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ET Doc. No. 03-122

Mr. Julius Knapp
Deputy Chief, Office of Engineering and Technology
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Dear Mr. Knapp,

The National Telecommunications and Information Administration (NTIA) is pleased to communicate to you the Federal government requirements for compliance measurement procedures for 5 GHz Unlicensed-National Information Infrastructure (U-NII) devices employing dynamic frequency selection (DFS). Based on the consensus recommendations reached by the International Telecommunication Advisory Committee-Radiocommunication (ITAC-R) Government/Industry Project Team, NTIA has prepared a final revision to the interim compliance measurement procedures contained in Appendix C of the 5 GHz U-NII R&O.[1] NTIA has fully supported the work of the Project Team which, among other things, has developed a consensus approach for DFS compliance and testing procedures. The attached final document reflects the recommended values and procedures for U-NII device testing and includes modified definitions, new response requirements, and reporting requirements compared to previous versions.

NTIA was also pleased to discuss equipment verification testing as a follow-up to device certification with FCC personnel at the January 2006 5 GHz management meeting attended by NTIA, FCC, and the Department of Defense. As part of the procedures needed to complete the required actions to enable use of the 5470-5725 MHz band, and continued use of the 5250-5350 MHz band, NTIA is looking forward to establishing the follow-up device certification procedures with the FCC in the near-term future. To facilitate this work, we designate Charles Glass (cglass@ntia.doc.gov, 202-482-1896) as the NTIA point-of-contact. NTIA would like to ensure that these procedures be developed and in place prior to the FCC's release of the final compliance measurement procedures.

We are confident that the final compliance and testing procedures will fully protect Federal government radars and will allow industry to move ahead quickly with the implementation of compliant DFS U-NII devices.

Sincerely,

Fredrick R. Wentland
Associate Administrator
Office of Spectrum Management

Enclosure

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[1] *Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, Report and Order, ET Docket No. 03-122, 69 Fed. Reg. 2677 (January 20, 2004) ("U-NII R&O").

COMPLIANCE MEASUREMENT PROCEDURES FOR UNLICENSED-NATIONAL INFORMATION INFRASTRUCTURE DEVICES OPERATING IN THE 5250-5350 MHz AND 5470-5725 MHz BANDS INCORPORATING DYNAMIC FREQUENCY SELECTION

1. INTRODUCTION

This document describes the compliance measurement procedures including acceptable instrument system configurations for performing *Dynamic Frequency Selection* (DFS) tests under FCC Part 15 Subpart E Rules required for Unlicensed –National Information Infrastructure (U-NII) equipment that operates in the frequency bands 5250 MHz to 5350 MHz and/or 5470 MHz to 5725 MHz.

2. SCOPE

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.

General information about radio device compliance testing facilities and measurement techniques are assumed to be known and not covered here.

3. REFERENCES

[1] Recommendation ITU-R M.1652

[2] ITU Resolution 229 (WRC-03)

4. DEFINITIONS, SYMBOLS AND ABBREVIATIONS

For the purposes of the present document, the following terms and definitions apply.

4.1 Definitions

Association: An active relationship between two wireless devices in which one device (referred to as a *Master Device* in this document) exercises certain control functions over other devices (referred to as a *Client Device* in this document).

Available Channel: A *Channel* on which a *Channel Availability Check* has not identified the presence of a *Radar Waveform*.

Burst: A series of radio wave pulses defined by pulse width, pulse repetition interval, number of pulses, and modulation to simulate radar transmissions.

Channel: Amount of spectrum utilized by a *Master Device* and any associated *Client Device(s).*

Channel Availability Check: A DFS function that monitors a *Channel* to determine if a *Radar Waveform* above the *DFS Detection Threshold* is present.

Channel Availability Check Time: The period of time during which a *Channel Availability Check* is performed.

Channel Closing Transmission Time: The total duration of transmissions, consisting of data signals and the aggregate of control signals, by a U-NII device during the *Channel Move Time.*

Channel Move Time: The time to cease all transmissions on the current *Channel* upon detection of a *Radar Waveform* above the *DFS Detection Threshold.*

Client Device: A U-NII device operating in *Client Mode.*

Client Mode: Operating mode in which the transmissions of the U-NII device are under control of the *Master Device.* A U-NII device operating in *Client Mode* is not able to initiate a network.

Dynamic Frequency Selection: An interference mitigation technique for U-NII devices to avoid co-channel operations with radar systems.

In-Service Monitoring: A DFS function that monitors the *Operating Channel* for the presence of a *Radar Waveform* above the *DFS Detection Threshold.*

DFS Detection Threshold: The required detection level defined by a received signal strength (RSS) that is greater than a specified threshold, within the *U-NII Detection Bandwidth.*

Master Device: A U-NII device operating in *Master Mode.*

Master Mode: Operating mode in which the U-NII device has the capability to transmit without receiving an external control signal and can perform *Network Initiation.*

Network Initiation: The process by which the *Master Device* sends control signals to *Client Device(s)* that allow them to begin transmissions.

Non-Occupancy Period: The time during which a *Channel* will not be utilized after a *Radar Waveform* is detected on that *Channel.*

Operating Channel: Once a U-NII device starts to operate on an *Available Channel* then that *Channel* becomes the *Operating Channel.*

Radar Waveform: A *Burst* or series of *Bursts* designed to simulate a radar signal.

<u>Uniform Channel Spreading:</u> The spreading of U-NII device *Operating Channels* over the 5250-5350 MHz and/or 5470-5725 MHz bands to avoid dense clusters of devices operating on the same *Channel.*

<u>U-NII Device:</u> Intentional radiators operating in the frequency bands in the 5150-5350 MHz and 5470-5825 MHz that use wideband digital modulation techniques and provide a wide array of high data rate mobile and fixed communications for individuals, businesses, and institutions.

<u>U-NII Detection Bandwidth:</u> The contiguous frequency spectrum over which a U-NII device detects a *Radar Waveform* above the *DFS Detection Threshold.*

4.2 Symbols

For the purposes of this document, the following symbols apply:

ATT	Attenuator
B	Number of Bins
Burst_Count	The number of *Bursts* within a single 12 second Long Pulse radar (waveform 5)
Ch_r	Channel occupied by a radar
D	Distance
Dwell	Dwell time per bin
G	Antenna gain (dBi)
N	Number of spectrum analyzer bins showing a U-NII transmission
F_H	Highest frequency at which detection occurs above the required value during the *U-NII Detection Bandwidth* test.
F_L	Lowest frequency at which detection occurs above the required value during the *U-NII Detection Bandwidth* test.
P_d1	Percentage of Successful Detections for Waveform 1
P_d2	Percentage of Successful Detections for Waveform 2
P_d3	Percentage of Successful Detections for Waveform 3
P_d4	Percentage of Successful Detections for Waveform 4
P_dN	Percentage of Successful Detections for Waveform N
S	Sweep Time
$T_{channel\_avail\_check}$	The 60 second time period required for the *Channel Availability Check*
T_{power_up}	Amount of time it takes a U-NII device to turn on, initialize, and then begin *Channel Availability Check*
T_0	Time instant
T_1	Time instant
T_2	Time instant
T_3	Time instant

4.3 Abbreviations

For the purposes of this document, the following abbreviations apply:

ALC	Automatic Level Control
AWG	Arbitrary Waveform Generator

CW	Continuous Wave
DFS	Dynamic Frequency Selection
EIRP	Equivalent Isotropic Radiated Power
FM	Frequency Modulation
IF	Intermediate Frequency
IL	Insertion Loss
IP	Internet Protocol
LO	Local Oscillator
MHz	Megahertz
MPEG	Moving Picture Experts Group[1]
msec	Millisecond
PRI	Pulse Repetition Interval
RDD	Radar Detection Device
RF	Radio Frequency
RMS	Root Mean Square
UUT	Unit Under Test
U-NII	Unlicensed National Information Infrastructure
μsec	Microsecond
VSA	Vector Signal Analyzer
VSG	Vector Signal Generator

5. TECHNICAL REQUIREMENTS FOR DFS IN THE 5250-5350 MHz AND 5470-5725 MHz BANDS

5.1 DFS Overview

A U-NII network will employ a DFS function to:

- detect signals from radar systems and to avoid co-channel operation with these systems.
- provide on aggregate a *Uniform Spreading* of the Operating Channels across the entire band. This applies to the 5250-5350 MHz and/or 5470-5725 MHz bands.

Within the context of the operation of the DFS function, a U-NII device will operate in either *Master Mode* or *Client Mode*. U-NII devices operating in *Client Mode* can only operate in a network controlled by a U-NII device operating in *Master Mode.*

Tables 1 and 2 shown below summarize the information contained in sections 5.1.1 and 5.1.2.

[1] MPEG is the name of a family of standards used for coding audio-visual information (e.g., movies, video, music) in a digital compressed format.

Table 1: Applicability of DFS Requirements Prior to Use of a Channel

Requirement	Operational Mode		
	Master	**Client (without DFS)**	**Client (with DFS)**
Non-Occupancy Period	Yes	Not required	Yes
DFS Detection Threshold	Yes	Not required	Yes
Channel Availability Check Time	Yes	Not required	Not required
Uniform Spreading	Yes	Not required	Not required
U-NII Detection Bandwidth	Yes	Not required	Yes

Table 2: Applicability of DFS requirements during normal operation

Requirement	Operational Mode		
	Master	**Client** (without DFS)	**Client** (with DFS)
DFS Detection Threshold	Yes	Not required	Yes
Channel Closing Transmission Time	Yes	Yes	Yes
Channel Move Time	Yes	Yes	Yes
U-NII Detection Bandwidth	Yes	Not required	Yes

The operational behavior and individual DFS requirements that are associated with these modes are as follows:

5.1.1 Master Devices

a) The *Master Device* will use DFS in order to detect *Radar Waveforms* with received signal strength above the *DFS Detection Threshold* in the 5250 – 5350 MHz and 5470 – 5725 MHz bands. DFS is not required in the 5150 – 5250 MHz or 5725 – 5825 MHz bands.

b) Before initiating a network on a *Channel*, the *Master Device* will perform a *Channel Availability Check* for a specified time duration (*Channel Availability Check Time*) to ensure that there is no radar system operating on the *Channel*, using DFS described under subsection a) above.

c) The *Master Device* initiates a U-NII network by transmitting control signals that will enable other U-NII devices to *Associate* with the *Master Device*.

d) During normal operation, the *Master Device* will monitor the *Channel (In-Service Monitoring)* to ensure that there is no radar system operating on the *Channel*, using DFS described under a).

e) If the *Master Device* has detected a *Radar Waveform* during *In-Service Monitoring* as described under d), the *Operating Channel* of the U-NII network is no longer an *Available Channel.* The *Master Device* will instruct all associated *Client Device(s)* to stop transmitting on this *Channel* within the *Channel Move Time.* The transmissions during the *Channel Move Time* will be limited to the *Channel Closing Transmission Time.*

f) Once the *Master Device* has detected a *Radar Waveform* it will not utilize the *Channel* for the duration of the *Non-Occupancy Period.*[2]

g) If the *Master Device* delegates the *In-Service Monitoring* to a *Client Device*, then the combination will be tested to the requirements described under d) through f) above.

5.1.2 Client devices

a) A *Client Device* will not transmit before having received appropriate control signals from a *Master Device.*

b) A *Client Device* will stop all its transmissions whenever instructed by a *Master Device* to which it is associated and will meet the *Channel Move Time* and *Channel Closing Transmission Time* requirements. The *Client Device* will not resume any transmissions until it has again received control signals from a *Master Device.*

c) If a *Client Device* is performing *In-Service Monitoring* and detects a *Radar Waveform* above the *DFS Detection Threshold,* it will inform the *Master Device.* This is equivalent to the *Master Device* detecting the *Radar Waveform* and d) through f) of section 5.1.1 apply.

d) Irrespective of *Client Device* or *Master Device* detection the *Channel Move Time* and *Channel Closing Transmission Time* requirements remain the same.

5.2 DFS Detection Thresholds

Table 3 below provides the *DFS Detection Thresholds* for *Master Devices* as well as *Client Devices* incorporating *In-Service Monitoring.*

[2] Applies to detection during the Channel Availability Check or In-Service Monitoring.

Table 3: DFS Detection Thresholds for Master or Client Devices Incorporating DFS

Maximum Transmit Power	Value (See Notes 1 and 2)
≥200 milliwatt	-64 dBm
< 200 milliwatt	-62 dBm

Note 1: This is the level at the input of the receiver assuming a 0 dBi receive antenna.
Note 2: Throughout these test procedures an additional 1 dB has been added to the amplitude of the test transmission waveforms to account for variations in measurement equipment. This will ensure that the test signal is at or above the detection threshold level to trigger a DFS response.

5.3 Response Requirements

Table 4 provides the response requirements for *Master* and *Client Devices* Incorporating DFS.

Table 4: DFS Response Requirement Values

Parameter	Value
Non-occupancy period	Minimum 30 minutes
Channel Availability Check Time	60 seconds
Channel Move Time	10 seconds See Note 1.
Channel Closing Transmission Time	200 milliseconds + an aggregate of 60 milliseconds over remaining 10 second period. See Notes 1 and 2.
U-NII Detection Bandwidth	Minimum 80% of the U-NII 99% transmission power bandwidth. See Note 3.

Note 1: The instant that the *Channel Move Time* and the *Channel Closing Transmission Time* begins is as follows:

- For the Short Pulse Radar Test Signals this instant is the end of the *Burst*.
- For the Frequency Hopping radar Test Signal, this instant is the end of the last radar *Burst* generated.
- For the Long Pulse Radar Test Signal this instant is the end of the 12 second period defining the *Radar Waveform*.

Note 2: The *Channel Closing Transmission Time* is comprised of 200 milliseconds starting at the beginning of the *Channel Move Time* plus any additional intermittent control signals required to facilitate a *Channel* move (an aggregate of 60 milliseconds) during the remainder of the 10 second period. The aggregate duration of control signals will not count quiet periods in between transmissions.

Note 3: During the *U-NII Detection Bandwidth* detection test, radar type 1 is used and for each frequency step the minimum percentage of detection is 90 percent. Measurements are performed with no data traffic.

6. RADAR TEST WAVEFORMS

This section provides the parameters for required test waveforms, minimum percentage of successful detections, and the minimum number of trials that must be used for determining DFS conformance. Step intervals of 0.1 microsecond for Pulse Width, 1 microsecond for PRI, 1 MHz for chirp width and 1 for the number of pulses will be utilized for the random determination of specific test waveforms.

6.1 Short Pulse Radar Test Waveforms

Table 5 – Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μsec)	PRI (μsec)	Number of Pulses	Minimum Percentage of Successful Detection	Minimum Number of Trials
1	1	1428	18	60%	30
2	1-5	150-230	23-29	60%	30
3	6-10	200-500	16-18	60%	30
4	11-20	200-500	12-16	60%	30
Aggregate (Radar Types 1-4)				80%	120

A minimum of 30 unique waveforms are required for each of the Short Pulse Radar Types 2 through 4. For Short Pulse Radar Type 1, the same waveform is used a minimum of 30 times. If more than 30 waveforms are used for Short Pulse Radar Types 2 through 4, then each additional waveform must also be unique and not repeated from the previous waveforms.

The aggregate is the average of the percentage of successful detections of Short Pulse Radar Types 1-4. For example, the following table indicates how to compute the aggregate of percentage of successful detections.

Radar Type	Number of Trials	Number of Successful Detections	Minimum Percentage of Successful Detection
1	35	29	82.9%
2	30	18	60%
3	30	27	90%
4	50	44	88%
Aggregate (82.9% + 60% + 90% + 88%)/4 = 80.2%			

6.2 Long Pulse Radar Test Waveform

Table 6 – Long Pulse Radar Test Waveform

Radar Type	Pulse Width (μsec)	Chirp Width (MHz)	PRI (μsec)	Number of Pulses per *Burst*	Number of *Bursts*	Minimum Percentage of Successful Detection	Minimum Number of Trials
5	50-100	5-20	1000-2000	1-3	8-20	80%	30

The parameters for this waveform are randomly chosen. Thirty unique waveforms are required for the Long Pulse Radar Type waveforms. If more than 30 waveforms are used for the Long Pulse Radar Type waveforms, then each additional waveform must also be unique and not repeated from the previous waveforms.

Each waveform is defined as follows:

1) The transmission period for the Long Pulse Radar test signal is 12 seconds.
2) There are a total of 8 to 20 *Bursts* in the 12 second period, with the number of *Bursts* being randomly chosen. This number is *Burst_Count.*
3) Each *Burst* consists of 1 to 3 pulses, with the number of pulses being randomly chosen. Each *Burst* within the 12 second sequence may have a different number of pulses.
4) The pulse width is between 50 and 100 microseconds, with the pulse width being randomly chosen. Each pulse within a *Burst* will have the same pulse width. Pulses in different *Bursts* may have different pulse widths.
5) Each pulse has a linear frequency modulated chirp between 5 and 20 MHz, with the chirp width being randomly chosen. Each pulse within a *Burst* will have the same chirp width. Pulses in different *Bursts* may have different chirp widths. The chirp is centered on the pulse. For example, with a radar frequency of 5300 MHz and a 20 MHz chirped signal, the chirp starts at 5290 MHz and ends at 5310 MHz.
6) If more than one pulse is present in a *Burst*, the time between the pulses will be between 1000 and 2000 microseconds, with the time being randomly chosen. If three pulses are present in a *Burst*, the random time interval between the first and second pulses is chosen independently of the random time interval between the second and third pulses.
7) The 12 second transmission period is divided into even intervals. The number of intervals is equal to *Burst_Count.* Each interval is of length (12,000,000 / *Burst_Count*) microseconds. Each interval contains one *Burst.* The start time for the *Burst*, relative to the beginning of the interval, is between 1 and [(12,000,000 / *Burst_Count*) – (Total *Burst* Length) + (One Random PRI Interval)] microseconds, with the start time being randomly chosen. The step interval for the start time is 1 microsecond. The start time for each *Burst* is chosen randomly.

A representative example of a Long Pulse Radar Type waveform:

1) The total test waveform length is 12 seconds.
2) Eight (8) *Bursts* are randomly generated for the *Burst_Count.*
3) *Burst* 1 has 2 randomly generated pulses.
4) The pulse width (for both pulses) is randomly selected to be 75 microseconds.
5) The PRI is randomly selected to be at 1213 microseconds.
6) *Bursts* 2 through 8 are generated using steps 3 – 5.
7) Each *Burst* is contained in even intervals of 1,500,000 microseconds. The starting location for Pulse 1, *Burst* 1 is randomly generated (1 to 1,500,000 minus the total *Burst* 1 length + 1 random PRI interval) at the 325,001 microsecond step. *Bursts* 2 through 8 randomly fall in successive 1,500,000 microsecond intervals (i.e. *Burst* 2 falls in the 1,500,001 – 3,000,000 microsecond range).

Figure 1 provides a graphical representation of the Long Pulse radar Test Waveform.

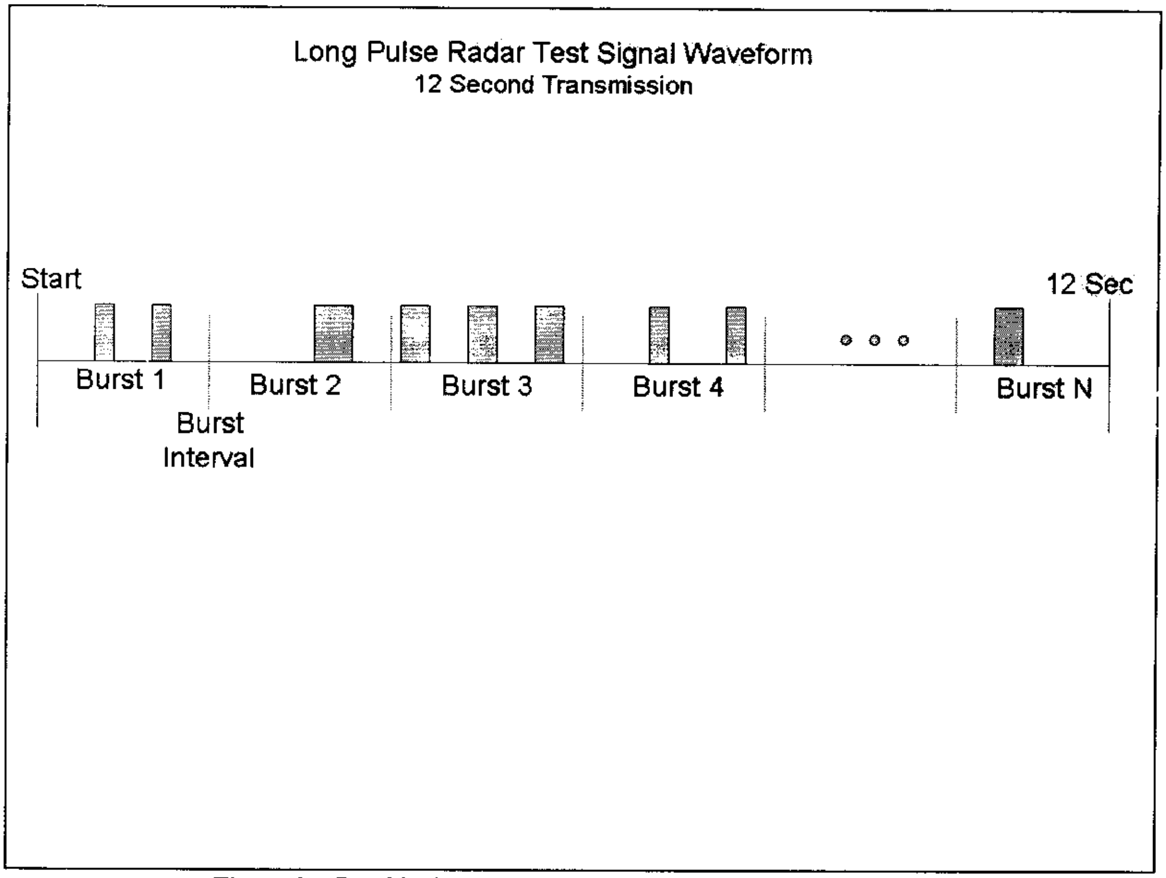

Figure 1: Graphical Representation of a Long Pulse Radar Type Waveform

6.3 Frequency Hopping Radar Test Waveform

Table 7 – Frequency Hopping Radar Test Waveform

Radar Type	Pulse Width (μsec)	PRI (μsec)	Pulses per Hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)	Minimum Percentage of Successful Detection	Minimum Number of Trials
6	1	333	9	0.333	300	70%	30

For the Frequency Hopping Radar Type, the same *Burst* parameters are used for each waveform. The hopping sequence is different for each waveform and a 100-length segment is selected from the hopping sequence defined by the following algorithm: [3]

The first frequency in a hopping sequence is selected randomly from the group of 475 integer frequencies from 5250 – 5724 MHz. Next, the frequency that was just chosen is removed from the group and a frequency is randomly selected from the remaining 474 frequencies in the group. This process continues until all 475 frequencies are chosen for the set. For selection of a random frequency, the frequencies remaining within the group are always treated as equally likely.

7. TEST PROCEDURES

7.1 Test Protocol

For a *Master Device*, the DFS conformance requirements specified in Section 7.8 will be verified utilizing one Short Pulse Radar Type defined in **Table 5**. Additionally, the *Channel Move Time* and *Channel Transmission Closing Time* requirements specified in Section 7.8 will be verified utilizing the Long Pulse Radar Type defined in **Table 6**. The statistical performance check specified in Section 7.9 will be verified utilizing all Radar Types (1-6).

For a *Client Device* without DFS, the *Channel Move Time* and *Channel Transmission Closing Time* requirements specified in Section 7.8 will be verified with one Short Pulse Radar Type defined in **Table 5**.

For testing a *Client Device* with *In-Service Monitoring*, two configurations must be tested.

1) The *Client Device* detects the *Radar Waveform*. The *Channel Move Time* and *Channel Transmission Closing Time* requirements specified in Section 7.8 will be verified utilizing Short Pulse Radar Type defined in **Table 5** and the Long Pulse Radar Type defined in **Table 6**. The statistical performance check specified in Section 7.9 will be verified utilizing all Radar Types (1-6). During this test, it must be ensured that the *Client Device* is responding independently based on the *Client Device's* self-detection rather than responding to detection by the *Master Device*. The signal level of the *Radar Waveform* as received by the *Client Device* must be set in accordance with the *DFS Detection Threshold* specified by the DFS technical requirements (**Table 3**).

2) The *Master Device* detects the *Radar Waveform*. The *Channel Move Time* and *Channel Transmission Closing Time* requirements specified in Section 7.8 will be verified utilizing Short

[3] If a segment does not contain at least 1 frequency within the *U-NII Detection Bandwidth* of the UUT, then that segment is not used.

Pulse Radar Type defined in **Table 5**. During this test, it must be ensured that the *Client Device* is responding to detection by the *Master Device* rather than self-detection by the *Client Device.*

For all tests of *Client Devices* (with or without *In-Service Monitoring*), the *Master Device* to which the *Client Device* is associated must meet the DFS conformance requirements.

Some of the tests may be performed more readily if a test mode for a *Master Device* (or Client Device with *In-Service Monitoring*) is provided that overrides the *Channel* selection mechanism for the *Uniform Spreading* requirement to allow a specific *Channel* to be set for startup (*Channel Availability Check*). In this mode it is preferable that the *Master Device* will continue normal operation upon starting (i.e. perform *Channel Availability Check* on the chosen *Channel* and begin normal operation if no *Radar Waveform* is detected – or respond normally if a *Radar Waveform* is detected during the *Channel Availability Check* or *In-Service Monitoring* on the chosen *Channel*). However, this mode of operation is not required to successfully complete the testing.

Other tests may be performed more readily if a test mode for a *Master Device* (or a *Client Device* with *In-Service Monitoring*) is provided that overrides the *Channel* move mechanism and simply provides a display that a *Radar Waveform* was detected. In this mode it is preferable that the UUT will continue operation on the same *Channel* upon detecting a *Radar Waveform*. However, this mode of operation is not required to successfully complete the testing.

Once a UUT is powered on, it will not start its normal operating functions immediately, as it will have to finish its power-up cycle first (T_{power_up}). As such, the UUT, as well as any other device used in the setup, may be equipped with a feature that indicates its status during the testing, including, for example, power-up mode, normal operation mode, *Channel Availability Check* status and radar detection events.

The test transmission will always be from the *Master Device* to the *Client Device.*

7.2 Conducted Tests

The sections below contain block diagrams that focus on the *Radar Waveform* injection path for each of the different conducted setups to be used. Each setup consists of a signal generator, analyzer (spectrum analyzer or vector signal analyzer), *Master Device*, *Client Device*, plus power combiner/splitters and attenuators. The *Client Device* is set up to *Associate* with the *Master Device*. The designation of the UUT (*Master Device* or *Client Device*) and the device into which the *Radar Waveform* is injected varies among the setups.

Other topologies may be used provided that: (1) the radar and UUT signals can be discriminated from each other on the analyzer and (2) the radar *DFS Detection Threshold* level at the UUT is stable.

To address point (1), for typical UUT power levels and typical minimum antenna gains, the topologies shown will result in the following relative amplitudes of each signal as displayed on the analyzer: the *Radar Waveform* level is the highest, the signal from the UUT is the next highest, while the signal from the device that is associated with the UUT is the lowest. Attenuator values may need to be adjusted for particular configurations.

To address point (2), the isolation characteristic between ports 1 and 2 of a power combiner/splitter are extremely sensitive to the impedance presented to the common port, while the insertion loss characteristic between the common port and (port 1, for example) are relatively insensitive to the impedance presented to (port 2, in this example). Thus, the isolation between ports 1 and 2 should never be part of the path that establishes the radar *DFS Detection Threshold*. The 10 dB attenuator after the signal generator is specified as a precaution; since many of the radar test waveforms will require typical signal generators to operate with their ALC turned off, the source match will generally be degraded from the closed loop specifications.

7.2.1 Setup for Master with injection at the Master

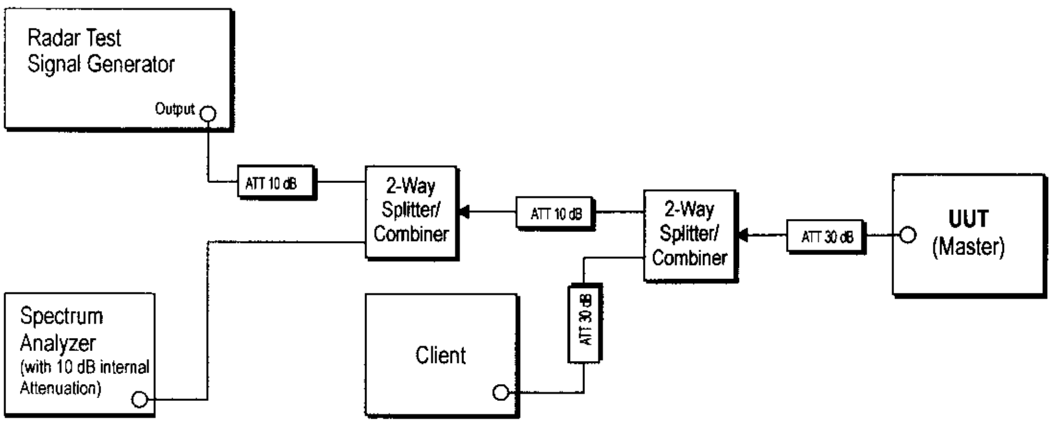

Figure 2: Example Conducted Setup where UUT is a Master and Radar Test Waveforms are injected into the Master

7.2.2 Setup for Client with injection at the Master

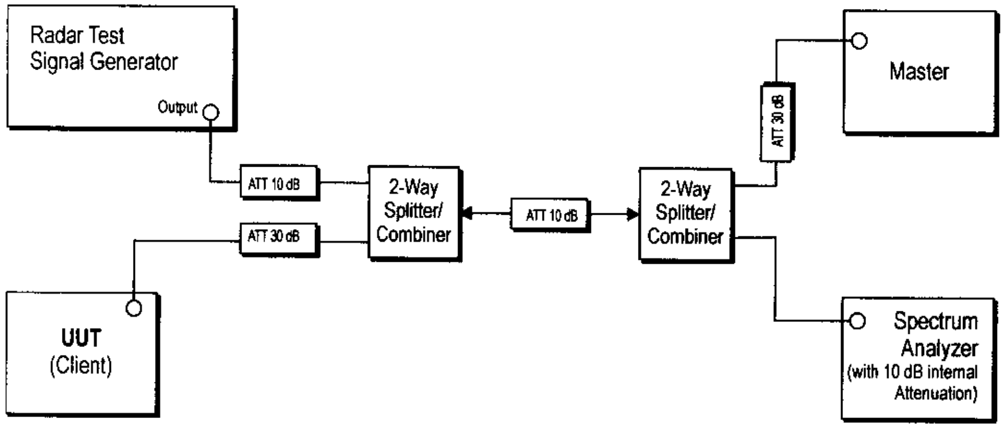

Figure 3: Example Conducted Setup where UUT is a Client and Radar Test Waveforms are injected into the Master

7.2.3 Setup for Client with injection at the Client

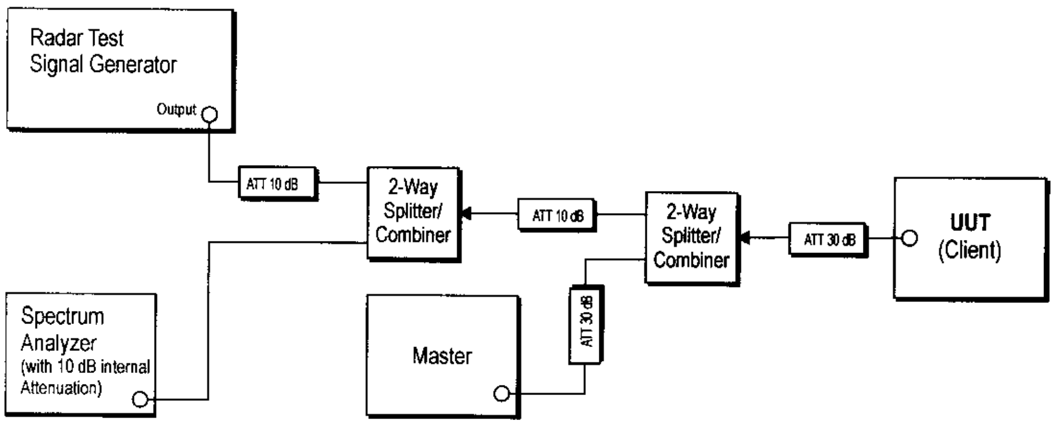

Figure 4: Example Conducted Setup where UUT is a Client and Radar Test Waveforms are injected into the Client

7.3 Radiated Tests

The subsections below contain simplified block diagrams that illustrate the *Radar Waveform* injection path for each of the different radiated setups to be used. The basic setup is identical for all cases.

7.3.1 Master with injection at the Master

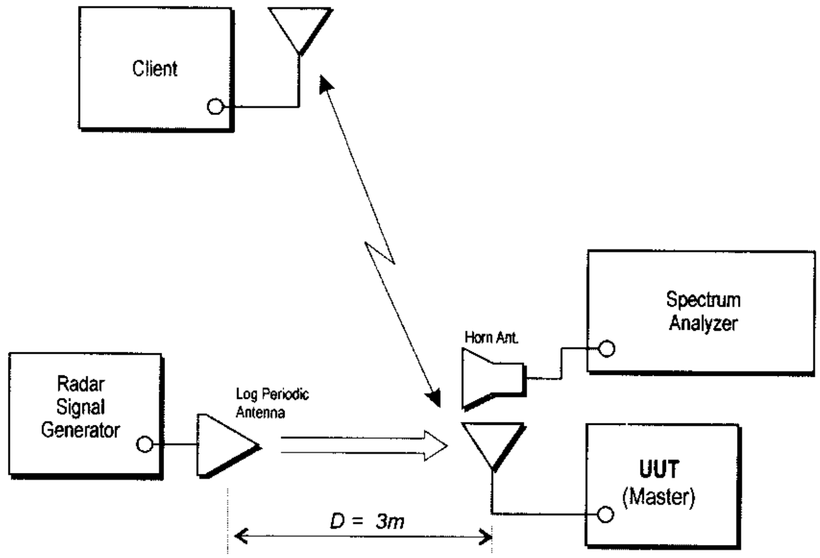

Figure 5: Example Radiated Setup where UUT is a Master and Radar Test Waveforms are injected into the Master

7.3.2 Client with injection at the Master

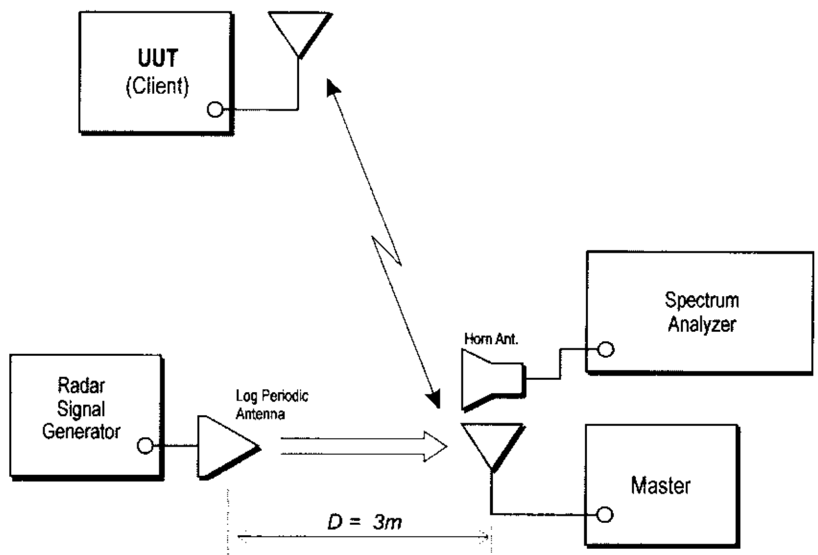

Figure 6: Example Radiated Setup where UUT is a Client and Radar Test Waveforms are injected into the Master

7.3.3 Client with injection at the Client

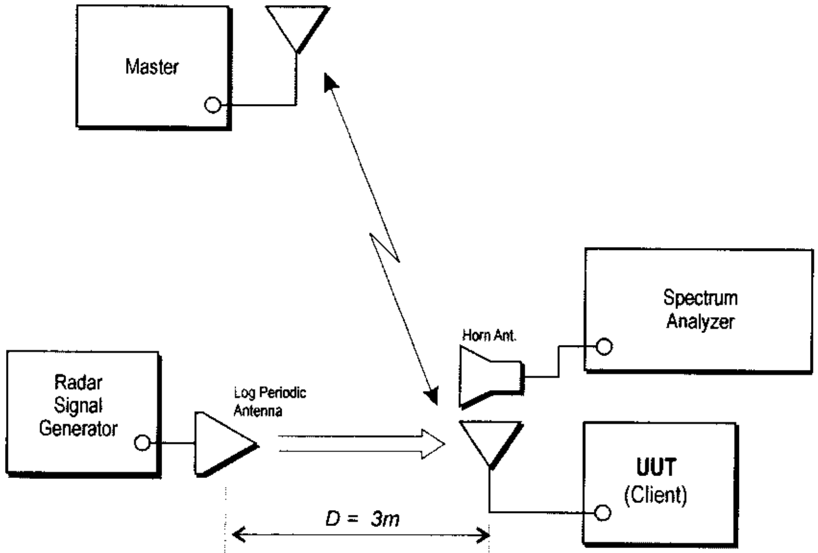

Figure 7: Example Radiated Setup where UUT is a Client and radar Test Waveforms are injected into the Client

7.4 Test Signal Generation

A complete test system consists of two subsystems: (1) the *Radar Waveform* generating subsystem and (2) the DFS monitoring subsystem. Method #1 and Method #2 subsystems are described for the *Radar Waveform* generating subsystem and the DFS monitoring subsystems. These two subsystems are independent such that the Method #1 subsystem for one function can be used with the Method #2 subsystem for the other function.

The Method #1 subsystems schematics and a parts list are available to those who are interested in replicating the custom hardware devices. The custom software and data files that control this subsystem will be made available by to those who are interested.[4]

The Method #2 subsystems used to generate simulated frequency hopping waveforms will be made available to those who are interested.[5]

Other instrument configurations may also used. However, any deviations from the subsystems described here must be submitted to the FCC for evaluation.

7.4.1 Radar Waveform Generating Subsystems

Computer control is not necessary to generate the short pulse *Radar Waveforms* however the Long Pulse *Radar Waveform* and Frequency Hopping *Radar Waveforms* by their nature require computer control. Both of the Frequency Hopping *Radar Waveform* generating subsystems can also generate the required Short Pulse *Radar Waveforms.*

[4] http://ntiacsd.ntia.doc.gov/dfs/

[5] http://www.elliottlabs.com/wireless/dfs_alternate_hopper.htm

A manually operated Short Pulse *Radar Waveform* generating subsystem is described, followed by descriptions of the computer controlled Frequency Hopping *Radar Waveform* generating subsystems.

7.4.1.1 Short Pulse Radar Waveform Generating Subsystem

Figure 8 shows the setup for the Short Pulse *Radar Waveform* generating subsystem.

The pulse generator is adjusted to the shortest rise and fall times. The pulse width, PRI, and number of pulses per *Burst* are set according to the Short Pulse *Radar Waveforms* (**Table 5**). The pulse generator is triggered manually. The trigger output from the pulse generator can also be connected to the DFS monitoring subsystem as required to synchronize the two subsystems.

The Signal Generator is set to the *Channel* center frequency and pulse modulation mode. The amplitude is adjusted to achieve the specified *DFS Detection Threshold* (**Table 3**).

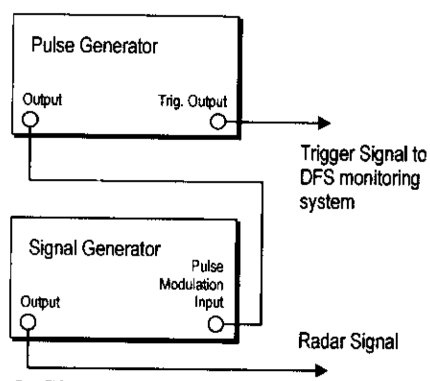

Figure 8: Short Pulse Radar Waveform Generating Subsystem

7.4.1.2 Method #1 Radar Waveform Generating Subsystems

With the exception of the Frequency Doubler and the DFS Test Box, the test and measurement system uses off-the-shelf components with vendor-supplied software and customized software.[6] **Figures 9a-9d** shows the example setup for the Method #1 *Radar Waveform* Generating Subsystems.

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[6] A complete description of the setup described in this document is available at http://ntiacsd.ntia.doc.gov/dfs/.

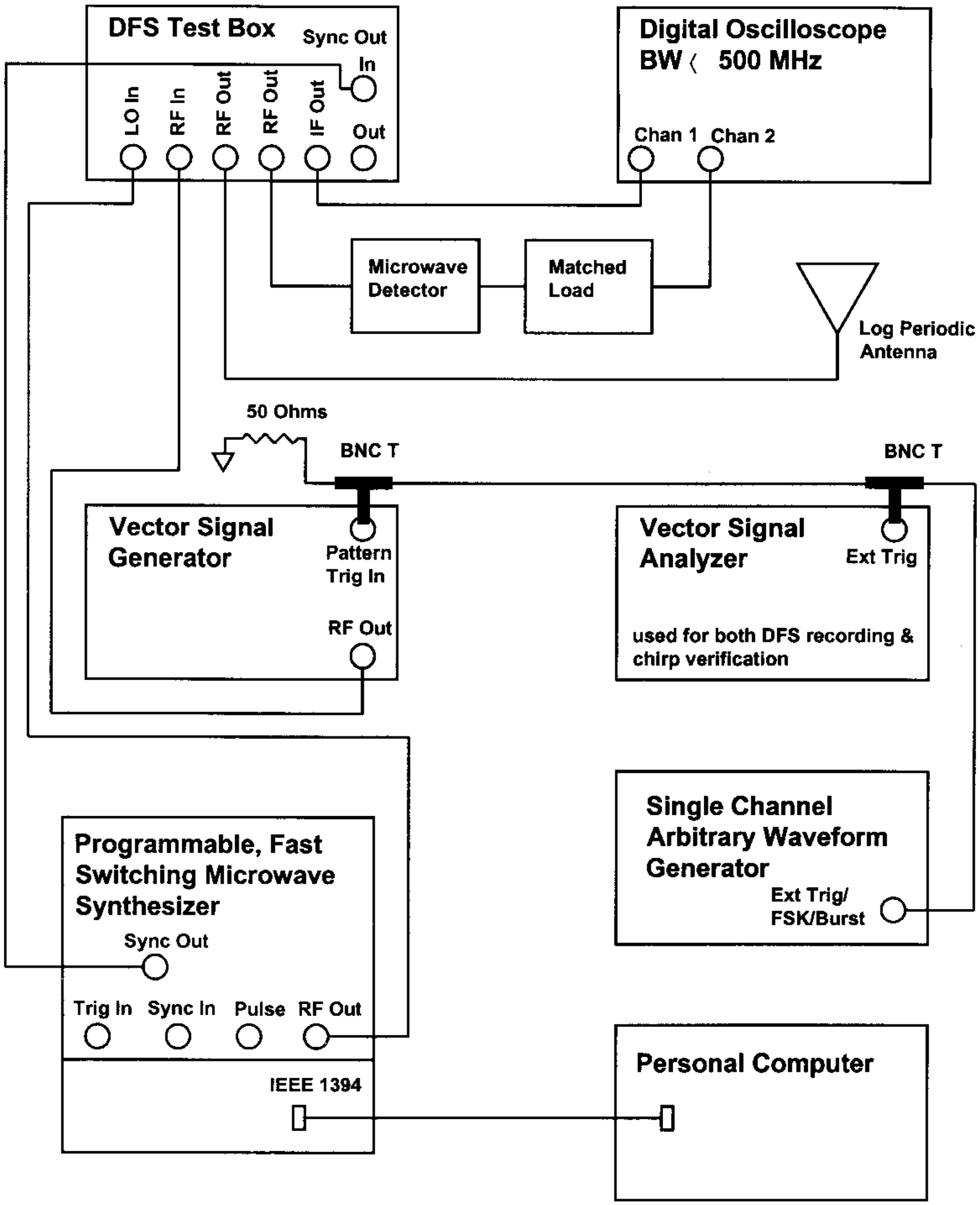

Figure 9a: Example Short and Long Pulse Radar Waveform Generator

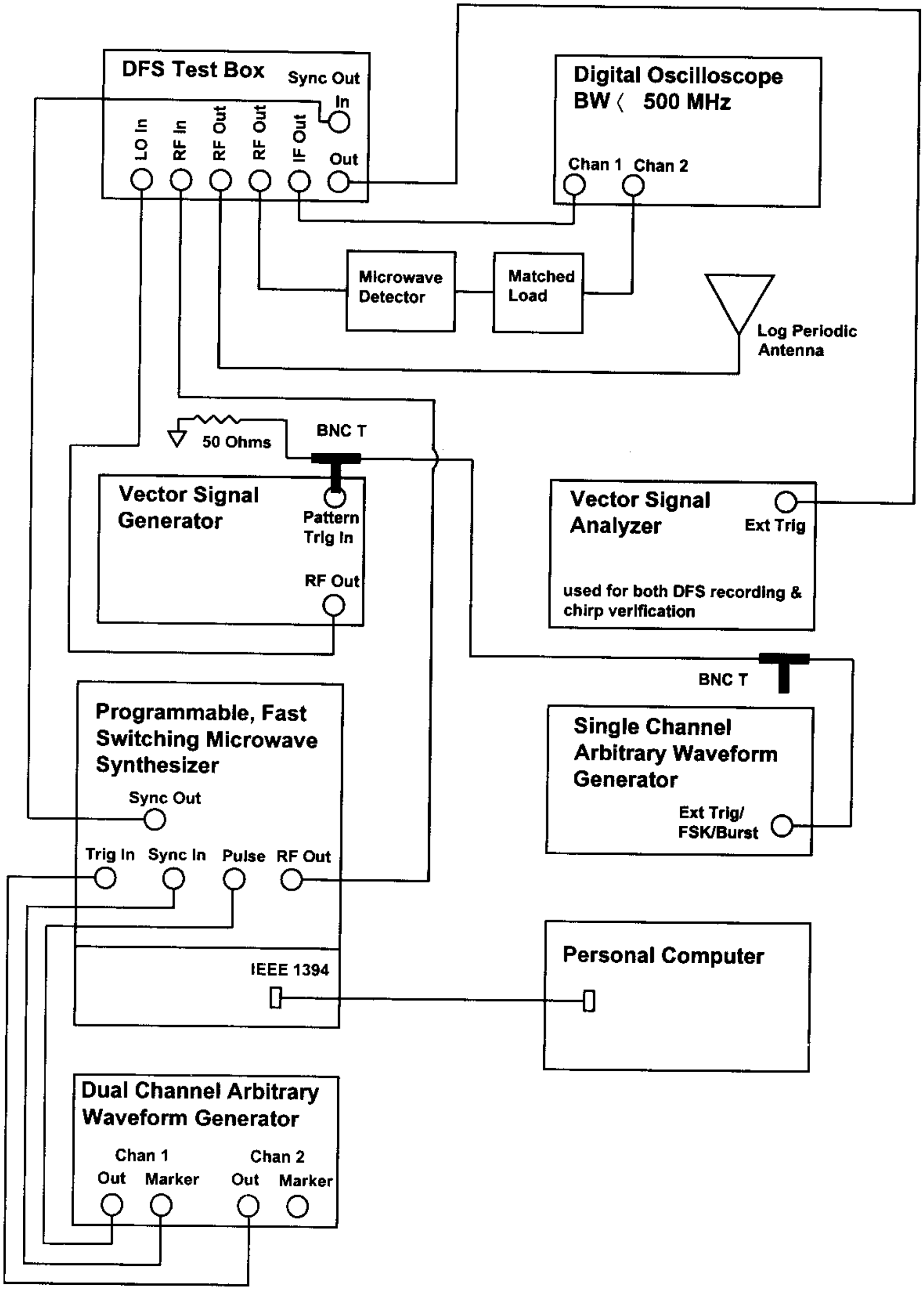

Figure 9b: ***Example Frequency Hopping Radar waveform Generator***

The first step in generating the Frequency-Hopping *Radar Waveform* is accomplished by entering 274 sets of hopping sequences of the randomized 475 hop frequencies into a frequency list stored in memory in the fast-switching microwave synthesizer.

Generation of the Frequency-Hopping *Radar Waveform* proceeds as follows: The center frequency of the microwave synthesizer is set according to the frequency list in the synthesizer's memory. The microwave synthesizer is set up to run for 10 seconds at a time (one *Burst* period).[7] During the ten-second-burst period, every 3 milliseconds the microwave synthesizer switches (hops) to the next frequency in the frequency list. The microwave synthesizer's center frequency is pulse modulated by a pulse train that consists of a *Burst* of 900 pulses (each with a 1 microsecond pulse width) that occurs at the beginning of the ten-second-burst period. The PRI of the *Burst* is 333 microsecond. Therefore, the hopping sequence length is 300 milliseconds and there are 9 pulses per frequency hop.

Because the pulses occur within the first 300 millisecond of the ten-second-burst period, only the first 100 frequencies out of a given set of 475 randomized frequencies are actually transmitted. Therefore, it is possible for none of the transmitted frequencies during a ten-second-burst period to fall within the receiver bandwidth of the U-NII device being tested. Whenever this occurs the particular ten-second-burst period will not included in the performance of the U-NII device.

[7] Up to 40 ten-second-burst periods may be run with unique random frequency hop sets. These 40 ten-second-burst periods may be transmitted one at a time or any number of them may be transmitted contiguously. After all 40 ten-second-burst periods have been transmitted, the test needs to be restarted at the beginning of either the current frequency list or a newly loaded, different frequency list.

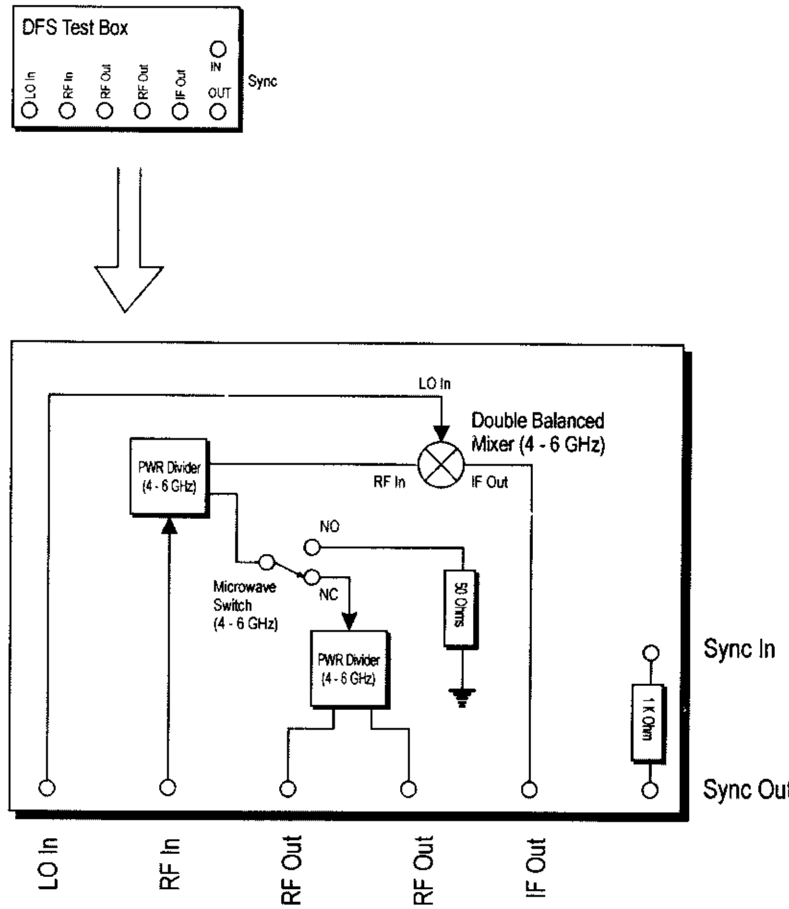

Figure 9c: Example DFS Test Box

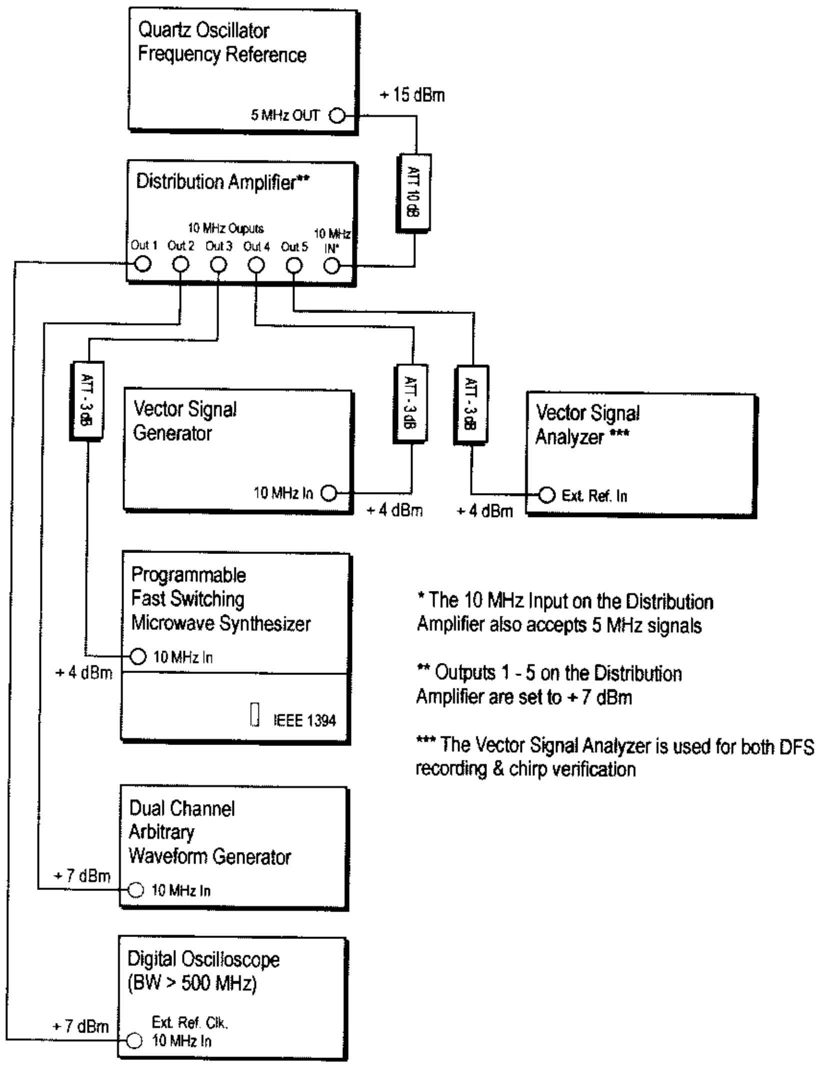

Figure 9d: Example Reference Oscillator Distribution

Quartz Oscillator Frequency Reference

The quartz oscillator provides a 5 MHz frequency reference signal that is distributed to the signal generators and measurement equipment via the distribution amplifier.

Distribution Amplifier

The distribution amplifier takes the 5 MHz frequency reference signal from the quartz oscillator, doubles it and distributes the resulting 10 MHz frequency reference signal to the critical signal generators and measurement equipment. This ensures synchronization of the signal generators and measurement equipment.

Digital Oscilloscope

The digital oscilloscope is used to examine the down-converted or detected radar transmissions in a full 500 MHz bandwidth. This is used to verify that the radar transmissions comply with the parameters as specified by the radar test waveforms.

Dual Channel Arbitrary Waveform Generator

The dual channel arbitrary waveform generator (AWG) is used when the system is configured to transmit frequency-hopping waveforms. The dual channel AWG produces two synchronized pulse trains that provide signals to control the fast-switching microwave synthesizer. One pulse train controls the microwave synthesizer switches (hops) to the next frequency in the frequency list. The other pulse train pulse modulates the RF output of the microwave synthesizer.

Microwave Detector and Matched Load

The microwave detector is used to monitor the envelope of the RF radar transmissions on the digital oscilloscope.

Radar Transmit Antenna

For radiated tests a log periodic antenna or equivalent directional antenna is used to transmit the *Radar Waveforms* to the DFS device during testing of the U-NII device.

Single Channel Arbitrary Waveform Generator

The single channel AWG is used when the *Radar Waveform* generator system is configured to transmit the Short Pulse Radar Type 1-5 waveforms. The single channel AWG is used to generate a trigger signal to begin transmission of the *Radar Waveform* and begin recording U-NII transmissions on the vector signal analyzer (VSA).

DFS Test Box

The DFS Test Box is constructed using off-the-shelf components.[8] The DFS Test Box facilitates signal routing and monitoring for the radar transmissions. The radar transmissions are routed to the RF input of the DFS Test Box. The IF output provides a down-converted version of the RF radar transmissions. Two ports are available for RF output. One is connected to the log periodic antenna for radiated testing of the U-NII devices or directly to the UUT for conducted testing. The other RF output is connected to a microwave detector to display the envelope of the RF radar transmissions. Both the IF output and the detector output can be observed on the digital oscilloscope in a full 500 MHz bandwidth. This allows observation of the frequency-hopping signal that hops across 475 MHz. Both the IF output and the detector output can be used to verify *Radar Waveform* characteristics. The detector output can also be used to verify that an RF output signal is present.

Vector Signal Generator

When the *Radar Waveform* generator system is configured to transmit the frequency-hopping signal, the vector signal generator (VSG) is used as a 5225 MHz continuous-wave (CW) signal source for the local oscillator (LO) input to the DFS Test Box. When the *Radar Waveform*

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[8] A complete description of the example DFS Test Box is available at http://ntiacsd.ntia.doc.gov/dfs/.

generator system is configured to transmit radar type 1-5 waveforms, the VSG is used to transmit the Short Pulse Radar Type 1-5 waveforms. The Short Pulse Radar Type 1-5 waveforms are created using custom software.[9] After the waveforms are created they are loaded into the VSG.

Personal Computer
The personal computer is used to generate and load the frequency-hopping list into and properly set up the fast-switching microwave synthesizer.

Fast-Switching Microwave Synthesizer
When the *Radar Waveform* generator system is configured to transmit the Short Pulse Radar Type 1-5 waveforms, the microwave synthesizer is used as a 5225 MHz CW signal source for the LO input to the DFS Test Box. When the *Radar Waveform* generator system is configured to transmit the frequency-hopping signal, the microwave synthesizer is used to transmit the frequency-hopping signal. Custom software is used to generate and load the hopping frequency list into and properly set up the fast-switching microwave synthesizer. A pulse train generated by the dual channel AWG controls when the microwave synthesizer switches (hops) to the next frequency in the frequency list. Another pulse train from the dual channel AWG pulse modulates the RF output of the microwave synthesizer to complete the generation of the frequency-hopping signal.

Vector Signal Analyzer
The VSA is used for two distinct purposes. One use is to verify the chirped radar transmissions of the Long Pulse Radar Type 5 waveforms. The FM demodulation capability is used to verify the chirp frequency range. The other use of the VSA is to provide 12 and 24 second recordings of the U-NII device transmissions, with fine-time resolution, during DFS testing. When Long Pulse Radar Type 5 waveforms are transmitted, the 24-second recordings (with a time between samples of approximately 675 nanoseconds) are taken; 12-second recordings (with a time between samples of approximately 390 nanoseconds) are taken when all other *Radar Waveforms* are transmitted.

The VSA receives a trigger signal from the *Radar Waveform* generator system to initiate a recording. When the *Radar Waveform* generator system is configured to transmit the Radar Type 1-5 waveforms, the single-channel AWG provides the trigger signal. When the *Radar Waveform* generator system is configured to transmit the frequency-hopping signal, the microwave synthesizer generates the trigger signal when the frequency-hopping radar transmission first falls within *U-NII Detection Bandwidth.*

7.4.1.3 Method #2 Simulated Frequency Hopping Radar Waveform Generating Subsystem
The simulated frequency hopping signal generator system uses the hardware that is used to manually generate short pulse *Radar Waveforms* shown in **Figure 8**, with the addition of a control computer and a *Burst* generator to create the hopping trigger pulse pattern. The simulated signal generation approach produces both time-domain and frequency-domain

[9] A complete description of the software is available at http://ntiacsd.ntia.doc.gov/dfs/.