www.nts.com
1.800.270.2516

Dynamic Frequency Selection (DFS) in 5GHz Unlicensed Bands

An Overview of Worldwide Regulatory Requirements

The advent of the 802.11a wireless market and the constant push to open up spectrum for unlicensed use required that a mechanism be implemented for spectrum sharing. Dynamic Frequency Selection (DFS) is the mechanism that was adopted to allow unlicensed devices to use the 5 GHz frequency bands already allocated to radar systems without causing interference to those radars. The concept of DFS is to have the unlicensed device detect the presence of a radar system on the channel they are using and, if the level of the radar is above a certain threshold, vacate that channel and select an alternate channel.

The regulatory requirements for DFS, along with requirements along with Transmit Power Control (TPC), have been adopted in Europe, the United States of America, and many other geographical areas. The following is an overview of the current DFS requirements for Europe, the USA, Canada, Taiwan, Australia, and Japan.

General Overview of DFS

Standards that incorporate DFS define various requirements for the detection of radars using the following terms:

- Channel Availability Check Time: The time a system shall monitor a channel for presence of radar prior to initiating a communications link on that channel. This is also referred to by the acronym CAC.
- Interference Detection Threshold: The minimum signal level, assuming a 0dBi antenna, that can be detected by the system to trigger the move to another channel.
- Channel Move Time: The time for the system to clear the channel and measured from the end of the radar burst to the end of the final transmission on the channel.
- Channel Closing Transmission Time: The total, or aggregate, transmission time from the system during the channel move time.
- Non-Occupancy Time: A period of time after radar is detected on a channel that the channel may not be used.
- Master Device: Device that has radar detection capabilities and can control other devices in the network (e.g. an Access Point would be considered a master device)
- Client Device: Device that does not initiate communications on a channel without authorization from a master device (e.g. a laptop WiFi card – note that a WiFi card that supports ad-hoc mode would be considered a master device)
- Radio Local Area Network (RLAN) or Wireless Local Area Network (WLAN): Generic terms for wireless systems such as 802.11a and 802.11n that operate in the 5GHz unlicensed bands.
- Uniform Loading or Uniform Spreading: A requirement in many DFS standards to achieve a uniform loading across the available spectrum over a number of devices. It can be achieved by random channel selection in a single device (such as an access point used in a home) or planned selection by a management tool over a large number of devices (such as a coordinated series of networks in a campus).

The operation of a system with DFS capability takes the following sequence (refer to Figure 1 on page 2):

The master device selects a channel and monitors that channel for potential radar interference for a minimum listening time (channel availability check time). No transmissions can occur during this period. If interference is detected then the system has to go and select another channel and repeat the channel availability check on the new channel (the original channel is added to a list of channels with radar).

Once a channel has been selected and passes the channel availability check, the network starts to use that channel.

While using the channel the network's master device continuously monitors for potential interference from a radar source (this is referred to as in-service monitoring). If interference is detected then the network master device issues commands to all other in-network devices to cease transmissions. The channel is added to the list of channels with radar and the master device then selects a new channel (one that is not on the list). The sequence starts again with a channel availability check.

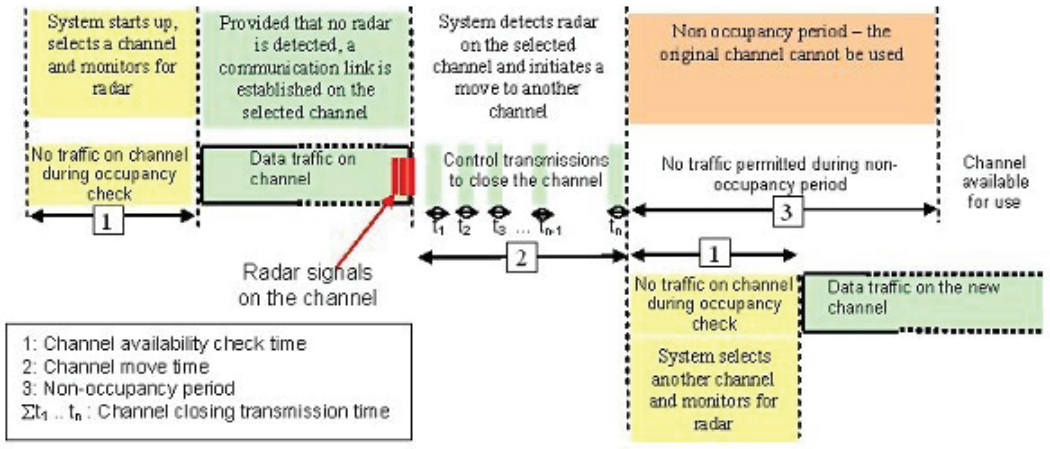

Figure 1: DFS Timing Requirements

A channel on the radar list can be purged once the non-occupancy period has elapsed for that channel

While master devices are required to employ interference detection capabilities, client device generally only need to be capable of responding to the master device's instructions to clear the channel. This means that client devices cannot employ active scanning techniques to find a network but must rely on passive scanning (listen- only) to find a network to join.

Point-to-point communication links operating in the DFS bands need to consider the implications of the radar interference potential at one end of the link will be very different from the interference potential at the other end of the link. or this reason it is expected that both ends of the link should be performing radar detection functions. The ETSI technical report TR 102 651 [1] provides additional guidance in implementing a DFS strategy for various wireless network configurations.

To evaluate the DFS functions of a system the regulatory standards describe waveforms to be used when evaluating DFS. These waveforms are defined in terms of the number of pulses, the pulse width and the pulse repetition frequency (or period) for the radar signal. The pulses may be modulated with an FM chirp, and may contain pulses of different widths and different periods. Manufacturers should always bear in mind that their radar detection algorithms should be designed to detect all radar systems.

European Union

ETSI standard EN 301 893 [2],the European Union's harmonized radio standard for unlicensed devices operating in the 5150 – 5350 MHz and 5470 – 5725 MHz frequency bands, contains DFS requirements. It specifies the types of waveforms that systems operating in the 5250 – 5350 MHz and 5470 – 5725 MHz bands should be able to detect, the maximum allowed values for closing and move times and the minimum channel availability check time. EN 301 893 does not require this feature for client devices provided that they:

- Operate below a power level of 200mW;
- Are not capable of initiating communication on a channel (in effect, this prohibits them from using active scanning to detect a wireless network);
- Only operate on a channel under control of a device with the detection capability (master device);
- Respond to the commands to move to another channel from the master device
- Meet the channel move time and channel closing transmission time.

To demonstrate the DFS capability a system (master/client pair) is evaluated for its ability to detect different pulse patterns in the presence of data traffic between the two (30% traffic is the requirement of EN 301 893). There are a total of seven different radar types.

Table 1: EN 301 893 Radar Parameters

	Pulse Width (µs)	PRF (PPS)	Pulses per burst[3]	Pulse Modulation	Bursts per Trial	Success Rate
Reference[1]	1	700	18	None	1	N/A
Type 1	0.5 - 5	200 - 1000	10	None	1	> 60%
Type 2	0.5 - 15	200 - 1600	15	None	1	> 60%
Type 3	0.5 - 15	2300 - 4000	25	None	1	> 60%
Type 4	20 - 30	2000 - 4000	20	Chirp, ±2.5 MHz deviation	1	> 60%
Type 5[2]	0.5 - 2	300 - 400	10	None	2 or 3	> 60%
Type 6[2]	0.5 - 2	400 - 1200	15	None	2 or 3	> 60%

[1] The reference waveform is used for validating Channel Availability Check (CAC) time, channel closing and channel move times.

[2] For waveforms 5 and 6 the radar bursts are interleaved. The difference between the pulse periods are 20 - 50 pps for type 5 and 80 - 400 pps for type 6. The pulse width and number of pulses per burst is the same for all bursts within the waveform.

[3] For the CAC and Off-Channel CAC requirements, the minimum number of pulses (for each PRF) for any of the radar test signals to be detected in the band 5600 MHz to 5650 MHz shall be 18. Radar types 3 and 4 are not used for CAC or Off-Channel CAC in the 5600-5650 MHz band.

EN 301 893 includes an Off Channel CAC which allows a device to scan channels for radar on a non-continuous basis while operating on another channel. This allows a system to immediately jump to a new channel, without having to perform the traditional CAC

The system (master/client combination) is considered to have met the DFS requirements if the timing and threshold parameters comply with the values listed in Table 2.

Table 2 EN 301 893 DFS Requirements

Parameter	Requirement
Minimum channel availability check time (CAC time)	60s outside 5600-5650 MHz 10 minutes for 5600-5650MHz sub-band
Off-channel channel availability check time	Up to 4 hours outside 5600-5650 MHz Up to 24 hours for 5600-5650MHz sub-band
Channel Move time	10s (maximum)
Channel Closing Time	1s (maximum)
Interference Detection Threshold	DFS Detection Threshold (dBm) = -62 + 10 - EIRP Spectral Density (dBm/MHz) + G (dBi) Shall not be lower than -64 dBm assuming a 0 dBi receive antenna gain.
Non-occupancy period	30 minutes (minimum)
Note – Client devices do not need radar detection capabilities unless they have an output power (eirp) that exceeds 200mW. All devices need to demonstrate compliance with the channel move and channel closing times.	

USA

The FCC opened up the 5150 – 5250 MHz and 5250 - 5350 MHz bands when it originally adopted the UNII rules into Part 15 Subpart E. The FCC added the 5470 – 5725 MHz band to the UNII rules by working with the wireless industry and the Department of Defense through the Department of Commerce, National Telecommunications and Information Administration (NTIA) and in 2003 released its Report and Order FCC 03-287 [3]. To allow unlicensed use of 5470 – 5725 MHz a requirement for DFS was proposed to cover both this new band and the existing 5250 – 5350 MHz band. The timing and threshold requirements were almost identical to those in EN 301 893, but the signal parameters were different and the FCC included a frequency hopping radar. It took almost three years for the parties involved to settle on an acceptable test procedure and radar parameters and the 5470-5725 MHz DFS procedures did not get released until January 2006. The final list of parameters for the six different radar waveforms are detailed in Table 3, Table 4 and Table 5. Where a range of values are listed, each parameter would be selected at random from the range of possible values for each trial.

Table 3 FCC Radar Waveforms 1-4 – Short Sequence Radar

Fixed Frequency Radar Type	Pulse Width (µsec)	PRI (µsec)	Pulses per burst	Minimum Detection Probability
0 - Fixed	1	1428	18	N/A
1 - Fixed	1	518 - 3,066	18 - 102	60%
2 - Variable	1 - 5	150 - 230	23 - 29	60%
3 - Variable	6 - 10	200 - 500	16 - 18	60%
4 - Variable	11 -20	200 - 500	12 - 16	60%
Average detection probability for types 1 - 4				80%
The minimum number of trials for each waveform is 30.				

Table 4 FCC Radar Waveform 5 – Long Sequence Radar					
Pulse Width (µsec)	PRI (µsec)	Chirp Width	Pulses per burst	Number of Bursts	Minimum Detection Probability
50 - 100	1000 - 2000	5 - 20 MHz	1-3	8 - 20	80%
The 12-second waveform is split into n equal intervals, where n is the number of bursts (e.g. for 10 bursts, the interval is 1.2s). A burst is contained within each interval. Within a burst the pulses have the same width and modulation, but not the same repetition interval The first pulse in the burst appears at a random time in the burst's interval. The minimum number of trials is 30.					

Table 5 FCC Radar Waveform 6 – Simulated Frequency Hopping Radar					
Pulse Width	PRI	Number of Pulses per Frequency Hop	Hopping Sequence Length	Hopping Rate	Minimum Detection Probability
1 µs	333 µs	9	300 ms	333 Hz	70%
Radar hops over the entire frequency range 5250 – 5724 MHz (475 channels) The radar hops across 475 channels in a random manner without using the same channel twice A 100 channel sequence is defined and applied ONLY if the sequence includes one or more frequencies that fall in the detection bandwidth of the device under test The minimum number of trials is 30					

Interference problems between 5 GHz unlicensed devices and radar systems were reported, lead to a temporary hold on the issue of grants for master devices in 2009 while the FCC worked on ways to mitigate this problem. Additional requirements were established relating to radio control software.

Devices are prohibited from including configuration controls (e.g. country code settings or other options to modify DFS functions) to change the frequency of operations to any frequency other than those specified on the grant of certification for US operation.

Devices must include security for the portion of software that controls compliance with FCC technical requirements. Information on the security measures must be provided in an application for certification.

Applications for certification of devices that have radar detection capabilities (master devices) also require a pre-grant sample audit test at the FCC (this means that products will not be certified until the FCC has successfully completed their own audit tests of the device against these DFS requirements). The FCC encourages the applicant to attend these tests to ensure that any special operating software is correctly loaded. Devices being tested by the FCC must contain special test software to facilitate a quick test. Those features are described in the FCC's document, KDB 905462 D04, available through the FCC online knowledge database [4].

Canada

Canada followed the original FCC requirements with regards to DFS for the 5250 – 5350 MHz and 5470 – 5725 MHz bands with the exception of not allowing operation in the 5600 – 5650 MHz sub-band. The technical standard RSS 247 has some very generic requirements (similar to the DFS requirements contained in FCC Part 15). Certifications are based on the FCC's test methods for evaluating DFS. No pre-certification testing at ISED Canada is required.

Australia/New Zealand

Australia and New Zealand require DFS capabilities for the 5250 – 5350 MHz and 5470 – 5725 MHz bands. The radio standard AS/NZS 4268 references the use of either EN 301 893 or FCC Part 15.407(h)(2) procedures for evaluating DFS capabilities. The AS/NZS 4268 standard and the associated frequency allocation (the LIPD Class Licence and GURL) prohibit the use of the 5600 – 5650 MHz sub-band.

Taiwan

The requirements for 5 GHz Wireless LAN devices are contained in the Low-power Radio-frequency Devices Technical Regulations LP0002. DFS is required for devices operating in the 5250-5350 MHz and 5470-5725 MHz band. Certification tests use the FCC's technical requirements and methods for evaluating DFS including the method of assuring a user cannot disable the DFS functions.

Japan

Japan's requirements for low power data communications systems operating in the 5GHz band (5150 – 5250, 5250 – 5350 and 5470 – 5725 MHz) include DFS and carrier sense capabilities. Carrier sense is required for all three bands and refers to the ability of a device to sense a continuous wave signal before transmitting its data if the signal is there it should wait until the signal has gone before sending its data.

The DFS requirements are similar to those for the FCC in terms of radar parameter and apply to the 5250 - 5350 MHz and 5470 – 5725 MHz bands. If radar-type signals are detected then, as with Europe and North America, the wireless network needs to move to another channel. The radar waveform parameters are different for the 5250-5350 MHz (refer to Table 6) and 5470-5725 MHz bands (refer to Table 7, Table 8 and Table 9).

Table 6 Japan Fixed Radar Parameters – W53 Band (5250-5350 MHz)

Radar Test Signal	Pulse Width (µsec)	Pulse Repetition Frequency PRF (pps)	Pulses/Burst	Detection Probability
Fixed Pulse 1	1.0	700	18	See note below
Fixed Pulse 2	2.5	260	18	
Device passes if it detects at least 15 of the first 20 trials or at least 11 times in the first 20 trials and at least 24 times in 40 trials.				

Table 7 Japan Fixed and Variable Radar Parameters – W56 Band (5500-5700 MHz)

Radar Test Signal	Pulse Width (µsec)	Pulse Repetition Frequency PRF (pps)	Pulses/Burst	Detection Probability
Fixed Pulse 1	1.0	700	18	See note below
Fixed Pulse 2	2.5	700	18	
Fixed Pulse 3	2.0	250	18	
Variable Pulse 4	1 - 5	4,347 - 6,667 Hz	23 - 29	
Variable Pulse 5	6 - 10	2,000 - 5,000 Hz	16 - 18	
Variable Pulse 6	11 - 20	2,000 - 5,000 Hz	12 - 16	
For each individual test signal type, the device passes if it detects at least 15 of the first 20 trials or at least 11 times in the first 20 trials and at least 24 times in 40 trials. In addition the mean of the probabilities needs to be at least 80%.				

Table 8 Japan Chirped Radar Parameters – W56 Band (5500-5700 MHz)

Radar Type	Pulse Width (µsec)	Chirp Width (MHz)	PRI (µsec)	Pulses/Burst	Number of Bursts
Chirp	50 - 100	5 - 20	1000 - 2000	1 - 3	8 - 20
Device passes if it detects at least 18 of the first 20 trials or at least 15 times in the first 20 trials and at least 32 times in 40 trials.					

Table 9 Japan Frequency Hopping Radar Parameters – W56 Band (5500-5700 MHz)

Radar Type	Pulse Width (µsec)	PRI (µsec)	Pulses/Hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)
Hopping	1	333	9	0.333	300
Device passes if it detects at least 16 of the first 20 trials or at least 11 times in the first 20 trials and at least 28 times in 40 trials.					

Conclusions

As the 5GHz bands have opened up in other geographic areas DFS requirements were included in each country's spectrum allocation. Similar types of channel access provisions, such as Listen before Talk or Adaptivity, will be a key regulatory tools to allow spectrum allocations to be shared by different wireless systems as our use of wireless technologies continues to expand.

[1] ETSI TR 102 651 V1.1.1 (2009-06) Technical Report, Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Guide to the implementation of Dynamic Frequency Selection (DFS), published by ETSI and available at http://www.etsi.org/standards

[2] Draft EN 301 893 V2.0.7, "5 GHz RLAN; Harmonized standard covering the essential requirements of article 3.2 of Directive 2014/53/EU", published by ETSI and available at http://www.etsi.org/standards

[3] Federal Communications Commission Report and Order FCC 03 287 released November 18, 2003

[4] Federal Communications Commission knowledge database at https://apps.fcc.gov/oetcf/kdb/index.cfm - enter 905462 in the Run Publication # Search field.

About NTS

National Technical Systems (NTS) provides test, inspection and certification services to help clients build better, stronger, safer, more reliable products and bring those products to market quickly and efficiently. Over the last 50 years, through a combination of acquisitions, innovations and organic growth we have grown to become one of the largest commercial test laboratory networks in North America. Our capabilities span a very wide spectrum, covering environmental, dynamics, EMC, wireless, product safety, materials, ballistics and more. NTS engineers and technicians have extensive knowledge of current test and conformity requirements, both domestic and international over a range of industries including aerospace, defense, telecom and energy.

NTS
24007 Ventura Blvd.
Suite 200
Calabasas, CA 91302

www.nts.com | 1.800.270.2516 | sales@nts.com