UNITED STATES GOVERNMENT

Memorandum

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SUBJECT: Peer Review of U-NII-4 to DSRC EMC Test and Measurement Efforts Phase I Test Report

Introduction

This memorandum is in response to your request dated February 9, 2018 to conduct a peer review of OET's Phase I U-NII-4/DSRC Test Report, and to provide a brief written report of our review, findings, and recommendations. You requested that the review should address the following subject areas:

1) Whether the scope of testing in terms of the detection and threshold conditions examined was appropriate and sufficient;
2) Whether the measurement methodologies used in the testing of the prototype devices to evaluate the coexistence abilities was appropriate;
3) Whether the scope of the testing was appropriate to evaluate the impact of transmissions in the U-NII-4 band to DSRC operation.
4) Whether the various tests performed were properly conducted consistent with the selected methodologies.

The subject U-NII-4/DSRC test report presents the results of the FCC Laboratory's first phase of testing of multiple Unlicensed National Information Infrastructure (U-NII) prototype devices and Dedicated Short Range Communications (DSRC) devices to assess the efficacy of proposed spectrum sharing mechanisms. The Commission has proposed a three-phase testing program to assess the potential compatibility of U-NII-4 and DSRC networks operating in the 5850 – 5925 MHz band. The lab test results from Phase 1 are expected to provide the necessary baseline data for performing analysis of specific operational scenarios and supporting "real world" empirical tests as part of the next phase of coexistence testing.

The IEEE 802.11 Tiger Team has put forth two proposed band sharing methods designated "Detect and Vacate" and "Re-Channelization." Both the Detect and Vacate and Re-Channelization proposals were modeled and tested in the Phase 1 testing. While some assumptions had to be made regarding the operation of future devices, and modifications to existing devices were needed to complete testing, we believe the test results provide an accurate foundation to build upon in the subsequent phases of testing.

The scope of the testing and measurement methodologies appear to be sufficient for Phase I level testing, as summarized below in the four subject areas. Future phases of testing should incorporate additional measurement methodologies and tests, as indicated in the summary below, and the following section that highlights two focused recommendations.

Subject Areas / Questions Posed

A. Was the scope of testing in terms of detection and threshold conditions appropriate and sufficient? YES

The detection threshold tests were performed by injecting a DSRC signal into the DSRC detectors of both a U-NII-4 Access Point and a U-NII-4 Station. The tests determined that the devices with detect and vacate capability can detect the presence of a valid 10 MHz DSRC transmission in any of the four lower DSRC channels simultaneously. The detection threshold tests confirmed that the DSRC detectors were capable of detecting a DSRC signal down to -95 dBm/10 MHz, and -96 dBm for a 20 MHz DSRC channel. A confirmation of the DSRC receiver sensitivity and the U-NII-4 detection level(s) of the DSRC signal was helpful in assessing the coexistence conditions.

The detection threshold appeared to be sufficient, and the corresponding DSRC BSM transmission rate of 10 Hz is sufficient for the scope of the testing. The use of a channel occupancy ranges from 55% to 95% for the U-NII-4 devices are also appropriate for the scope of the test plan.

B. Were the measurement methodologies used in testing the prototype devices to evaluate coexistence abilities appropriate? YES

In order to evaluate the coexistence abilities of prototype devices utilizing the Detect and Vacate methodology, measurements were conducted to determine the DSRC Detection Threshold and Channel Move Time of the U-NII-4 devices. With regard to the Detection Threshold, the test methodology provided sufficient data points under both clear channel conditions and with noise injected to draw meaningful conclusions about how the devices would function in real-world applications. While the noise level in a real-world application may not be known, we believe that the -90 dBm level was appropriate to simulate a busy channel.[1]

The technique for determining Channel Move Time under the Detect and Vacate methodology was similar to that used for measuring the Detection Threshold. The probability of detection was determined by evaluating the number of detections and missed detections over 50 trials at each of a number of DSRC signal levels presented to the U-NII-4 device. The test was conducted with both a clear channel and with injected noise.

For the Re-Channelization Method, the Detection Threshold and Coexistence Scenarios were measured. The Detection Threshold test methodology was the same as that used in the Detect and Vacate tests, and appeared to be appropriate. The set-up for Coexistence Scenarios required connecting the U-NII-4 and DSRC devices in such a way that they could detect each other's signals. Adjusting a signal attenuator along the common path of the signal flow between the U-NII-4 and DSRC devices permitted varying levels of interfering signals to enter

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[1] The issue of "noise type" is discussed in more detail in the section below on Focused Recommendations.

each device. The set-up appeared to properly simulate conditions when a U-NII-4 device would need to implement mitigation modes for coexistence.

The test methodologies and set up appeared appropriate for this level of testing. U-NII-4 devices were appropriately configured for testing, including the use of various loading factors. Both 10 MHz and 20 MHz DSRC options were tested. The defined DSRC receiver sensitivity used in the tests all appeared appropriate, along with output power levels, channel settings, modulation and coding schemes used for both devices.

The methodologies provided an objective assessment of the various measurements, and the effectiveness of the mitigation measures. As noted in the report, future tests should consider Doppler and other effects resulting from the mobility of the devices.[2]

C. Was the scope of the testing appropriate to evaluate the impact of transmissions in the U-NII-4 band to DSRC operation? YES

In Phase I testing, measurements were done with the devices connected by wire instead of open air testing to eliminate uncertainties due to antennas. Loading affects were simulated with loading factors ranging from 55% to nearly 95%. This set-up provided an adequate operational model to get baseline measurements. Although atmospheric effects were not accounted for, the results from the test set-up likely provide accurate data showing the impact of U-NII-4 band transmissions to DSRC operation.

The tests were done appropriately under both clear channel conditions and with noise injected into the channel to simulate more stressed operational conditions. The tests also appropriately measured the potential for interference to the first, second, and third adjacent DSRC channels.

The report also appropriately recommends that additional testing should be done in the next phases of the study to determine the potential of adjacent channel interference using different antenna, and to consider the multipath and fading channel characteristics. Two areas that we believe are worth further investigation are, a) the measurement of the channel-move time (i.e., the elapsed time between detection of a DSRC signal and U-NII-4 device retransmission to a backup U-NII channel), and b) adjacent channel coexistence in relatively strong RF signal power conditions. This will help in further understanding the interference impact to the DSRC receivers during field testing and realistic operating use cases.

D. Were the tests properly conducted consistent with the selected methodologies? YES

All tests seem to have been conducted in a manner consistent with the selected methodologies. The test for the re-channelization method was limited because the existing DSRC devices have not yet implemented the 20-MHz channel capability. However, modifications to the test equipment were made in order to mimic 20-MHz channel operation. While the modified DSRC devices may not operate in an identical fashion as future industry-generated 20-MHz DSRC devices, they represent the best approximation that can be made at this time, and therefore the best possible test set-up.

The tests appeared to be properly conducted and provided consistent, repeatable results. Test devices were connected by wire and placed in shielded enclosures and a shielded room to provide improved RF shielding to reduce the potential of errant RF signals from contaminating the test results.

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[2] The section below on Focused Recommendations discusses strong signal coexistence conditions in more detail.

Focused Recommendations

Strong signal intermodulation testing --

All of the U-NII-4/DSRC adjacent coexistence tests were performed with relatively weak desired signals (e.g., -90 dBm). We find increasing evidence of the importance to characterize the dynamic range and effectiveness of receivers in environments over a wide range of weak to strong power levels. The consequences of not performing strong signal tests is that test results from conventional weak signal tests may imply that devices that have adequate adjacent signal rejection performance with relatively weak desired signals, will also perform adequately in strong signal conditions. We believe that this may not be true in certain settings (e.g., in-vehicle, with U-NII-4 and DSRC transmitters and receivers in close proximity to each other), and should be tested and characterized in the lab, not only in field tests. Devices that perform well in the weak signal realm, may not perform similarly well in strong signal conditions, often due to inadequate design for high dynamic range performance. We find that industry standards and the Commission's certification tests of transmitters and basic receiver performance, typically do not cover the high dynamic range that may be representative of the RF environments in which some devices will operate in the field.

A case that illustrates this is with 800 MHz public safety receivers adjacent to terrestrial mobile wireless systems. The presentation by Pericle Communications at the Public Forum on 800 MHz Spectrum Sharing is illustrative.[3] While the specific 800 MHz band, specific radio services, and the range of power levels, are all different in 800 MHz in contrast to the DSRC and U-NII-4 5.9 GHz band, we believe that this 800 MHz case illustrates the possible consequences of a field environment with a wide dynamic range of adjacent RF signal conditions. In particular, slide #9 shows that all of the public safety receivers performed adequately in weak signal conditions (left side of the chart). Some public safety receivers also performed well in strong signal conditions (right side of the chart), and others did not perform well in strong signal conditions (i.e., with much lower intermodulation rejection performance at high power levels in contrast to low power levels). We recommend that modeling representative field scenarios in future DSRC test phases, should guide future lab testing of production DSRC and U-NII-4 devices, and future lab tests should include dynamic range tests as illustrated in Pericle Communications' presentation. While there are obvious differences in both the system architectures and technologies between the 800 MHz and 5.9 GHz bands (high site, high-powered narrowband vs. low-power multi-carrier OFDM broadband), we believe that these tests would yield important results.

Modeling & measurement of receiver effects in non-Gaussian RF impulse noise environments --

We find that it is common for lab tests to include various levels of Gaussian noise, and this was appropriately done in the tests that we reviewed. However, we also recognize that real-world field environments rarely have RF noise environments that are truly Gaussian in nature. Instead, non-Gaussian impulse noise is more common in the field, and the non-Gaussian nature of these environments can be quite variable. Impulse noise power can be 20-30 dB or more than mean Gaussian noise power, and we believe it is important to characterize the effects of non-Gaussian impulse noise on receiver performance.[4] We recommend that planning for future phases of field testing, include an analysis of the types of non-Gaussian noise that may be representative of DSRC / U-NII-4 operation in the field, and that future lab testing of production devices include both Gaussian and non-Gaussian noise. We also recognize that RF environments in the field will change over time, and an example of this is found in the NTIA measurements of man-made noise in the 136-138 MHz VHF meteorological satellite band.[5] In general, we believe that it is difficult to predict the degradation effects of RF impulse noise on a

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[3] See, Pericle Communications presentation at the link titled, "800 MHz Public Safety Interference Explained", at the Public Forum on 800 MHz Spectrum Sharing, Nov. 6, 2017; https://www.fcc.gov/news-events/events/2017/11/public-forum-800-mhz-spectrum-sharing

[4] 20 dB = 100 times higher in relative power; 30 dB = 1,000 times higher in relative power.

[5] See, "Man-Made Noise in the 136 to 138-MHz VHF Meteorological Satellite Band, NTIA TR 98-355, September 1998, Achatz, Lo, Papazian, Dalke, Hufford; https://www.its.bldrdoc.gov/publications/details.aspx?pub=2386.

particular radio service without testing the subject radios in the lab. Modern modulation and coding techniques may effectively negate the effects of impulse noise in advanced receivers, however, the potential non-linear effects of broadband noise impulses that may drive sensitive receivers into saturation and overload should be characterized in the lab, before these conditions are encountered in the field.