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RLAN 5 GHZ INTERFERENCE TO C-BAND METEOROLOGICAL RADARS IN EUROPE : SOLUTIONS, LESSONS, FOLLOW-UP

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1 INTRODUCTION

RLAN 5 GHz were authorised in the 5 GHz range following a decision made at the World Radiocommunication Conference in 2003 (WRC-07). After a period during which European Radio Authorities adopted relevant Decisions and telecommunication industry issued the necessary Standard, RLAN 5 GHz roughly started to be deployed in the 2005/2006.

About at the same time, some interference were experienced by C-Band meteorological radars and facing increasing number and spreading over Europe of these interference events, the European meteorological services, organised within EUMETNET, undertook actions through radio Authorities to find relevant solutions to this critical issue.

After constructive analysis and discussions with the RLAN industry, a global "package" solution was defined, specified and agreed in 2008 including, end 2008 the issuing of the necessary revision of the European Telecommunications Standard Institute (ETSI) Standard on RLAN 5 GHz and a EUMETNET Recommendation on C-Band meteorological radars.

2 REGULATORY BACKGROUND

The allocation of the 5150-5350 MHz and 5470-5725 MHz to the mobile service for the implementation of Wireless Access Systems (WAS), including RLANs, was made, on a co-primary basis, at the International Telecommunication Union (ITU) World Radiocommunication Conference 2003 (WRC-03), under the conditions of the Radio Regulations Footnote N° **5.446A** :

> **"***The use of the bands 5 150-5 350 MHz and 5 470-5 725 MHz by the stations in the mobile service shall be in accordance with Resolution* ***229 (WRC-03)****.   (WRC-03)*"

This Resolution **229 (WRC-03)** specifies the conditions under which this allocation is to be considered, in particular with regards to sharing with Radiodetermination / Radiolocalisation services (i.e. radars) in the 5250-5350 and 5470-5725 MHz bands, recognising in particular, that "*studies have shown that sharing between the radiodetermination and mobile services in the bands 5 250-5 350 MHz and 5 470-5 725 MHz is only possible with the application of mitigation techniques such as dynamic frequency selection*".

The DFS principle is recognising the fact that RLAN operating co-channel with a radar will interfere with the radar and that there is hence a need to ensure channel avoidance. To do so, the RLAN DFS mechanism has to perform a scan of a given channel and perform a radar signal detection prior any use of this channel. If a radar signal is detected, then this channel becomes unavailable for use and the RLAN has then to find another channel.

To this respect, Resolves 8 of Resolution 229 (WRC-03) makes mandatory Annex 1 of Recommendation ITU-R M.1652 that provides the general DFS requirements for the purpose of protecting radiodetermination systems. One can in particular note the following specific paragraph in section 2.3, focusing on the "meteorological radars" band, stating that :

"*Additionally, in the band 5 600-5 650 MHz, if a channel has been flagged as containing a radar, a 10 min continuous monitoring of the flagged channel is required prior to use of that channel. Otherwise, other appropriate methods such as channel exclusion would be required*."

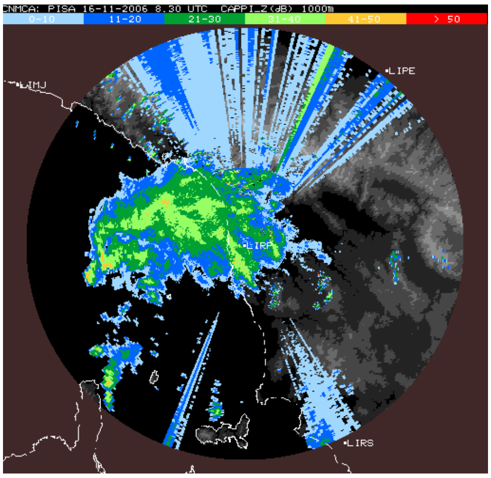
Following WRC-03, both the European Communication Committee (ECC) and the European Commission translated this International regulation into European Decisions, adopting respectively Decision ECC/DEC/(04)08 (9 July 2004) and Decision 2005/513/EC (11 July 2005) on "*the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)*".

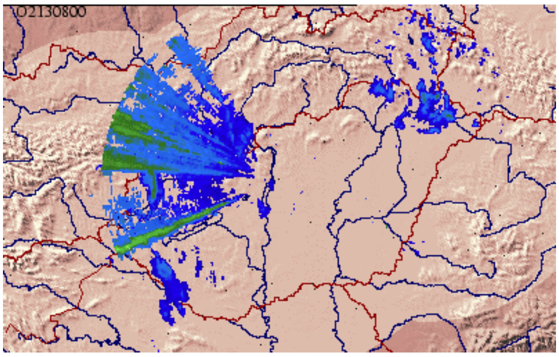
Noting that Decision 2005/513/EC is of mandatory application, it has to date been translated into national regulations in the all 27 European member states, providing a "non-licenced" and general authorisation status for RLAN.

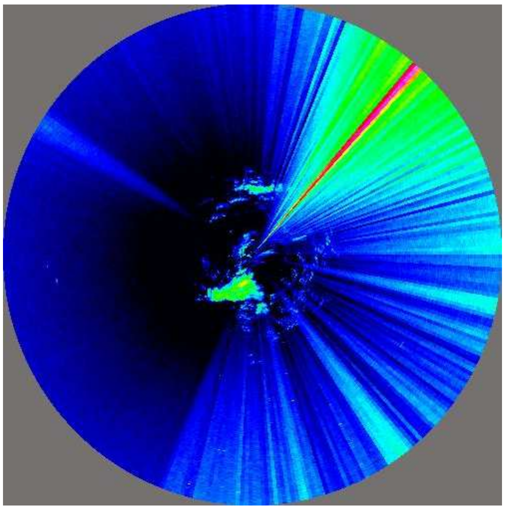
This means that from that date, RLAN can be used all over Europe without any specific authorisation provided they are compliant with the ETSI Standard EN 301 893, providing in particular Dynamic Frequency Selection (DFS) parameters.

3 RLAN INTERFERENCE TO METEOROLOGICAL RADARS

Initial cases of interference from 5 GHz RLAN to meteorological radars in the C band (5600-5650 MHz) were reported in 2005 by the Hungarian and Polish meteorological services. Subsequently, about 10 other European meteorological services have now experienced and reported similar interference events.







These interference pictures above clearly show that interference from <u>one single</u> RLAN device can be of an harmful nature. The abovementioned interference cases were solved on a case-by-case basis by actions of National Radio Administrations (NRA), taking "advantage" that the RLAN market was not developed (only few equipments).

However, recognising that the industry target is of several millions of these devices deployed in Europe, such case-by-case actions would not be practicable in the future, justifying the need for a global long-term solution on a European coordinated basis.

EUMETFREQ therefore undertook several actions at the European Commission and the ECC levels, raising these interference issues and requesting relevant and urgent actions toward a global solution before reaching a point of no return, i.e. before the mass-market development of RLAN in the 5 GHz band.

In support of these actions, specific testing were performed early 2007 by Météo France and the French Radio Administration (ANFR) under the EUMETFREQ umbrella that confirmed that 5 GHz RLAN DFS feature are deficient to detect all meteorological signals and hence to avoid transmitting in the corresponding channel.

Facing the interference reports and testing results, the European Commission requested EUMETNET and the RLAN industry to work together understanding the rationale behind these problems and propose relevant technical solutions.

Some interference cases reported in Europe were due to RLAN 5 GHz equipment for which the DFS feature was intentionally switched-off by the user. The DFS being mandatory, this possible access to the user of the DFS control mechanism was certainly not satisfactory and the RLAN industry reacted quite rapidly in 2006/2007, issuing the a version V1.4.1 of EN 301 893 stating that "*DFS controls (hardware or software) related to radar detection shall not be accessible to the user so that the DFS requirements described …. can neither be disabled nor altered*".

Subsequently, EUMETNET, through its EUMETFREQ and OPERA programmes undertook a general enquiry on detailed emissions characteristics of all European C-Band meteorological radars that confirmed the specificities of meteorological radars compared to other radar types, in particular concerning the use of staggered/interleaved PRF, short pulses, various scanning strategies as well as "zero check" without emissions, characteristics not covered in the version of the 5 GHz RLAN ETSI standard in-force by that time (EN 301 893 V1.3.1 and V1.4.1).

Indeed, as far as DFS parameters are concerned, these versions of the ETSI RLAN Standard were only considering "simple" radars characteristics over the whole 5250-5350 and 5470-5725 MHz bands:

- Pulse widths down to 1 µs (whereas most meteorological radars were reported using 0.8 µs or even 0.5 µs pulses)
- fixed PRF (whereas most radars were reported using variety of different emissions schemes, staggered PRF in particular)
- Channel Availability Check (CAC) of 1 minute (not consistent neither with initial requirements from ITU-R recommendation M.1652 nor with radar scanning strategies, in particular with respect to the "zero check" without emission).

4 THE EUROPEAN UNION TCAM DECISIONS

The European Union TCAM group is, among others, responsible for the survey of application of the so-called "R&TTE" Directive (**1999/5/EC)** that regulates the putting on the market of telecommunications equipments.

Following EUMETNET intervention, TCAM allowed first for a general recognition and support on the imperious necessity to ensure protection of meteorological radars and secondly for drawing a general picture of the necessary actions toward solving the issue, including RLAN modifications as well as possible efforts to be made by the meteorological community in future design and operation of meteorological radars.

Indeed, following the analysis of the situation and considering specificities of meteorological radars, it appeared that a solution allowing for long-term coexistence between meteorological radars and RLAN should first be specific to the 5600-5650 MHz band (in which most radars are operated) and secondly could not only rely on a further revision of the RLAN ETSI Standard but was also requiring some considerations on radars operational characteristics.

The following EUMETNET position and commitments were therefore proposed to EU TCAM:

- "*Our preferred solution would have been to request an exclusion of RLAN from the 5600-5650 MHz band. As this is no longer easily achievable we suggest a compromise solution*
- *If the RLAN industry accept the necessary modifications, EUMETNET would have to take its part of the constraints; that could be at a maximum:*
    - *Accept a 2 phase approach of the ETSI standard revision, provided that Zero Check issue is solved at the beginning (since it will also allow solving issue for most emission schemes)*
    - *Move all radars in the 5600-5650 MHz (or accept interference for those outside the band)*
    - *Accept for some radar to add one 1 or 2 detectable signal in the overall scanning strategies (this also apply to future developments)*
    - *Draft a EUMETNET Recommendation (EUMETFREQ and OPERA) to summarise the state of the art of solution to ensure an efficient sharing conditions with RLAN (including immunity and OOB).*
- *Reinforcing as a closing statement, the opinion that if Industry can not achieve or implement the EUMETFREQ offered mitigation, we will have to return to our preferred option of RLAN exclusion from the 5600-5650 MHz band.*

Consistently, EU TCAM decided that :

- ETSI shall issue a version V1.5.1 of EN 301 893 (including detection of staggered / interleaved PRF, pulses width down to 0.8 µs and a CAC extended to 10 minutes)
- The previous version of EN 301 893 will be withdrawn by the 1st July 2010
- By the 1st April 2009, all RLAN shall be compliant with V1.5.1 requirements related to the 5600-5650 MHz band or, alternatively exclude this band from their operating band.
- ETSI shall issue a version V1.6.1 of EN 301 893 (equal to version 1.5.1 + 0,5 µs detection) before end 2009
- The version V1.5.1 of EN 301 893 will be withdrawn by the 31st December 2012.

5 MODIFICATIONS TO ETSI EN 301 893

The table below provides an overview of the modifications to the ETSI RLAN 5 GHz Standard EN 301 893 as agreed during this process in EN 301 893 V1.5.1 and expected in EN 301 893 V1.6.1, compared to those pertaining to previous version.

One would note that, whereas a number of modifications apply to all RLAN channels (i.e in the 5250-5350 and 5470-5725 MHz bands), these new versions provides specific RLAN DFS parameters for the 5600-5650 MHz band related to an extended CAC time of 10 minutes together with a 99.99 % detection probability.

	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

Note 1: The alternative "Off-Channel" CAC process consists of an RLAN operating in another channel that will verify on a non-continuous and statistical basis possible meteorological radar signal detection. This process is based on short-time slots detection periods (down to few ms) over a sufficiently long period of time (several hours)

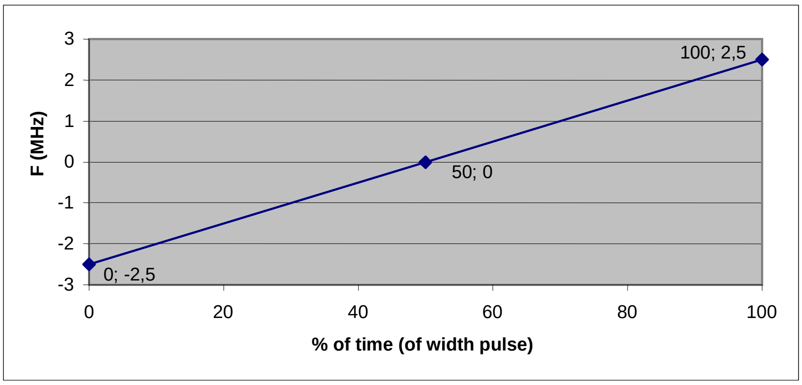
Note 2: The corresponding probability relates to the detection of one single radar burst (18 pulses for the 5600-5650 MHz band) over the CAC time period.

Parameters of radar test signals (extract from EN 301893 V1.5.1)

Radar test signal # (see notes 1 to 3)	Pulse width W [µs]		Pulse repetition frequency PRF (PPS)		Number of different PRFs	Pulses per burst for each PRF (PPB) (see note 5)
	Min	Max	Min	Max		
1	0.8	5	200	1000	1	10 (see note 6)
2	0.8	15	200	1600	1	15 (see note 6)
3	0.8	15	2 300	4000	1	25
4	20	30	2 000	4000	1	20
5	0.8	2	300	400	2/3	10 (see note 6)
6	0.8	2	400	1200	2/3	15 (see note 6)

NOTE 1: Radar test signals 1 to 4 are constant PRF based signals. See figure D.1. These radar test signals are intended to simulate also radars using a packet based Staggered PRF. See figure D.2.

NOTE 2: Radar test signal 4 is a modulated radar test signal. The modulation to be used is a chirp modulation with a ±2,5MHz frequency deviation which is described below.



NOTE 3: Radar test signals 5 and 6 are single pulse based Staggered PRF radar test signals using 2 or 3 different PRF values. For radar test signal 5, the difference between the PRF values chosen shall be between 20 and 50 pps. For radar test signal 6, the difference between the PRF values chosen shall be between 80 and 400 pps. See figure D.3

NOTE 4: Apart for the *Off-Channel CAC* testing, the radar test signals above shall only contain a single burst of pulses. See figure D.1, D.2 and D.3.
For the *Off-Channel CAC* testing, repetitive bursts shall be used for the total duration of the test. See figure D.4. See also clause 4.7.2.2.

NOTE 5: The total number of pulses in a burst is equal to the number of pulses for a single PRF multiplied by the number of different PRFs used.

NOTE 6: For the CAC and Off-Channel CAC requirements, the minimum number of pulses (for each PRF) for any of the radar test signals to be detected in the band 5600 to 5650 MHz shall be 18.

6 RELEVANT PROTECTION OF METEOROLOGICAL RADARS

As described in the tables above, RLAN DFS encompasses 2 main modes :

- **the CAC (Channel Availability Check) mode**: before transmitting on a given channel, the RLAN is on receive only mode during the CAC time; If no radar is detected, it can start using the channel

  and

- **the ISM (In-Service Monitoring) mode:** while using a given channel, the RLAN still need to constantly monitor this channel in case a radar signal shows-up

Both modes are important but for meteorological radars, one can certainly highlight the combination of the DFS Channel Availability Check (CAC) time increase to 10 minutes and CAC detection probability of 99.99% that, together with the "minimum detectable signal" concept applied to meteorological radars (at least 1 signal every 10 minutes) represents the major tool to ensure relevant protection of meteorological radars (i.e. one maximum possible short interference events within a minimum period of 10 days, assuming a large deployment of RLANs in urban areas).

As such, EUMETNET is confident that this "package solution" would provide a satisfactory long-term coexistence between meteorological radars and RLAN.

Indeed, another important point to raise is that such solution will allow for future radar developments without a need for new RLAN DFS parameters (that would in any case be totally unrealistic, facing millions RLAN that would more than likely be already deployed).

For future design of meteorological radars that would consider new signal types / technologies, the only constraint would then be to insert in the overall scanning strategies in-between these new signal signals 1 or 2 signals detectable by RLAN (i.e at least based on the modified versions V.1.5.1 or V.1.6.1).

In the process of finding a solution to ensure a global and long-term coexistence between RLAN and meteorological radars, it would of course have made no sense that both applications develop themselves without taking into account the design of the other application.

For meteorological radars, it would indeed not have been reasonable to expect that RLAN regulation and design would be timely modified in view of reacting and following each new characteristic of radars emission schemes. On the other hand, it would of course not have been satisfactory to limit all radar emissions to existing parameters, hence constraining their future development (foreseeable or not).

7 MINIMUM DETECTABLE SIGNALS CONCEPT

To allow that during a 10 minutes CAC at least 1 signal be seen and detected by RLANs, the EUMETNET commitment has to be considered in relation with scanning strategies durations and could be summarised as follows:

- As a general statement : make sure that, when considering consecutive strategies, the interval between detectable signals be lower than 10 minutes
- for the typical 10 to 15 minutes scanning strategies, transmit 2 detectable signals (at relevant interval)
- for scanning strategies lower than 10 minutes, transmit 1 detectable signal

By detectable signal, one should understand:

- operation at minimum elevation used by the radar, to ensure that all RLAN in the potential "interference area" would be able to detect it,
- Fixed, Staggered or interleaved PRF within the range 250 – 1200 Hz. It has to be noted that the highest the PRF, the highest the number of detected pulses.
- Pulse width higher or equal than 0.8 µs (based on EN 301 893 Standard version V1.5.1), at initial step and then, 0.5 µs when version V1.6.1 of the EN 301 893 standard will be the only version in force (i.e. 1st January 2013). It is important to note that during quite a while equipment based on V1.5.1 will remain in use so that it is strongly encouraged to use pulse width higher than 0.8 µs as long as possible.
- Lowest possible rotation speed to ensure a minimum 18 pulses detection by the RLAN when the radar main beam is passing over the RLAN location. The minimum number of pulses is a combination of the 3 dB beamwidth (0.9° for 45 dBi antenna), the PRF of the signal (or the minimum PRF for staggered PRF) and the rotation speed (RPM) using the following formula :

  $$N = (0.9 \times PRF)/(RPM \times 6)$$

  Where N is the minimum number of pulses detected

  Note : for detectable signals based on interleaved PRFs (multi-PRT), the minimum 18 pulses apply to each of the PRF. In this case, the above formula is to be applied using the highest PRF figure of the emitted signal and with a minimum number of pulses N = 18 x n, n being the number of different PRFs in the signal.

Of course, these characteristics represent minimum parameters to fulfil relevant RLAN detection but, when possible and practicable, simpler characteristics (fixed PRF, high PRF figure, lowest rotation speed, large pulses) are recommended to be used to minimize the probability of non-detection events.

8 LESSONS

In Frequency Management, reacting upon interference and modifying regulations after such events, even though practicable in many cases, is somehow a proof of failure.

EUMETNET actions indeed allowed to find a satisfactory long-term coexistence solution but the process was painful and constantly under the risk of seeing more and more interference cases. In addition, although this “package” solution is now in-force, it has no effect on RLAN equipments that were already deployed (hopefully few) and European meteorological services would have to live with these “non-compliant” equipments up to their life time, under continuous risk of interference (although limited).

Frequency management is a prospective and long-term process, aiming at taking decisions to avoid any difficulty in the future.

Actually, the European meteorological community is currently facing consequences of Decisions taken more than 6 years ago. During this whole process, it was absent and was therefore not able to argue about specificities of meteorological radars

At that time, only the Australian and Canadian NMHs were involved, resulting, at their national basis, on a non-autorisation of RLANs in the 5600-5650 MHz

It is more than likely that a consistent involvement of the European meteorological community at that time could have resulted in a total different situation, and probably in a global exclusion of the 5600-5650 MHz band for RLAN 5 GHz.

The European “RLAN 5 GHz issue” is certainly symptomatic and it also makes no doubt that without recent actions within a still positive timeframe, this issue could have seen **disastrous conclusions** :

– Uncontrolled deployment of a very large number of “non detecting” RLAN, impossible to manage by NRA, i.e. a *de facto* **pre-emption of the band**

– Although “Primary”, for the meteorological services it would have lead to the **loss of the band**, moving meteorological radars in another band, with obvious operational and financial consequences (estimated between 3 and 400 M€ in Europe)

The major lesson of this “RLAN 5 GHz issue” is therefore that the meteorological community in general (each national meteorological service, radar users and manufacturers), fully relying on radio-frequencies, cannot afford anymore to leave aside Frequency Management and not involve itself to argue about its essential protection requirements, without putting at risk future operation of meteorological radars.

Another important lesson is that Short-Range devices (SRDs), such as RLAN 5 GHz, that present a potential for mass-market deployment and are by nature operating on a non-licenced basis, represent nowadays a major threat. Indeed, if not adequately considered and studied before their authorisation and not satisfactorily regulated, they can reach rapidly a “point-of-no-return” under which interference occurrence could be such that the Radio Authorities would not have any practicable mean to make them cease, leading to a *de facto* lost for meteorological radars, although such SRD operate on a “non-protection and non-interference” basis.

9 FOLLOW-UP

Although a preferred solution would have been to exclude RLAN from the 5600-5650 MHz band, the European meteorological community is confident that the “package solution” would provide a satisfactory coexistence between meteorological radars and RLAN.

However, obviously, the efficiency of this “package solution” will need to be monitored and verified together with National Radio Authorities in the following years, putting under scrutiny RLAN 5 GHz market penetration and deployment in the light of possible new interference events.

Unfortunately, RLAN 5 GHz is one issue, but radio-frequency management is a prospective, long-term and never-ending process, and there are number of other radio applications that are or will be willing using C-Band, with a particular stress on increasing demand for non-licensed and mass-market equipments such as Short-Range devices, Ultra-Wide Band Devices, …

EUMETNET, within its EUMETFREQ programme, is deeply involved in Frequency Management and will maintain its implication to avoid any negative consequence in the future.

This was the case recently when, in Europe, possible use of RLAN 5 GHz on-board aircraft was considered following a request from the Boeing Company.

EUMETNET was indeed heavily concerned and, this time, did react before such equipment be deployed. Although not mass-market, the potential interference situation, compared to ground RLAN, could be even worst since airplanes will be almost 100% line-of-sight from radars, hence not mitigated by any shielding attenuation, and would be in simultaneous visibility of numerous radars (7 to 10). In particular, due to the speed of aircraft, the RLAN DFS CAC extended to 10 minutes to ensure protection of meteorological radars is inefficient in this case.

The current process in Europe is under finalisation since the corresponding ECC Report being currently in its "public consultation" phase. One can however highlight that this draft report is currently stating that "*to facilitate the implementation of RLAN on board aircraft in other parts of the 5 GHz band, the Aviation industry should avoid the use of channels falling in the 5600-5650 MHz range by any means not relying on DFS*"

10 Conclusions

The World is moving fast and the Telecommunications World even faster.

The meteorological community should be aware that meteorological radars are operated in a moving environment and that, S-Band, C-Band or X-Band radars have neither exclusive nor time unlimited rights in these frequency bands but are constantly under possible threats of new radio applications.

Frequency Management is a prospective, long-term and never-ending process that has to be kept under constant scrutiny to safeguard meteorological activities and meteorological radar operation in particular.

On this basis, deep involvement in Frequency management processes together with close contacts with the National Radiocommunications Authorities are necessary if not mandatory, not only from meteorological services, but from all bodies whose activities are related to meteorological radars, starting from radar manufacturers.

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