REPORT ITU-R M.2115

Testing procedures for implementation of dynamic frequency selection

(2007)

1 Introduction

Resolution 229 (WRC-03) invites the ITU-R to undertake studies on suitable test methods and procedures for the implementation of dynamic frequency selection (DFS), taking into account practical experience.

Currently several administrations and/or standards organizations have developed DFS test methodology.

This Report consolidates the DFS test methodology used and findings across several administrations, as shown in several Annexes. Information is provided on the test methodologies in place in various administrations and/or regional groups to test compliance with DFS requirements. These procedures may be updated over time, and as technology evolves. As a result, web links are provided (in some cases) to the test methodologies themselves, so that the most up-to-date information may be obtained.

2 Background

The Dynamic frequency selection (DFS) requirements mandated by Resolution 229 (WRC-03) contained in Recommendation ITU-R M.1652 Annex 1 are broken down into three functional areas:

– detection requirements;

– operational requirements;

– response requirements.

From a spectrum management view point, testing for these requirements are quite different than the normal field strength or power flux density requirements and a clear description of the methods and process for testing will ease manufacturers' ability to show compliance with the administrations rules.

Conformance testing provides a means to analyse equipment operations against set functional requirements prior to authorization of devices within an administration.

To successfully develop conformance test procedures certain descriptions are required to enable manufacturers to develop equipment that will meet or exceed administration requirements.

3 Equipment setup

The test procedures for implementation of DFS in the 5 250-5 350 MHz and 5 470-5 725 MHz bands should include a full description of the equipment used to transmit test waveforms and monitor DFS reactions as prescribed in Recommendation ITU-R M.1652.

4 Test methodology

The test procedures for implementation of DFS in the 5 250-5 350 MHz and 5 470-5 725 MHz bands should also include a comprehensive description of the test methodology used for compliance. This should have at a minimum the waveforms to be tested and procedures to be followed during testing.

5 Detection requirements

There should be a clearly defined detection requirement for each test waveform utilized to ensure that manufacturers and test facilities have a clear understanding of the metric to be applied to each. If multiple requirements will be placed on a data set (i.e. individual waveform detection requirement with an overall group of waveforms having an additional requirement) these should also be clearly defined.

Annex 1

Japan

1 Background

In Japan, technical compatibility requirement, including the frequency sharing study and measurement procedures are addressed by the committee formed by the Information and Communications Council (hereinafter “Council”).

With regard to RLAN devices in the 5 GHz band, the Council has set up a technical committee on wireless access systems in the 5 GHz band which has undertaken the role of studying technical requirements for such RLAN devices. Based on the Council Report, MIC (Ministry of Internal Affairs and Communications) regulates technical requirements to facilitate development of type acceptance testing procedures.

2 Scope

DFS requirements were institutionalized in the 5 250-5 350 MHz band in May 2005 and 5 470-5 725 MHz band in January 2007. On the same day, the notification of WAS test procedure was published. The Association of Radio Industries and Businesses (ARIB - the private standards organization in Japan) published the revision of ARIB Standard T-71 based on IEEE 802.11 CSMA/CA standards and incorporates regulatory requirements including DFS functionality in Japan.

DFS requirements in Japan are composed of those given in Recommendation ITU-R M.1652 Annex 1, harmonized international requirements and those for protecting Japan’s specific radars.

3 Procedures

The DFS capability can be verified through the examination of detection probability. It must be repeated many times to obtain accurate test results. It is time consuming and may reflect to the cost impact to WAS devices. Therefore, Japan adopted the method of testing procedures to enable relatively more accurate pass/fail decision under relatively smaller cycle of testing. These considerations are introduced in following attachment for reference. To achieve further reduction of testing items which conform to DFS function to various kinds of radars, similar radar types are grouped, and random sample testing method within grouped radars was adopted.

The latest version of mandated DFS requirements and test procedures in Japan can be obtained from MIC publications Download Area Website (http://www.tele.soumu.go.jp/e/equ/tech/5ghz.htm).

Appendix 1
to Annex 1

An example of DFS test methods and calculation result for DFS detection probability

This Attachment shows an example of DFS test methods and a calculation result of the probability of DFS detection during in-service monitoring. The calculation targets a rotating meteorological radar and WAS devices based on the IEEE 802.11a standard.

1 Parameters in design of DFS test method

The following parameters are required to design DFS test methods, because the probability of DFS detection is largely dependent on them:

– margin to the detection threshold;

– data traffic;

– decision threshold by detected pulses.

1.1 Margin to the detection threshold

There is a margin between the detection threshold defined in Recommendation ITU-R M.1652 Annex 1 and the necessary detection threshold described in Recommendation ITU-R M.1652 Annex 5. Therefore the WAS devices can receive the signal above the threshold out of the main beam of radar. For this reason, the analysis time during in-service monitoring is redefined as the period during which the WAS receives the radar signal above the threshold in one sweep. Consequently, the analysis time is calculated as "$2 \cdot \theta_{offset}$/Scan rate", where θ_{offset} is the off-axis angle and the antenna gain of off-set θ_{offset} is below the peak by the margin.

1.2 Data traffic

Step 3 of Recommendation ITU-R M.1652 Annex 4 defines available time for in-service monitoring as only listening periods; however, idle time during which the WAS devices have no transmitting data is also available for in-service monitoring. Since the idle time depends on data traffic among the WAS devices, the data traffic is an important factor for the detection probability.

It is noted that the data traffic for IEEE 802.11a based devices increases when the packet loss occurs by interference from the radar, because the WAS devices resend the lost packet instead of idling.

Therefore, the important factor will be the radio-transmitting activity ratio such as Talk/Listen timing, because, recently the chipset companies who have 802.11a function, have implemented enhanced functions such as the large packet mode, the fast burst mode, etc., and random back-off timing must be considered additionally.

1.3 Decision threshold by detected pulses

The WAS devices with typical implementations recognize the radar signal by detecting each pulse rise/fall. Therefore, the number of the pulses received in the available time is a key factor for the probability of detection. Such devices use a pulse counter to determine radar detection. To avoid false alarm, a number larger than one is set as a decision threshold by detected pulses.

2 Calculation

2.1 Calculation procedure

Considering the parameters addressed in the above sections, the calculation of the DFS detection probability based on the methodology in Recommendation ITU-R M.1652 Annex 4 is demonstrated as follows.

Step 1: Determine the number of pulses, N_p, received in the analysis time as follows:

$$N_p = 2 \cdot \theta_{offset}/\text{Scan rate} \cdot \text{Pulse repetition rate}$$

Step 2: For simplicity of calculation, since analysis time is usually much longer than the radar pulse repetition period, the probability of detection, P_d, that one radar pulse falls into a listening period during the radar pulse repetition period is set as the average time ratio of the listening periods to the total time. Then, calculate the probability, $P(m)$, wherein the WAS device detects m pulses within the analysis time as follows:

$$P(m) = \binom{N_p}{m} P_d{}^m (1 - P_d)^{N_p - m}$$

Step 3: Calculate probability, $P(m, N_p)$, wherein the WAS device detects more than m pulses within the analysis time as follows:

$$P(m, N_p) = 1 - \sum_{i=0}^{m-1} P(i)$$

Step 4: Probability of detection in n rotations:

Q: probability of detection in one rotation

Q_S: probability of detection in n rotations

$$Q = P(m, N_p)\left(1 - P(m, N_p)\right)^{n-1}$$

$$Qs = \sum_{i=1}^{n} Q = 1 - (1 - P(m, N_p))^n$$

2.2 Calculation example of radar detection probability for a meteorological radar deployed by an administration in Region 3

According to the procedure based on Recommendation ITU-R M.1652 Annex 4, the probability of DFS detection for meteorological radar deployed by an administration in Region 3[1] is calculated as the following table.

	Radar type	**Antenna horizontal scan type (360°)**
Radar	Platform	Ground
	Tuning range (MHz)	5 250-5 350
	Tx power into antenna peak (kW)	250
	Receiver IF3 dB bandwidth (MHz)	1.6
	Antenna main beam gain (dBi)	43
	Pulse width (μs)	2.5
	Pulse repetition rate (pps)	260
	$N = k\,T\,B\,F$ (dBm)	–109
	$N - 6$ dB	–115
	Scan rate (degrees/s)	24
WAS	e.i.r.p. (dBm) indoor	23
	Bandwidth (MHz)	18
	DFS threshold for protection (TDFS)	–64

Necessary detection threshold (dBm)	–43.5 (Note 2)
Margin to detection threshold (dB)	20.5
Analysis time in one rotation (ms)	192
$N_{p:}$ Number of pulses received within the analysis time	50
P_d (Note 1)	0.3157
Decision threshold by detected pulses (Note 4)	4
Q: Probability of radar detection (%) in one rotation	99.999

NOTE 1 − This calculation assumes that the data is transmitted between the master device and the client device fully at a data rate of 54 Mbit/s.

NOTE 2 − The necessary detection threshold is calculated using the method described in Recommendation ITU-R M.1652, Annex 5.

NOTE 3 − The antenna pattern in Recommendation ITU-R M.1652 Annex 6 is used in this calculation.

NOTE 4 − Substituted for “*m*”.

[1] This radar is planned to be added to Recommendation ITU-R M.1638.

2.3 Example of DFS test method to judge detection ability effectively

2.3.1 Test signal

Considering testing WAS devices at conformity assessment bodies, it is not practical to measure the radar detection ability using real radar pulses and thousands of trials to show almost 100% radar detection ability. For this reason, the administration adopts test signals and detection probability to this signal for the purpose of WAS conformance testing. In the case of the meteorological radar shown above, the following test signal and detection probability are used.

TABLE 1

Test signal and detection probability for meteorological radar

	Pulse width (µs)	**Pulse repetition rate (pps)**	**Number of pulses**	**Detection probability (%)**
For Meteorological Radar on 2.2	2.5	260	18	60

Figure 1 shows that detecting this test signal at 60% is equivalent to detecting radar approximately 90.2% in the worst case and approximately 99.8% in the best case within the analysis time in one rotation. The test signal detection probability of 60% can be achieved at P_d of 0.2244 which would be caused by adoption of a lower transmission speed.

2.3.2 Required number of trials to minimize fault pass, fault fail decision and test time consumed

The detection probability $P(l)$ is distributed as binomial since it can be considered as independent between trials.

$$P(l) = \binom{N}{l} P^l (1-P)^{N-l}$$

where:

N : number of trials per test for each test signal

l : number of detection success trials per test

P : radar detection probability of UUT for infinite number of trials.

Test success probability Ps can be calculated as accumulated binomial distribution of the above:

$$Ps = \sum_{i=l}^{N} P(i) = \sum_{i=l}^{N} \binom{N}{i} P^i (1-P)^{N-i}$$

where:

l/N : specified minimum detection ratio, such as 0.6 to 0.7.

The relation between radar detection probability of the unit under test (UUT) and test success probability is shown in Fig. 2. Here, the minimum detection ratio is 0.6 and the number of trials per test signal is 10, 20, 40 and 100. Table 2 shows the probabilities of fault pass and fault fail.

FIGURE 1

Probability of radar detection by a DFS device which can detect test signals of 18 pulses at 60% probability

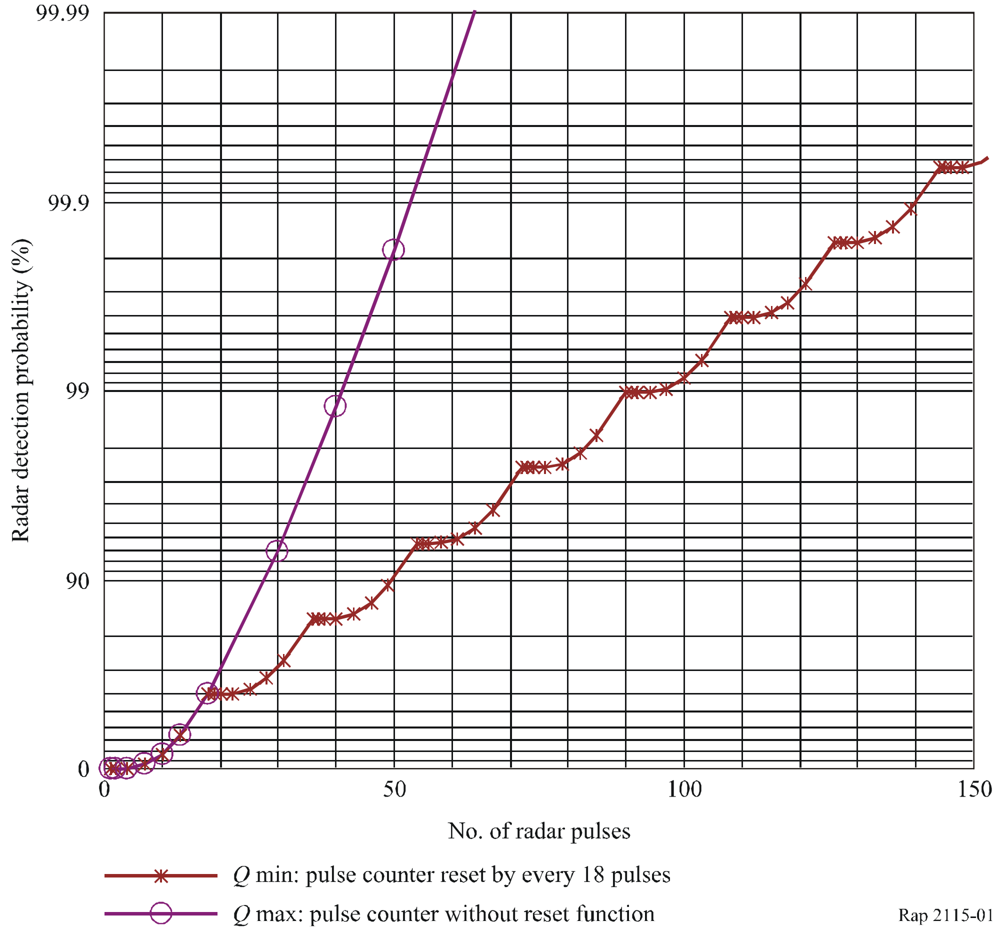


FIGURE 2

Radar Detection probability *P* of UUT vs. Test success probability, *P*

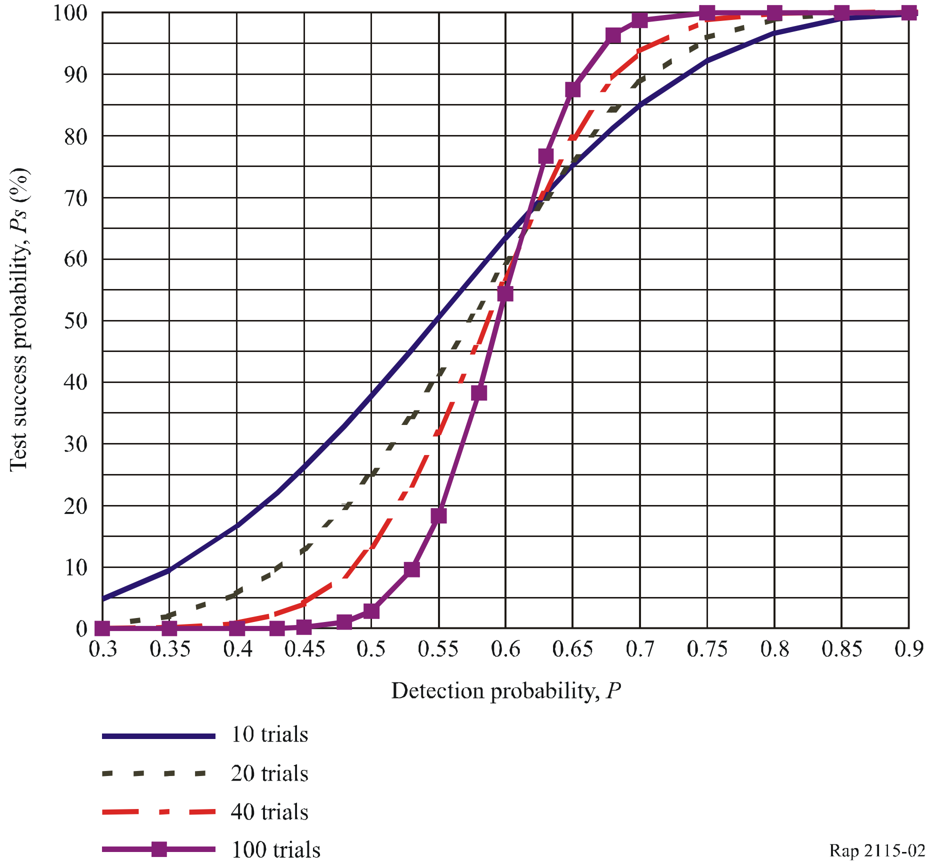


TABLE 2

Fault pass fail probability at minimum detection ratio of 0.6

Detection probability of UUT *P*	**More than No. of detection out of No. of trials**				
	6 out of 10	**12 out of 20**	**24 out of 40**	**60 out of 100**	
0.30	4.7%	0.5%	0.0%	0.0%	Fault pass probability
0.40	16.6%	5.7%	0.8%	0.0%	
0.50	37.7%	25.2%	13.4%	2.8%	
0.70	15.0%	11.3%	6.3%	1.2%	Fault fail probability
0.80	3.3%	1.0%	0.1%	0.0%	
0.90	0.2%	0.0%	0.0%	0.0%	

As can be seen in Fig. 2 and Table 2, the smaller the number of trials the greater is the probability of fault pass and fault fail. As an example, approximately 38% of UUT with a detection probability of 0.5 would pass this test, if the number of trials is limited to 10. On the other hand, 15% of UUT would fail this test even though the detection probability is 0.7. The former should receive a fail decision and the latter a pass decision, since the detection probabilities of UUT are less or more than the specified minimum detection ratio of 0.6.

This uncertainty, due to a lack of trials, would also affect the design specification of detection probability of UUT. Most equipment manufacturers apply a higher detection probability as their design specification since this test is costly and their aim is a pass within one time. If they plan to pass this test with more than 99% accuracy, the detection probability listed in Table 3 would be the minimum requirement.

TABLE 3

Required design detection probabilities to achieve test success of 99% accuracy

	Number of trials				
	10	**20**	**40**	**60**	**100**
Required design detection probabilities to achive test success of 99%	0.850	0.800	0.754	0.730	0.701

The design detection probability is the function of the number of trials. The smaller the number of required trials, the higher is the design detection probability. It also becomes more difficult to realize the required detection probability.

It is desirable that the number of trials be large enough to achieve an accurate decision and avoid unnecessary extremely high design detection probabilities, as much as possible. On the other hand, this test is time consuming. From the detection fail trial, the next trial can continue as it is. However, the detection success trial requires a “Reset period” which re-establishes the simulated in-service condition (ready for test) from the transmission cease state for following a trial since the transmission of UUT ceases by radar detection. Reset may take several minutes. Then, this test requires several hours and is costly and ineffective if a large number of trials is applied. Therefore, it is required that a reasonable number of trials within allowable fault pass and fault fail probabilities be adopted to minimize the required test elapsed time.

From Table 2, let’s pay attention to the UUT detection probability of 0.5, the fault pass probability becomes half if the number of trials applied is 40 instead of 20. The fault pass unit ratio becomes one (1) out of eight (8) instead of one (1) out of four (4). The 40 trials may be assumed as an appropriate number to avoid undertaking this test with such low detection probability of UUT. In this case, from Table 3, a detection probability of 0.75 would be required as the design specification, if the test success probability of 99% is to be achieved.

If the administration adopts 40 as the number of trials per test, it would take more than two (2) hours to obtain a successful test result per test signal, if the reset period is estimated at 5 min. To further reduce this elapsed time, the following two-stage Pass/Fail criteria can be considered.

1st stage: Mandatory 20 trials

Number of successes to detect	0-10	11-14	15-20
Pass/Fail	Fail	Go to 2nd Stage	Pass

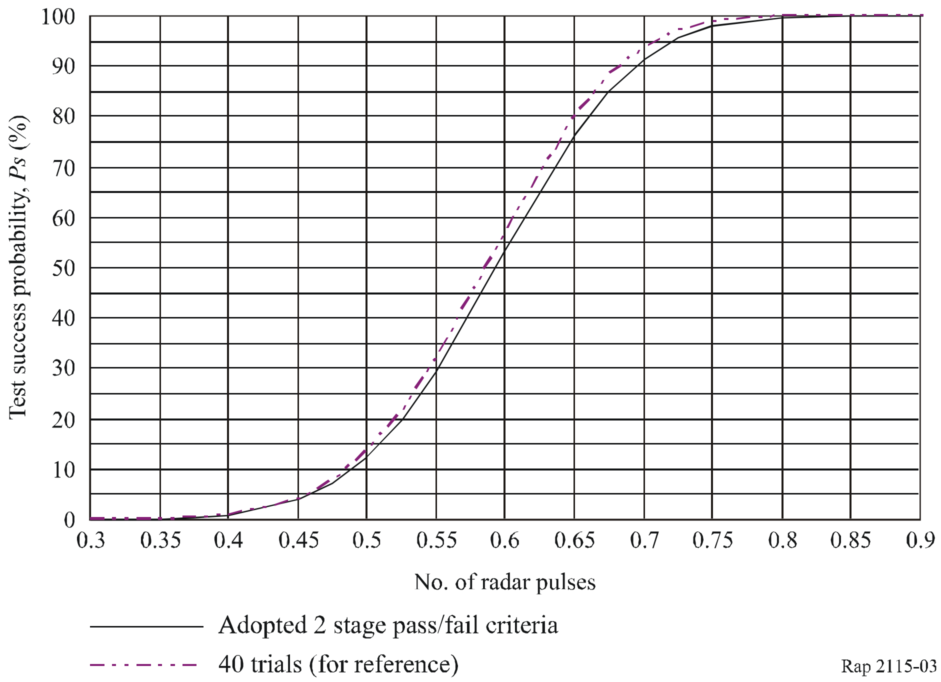
2nd stage: Supplementary 20 trials

Number of successes to detect for 40 trials	11-23	24-34
Pass/Fail	Fail	Pass

Figure 3 shows the relation between radar detection probability *P* of UUT and test success probability *Ps* under the above two-stage pass/fail criteria.

FIGURE 3

Test success probability under adopted two-stage pass/fail criteria



If the detection probability of UUT is 0.75, more than 62% of UUT will be successful within the 1st stage and within 75 min. On the other hand, 60% of UUT, for which the detection probability is 0.5, will be screened within 50 min in the 1st stage. Note that, in this two-stage Pass/Fail criteria, the screening point has been set to less than ten (10) instead of (9) to reduce fault pass probability around the detection probability of 0.6, and to obtain a balanced-shape test success probability.

Annex 2

United States of America

1 Background

Within the United States, the FCC has established procedures for conformance testing of Wireless Access Systems, including RLANs, in the 5 250-5 350 MHz and 5 470-5 725 MHz bands to comply with FCC rules, including DFS. These rules represent the result of comprehensive rulemakings that provide the maximum flexibility to the manufacturers while maintaining protection of vital government systems.

2 Scope

The FCC procedures for testing conformance with DFS requirements were adopted in a *Memorandum Option and Order* in 2006. This text contains the compliance measurement procedures including acceptable instrument system configurations for performing DFS tests under the FCC Rules required for equipment that operates in the frequency bands 5 250-5 350 MHz and/or 5 470-5 725 MHz. The scope of this document includes applicable references, definitions, symbols and abbreviations with an overview of the DFS operational requirements, test signal generation and methods of measuring compliance. The methods include calibration and test procedures for conducted and radiated measurements. Either conducted or radiated testing may be performed. Equipment with an integral antenna may be equipped with a temporary antenna connector in order to facilitate conducted tests. When the antenna cannot be separated from the device and a radio frequency (RF) test port is not provided, radiated measurements will be performed.

3 Procedures

The FCC procedures for conformance testing of devices with DFS requirements in the 5 250-5 350 MHz and 5 470-5 725 MHz bands can be found at:
http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-96A1.pdf.

These testing procedures offer specialized testing to accommodate the adaptive techniques utilized for detection and avoidance of radar systems and are only directly applicable to the stated bands.

Annex 3

Europe

1 Background

Within Europe, test procedures for telecommunications equipment are normally addressed by ETSI (European Telecommunications Standards Institute). With regard to RLAN devices in the 5 GHz band, ETSI has a Technical Committee (TC) on broadband radio access networks (BRAN) which has undertaken the role of defining the technical requirements and developing the necessary test procedures for such RLAN devices.

In those countries which are within the European Union (EU) and EFTA, there is the Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (the "R&TTE Directive") which sets provisions for the testing and placing on the market of radio equipment. Whilst the directive sets the framework, the specific requirements which need to be met for each type of equipment/frequency band will be detailed in individual "Harmonized Standards".

In addition to the EU and EFTA countries, ETSI standards are used in the other European countries as well as some countries outside Europe.

2 Scope

ETSI BRAN has developed a European harmonized standard (Norm) EN 301 893 "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements of Article 3.2 of the R&TTE Directive", which includes the specific requirements and test methods (including those for DFS) for confirming satisfactory operation of 5 GHz RLANs.

The DFS requirements contained in EN 301 893, are as close as possible to those given in the Annex 1 of Recommendation ITU-R M.1652. Although the DFS requirements are applicable on the network, the ETSI standard details how these requirements and the corresponding conformance tests were transposed on a device level.

Section 4.6 of EN 301 893 contains the specific performance requirements that the DFS mechanism must meet, whilst § 5.3.7 contains the conformance tests related to DFS.

It may be relevant to note that ETSI BRAN has also developed a draft European harmonized standard EN 302 502 on fixed broadband data transmission systems operating in the band 5 725-5 875 MHz, which is very similar to the mechanism described in EN 301 893.

3 Procedures

The latest version of the EN 301 893 can be obtained from the ETSI Publications Download Area website (http://pda.etsi.org/pda/queryform.asp). The latest version of the document (as of June 2007) is v.1.3.1.

Annex 4

Canada

Canadian certification rules for licence-exempt Local Area Network devices in the 5 150-5 350 MHz and 5 470-5 825 MHz range can be found in Radio Standards Specification 210, Annex 9: Local Area Network Devices: http://strategis.ic.gc.ca/epic/site/smt-gst.nsf/en/sf01320e.html.

Canadian rules require channel exclusion at 5 600-5 650 MHz, as per Recommendation ITU-R M.1652, to protect meteorological radars.