European Commission

JRC TECHNICAL REPORT

An analysis of issues related to radio frequency coexistence of Meteorological Radar Sensor operating in the C band with Wireless Local Area Networks

Policy and technical options to mitigate the issues of RF coexistence

2022
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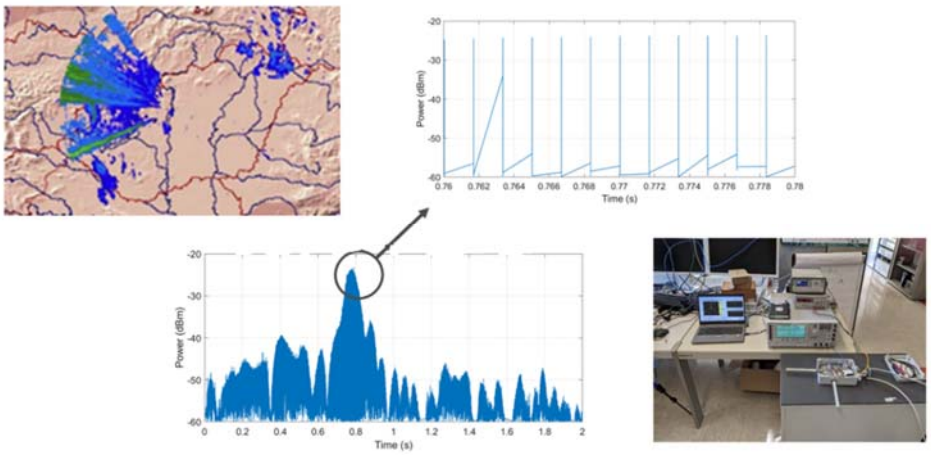

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Abstract

The issue of interference to meteorological radars from Wireless Local Area Network (WLAN) and Radio Local Area Network (RLAN) or WAS/RLAN[1] 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 WLAN/RLAN and WLAN, which may lead to causing interferences in weather 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 report is the result of an initial preliminary analysis of the extensive and available documentation on this topic. This report does not aim to replicate the analysis already conducted by the various organizations (e.g., CEPT, ADCO RED, 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.

[1] At ETSI level and at CEPT level, WLAN it is called WAS/RLAN (Wireless Access Systems)/ Radio Local Area Network.

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
V6	Updated after feedback received by the participants to the meeting on 17/02/2021. Started to draft section V.	19/03/2021
V7	Updated after ADCO RED meeting, comments from France and EUMETNET. Completed the first draft of section V: potential options. Submitted for feedback on section V	26/03/2021
V8	Updated on the basis of the comments received from the stakeholders on v7 of the document. Input document for the discussion on the 25th of May 2021.	12/05/2021
V9	Updated after web call of 25th of May 2021	25/05/2021
V10	Transformed Template to JRC Technical report. Final revision for internal submission in JRC Pubsy system	28/05/2021
V11	Updated after meeting of 18 June 2021	12/07/2021
V12	Updated on the basis of the initial comments JRC editorial board	14/07/2021
V13	Corrections	10/09/2021
V14	Updated after final approval by JRC editorial board	11/10/2021
V15	Conversion to public document. Updates due to new regulation.	16/07/2022

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 or weather radars (the two terms are used with the same meaning in this report) 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-band (5600-5650 MHz band), 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 WLAN/RLAN and WLAN, was set in the bands of 5.150–5.350 and 5.470–5.725 GHz.

Note: because different references used as input to this document use the terms WLAN, RLAN and WAS with the same meaning, the terms are used interchangeably in this document. For example, at ETSI level and at CEPT level, WLAN it is called WAS/RLAN (Wireless Access Systems)/ Radio Local Area Network while in ADCO RED or in the industry domain WLAN/RLAN is often used. Then, the term WLAN/RLAN is used to indicate either WAS/RLAN or WLAN/RLAN unless a reference (e.g., a study, scientific paper) specifically uses one of the two terms (e.g., WLAN/RLAN).

Note: the list of acronyms is provided near the end of this report.

On the basis of (WRC-03) weather radars[2] and WLAN/RLAN are expected to coexist in the same radio frequency bands with WLAN/RLAN on the basis of the conditions defined in ECC/DEC/(04)08 (ECC 2004), (ECC 2005) and (ETSI 2017). Then, the WLAN/RLAN, is required to implement the Dynamic Frequency Selection (DFS) to detect the radar signals and avoid the usage of the corresponding identified radars channels by WLAN/RLAN.

We could also highlight that the whole C-band radar (5250-5850 MHz) is not used by meteorological radars in the same way across the frequency bands in this frequency range. Mainly 5600-5650 MHz band is used by weather radars. In addition, some frequency bands are now designed for WLAN/RLAN: 5150-5350 MHz and 5470-5725 MHz (ECC 2020a).

The note does not aim to describe in detail the meteorological radars, WLAN/RLAN 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).

1.1 Context of the problem

The main problem is that many cases of interference have been reported on 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) and other actions but cases of interference are still reported today. It is noted that CEPT provides an annual interference statistic, including interferences into Weather Radars: https://cept.org/ecc/groups/ecc/wg-fm/fm-22/client/introduction/annual-radio-interference-statistics-and-special-interference-cases (CEPT FM 2021b). Then, interferences to weather radars are a long standing problem, which is not resolved yet. In fact, it is not even confirmed that all cases of interference are due to WLAN/RLAN.

1.2 Scope of this report

The scope of this report is to:

[2] While this report investigates coexistence for weather radar, it is noted that various types of radars are using 5GHz bands (in particular meteorological radars transmitting at 5.6 GHz but also defense/military radars)

- Report on the activities and meetings where the JRC participated to discuss the problem of coexistence of radar with WLAN/RLAN equipment in the 5GHz band.
- Identify a number of key policy/implementation/enforcement options for the resolution of the coexistence problem from a number of inputs.
- Assess the identified key policy/implementation/enforcement on the basis of the feedback and assessment of key stakeholders in this area (e.g., ADCO RED, EUMETNET, CEPT) and along different key metrics.
- Recommend a subset of options for further actions along various dimensions: regulatory, enforcement, organizational, technical and experimental dimensions.

Note: In this report, enforcement refers to relevant actions from either national market surveillance authorities to guarantee the correct application of Radio Equipment Directive (RED – 2014/53/EU) or from spectrum monitoring authorities to identify and solve interferences so to guarantee the lawful use of spectrum according the national frequency allocation which in the case of WLAN/RLAN 5 GHz implements the EC Decision RLAN 5 GHz (Commission Decision 2005/513/EC). Note that this regulation has been recently replaced by 2022/179/EC (EC 2022). It is up to each Member States (MS) to organise these activities at national level. National surveillance authorities are cooperating within ADCO RED, spectrum authorities are cooperating in CEPT FM 22.

1.3 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).

- WGFM(21)050Annex 22. ECC options that may assist in the alleviation of interference to meteorological radar from WAS/RLAN at 5.6-5.65 GHz.

This document (FM 2021) lists the proposed options by FM (FM57) to resolve the coexistence issue. The options have been inserted/taken care in the list of potential options presented in Table 1.

- 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 WLAN/RLAN (EUMETNET 2008)

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 WLAN/RLAN and their potential for interference. Reference (EUMETNET 2008). It was a follow-up of TCAM as the counterpart commitment of EUMETNET of the revision of the WLAN/RLAN 5 GHz ETSI standard.

- ADCO RED. State of play joint cross-border. ADCO RED common action on WLAN/RLAN 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 WLAN/RLAN to weather radars. Reference (ADCO 2020)

- EC Decisions and 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. Note that this regulation has been replaced by (EC 2022) Commission Implementing Decision (EU) 2022/179 of 8 February 2022 after the completion of this report.
- (2007/90/EC) https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32005D0513

1.4 Structure of the technical report

- 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.
- Section 4 describes the progress on the enforcement 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 WLAN/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 5250 MHz to 5 850 MHz (C band) with WLAN/RLAN.

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

The following organizations and their representatives have been contacted in the preliminary analysis. The table is sorted according to the organization.

Name/Surname	Organization
Lucio Cocciantelli	ADCO RED Chair (OFCOM (CH))
Ralf Trautmann	Chairman of CEPT ECC FM 22
Ales Brabinek	DG CNECT B.4
MARTIN Ruediger	DG CNECT E.3
Pierfrancesco Sammartino	DG GROW C.3
Igor Minaev	ETSI officer in ETSI TC BRAN
Stefan Bach	Representative of Bundesnetzagentur in ETSI TC BRAN
Robin Donoghue	Representative of ECO, the permanent office supporting the CEPT, including its Electronic Communications Committee (ECC)
Doriana Guiducci	Representative of ECO, the permanent office supporting the CEPT, including its Electronic Communications Committee (ECC), (also participating to CEPT FM57)
Jaime Afonso	Representative of ECO, the permanent office supporting the CEPT, including its Electronic Communications Committee (ECC)
Hai Zhou	Representative of Huawei in ETSI TC BRAN

2.2 Non compliance of WLAN/RLAN equipment

Non compliance indicates that the equipment is not compliant with the applicable requirements.

The non compliance of WLAN/RLAN equipment may happen in the following main areas:

- Wrong or sub-performing implementation of the DFS function, which gives false information to the WLAN/RLAN transmitter, which starts transmission even in presence of radar signals.
- Non compliance to the technical specifications for the WLAN/RLAN 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).
- No DFS function is implemented in the WLAN/RLAN equipment.
- Administrative non-compliance and technical non-compliance, that may not lead to interferences.

In all these cases, it seems that it is a problem of non-compliance to the requirements, which is a problem of enforcement. Enforcement covers market surveillance **and** interference solving. 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. There is a need to implement a set of options in order to reverse the trend.

In this context, action item 1 of the ECC action Plan (ECC 2017a) states 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".

Regarding the last point, it was noted that the Group of Administrative Co-operation under the Radio Equipment Directive (ADCO RED) adopted the 9th joint cross-border RED Market Surveillance campained on WLAN/RLAN 5GHz on 20th March 2019 (ADCO 2020). It lists in detail the reasons for non-compliance of 5GHz WLAN/RLAN equipment. (See Section C.1.) 85% of the devices checked were administrative non-compliant. 77% thereof was assessed against the marking requirement. "Only" 35% of the devices were technical non-compliant, where the highest level of technical non-compliance was assessed against the In-Service Monitoring requirement (25%). These findings show, that non-compliance neither means that a device is technical non-compliant, nor that even technical non-compliant devices can cause interferences to weather radars.

2.3 Misuse of the WLAN/RLAN equipment

Misuse of WLAN/RLAN equipment means that the WLAN/RLAN it is mismanaged or tampered with in the field. Misuse may happen in the following main areas:

- Disabled DFS function, which would also not provide to the WLAN/RLAN equipment the information to avoid radar signals. Requirements should prevent the user to disable the DFS function in the Human User interface (e.g., written in the user manual). If it is not the case, then this would be a non-compliance.
- Change of the country settings to alter the use of the frequency bands. Requirements should prevent the user to disable the change of country settings in the Human User Interface (e.g., written in the user manual). If it is not the case, then this would be a non-compliance.
- Placement of the WLAN/RLAN transmitted in challenging wireless propagation conditions, which may negatively impact the accuracy of the DFS function (Saltikoff 2016), (Vaccarono 2019).
- Replacement of the WLAN/RLAN original antenna with an antenna with higher gain.

2.4 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 if 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 Radio Equipment Directive (RED) 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)[3] and 4[4] of the Directive, new updates of specific software which introduces major changes in configurations may not be previously tested and/or prevented. It has been reported that work has been launched in order to draft delegated act under the RED in Article 4.1.

2.5 Change of member states setting

One issue identified by ADCO RED in (ADCO 2020) is the possibility that a WLAN/RLAN equipment is used in another country 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 defined in (ECC 2004),(ETSI 2017) shall be used in all EU member states. 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 where DFS could be deactivated.

Stakeholders interviewed on this issue claimed that a change of configuration should not be allowed by the equipment manufacturer. In addition, each WLAN/RLAN equipment sold in a specific nation should be configured with the proper configuration setting at the time of placement in the market. The requirements are harmonized in the EU and DFS (ETSI 2017) and shall be used in all EU MSs. Additional rules should be defined for equipment purchased outside Europe. For example, the country of use should be indicated at the time of purchase so that the vendor can configure the proper setting or select the specific model.

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 WLAN/RLAN equipment in section 4.2.9 User Access Restrictions.

[3] 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

[4] 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.

On the other side, it was also remarked the possibility for users to purchase through internet channel, products which may not be compliant with EU regulation but they are still imported and used in the European Union.

2.6 Difficulties in enforcement

Various sources (ADCO 2020), (Tristant 2017) highlighted the difficulty to perform enforcement in the member states. One difficulty is that the distance between weather radar systems and WLAN/RLAN equipment can be quite large. A range spanning from few hundreds of meters to 181 km is mentioned in (Tristant 2017) and around 50 km in (Vaccarono 2019).

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

Market surveillance authorities have a set of measures to be used when finding a non-compliant product: from no action to recall of all sold products. Such a recall would help to decrease the risk of interferences. The measure decided has to be proportionate to the non-compliance and based on a risk assessment (case by case assessment). Usually, a technical non-compliance will be sanctioned with a sales ban. This means that the product cannot be made available any more on the market, but all products that have been already sold can be operated as normal. To overcome this problem and to have the background for issuing not only a sales ban, but a recall of the already sold products, market surveillance authorities would need to have a strong justification (in some countries, such a recall has to be decided by a court). Such a justification should be provided by the radio regulators, e.g., from ECC. At the time of writing this report (May 2021) a liaison statement from ADCO RED to ECC is in preparation.

From an interference resolution point of view, the aim of the national managing interference responsible authorities is to stop the interference as soon as possible and to avoid recurrent interference from same source. Interferences to meteorological radars are complex and time-consuming to investigate, notably for the identification and localization of the interfering source due to number of reasons as density of installed outdoor RLANs constantly rising, wide area to search (the interfering source can be more than 100 km away), interfering source may be emitting only intermittent, very low RLAN signal, etc. See FM(19)090 FM22 Report on the technical, operational and legal difficulties in enforcing the regulatory framework for RLAN at 5 GHz for more detailed description of interference resolutions issues.

2.7 Lack in the information on the interferences cases

To be able to determine the causes of interference, the interferences cases should be documented with enough detailed information permitting to reconstruct the case. This means that interference managing persons should not only solve the interference, but also collect some information such as:

- Identification of the product (Brand, Type, model, S/N)
- Operating frequency and channel bandwidth (MHz)
- Transmitted power (dBm)
- Antenna gain (dB)
- Software version
- Bought by... on ....

- ....

2.8 Deficiencies in weather radar systems design and/or implementation (Case A: insufficient technical implementation)

The first case (Case A) is more general and it refers to non-compliance to technical specifications or compliance to outdated specifications, which may lead to issue of interference.

Interference from WLAN/RLAN 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[5].

The RED directive (EC 2014) in Article 3(2) states that "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".

2.9 Deficiencies in weather radar systems design and/or implementation (Case B: not adequate filters)

The second case (case B) of deficiencies in the weather radar systems design and implementation is based on the lack of adequate filters.

It is noted that the vast majority of interference cases are usually in-band to the radar and it would be challenging to improve the receiver filtering capabilities. More research is needed in this area.

In the case of adjacent interference, RF power due to emissions from WLAN/RLAN 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).

It was also noted that many member states have been monitoring this issue and they have already taken measures to address coexistence problem in this band or other bands. For example, in France, all weather radars have been updated with better filtering few years ago when 4G has been introduced in 2.6 GHz (requiring better filtering of 2.7 GHz radars including for weather radars. A filtering update of 5.6 GHz radars has also been done and the relevant filtering is conformant with current draft ETSI standard (ETSI 2017).

2.10 Hidden node

The hidden node problem in cognitive radio systems and detect and avoid functions like the DFS appears when the equipment (e.g., a WLAN/RLAN 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.

[5] At the time (May 2021) of writing this version of the technical report (version 6), the technical specification are not fully defined yet.

In Figure 1, the radar systems has the coverage indicated by the blue transparent area, where WLAN/RLAN 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/RLAN standards, while the DFS enabled equipment is a WLAN/RLAN router/switch with more powerful capabilities than User Equipment and it is therefore equipped with DFS capabilities as described in (ETSI 2017).

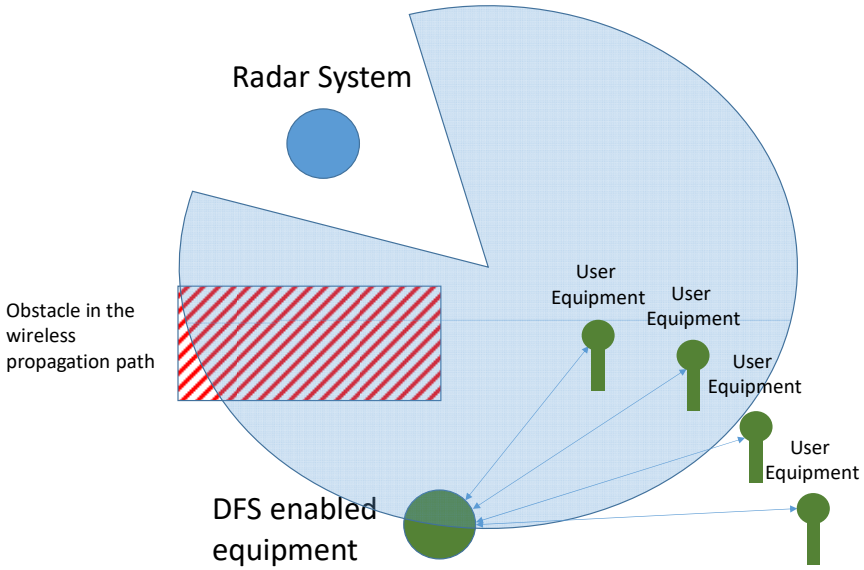

Figure 1 Hidden node problem

The hidden node problem is based on the 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/RLAN 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. It is noted that the DFS specification (ETSI 2017) includes already a margin in order to address such hidden mode configuration. The last version of standard imposes that the equipment in slave mode integrates DFS functions.

4) All devices should have the DFS function activated. The mobile devices should report it back to the router and then the router must change frequency.

For example, in the WLAN/RLAN radio links design at 5 GHz (as in the HiperLAN) both end points of the radio link should (or preferably must) 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).

On the other side, the feedback from the national enforcement authorities is that the hidden node problem is unlikely to be the reason for the reported interferences.

2.11 Evolution of the technology

The coexistence of two different radio services (WLAN/RLAN and meteorological radars) can be hampered if the technological evolution of one of the two radio services does not take in consideration the 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/RLAN should also support these changes. This can be challenging to achieve in the field as different models with different implementations may coexist in the field. In turn, this imposes constraints on the technology evolution of radar because radar specifications, which deviate from the ones used by DFS (ETSI 2017) may increase the risk of interference. One mitigation path would be a requirement in radar weather design to transmit a minimum number of detectable signals over scanning strategies (EUMETNET 2008).

It was noted that the evolution of weather radars and DFS availability to detect them have been already addressed (the issue have been initially raised in TCAM (2008)). The community of the weather radar stakeholders agreed to maintain a minimum of radar signals to be identified by the DFS, as described in the EUMETNET Recommendation on ”C-Band Meteorological radars design to ensure global and long-term coexistence with 5 GHz RLAN” (EUMETNET 2008). It was also mentioned in ITU-R recommendation M.1849.

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 ? On the other side, it was highlighted that the mention of frequency hopping radars in (ETSI 2017) only targets defense radars and not weather radars. At this stage, there is still no solution to detect such radar.

2.12 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 EIRP 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 EIRP. On the other side, the WLAN/RLAN antenna gain does not intervene in the DFS efficiency since it applies to both the detection by WLAN/RLAN and its potential interference to radars, the net margin of DFS link budget is antenna gain agnostic. However, since WLAN/RLAN in this band is limited to 30 dBm EIRP, using high antenna gain may lead to higher EIRP and hence non-compliance but it should not lead to meteorological radar interference, except of course if DFS is not working.

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

Different actions are possible 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 enforcement

From the identified documents (EUMETNET 2017), (ADCO 2019), (ADCO 2020), enforcement 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 enforcement.

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 enforcement. 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/RLAN 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 V1.5.1. and subsequent revisions of ETSI EN 301 893[6] 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 execute an experimental studies based on the current DFS specification but changing the most significant parameters to evaluate the performance of DFS when the signal characteristics and the wireless propagation path (e.g., attenuation, fading) of the weather radar signals are modified.

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

Table 1 Progression of ETSI EN 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

[6] EN 301 893 modifications were discussed in length in TCAM and ETSI in 2007-2008, ending up with a 2 phases approach for revisions V.1.5.1 and subsequently V.1.6.1.

301 893 V1.5.1	RTTED	July 2010		New test signals to cover specific meteorological radars (staggered, interleaved) with pulse width down to 0.8 micro seconds. New DFS parameters to specifically address the 5600-5650 MHz band (CAC of 10 minutes, 99.99% detection probability, …)
301 893 V1.6.1	RTTED	11.4.2012	31.12.2014	Pulse width was scaled down to 0.5 micro seconds.
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 Annex 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 for 5GHz weather radar/WLAN/RLAN coexistence

The Radio Spectrum Committee (RSC) meeting number 73 (RSC #73) took place in 9/10 December 2020. In RSC #73, the JRC has received positive feedback on the spearheading actions to foster coordination on enforcement for 5GHz weather radar/WLAN/RLAN coexistence.

Then 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 subsections. 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 WLAN/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 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. It is noted that there are already actions by ADCO RED and FM22 in this direction.

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 (now DG DEFIS)
Vega Fidalgo Luis Miguel	DG GROW (now DG DEFIS)
Brabinek Ales	DG CNECT
Cocciantelli Lucio	ADCO RED (OFCOM Switzerland)
Meinders Ludger	German Bundesnetzagentur
Trautmann Ralf	CEPT ECC FM22
Winkelmann Stephan	German Bundesnetzagentur
Tristant Philippe	EUMETNET
De Faria Jerome	ANFR
Talbot Stephen	CEPT ECC FM57
Eric allaix	Meteo France
Mora Andrea	ANFR
Oteo Ortiz Diego	Telecom Equipment Market Surveillance Unit, MINECO, Spain
Guillermo García	Telecom Equipment Market Surveillance Unit, MINECO, Spain
Santiago Pascual	Telecom Equipment Market Surveillance Unit, MINECO, Spain
Robin Donoghue	European Communications Office (ECO)
Petermann Eric	EUMETNET

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 WLAN/RLAN in the 5 GHz band. EC remarked that this meeting is focused on 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 ways 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 4.2.

The meeting included a number of presentations, which were presented according to the agenda (see 4.1.2).

Lucio Cocciantelli, from OFCOM (CH) and chairman of ADCO RED, provided a presentation on 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 EU of radio equipment (article 1(1) RED). On the other side, the Directive 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/RLAN at 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, use of non-compliant WLAN/RLAN (e.g., missing DFS). This is only a partial list of reasons and this list does not exclude 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/RLAN 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/RLAN'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 identified 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 (ETSI 2017).

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/RLAN non-compliance, which created interferences, but the presenter highlighted 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 analysed) 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 WLAN/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 deeper 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 between the weather radar and the supposed source of interference (e.g., dozens of km) make also difficult to pinpoint the source of interference. In addition, it was remarked that it is difficult to extract realistic and useful statistics from only 62 cases whereas several hundreds of cases are reported every year in EU.

It was also noted at the meeting that these 62 cases sent to ADCO RED related to those 8 countries are definitively not the only cases in those countries. They are the cases for which detailed enquiry of the interferences sources have been undertaken … i.e. a minority of cases. During this period (2017 and 2018), for these 8 countries (BE, CZ, EE, FR, LV, LT, NL, ES), the number of reported cases to FM22 was 179 in 2017 and 153 in 2018, without counting Spain that did not provided a specific number but said that they were overwhelmed by interference on all of their radars (15 radars). It was suggested that a close cooperation between JRC and EU services with meteo services may allow to get an overview of real situation.

Then, there is still a relevant issue for enforcement that the reported information may not be complete or precise. In particular, the following information are needed for a complete reporting: a) the location (eventually approximate) of the interferer, b) if all meteorological radars are impacted or only some in an area. Another area, where market surveillance and monitoring can be significantly improved is the checking of the compliance status of the specific instance of WLAN/RLAN equipment in the field even after a successful compliance of the WLAN/RLAN equipment model before the entry in the market.

It was also discussed if point to point WLAN/RLANs 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/RLAN 5 GHz for point to point links ?

It was also remarked that there could be a difficult balance to provide to the national authorities a comprehensive view of the interference cases and the need to avoid an ”information overload” problem.

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 WLAN/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). He mentioned that these short-lasting cases are increasingly important but are difficult to report to National Regulatory Authorities (NRA).

ECC initiated an action plan in March 2017 to envisage the Activation of Article 5 of the RE Directive (registration of WLAN/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 cases of interference were caused by WLAN/RLAN equipment where the DFS function was disabled (even if it should not be because it would make the WLAN/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 WLAN/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 enforcement and/or operational conditions applied to WLAN/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 WLAN/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 WLAN/RLAN are not present (but other services are present). The advantage and disadvantages of this option are discussed in section 4.2.

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 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 EN 301 893 (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 (e.g., 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 should be still in contact to

ETSI TC BRAN (responsible for the drafting of ETSI EN 301 893 (ETSI 2017)), even if it was reported that the collaboration between EUMETNET and ETSI is currently (February 2021) stopped.

The monitoring and enforcement of WLAN/RLAN equipment was one of the central points of discussion. Enforcement authorities should be equipped with adequate tools to detect non-compliant WLAN/RLAN equipment either because 1) the DFS is disabled, 2) the WLAN/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 WLAN/RLAN equipment to be monitored. Some automatisms are needed either on the WLAN/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, WLAN/RLAN equipment manufacturers, vendors, installers). In particular, it was noted that the role of the installer is often forgotten but it could have an important influence on the origin of the issue (see section 2).

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: from the large number of reported interference cases seen by the weather radar community, a smaller number is reported by interference monitoring administrations to FM22 and finally only a limited amount is reported by the enforcement authorities to ADCO RED.
- There are still some technical aspects which are not fully clear. For example, the report of transient cases of interferences. Where they originate from ? Are they all coming from a WLAN/RLAN use? Has the origin been definitively resolved ?
- Effective tools for monitoring WLAN/RLAN equipment must be investigated for potential implementation. Such tools could detect the status of the WLAN/RLAN equipment (e.g. current version of the software related to a specific version of the ETSI standard and DFS function implementation), or the log data (the DFS function execution is generally logged). It was noted that, in relation to the version of the standard, the date when the equipment has been placed on the market is of great importance
- 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 WLAN/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 WLAN/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 (see reference (CEPT FM 2020))

Then, Ralf Trautmann, Chairman FM 22, responded to the statements above:

- Market surveillance cannot prevent that users, in particular those operating professional networks, download illegal software and deactivate DFS.
- The monitoring services in CEPT reported in the last years only a few hundreds of interference cases per year.

- Reporting short time interferences is useless because these interferences cannot be resolved afterwards.
- Sharing frequency bands always implies the risk of interference.
- Registration of outdoor WLAN/RLANs is contradictory to general authorization.
- Removing 5 GHz WLAN/RLANs, shifting their frequency and banning outdoor use will not be feasible because of the huge number of devices.

4.2 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 WLAN/RLAN was also discussed at the Expert Group on Radio Equipment (EG RE) on 24 February 2021. JRC provided an update on the activities including a report on the meeting of 17 February 2021 (see previous section 4.1) for enforcement. ADCO RED was present and its 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 updates on the work.

4.3 Radio Spectrum Committee meeting #74 on 9/10 March 2021.

On 9th/10th March 2021, the JRC has provided a presentation on the current status of work on this problem of weather radar coexistence with a plan of the activities until summer 2021. The results from the previous meetings (including the meeting on 17 February 2021 described in section 4.1) were presented. RSC has been informed that an initial set of options to resolve this issue was discussed at the ECC meeting in March 2021. EUMETNET has also presented the concept of a RFI monitoring tool to monitor over time the « RLAN-type » interference experienced by the European radars network to assess the efficiency of future measures in improving the situation.

For additional details, see minutes RSCom March (RSCOM 21-15rev2).

4.4 ADCO RED meeting 23/24 March 2021.

The JRC was invited to give an update on the study for the weather radar coexistence problem at the ADCO RED meeting on 23/24 March 2021. A revised version of this technical report was presented with the list of options. Some of the options were discussed and comments were provided but comments can be received and addressed outside the meeting. It was remarked that the options are not mutually exclusive and that the proposed solution could be based on a combination of options. The plan is to give the stakeholders the possibility to provide feedback on the list of options and the related qualitative analysis during the month of April 2021 so that this document can be updated and finalized before or during summer 2021.

5 Potential options for a way forward

The aim of this section is to identify the potential options to mitigate the weather radar coexistence problem at a technical, organizational or policy/regulatory level. This is a qualitative assessment based on experience of the stakeholders and similar options discussed in literature. It has been highlighted that a set of options is needed to inverse the current trend.

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, which are based on the experience of the enforcement experts 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.
- Responsible entity (leading role): Entity which launches the implementation of the option (possible follow up to others entities). Potential entities can be: EC, Member states, radar vendors/manufacturer, WLAN/RLAN vendors/manufacturer and distributors, CEPT, EUMETNET, meteorological organizations, ECC, ADCO RED and so on.
- Metrics of evaluation (beyond the mentioned advantages/disadvantages or to provide a summary of advantages/disadvantages): Positive impact to the resolution of the issue, Technical 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. The metrics of evaluation are described in detail in the following subsection 5.2.

5.2 Metrics of evaluation

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

- *Positive impact to the resolution of the issue*. This metric of evaluation is used to give an indication on how much the proposed option is capable to reverse the current trend of interferences, resolving or mitigate the coexistence issue between weather radars and WLAN/RLAN.
- *Technical 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 function mechanism could be quite complex to implement and/or it would require the implementation of complex processing algorithms.
- *Organizational complexity*. This metric of evaluation provides an indication on how complex is the proposed option to be implemented and relevant initiatives to trigger it. For example, the proposed option may require the set-up of new processes/ update of current radio framework (EC/ECC)/ improvement of RED framework (e.g. delegated act)/ ETSI (update of Harmonized Standards) or governance bodies for enforcement (improvement of national rules).
- *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 WLAN/RLAN equipment can be expensive and/or it would require additional costs for administrations.

- *Deployment cost*. This metric of evaluation provides a qualitative indication of the deployment costs to implement this solution.
- *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 WLAN/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 creates additional hazards or unplanned issues.
- *Time duration of execution.* This metric of evaluation assesses in a qualitative way the potential duration of the execution of the proposed option. A High value is negative because it would postpone the resolution of the coexistence issue.

The ratings are based on the following values:

- **Low**. The negative impact of the option is minimal or non-existent. For example, the creation of a database to record the location of p-to-p and p-to-mpt equipment can be low from the technical complexity point of view, because just a location in a database must be recorded.
- **Medium**. The negative impact of the option is significant but not so severe. For example, the installation of radio monitoring station co-located with a weather radar can be expensive but not so dramatically expensive like replacing the weather radar equipment.
- **High**. The negative impact of the option is quite severe. For example, the replacement or upgrade of the p-to-p and p-to-mpt equipment to use another frequency band can be quite expensive or it may take a long time to implement.
- **Very High** (this value is rarely used). The negative impact of the option is extremely severe. For example, the replacement or upgrade of all WLAN/RLAN equipment to use another frequency band can be extremely expensive or it may take a very long time to implement.

5.3 Detailed description of the options

This section describes more in detail the options identified in the second column of Table 1. Each option is described more in detail in the following subsections. In particular, each subsection elaborates on how the values for the metrics were defined and assigned.

In the summary and conclusions section of this report, the options will be summarized to indicate:

a) which options will be considered for a subsequent analysis or action phase and which ones will be discarded,

b) if the options can help to prevent interference (ex-ante measures) or help to identify and solve interference (ex-post measures).

c) Annex 3 shows the responsible entity that deals with the implementation of each option and if, in some cases it will be necessary the collaboration amongst entities.

Note: after the analysis has been performed some options have been discarded for future analysis and actions due to the reasons described in the related sub-section. Each of the discarded options is identified with the sentence:

This option is discarded for future actions on the base of the analysis and considerations below.

There are also cases where the option may not be applicable unless evidence is brought forward: for example in the case supposed out of band interference. Then, the option is set in status SUSPENDED until evidence is provided

5.3.1 Turn ECC Report 192, into a Recommendation

This option is derived from (CEPT ECC 2021). This option proposes to turn ECC report 192 into a recommendation with the objective to amplify the need to exercise rigorous and consistent enforcement in order to provide guidance to stakeholders (e.g., manufacturers, notified bodies and authorities) and to decrease the amount of interferences (e.g., rogue products or misuse of legitimate products as discussed in the rest of this report). ADCO RED should be involved for the part concerning market surveillance.

Responsible entity: ECC (recommendation) including collaboration between ADCO RED and ECC, member states (enforcement).

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** noting that neither ECC Report 192 nor a subsequent recommendation imposes regulatory obligations.
- *Technical Complexity*. Value=**Low.**
- *Organization Complexity*. Value=**Medium.** There may be the need to create additional processes or interfaces among organizational structures. Processes are fixed by ECC´s Rules of Procedure (RoP) and Working Methods (WM)s. The complexity lays in the work to practically develop the Recommendation based on the report.
- *Implementation Cost*. Value=**Low**. The option may only require the creation of new IT interfaces to exchange information or it may be not even the case.
- *Deployment cost*. Value=**Low**. Any deployment in terms of equipment is needed. The costs depend from the level of "readiness" of Member States to follow the Recommendations contained in a potential future ECC Recommendation.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. The identification of the non-compliant equipment may be still challenging to implement.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. No other issues are identified.
- *Time duration of execution.* Value=**Medium.** Set up of new processes and interfaces may require some time among all the European member states. The development of an ECC Recommendation requires a certain time, depending of the workload in ECC. The "execution" (= implementation) of the Recommendations in the Member States depends from their readiness to implement them.

5.3.2 Database for fixed outdoor p-to-p and p-to-mpt equipment

This option is derived from (CEPT ECC 2021). This option proposes the creation of a database for fixed outdoor p-to-p and p-to-mpt equipment where the WLAN/RLAN stations shall be registered. This registration shall provide geolocation of the stations, the SSID and MAC addresses of the equipment. This data base will be used by spectrum monitoring, interference monitoring/enforcement authorities and weather radars authorities to correlate a source of interference with the potential cause due to a

p-to-p and p-to-mpt equipment and will largely contribute to reduce the technical complexity to identify and locate the interference sources (including intermittent or transient interferences) (see document FM22 (19)02 Annex 2 (CEPT 2019)). We remind that it is relatively easy to pinpoint the azimuth of the source of interference from the radar output but the range is the problem since the search on the road is difficult due to the possible long range, urban areas with multiple outdoor WLAN/RLANs installed and reflections on buildings, WLAN/RLANs emitting only in an intermittent way and the low level of WLAN/RLAN signals (see (CEPT 2019)).

Responsible entity: EU Commission (review the sub class 1 framework) + Member states (implement the framework and data bases).

Notes:

- Currently, according to RED Subclasses of Class 1 (January 2020) – RED[7], WLAN/RLAN are Class 1 equipment. This means that they can be operated without any restriction in all member states. Implementing Registration obligation for outdoor WLAN/RLAN equipment is a national measure (authorisation framework).
- It is noted that monitoring and enforcement is a national issue. If a Member State feels it has a need to develop a database to register its RLANs it should be free to do so. Some experts participating to the elaboration of this report are the opinion that any obligation to develop databases or to feed into such, would put an inappropriate burden on MS authorities. In particular, noting the interference statistics with very diverging numbers in different countries as provided by CEPT. This should remain a national implementation. On the other side, EUMETNET noted that the negative effects of the radar interference are also a significant burden on the weather radar community and this should be taken in consideration.
- Finally, it is also to be noted that this measure could help to determine the source of an interference but would not impede it.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue.* Value=**Medium** because it does not avoid interferences. It would improve the knowledge of the position of registered p-to-p and p-to-mp equipment only and may herewith help the enforcement authorities to locate registered equipment. It will improve interference handling with an easier identification of the registered interferers and support the enforcement.
- *Technical Complexity*. Value=**Low**. The location, SSID and MAC address of the WLAN/RLAN equipment must be registered.
- O*rganization Complexity*. Value=**Medium**. EU legislation (update of subclass 1: to withdraw entry 54: RLAN 5 GHz from the list) should be firstly amended and then the national legislation should be also amended. National authorities shall manage the database, information is provided by users of the p-to-p and p-to-mpt equipment, what may require to set legal obligations first. Note that a national authority must be designated to manage the database.
- *Implementation Cost*. Value=**Medium**. The option requires the recording of the p-to-p and p-to-mp equipment and the creation of a database for consultation by various authorities (spectrum monitoring and enforcement).
- *Deployment cost*. Value=**Low/medium**. This option would require a change in the processing of interference monitoring and may be render more efficient by upgrading existing weather radar which can be quite expensive.

[7] See EG RE (05)04 - RED Subclasses of Class 1 (January 2020) – entry 54

- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way*. Value=**Medium**. This option would help to identify the source of interference, including intermittent interference, if it is p-to-p and p-to-mpt equipment but it is not helpful to identify and locate sources of interference due to other (i.e., consumer market) WLAN/RLAN equipment (see document FM 22(19) 02 annex 2, (CEPT 2019)).
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low/medium**. Such option may not be in line with current EU and national regulations (WLAN/RLAN are operated under a general licence regime). No other issues are identified. In case of non registered fixed outdoor p-to-p and p-to-mpt equipment (intentionally or not), the situation remains as it is today.
- *Time duration of execution*. Value= **Medium**. The implementation of a database and the prerequisite legal frame will require a lead time before the operational phase. The recording of the location of p-to-p and p-to-mp should not take considerable time.

5.3.3 Highlight the band 5350-5470 MHz as an alternative to 5600 - 5650 MHz

This option is derived from (CEPT ECC 2021). The option recommends to configure, replace or upgrade the existing C-band radars to use only the band 5350-5470 MHz to avoid problems of coexistence in the 5600 MHz-5650 MHz band with WLAN/RLAN equipment. This option should be applied only in a case by case basis, it means only specific and few radars could migrate in case of positive result of current ECC study. The implementation of this option will not solve the issue by itself, but it may provide accompanying possibilities to alleviate the situation for weather radars and hide the difficulties of individual CEPT administrations/EU Member States to deal effectively with spectrum sharing using advanced/software defined mitigation techniques for licence-exempt use. This might lead to some impact on incumbent services in the targeted band. There is a strong requirement for guidance on coordination/compatibility with incumbent services (other radars, Copernicus…) since new interference cases may appear.

Responsible entity: ECC (technical studies are ongoing at CEPT level) to confirm possible conditions for usage of weather radar in 5350-5470 MHz frequency band while coexisting with other services as Copernicus and follow up. Then, as suggested by EUMETNET, the decision to migrate the radar bands should remain on a case by case basis.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because most cases of interference are expected to disappear.
- *Technical Complexity*. Value=**Medium**. The upgrade of the C-band radars to avoid the use of 5600 MHz-5650 MHz band and use the 5350-5470 MHz frequency band should not be particularly complex also because there are already radars using the 5350-5470 MHz frequency band. However, it should be take into account that there is a need of technical assessments previous to the migration.
- *Organization Complexity*. Value=**Low**. This option does not require the creation of new organization processes and entities.
- *Implementation Cost*. Value=**Low/Medium**. The option only requires the implementation of weather radar in a different band and it may require specific hardware and software development.
- *Deployment cost*. Value=**Medium/High**. This option would require the upgrade of existing weather radars which can be quite expensive, depending on the radar type/brand. Funding mechanism may be required.

- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way*. Value=**Low**. The feedback from the stakeholders seem to indicate that most of the reported interference cases are related to the specific band 5600-5650 MHz band and remain unchanged .
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. The value is low if it is assumed that the use of other bands (apart from the frequency band 5600-5650 MHz) should be safe from interference.
- *Time duration of execution*. Value=**Medium**. The replacement of weather radar equipment may take a long time, however the migration will be limited, it means only certain radars will migrate.

5.3.4 Exclude the use of 5600 – 5650 MHz band by WLAN/RLAN equipment

This option is derived from (CEPT ECC 2021). As described in the previous subsections (e.g., section 4.1) most of the interference cases do happen in the 5600-5650 MHz band. Then this proposal is to modify the spectrum regulation to exclude the use of 5600-5650 MHz band by all WLAN/RLAN equipment. This restriction can be easily implemented in corresponding harmonised standard but prior requires an update of the current EC framework.

This option has the potential to remove all the cases of interference on the assumption that this are due to WLAN/RLAN equipment but it would have a high impact considering the huge amount of WLAN/RLAN equipment already deployed in the field.

Two options can be considered:

- 1 – to apply this only to the new WLAN/RLAN equipment placed on the market
- 2 – to also upgrade existing WLAN/RLAN equipment

Responsible entity: European Commission and ECC (it will require revision of EU and ECC Decisions) and follow up: MS to implement EC Decision, ETSI to update the WLAN/RLAN Harmonised standard in order to exclude 5600-5650 MHz from WLAN/RLAN operating band. The EU Decision should also forbid MS to authorise at national level the use of 5600-5650 MHz by WLAN/RLAN. Today, in most EU Decisions on frequency harmonisation, the EU Decision prescribes the minimum spectrum that MS should made available but MS are generally allowed to allocate more spectrum.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue.* Value=**Low** because of the side effects of the replacement costs, difficulty of enforcement and also the negative feedback to the European spectrum management strategy.
- *Technical Complexity*. Value=**Low.** This option excludes the use of 5600 – 5650 MHz band by WLAN/RLAN equipment but WLAN/RLAN equipment can use other frequency bands identified in the regulation.
- *Organization Complexity*. Value=**Low.** This option does not require the creation of new organization processes and entities.
- *Implementation Cost*. Value=**Low**. The option only requires the implementation of WLAN/RLAN equipment in a different band.
- *Deployment cost*. Value=**Low**/**High**. If only applied to new WLAN/RLAN (Option 1), then the cost will be low. If the upgrade of existing WLAN/RLAN is required (option 2), it can be quite

expensive. In fact, because of the large number of WLAN/RLAN devices already in use, the value could be exceptionally raised to **Very High**.

- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. It is not confirmed that all cases of interference are because of non-compliance of WLAN/RLAN equipment but the feedback from the stakeholders seems to indicate that most of the reported interference cases are related to this specific band (5600-5650 MHz band). If this is the case, this option may effectively remove most of the interference cases.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low/High**. The value is low if it is assumed that WLAN/RLAN will indeed be excluded from the 5600-5650 MHz. This will require a significant market surveillance activity over time. It may hence turn to high if the market surveillance is not efficient.
- *Time duration of execution.* Value=**High.** The replacement of WLAN/RLAN equipment may take a long time considering the large amount of devices already are in the market and in use and the update of the harmonised standard, so a considerable lead time would be needed. A value of **Very High** could also be recommended.

5.3.5 Remove the use of 5600-5650 MHz band by fixed outdoor p-to-p and p-to-mpt equipment

This option is derived from (CEPT ECC 2021). As described in the previous subsections (e.g., section 4.1) most of the interference cases do happen in the 5600-5650 MHz band and there have been suggestions that these cases of interferences can be due to outdoor p-to-p and p-to-mpt equipment (one potential reason could be the high directional beams). Nevertheless this should not lead to meteorological radar interference if DFS is not working. Then this proposal is to modify the spectrum regulation to exclude the use of 5600-5650 MHz band by fixed outdoor p-to-p and p-to-mpt equipment. This restriction requires an update of the current EC legislative framework.

Note: the use of 5600-5650 indoor by WLAN/RLAN equipment (apart from p-to-p and p-to-mpt) remains but the user should be informed about the restriction and have the possibility to disable those frequencies when used outdoor.

Responsible entity: Responsible entity: European Commission and ECC (it will require revision of EU and ECC Decisions). Note that a possible action to update the related Harmonized Standard (HS) should be further assessed after the revision of EU and EC Decisions but the national frequency tables may be updated if needed.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because this option is related only to a specific subcategory of the WLAN/RLAN equipment while the majority of the equipment will be unaffected.
- *Technical Complexity*. Value=**Low.** This option excludes the use of 5600 – 5650 MHz band by p-to-p and p-to-mp WLAN/RLAN equipment but this equipment can use other frequency bands identified in the regulation.
- *Organization Complexity*. Value=**Low.** This option does not require the creation of new organization processes and entities.
- *Implementation Cost*. Value=**High**. The option requires the update of the harmonised standard for WLAN/RLAN equipment regarding its use in a different band.

- *Deployment cost*. Value=**High**. This option would require the upgrade of existing p-to-p and p-to-mpt equipment which can be expensive.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**High**. It is not confirmed that all cases of interference are due to p-to-p and p-to-mpt equipment. Then this option would not remove other cases of interference due to other reasons, which is a disadvantage. On the other side, it should be considered that options can be combined to solve the overall issue. Furthermore, enforcement will be difficult to implement by market surveillance authorities: they have only the possibility to verify the user restrictions in this context – the possibility of placing this type of equipment on the market without preventing unauthorized use will remain (this could be simplified if the whole band would be excluded, but, as explained in the previous option 5.3.4, it might be difficult to set it up). Another point is that, without retroactive application of this rule, the current equipment placed on the market (stored until the final adoption of the regulatory act) could remain to be a potential problem of interference even if a recall from the users of non compliant products could solve this problem.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. Moving the use of the fixed outdoor p-to-p and p-to-mpt equipment to another band would not create other issues if the new spectrum band is chosen carefully.
- *Time duration of execution.* Value=**Medium.** Even if the number of p-to-p and p-mpt are not many like other WLAN/RLAN equipment instances, the time requested to replace the fixed outdoor p-to-p and p-mpt may require some lead time for the network providers. Additionally, it is needed to take into account the time to place on the market the new equipment compliant with the new regulatory framework or the need to perform a software update of existing equipment.

5.3.6 Collaboration between ECC, ADCO RED and EC by creating new processes or strengthening existing processes.

This option is derived from (CEPT ECC 2021). The objective is to improve the collaboration between ECC, ADCO RED and EC, through a focus on the weather radar interference issue from an organizational point of view to:

a) first mitigate the information unbalance between weather radar reporting, monitoring and member states reporting and

b) second to help to take relevant decisions toward solving the issue.

It seems that the information unbalance is one of the most serious issues for enforcement. Market surveillance and monitoring activities on 5 GHz WLAN/RLAN have significantly increased since the first publication of ECC Report 192 (2014). However, this has not stopped the continuous increase, taking CEPT as a whole, in the number of reported interference cases.

This collaboration could also include a check on the enforceability of rules before EC and/or ECC decisions would be adopted.

The proposal could include the creation of a forum, which meets periodically (e.g., twice a year) with a wider participation of all the involved stakeholders. It could identify/resolve potential issues in a more efficient way or at least raise their visibility of the main issues. There are already examples of successful forum initiatives in other domains (e.g., Tachograph forum). This option does not aim to replace existing experts' groups or organizations identifying concrete actions to be implemented to solve the issues.

Responsible entity: collaboration amongst European Commission, ADCO RED and ECC.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because the improvement of the processes can make the enforcement actions more efficient and mitigate the information unbalance.
- *Technical Complexity*. Value=**Low.** In reality, this depends by the new processes, which could be put in place. For example, the weather radar interference data from the weather radar community could be sent electronically to the national authorities in real time, rather than to prepare a specific report every time.
- *Organization Complexity*. Value=**Medium.** Since this option is mostly focused on the definition of new organizational processes, there may be changes in the relationships between the organizations. The value is medium because the set-up of such a forum would require the approval and the coordination among the main stakeholders' organizations in order to implement concrete actions.
- *Implementation Cost*. Value=**Low**. Potential deployment costs of an ICT infrastructure to support new processes are discussed in the next bullet.
- *Deployment cost*. Value=**Low**. In reality, this depends on the new processes, which could be put in place and they would require an ICT infrastructure to support them.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. Processes for a closer coordination among the involved stakeholders can help to improve the detection and resolution of cases of interference, but it may not resolve all of them.
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. This value is low because this option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders.
- *Time duration of execution.* Value=**Medium.** It actually depends on the type of new processes or changes to existing processes. The set-up of such a forum would require limited amount of time and resources as existing EC tools can be used.

5.3.7 Investigate other sources of interference beyond WLAN/RLAN

This option has the goal to identify other possible reason of interference beyond the WLAN/RLAN equipment. This could be amateur radios or other services coexisting in the frequency bands where weather radars can operate as defined in (ECC 2020a). It should also be ensured that once the problem with WLAN/RLAN is solved, there are not new cases of interferences due to that reason.

Note: some stakeholders suggested to remove this option because other interferences sources are considered out of scope of the report. On the other side, other stakeholders suggested to keep it because some reported interferences may not due to WLAN/RLAN. For this reason, this option is kept, but it is set to SUSPENDED status until it is not found evidence that other sources of interference exist apart from the one originating from WLAN/RLAN.

Responsible entity: member states of EU.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium**. The characteristics of the X band are different of C band and the weather radars will be less efficient.

- *Technical Complexity*. Value=**Medium.** The identification of other sources of interference can be quite difficult especially in the case of devices with no clear fixed location (e.g., amateur radios).
- *Organization Complexity*. Value=**Low.** This is a technical solution and the impact on the organization complexity is limited.
- *Implementation Cost*. Value=**Low** because radio monitoring systems are relatively cost effective.
- *Deployment cost*. Value=**N/A.** It depends on the type of interference.
- Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way. Value=**High**. The investigation may conclude that there are no other sources of interference
- Potential Risk of the proposed approach to generate other not planned issues. Value=**Low**. The value is low since it is just an investigation.
- *Time duration of execution.* Value=**Medium.** The investigation on the other potential sources of interference may take considerable time.

5.3.8 Replace C-band radars with X-band radars

This option is discarded for future actions on the base of the analysis and considerations below.

This option proposes to replace (partially or totally) the C-band radars with a network of X-band weather radars. This would remove the problem of interference and it is somewhat equivalent to move to another frequency band (see also 5.3.3) 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. In addition, the cost and complexity of replacement of C-band radars with X-band radars, can be significant because a C-band radar may need to be replaced by between 10 and 20 X-band radars due to their (i.e., X-band radar) limited coverage/range compared to C-band radars. The issue of finding relevant locations to implement these X-band radars will also be a complicating factor.

Responsible entity: EUMETNET

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because the implementation of this option would be considered too expensive.
- *Technical Complexity*. Value=**Low/Medium.** X-band radars already exist, but managing so many radars in a single network has never been done and it will hence represent a serious challenge.
- *Organization Complexity*. Value=**High** because, in addition to launch the procurement of new equipment (X-band weather radars) to replace the existing C-band weather radars, it will require to find relevant locations to implement so many radars, with all required authorisations, building new towers, providing energy and connections and so on.
- *Implementation Cost*. Value=**Low/medium.** X-band radars already exist but managing such a high number of radars will require additional work to duly integrate their different data and it will hence represent a serious challenge.

- *Deployment cost*. Value= **High** because C-band radars must be replaced with X-band radars in a much larger number (10-20 times more). The cost can even be very high since it will also require to build new towers, building new towers, providing energy and connections.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. Basically, this option is equivalent to move the C-band radar operation to another band with the advantage that X-band radars do already exist.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**High**. The performance of the X-band radars is different from C-band radars and the removal of C-band radars could have the effect of removing the access to important information by the meteorological community. In addition, considering the high number of radars to be deployed, it is far from being guaranteed that the necessary radio frequencies will be available to deploy all radars without creating interference to other weather radars in the network, but also other X-band radars (civil aviation, maritime, military, coast guards, ...).
- *Time duration of execution.* Value=**High** because it will take considerable time to replace the C-band radars with X-band radars.

5.3.9 Improve radio localization of sources of interference by meteorological service

This option proposes the installation on the weather radar site of RF monitoring and radio location systems to estimate the range at which WLAN/RLAN equipment (which is creating interference) is located. 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. This should also help to determine the source of the interferences (especially short time interferences) based on the footprint of the detected interference.

Responsible entity: EUMETNET. Meteorological organisations.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because it would help a more efficient localization of the source of interference.
- *Technical Complexity*. Value=**Low/Medium.** RF monitoring systems are not difficult to implement especially in this frequency range. However, coexistence with the radar transmitted signals is to be addressed.
- *Organization Complexity*. Value=**Low.** This is a technical solution and the impact on the organization complexity is limited.
- *Implementation Cost*. Value=**Low** because RF monitoring systems are relatively cost effective.
- *Deployment cost*. Value= Value=**Medium** because every weather radar station must be equipped with a RF monitoring system.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. This solution could be quite effective in locating the source of interference both for transient and permanent sources of interference and it can address both compliant and non-compliant WLAN/RLAN equipment. On the other side, it is noted that the identification of WLAN/RLAN MAC address will be missing.

- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Medium**. Impacts on meteorological radars operations still need to be studied since these monitoring systems may only work when radars are not transmitting.
- *Time duration of execution.* Value=**Medium.** The value is medium because new technical specifications must be put in place for the RF monitoring stations and then RF monitoring systems must be implemented and deployed for every weather radar.

5.3.10 Install interference monitoring stations

This option is discarded for future actions on the base of the analysis and considerations below.

This option is similar to the option described in 5.3.9 but with the difference that the interference monitoring stations to locate the source of interference do not need to be placed in correspondence to the weather radar stations but they can be placed in other sites.

Note: It was remarked that this option is not really feasible in this frequency range. There should be hundreds of thousands of stations and meteorological radars and they should have a sensitivity not possible for monitoring equipment. It is highly recommended to support only option 5.3.9. On the other side, other stakeholders would like to keep it.

Responsible entity: member states of EU.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** due to the practical difficulty on deploying so many monitoring stations.
- *Technical Complexity.* Value=**Low**. Implementation of RF monitoring systems are not difficult to implement especially in this frequency range is not suitable for a fixed monitoring stations. The low level of WLAN/RLAN emissions and the density of RLANs may impact negatively the implementation of this option.
- *Organization Complexity*. Value=**Low.** This is a technical solution and the impact on the organization complexity is limited.
- *Implementation Cost*. Value=**Low** since RF monitoring systems are relatively cost effective. This option targets the deployment only of cost effective monitoring stations (up to 1000 Euro), not high range monitoring stations which could cost in the range of 100,000 Euro.
- *Deployment cost*. Value=**Medium/High** because a network of RF monitoring stations must be implemented, which can be expensive to make. The cost can be high depending on the density, precision and features required for the radio monitoring systems.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. In comparison to the option of installing RF location systems in the weather radar stations, this option may generate different data (e.g., other sources of RF emission power), which may not point exactly to the source of interference.
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. As a monitoring system, there are no foreseen negative impacts.
- *Time duration of execution.* Value=**Medium.** The value is medium because new technical specifications must be put in place for the RF monitoring stations and then RF monitoring systems must be implemented and deployed.

5.3.11 Creation of a geo-location database to record the position of the weather radars

This option proposes the creation of a geo-location database to record the position of the weather radars. This information can be provided either to WLAN/RLAN equipment to better calibrate the DFS or to create exclusion zones where WLAN/RLAN equipment should not be placed. In the first case, the implementation would be quite complicated because the list must be maintained and downloaded to the WLAN/RLAN equipment. In the second case, the implementation is relatively simple because it is only done at the installation time of the WLAN/RLAN equipment. Implementation of new features in the WLAN/RLAN equipment is required. These implementations are made through the harmonised standard (HS).

Note: this solution requires a EU Decision that add this requirement to the EU Decision on the use of this frequency band so to oblige the implementation in the equipment. The use of a HS is not mandatory. Fulfilling the essential requirements is mandatory. A manufacturer may implement other solutions.

Responsible entity: EU Commission (review the framework) + Member states (implement the framework). EUMETNET (only for the database), WLAN/RLAN vendors + ETSI and installers.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** for a number of reasons including the technical difficulty to maintain the list and location of the weather radars and because this solution is considered to have the same potential to solve or not to solve the issue as the current DFS-based identification of radar locations. In addition, the drawback of changing the DFS-based system to a weather radar database system is: 1) this would require to start the whole standardisation process anew and 2) legacy devices would still be in the market for a long time, which would not exploit the database of the weather radars.
- *Technical Complexity*. Value=**Low/Medium.** The collection of the geographical information of the weather radars is relatively easy to implement to create exclusion zones for the placement of WLAN/RLAN equipment. The implementation of new functions in the WLAN/RLAN equipment to take advantage of this information may be more challenging and Value=**Medium**.
- *Organization Complexity*. Value=**Medium.** This is a technical solution and the impact on the organization complexity is limited.
- *Implementation Cost*. Value=**Low/Medium.** It is Low for the implementation of an exclusion zone, while it is Value=Medium for the implementation of new functions in the WLAN/RLAN equipment to take advantage of the geo-location database information.
- *Deployment cost*. Value=**Medium.** New software versions of equipment should be deployed in the field for the implementation of new functions in the WLAN/RLAN equipment to take advantage of the geo-location database information.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**High**. This solution will not address cases of non-compliance or misuse of the WLAN/RLAN equipment.
- Potential Risk of the proposed approach to generate other not planned issues. Value=**Low**. There are no foreseen negative impacts.
- *Time duration of execution.* Value=**Low**/**Medium/High***.* The value is medium to high because new technical specifications must be put in place (in particular new versions of ETSI standard) and new software or equipment must be deployed for the implementation of new functions in the WLAN/RLAN equipment to take advantage of the geo-location database information. It is Value=Low for the use of the geo-location database for exclusion zones.

5.3.12 Network of WLAN/RLAN nodes to mitigate hidden node problem

This option is discarded for future actions on the base of the analysis and considerations below.

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 WLAN/RLAN nodes which exchange messages on the results of the DFS execution.

The exchange of the information among the WLAN/RLAN devices is something completely new, which would have an impact on the DFS implementation and the deployment of WLAN/RLAN.

In this configuration, a specific report from the cases registered need to be produced. Indeed, since the version 1.8.1 of the standard EN 301 893, the use and the rules for WLAN/RLAN used as slaves have been more precisely defined. So if the current interference cases show that these cases exist on equipment placed on the market under this version, the cases need to be deeply studied to consider a possible modification of the standard in consequence.

Note: some stakeholders proposed to delete this option because considered not relevant.

Responsible entity: MS, WLAN/RLAN installers, providers and vendors.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because it was concluded that the hidden node problem may be responsible for no or very limited cases of interference.
- *Technical Complexity*. (a) Value=**Low.** The technical specifications for a network of WLAN/RLAN (e.g., master stations) may not be difficult to implement as such specifications could be derived from standard ETSI EN 301 893.
- *Organization Complexity*. Value=**Low.** This is a technical solution and the impact on the organization complexity is limited.
- *Implementation Cost*. (a) Value=**Medium.** The replacement of WLAN/RLAN equipment can be significant even if it may be limited to the master devices only.
- *Deployment cost*. (a) Value=**Medium.** New software versions of equipment should be deployed in the field.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. This solution will not address cases of non-compliance or misuse of the WLAN/RLAN equipment.
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. As a monitoring system, there are no foreseen negative impacts.
- *Time duration of execution.* (a) Value=**Medium.** The value is medium because new technical specifications must be put in place and new software or equipment must be deployed.

5.3.13 Monitoring systems of WLAN/RLAN equipment configuration and status

This option proposes the creation of a monitoring system to ensure that the WLAN/RLAN devices (e.g., WiFi APs) are conformant to the technical specifications: software version, DFS enabled and national settings. This would require the creation of monitoring applications in each MS, which are connected to the WLAN/RLAN in the national area. The number of WLAN/RLAN nodes to monitor could be limited only to the one in the vicinity of weather radar stations. The effort to create some application and

manage it may be considerable. In addition, it can be argued that it may not be legal for a national authority to gain access to a WLAN/RLAN as it may also generate privacy risks.

Note: some stakeholders proposed to delete this option because considered not relevant. The creation of such a monitoring system can be complex to activate and manage. The investment to implement this option could be disproportionate. It also goes in a direction opposite to main trends in monitoring.

Responsible entity: member states, WLAN/RLAN installers, providers and vendors.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because it may report on cases of interference only after the interference happened.
- *Technical Complexity*. (a) Value=**Low.** A monitoring application to collect data from WLAN/RLAN equipment is not technically challenging. Telecom providers have already similar monitoring applications for FCAPS (Fault, Configuration, Accounting, Performance, Security). In fact, the national authority could lean on telecoms providers to provide such data.
- *Organization Complexity*. Value=**High.** The set-up of such a monitoring application may face difficult (if not impossible) legal hurdles to give access to the national authorities to the WLAN/RLAN equipment.
- *Implementation Cost*. (a) Value=**Low.** A monitoring application is not expensive to implement as telecommunication providers have already similar functions. In addition, the retrieval of data would be limited to the DFS function, software versions and so on.
- *Deployment cost*. (a) Value=**Medium.** It has to be investigated if the collection of the needed data would require modifications in the software of already used WLAN/RLAN equipment.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. This solution may be useful to monitor the status of field compliance of WLAN/RLAN equipment, but it may not address other sources of interference.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Medium**. Access to WLAN/RLAN equipment through a fixed communication channel may face legal hurdles including privacy risks, which may create a regulatory backlash.
- *Time duration of execution.* (a) Value=**Medium.** The value is medium because the implementation of a monitoring application may be easy to achieve (also in collaboration with telecom providers) but the legal hurdles can be significant and they may require time to be resolved.

5.3.14 Research new interference cancellation schemes in weather radars

This option is discarded for future actions on the base of the analysis and considerations below.

There has been considerable effort in interference cancellation systems in radar (both hardware and software) but with variable success. The problem is that interference cancellation techniques may degrade the performance of the radar function leading to quite a large loss of data. This may be a solution for limited amount of interference but it cannot work for large disruptions as we have on many radars.

This option investigates the application of interference cancellation techniques for in-band interference (the out-of-band or adjacent interference is investigated in 5.3.15).

Note: some stakeholders proposed to delete this option because considered not relevant.

Responsible entity: EUMETNET, weather radar manufacturers.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because there has been already a considerable amount of effort to implement interference mitigation techniques.
- *Technical Complexity*. (a) Value=**Medium.** New technical specifications must be defined.
- *Organization Complexity*. Value=**Low** as this is technical option and no new processes must be defined.
- *Implementation Cost*. (a) Value=**Medium.** Addition of new interference cancellation techniques may be expensive.
- *Deployment cost*. (a) Value=**High.** Addition of new interference cancellation techniques may be expensive for the already deployed equipment.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. If the new interference techniques are well designed, they may limit the majority of interference cases even due to non-compliant WLAN/RLAN equipment.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**High**. It has been reported at the meetings (e.g., section 4.1) that interference cancellation techniques may decrease the performance of the weather radar to perform their primary function.
- *Time duration of execution.* (a) Value=**Medium.** Addition of new interference cancellation techniques may take a long time to define the technical specifications, implement them in the equipment and deploy the new equipment or update existing equipment. On the other side, there is an extensive scientifically and technical literature on interference cancellation techniques, which can be consulted.

5.3.15 Mitigate adjacent band interference

Some authors (Naik 2018),(Blanck 2013) of weather radar coexistence studies with WLAN/RLAN reported the possibility that adjacent interference may also be the cause of interference even in DFS compliant WLAN/RLAN equipment. This may be due to non-optimal transmission filters in the WLAN/RLAN equipment or non-optimal receiver filters in the weather radar. This may be an aspect of non-compliance against the existing technical specifications or the need to improve the technical specifications. Then, an investigation should be conducted to evaluate this potential interference threat. The metrics of evaluation are defined on both cases that: a) the worst outcome that technical specifications must be updated and equipment must be updated and b) that only a few manufacturers models must be equipped with adequate filters.

Note: some stakeholders proposed to delete this option because considered not relevant. Most of the cases investigated by spectrum control authorities are caused by in-band emissions generated by RLAN devices. This option is kept, but it is set to SUSPENDED status until it is not found evidence that other sources of interference exist apart from WLAN/RLAN.

Responsible entity: EUMETNET, Weather radar manufacturers.

The values of the metrics have been assigned on the basis of the following considerations for both cases (a) and (b):

- *Positive impact to the resolution of the issue*. Value=**Low** because even if cases of adjacent band interference are identified, the majority of issues of coexistence will remain.

- *Technical Complexity*. Value=**Low/Medium**. (a) Value=Medium**.** New technical specifications/radar must be defined to remove the risk of adjacent interference, (b) Value=Low**.** Only the non-compliant models must be updated and the deployed devices of the non-compliant model should be recalled.
- *Organization Complexity*. Value=**Low** both for use cases (a) and (b).
- *Implementation Cost*. (a) Value=**Low/Medium**. For option (a), value=Medium because the addition of new filters may be expensive but it can be less expensive than other options where new sophisticated algorithms or communication channels must be implemented in the equipment. For option (b) the value=Low if it is assumed that only a limited number of models are non-compliant from this point of view.
- *Deployment cost*. Value=**Low/Medium**. For option (a), value=High. Addition of new filters may be expensive for the already deployed equipment. For option (b). value=Low if it is assumed that only a limited number of models are non-compliant from this point of view.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. The perception of the stakeholders is that this specific cause of interference may be only responsible for a limited number of interference cases. Then, all the cases of in-band interference will not be resolved with this option.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this action will generate very limited or non-existent new issues. The only risk is that the addition of filters in the equipment may decrease the performance of the devices to implement their functions (e.g., decreased capability to report weather conditions).
- *Time duration of execution.* Value=**Low/High.** For option (a), the value=High because the addition of new filters may take a long time to define the technical specifications, implement them in the equipment and deploy the new equipment or update existing equipment. For option (b) the value is low if it is assumed that only a limited number of models are non-compliant from this point of view. In this case, technical specifications do not need to be defined.

5.3.16 Issue a recall of DFS non-compliant products

This option is not technical but it is an enforcement option where based on a risk assessment, DFS non-compliant products would be recalled from the market.

Responsible entity: Member states.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because it could be an effective tool to remove interfering WLAN/RLAN equipment.
- *Technical Complexity*. Value=**Low.** The value low is assigned because no or limited technical changes are needed.
- *Organization Complexity*. Value=**Medium**. One difficulty is the collection and definition of the evidence for the recall action to avoid recourses by the vendors.
- *Implementation Cost*. Value=**Low.** This value is low because there is no or limited implementation effort in the production of new equipment.
- *Deployment cost*. Value=**Low**. This value is low because the recall has to be done by the manufacturer.

- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. This value is medium because problems of interference due to misuse of equipment or other reasons outside compliance (e.g., hidden node problem) may not be resolved.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this action will generate very limited or non-existent new issues.
- *Time duration of execution.* Value=**Low**. This value is low because the harmonization of the recall actions should not take a large amount of time.

5.3.17 Increase the fines for non-compliant manufacturers

This option is an enforcement option where fines for non-compliant manufacturers are harmonized across Europe and they are made significant (e.g., percentage of the manufacturer revenue in Europe for the non-compliant model). It is noted that this option would require changes of the legal basis in some Member States and has to be proportionate. However, the positive impact will grow up within the time.

Responsible entity: European Commission (Recommendation), member states (MS)

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because it may take time to implement while interference cases may be still present.
- *Technical Complexity*. Value=**Low**. No or limited technical changes are needed.
- *Organization Complexity*. Value=**Medium**. The harmonization of the fines across EU and the exchange of information among member states will require some effort.
- *Implementation Cost*. Value=**Low**. There is no or limited implementation effort in the production of new equipment.
- *Deployment cost*. Value=**Medium**. The generation of the fines has to be based on evidence collected through monitoring systems, which will require some effort to deploy.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way*. Value=**Medium**. Problems of interference due to misuse of equipment or other reasons outside compliance may not be resolved. Publicizing the WLAN/RLANs that have been found non-compliant should also be of interest but such publication should be able only at the end of legal non-compliance procedure. No publication of a non-compliant equipment can be done during the contradictory process and the judiciary process if one is engaged. Only if the manufacturer/ distributor does not process to a corrective action that is agreed by the administration, it is possible to raise a sanction and publicize the case. (see document FM22 (19)02 Annex 2 (CEPT 2019)).
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. This action will generate very limited or non-existent new issues.
- *Time duration of execution*. Value=**Medium**. This value is medium because the negotiation of the measure amongst member states to harmonize the fines and their increase could take a long time.

5.3.18 Increase the fines for non-compliant users (equipment misuse)

This option is not technical but it is an enforcement option where sanctions (administrative fine, penal sanction, seizing of the equipment, etc) for users of a WLAN/RLAN causing an interference to a weather radar are of a significant level, they are harmonized across EU and/or they are increased significantly to the current state of art. Furthermore, sanctions should be applicable for any case of interference caused by an WLAN/RLAN without the need to determine precisely what is not compliant in the WLAN/RLAN, including cases of tampering the WLAN/RLAN.

Responsible entity: European Commission (Recommendation), MS.

It is noted that this option would require changes of the legal basis in some MS.

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Low** because it may take time to implement while interference cases may be still present.
- *Technical Complexity*. Value=**Low.** No or limited technical changes are needed.
- *Organization Complexity*. Value=**Medium**. The harmonization of the fines and sanctions across EU and the exchange of information among member states will require some effort and is generally edcited in a national legislation.
- *Implementation Cost*. Value=**Low.** There is no or limited implementation effort in the production of new equipment.
- *Deployment cost*. Value=**Medium**. The generation of the fines has to be based on evidence collected through monitoring systems, which will require some effort to deploy.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. Applicable and applied sanctions will work as a preventive means encouraging end users to require their suppliers or installers to be serious on the conformity of the WLAN/RLAN installed, especially if resolved interference cases with applied sanctions can be publicized. The sanctioned end user will go back to its supplier or installer who will themselves go back to the distributor. This will lead to a virtuous circle.
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. This action will generate very limited or non-existent new issues.
- *Time duration of execution.* Value=**Medium**. The negotiation of measure amongst member states to harmonize of the fines and their increase should not take long.

5.3.19 Implement a cooperative communication channel between radar and WLAN/RLAN equipment manufacturers

This option is discarded for future actions on the base of the analysis and considerations below.

This is a technical option where it is envisaged to define a standard for the communication of information between radar systems and WLAN/RLAN equipment to implement cooperative spectrum sharing functions. In cooperative spectrum sharing, the nodes participating to the sharing of the RF frequency spectrum periodically exchange information to coordinate the access to the spectrum (see an example for a proposal for radar and cellular networks in (Martone 2019) or (Guerci 2015)). The rules of usage of the spectrum are defined in the radio frequency spectrum regulations but the implementation of the 'etiquette' for spectrum sharing would require the definition of specific algorithms described in the standards and implemented both in the radar and the WLAN/RLAN

equipment. An example of such implementation would be a communication protocol between radar and WLAN/RLAN devices which would provide their own physical location, transmission parameters (e.g., emission power, modulation scheme, duty cycle), characteristics of the antennas and so on. This would be a stronger cooperation mechanism than the DFS function since the WLAN/RLAN and radar equipment will receive a more detailed set of information and my means which are more robust against wireless propagation effects (e.g., attenuation multipath).

Note: It is noted that some member states expressed strong doubts on the practicality of such a mitigation tecnique since it is only described/implemented in the research domain at this stage. At this moment only DFS is identified as a mitigation technique in terms of regulatory framework.

Responsible entity: WLAN/RLAN vendors, radar vendors, standardization bodies.

The values of the metrics have been assigned on the basis of the following considerations:

- Positive impact to the resolution of the issue. Value=**Low.**
- *Technical Complexity*. Value=**High.** Protocols for cooperative exchange of information between participants to spectrum sharing have been proposed in research literature but a practical implementation would require the definition of technical specifications (e.g., harmonized standards) and implementations both in the WLAN/RLAN and weather radar systems.
- *Organization Complexity*. Value=**Medium**. The effort is mostly related to the definition of technical specifications in standardization bodies.
- *Implementation Cost*. Value=**Medium/High.** The cost would be high because it would require the WLAN/RLAN equipment and weather radar equipment to implement an additional communication protocol, theoretically able to cover the large distances related to weather radar coverage areas. Alternatives with value= Medium would be to equip only the master WLAN/RLAN equipment or to use the fixed communication link and an application designed to transfer the information among weather radars and WLAN/RLAN equipment.
- *Deployment cost*. Value=**Medium/High**. The deployment costs are high because new equipment must be deployed in the field. The alternative where a fixed link is used can be value=medium because a back end application can be deployed.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Medium**. The proposed approach would be able to considerably mitigate the case of interference, because WLAN/RLAN equipment and weather radar would be able to exchange information and avoid cases of interferences. There is still the problem of WLAN/RLAN equipment where this communication protocol is disabled (non-compliant WLAN/RLAN or weather radar equipment). The possibility of network outages must also be considered for the fixed network solution.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders for the drafting of the technical specifications.
- *Time duration of execution.* Value=**High**. The definition of the technical specifications, implementation of the communication protocol, standardisation process in the equipment (both WLAN/RLAN and weather radar) may take considerable time.

5.3.20 Registration of the Technical Construction File for outdoor WLAN/RLAN

This is an option related to activation of Article 5 of the RE Directive 2014/53/EU (Registration of radio equipment types within some categories). The aim of this option is to mandate WLAN/RLAN of type

outdoor taking into account that this kind of radio equipment is affected by low levels of compliance with the essential requirements set out in Article 3 of RE Directive (see ADCO 2018 results of market surveillance campaign). This registration shall be made before this kind of equipment is placed on the market. The registration process could be made through a database managed by an entity defined taking into account what is stated in the RE Directive. The procedure for the activation of Article 5 of RE Directive is set out by the same Directive. This measure leads to persuade WLAN/RLAN manufacturers to place in the market only compliant equipment.

It should be noted that an activation of Article 5 requires a low level of compliance. The proportionality of a potential activation should be carefully analysed. The registration would mostly concern compliant equipment. Therefore, it seems disproportionate to penalise compliant equipment in an undue manner.

Responsible entity: EC (delegated act + EC Decision)

The values of the metrics have been assigned on the basis of the following considerations:

- Positive impact to the resolution of the issue. Value=**Low.**
- *Technical Complexity*. Value=**Medium.** Any technical development in terms of equipment is needed. An EU database should be implemented and it should be able to deliver the registration information.
- *Organization Complexity*. Value=**Medium**. Collaboration amongst European Commission and member states is necessary to put in place this measure.
- *Implementation Cost*. Value=**Medium.** Investment on resources to implement the database are needed.
- *Deployment cost*. Value=**Low**. There is no need to deploy new equipment.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. This option leads to persuade manufacturers to place in the market, compliant equipment which is considered one of the main causes of interferences caused by WLAN/RLAN.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this option will generate very limited or non-existent new issues.
- *Time duration of execution.* Value=**High**. This value is high because the procedure to activate the Article 5 of RED could take long time.

5.3.21 Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of activity ratio higher than 30 % on DFS efficiency

This is a technical option where it is envisaged to carry out a series of tests on different WLAN/RLAN equipment to verify the assessement foreseen in clause 5.3.1.2 'Test transmission sequences for DFS tests' (verifying the transmitter minimum activity ratio of 30 %) of the standard EN 301 893. This option will determine if the DFS functionality is inefficient when the load rate exceeds 30%. Several authorities have already observed issues with that phenomenon pointing out that several manufacturers only adjust their equipment to this value of 30%. Several interferences could come from the inefficiency of the DFS following this problem. Based on the results obtained from the tests carried out, it will be necessary to identify the possible improvements and modifications of the harmonised standard in consequence.

Responsible entity: EC DG JRC (based on results to assess the need for improvement of WLAN/RLAN Harmonized Standard).

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue.* Value=**Medium** because it can enhance the understanding on potential issues in the technical implementation of the coexistence mechanism.
- *Technical Complexity*. Value=**Medium.** It is necessary to collect several reference equipment in order to have the most representative possible result. The various tests carried out must take into account different load rates (> 30%: 50%, 70%; 90%) making it possible to verify the bad behavior of the DFS system.
- *Organization* Complexity. Value=**Medium.** The implementation of this technical option requires a laboratory allowing such a series of tests and foresee a possible need to modify the standard.
- *Implementation* Cost. (a) Value=**Medium.** The set up of this option is not expensive to implement if the equipment is provided by stakeholders. Nevertheless, it will be difficult for these latters to provide the equipment.
- *Deployment* cost. (a) Value=**Medium.** An update of the WLAN/RLAN equipment will be necessary. This is generally done by software.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. This solution may be useful to identify a problem of functionality with the DFS system. This option could solve a portion of the interferences cases, especially in relation to the new equipment placed on the market.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders to define the necessary technical specifications in the standard.
- *Time duration of execution.* (a) Value=**Medium.** The time duration of execution is medium because it needs to take the time to perform the tests and implement the adapted modification of the standard.

5.3.22 Specific study to be carried out on WLAN/RLAN issues: Set up of the combination of the transmitter's power + antenna gain shall not exceed the allowed power limits for RLAN

This is a technical option where it is envisaged to carry out a series of tests on different WLAN/RLAN equipment to verify that the allowed power limits for a WLAN/RLAN cannot be exceeded. When the device allows the possibility to configure the antenna gain and the WLAN/RLAN power, the antenna gain shall only be modifiable with respect to the authorised power allowed by the WLAN/RLAN equipment. Several authorities have already observed issues with the possibility/facility offered by the manufacturer to the user to exceed these limits. This option will not solve directly the interference cases but the presence of strong emission power is often mentioned during the investigations. This issue exacerbates the work done by spectrum control authorities as the radius of investigation to find the origin of the interference is strongly widened. Based on the results obtained from the tests carried out, it will be necessary to identify the possible improvements and modifications of the harmonised standard in consequence.

Responsible entity: EC DG JRC (based on results to assess the need for improvement of WLAN/RLAN Harmonized Standard)

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue.* Value=**Medium** because it can enhance the understanding on potential issues in the technical implementation of the coexistence mechanism.
- *Technical Complexity.* Value=**Medium**. It is necessary to collect several reference equipment devices in order to have the most representative possible result. The various tests carried out must take into account the different possible combination gains.
- *Organization Complexity*. Value=**Medium**. The implementation of this technical option requires a laboratory allowing such a series of tests and foresees a possible need to modify the standard.
- *Implementation Cost.* Value=**Medium**. The set up of this option is not expensive to implement if the equipement is provided by stakeholders. Nevertheless, it will be difficult for these latters to provide the equipment.
- *Deployment cost.* Value=**Medium**. An update of the WLAN/RLAN equipment will be necessary. This is generally done by software.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value= **Medium**. This solution may be useful to identify the problem of the power limit exceeded and reduce the search area for spectrum control authorities and reduce the number of interference cases but not solve all the interference.
- *Potential Risk of the proposed approach to generate other not planned issues*. Value=**Low**. This value is low because this option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders to define the necessary technical specifications in the standard.
- *Time duration of execution*. Value=**Medium**. The time duration of execution is medium because it needs to take the time to perform the tests and realise the adapted modification of the harmonized standard.

5.3.23 Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of WLAN/RLAN installation position (vertical/ horizontal)

This is a technical option where it is envisaged to carry out a series of tests on different WLAN/RLAN equipment devices to verify the impact of WLAN/RLAN installation position (vertical / horizontal) on the DFS efficiency. This option will determine the capacity of the WLAN/RLAN to detect the radar signature and the impact of the installation position on the DFS implementation. Some authorities have been informed by manufacturers that this position had an influence on the accuracy of the execution of DFS. Based on the results obtained from the tests carried out, it will be necessary to identify the possible improvements and modifications of the harmonised standard in consequence.

Responsable entity: EC DG JRC (based on results to assess the need for improvement of WLAN/RLAN Harmonized Standard)

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because it can enhance the understanding on potential issues in the technical implementation of the coexistence mechanism.
- *Technical Complexity*. Value=**Medium.** it is necessary to collect several reference equipment devices in order to have the most representative possible results. The various tests carried out must take into account different positions of installation of the WLAN/RLAN equipment to verify the behavior of the DFS system.

- *Organization Complexity*. Value=**Medium.** the implementation of this technical option requires a laboratory allowing such a series of tests and to foresee a possible need to modify the standard.
- *Implementation Cost*. Value=**Medium.** The set up of this option is not expensive to implement if the equipment is provided by stakeholders. Nevertheless, it will be difficult for the manifacturers/vendors to provide the equipment.
- *Deployment cost*. Value=**Medium.** An update of the WLAN/RLAN equipment will be necessary.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. This solution may be useful to identify a problem of functionality with the DFS system. This option could solve a part of the interferences cases.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders to define the necessary technical specifications in the harmonized standard.
- *Time duration of execution.* Value=**Medium**. The time duration of execution is medium because it needs to take the time to perform the tests and realise the adapted modification of the standard.

5.3.24 Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of the Application of clause 4.2.6.2.1 of standard ETSI EN 301 893

This is a technical option where it is envisaged to carry out a series of tests on different WLAN/RLAN equipment to verify the applicability procedure foreseen in clause 4.2.6.2.1 ('Applicability') and defined by the sentence: '*The radar detection requirements specified in clause 4.2.6.2.2 to clause 4.2.6.2.4 assume that the centre frequencies of the radar signals fall within the central 80 % of the Occupied Channel Bandwidth of the WLAN/RLAN (see clause 4.2.2).*'. This option will determine the DFS implementation when the figure of 80% is well achieved and to determine if the value of 80% is appropriate and especially that there is no impact on the radar when the latter's signals are lower than this 80% floor value. Based on the results obtained from the tests carried out, it will be necessary to identify the possible improvements and modifications of the standard in consequence.

Responsable entity: EC DG JRC (based on results to assess the need for improvement of WLAN/RLAN Harmonized Standard)

The values of the metrics have been assigned on the basis of the following considerations:

- *Positive impact to the resolution of the issue*. Value=**Medium** because it can enhance the understanding on potential issues in the technical implementation of the coexistence mechanism.
- *Technical Complexity*. Value=**Medium.** It is necessary to collect several reference equipment devices in order to have the most representative possible results. The various tests carried out must take into account the detection of radar signatures with radar signals falling within different percentages of central Occupied Channel Bandwidth of the RLAN.
- *Organization Complexity*. Value=**Medium.** the implementation of this technical option requires a laboratory allowing such a series of tests and foresee a possible need to modify the harmonized standard.
- *Implementation Cost*. Value=**Medium.** The set up of this option is not expensive to implement if the equipment is provided by stakeholders. Nevertheless, it will be difficult for the vendors to provide the equipment.

- *Deployment cost*. Value=**Medium.** An update of the WLAN/RLAN equipment will be necessary. This is generally done by software.
- *Potential Risk of the proposed approach to not be able to mitigate the issue in a definitive way.* Value=**Low**. This solution may be useful to identify a problem with the implementation of the DFS function. This option could solve a part of sporadic/transient interferences.
- *Potential Risk of the proposed approach to generate other not planned issues.* Value=**Low**. This value is low because this option will generate very limited or non-existent new issues apart from taking additional time from the involved stakeholders to define the necessary technical specifications in the standard.
- *Time duration of execution.* Value=**Medium**. The time duration of execution is medium because it needs to take the time to perform the tests and realise the adapted modification of the standard.

5.4 Summary Table of the options

Table 1 summarizes the evaluation of the options listed in the previous subsections 5.3.X.

Note: even if all the possible options suggested by different sources have been presented for completeness, some options have been suggested by stakeholders to be not/applicable or not relevant. They are the options flagged in the previous subsections as DISCARDED or SUSPENDED. Instead of removing them from the list and section 5, they have been kept because their relevance or applicability may change in the future. These specific options are highlighted with a RED number in the first column of the option identifier.

Table 1 Qualitative assessment of the proposed options

Option identifier (red identifiers are options indicated by stakeholders as not relevant or applicable now)	Description of the option (please relevant section 5.3.x for details)	Advantage of this option	Disadvantage of this option	Source	Responsible Entity	Positive impact to the resolution of the issue.		Technical 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 has not stopped the continuous increase, taking CEPT as a whole, in the number of reported interference cases.	(FM 2021)	Collaboration between ADCO RED and ECC	Low	Low	Medium	Low	Low	Medium	Low	Medium
2	Database for fixed outdoor p-to-p and p-to-mpt equipment Revise ECC/DEC(04)08 and Commission Decision 2005/513/EC include the use of a database for fixed outdoor p-to-p and p-to-mpt equipment through mandatory registration of SSID, MAC, address (as proposed by FM22). Identification of location of outdoor WLAN/RLAN). Note that this decision has been replaced by Commission Implementing Decision (EU) 2022/179 of 8 February 2022 on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks and repealing Decision 2005/513/EC.	Provides mechanisms to spectrum monitoring and enforcement experts to handle meteorological radars interferences caused by WLAN/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. It was commented that this solution would be highly useful to ease the finding of interference WLAN/RLAN sources since some EUMETNET members are able to provide MAC address and SSID of interferers. There is also the possibility to reuse solutions already in operation.	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. A change in the regulation should occur to oblige the registration. This means that it cannot be deployed rapidly and there is a need of a harmonised approach.	(FM 2021)	European Commission. Member states and ECC	Medium	Low	Medium	Medium	Low/Medium	Medium	Low/Medium	Medium

3	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 WLAN/RLANs. Should avoid any WLAN/RLAN interference to meteorological radars and hence provide a long-term solution. This solution is applied in many countries worldwide (Canada, Australia, Japan, …) and has shown its efficiency.	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 and EC 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, …). It is a measure that can break the confidence on sharing bands for services already in place.	(FM 2021)	ECC	Medium	Medium	Low	Low/Medium	Medium/High	Low	Low	Medium
4	Exclude the use of 5600 – 5650 MHz band by WLAN/RLAN equipment Revise ECC/DEC(04)08 and Commission Decision 2005/513/EC 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 WLAN/RLAN use, both indoor and outdoor. May reduce the number of administrations who can implement the revised ECC Harmonisation measure.	(FM 2021)	European Commission and ECC	Low	Low	Low	Low	Low/High/Very High	Medium	Low/High	High/Very High

5	Remove the use of 5600-5650 MHz band by fixed outdoor p-to-p and p-to-mpt equipment Revise ECC/DEC(04)08 and Commission Decision 2005/513/EC to remove the use of 5600-5650 MHz band by fixed outdoor point to point and point to multipoint equipment. Note that 2005/513/EC has been replaced by 2022/179/EC.	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 2021)	European Commission and ECC	Medium	Low	Low	High	High	High	Low	Medium
6	Collaboration between ECC, ADCO and EC by creating new processes or strengthening existing processes 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 WLAN/RLAN have significantly increased since the first publication of ECC Report 192 (2014). However this has not stopped the continuous increase, taking CEPT as a whole, in the number of reported interference cases.	(FM 2021) (This report)	EC, ADCO RED and ECC	Medium	Low	Medium	Low	Low	Medium	Low	Medium

7	Investigate other sources of interference beyond WLAN/RLAN 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 WLAN/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 WLAN/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)	EU Member states	Medium	Medium	Low	Low	N/A	High	Low	Medium

8	Replace C-band radars with 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. Provides national administrations with information on the conditions for possible radar band migration on a case by case basis.	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. In addition, the cost of replacement of C-band radars with X-band radars, can be significant because a C-band radar may be replaced by between 10 and 20 X-band radars due to their limited coverage. This option will require to find relevant locations to implement so many radars, with all required authorisations, building new towers, providing energy and connections and so on. It will represent a challenge to ensure relevant management of so many radars in a single network (which has never been done before). In addition, this option may lead to spectrum congestion in the X-band (With weather radars and other types of radars).	(Saltikoff 2016)	EUMETNET	Low	Low/Medium	High	Low/Medium	High	Low	High	High/Very High

9	Installation of monitoring stations to report (possibly in an automatic way) interference in the field. Monitoring put in place by EUMETNET: RFI-detection algorithm has been set up within EUMETNET OPERA programme (responsible for the European radar network) with the aim to generate a comprehensive and centralized monitoring how radio frequency interferences (RFI) caused by WLAN/RLAN devices affect the radar measurements within the OPERA network	Monitoring stations would be able to provide a ground truth which can be used to determine the reason and source of the interference. Current trend in monitoring is moving in the opposite direction due budget constraint and also evolution of radio usages. This tool will allow to determine in a consistent manner over all radars of the network and over time, the level of disturbances within the OPERA network. It will provide a relevant way to ensure a comparison of the situation over time, with possible display of the data at regular timeframe (daily, monthly, …). It will hence allow to provide at regular time a global set of data to determine the RFI trend and hence judge on the efficiency of the measures that would be proposed.	The installation of monitoring stations in the european member states can be costly unless they can be associated/deployed on existing infrastructures (cellular networks ?) It will probably not be able to detect all interference cases, such as very short (in time) or weak signals,	RSC #74	member states of European Union	Medium	Low/Medium	Low	Low	Medium	Low	Medium	Medium

10	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)	EUMETNET, Meteorological organisations.	Low	Low/Medium	Low	Low	Medium	Low	Low	Medium
11	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 WLAN/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 WLAN/RLAN devices (e.g., WiFi APs) the location of the weather radars.	WLAN/RLAN devices (e.g., WiFi APs) must be equipped to connect and receive information from the geo-location database.	(Paisana 2014), (Khan 2016)	EUMETNET	Low	Low/Medium	Medium	Low/Medium	Medium	High	Low	Low/Medium/High

12	Network of WLAN/RLAN nodes to mitigate hidden node problem 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 WLAN/RLAN which exchange messages on the results of the DFS functionality.	This solution could mitigate the ”hidden node” problem.	The exchange of the information among the WLAN/RLAN devices is something completely new, which would have an impact on the DFS implementation and the deployment of WLAN/RLAN. In this configuration, a specific report from the cases registered need to be produced. Indeed, since the standard ETSI EN 301 893 V1.8.the use and the rules for WLAN/RLAN equipment used as slave device has been more precisely defined. So if the current interference cases shows that these cases exist on equipment placed on the market under this version, the cases needs to be deep studied to consider a possible modification of the standard in consequence.	(Han 2016)	member states, WLAN/RLAN installers, providers and vendors	Low	Low	Low	Medium	Medium	Medium	Low	Medium
13	Monitoring systems of WLAN/RLAN equipment configuration and status Implement a retrieval interface to check whether a monitoring system to ensure that the WLAN/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.		member states, WLAN/RLAN installers, providers and vendors	Low	Low	High	Low	Medium	Medium	Medium	Medium

14	Research new interference cancellation schemes in weather radars 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 hardware and sotware) but with variable success. The problem is that interference cancellation techniques may degrade the performance of the radar function leading to quite a large loss of data. This may be a solution for limited amount of interference but cannot work for large disruptions as we have on many radars.	(Han 2016)	EUMETNET, radar manufacturer.	Low	Medium	Low	Medium	High	Low	High	Medium
15	Mitigate adjacent band interference Even if DFS activated, some interference cases were reported due to adjacent bands interference. Widen the guard band between weather radar and WLAN/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 WLAN/RLAN or weather radar applications	(Naik 2018),(Blanck 2013)	EUMETNET, Weather radar manufacturer.	Low	Low/Medium	Low	Low/Medium	Low/Medium	Medium	Low	Low/High
16	Issue a recall of DFS non-compliant products Reports indicates that most of the interference are due to the non-compliance of equipment produced by a limited number of models/brands. This solution could limit the case of interference.	Reports indicates that most of the interference are due to a limited number of brands for different models. This solution could limit the case of interference.	There is also the risk that when tested against a standard and the equipment is non-compliant there is nothing to discuss. At the end, the manufacturers that would receive the fine would be those shown as producing non-compliant WLAN/RLAN anyhow. This measure can lead to the need to change legal framework in some MSs to be able to implement this measure.	(FCC 2019)	EU member states	Medium	Low	Medium	Low	Low	Medium	Low	Low

17	Increase the fines for non-compliant manufacturers	This would increase pressure on vendors for product compliance		This report	EU member states	Low	Low	Medium	Low	Medium	Medium	Low	Medium
18	Increase the fines to misuse of WLAN/RLAN equipment for users to avoid misuse in the field.	This would increase pressure on users to avoid tampering with the WLAN/RLAN equipment.	There is still the risk that users misusing the WLAN/RLAN equipment will not be detected	This report	EC and member states	Low	Low	Medium	Low	Medium	Medium	Low	Medium
19	Implement a cooperative communication system between weather radar and WLAN/RLAN	Interference issues between weather radars and WLAN/RLAN due to hidden node, DFS not working may disappear.	The set up of such communication systems may be quite complex from a technical and deployment point of view. It may not solve problems related to non-compliant WLAN/RLAN equipment and misuse.	(Zhao 2007), (Griffiths 2014)	RLAN. Radar vendors,ESO radar vendors, standardization bodies	Low	High	Medium	High/Medium	High/Medium	Medium	Low	High
20	Registration of the Technical Construction File for outdoor WLAN/RLAN	Amplifies the DFS requipement to be fulfilled for WLAN/RLAN out door EC central system easy to implement (due central system in place)	Assessment of the option to be done at EG RE Delegate act needed to implement the option		EC and ember states	Low	Medium	Medium	Medium	Low	Low	Low	Medium

21	Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of activity ratio higher than 30 % on DFS efficiency WLAN/RLAN issues specific study to be carried out: Assessment of the impact of activity ratio higher than 30 % on DFS efficiency (see 'transmitter minimum activity ratio of 30 %' in clause : 5.3.1.2 Test transmission sequences for DFS tests of the standard EN 301 893.)	To determine that the load rate, when exceeded by 30%, makes the DFS functionality inefficient. Several authorities have already observed this phenomenon. Based on lesson learnt from the tests, this option would be useful to identify the relevant improvement of HS in order to reduce the risks of DFS malfunctioning. It can also improve the legal basis for market surveillance autorities.	Need to carry out a series of tests on different WLAN/RLAN equipment: tests activity ratio higher than 30 % on DFS efficiency Possible follow up update of HS in order to clarify transmitter activity ratio and interaction with DFS efficiency	New	JRC	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium
22	Specific study to be carried out on WLAN/RLAN issues: To Check in the setting interface that the combination of the transmitter's power + antenna gain shall not exceed the allowed power limits for WLAN/RLAN. Requirements: When the device allows the possibility to configure the antenna gain and the WLAN/RLAN power, the antenna gain shall only be modifiable with respect to the authorised power allowed by the WLAN/RLAN equipment.	The power emitted by the RLANs is often pointed out as appearing to be anormally high to be able to reach these distances. The strengthening of technical specifications would help to reduce the possibility of exceeding RLANs power limits.	Need to carry out a series of tests on different WLAN/RLAN equipment Possible follow up update of HS	New	JRC	Medium	Medium	Medium	Medium	Medium	Medium	Low	Medium

23	Specific study to be carried out on WLAN/RLAN issues: To assess the impact of WLAN/RLAN installation (vertical / horizontal) and its capacity to detect radar signature from the DFS (Impact of radar location/angle : vertical/horizontal on identification of the radar signature). Justification: Depending of the product characteristics, some device with internal antenna can be installed on a ceiling or against a wall, the position of the device is therefore either vertical or horizontal.	Some manufacturers have indicated that the positioning of their device (and therefore the direction of orientation of their integrated antenna) could have an influence on the detection of radar signatures and therefore the proper functioning of the DFS. The advantage of this option could be to determine the influence of this phenomenon and to revise the standard accordingly in order to limit the interference cases. A clear specifications consolidate the legal procedure for market surveillance autorities.	Need to carry out a series of tests on different WLAN/RLAN equipment Possible Follow up update of HS : assessment of the impact of position vertical/horizontal *on its capacity to identification of the radar signature*	New	JRC	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium
24	Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of the Application of clause 4.2.6.2.1 of standard ETSI EN 301 893. sentence: “The radar detection requirements specified in clause 4.2.6.2.2 to clause 4.2.6.2.4 assume that the centre frequencies of the radar signals fall within the central 80 % of the Occupied Channel Bandwidth of the WLAN/RLAN (see clause 4.2.2).”	To determine that the value of 80% is appropriate and especially that there is no impact on the radar when the latter's signals are lower than this 80% floor value.	Need to carry out a series of tests on different WLAN/RLAN equipment: test the detection of radar signatures with radar signals falling within different percentages of central Occupied Channel Bandwidth of the RLAN. Possible follow up update of HS in order to clarify transmitter activity ratio and interaction with DFS efficiency.	New	JRC	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium

5.5 Potential options as ex-ante and ex-post measures

Figure 2 shows the implementation of the options developed and described in section 5 taking into account two main phases. The first one is the placement in the market of WLAN/RLAN equipment, the second one is the event of interference and how the different options can help to prevent interference (ex-ante measures) or help to solve them (ex-post measures).

The colour code red is used to identify the options which have been set to DISCARDED or SUSPENDED for further analysis.

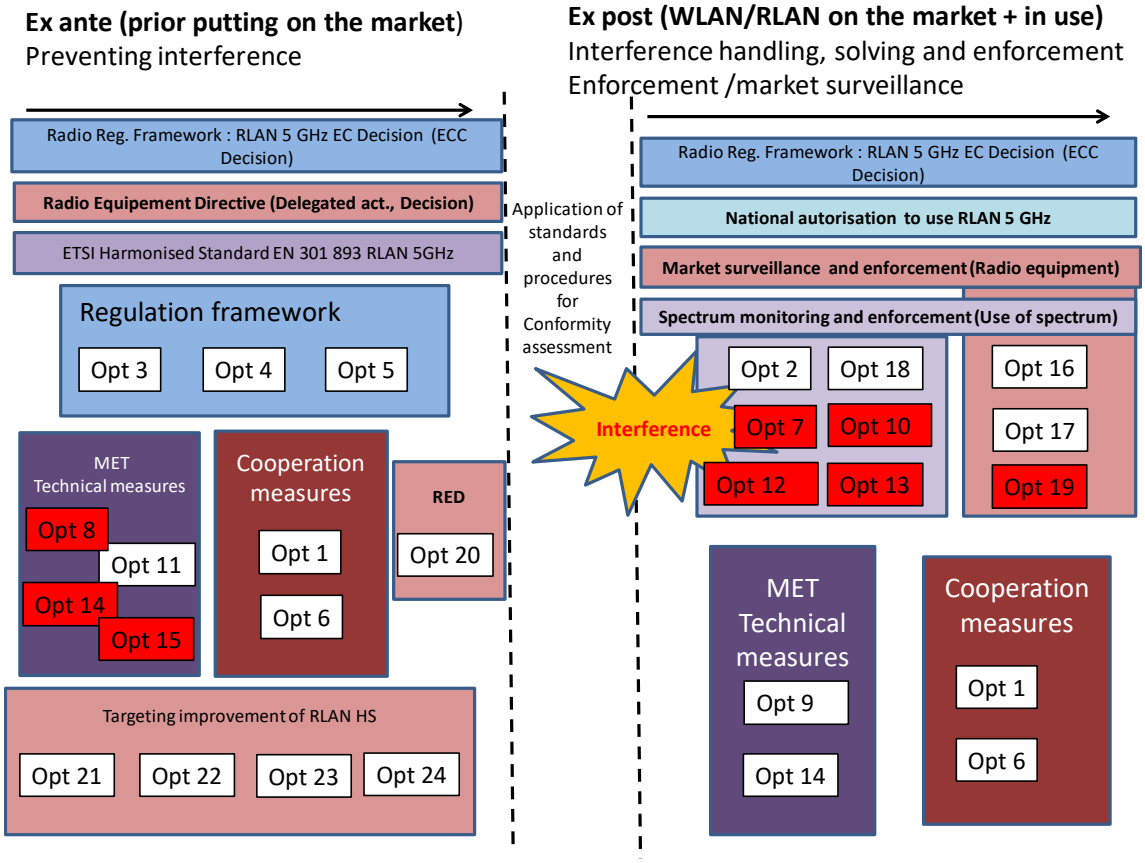

Figure 2 Placement of the policy options in two main phases of Ex ante (prior market placement of equipment) and Ex post (after placement of WLAN/RLAN equipment)

5.6 Stakeholders and implementation of options

On the basis of the indications in Table 1 regarding associated roles, Figure 3 summarizes how each entity or group of entities is involved in the different policy options. MET indicates both EUMETNET and weather radar vendors and manufacturers.

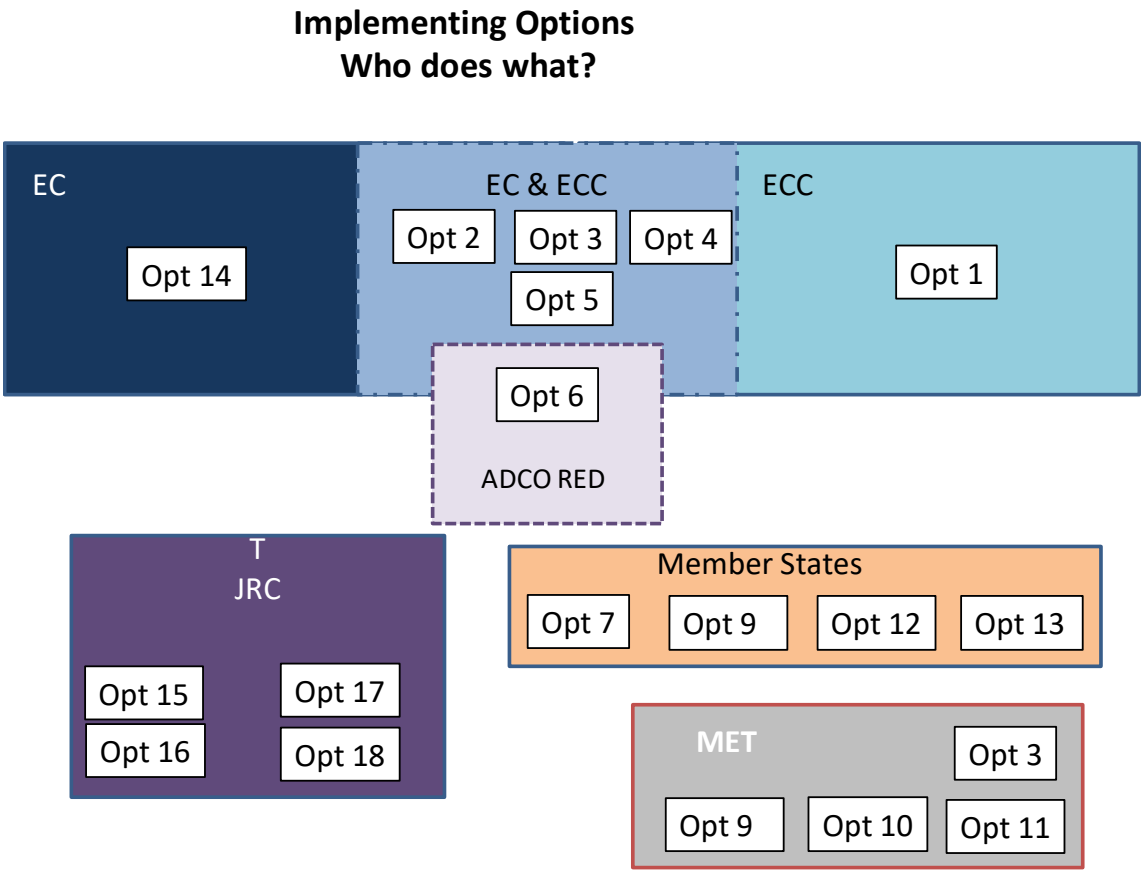

Figure 3 Association of policy options to roles

5.7 Analysis and summary of the evaluation

This section describes the summary of the evaluation on the basis of the metrics and the results of the evaluation with the recommended options.

A quantitative evaluation is provided by assigning Low=1, Medium=3, High=5 and Very High=7. Since each option may have varying values, it is provided the lowest value and the higher value. N/A is set equal to 3.

This quantitative analysis is only indicative and it assigns same weight to all the metrics of evaluation which may not be correct, because some metrics can be more important and relevant than others.

As in the previous subsections, the options marked in red are identified as discarded and/or suspended.

The positive metric already identified in Table 1 must also be taken in consideration. It is not considered in Table 2.

Table 2 Indicative estimate of the options

Option Id	Short Description	Lower value	Higher Value

1	Turn ECC Report 192, into a Recommendation to provide guidance to manufacturers and notified bodies and to provide guidance to enforcement authorities.	13	13
2	Database for fixed outdoor p-to-p and p-to-mpt equipment.	13	17
3	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).	13	17
4	Exclude the use of 5600 – 5650 MHz band by WLAN/RLAN equipment.	13	25
5	Remove the use of 5600-5650 MHz band by fixed outdoor p-to-p and p-to-mpt equipment.	21	21
6	Collaboration between ECC, ADCO RED and EC by creating new processes or strengthening existing processes.	13	13
7	Installation of monitoring stations to report (possibly in an automatic way) interference in the field.	11	13
8	Investigate other sources of interference beyond WLAN/RLAN	17	17
9	Replace C-band radars with X-band radars.	23	29
10	Improve the radio location of interfering sources (e.g., WiFi AP).	13	15
11	Creation of a geo-location database to record the position of the weather radars.	13	21
12	Network of WLAN/RLAN nodes to mitigate hidden node problem	15	15

13	Monitoring systems of WLAN/RLAN equipment configuration and status	19	19
14	Research new interference cancellation schemes in weather radars	21	21
15	Mitigate adjacent band interference	9	18
16	Issue a recall of DFS non-compliant products	11	11
17	Increase the fines for non-compliant manufacturers	15	15
18	Increase the fines to misuse of WLAN/RLAN equipment for users to avoid misuse in the field.	15	15
19	Implement a cooperative communication system between weather radar and WLAN/RLAN	23	27
20	Registration of the Technical Construction File for outdoor RLAN	17	17
21	Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of activity ratio higher than 30 % on DFS efficiency	17	17
22	Specific study to be carried out on WLAN/RLAN issues: To Check in the setting interface that the combination of the transmitter's power + antenna gain shall not exceed the allowed power limits for RLAN.	19	19
23	Specific study to be carried out on WLAN/RLAN issues: To assess the impact of WLAN/RLAN installation (vertical / horizontal) and its capacity to detect radar signature from the DFS (Impact of radar location/angle : vertical/horizontal	17	17

	on identification of the radar signature).		
24	Specific study to be carried out on WLAN/RLAN issues: Assessment of the impact of the Application of clause 4.2.6.2.1 of standard EN 301 893.	17	17

6 Experimental studies to support coexistence of weather radar with WLAN/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 WLAN/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 WLAN/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.

Additional experimental studies may originate from the options identified in Section 5. In particular, the options described in sub-sections 5.3.9, 5.3.15, 5.3.21, 5.3.22, 5.3.23, 5.3.24.

7 Conclusions

This preliminary report has investigated a number of policy options to mitigate and resolve the problem of coexistence of weather radar and WLAN/RLAN equipment in the 5GHz band. A number of policy options have been identified from a number of sources including EC, CEPT, ADCO RED, EUMETNET, Standardization bodies and research studies. The options have been evaluated on the basis of different metrics and validated by the enforcement and stakeholders community in various rounds of consultations, reviews and corrections. A number of policy options have been discarded because not practically feasible in the short term. Other options have been suspended until further evidence is provided. A total of 16 policy options have been selected for future actions in various enforcement dimensions: regulatory, technical, experimental and organizational.

This report concludes the analysis and filtering of policy options. Further actions will be focused on the implementation of specific options by the identified entities (e.g., JRC, member states). The experimental activities by the JRC (e.g., options described in 5.3.9, 5.3.15, 5.3.21, 5.3.22, 5.3.23, 5.3.24. and potential others) will be carried on by the JRC in its experimental facilities in the second half of 2021. In parallel, JRC can contribute and support specific enforcement actions with ADCO RED, DG DEFIS and CNECT and the stakeholders' community based on the options selected in this report. Finally, similar sharing problems discussed in CEPT can also benefit by the contribution by the JRC and the findings of this report on a case-by-case basis in 2021 and 2022 depending on the Commission priorities.

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List of abbreviations and definitions

Abbreviation	Definition
ADCO RED	Administrative Co-operation group under the Radio Equipment Directive
ANFR	Agence Nationale des Frequences
BFWA	Broadband Fixed Wireless Access
CEPT	European Conference of Postal and Telecommunications Administrations
CNECT	DG Directorate-General for Communications Networks, Content of EC
dB	decibel
dBm	decibel-milliwatts
DFS	Dynamic Frequency Selection
DG	Directorate General
E.I.R.P.	Equivalent Isotropically Radiated Power
EC	European Commission
ECC	Electronic Communications Committee
ECO	European Communications Office
ESOs	European Standards Organizations
ETSI	European Telecommunications Standards Institute
EU	European Union
EUMETNET	European Meteorological Network
FM	Frequency Management
GROW	DG Internal Market, Industry, Entrepreneurship & SMEs
HIPERLAN	High Performance Radio
HS	Harmonized Standard
HUI	Human User Interface
IEEE	Institute for Electrical and Electronics Engineers
IoT	Internet of Things

ITU	International Telecommunication Union
JRC	DG Joint Research Centre of EC
MAC	Medium Access Control
MINECO	Ministerio de Economía y Competitividad
MS	Member State
NRA	National Regulatory Authorities
NWP	Numerical Weather Prediction
OoB	Out Of Band
p-to-mpt	Point to MultiPoint
p-to-p	Point to Point
RED	Radio Equipment Directive
RF	Radio Frequency
RFI	Radio Frequency Interference
RLAN	Radio Local Area Networks
RoP	Rules of Procedure
RSC	Radio Spectrum Committee
RSPG	Radio Spectrum Policy Group
Rx	Receiver
S/N	Serial Number
SSID	Service Set IDentifier
TCAM	Telecommunication Conformity Assessment and Market Surveillance Committee
TDWR	Terminal Doppler Weather Radars
TPC	Transmit Power Control
Tx	Transmitter
WAS	Wireless Access Systems
WGFM	Working Group Frequency Management
WiFi	Wireless Fidelity ISO/IEC local area network standard (IEEE 802.11 family)

WLAN	Wireless Local Area Network (in this report WLAN/RLAN is considered a synonym of RLAN)
WM	Working Methods
WMO	World Meteorological Organisation
WRC	World Radio Conference

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