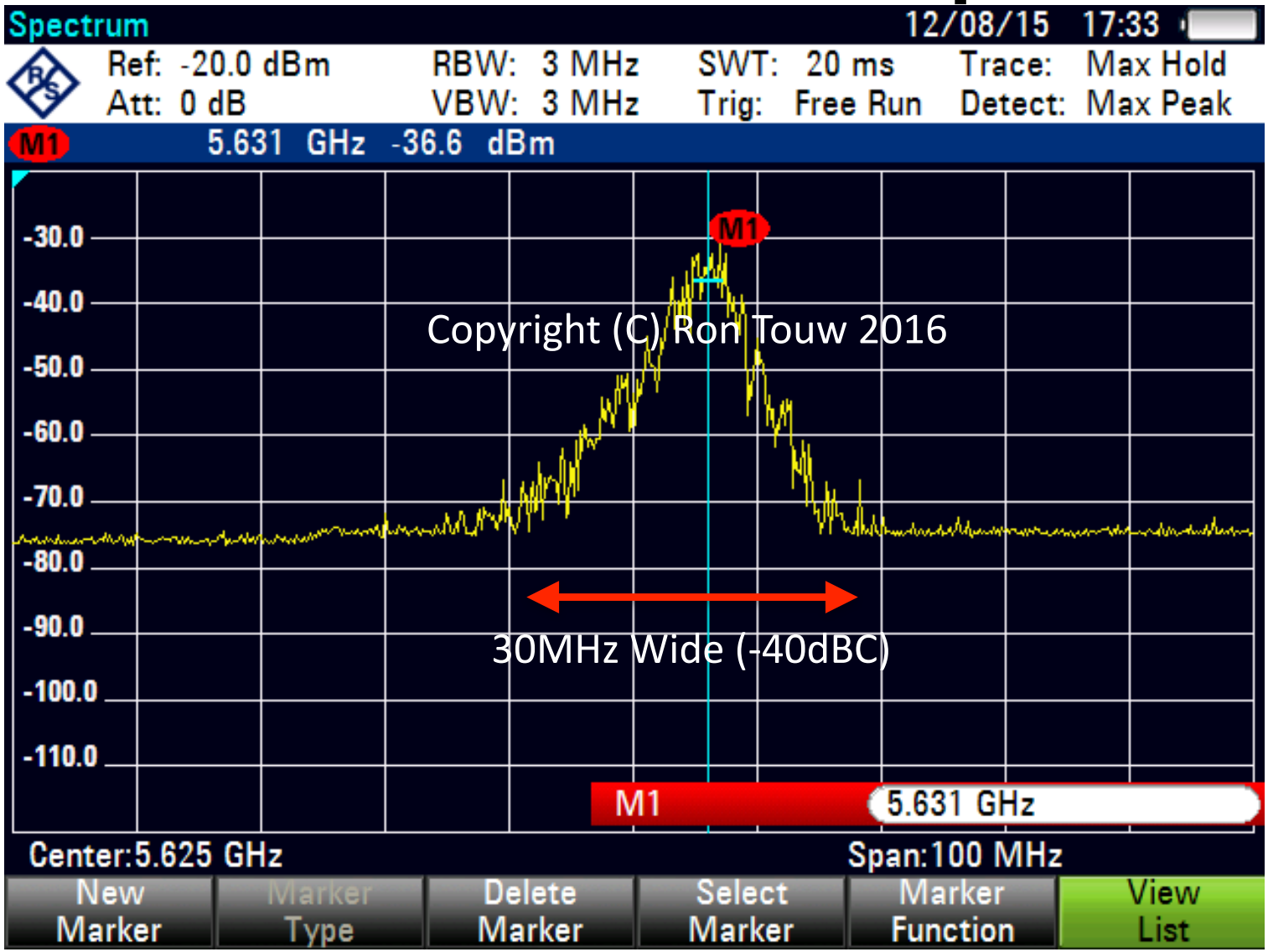
No	Country	Location	Status	Latitude	Longitude	D ant.	Beam width	Gain	Freq uency
1	United Kingdom	Clee Hill	1	52.3981	-2.5936	3.66	1	43	5.607
2	United Kingdom	Hameldon Hill	1	53.7542	-2.2864	3.66	1	43	5.62
3	United Kingdom	Chenies	1	51.69	-0.53	3.66	1	43	5.623
4	United Kingdom	Castor Bay	1	54.5	-6.34	3.66	1	43	5.64
5	United Kingdom	Predannack	1	50.002	-5.2211	3.66	1	43	5.625
6	United Kingdom	Ingham	1	53.335	-0.5564	3.66	1	43	5.627
7	United Kingdom	Crugygorllwyn	1	51.9794	-4.4433	3.66	1	43	5.642
8	United Kingdom	Jersey	1	49.18	-2.22	0	1	0	0
9	United Kingdom	Hill Of Dudwick	1	57.4317	-2.0347	3.66	1	43	5.624
10	United Kingdom	Druim a'Starraig	1	58.2111	-6.1797	3.66	1	43	5.624
11	United Kingdom	Cobbacombe Cross	1	50.9636	-3.4508	3.66	1	43	5.609
12	United Kingdom	Holehead	1	56.0183	-4.2169	3.66	1	43	5.624
13	United Kingdom	Munduff Hill	1	56.2144	-3.3092	3.66	1	43	5.643
14	United Kingdom	Thurnham	1	51.2942	0.6064	4.3	1	45	5.63
15	United Kingdom	Dean Hill	1	51.0297	-1.6531	3.66	1	43	5.627
16	United Kingdom	High Moorsley	1	54.8031	-1.4739	0	1	0	5.628

Source: http://www.eumetnet.eu/opera092013/a_start.html

UK Met Office Radar Spec

- Dish size approx. 4m with a gain of 43dBi
- Beamwidth 1 deg
- 250 KW Peak Power
- Operates between 5600-5650MHz
- Approx. Operational Range 150-200km
- Helical Scan - Vertical 10°/Sec, Horizontal 0 or 0.6°/Sec to 36°/Sec (1 full scan takes about 15 minutes)
- Two major modes
  - Normal - 2µS with 300Hz Pulse Repetition Rate
  - Doppler - 0.5µS with 1200Hz Pulse Repetition Rate

Met Office Radar Spectrum



DFS - How does it work?

- Two main modes of detection:
  - CAC - Channel Availability Check.
    - A check done before operation on any channel
  - ISM - In-Service Monitoring
    - A check made constantly all the time while actually operating on any channel

DFS - How does it work?

- CAC - Channel Availability Check.
  - Before transmitting on any new channel, radio must monitor the channel for 60 seconds.
  - On 5600-5650 this channel availability check is extended to **10 minutes**
  - If no Radar is detected, operation can begin and ISM mode is started.

DFS - How does it work?

- ISM - In-Service Monitoring.
  - While operating on a channel, the radio monitors for radar pulses. If found, it ceases operation and change to a new frequency
  - If the radio has already checked the new channel during the ISM phase prior to it detecting radar, the CAC phase can be skipped for the new channel and start operation immediately, otherwise, a **new** CAC time must be started!

DFS - The downside!

- To ensure compliance with regulations, Radar Pulse Detection during CAC and ISM requires high sensitivity, especially from frequency hopping radar
  - **False positives** or real radar detections can lead to lengthy periods of in-activity due to 30 minute “barring” of any channel
  - PtP and PtMP links using 5GHz therefore prone to drop outs for **lengthy** periods
- Due to high volume of link drop outs, many WISPs were disabling or bypassing DFS with hacks

DFS - The downside!

- However, to permit disablement of DFS on some vendors hardware, required using old firmware
- Some older firmware were vulnerable to attack due to weaknesses in the software
- One UK WISP had an outage for their 1000's of customers for **over a week** due to a virus in their radio equipment because they were using old firmware just to allow them to disable DFS!
- Dilemma! As using DFS can cause high level of link failures!

DFS - The downside!

- Forcing WISPs to use DFS has in turn increased problems from false positives
- Many false positives are self-inflicted by poor installations
  - Using 1.5KW EiRP (yes!) causes high levels of reflections from nearby surfaces which is in turn interpreted as radar pulses
  - Installing close to other reflective objects (sloping roofs, edges of buildings, solar panels etc)

DFS - The downside!

- To reduce false positives
  - Reduce EiRP to legal limits (30/36dBm)
  - do not install with reflective surfaces within Fresnel Zone or close to antenna
  - communicate with manufacturer to encourage software improvements?
  - update to latest firmware?

DFS & MikroTik
So - What's changed?

- MikroTik has enforced mandatory DFS on 5GHz from v6.37 onwards
  - (However DFS has been mandatory since at least 2003!)
- So why now?
- Because they **have to** if they wish to continue to trade in Europe and USA. (Also possibly in other regulatory domains too).

DFS - MikroTik style

- How does MikroTik implement DFS from v6.37 onwards?
  - On power up, initial CAC is performed on the frequency set into the frequency field and if that detects Radar, it then starts with the scan list
  - DFS checks are **only** performed in ‘bridge’ & ‘ap-bridge’ modes **not** any ‘station’ modes

DFS - MikroTik style

- CAC Time is **1 minute** (outside of 5600-5650MHz)
  - Therefore for **each** frequency scanned that could detect radar in the very last second, there will be a minimum of 1 minute per channel before the link becomes operational. Minimum! I.e. if you have 6 consecutive freqs with radar, that's **6 minutes waiting time!**
- CAC Time in the band 5600-5650MHz is **10 minutes**
  - Therefore 4 consecutive failed frequencies (5600, 5620, 5640, 5660) is a **40 minute wait!**

DFS Solutions?

- Identify multiple possible available channels and place them into scan list - do not use ‘default’ scan list for outdoor links. (As otherwise indoor channel 5180MHz will almost certainly be selected for operation!)
- Populate the scan-list with enough standby frequencies to ensure the link can hop to a new channel you know is available in the area
- Use the scanning tools within RouterOS to identify any spare channels

DFS Solutions?

- Rotate AP and STN modes around so that AP being triggered with radar is now facing 180 degrees other way (STN modes do not perform DFS Radar checks)
- Move spectrum usage around so that antennas facing towards known Weather Radar locations are not using 5600-5650MHz
- Check before installing any new links if the antennas are pointing directly at a known radar site

DFS Solutions?

- Use narrower beamwidth antenna
- Consider moving existing links from 5GHz onto other unlicensed or light licensed bands
  - E.g. 17GHz (not UK), 24.1GHz, 64-66GHz, 73.375-75.875GHz, 83.375-85.875GHz
- Or purchase carrier grade licensed links - E.g. 6GHz, 7.5GHz, 13GHz, 15GHz, 18GHz, 23GHz, 26GHz, 38GHz, 52GHz, 55GHz, 70/80GHz (however expensive hardware and annual Ofcom license fee!)

DFS Solutions?

- Or, as a last resort, if you are **truly** adamant there is no real radar, your EiRP is within legal limits and all your alerts are from false reflections and you are sure Ofcom isn't going to come calling and take all your kit away?

- Use "super channels"
  - but how long will that be available for?!

And finally - CAPsMAN v2?

- Q. Have the DFS settings been removed?
- Q. Has anything changed with v6.37 re DFS?

- A. No - As it never supported DFS anyway!

Thank You!

By Ron Touw

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References

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- “Fact Sheet No 15 by UK Meteorological Office” https://goo.gl/g6BE9h
- “Safeguarding our Observations by UK Meteorological Office” https://goo.gl/zxdXPD
- “Spectrum Sharing in the 5 GHz Band DFS Best Practices by The Wifi Alliance” https://goo.gl/FoMhtl

References

- “SE(12)034 Extract of the response to the WGFM questionnaire on the current status of DFS in the 5GHZ frequency band” https://goo.gl/q7B0Hx

History of EN 302 502 (5GHz Band C / U-NII-3)

- v1.1.1 (Oct 2006)
  - CAC Time 60s
  - Non-Occupancy Period 30 mins
  - Channel revalidation time 24h
  - Minimum Pulse width 1µS
  - variable PRFs from 200-4000Hz
  - Detection threshold = (-69dBm+Antenna gain)

History of EN 302 502 (Ofcom Band C / U-NII-3)

- **v1.2.1 (June 2008) latest version**
  - No changes to DFS standard compared to v1.1.1

Overview of EN 301 893 (Ofcom A&B / U-NII-1/2A/2C)

- This however **has** changed enormously over the years!
- 2001 Initial draft v1.1.1
- 2002 adopted as v1.2.1
- 2003 updated as v1.2.3
- 2005 updated as v1.3.1
- 2007 updated as v1.4.1
- 2008 updated as v1.5.1

Overview of EN 301 893 (Ofcom A&B / U-NII-1/2A/2C)

- 2011 Draft v1.6.0, then published as v1.6.1
- 2012 Draft v1.7.0, then published as v1.7.1
- 2014 Updated as v1.7.2
- 2015 Draft v1.8.0 then finally adopted as v1.8.1 in March 2015

- **v1.8.1 is latest version**

What changed in EN 301 893?

- v1.1.1 Original Draft (2001)
  - mentions DFS but no standard defined
- v1.2.1(2002)
  - DFS now defined.
    - CAC 10s, Detection Threshold -52dBm, min Pulse Width 0.2µS, PRF 330 and 700
    - Meterological radar defined as PRF 330, pulse width 2µS

What changed in EN 301 893?

- v1.2.3 (Aug 2003)
  - Increased CAC to 60s, decreased Signal Detection Threshold to -64dBm (assumes a 0dBi antenna), added Pulse Width of 1µS, added new PRF of 1800
  - “Added “Uniform Spreading” - to randomly select a channel from all 14 available channels (to protect Satellite uplinks)

What changed in EN 301 893?

- v1.3.1 (July 2005)
  - Chirp* mode and Variable PRF 200-4000 as a result of input from French Military) **Added non-occupancy for 30 minutes!**

**Chirp mode = signal is freq swept +/- 2.5MHz during pulse*

What changed in EN 301 893?

- v1.4.1 (June 2007)
  - Makes it very clear that DFS is **mandatory**
  - *“DFS controls (hardware or software) related to radar detection shall not be accessible to the user so that the DFS requirements described in clauses 4.7.2.1 to 4.7.2.4 can neither be disabled nor altered”*
- This came about because regulators discovered that end users / installers were able to disable DFS

What changed in EN 301 893?

- v1.5.1 (Dec 2008)
  - Reduced Signal Detection Threshold to -62dBm, reduced minimum Pulse Width to 0.8µS. Adds **10 minutes CAC time** and increased probability of detection for **5600-5650MHz** from 60% to 99.99%
  - Allows the radio to perform radar checks on **other** channels and add them into a list of available channels for **immediate** use in case of radar detection on current channel

What changed in EN 301 893?

- v1.5.1 (Dec 2008)
  - Makes Section 4.7.2.6 (Uniform Spreading) mandatory!
  - "*DFS controls (hardware or software) related to radar detection shall not be accessible to the user so that the DFS requirements described in clauses 4.7.2.1 to **4.7.2.6** can neither be disabled nor altered.*"

What changed in EN 301 893?

- v1.6.0 (Final Draft) (2011)
  - reduced Pulse width to 0.5µS to further protect Meteo Radar
  - minor changes to timings of “Off-Channel CAC” checks
- v1.6.1 (Nov 2011)
  - No major changes from v1.6.0 Final Draft

What changed in EN 301 893?

- v1.7.0 (Final Draft) 2012
  - v1.7.1 (May 2012)
  - v1.7.2 Draft (2014) Adds more draft restrictions upon the end user

What changed in EN 301 893?

- v1.7.2 Draft (2014)
  - "*The equipment **should** not allow the user to change the country of operation and/or the operating frequency band if that results in the equipment no longer being compliant with the DFS requirements*"
  - ("should" = **recommendation only**)

What changed in EN 301 893?

- v1.7.2 Draft (2014)
  - *“The equipment **should** not accept software and/or firmware which results in the equipment no longer being compliant with the DFS requirements, e.g. Software and/or firmware provided by the manufacturer but intended for other regulatory regimes, modified software and/or firmware where the software and/or firmware is available as open source code, previous versions of the software and/or firmware (downgrade)”*

What changed in EN 301 893?

- v1.8.0 Final Draft (2015)
- **v1.8.1 (March 2015) is Current version**
- Still contains section 4.9.2 regarding the requirement that hardware **should** not permit downgrades to bypass DFS etc
- It is “**should**” now - but “**shall**” later?