NTIA Technical Memorandum 18-527

Procedures for Laboratory Testing of Environmental Sensing Capability Sensor Devices

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technical memorandum

U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

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November 2017

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ABBREVIATIONS AND SYMBOLS

CBRS	Citizens Broadband Radio Service
CBSD	Citizens Broadband Radio Service Device
DFS	dynamic frequency selection
DPA	dynamic protection area
ESC	environmental sensing capability
FCC	Federal Communications Commission
GN	Gaussian noise
ITS	Institute for Telecommunication Sciences
LNA	low noise amplifier
LTE	Long Term Evolution
NTIA	National Telecommunications and Information Administration
OoB	out of band
OoBE	out of band emissions
OSM	Office of Spectrum Management
PCT	pre-certification testing
PN	Public Notice
PW	pulse width
PRR	pulse repetition rate
RB	resource block
RMS	root mean square
RSEC	radar spectrum engineering criteria
RF	radio frequency
SAS	spectrum access system
SE	standard error
U-NII	unlicensed national information infrastructure
VSG	vector signal generator

EXECUTIVE SUMMARY

The Federal Communications Commission (FCC) has adopted rules for Citizens Broadband Radio Service (CBRS) systems in the 3550–3650 MHz (3.5 GHz) band. This band is currently used mostly by radar systems; the intention of the new rules is to begin sharing of this radio band between radar systems and new communication systems. Even more sharing is anticipated in the future when new radar systems that are currently in development are eventually fielded in this band.

This 3.5 GHz band sharing is to be based upon detection of radar signals by CBRS systems, followed by mitigation steps to prevent harmful interference to incumbent radar receivers from the new CBRS transmitters,[1] called Citizens Broadband Radio Service Devices (CBSDs). A linchpin of this detect-and-avoid band spectrum sharing approach for CBRS systems will be Environmental Sensing Capability (ESC) sensors that will reliably detect and alert spectrum access system (SAS) administrators to the presence of Federal radar systems operating locally in the band. Working together as detectors and administrators, respectively, the ESCs and SASs will be responsible for ensuring that CBSD transmitters that may cause harmful interference to local Federal radar systems are either moved in frequency, powered down, or turned off to protect radar receivers.

The FCC requires ESCs, SASs, and CBSDs to be tested and then certified based on those test results. The testing of SASs and CBSDs is addressed in separate documents. This NTIA Technical Memorandum describes procedures and radar waveforms that will be used for testing 3.5 GHz ESCs for their responses to radar pulses in a laboratory environment. These test procedures and injected waveforms will be used to gather data on ESC pulse-detection performance. The ESCs that will be tested will be provided by companies (applicants) that intend to operate them in the field. The data gathered via these laboratory performance tests will be provided to the FCC to support that agency’s certification process for eventual ESC field operations by each applicant.

This document is the best guideline for ESC laboratory testing that can be compiled by the government at the time of publication. This document is not necessarily comprehensive regarding all testing that ultimately may or should ever be performed on any ESC system. Technical procedures and approaches described in this report may be deleted, expanded, or otherwise modified in the future as experience is gained with ESCs. Such changes would be based on inputs from industry and government agency stakeholders, and on contingencies that may arise from changes in future ESC certification requirements and in the designs of future ESC systems. However, no near-term change to the described testing procedures or radar signal parameters for ESCs as given in this document is expected.

[1] Mobile user equipment (UE) transmitters may also cause some interference to radars. But CBSDs are considered to be the dominant interferers due to their antenna heights and power levels. We will therefore refer to them as the only interference source for radar receivers throughout this report.

PROCEDURES FOR LAB TESTING OF ENVIRONMENTAL SENSING CAPABILITY SENSOR DEVICES

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A planned procedure is described for testing 3.5 GHz environmental sensing capability (ESC) devices for their responses to radar pulses in a laboratory environment. These test procedures will be used to gather data on ESC pulse-detection performance. The data gathered via these procedures will be provided to the Federal Communications Commission (FCC) to support that agency's certification process for eventual ESC field operations. This document is the best guideline for ESC laboratory testing that can be compiled by the government at the time of publication. This document is not necessarily comprehensive regarding all testing that ultimately may or should ever be performed on any ESC system. Technical procedures and approaches described in this report may be deleted, expanded, or otherwise modified in the future as experience is gained with ESCs. Such changes would be based on inputs from industry and government agency stakeholders, and on contingencies that may arise from changes in future ESC certification requirements and in the designs of future ESC systems. However, no near-term change to the described testing procedures or radar signal parameters for ESCs as given in this document is expected.

Keywords: Citizens Broadband Radio Service (CBRS); Citizens Broadband Service Device (CBSD); environmental sensing capability (ESC); radar; radar detection; radar waveforms; spectrum access system (SAS); spectrum sharing

1. INTRODUCTION

The Federal Communications Commission (FCC) has adopted rules for Citizens Broadband Radio Service (CBRS) systems in the 3550–3650 MHz (3.5 GHz) band.[4,5] This band is currently

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[3] The last three authors are with the Office of Spectrum Management (OSM), NTIA, U.S. DoC, Washington, DC 20230.

[4] 47 C.F.R. Part 96 - Citizens Broadband Radio Service; Amendment of the Commission's Rules with Regard to Commercial Operation in the 3550-3650 MHz Band, GN Docket No. 12-354, *Report and Order and Second Further Notice of Proposed Rulemaking*, FCC 15-47, 30 FCC Rcd 3959 (2015); Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket No. 12-354, *Order on Reconsideration and Second Report and Order*, FCC 16-55, 31 FCC Rcd 5011 (2016).

[5] Mobile user equipment (UE) transmitters may also cause some interference to radars. But CBSDs are considered to be the dominant interferers due to their antenna heights and power levels. We will therefore refer to them as the only interference source for radar receivers throughout this report.

used mostly by radar systems; the intention of the new rules is to begin sharing of this radio band between radar systems and new communication systems. Even more sharing is anticipated in the future when new radar systems that are currently in development are eventually fielded in this band.

This 3.5 GHz band sharing is to be based upon detection of radar signals by CBRS systems, followed by mitigation steps to prevent harmful interference to incumbent radar receivers from the new CBRS transmitters, called Citizens Broadband Radio Service Devices (CBSDs). A critical component of CBRS systems will be Environmental Sensing Capability (ESC) sensors that reliably detect and alert their associated spectrum access system (SAS) administrators to the presence of Federal radar systems operating in the 3.5 GHz band [1]. Each SAS will be responsible for ensuring that CBSD transmitters that may cause harmful interference to Federal radar systems in their coverage areas take mitigating actions (e.g., move in frequency, power down, or turn off).

The ESCs and SASs will be the technical linchpins of the detect-and-avoid band spectrum sharing approach for CBRS systems. The FCC requires ESCs and SASs to be tested and then certified based on partly on test results. The testing of SASs is addressed in separate documents. This NTIA Technical Memorandum describes procedures and radar waveforms that will be used for testing 3.5 GHz ESCs for their responses to radar pulses in a laboratory environment. These test procedures and injected waveforms will be used to gather data on ESC pulse-detection performance. The ESCs that will be tested will be provided by companies (applicants) that intend to operate them in the field. The data gathered via these laboratory performance tests will be provided to the FCC to support that agency's certification process for eventual ESC field operations by each applicant.

The major Department of Defense (DoD) radar currently operating in the 3.5 GHz band is known as Shipboard Radar 1. It is an older and relatively simple pulse-modulated radar that uses a pulse width (PW) of about 0.9 microseconds[6] and a fixed pulse repetition rate (PRR) of about 1000 pulses per second while running on a single frequency per radar [2], [3]. However, for the analyses of the interactions of the ESC sensors, CBSD stations, and Federal radar systems, the Shipboard Radar 1 was not the only radar waveform considered. Additional shipborne radar systems and ground-based radar systems, operating both in-band and in an adjacent band, were also considered in the analyses. All of these radar systems need to be protected and some leeway must be provided for future systems as well.

To properly test ESCs for their ability to detect radar signals, specific parameters will be developed and used for radiofrequency (RF) test signals. These RF signals will be programmed into vector signal generators (VSGs) to test the ESC's response to the test waveforms. The ESC's ability to take appropriate actions to notify the associated SAS upon detection and declaration of the waveforms is also to be tested.[7, 8]

[6] As measured at the 3 dB power points on the detected pulse envelope.

[7] SAS testing will be performed separately. If an ESC unit cannot be tested without a SAS interface, then the ESC test protocols will require that a minimal SAS interface be provided, only as much as is required to complete ESC tests.

This Technical Memorandum lists 3.5 GHz test radar waveforms that will be used for ESC testing. It describes the procedures in which these waveforms will be used to test an ESC's ability to reliably detect and declare radar waveforms in a timely manner, by producing some type of notification flag or announcement to the personnel conducting the tests that detection has occurred. Key performance indicators for ESC sensors are:

1) Timely detection of radar pulses at a specified power threshold of -89 dBm/MHz in ESC receiver circuits

2) Ninety-nine percent (99%) ESC probability of radar declaration within 60 seconds at the specified detection threshold

3) ESC detection and declaration in the presence of CBSD-like (Gaussian noise) environmental background radiation at a specified root mean square (RMS) power of -109 dBm/MHz in an ESC receiver circuit

4) Verification that ESC detection and declaration occurs across the entire 3550–3650 MHz band

5) Demonstration of proper ESC operation in the presence of high-power radar signals, those signals being both in-band (3.5 GHz band) and adjacent band (out of band (OoB)).

This Technical Memorandum has been written so that Industry and and Federal agency stakeholders can better understand ESC performance objectives and the methods and procedures that will be used to test them.

[8] The necessary distinction between detection of radar pulses by an ESC and the declaration by an ESC that a radar is in a dynamic protection area (DPA) is described in [4].

2. BACKGROUND

In the past two years the National Telecommunications and Information Administration (NTIA) undertook a test program with industry to investigate the effects of radar pulses on Long Term Evolution (LTE) receivers, publishing two reports [5], [6] on the results. The radar waveforms used in those tests were developed by reviewing the technical characteristics of two operational systems and adding variability to the pulse widths, pulse repetition rates (PRRs), and pulse modulations so that various current and future radar systems' parameters would be addressed without specificity to any one system. For 5 GHz unlicensed national information infrastructure (U-NII) dynamic frequency selection (DFS) rules, a similar set of test certification radar waveforms was developed, and that set has been used by the FCC for device certification since 2006, with some revisions having been made along the way to address new technology.

Like the radar waveforms that were used for [5] and [6], the DFS radar test waveforms (called bins) parametrically span the space of pulse widths, PRRs and modulations for present and future radars in the 5 GHz band; however, the DFS waveforms do not represent any one specific existing or future 5 GHz radar waveform. Those bins' technical characteritics are published in the Code of Federal Regulations (CFR). In the development of the 3.5 GHz Report and Order the FCC elected not to publish any specific radar test waveforms to be used for ESC certification. The FCC decided to rely instead on using a non-CFR vehicle (this Technical Memorandum) for publication of those waveforms.

This Technical Memorandum provides guidance to industry for the FCC certification process for the test and evaluation of ESCs. NTIA's research and engineering laboratory in Boulder, Colorado, the Institute for Telecommunication Sciences (ITS), with assistance from NTIA's Office of Spectrum Management (OSM), will perform the ESC certification tests described in this Technical Memorandum.

3. 3.5 GHZ RADAR TEST WAVEFORM BINS

3.1 Waveforms for Full ESC Performance Certification

Radars that operate in and adjacent to the 3.5 GHz band use two pulse types: unmodulated (code-designated P0N in their Government Master File assignments) and frequency/angle modulated (with assignments designated Q3N, chirped). Note that there is no constraint on existing or future Federal radar designs or developments for the 3.5 GHz band; current and future radar transmitters and receivers must only meet the Radar Spectrum Engineering Criteria (RSEC) requirements [7].

Table 1 lists the range of P0N and Q3N signal parameters proposed for FCC certification of 3.5 GHz ESC monitoring systems. The test-signal parameters encompass the parameter range of current and future 3.5 GHz radar signals that ESCs must be able to detect. If new (future) radar systems eventually have pulse parameters that exceed those of Table 1, the testing parameters will be modified accordingly and industry will be expected to detect them as well, with reasonable notice.

Radar test signals will be created by selecting from the range of pulse widths, chirp bandwidths, and PRRs listed in Table 1. In any one waveform burst, the parameters will be fixed to a randomly (or pseudo-randomly) value chosen for it but bounded by the minimum and maximum values of Table 1.

Each row of the table is called a waveform bin; the first row is Bin 1, the second row is Bin 2, and so forth through Bin 5 in the last row. Each bin as shown in the rows of Table 1 represents a parameter that encompasses specific existing or anticipated future radar designs. For each bin, multiple waveforms will be generated for the tests, but they will always be bounded by the upper and lower limits for the waveform parameters.

A delta is provided for each waveform parameter in Table 1. These deltas are the minimum step size that will be used when varying any given parameter within its available range. But any given change in a parameter from one testing trial to the next may be larger than the stated delta. For example in Waveform P0N #1 (Bin 1), one series of test pulses could be each be 0.5 μs wide in a first trial. For the next trial for that bin the pulse width might be set to 0.6 μs wide, but 0.7, 0.8, 0.9 μs, etc., might as well be used. Likewise, PRR may change between trials, but again only in accord with the minimum delta listed for PRR for each bin. For the chirped waveforms, the pulse width, PRR, and chirp width may all change from one burst of pulses to the next.

A single burst (group) of pulses (see [4] for some examples of pulse bursts) for each bin defines a single trial or event and is used to simulate the dwell of a radar's directional antenna beam as it would momentarily (for a few milliseconds) illuminate an ESC receiver. ESC are supposed to detect those bursts of pulses. A test log maintained by the test engineers will indicate a "yes" if the event (a burst of pulses fired into the ESC) is detected or "no" if the event is not detected. The test waveform parameters will be held constant for all pulses within each burst, but may be varied from one burst to the next. An ESC under test will be given up to five seconds to respond to each burst of pulses, to indicate that it has detected the event.[9] The test log will note that the ESC failed to detect a burst for a given trial if the indication is not given in that five second window. The delta insures that the minimum value of the change for that particular parameter is adhered to.

In Table 1, *Δ* is the change increment for any given waveform parameter, and is the minimum increment for changes in that parameter when generating the test waveforms. *Min Burst* is the minimum burst length for pulses. Chirped-pulse frequencies will be the center frequency of the pulses.

Table 1. Radar signal parameter bounds for 3.5 GHz ESC compliance testing.

Pulse Modulation	**Pulse Width (μs)**	**Chirp Width (MHz)**	**PRR (pulses per second)**	**Pulses per Burst (Min to Max)**	**Comments**
P0N #1	0.5 to 2.5 Δ = 0.1	N/A	900-1100 Δ = 10.0	15 to 40 Min Δ = 5	Similar to currently deployed Radar 1
P0N #2	13-52 Δ = 13	N/A	300-3000 Δ = 10.0	5 to 20 Δ = 5	Simulates possible phase-coded waveforms that could be used in future radar modulations
Q3N #1	3-5 Δ = 1.0	50-100 Δ = 10	300-3000 Δ = 30	8 to 24 Δ = 2	Simulates possible future multi-function Q3N-type radar • Short τ • Wide Bc
Q3N #2	10-30 Δ = 1.0	1-10 Δ = 1	300-3000 Δ = 50	2 to 8 Δ = 2	Simulates possible future multi-function Q3N-type radar • Intermediate τ • Intermediate Bc
Q3N #3	50-100 Δ = 5.0	50-100 Δ = 10	300-3000 Δ = 100	8 to 24 Δ = 2	Simulates possible future multi-function Q3N-type radar • Wide τ • Wide Bc

For each waveform, MATLAB® code will be used to generate random files bounded by the waveform's limits for each parameter, and then loaded (programmed) into a VSG to generate random waveforms at the radio frequency (RF) level. The radar signal parameters will be selected randomly. (e.g., by a uniform distribution). Any additional inputs that might be needed such as LTE or random Gaussian noise (GN) will likewise be generated by a VSG.[10] ESC designers interested in the relationship between the measured signal power and the optimal measurement bandwidths for frequency-modulated pulsed signals may consult [8]; the authors of that report can be contacted for additional information or clarification about that topic.

[9] This requirement will not apply to a bin not listed in Table 1, called Bin 1 Lite. As noted in Appendix A, ESCs will be given 60 seconds to respond to a series of bursts spaced 3.9 seconds apart duing Bin 1 Lite testing.

[10] Each ESC operator (applicant) applying for operational ESC status with the FCC may contact the ITS authors of this Technical Memorandum to obtain the MATLAB code used to generate the waveforms.

3.2 Bin 1 Lite Waveform Testing for Optional (Interim) ESC Performance Certification

Every ESC design will be required to eventually pass certification tests using the five waveform bins described in Table 1. In the interest of moving ESC certification forward in the timeliest possible fashion, however, a single optional, interim waveform will be made available for a certification to temporarily deploy and operate ESCs at field sites. This waveform is a restricted version of P0N #1 (Bin 1); it is called Bin 1 Lite. Appendix A of this Technical Memorandum provides a full description of this waveform.

Bin 1 Lite is supposed to replicate the waveform of Radar 1 that is already deployed and operational in the sharing band. As further described in the Appendix, applicants may exercise a completely voluntary option to obtain preliminary, temporary certification for ESC operations by only passing Bin 1 Lite testing. But whether or not they exercise that option, all ESC designs will eventually be required to pass certification testing with all five of the bins shown in Table 1 in order to maintain long-term operation of their ESCs in support of SAS and CBSD networks in the field.

3.3 Pre-Certification Testing (PCT) of ESCs at the ITS Boulder Laboratory

Performance testing of ESCs at the ITS Boulder laboratory will generate data that will be submitted to the FCC for authorization to operate ESCs at field sites. This is called certification testing. But prior to each ESC's certification testing, each applicant will bring their ESC to the Boulder laboratory for up to a week (40 working hours) of so-called pre-certification testing (PCT).

PCT will be a very important part of the ESC certification testing process, even though it will itself involve no actual certification testing. Fundamentally, the purpose of PCT is to allow applicants to experiment with their ESC designs, with the support of ITS engineers, to see how well their designs are able to function when they are exposed to the same waveforms (the regular Bins 1-5 and the Bin 1 Lite waveform, if desired) as will be used in certification testing.

Unlike certification test results, PCT results will not be used to support applications to the FCC for ESC certification; the PCT results will not affect certification prospects of any ESC. In fact, no formal tests will be performed on ESCs during PCT. The purpose of PCT is to allow applicants' ESC design and development engineers to work with ITS engineers to gain experience with their devices in the testing environment without any formal testing being done.

Some identified tasks for each ESC during PCT are:

- Allow ITS engineers to show applicants' ESC engineers the ITS system for injecting radar pulses and GN into their ESCs during subsequent certification testing.

- Expose each ESC design (including prototypes) to all five of the pulse waveform bins of Table 1, with and without background GN, to help applicants ascertain whether they might want to pursue the option for initial Bin 1 Lite testing versus exercising the option of going directly to certification with the five bins of Table 1.

- Work with ESC engineers on detection performance of Bin 1 pulses, with and without background GN, to help applicants ascertain whether they might want to pursue the option for initial Bin 1 Lite testing versus exercising the option of going directly to certification with the five bins of Table 1.

- Examine ESC performance with Bin 1 Lite waveform, both with and without background GN, for applicants who plan to obtain initial, temporary FCC certification to operate their ESCs with Bin 1 Lite waveform testing.

- Establish, with ITS engineers, the physical connection protocols required for each ESC, both for RF pulse injection and for detection-alert outputs.

- Allow ITS engineers to note the structure of messages an ESC sends when it has detected a radar burst.

- Allow ITS engineers to note the structure of messages an ESC sends when it is communicating a radar declaration to a SAS (if different from the message generated by an ESC when a radar burst has been detected).

- Check ESC performance with radar pulse frequencies being varied across the entire 100 MHz of the 3.5 GHz sharing band on a burst-to-burst basis.

- Observe ESC behavior and performance in the presence of radar pulse levels at the saturation levels shown and described in [10].

- Observe ESC behavior and performance when the -89 dBm/MHz detection threshold is always exceeded by the radar main beam, sidelobes, and backlobes. This condition will occur when a radar does not transmit as a ship moves close to shore (runs quiet), and is turned on when a ship is already either very close to shore or is in port.

- Examine the adequacy of ESC RF front end filtering for rejection of high-power OoB pulses (transmitted by radars running below the lower edge of the 3.5 GHz sharing band).

- Observe ESC behavior and performance when pulses that are supposed to be detected by the ESC are injected along with a second set of pulses that represent OoB emissions from a radar that operates in an adjacent band, below the lower edge of the 3.5 GHz sharing band.

4. TEST PROCEDURES AND TYPES

4.1 Procedures

From past experience, we have found that the best way to perform tests like these in a laboratory is to use closed loop methods in which a network of RF cables, combiners and splitters is used to inject radar waveforms and other waveforms (for these tests, GN) into receivers. Such a set-up is shown in the block diagram of Figure 1. Using hardline coupling between the testing hardware and the device under test (DUT, in this case an ESC), propagation factors are eliminated (i.e., controlled in the test and deterministic) from the test and the results are solely based on the calibrated power levels of the injected RF energy and the ESC's ability to detect the waveforms.

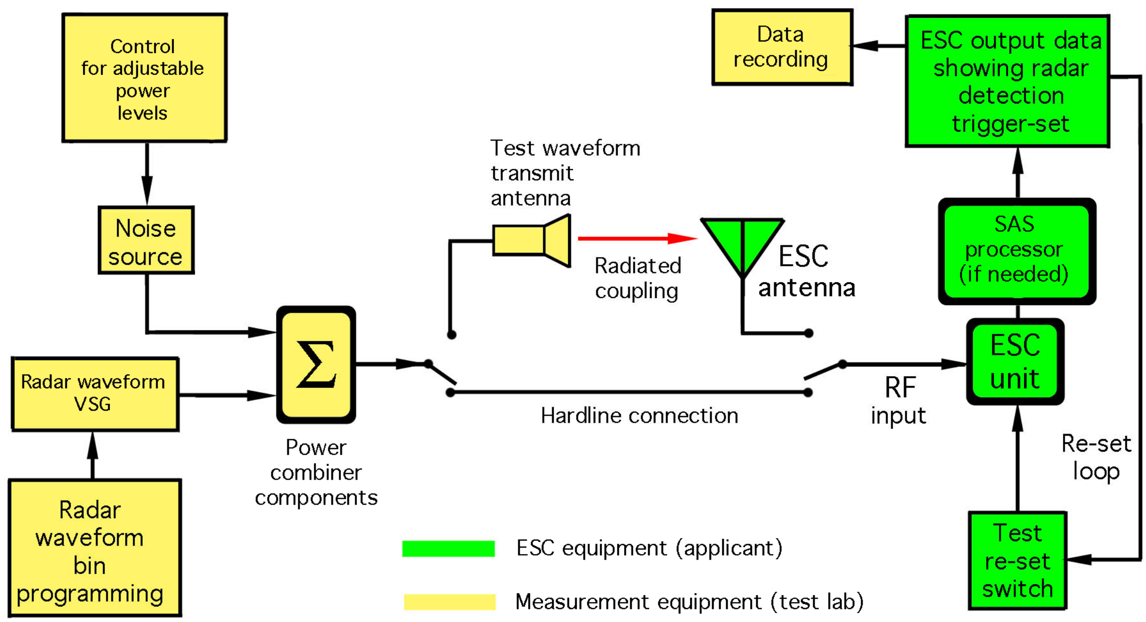

Figure 1. Schematic block diagram for ESC performance testing.

Radiated tests require calibration of the received power level of the radar pulses through the ESC antennas, a step that can be obviated if the coupling is done via hardline instead. Although from the standpoint of expedited testing (and to some extent for simpler testing) it is preferable to couple the ESC to the test system on a hardline, the testing can be performed utilizing radiative coupling. Radiated testing may be necessary if the ESC has an integral (built-in) antenna that cannot be disconnected from the sensor's body (see the process flowchart in Figure 2, below). In Figure 1, this option for radiated versus hardline coupling is drawn as a switch between the two possible test paths. (The switch shown in the figure is not a real hardware switch, but rather is a logical procedure-option switch.)

For these tests, each radar waveform bin in Table 1 (or the Bin 1 Lite waveform if that option is pursued by an applicant) is evaluated for a (nominal) minimum of 100 trials per waveform. (See [4] for details about the number of trials required to determine probability of declaration.) Each trial consists of a burst of pulses with the peak power levels of the radar pulses set to a constant value as measured in a 1 MHz bandwidth at the ESC's antenna input, for every waveform type. Each trial will be unique but will be bounded by that waveform's upper and lower limits on the pulse width, PRR, and pulse-chirp bandwidth as shown in Table 1. Custom MATLAB environment code will be used to produce random numbers to generate the test waveforms for each trial for each waveform type.

4.2 Background Noise Component in ESC Testing

ESCs are expected to operate and detect-declare (see [4]) radar signals in the presence of background noise from individual nearby CBSDs plus aggregates of more CBSDs at larger distances from the ESCs. Thus, a phase of 3.5 GHz ESC testing is needed in which background noise will be present when the ESCs are tested for radar detection responses. Industry has reported that early, initial CBSD deployments are expected to utilize LTE based air interfaces, at least during initial deployments in the CBRS system, and that other types of wireless broadband may also be deployed at some point. But no specific type of air interface or technology is specified or required by the FCC rules for CBSDs.

LTE signals switch individual resource blocks (RBs) on and off non-deterministically. RB duty cycles are low (usually transmitting during just a few percent of any given time interval). The non-deterministic and low duty cycle behavior of LTE RBs mean that LTE signals do *not* have definable average power levels. The non-deterministic, impulsive, and non-definable characteristics of LTE signals make them unsuitable for laboratory certification purposes, as there is no way to set up a realistic, repeatable LTE signal with a defined mean power level for such testing. Putting together aggregates of individual LTE signals to produce "aggregate LTE" signals is still more problematic for laboratory certification testing purposes.

Another problem with using LTE signals for certification test purposes is that LTE signals are not theoretically tractable for analytical purposes because LTE signals lack the first-order statistics (e.g., definable mean power levels) that are needed for theoretical modelling. This means that there is no practical[11] way to check actual measurement results of LTE-derived interference testing against theoretical LTE models. There is no single agreed source of LTE signal generation for background interference certification testing purposes. This means that LTE signals cannot be implemented by multiple test-and-certification labs with any guarantee that labs are using comparable LTE testing signals.

If LTE is implemented for testing, then the LTE signal must either be a recording of an actual LTE, played in a continuous loop, or else it must be generated synthetically using a programmable VSG. In neither case is true LTE being used—both approaches generate and use an artificial sort of LTE signal.

There is an alternative to using true LTE signals for interference testing, and that is GN. LTE base station emissions have the same statistical characteristics as GN, as described at length in Appendix A of [9]. GN has all of the characteristics that LTE lacks for use in laboratory

[11] Some comparison might conceivably be achievable between a vast number of laboratory tests using LTE signals and millions of theoretically simulated interference data points using LTE signals. But the scale of effort would be a project in itself; it is beyond the scope of this testing and certification effort.

certification testing: it has a well-defined set of first-order characteristics (including a well-defined average power level and well-defined statistical fluctuations around that mean); its impulsiveness is well-defined in terms of known amplitude-probability distributions; and it can be implemented independently by all testing laboratories without recourse to any pre-recorded or pre-generated LTE reference sequence that all testing labs would have to copy from some original, certified source.[12] And GN can be implemented in theoretical models for comparison of actual test results to predicted results. The only characteristic of GN that needs to be defined for laboratory testing purposes is the mean power level that will be coupled into the ESC receivers via the testing system, in combination with the radar waveforms.

An additional advantage of using GN for interference testing purposes is that GN is always completely uncorrelated with any signal structure; GN can be considered to be worst-case for interference testing purposes, as compared to using any other signal type for interference-case performance testing.

As shown in Figure 1, this background noise component will be added to the radar pulses during testing. This option is shown as a logical switch in Figure 1 that allows the noise component to be added into the signal chain. A VSG will be programmed to produce an emission that looks like a GN in the 100 MHz bandwidth of the sharing band.[13]

Each ESC will first be tested for each radar waveform type, as described above, with no additional background GN, i.e., in a "clean" RF environment in which the radar pulses are the only component that the ESC needs to address. If an ESC fails "clean environment" testing for a given radar waveform, testing with that waveform will go no further. But if the ESC passes radar waveform testing in the clean RF environmental condition, then the testing will progress to another stage. The goal of this phase of the ESC testing will be to determine whether each ESC still detects-declares radar pulses at the specified performance level of 99% with 1% standard error (SE) in the presence of -20 dB of GN noise power in a 1 MHz bandwidth. In this second stage for each waveform, GN will be added at a level of -20 dB RMS GN power below the peak radar pulse power. If the peak radar pulse power is -89 dBm/MHz, then the GN will be injected at an average RMS power level of -109 dBm/MHz.[14] As already noted, this GN power level will be maintained across the entire 100 MHz of the sharing bandwidth.

4.3 ESC Configurations for Testing

ESC configuration will include both pre-certification lab work and certification-stage work. Figure 2 shows the process flow for ESC preparation by applicants, and the process by which NTIA will determine whether ESC tests will be performed with radiated or hardline coupling.

[12] An original certified LTE source would itself have to be agreed to by all parties, maintained in a central repository with ongoing customer support, and made available indefinitely.

[13] GN is mathematically-statistically defined and can therefore be generated without the use of any standard recording or reference file data. But for convenience, ESC designers can contact ITS engineers to obtain a copy of the MATLAB file used by ITS to generate the GN signal, if desired.

[14] If applicants wish to have their ESCs tested at higher levels of GN than the default of -20 dB average, they can request such levels. But then all testing will be done at those levels and if the devices fail at those levels they will fail this part of the testing overall.

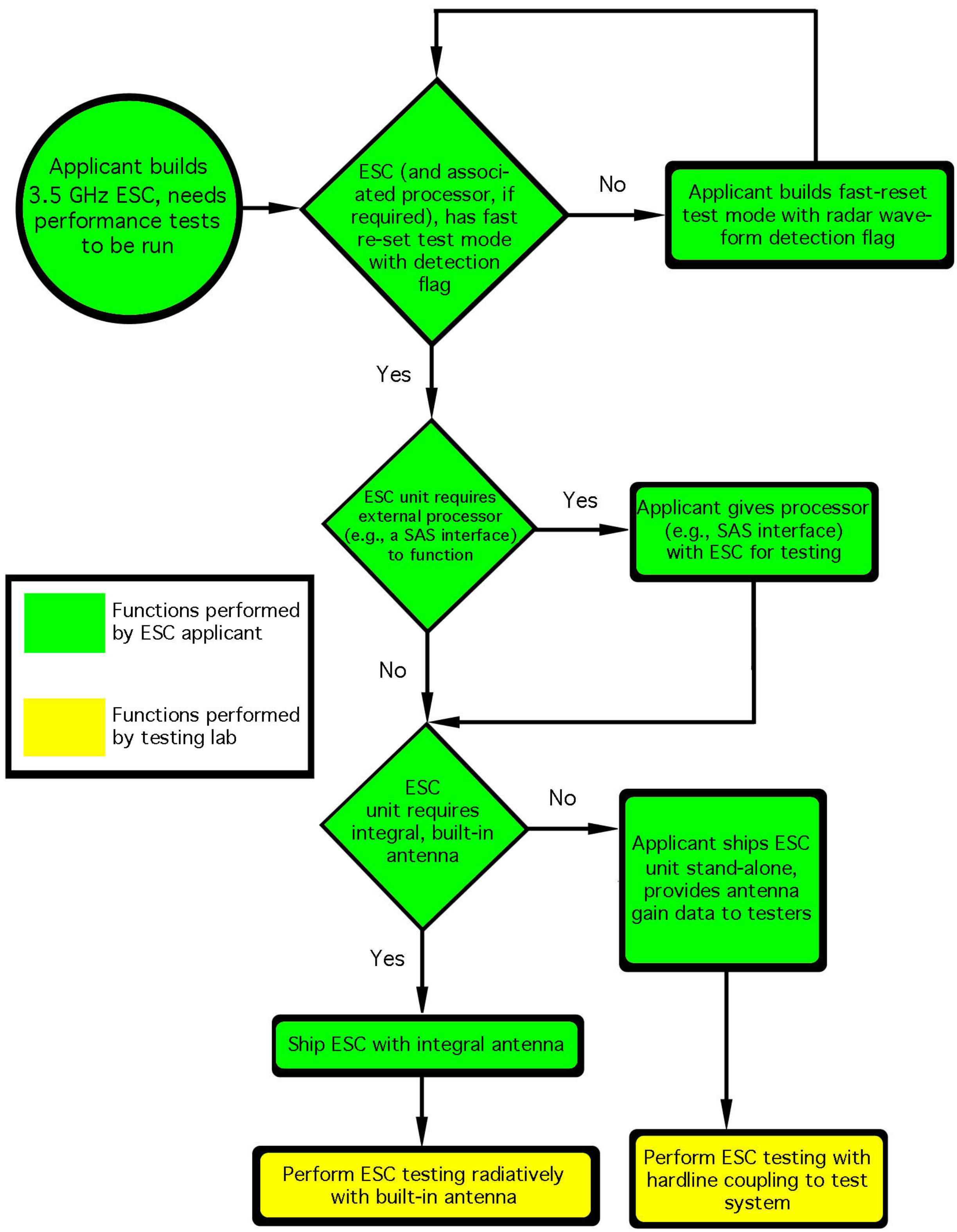

Figure 2. Process flowchart for ESC test preparation and radiative versus hardline coupling to the testing system.

Applicants are expected to provide a test harness for their ESC sensor to enable the tester to rapidly reset (in a few seconds) the ESC sensor following each test trial and to measure ESC outputs such as detection events, declaration of radar presence, which CBSD channel (or radio frequency) the radar was detected on, and any other data that the ESC sensor will communicate to the ESC decision system or associated SAS.

4.3.1 ESC Post-Detection Fast-Reset Capability Requirement

As shown in Figure 2, NTIA will not test ESC units unless they incorporate a built-in, post-radar waveform detection fast-reset (a few seconds) capability. That is, they must either automatically re-set after radar waveform detections or else they must have a manual fast re-set capability. This capability would presumably be used only for testing compliance purposes and need not be integrated or included in field-deployed ESCs.

4.3.2 Tester-Readable Radar Waveform Detection Event Requirement

The ESCs must have an output that shows radar waveform-burst detections every time they happen. The detection-event outputs need to be readable by the testers, either in a machine-readable format (e.g., by a PC) or as a visual output of some sort.

4.3.3 Stand-Alone ESCs Versus ESCs Requiring Additional Gear for Detection

Some ESC designs will determine internally, without reference to outside systems such as the SAS or central processing centers, whether a radar waveform is present. Such ESC units will be tested stand-alone. But for ESC designs that require communication with an outside system (e.g., ESC designs in which the ESC is simply an RF front-end and downconverter that feeds a raw RF data stream to another system, such as a SAS or some other sort of central processor), the ESC units that are supplied for testing will need to be shipped to the testers with enough adjunct equipment to stand in for this outside-ESC capability. The outside processing units will themselves need to be provided with an output that the testers can read and a fast-reset capability to be used after each radar waveform detection. Again, the fast-reset capability is expected to be a test-only mode for the ESCs and their associated processors.

4.3.4 ESCs Using Integral Versus Detachable Antennas

Some ESC designs may have integral built-in antennas that cannot be disconnected from the ESC receiver electronics. These units will be tested using radiated coupling, with the waveforms radiated into the ESC antenna as shown in Figure 1 and described in the process flowchart of Figure 2. Other ESCs may use antennas that can be disconnected from the receiver electronics. These ESCs will be tested with hardline connections to the testing system, again as shown in Figures 1 and 2.

ESCs with detachable antennas may be shipped to the testers along with their (detached) antennas, for optional radiated testing if time permits. Whether those antennas are shipped or not, the testers will need to be provided with antenna gain data for the ESC antennas, so that the antenna gain values can be added (or subtracted, as the case may be) to the required radar waveform detection threshold power levels within the ESC receivers during testing.

It is emphasized that all ESC testing will be performed with peak radar pulse power levels adjusted to -89 dBm/MHz at the RF input port of the ESC. Likewise GN will always be adjusted to -109 dBm/MHz RMS average at the same RF input port.

4.3.5 3.5 GHz Test Types: Clean RF Environment vs. Added Signals & Noise

For the 3.5 GHz tests, two types are anticipated to be required: detection of the radar waveform bins (with and without background noise interference) as drawn from the five waveform rows of Table 1, or else Bin 1 Lite, and a frequency-range detection test (multiple frequencies checked across the 3.5 GHz band), described more fully below.

4.3.6 Radar Waveform Detection in a Clean Environment

In this testing, the ESC will be required to detect to a given probability (99% with a 1% SE) for each of the waveform bins, both in a clean RF environment and in one with GN added. (Refer to [4] for more information about the probability of detection and declaration of individual radar pulse bursts.) An ESC will be injected with the radar bursts at calibrated power levels and it must indicate to the test operators via some means that it has detected the radar pulse burst. Note that the radar signal power that the ESC must detect will always be referenced and calibrated in a 1 MHz reference bandwidth. So for the ESC certification testing the radar signal power presented to its receiver will be set to those power levels as measured and calibrated in a 1 MHz resolution bandwidth in the spectrum analyzer. The video bandwidth will be set to 3 MHz.

Table 2. Radar waveform detection thresholds for 3.5 GHz ESC testing, no added noise.

Pulse Modulation	Power Detection Threshold	Comments
P0N #1	-89 dBm/MHz	
P0N #2	-89 dBm/MHz	Input power for ESC testing will be adjusted to -89 dBm/MHz even though optimal radar-pulse detection bandwidth may differ from 1 MHz
Q3N #1	-89 dBm/MHz	Same as note above.
Q3N #2	-89 dBm/MHz	Same as note above.
Q3N #3	-89 dBm/MHz	Same as note above.

4.3.7 Radar Waveform Detection with Added Gaussian Noise

GN will be added to the radar waveforms (Figure 1) to replicate the operation of ESCs in crowded RF environments that are expected in the band-sharing scenarios for these units as they proliferate. This will simulate the background RF noise in the environment, increasing as CBSD systems are built out and those transmitters' spurious and out-of-channel emissions gradually increase the background noise levels.

Table 3. Radar waveform detection thresholds for 3.5 GHz ESC testing, with noise added.

Pulse Modulation	Pulse Power Detection Threshold	GN Level
P0N #1	-89 dBm/MHz peak	-109 dBm/MHz average
P0N #2	-89 dBm/MHz peak	-109 dBm/MHz average
Q3N #1	-89 dBm/MHz peak	-109 dBm/MHz average
Q3N #2	-89 dBm/MHz peak	-109 dBm/MHz average
Q3N #3	-89 dBm/MHz peak	-109 dBm/MHz average

4.3.8 Radar Waveform Detection with Added OoB Emissions from Adjacent-Band Radars

Consideration needs to be given to the scenario in which OoB emissions from a radar operating below the sharing band edge (i.e., below 3500 MHz) occur at a substantial power level on the same frequency as the fundamental of a radar that is operating *within* the sharing band. This problem is unbounded and quantitative tests cannot be constructed to address it. It will instead be addressed with each ESC applicant when they bring their ESC devices to the Boulder laboratory for their week of pre-certification testing. Each ESC applicant will be shown the problem at the Boulder laboratory at that time, and will be invited to work to make their ESC avoid this problem in actual field operation.

4.3.9 ESC Radar Detection Testing Bandwidth

For each of the bins, ESCs will be tested across the entire operating range to ensure detection of radar signals at the middle and at the edges of the band. For Bin 1 Lite the radar pulse frequencies will be adjusted to be integral multiples of 10 MHz (e.g., 3590 and 3610 MHz). For all other bin testing there will be no such quantization of tuned radar pulse frequencies. E.g., those pulses may be tuned to 3593.2 or 3613.7 MHz.

4.3.10 Pre-Certification Opportunity for Applicants to Subject their ESCs to Saturation Power Levels

The radars in the 3550–3650 MHz band have very high effective isotropic radiated power (EIRP) levels, making it possible for their emissions to saturate or overload ESC receivers. Pre-certification testing will include opportunities for applicants to see how well their ESCs perform in this environment. NTIA has published a report [10] on this issue which provides the results of measurements of low noise amplifier (LNA) performance and prototype 3.5 GHz receiver performance for this and the predictions of power levels within which they will have to operate. Pre-certification testing will also provide ESC applicants with the opportunity to observe how well their devices perform when they are subjected to saturation power levels from adjacent-band (below the sharing band) radar pulses. During pre-certification testing, ITS engineers will discuss the advisability of including good RF front-end filtering on ESC receivers to reduce power in the ESCs from adjacent-band radar signals.

4.3.11 Pre-Certification Observation of ESC Performance when Immersed in Radar Pulses that Always Exceed the Detection Threshold

As noted above, a scenario that will occur during actual ESC deployments will be that in-band radars (radars operating in the sharing band) will be not radiate until those radars are very close to shore or are in port. In these cases, the local ESCs will see radar energy that will turn on abruptly at power levels that are so high that all of the sidelobes and backlobes in the radars' radiation patterns will continually exceed the detection threshold of -89 dBm/MHz. The ESCs will be immersed in radar pulses that will form a continual stream that will always exceed the detection threshold. This scenario will be played out during pre-certification tests in Boulder, so that applicants can see the problem and will be able to observe how their ESCs perform under this condition.

5. ESC TEST-RESULT PERFORMANCE REQUIREMENTS

The ESC's detection performance for each radar waveform type and the overall aggregate level will be recorded. Table 4 shows an example of how the performance results may be organized.

Table 4. Example of how ESC radar detection and declaration performance results may be organized.

Waveform Bin	Number of Trials	Burst Detection Probability	Probability of Declaration (99% needed)	Standard Error of Probability of Declaration (1% needed)
P0N #1 no GN				
P0N #2 no GN				
Q3N #1 no GN				
Q3N #2 no GN				
Q3N #3 no GN				
P0N #1 w. GN				
P0N #2 w. GN				
Q3N #1 w. GN				
Q3N #2 w. GN				
Q3N #3 w. GN				

Pre-certification test results and observations will not count for or against the certification of an ESC. The results of regular certification testing, including some equivalent of Table 4, will be provided by ITS to the FCC. Copies of the testing data will be provided as well to NTIA/OSM and spectrum sharing stakeholder agencies, including, e.g., the Navy.

In addition to tabulated results in a form like Table 4, other pertinent ESC performance characteristics will be noted for the FCC, especially whether an ESC successfully detects radar pulses at all tested frequencies across the entire sharing band.

Certification of ESCs for field operations will be provided by the FCC; the ITS Boulder laboratory will only test ESCs in accordance with the plan presented in this Technical Memorandum.

6. REFERENCES

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APPENDIX A: APPROACH FOR BIN 1 LITE ESC TESTING

An option called Bin 1 Lite (P0N1 Lite) ESC waveform performance certification testing has been made available to industry by the government. Bin 1 Lite testing will be an option for applicants to obtain preliminary, temporary certification for the deployment and use of their respective ESCs. The conditions for exercising this option are:

- Every ESC applicant may choose to perform Bin 1 Lite testing of their ESC design prior to the rest of their ESC certification testing. Alternatively, any applicant may elect to *not* perform Bin 1 Lite testing and instead just do regular testing of all five radar bin waveforms as specified in the main body of this Technical Memorandum.

- If an applicant chooses to have Bin 1 Lite testing performed, and if they pass that testing, they can deploy their ESCs on that basis for an interim, temporary period of time.

However, all applicants will still, within that interim time frame, need to submit their ESCs for full Bin 1 testing along with testing of the other four radar waveform bins 2 through 5. They must pass that ultimate series of certification tests as described in the main body of this Technical Memorandum in order to keep their ESCs running in the field in support of their associated SASs.

A.1 Time Available for ESC Testing Including Bin 1 Lite.

The total available time for certification testing of each ESC is ten working days = 80 working hours. This limit is based on two things: available time resources at the ITS Boulder laboratory for getting the certifications done within a timely interval (ESCs from M number of applicants tested within N number of months); and available funds for the testing.[15]

The time taken for Bin 1 Lite testing *will be counted against the total available certification time of 80 working hours*. This means, for example, that if Bin 1 Lite testing takes three working days, then an applicant would have only another seven working days remaining for the rest of their ESC's certification testing against all five of the full-up radar waveform bins, including the regular Bin 1 waveform tests. Bin 1 Lite certification testing must therefore proceed as quickly as possible. We strongly recommend that no applicant should take more than two working days to get Bin 1 Lite tests completed. Otherwise there will be problems with getting all of the certification testing completed within our time and funding constraints. In effect, we are constrained to take no more than two working days to perform Bin 1 Lite certification testing on any given ESC.

[15] As noted in this Technical Memorandum's main body, an additional week (40 working hours) of pre-certification test work will be performed at ITS Boulder for each ESC applicant to gain familiarization with the certification test approaches and procedures, and for selected ESC checks to be performed by ITS on system behaviors that cannot be tested quantitatively in the subsequent, regular certification tests.

A.2 Technical Features of Bin 1 Lite Certification Testing Compared to Full Bin 1.

Table A-1 shows the technical features of Bin 1 Lite certification testing compared to the full Bin 1 radar waveform. To repeat for emphasis, every ESC design will eventually have to pass certification tests against the full Bin 1 waveform, even if they are initially subjected to, and pass, the Bin 1 Lite testing.

Table A-1. Bin 1 Lite ESC testing features compared to Full Bin 1.

Radar Certification Testing Waveform Parameter	Bin 1 Lite Value	Full Bin 1 Value
Pulse Width	0.9 microsecond with small variation (because with each trial taking 60 seconds there will not be time for a series of variations) (See main text.)	Varied per range given in main body of [A-1] (See text below.)
Pulse Repetition Rate	1 kHz with small variation (because with each trial taking 60 seconds there will not be time for a series of variations) (See main text.)	Varied per range given in main body of [A-1] (See text below.)
Detection Power Threshold	-89 dBm/MHz	-89 dBm/MHz
Frequency Control of Pulses	Constant for 60 seconds at a time but will be varied from one 60-second interval to the next. Entire 100 MHz will be exercised, with pulses always on a 10 MHz increment (e.g., 3610 MHz, 3620 MHz) ($\Delta = \pm$ 1 MHz)	Will be varied from one burst to the next (i.e., roughly every 5 seconds when each new burst is emitted). Entire 100 MHz will be exercised. (Δ = N/A)
Testing Noise Condition	One set sans background noise and a second set with background noise if the ESC passes the noiseless round	One set sans background noise and a second set with background noise if the ESC passes the noiseless round
Background Gaussian Noise Level	-109 dBm/MHz RMS	-109 dBm/MHz RMS
Number of Pulses per Burst	19 ($\Delta = \pm$ 2)	15 to 40 (Minimum $\Delta \geq 5$)
Time Interval between Bursts	Interval will be fixed at 3.9 seconds; $\Delta = \pm$ 0.1 sec	As fast as testing allows (maybe around 5 seconds). Interval will not be fixed.
Time per Detection/Declaration Trial	60 seconds	About 5 seconds (for trigger and reset of each burst of 20 pulses)
Number of Trials Needed to Achieve Standard Error of 1% on ESC Performance (per [A-1])	Depends on ESC performance: 900 for 90% performance; 99 for 99% performance. (See text below and [A-1].)	Depends on ESC performance: 900 for 90% performance; 99 for 99% performance. (See text below and [A-1].)
Time Required to Perform a Round of Tests, With or Without Background Noise	Two working days for 90% performance; 1.5 hours for 99% performance.	1.25 hours for 90% performance; Two minutes for 99% performance.

Radar Certification Testing Waveform Parameter	Bin 1 Lite Value	Full Bin 1 Value
Number of Rounds Required in Testing	Two: One sans background and one with background noise	Two for each of the five regular bins
Total Testing Time Required for All Rounds	Up to four days if ESC has only 90% performance (NOT an option, obviously). Three hours for 99% performance.	80 working hours or less for all five bins. This includes any time taken for optional Bin 1 Lite testing.
Frequency Control of Pulses	Hold single frequency for 60 seconds at a time	Change frequency from one burst to the next
Power Control of Pulses	Fixed at -89 dBm peak power in 1 MHz bandwidth. But some bursts will be missed within every 60 seconds to replicate time-varying propagation at any real-world ESC site (see text below).	Fixed at -89 dBm peak power in 1 MHz bandwidth.
Picket Fence Problem	Between 9 to 12 bursts will be provided to the ESC within each 60 second interval. Picket pattern in each 60-second interval picked out pseudo-randomly.	N/A; this problem does not occur for single-burst testing.

A.3 Comparison of Bin 1 Lite to Full Bin 1.

Each row of Table A-1 is discussed in this section. As discussed below, the Bin 1 Lite option forces us to invoke some testing conditions that do not occur in the full Bin 1 testing, because Bin 1 Lite requires 60 seconds of a series of bursts for each trial. The use of multiple bursts per trial, for a total of 60 seconds at a time, introduces new testing features that do not occur for the regular Bin 1 test series.

A.3.1.1 Pulse Width. Bin 1 Lite pulse widths are restricted to a narrower range than the full Bin 1 pulse width space. Table A-2 shows the comparison of pulse characteristics between Bin 1 Lite and the full Bin 1. As will be discussed in Section A.4, there may not necessarily be enough time available to exercise much of even this restricted range for Bin 1 Lite tests.

Table A-2. Comparison of pulse characteristics between Bin 1 Lite and Bin 1.

Radar Waveform Pulse Parameter	Bin 1 Lite	Full Bin 1
Pulse Width	0.8-1.4 microsecond ($\Delta \geq 0.1$ microsecond)	0.5-2.5 microsecond ($\Delta \geq 0.1$ microsecond)
Pulse Repetition Rate	975-1025 per second ($\Delta \geq 10$)	900-1100 per second ($\Delta \geq 10$)
Pulses per Burst	19 ($\Delta = \pm$ 2/burst)	15 to 40 (Minimum $\Delta \geq 5$)

A.3.1.2 Pulse Repetition Rate. Table A-2 shows the restricted pulse repetition rate range for Bin 1 Lite compared to the full Bin 1 range. As discussed in Section A.4, there may not necessarily be enough time available to exercise much of even this restricted range for Bin 1 Lite tests.

A.3.1.3 Detection Power Threshold. The power detection/declaration threshold, -89 dBm/MHz of peak pulse power, will be identical for Bin 1 Lite and full Bin 1. This is the power level that will be adjusted at the antenna input port on each ESC receiver. (ESCs may use whatever antennas they want; ESC antennas will not be certified via any testing.)

A.3.1.4 Frequency Control of Pulses. Bin 1 Lite testing will hold a single frequency for all emitted pulses for 60 seconds at a time, consistent with the normal behavior of Radar 1. But the frequency of the Bin 1 Lite pulses will be changed from one 60 second group to the next. That is, one 60 second group may have all of its pulses tuned to 3610 MHz, but the next 60 second group may have all of its pulses tuned to 3580 MHz. All ordinarily used radar channels in the 100 MHz of proposed shared spectrum will be exercised in the course of a round of Bin 1 Lite testing. These channels will be set at 10 MHz increments in the sharing band (e.g., 3600, 3580, 3630 MHz), consistent with the ordinary (but not required) tuning of field-deployed Radar 1 units. The frequency setting will be to an accuracy of ±1 MHz, consistent with the measured accuracy of Radar 1’s tuning. The frequency variation will be controlled on a pseudo-random basis throughout each of the two rounds (with and without background noise, see below) of Bin 1 Lite testing.

A.3.1.5 Testing Noise Condition. Background Gaussian noise (GN) will be handled identically for both Bin 1 Lite and the full Bin 1: First, a set of performance data will be collected without background GN. If an ESC passes that round, then and a second set of data will be collected in which background GN is injected at an RMS power level of -109 dBm/MHz at the ESC antenna input port. Note that doing all testing *without* noise and then again *with* noise doubles the total testing time. To say it another way, only half of the available Bin 1 Lite testing time can be taken with non-noise conditions; the other half of the time will be required to repeat all of the tests with noise present. If, as mentioned above, we have a maximum of two working days to do Bin 1 Lite tests, then all non-GN tests (Round 1 of Bin 1 Lite) must be run in just one working day and all GN tests (Round 2 of Bin 1 Lite) must be run the next day.

A.3.1.6 Background Gaussian Noise Level. For both Bin 1 Lite and full Bin 1 tests, the injected GN level will be -109 dBm/MHz RMS at the ESC antenna input port.

A.3.1.7 Number of Pulses per Burst. Bin 1 Lite will have 19 pulses per burst, with a delta of ±2 pulses per burst. This value and its variability encompasses the number of pulses that have been measured within the 3 dB beamwidth of Radar 1. This will be considerably more restrictive than for the full Bin 1 testing, during which the number of pulses per burst will range between 15 and 40.

A.3.1.8 Time Interval Between Bursts. Bin 1 Lite tests will be performed with an interval of 3.9 seconds between bursts, ±0.1 sec. This will differ from the full Bin 1 waveform testing, in which there will be no fixed interval between bursts.

A.3.1.9 Time per Detection/Declaration Trial. This parameter is where Bin 1 Lite testing will radically differ from the full Bin 1 tests. In the full Bin 1 testing, a burst will be fired into an ESC at an irregularly varying interval that will be repeated as quickly as an ESC can detect, report and then reset itself. This might be something like five seconds between bursts. For Bin 1 Lite, in contrast, not only will the pulse bursts occur at exact 3.9 second intervals, but the ESCs will be given 60 seconds to report (declare) any radar activity. This means that, for Bin 1 Lite, each trial (not each performance data point, which requires multiple trials) will require one minute to complete. The difference between about five seconds per trial versus 60 seconds per trial has the potential to significantly lengthen the time required to gather a data set for a given waveform condition in Bin 1 Lite testing (by a factor of 60/5 = 12, more than an order of magnitude). The next subsection discusses the implication that this has for achieving the 1% SE that the government requires for ESC compliance testing results.

A.3.1.10 Number of Trials Needed to Achieve Standard Error of 1% on ESC Performance. The government requires the SE of ESC compliance test results to be within 1% at a radar declaration performance level of 99% within a period of one minute. As [A-1] explains, this does not mean that most testing should be (or even can be) performed with one-minute intervals between each trial. The reason is that (again as explained in [A-1]) the number of trials to achieve SE = 1% at 90% performance is 900, while the number of trials required to achieve SE = 1% at 99% performance is only 90.

A.3.1.11 Time Required to Perform a Round of Tests, With or Without Background Noise. At a performance level of 90% and a time per trial of one minute, it will require two working days to achieve the SE requirement. This would be virtually all of the time available for *all* Bin 1 Lite testing. So, clearly, Bin 1 Lite testing cannot proceed to any kind of completion within the time available if the ESC is only performing at a 90% declaration rate. *Bin 1 Lite testing can only proceed to completion within the time available if ESC performance is at or very close to 99%.*

A.3.1.12 Number of Rounds Required in Testing. A minimum of two rounds of testing will be required to complete Bin 1 Lite testing: One round without noise and another round with noise being injected. To complete all Bin 1 Lite testing in two days means each round cannot exceed one working day to complete.

A.3.1.13 Total Testing Time Required for All Rounds. As already noted, all Bin 1 Lite testing for all rounds needs to be contained within two working days (16 working hours). Otherwise not enough time will be available to finish all regular testing of the full Bin 1 and Bins 2-5 at a later date.

A.3.1.14 Power Control of Pulses. Bin 1 Lite testing is supposed to replicate the "real world" as closely as possible for Radar 1. NIST and ITS measurement results for Radar 1 signals received on-shore show that received radar power can vary by 20 dB or more within each 3.9 second beam rotation interval. This sort of temporal variation in received radar power has been seen to occur frequently (i.e., it is not an uncommon or freak event). Therefore, it is highly unrealistic to hold radar pulse power at exactly -89 dBm/MHz per radar burst for all bursts within any given 60-second interval; such behavior is not expected at all in the "real world." A true, real-world scenario that will occur for Radar 1 units off-shore is that their pulse bursts will reach an ESC shore station at -89 dBm/MHz only sporadically when the radar transmitters are at the far edges of Dynamic Protection Areas (DPAs). Therefore, during Bin 1 Lite testing the ESCs will not consistently be exposed to detectable pulse bursts once every 3.9 seconds for a full 60 seconds. Instead, pulse bursts will be injected only sporadically for every 60 second interval. (This problem does not occur for full Bin 1 through 5 testing because in that testing every burst is a stand-alone detection event; the power can be (in fact needs to be) held constant from one burst to the next.) The next section explains how these bursts will be distributed within 60-second intervals.

A.3.1.15 Picket Fence Problem. The preceding paragraph introduces the 'picket fence' problem for Bin 1 Lite testing. (This problem does not exist for the full Bin 1 testing but it is forced into existence when multiple bursts have to be incorporated into each trial, which is a Bin 1 Lite requirement.) The notional picket fence is a radar burst occurring every 3.9 seconds for 60 seconds at a time, for an (integer rounded) total of 15 burst intervals per 60 seconds. There are 15 potentially available pickets in the fence for every 60 second trial. But as noted above, in the real world scenario that must be fulfilled for Bin 1 Lite testing, many of these pickets will be missing their occupying pulse bursts when a radar is at the far edge of a DPA and its pulses will therefore only sporadically reach an ESC station at the -89 dBm/MHz peak power detection threshold.

To address this problem, the Bin 1 Lite testing will be done with some missing pickets in every 60-second interval. The ESCs will be exposed to between 9 to 12 pickets in every 60 seconds: They will always get at least 9 bursts per 60 seconds (which is arguably generous for a radar at the edge of a DPA) but they will never be given more than 12 out of the possible 15 that could occur. The manner of picking the number of pickets per 60 seconds, and their distribution, will be random or pseudo-random within each 60 second interval.

A.4 Summary

This Appendix explains and describes some technical challenges and issues that must be addressed for Bin 1 Lite ESC certification tests. The fundamental, driving constraint for this testing is that it needs to be completed within about two working days in order to have enough time remaining for subsequent, full Bin 1 through 5 radar waveform certification testing.

This tight time constraint means that it will only be practical to run between 90 and perhaps, at the most, about 200 trials of 60 seconds each for each round (two rounds total, one without background noise and the other with background noise) of the Bin1 Lite testing. The minimum of 90 trials will be consistent with the government's requirement for 99% declaration performance with SE of 1%; 200 trials would be consistent with a declaration performance of 98%. Less than about 98% performance will force more than 200 trials to obtain the required SE of one percent; that eventuality will cause the testing to go longer than the two days that will be available.

When Bin 1 Lite tests are running, if the test engineers see that radar declarations are not rapidly converging on a performance level of 0.98 or 0.99, they will have to terminate testing or at least inform an applicant before they are very far into the two-day window that they are not going to have time to test their ESC completely for Bin 1 Lite performance and certification with the required 1% limit on SE interval.

A.5 References

[A-1] Sanders, F. H., "Distinction Between Radar Declaration and Pulse Burst Detection in 3.5 GHz Spectrum Sharing Systems," NTIA Technical Memorandum TM-18-526, National Telecommunications and Information Administration, U.S. Department of Commerce, Oct. 2017. https://www.its.bldrdoc.gov/publications/3182.aspx

NTIA FORM 29 (4-80)	U.S. DEPARTMENT OF COMMERCE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

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7. AUTHOR(S) Frank H. Sanders, John E. Carroll, Geoffrey A. Sanders, Robert L. Sole, Jeffery S. Devereux and Edward F. Drocella		9. Project/Task/Work Unit No. 3152012
8. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Telecommunication Sciences National Telecommunications & Information Administration U.S. Department of Commerce 325 Broadway Boulder, CO 80305		10. Contract/Grant Number.
11. Sponsoring Organization Name and Address National Telecommunications & Information Administration Herbert C. Hoover Building 14th & Constitution Ave., NW Washington, DC 20230		12. Type of Report and Period Covered
14. SUPPLEMENTARY NOTES		

15. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

A planned procedure is described for testing 3.5 GHz environmental sensing capability (ESC) devices for their responses to radar pulses in a laboratory environment. These test procedures will be used to gather data on ESC pulse-detection performance. The data gathered via these procedures will be provided to the Federal Communications Commission (FCC) to support that agency's certification process for eventual ESC field operations. This document is the best guideline for ESC laboratory testing that can be compiled by the government at the time of publication. This document is not necessarily comprehensive regarding all testing that ultimately may or should ever be performed on any ESC system. Technical procedures and approaches described in this report may be deleted, expanded or otherwise modified in the future as experience is gained with ESCs. Such changes would be based on inputs from industry and government agency stakeholders, and on contingencies that may arise from changes in future ESC certification requirements and in the designs of future ESC systems. However, no near-term change to the described testing procedures or radar signal parameters for ESCs as given in this document is expected.

16. Key Words (Alphabetical order, separated by semicolons)

Citizens Broadband Radio Service (CBRS); Citizens Broadband Service Device (CBSD); environmental sensing capability (ESC); radar; radar detection; radar waveforms; spectrum access system (SAS); spectrum sharing

17. AVAILABILITY STATEMENT	18. Security Class. (This report)	20. Number of pages
☒ UNLIMITED.	Unclassified	27
☐ FOR OFFICIAL DISTRIBUTION.	19. Security Class. (This page) Unclassified	21. Price:

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