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RADIO SPECTRUM COMMITTEE

Working Document

Subject: **Presentation on preliminary findings of JRC study regarding interference from 5 GHz WAS/RLANs to meteorological radars - update**

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JRC Technical Note

Radio frequency coexistence of Meteorological Radar Sensor operating in the frequency band 5 250 MHz to 5 850 MHz (C band) with Wireless Local Area Networks

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Version 5.0

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Joint Research Centre

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Abstract

The issue of interference to meteorological radars from Wireless Local Area Network (WLAN) and Radio Local Area Network (RLAN) systems operating in the 5 GHz band are on the agenda of several groups and committees since long time as initial issues of coexistence are dated more than 10 years ago. Radio Frequency Interference (RFI) is one of the main issues in weather radar community as data quality and post-processing algorithms can be negatively impact by interferences. On the basis of the World Radiocommunications Conference in 2003, C-band radars share their operational frequency band with RLAN and WLAN, which may cause harmful interferences in radar systems.

The European Commission Joint Research Centre (EC DG JRC) has started to investigate in 2020 the matter of coexistence between meteorological radars as part of the overall activity on radio frequency coexistence between wireless services. This technical note is the result of an initial preliminary analysis of the extensive and available documentation on this topic. This note does not aim to replicate the analysis already conducted by the various organizations (e.g., CEPT, ADCO, EUMETNET, ETSI), involved in this matter but to summarize the key open issues still outstanding and the potential actions, which can be conducted by the EC JRC to mitigate this issue.

This technical note may be eventually expanded to a full report if the JRC will be authorized to continue this analysis.

DISCLAIMER: At the time of writing this version of the document (version 5 of 2 March 2021), this technical note is work in progress and it is not an official document of the European Commission. The final version of this technical note can be significantly different from this version and it can be published in a different form (e.g., JRC Technical report or JRC Science for Policy report).

Revision History

Version	Notes	Data
V1	First version	10/10/2020
V2	Second version after initial round of consultations	12/11/2020
V3	Third version after internal review by DG JRC. Submitted to RSC meeting on 10/12/2020	5/12/2020
V4	New version updated on the basis of the comments submitted at the RSC meeting on 10/12/2020.	21/12/2020
V5	Updates for: • First Workshop for Enforcement and market surveillance for 5GHz radar coexistence with RLAN. • Commission expert group on Radio Equipment. • First draft of section 5 • First draft of section 6.	02/03/2021

1 Introduction

The use of radio frequencies for the observation of environmental phenomena is an important part of effective early warning and emergency management system to mitigate loss of life and damage to property from natural hazards. In this context, meteorological radars perform precipitation and wind measurements that play a crucial role in the immediate meteorological and hydrological alert processes (ECC 2017).

In Europe, most weather radars are operating at C frequency bands (around 5.6 GHz), sharing the same frequency band with Radio Local Area Network (RLAN) and Wireless Local Area Network (WLAN). Since the World Radiocommunication Conference in 2003 (WRC-03), the primary allocation for Wireless Access Systems including RLAN and WLAN, was set in the bands of 5.150–5.350 and 5.4750–5.725 GHz.

Note: because different references used as input to this document use the terms WLAN and RLAN with the same meaning, the terms are used interchangeably in this document.

Then, meteorological radars and WLAN/RLAN are expected to coexist in the same radio frequency bands with WLAN/RLAN as secondary user and the radar as primary user. Then, the WLAN/RLAN (the two terms are used with the same meaning in this note), is required to implement the Dynamic Frequency Selection (DFS) to detect the radar signals and avoid the usage of the radio frequency bands.

The note does not aim to describe in detail the meteorological radars, WLAN technologies or the DFS function as they are well described in various documents (see Input documents section below). In particular, (ECC 2017) and (ETSI 2017).

The work reported in this technical note is composed by three main activities:

- A preliminary analysis of the problem, which was reported at RSC#73 to identify key actions for the Joint Research Centre for this problem.
- An activity focused on enforcement/market surveillance, which also includes an analysis of the potential options to mitigate the issue of interference.
- Experimental activities to investigate specific technical aspects.

1.1 Context of the problem

The main problem is that many cases of interference have been reported by the meteorological radars since 2006. This is due to a number of reasons which have been partially mitigated in the past through the revision of technical specifications (ETSI 2017) but which they are still reported today. Then, this is a long standing problem, which is not completely resolved yet.

This note identifies and reports the issues identified in literature and discusses the potential reasons and mitigation approaches.

1.2 Input documents in the preliminary analysis

A number of input documents have been used to conduct the analysis. The main documents are presented here but the entire list of references used in the analysis is presented in the references section.

- ECC Report 192. The Current Status of DFS (Dynamic Frequency Selection) In the 5 GHz frequency range

The main ECC Report, which present the status of the implementation of DFS, identifies potential reasons of interference and report on the various activities by the member states. Reference (ECC 2017).

- ETSI EN 301 893 V2.1.1 (2017-05). 5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU.

The ETSI standard, which describes the DFS function. Reference (ETSI 2017)

- EUMETNET. Recommendation on C-Band Meteorological radars design to ensure global and long-term coexistence with 5 GHz RLAN

The recommendation by EUMETNET members operating in C-Band meteorological radars to take in account in the design of these radars the coexistence with 5 GHz RLAN and their potential for interference. Reference (EUMETNET 2017).

- ADCO RED. State of play joint cross-border. ADCO RED common action on WLAN 5 GHz

Report on the activities of the sub-group on cross-border market surveillance (ADCO RED SG MSC) and their interaction with (CEPT ECC FM 22). Reference (ADCO 2019)

- FM(19)097_LS from ADCO RED to ECC and WG FM on the common action on 5GHz RLAN

Recent LS from ADCO RED to ECC on the common action of interference of 5GHz RLAN to weather radars. Reference (ADCO 2020)

- ECC decisions

Following WRC-03, both the ECC and the European Commission translated this International regulation into European regulations, adopting respectively ECC Decision:

ECC/DEC/(04)08 https://docdb.cept.org/download/3948246a-1552/ECCDEC0408.PDF

(2005/513/EC) https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007D0090

(2007/90/EC) https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32005D0513

1.3 Structure of the technical note

- Section 2 describes the findings from the preliminary phase of the study where a desktop research activity was conducted to identify the reported issues in literature and input documents.
- Section 3 identifies potential actions for future contributions by EC JRC at the end of the preliminary study. The enforcement/market surveillance aspect was identified in RSC#73 as key task for the JRC.
- Section 4 describes the progress on the enforcement/market surveillance aspect (which was the outcome of the preliminary study in section 3) including relevant meetings and workshops.
- Section 5 identifies the key options to mitigate the risk of interference of RLAN with weather radars and their evaluation on the basis of a number of qualitative metrics.
- Section 6 describes the planned experimental studies.

2 Preliminary analysis of the outstanding issues

This section identifies and describes the findings of the preliminary analysis on the problem of Radio frequency coexistence of Meteorological Radar Sensor operating in the frequency band 5 250 MHz to 5 850 MHz (C band) with Wireless Local Area Networks.

2.1 List of organizations and representatives, which have been contacted in the preliminary analysis

The following organizations and their representatives have been contact in the preliminary analysis.

Name/Surname	Organization
Pierfrancesco Sammartino	DG GROW C.3
Ales Brabinek	DG CNECT B.4
MARTIN Ruediger	DG CNECT E.3
Stefan Bach	Representative of Bundesnetzagentur in ETSI TC BRAN
Hai Zhou	Representative of Huawei in ETSI TC BRAN
Igor Minaev	ETSI officer in ETSI TC BRAN
Lucio Cocciantelli	Bakom. Swiss Federal Office of Communications
Robin Donoghue	ECO
Doriana Guiducci	ECO (also participating to CEPT FM57)
Jaime Afonso	ECO
Ralf Trautmann	Representative of Bundesnetzagentur in CEPT FM 22

2.2 Change of member states setting

One issue identified by ADCO RED in (ADCO 2020) is the possibility that a WLAN equipment is used in another nation on which it was initially configured. This may happen if the equipment provides the capability to the users for the change of national settings and it is not clearly documented which configuration of the devices are allowed for each nation. The requirements are harmonized in the EU and DFS (ETSI 2017) shall be used in all EU MS. Therefore changing the country/nation name in the settings from one UE member state to another UE member state won't have negative effects. The issue comes when changing to a non-EU nation.

Stakeholders interviewed on this issue claimed that a change of configuration should not be allowed by the equipment manufacturer. In addition, each WLAN equipment sold in a specific nation should be configured with the proper configuration setting at the time of placement in the market.

The documentation attached to the equipment should clearly state which configuration is allowed for each member state. This is consistent with Article 10(10) of the RED:

"In cases of restrictions on putting into service or of requirements for authorisation of use, information available on the packaging shall allow the identification of the Member States or the geographical area within a Member State where restrictions on putting into service or requirements for authorisation of use exist. Such information shall be completed in the instructions accompanying the radio equipment. The Commission may adopt implementing acts specifying how to present that information. Those implementing acts shall be adopted in accordance with the advisory procedure referred to in Article 45(2)".

In addition, Article 10(2) of the RED applies:

"Manufacturers shall ensure that radio equipment shall be so constructed that it can be operated in at least one Member State without infringing applicable requirements on the use of radio spectrum".

In addition, we highlight that (ETSI 2017) has defined requirements and rules for the changes of the configurations in the RLAN equipment in section 4.2.9 User Access Restrictions.

2.3 Change of software/configurations by the equipment or third party manufacturer

Another potential issue is the possibility of change the software/configurations by the equipment, which can cause harmful interference is the equipment has software defined radio like capability (i.e., software changes can impact the radio frequency spectrum occupancy) (ADCO 2020). Software is a component of the radio equipment when it is placed on the market and the compliance to Article 3(2) of the Directive ensures that the software does not affect the efficient use of radio spectrum. However, the uploads of certain software may compromise the demonstrated compliance. In the absence of delegated acts pursuant Article 3(3)(i)[1] and 4[2] of the Directive, new updates of specific software which introduces major changes in configurations may not be previously tested and/or prevented.

2.4 Hidden node problem

The hidden node problem in cognitive radio systems and detect and avoid functions like the DFS appears when the equipment (e.g., a WLAN system) implementing the DFS does not detect the presence of the primary user in the spectrum (e.g., the radar system) (Paisana 2014).

An hidden node situation is shown in Figure 1 and it may happen when the DFS enabled equipment does not see the radio transmission by the radar system because the propagation channel between the radar system and DFS equipment is characterized by strong fading or shadowing (Safavi-Naeini 2015). Then, the DFS enabled equipment makes an error as it declares the primary user absent and commences its own transmission.

In Figure 1, the radar systems has the coverage indicated by the blue transparent area, where WLAN equipment is also located (User Equipment and DFS enabled equipment). In this scenario, the User Equipment is a terminal like a mobile phone or an IoT device using WLAN standards, while the DFS enabled equipment is a WLAN router/switch with more

[1] Radio equipment supports certain features in order to ensure that software can only be loaded into the radio equipment where the compliance of the combination of the radio equipment and software has been demonstrated

[2] Manufacturers of radio equipment and of software allowing radio equipment to be used as intended shall provide the Member States and the Commission with information on the compliance of intended combinations of radio equipment and software with the essential requirements set out in Article 3. Such information shall result from a conformity assessment carried out in accordance with Article 17, and shall be given in the form of a statement of compliance which includes the elements set out in Annex VI. Depending on the specific combinations of radio equipment and software, the information shall precisely identify the radio equipment and the software which have been assessed, and it shall be continuously updated

powerful capabilities than User Equipment and it is therefore equipped with DFS capabilities as described in (ETSI 2017).

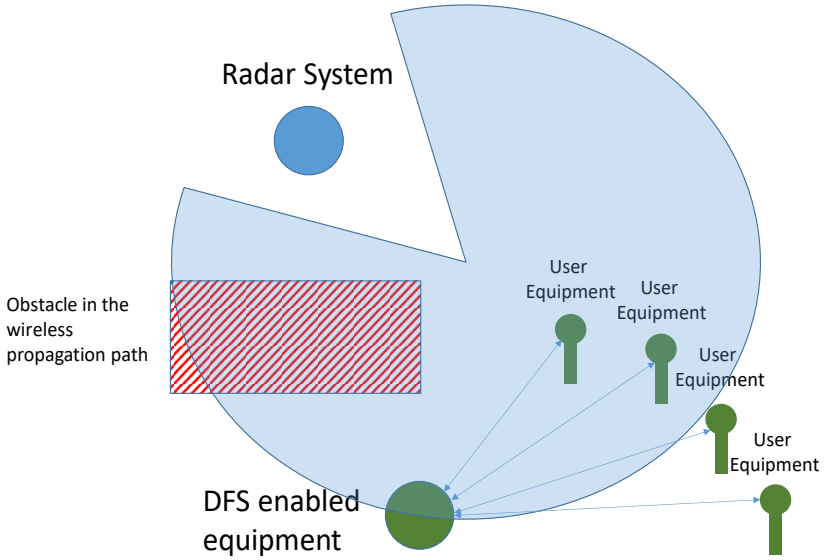

Figure 1 Hidden node problem

The hidden node problem presence of natural or man made obstacles. Considering that meteorological radars have usually a long range, the wrong placement of DFS enabled equipment may create this problem and it would be difficult to identify the offending device because the coverage area of the meteorological radar would be quite large.

Potential mitigation techniques to address these shortcomings could be:

1) A more careful placement of the DFS system or separate the function of the DFS from the main WLAN router/switch functions. The disadvantage of this mitigation technique is the additional cost to separate the functions.
2) Presence of more than one DFS enabled devices in the network, which are placed in different locations in the geographical area. The disadvantage of this mitigation technique is also similar to the previous one because more than one device must be equipped with DFS capability. See also the DFS technical specifications in (ETSI 2017) and the master slave configurations.
3) Improve the efficiency of the DFS function in terms of detection of the radar signal to overcome the attenuation of the radar signal.

For example, in the WLAN radio links design at 5 GHz (as in the HyperLAN) both end points of the radio link can be equipped with DFS capability to mitigate the hidden node problem because both end points may detect the radar signal. There is an extensive literature in the research community on radar – communication spectrum sharing where this kind of problem is discussed. The interested reader may refer to (Safavi-Naeini 2015) and (Labib 2017).

2.5 Non compliance of Receiver Requirements in the weather radar systems

Interference from WLAN systems could arise if the receiver requirements in the weather radar systems are not properly implemented. For example, the radar systems may not be sufficiently frequency selective (ADCO 2019). Receiver requirements are defined in section

4.2.2 of (ETSI 2020) or previous version of the standards or related standards, which were used for the compliance/assessment of the weather radars.

The RED directive (EC 2014) in Article 3(2) "Radio equipment shall be so constructed that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference" refers to this requirement.

Non-compliance to technical specifications or compliance to outdated specifications may lead to issue of interference. For example, RF power due to emissions from WLAN in adjacent bands can be collected by the weather radars. As a consequence, it is important that radars are designed to improve the out-of-band signal rejection of the radar receiver, with a particular focus on the image-frequency (Tristant 2017).

2.6 Non compliance of WLAN transmitter requirements

The non compliance of WLAN transmitters may happen in the following main areas:

- Wrong implementation of the DFS function, which gives false information to the WLAN transmitter, which starts transmission even in presence of radar signals.
- Disabled DFS function, which would also not provide to the WLAN transmitter the information to avoid radar signals.
- Non compliance to the technical specifications for the WLAN transmitter function, which would generate adjacent band interference.
- Challenging wireless propagation conditions, which may negatively impact the accuracy of the DFS function (Saltikoff 2016), (Vaccarono 2019)

In all these cases, it seems that it is a problem of non-compliance to the technical specifications, which is a problem of enforcement and market surveillance. See also the first option described in (CEPT FM 2020), which recommends to turn ECC Report 192, into a Recommendation. In (CEPT FM 2020), it was mentioned that this option would amplify the need to exercise rigorous and consistent enforcement, but it was also noted that increased efforts for enforcement were already carried on with limited effect.

2.7 Evolution of the technology

The coexistence of two different radio services (WLAN and meteorological radars) can be hampered if the technological evolution of one of the two radio services does not take in consideration a related evolution of the other radio service. For example, the technical specifications of meteorological radars can change to increase their efficiency, but then the DFS function in the WLAN should also support these changes. For example, the DFS technical specifications in (ETSI 2017) state that the DFS function as "described in the present document is not tested for its ability to detect frequency hopping radar signals". What is the technical specification of the meteorological radars change to support frequency hopping radar signals ?

2.8 Reported interference issues due to radio links or high gain antennas

Some sources (ADCO 2020) highlighted that most of the reported cases of interference (79%) are due to point to point links with directional antennas. An example of interference is proven in (Vaccarono 2019) in the Piedmont region in Italy. In (ECC 2020), it is mentioned that high gain antennas were used resulting in E.I.R.P. levels above the regulatory limits but this should not be a problem if the DFS function performs as specified and requirements are respected like maximum E.I.R.P..

2.9 Difficulties in enforcement and market surveillance

Various sources (ADCO 2020), (Tristant 2017) highlighted the difficulty to perform enforcement and market surveillance in the member states. One difficulty is that the distance between radar systems and WLAN equipment in some case of interference can be quite large. Few hundreds of meters to 181 km are mentioned in (Tristant 2017) and around 50 Kms in (Vaccarono 2019).

In addition, the deployment of WLAN equipment has increased considerably in recent years and it would be difficult to pinpoint the specific instance of WLAN equipment, which is creating interference.

3 Potential way ahead for the Joint Research Centre after the preliminary analysis

Different actions are possibile for the European Commission DG Joint Research Centre (EC DG JRC) on the basis of its impartial role among the involved stakeholders. These actions are based on the neutral role of EC DG JRC, the capabilities offered by the existing laboratories and scientific/technical skills of the JRC personnel.

3.1 Organizing a workshop among the relevant stakeholders focused on market surveillance

From the identified documents (EUMETNET 2017) ,(ADCO 2019), (ADCO 2020), market surveillance in the field remains one of the most significant challenges and a strong coordination among the main stakeholders is one of the most effective way to implement an effective market surveillance.

The European Commission Joint Research Centre has a long history in acting as a neutral party and facilitator for the cooperation among different stakeholders in different domains.

The EC JRC could organize a workshop in 2021 (either virtual or physical) aimed at improving existing process and identifying new processes to be set up to improve the coordination for market surveillance. Additional potential tasks could be the creation of a common knowledge database, identification of actions and main contact points.

Potential participants could be National Radio Administrations (NRA), ADCO RED, ETSI TC BRAN representatives, EUMETNET, CEPT FM22 and CEPT FM57, WLAN manufacturers and so on.

3.2 Experimental study on Dynamic Frequency Selection (DFS)

There is a general consensus that the DFS function defined in (ETSI 2017) is well designed for the purpose on the basis of models and simulations. On the other side, terrain or particular configuration of radars may make the detection of radar signals ”difficult” in certain conditions (EUMETNET 2017). In particular, the specific characteristics of meteorological radars have been mentioned in (EUMETNET 2017) and (Tristant 2017). The specificities of meteorological radar were already taken in consideration in revision of ETSI EN 301 893 V1.6.1. and subsequent revisions of ETSI EN 301 893 but issues of coexistence are still reported. See Table 1 with details on the different versions of ETSI EN 301 893, the end date of ’End of presumption of conformity’ and a brief discussion on the differences among the different versions. The challenges for the DFS function to detect radar signals in difficult wireless propagation conditions has also been highlighted in (Saltikoff 2016) and (Vaccarono 2019).

JRC can conduct an experimental study based on the current DFS specification but with a variation of the most significant parameters to evaluate the performance of DFS at the variation of the radar signal characteristics and the wireless propagation path (e.g., attenuation, fading).

Because of the critical role of the ETSI EN 301 893 standard and its evolution, Table 1 summarize the key dates for each version and the most significant changes between one version and another.

Table 1 Progression of ETSI 301 893 and further revisions

EN	Directive	First Publication in the OJ	End of presumption of conformity	DFS evolution and changes in comparison to the previous version
301 893 V1.6.1	RTTED	11.4.2012	31.12.2014	N/A

301 893 V1.7.1	RTTED	23.10.2012	31.12.2016	Addition of section F for information about the equipment submitted to the test laboratory prior to the testing. It contains product information as well as other information which might be required to define which configurations shall be tested, which tests shall be performed as well as the test conditions. Addition of definitions and acroynms and changes to section 4.9 Adaptivity(Channel Access Mechanism)
301 893 V1.8.1	RTTED	10.7.2015	30.11.2018	Significant modifications of the Load Based Element which may implement a spectrum sharing mechanism based on the Clear Channel Assessment (CCA) mode using "energy detect" (4.8.3.2). Modifications to the user access restrictions. Modifications to Measurement of the emissions identified during the pre-scan. Addition of B.5 Guidance on the use of radiation test sites.
301 893 V2.1.1	RED	8.6.2017	N/A	Significant modifications to section 5.4.9 Adaptivity (channel access mechanism) in particular to the testing methods.

4 Enforcement/Market surveillance for 5GHz weather radar/RLAN coexistence

As a follow up of RSC #73, where the JRC has received positive feedback on the spearheading actions to foster coordination on Enforcement/Market surveillance for 5GHz weather radar/RLAN coexistence, the JRC has organized a virtual meeting on this topic. The organization and the minutes of the meeting are described in detail in the following subsection. In addition, the participation to 9th meeting of the Expert Group on Radio Equipment is also discussed.

4.1 Virtual meeting on 17/02/2021 for the Enforcement for Radio frequency coexistence of Meteorological Radar Sensor operating in the frequency bands 5 250 MHz to 5 850 MHz (C band) with RLAN.

4.1.1 Scope of the meeting.

Enforcement of the rules is placed at national level under the responsibility of market surveillance authorities and interference resolution authorities. A strong coordination among both authorities is one of the most effective way to enforce an effective enforcement of the rules. Market surveillance takes place from the moment that a product is made available on the market and cannot act anymore against products in use.

Once products are in use, enforcement is done by interference resolution authorities. Action is taken as soon as a radio service is interfered with the aim to solve the interference.

The European Commission Joint Research Centre has a long history in acting as a neutral party and facilitator for the cooperation among different stakeholders in different domains.

The workshop aims at improving existing processes and identifying new processes to be set up to improve the coordination between market surveillance and interference resolution. Additional potential tasks could be the creation of a common knowledge database, identification of actions and main contact points.

DISCLAIMER: The following minutes of the meeting have not been confirmed by the participants to the meeting on 17 February 2021 and they may contain uncomplete or incorrect information at the time of writing this version of the document (2 March 2021).

4.1.2 Planned agenda:

Time	Item
15:00-15:15	Context and state of play (EC)
15:15-15:30	Presentation by ADCO RED
15:30-15:45	Presentation by CEPT FM 22 (German Bundesnetzagentur)
15:45-16:00	Presentation by EUMETNET
16:00-16:45	Discussion on enforcement: • From a market surveillance point of view • From an interference resolution point of view • Ensuring coordination • Prioritization of the actions • Definition of new processes or improvement of existing ones
16:45-17:00	Wrap up of the meeting and identification of actions.

4.1.3 List of Participants:

Surname Name	Organization
Baldini Gianmarco	DG JRC
Sammartino Pier Francesco	DG GROW
Vega Fidalgo Luis Miguel	DG GROW
Brabinek Ales	DG CNECT
Cocciantelli Lucio	BAKOM Switzerland
Meinders Ludger	German Bundesnetzagentur
Trautmann Ralf	German Bundesnetzagentur
Winkelmar Stephan	German Bundesnetzagentur
Tristant Philippe	EUMETNET
De Faria Jerome	ANFR
Talbot Stephen	CEPT FM57
Eric allaix	Meteo France
Mora Andrea	ANFR

Oteo Ortiz Diego	MINECO
Robin Donoghue	CEPT FM57
Petermann Eric	EUMETNET
Chaveau Didier	ANFR

4.1.4 Meeting Minutes

After an initial round of presentations, the EC (DG JRC, DG GROW, DG CNECT) provided a brief overview of the issue of coexistence of weather radars against RLAN in the 5 GHz band. EC remarked that this meeting is focused on Market Surveillance and Enforcement rather than the technical aspects of the related technologies and wireless standards (e.g. the DFS) even if these aspects were discussed when relevant (e.g., to improve the monitoring of the DFS function). The aim of the workshop is to identify a number of key actions and way forward, which are summarized at the end of this section and which are part of the extensive list of options for the mitigation of the issue presented in section 5.

The meeting included a number of presentations, which were presented according to the agenda (see **Error! Reference source not found.**).

Lucio Cocciantelli from Swiss BAKOM provided a presentation on behalf of ADCO RED, which identified the following key points in regard to the aspect of enforcement:

- The radio equipment directive (RED; 2014/53/EU) establishes a regulatory framework for the making available on the market and putting into service in the Union of radio equipment (article 1(1) RED) and does not cover software update/upload in radio equipment in use.
- National legislation (non harmonised) should be in place for the control of the correct use of the radio spectrum, including interference finding and resolution.

Then, potential reasons for interference were listed including non compliant use of compliant WLAN of the point of time of its making available on the market (e.g., because of higher antenna gain, download of new firmware, changed configuration), poor immunity of the radar, poor receiver, use of non compliant WLAN (e.g., missing DFS). This is only a partial list of reason and it is not excluding many other reasons. The issue of interference is not recent and it is going on for at least 10 years without a clear solution. A first joint campaign was conducted between November 2012 and March 2013 with a focus on the compliance of DFS on WLAN equipment with the following results:

- 101 checked samples
- 35% avoided frequency bands where DFS is mandatory.
- 95% had DFS implemented where mandatory
- 34% where the user may deactivate DFS
- (91% cases by using WLAN's original or provided on manufacturer's web site firmware)
- 59% with possibility for users to change "Region of use"

As a consequence of the many identifed cases of non compliance, it was requested to improve the cooperation at national level between interference management and market surveillance authorities and input was provided to ETSI for an update of ETSI EN 301 893.

A second joint campaign was organized in 2018 with the following set of conditions and findings:

- 40 checked samples
- Outdoor devices had a higher non-compliance with DFS requirements (60%) than indoor devices (20%)
- Indoor devices were most often declared compliant against EN 301 893 V 2.1.1, outdoor with EN 301 893 V 1.8.1
- 35% with non compliances with DFS related requirements
- 43% with possibility for users to change "Region of use"
- None were fitted with the geo-location capability

This second recent campaign showed that there are still many cases of non-compliance which must be addressed. A common action was triggered to report the cases of WLAN non compliance, which created interferences, but the presenter highlight that there is still a significant information imbalance between the reported cases of interference (in large number), the ones reported by radio monitoring authorities (still significant but less than the one in the previous step) and the ones reported by market surveillance authorities (even less than the previous step). The lessons learnt from the common action (where 62 interferences cases in 8 countries were analyzed) were that:

- 87% of the issues are due to only 2 brands
- 79% due to point to point links with directional antennas
- The longest radio link, which caused harmful interferences to meteorological radar, exceeded 80 km.
- The outdoor use of 5GHz RLAN in the DFS relevant bands may be considered to be more critical.
- 47% with inactive DFS
- DFS deactivation mostly by selection of other country of use
- Few cases due to change of firmware to deactivate DFS

It was also highlighted that there are significant difficulties to collect the information needed for a deep analysis. Potential reasons (discussed in the continuation of the meeting) were that many cases of interferences are of transient nature and it is difficult to collect information in real time. The large distances (dozens of KMs) make also difficult to pinpoint the source of interference.

Then, there is still a relevant issue for enforcement and market surveillance that the reported information is not complete or precise. In particular, the location of the interferer, if all meteorological radars are impacted or only some in an area, the status of the WLAN equipment in the field even after a successful compliance before the entry in the market. It was also discussed if point to point WLANs should be really allowed by the regulation because the high directionality of the links can increase the risk of interference.

Then, the presentation concluded with the following recommendations:

- Each interference case should be announced to the national radio monitoring authority. This is to mitigate the issue of information unbalance.
- There is the need to collect detailed information on each interference case allowing an analysis to determine the source of interference.
- Increase cooperation between market surveillance authorities and interference managing authorities (ECC/FM22 - ADCO/RED)
- Empowerment of interference management authorities (e.g., possibility to cease equipment that caused interferences)
- Continue the contacts with the two brands with most interference cases

- Prohibit the use of WLAN 5 GHz for point to point links ?

The following presentation by Ludger Meinders mentioned some of the points already discussed by the previous presentation and the actions already implemented to mitigate this issue.

Then, Philippe Tristant from EUMETNET provided a presentation on the point of view of the weather radar organization.

Weather radar are a very important asset for weather monitoring. Since 2006, the number of interference cases has increased. The studies by ECC (ECC 2017) and ADCO-RED (ADCO 2019), (ADCO 2019a) and (ADCO 2020) point out that most of the cases of interferences seem due to non compliant RLAN equipment. In addition, the EUMETNET enquiries show that the percentage of meteorological radars in Europe having experienced interference is increasing (72% in 2015 to 88% in 2019), as is also the total number of interference (dramatic increase in short-lasting interference).

ECC initiated an action plan in March 2017 to envisage the Activation of Article 5 of the RE Directive (registration of RLAN equipment before the placing on the market) but it was not executed. In particular, the ECC action plan in Item 1 stated that "Make sure that ECC Report 192 findings and guidelines are from now fully applied by national enforcement authorities, with particular stress on the fact of not leaving any non-compliant equipment in use". The findings from the activity of monitoring and enforcement have shown that most case of interference were caused by RLAN equipment where the DFS function was disabled (even if it should not be because it would make the RLAN equipment not compliant because DFS is mandatory) or even completely missing. There have also been reported cases where the DFS was activated but the RLAN equipment was still creating interference. Further studies are needed in this area because this has been reported by other sources as well.

The conclusions of the presentation were not optimistic for a quick resolution of the problem even if there is a severe need to address this issue in the near future. The reasons are:

- Reality has to be faced by EU administrations that the current situation will not improve without a drastic change of actions in frequency monitoring /enforcement and/or operational conditions applied to RLAN in the 5600-5650 MHz band.
- During the last WGFM, some EU countries raised the fact this issue has to be addressed in the context of a more than likely increase of RLAN 5 GHz usage over time. Then, this problem may worsen in the future.

There is the risk that the weather community will lean towards the option to migrate to the band 5350-5470 MHz where RLAN are not present (but other services are present). The advantage and disadvantages of this option are discussed in section 5.

After the round of presentations, the discussion started on the potential solutions to mitigate these problems of interference.

One of the main issues for enforcement/market surveillance is related to transient interferences, which do not allow the enforcement authorities to record enough information on the interference, but which still create denial of service situations to the weather radar. This could be one of the reasons for the informational unbalance between the weather radar community, the radio monitoring system and the market surveillance authorities, but there could other reasons as well.

There seems a general consensus that the recent version of the standard ETSI TS 102 893 (ETSI 2017) is technically sound as it has been revised a number of times with the direct input of the weather radar community and ADCO RED. On the other side, it has been also remarked that non ideal conditions of propagation are present in the field (hidden node problem, multipath and attenuation), which may affect the DFS effectiveness. There is also

the aspect of the technological evolution of the radar systems which means that the weather radar manufacturers community must be still in contact to ETSI TC BRAN (responsible for the drafting of ETSI TC 102 893).

The monitoring and enforcement of RLAN equipment was one of the central points of discussion. Enforcement authorities should be equipped with adequate tools to detect non-compliant RLAN equipment either because 1) the DFS is disabled, 2) the RLAN equipment does not have it or the 3) DFS is not operating correctly. As in other domains, the problem of an effective enforcement is the limited amount of enforcement resources in comparison to the large amount of RLAN equipment to be monitored. Some automatisms are needed either on the RLAN equipment itself, on the weather radars (which are the first to detect interference) or with additional equipment (e.g., radar monitoring stations). On the other side, some automatism can be complex or expensive to implement. There was a consensus that the enforcement is the most critical aspect and which would require the closest coordination among the main parties (EC, CEPT, EUMETNET, ADCO-RED, ETSI, member states, RLAN equipment vendors).

To summarize the following key aspects were identified as outcome of the meeting:

- There is the need for a closer coordination (and related processes and tools) for enforcement purposes. In particular, it is needed to resolve or mitigate the information unbalance (i.e., from the large number of reported interference cases seen by the weather radar community only a limited amount is reported by the enforcement authorities)
- There are still some technical aspects which are not fully clear. For example, the report of transient cases of interferences. Where they originate from ?
- Effective tools for monitoring RLAN equipment must be investigated for potential implementation. Such tools could detect the status of the RLAN equipment (e.g., current version of the software related to a specific version of the ETSI standard and DFS implementation), or the log data (DFS execution is generally logged).
- A step by step approach could be adopted to single out clearer cases of interference and work on mitigation solutions: specific non compliant brands, point to point or point to multipoint RLAN and so on.
- Investigate the possibility to activate article 5 of the RED.
- Provide more powerful means to enforcement authorities: recall, larger fines for RLAN non-compliant equipment.
- JRC will conduct a more detailed analysis on the potential options for a way forward taking in consideration the documents produced so far, the literature review on this topic and the list of options defined in FM57.

4.2 Discussion on Radio frequency coexistence of Meteorological Radar Sensor operating in the frequency bands 5 250 MHz to 5 850 MHz (C band) with RLAN at the 9th meeting of the Expert Group on Radio Equipment (EG RE) on 24 February 2021 coordinated by DG GROW

The matter of Radio frequency coexistence of Meteorological Radar Sensor operating in the frequency bands 5 250 MHz to 5 850 MHz (C band) with RLAN was also discussed at the Expert Group on Radio Equipment (EG RE) on 24 February 2021. JRC provide an update on the activities including a report on the meeting of 17 February 20201 (see previous section 4.1) for enforcement. ADCO RED was present and his representative provided an overview of the problem. The matter of the application of article 5 was also discussed. The JRC will continue to participate to the meetings of EG RE to provide update on the work.

5 Qualitative evaluation of the potential options for the mitigation of the issue of weather radar coexistence.

This section aims to identify the potential options for the mitigation of the issue of weather radar coexistence. The options are presented in a table described in the following sub section.

5.1 Structure of the options table

In this subsection, Table 1 aims to provide the list of the potential options which have been presented and discussed by the experts contacted during the study, which have emerged during the meetings or which have been suggested by the referenced studies and presentations.

In the table, the following columns are used:

- Description of the option.
- Advantages of this option
- Disadvantage of this option
- Source: References of document/study, which suggested this option
- Metrics of evaluation (beyond the mentioned advantages/disadvantages or to provide a summary of advantages/disadvantages): Tecnical Complexity, Organization Complexity, Implementation Cost, Deployment Cost, Potential Risk of the proposed option to not be able to mitigate the issue in a definitive way, Potential risk of the proposed option to create other not planned issues.

5.2 Metrics of evaluation

The metrics of evaluation are described in detail in the following bullet list:

- *Tecnical Complexity*. This metric of evaluation provides an indication on how complex is the implementation or deployment of the proposed option. For example, a new DFS mechanism could be quite complex to implement and/or it would require the implementation of complex processing algorithms.
- *Organization Complexity*. This metric of evaluation provides an indication on how complex if the organization complexity of the proposed option. For example, the proposed option may require the set up of new processes or governance bodies for enforcement.
- *Implementation Cost*. This metric of evaluation provides a qualitative indication of the implementation costs to implement this solution. For example, the implementation of new filters in the weather radar or DFS hardware in the RLAN equipent can be expensive.
- *Deployment cost*. This metric of evaluation provides a qualitative indication of the deployment costs to implement this solution. For example, if the option proposes to change the operating frequency band of the weather radar, the replacement of the old radar equipment and the deployment of the new radar equipment can be significantly expensive.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* This metric of evaluation assesses in a qualitative way if the proposed option is not able to completely resolve the issue of coexistence with RLAN devices. For example if the option proposes to change the operating frequency band of the weather radar, the potential risk of coexistence will be quite limited.
- *Potential Risk of the proposed approach to generate other not planned issues.* This metric of evaluation assesses in a qualitative way if the proposed option create additional hazards or unplanned issues. For example if the option proposes to

change the operating frequency band of the weather radar, it may not be clear if other issues of coexistence may appear with other wireless services in the frequency band to migrate.

- *Time duration of execution.* This metric of evaluation assesses in a qualitative way the potential duration of the execution of the proposed option. An High value is negative because it would postpone the resolution of the coexistence issue.

All the metrics described above are negative with the meaning that an higher value (X-high) has a negative effect for the implementation of the option. Then, the optimal option would have the lowest scores.

DISCLAIMER: The following Table 1 is work in progress at the time of writing this document (2 March 2021) and it is not by any means final. It may be not complete or it may contain not correct information. The content of Table 1 will be further analyzed by relevant stakeholders: the participants to the meeting on 17 February 2021 from section 4.1 and additional experts when needed. In particular the experts will be requested to express an evaluation on the metrics, which will be reported in the new version of this document.

Table 1 Qualitative assessment of the proposed options

Option identifier	Description of the option	Advantage of this option	Disadvantage of this option	Source	Tecnical Complexity	Organization Complexity	Implementation Cost	Deployment cost	Potential Risk to not be able to mitigate the issue	Potential Risk to generate other not planned issues	Time duration of execution
1	Turn ECC Report 192, into a Recommendation to provide guidance to manufacturers and notified bodies and to provide guidance to enforcement authorities.	Amplifies the need to exercise rigorous and consistent enforcement.	Market surveillance and monitoring activities on 5 GHz WAS/RLAN have significantly increased since the first publication of ECC Report 192 (2014). However this hasn't stopped the continuous increase, taking CEPT as a whole, in the number of reported interference cases.	(FM 2020)	Low	High	Medium	Medium	High	Low	Medium

	Revise ECC/DEC(04)08 include the use of a database for fixed outdoor p-to-p and p-to-mpt equipment through mandatory registration of SSID, MAC, address and location (as proposed by FM22).	Provides mechanisms to spectrum monitoring and enforcement experts to handle meteorological radars interferences caused by WAS/RLAN fixed outdoor installations. A new Incentive of using compliant equipment. Improve locating and identifying the interfering source. May provide a reduction in resources needed for investigation and enforcement.	Users might not register equipment into the database, either intentionally or unintentionally. In case of simple database without some automatic management, it may contain users who do not have operational equipment. Requires additional administrative resources, where no database exists.	(FM 2020)	Medium	High	Medium	High	High	Low	medium
2	Highlight the band 5350-5470 MHz as an alternative to 5.6 GHz via possible guidance on possible migration strategies in an ECC output (where the ECC output could include the sharing issues with EESS satellites).	Provides national administrations with information on the conditions for possible radar band migration on a case by case basis. May be an effective action for some radars (e.g. in urban areas) that are particularly exposed to potential interference by RLANs. Should avoid any RLAN interference to meteorological radars and hence provide a long-term solution.	Additional cost to replace existing radars in order to change band. The implementation of this option will hide the difficulties of individual CEPT administration, and ECC as a whole, around dealing effectively with spectrum sharing using advanced/software defined mitigation techniques for license-exempt use. Requirement for compatibility studies with incumbent services (other radars, Copernicus, …)	(FM 2020)	Low	Medium	High	High	Low	High	High

3	Revise ECC/DEC(04)08 to exclude the use of 5600 – 5650 MHz band by WAS/RLAN equipment.	This should facilitate actions by administrations to prevent interference with radars as use would be non-compliant in its entirety. Simple restriction that applies to all equipment and can be easily implemented in corresponding harmonised standard.	Legacy equipment can and will remain in place for some time, there will be the need for a transitional period. Reduced spectrum availability for 5GHz WAS/RLAN use, both indoor and outdoor. May reduce the number of administrations who can implement the revised ECC Harmonisation measure.	(FM 2020)	Low	High	Low	High	Low	Low	Medium
4	Revise ECC/DEC(04)08 to remove the use of 5600-5650 MHz band by fixed outdoor point to point and point to multipoint equipment	This should facilitate actions by administrations to prevent interference with radars from fixed outdoor pt to pt and pt to mpt use. This should facilitate actions by administrations to prevent interference on radars by targeting only the main interference scenarios.	Legacy equipment can and will remain in place for some time, there will be the need for a transitional period. Reduced spectrum availability for fixed outdoor 5GHz pt to pt and pt to mpt use. May reduce the number of administrations who can implement the revised ECC Harmonisation measure	(FM 2020)	Low	Medium	Low	Medium	Medium	Medium	Low

5	Improve collaboration between ECC, ADCO and EC, through a focus on the weather radar interference issue from an organizational point of view to mitigate the information unbalance between weather radar reporting, monitoring and member states reporting	It seems that the information unbalance is one of the most serious issues for enforcement/market surveillance.	Market surveillance and monitoring activities on 5 GHz WAS/RLAN have significantly increased since the first publication of ECC Report 192 (2014). However this hasn't stopped the continuous increase, taking CEPT as a whole, in the number of reported interference cases.	(FM 2020) (This report)	Low	Medium	Low	Medium	Medium	Low	Low
6	Installation of monitoring stations to report (possibly in a automatic way) interference in the field	Monitoring stations would be able to provide a ground truth which can be used to determine the reason and source of the interference.	The installation of monitoring stations in the european member states can be costly unless they can be associated/deployed on existing infrastructures (cellular networks ?)	This report	Low	Medium	High	High	Medium	Low	Medium

7	According to ERC report 25 (pag 129 of ECC 2020a), the frequency bands 5650 MHz - 5725 MHz used by weather radar are also used by other applications (e.g., Amateur, Radio determination applications). If not done already, an investigation should be done to ensure that interferences do not originate from applications apart from RLAN. While most of the reported case of interference are in 5600 MHz - 5650 MHz (presumably because most of the weather radars operates in that band) it is also possible that amateur radio generates adjacent band interference.	This would clarify if reported interferences are due to RLAN or other applications coexisting in the same thus restricting the search space of the issue.	This effort could be a distraction from the real cause of interference.	(ECC 2020a)	Low	Low	Low	Low	High	Low	Low
8	Replace (partially or totally) the C-band radars with a network of X-band radars.	This would remove the problem of interference and it is somewhat equivalent to move to another band with the advantage that X-band radars are already available and they must not be designated from scratch.	Limited Doppler capabilities in the X band as well as higher susceptibility to heavy rains would prevent the use of such a solution as replacement of most current radar networks.	(Saltikoff 2016)	Low	Low	Medium	High	Low	Medium	High

9	Improve the radio location of interfering sources (e.g., WiFi AP). While the azimuth of the device is known from the weather radar data, it is not easy to locate the device in range as the ground-based equipment cannot easily replicate the propagation conditions of the weather radar nor perhaps have similar sensitivity or have robust search capability and capacity. A potential solution would be to install radio monitoring systems for the devices operating in the weather radar frequency band (e.g., WiFi AP)	In combination with the azimuth the radio monitoring system can provide the approximate distance of the interfering devices on the basis of the received information defined in the related wireless standard.	Each existing radar station must be equipped with radio monitoring system if the price of such devices has decreased in recent times.	(Saltikoff 2016)	Low	Low	Low	Medium	Medium	Low	Medium
10	Creation of a geo-location database to record the position of the weather radars. The geo-location database can be used to improve the DFS function in the RLAN or (in the extreme case) it can be used to create exclusion zones.	The definition of the geo-location database could help to mitigate the issue of interference by providing to the RLAN devices (e.g., WiFi APs) the location of the weather radars.	RLAN devices (e.g., WiFi APs) must be equipped to connect and receive information from the geo-location database.	(Paisana 2014), (Khan 2016)	Low	Medium	Medium	Low	Medium	Low	Medium
11	Even with a well designed DFS, there could be cases of interference due to the ”hidden node” problem. This problem could be mitigated by creating a network of RLAN which exchange messages on the results of the DFS.	This solution could mitigate the ”hidden node” problem.	The exchange of the information among the RLAN devices is something completely new, which would have an impact on the DFS implementation and the deployment of RLAN.	(Han 2016)	Medium	High	Low	Medium	Medium	Low	High

12	Implement a monitoring system to ensure that the RLAN devices (e.g., WiFi APs) are conformant to the spectrum sharing conditions: software version, DFS enabled and national settings.	If implemented, this monitoring system will ensure that the WiFi AP has the DFS activated with the proper configuration.	The creation of such a monitoring system can be complex to activate and manage.		Low	Medium	High	Medium	Low	Low	Medium
13	Investigate and Implement interference cancellation schemes in weather radar to mitigate interferences.	If implemented, interference cancellation can mitigate the risk of interference even in presence of non-compliance spectrum sharing devices.	There has been considerable effort in interference cancellation systems in radar (both hardward and sotware) but with variable success	(Han 2016)	Depends on the technique	Depends on the technique	Depends on the technique	Depends on the technique	Depends on the technique	Depends on the technique	Depends on the technique
14	Even if DFS activated, some interference cases were reported due to adjacent bands interference. Widen the guard band between weather radar and RLAN devices (e.g., WiFi APs) to mitigate adjacent band interference as reported.	Widen the guard band would mitigate the issue of adjacent band interference.	The increase of the guard bands will limit the spectral bands resources for RLAN or weather radar applications	(Naik 2018), (Blanc k 2013)	Low	Medium	Medium	High	Medium	Low	Medium
15	Increase the fines to non compliant RLAN manufacturers or escalate to forbid access to market.	Reports indicates that most of the interference are due to a limited number of models/brands. This solution could limit the case of interference.	There is the risk that manufacturers are blamed for issue of interference due to other causes (e.g., specific environment conditions, radar technology evolution and so on)	(FCC 2019)	Low	Medium	Low	Medium	Medium	Low	Low

16	Creation of a permanent forum with related knowledge management database to support enforcement actions.	The information on 5GHz radar coexistence is now fragmented on a large number of sources. The forum could be an opportunity to assess together the issue of interference.	There is the risk that the forum will not generate practical actions to mitigate the problem of intereference	(this report)	Low	Medium	Low	Low	High	Low	Low

5.3 Analysis of the options

TBC

6 Experimental studies to support coexistence of weather radar with RLAN.

The Joint Research Centre in the European Commission has experimental facilities to conduct studies of coexistence among different services. On the basis of the analysis of the documents identified in the previous sections of this report (in particular section 3.2), the following experimental activities are planned to support the mitigation or resolution of the problem of interference to weather radar operation by RLAN in the 5GHz band:

1. There is a general consensus that the DFS defined in ETSI EN 301 893 V2.1.1 (2017-05) is well designed to detect the presence of the radar signals in the test conditions defined in the standard. On the other side, the real propagation conditions in the field can vary significantly from the specifications of ETSI EN 301 893. It would be useful to evaluate the performance of DFS in presence of different degrees of attenuation and fading conditions due to multipath or presence of obstacles. The JRC can conduct a study where a weather radar signal is subject to different propagation channel conditions to investigate the performance of the DFS algorithm. If weather radar systems are available, a real signal from a weather radar will be used, otherwise simulated signals from a signal generator will be used.
2. It was reported in literature (Naik 2018),(Blanck 2013) that adjacent band interference is possible even after a successful execution of the DFS algorithm. This could be one of the potential reasons why interference cases are reported even when the DFS is confirmed to be working. As in the previous case, if weather radar systems are available, a real signal from a weather radar will be used, otherwise simulated signals from a signal generator will be used.
3. The localization of an interfering RLAN equipment can be difficult to achieve by a weather radar even if the interference impact is clearly visible in the radar image. While the azimuth of the device is known from the weather radar data, it is not easy to locate the device in range. A feasibility done will be done if resources will be available after the first two tasks above.

References

(ADCO 2019)	9th RED Common Action on WLAN 5 GHz https://ec.europa.eu/docsroom/documents/35662/attachments/1/translations/en/renditions/native Last accessed. November 2020.
(ADCO 2019a)	FM(19)097 LS to ECC on the common action on 5GHz RLAN April 2019
(ADCO 2020)	ADCO RED Report on WLAN 5 GHz. Joint meeting TCAM-ADCO RED-RSC https://ec.europa.eu/docsroom/documents/35662/attachments/1/translations/en/renditions/native 17th September 2020.
(Blank 2013)	Blank, R., & Strickling, L. E. (2013). Evaluation of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6406 (b) of the Middle Class Tax Relief and Job Creation Act of 2012. Department of Commerce, Technical Report.
(CEPT 2020)	CEPT report 73 to the European Commission in response to the Mandate "to study feasibility and identify harmonised technical conditions for Wireless Access Systems including Radio Local Area Networks in the 5925-6425 MHz band for the provision of wireless broadband services" https://docdb.cept.org/download/0d0696a1-89ae/CEPT%20Report%2073.pdf Last accessed October 2020.
(CEPT FM 2020)	Options for weather radars at 5.6 GHz. https://cept.org/Documents/wg-fm/61160/fm-20-164annex14_options-for-weather-radars-at-56-ghz. Last accessed November 2020.
(EC 2014)	Official Journal of the EU L 153/62 "DIRECTIVE 2014/53/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April2014 on the Harmonisation of the Laws of the Member States Relating to the Making Available on the Market of Radio Equipment and Repealing Directive 1999/5/EC", May 2014
(ECC 2017)	ECC Report 192: The Current Status of DFS (Dynamic Frequency Selection) In the 5 GHz frequency range. November 2017 https://docdb.cept.org/download/96969047-6c70/ECCRep192.pdf Last accessed November 2020.
(ECC 2020)	CEPT Report 73. Report from CEPT to the European Commission in response to the Mandate to study feasibility and identify harmonised technical conditions for Wireless Access Systems including Radio Local Area Networks in the 5925-6425 MHz band for the provision of wireless broadband services" March 2020.

	https://docdb.cept.org/download/0d0696a1-89ae/CEPT%20Report%2073.pdf Last accessed November 2020.
(ECC 2020a)	THE EUROPEAN TABLE OF FREQUENCYALLOCATIONS AND APPLICATIONS IN THEFREQUENCY RANGE 8.3 kHz to 3000 GHz (ECA TABLE) Approved November 2020. https://docdb.cept.org/download/2ca5fcbd-4090/ERCReport025.pdf. Last accessed March 2021.
(ETSI 2017)	ETSI EN 301 893 V2.1.1 (2017-05) 5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU
(ETSI 2020)	ETSI EN 303 347-2 (2020-06) Meteorological Radars; Harmonised Standard for access to radio spectrum; Part 2: Meteorological Radar Sensor operating in the frequency band 5 250 MHz to 5 850 MHz (C band)
(EUMETNET 2017)	EUMETNET. Recommendation on C-Band Meteorological radars design to ensure global and long-term coexistence with 5 GHz RLAN. Recommendation by EUMETNET members operating C-Band meteorological radars to take in account in the design of these radars the coexistence with 5 GHz RLAN and their potential for interference. https://www.eumetnet.eu/wp-content/uploads/2017/01/OPERA_2008_12_Recommendation_RLAN.pdf. Last accessed October 2020.
(FCC 2019)	FCC TAKES ACTION AGAINST COMPANIES THAT INTERFERED WITH FAA WEATHER RADAR IN PUERTO RICO. https://docs.fcc.gov/public/attachments/DOC-359216A1.pdf. Last accessed February 2021.
(FM 2020)	CEPT FM57. Proposal on draft Elements for options for weather radar in 5.6 GHz due to WAS-RLAN interference. https://www.cept.org/ecc/groups/ecc/wg-fm/fm-57/client/meeting-documents/?flid=9822. Last accessed February 2021.
(Han 2016)	Han, Y., Ekici, E., Kremo, H., & Altintas, O. (2016). Spectrum sharing methods for the coexistence of multiple RF systems: A survey. Ad Hoc Networks, 53, 53-78.
(ITU 2019)	M.1849-2 (01/2019) Technical and operational aspects of ground-based meteorological radars.
(Joe 2007)	Joe, P., Whetten, F., Scott, J., & Whetten, D. (2007, August). Airborne RLAN and weather radar interference a C-band. In 33rd Conf. on Radar Meteorology.
(Khan 2016)	Khan, Z., Lehtomaki, J. J., Vuohtoniemi, R., Hossain, E., & DaSilva, L. A. (2016). On opportunistic spectrum access in radar bands: Lessons learned from measurement of weather radar signals. IEEE Wireless Communications, 23(3), 40-48.
(Labib 2017)	Labib, M., Marojevic, V., Martone, A. F., Reed, J. H., & Zaghloui, A. I. (2017). Coexistence between communications and radar systems: A survey. URSI radio science bulletin, 2017(362), 74-82.

(Moon 2017)	Moon, J., & Ryu, C. (2017). WiFi (RLAN) and a C-Band Weather Radar Interference. Journal of the Chosun Natural Science, 10(4), 216-224.
(Mueck 2019)	M. D. Mueck, B. Badic, H. Ahn, P. Bender, S. Choi and V. Ivanov, "Market Access for Radio Equipment in Europe Enabled by the Radio Equipment Directive: Status, Next Steps and Implications," in IEEE Communications Magazine, vol. 57, no. 12, pp. 20-24, December 2019, doi: 10.1109/MCOM.001.1900334
(Naik 2018)	Naik, G., Liu, J., & Park, J. M. J. (2018). Coexistence of wireless technologies in the 5 GHz bands: A survey of existing solutions and a roadmap for future research. IEEE Communications Surveys & Tutorials, 20(3), 1777-1798.
(Paisana 2014)	Paisana, F., Marchetti, N., & DaSilva, L. A. (2014). Radar, TV and cellular bands: Which spectrum access techniques for which bands?. IEEE Communications Surveys & Tutorials, 16(3), 1193-1220.
(Paisana 2014a)	Paisana, F., Miranda, J. P., Marchetti, N., & DaSilva, L. A. (2014, April). Database-aided sensing for radar bands. In 2014 IEEE International Symposium on Dynamic Spectrum Access Networks (DYSPAN) (pp. 1-6). IEEE.
(Safavi-Naeini 2015)	Safavi-Naeini, H. A., Roy, S., & Ashrafi, S. (2015). Spectrum sharing of radar and Wi-Fi networks: The sensing/throughput tradeoff. IEEE Transactions on Cognitive Communications and Networking, 1(4), 372-382.
(Saltikoff 2016)	Saltikoff, E.; Cho, J.Y.; Tristant, P.; Huuskonen, A.; Allmon, L.; Cook, R.; Becker, E.; Joe, P. The threat to weather radars by wireless technology. Bull. Am. Meteorol. Soc. 2016, 97, 1159–1167.
(Tristant 2017)	C-band meteorological radars Threats related to RLAN 5 GHz https://www.itu.int/en/ITU-R/study-groups/workshops/RSG7-ITU-WMO-RSM-17/Documents/C-band%20meteorological%20radars%20Threats%20related%20to%20RLAN%205%20GHz.pdf. Last accessed November 2020.
(Vaccarono 2019)	Vaccarono, M., Chandrasekar, C. V., Bechini, R., & Cremonini, R. (2019). Survey on Electromagnetic Interference in Weather Radars in Northwestern Italy. Environments, 6(12), 126.

List of abbreviations and definitions

DFS	Dynamic Frequency Selection
ECC	European Electronic Communications Committee
ETSI	European Telecommunication Standards Institute
OoB	Out-of-Band
RED	Radio Equipment Directive
RF	Radio Frequency
RLAN	Radio Local Area Network
WLAN	Wireless Local Area Network
WRC	World Radio Conference

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