UNITED STATES GOVERNMENT

memorandum

DATE: July 31, 2007

TO: The Record

FROM: Julius Knapp
Chief, Office of Engineering and Technology

SUBJECT: Peer Review of Prototype TV White Space Device Study

The following information and comments are submitted in response to the July 20, 2007 memorandum of the peer review panel that provides their report on the review of an empirical-based technical evaluation of two prototype TV-band white space devices delivered to the Office of Engineering and Technology's (OET) Laboratory in May, 2007. The study and its findings are set forth in a report entitled "Evaluation of the Performance of Prototype TV-Band White Space Devices", OET Report FCC/OET 07-TR-1006. This study examined the performance of the "detect and avoid" techniques used by those personal/portable television white space device (WSD) prototypes to evaluate their ability to detect television channels occupied with incumbent signals (digital or analog TV and wireless microphones). In addition, for that prototype provided with transmission capability, the output emissions were characterized, an anecdotal interference test with respect to DTV operation was performed, and the interference potential with respect to wireless microphone operations was examined. The peer review of this study was performed pursuant to the Office of Management and Budget's requirement under the Information Quality Act that influential scientific assessments be subject to peer review to enhance the quality and credibility of the government's scientific information.

The peer review addressed the following subject areas: 1) whether the scope of testing in terms of spectrum sensing abilities and signal conditions examined was appropriate and sufficient; 2) whether the measurement methodologies used in the testing of the prototype devices spectrum sensing abilities was appropriate; 3) whether the scope of testing of Prototype A (the device with transmitting capability) for its potential to cause interference to digital TV, analog TV, and wireless microphone signals was appropriate; and, 4) whether the various tests performed were properly conducted consistent with the selected methodologies.

The panel found that the overall scope of the spectrum sensing testing was appropriate, that the measurement methodologies used in the testing of the prototype devices were appropriate, that the scope of the testing of the Prototype A device for its potential to cause interference to digital TV and wireless microphones was appropriate, given the study's stated constraints, and that the tests were properly conducted consistent with the selected methodologies. The review panel further found that the testing was well done and thorough.

The panel also made further recommendations regarding the content of the subject report on the testing that was performed and with respect to supplemental tests that could be of value in a test program that was less constrained by time. The content-related recommendations have been incorporated into the report. OET is responding to the panel's remaining comments herein. The following paragraphs provide a complete list of the comments/recommendations offered by the panel (ordered according to the subject area under which they were presented) followed by the OET response.

1) Whether the scope of testing in terms of spectrum sensing abilities and signal conditions examined was appropriate and sufficient.

The review panel felt that it would have been useful to have tested stronger N-1 and N+2 signals as well because higher level adjacent channel OTA signals can exist at a DTV receiver (see, e.g., Table 5-1). Higher level adjacent channel signals might have affected Prototype B's ability to sense a co-channel signal more than the moderate-level adjacent channel signal tested and the panel believes that it would have been interesting to have examined this condition. In addition, the review panel believes that if more time had been available to conduct the test, it would be more realistic to have tested multiple, adjacent DTV signals at the same time, rather than testing only a single adjacent channel at a time.

We agree with both points made by the review panel. Tests utilizing higher-power level adjacent-channel signals with DTV signals placed on multiple adjacent channels would have provided additional useful and interesting resulting data. In fact, we also believe that such tests should place the multiple DTV signals on specific adjacent channels so as to produce third-order inter-modulation products in the fundamental channel. However, there were several practical limitations to performing such tests within the scope of this test program. First, because they required multiple trials at each data point (30-independent trials were used after finding that results from smaller number of trials were often misleading), these types of bench tests are time consuming. Secondly, the number of DTV signals that can be generated in the laboratory setting was practically limited by the availability of an equal number of ATSC signal simulators. Although we did have access to another DTV signal generator, it was of a different make from the two utilized in the tests, and the measured waveform (particularly with respect to the filter skirts) differed somewhat from the waveform produced by the two simulators used. Finally, since these tests were somewhat unique, there was little guidance to draw upon in their design. While the IEEE 802.22 draft measurement standard provided useful initial guidance, it does not yet offer much specificity with respect to appropriate adjacent-channel placement and signal amplitude test combinations. Perhaps the results of this program will prove to be useful guidance to future efforts to evaluate similar "detect and avoid" wireless technologies.

Notwithstanding these acknowledged limitations to the bench tests, we believed that the field tests designed to evaluate the performance of the prototype scanning/sensing function in a "real world" environment would provide results under a wider range of channel-amplitude combinations than could be simulated in the laboratory. However, when designing the tests, we did not anticipate that the manufacturer of the Prototype B device would request exemption from the field tests. As a result of this exemption, and because of the observed limitations in the bench tests, the scanning/sensing capability of that prototype cannot be claimed to have been fully evaluated. This recognition is precisely why the overall detection capability performance for this prototype was reported as unknown in Section 6.1.2 of the report.

Due to the limited time available to conduct the test, the review panel agrees that it may not have been feasible to take actual measurements of received TV signals. But the review panel feels that since the success of the WSD in sensing TV signals is dependent on the strength of those signals, it would have been useful to have taken some sample measurements to perhaps quantify one or more "high," "medium," and "low-signal" stations, to try to examine the correlation between TV signal level and sensing capability in the field, and to see how those results compared with the results obtained in the bench tests. If, for example, information was known at Site 1 about the signal levels of Channels 21, 23, *25, 30, and 31, where the WSD made perfect decisions (see Table 3-2), versus the signal levels of Channels 43, 44, 47, and 49, where a number of incorrect decisions were made, then possible correlations between signal level and WSD sensing capabilities could have been made. Similarly, at Site 2, where the WSD no longer performed perfectly at Channels 21, 23, and 25 (see Table 3-5), information about the signal level on those channels, as well as information about the signal levels of N-1, N-2, N+1, and N+2 channels, might have enabled an analysis of the correlation between signal level of the channels being tested, the signal levels of first and second adjacent channels, and the WSD's sensing capabilities.*

As discussed in the text of the report, and in apparent consensus with the peer review panel, measurements of DTV signal levels to a statistically meaningful degree at each location where the scanning/sensing component of the prototype was tested was not practical within the scope of this program. The time-varying nature of a DTV signal requires either that measurements be performed over relatively long time periods or that multiple measurements be performed at different times of the day. If such measurements were to be performed, then they should be done so at each location at which the scanner was tested (4-5 per test site). However, the type of locations utilized in these tests were residential living spaces and as such, represent difficult propagation conditions in which to perform signal strength measurements. Multi-path propagation due to clutter reflections in such an environment means that significant differences in measurement results can be obtained within small displacements of the measurement antenna. Therefore, a significant number of repeat measurements would be necessary to determine a relevant mean DTV signal level for each occupied channel.

Unfortunately, the order in which these tests were scheduled also contributed to this limitation. The schedule involved performing the field tests prior to the bench tests. As a result, the outcomes of the bench tests were unknown at the time the field tests were performed. With the advantage of hindsight, we would most certainly have performed some limited measurements of the signal strength associated with the occupied channels at each test site.

Nonetheless, we agree that such information could have provided better insight into the anomalies observed in the performance of the signal detection capability. However, we also recognized that in order for these tests to be completed in time to provide relevant input to the ongoing rulemaking proceeding, efforts to troubleshoot or diagnose the prototype performance must be considered beyond the scope of the project.

2) Whether the measurement methodologies used in the testing of the prototype devices spectrum sensing abilities was appropriate.

Three different Part 74 wireless microphone systems were used in these tests, but digitally modulated wireless microphones were not tested. Regarding these tests, the review panel did note that a continuously modulated signal was used to modulate the wireless microphones while the scanning was being performed. Typical analog wireless microphone use will often be a continuous carrier intermittently modulated (such as, for example, use during news reports, program production, speeches, etc.). Therefore it should be pointed out that the continuously modulated signals used in the testing likely represent "best case" detection opportunities. Given more time, the review panel felt that an additional test could be done using an unmodulated carrier or intermittently modulated carrier to represent "worst case" detection opportunity.

While it may be true that a continuously modulated signal represents the "best case" for sensing of a wireless microphone by the white space device scanner, considering that Prototype A exhibited virtually no capability to sense a "best case" signal, there seemed to be no point in attempting to sense "worst case" signals. That said, following the suggestion from the peer review panel, informal testing was performed to check the ability of the devices to sense a signal without modulation other than the pilot tones which are always present. Prototype A still failed to sense the microphone signal but it was found that Prototype B would sense the signal at levels approximately 5 dB lower than with standard test modulation. Because of the very poor performance of Prototype A, an attempt was made to see if increasing the modulation frequency and deviation of the microphone signal would improve its performance. Increasing the modulation frequency to 2500 Hz and the deviation to 40 kHz showed no improvement in the ability of Prototype A to detect a microphone.

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3) Whether the scope of testing of the first prototype (the device with transmitting capability) for its potential to cause interference to digital TV, analog TV, and wireless microphone signals was appropriate.

It is the opinion of the review panel that the scope of the testing of the first prototype device for its potential to cause interference to digital TV and wireless microphones was appropriate, given the study's stated constraints. However, the review panel did not observe any discussion in the report describing tests that may have been done to analyze potential interference to analog TV signals.

The report admittedly focuses on the potential impact from unlicensed white space devices to the reception of DTV signals more so than on similar concerns with respect to analog (NTSC) TV signals, particularly in those bench tests performed to determine the minimum signal detection threshold. The primary reason for this is that the proposed date for the introduction of unlicensed white space devices into the TV-broadcast spectrum is after the mandatory date for transition from analog to digital signals (*i.e.*, after February 17, 2009). After that time all full-service television stations will be broadcasting in digital format only. Although it's recognized that some television stations (*e.g.*, low-power TV) will be permitted to continue analog broadcasts, the potential impact to the consumers of full-service OTA DTV broadcasts was considered to be a priority consideration. Nevertheless, the field tests of the scanner did include an assessment of the detection capability of the prototype device (limited to Prototype A) with respect to analog TV signals and determined that the function performed better for that purpose.

The panel recognizes that use of OTA signals produces only anecdotal results and concurs with the report's observations on "OTA Interference Tests" in Section 6.3, but the panel believes that it would have been useful for a few additional tests to have been conducted to try to analyze interference to TV reception under various, additional conditions.

For example, in the test the WSD was placed in the main beam of the DTV antenna in the direction of the DTV station, which maximized the WSD's potential to cause interference to DTV reception. The panel believes that it would have been useful to have placed the WSD "off-beam" at two or three different angles and observed the results. Similarly, because the DTV antenna was pointed directly at the DTV station to achieve maximum signal, this produced a best-case scenario for the WSD in terms of its ability to cause interference to DTV reception. So perhaps a test where the DTV antenna did not point directly at the DTV station could have been done so that an examination of the effect of the WSD on DTV reception could have been made under a weaker DTV signal condition.

It can prove very difficult to replicate interference interaction scenarios in field testing with over-the-air signals, particularly when one of the radio services involved is a point-to-multi point application such as represented by the television broadcast service. Finding suitable test sites where a pertinent interaction scenario is represented presents just one impediment to such testing. Another hindrance to this type of testing is the lack of control that can be exercised over the desired signal levels. Finally, as previously discussed, the statistical nature of many of the technical parameters requires that multiple trials be performed over a representative set of receivers in order to produce statistically meaningful test results. While we agree that more data is always preferential to less, we also recognized that the scope of the project would limit how much of this type of testing could be performed. That was the primary rationale for selecting a “near” worst-case interaction scenario for the test (an absolute worst-case scenario would have been preferable). It was our opinion that the scenario examined was adequate to demonstrate both the interference potential from co-channel interactions should the “detect and avoid” implementation fail, and the potential for adjacent-channel interference relative to the degree of the transmit filtering employed. While it’s true that the interference distances determined would likely change under different interaction assumptions, given those issues already discussed, the results would nonetheless still have to be considered anecdotal.

With regard to the OTA test that was performed, we agree with the panel in that by orienting the receive antenna so that it was pointed off-axis from the desired station’s broadcast tower, we could have effectively reduced the desired signal power for this test. In fact, we did experiment with this method while setting up, but decided against implementing it in those tests performed for the record for several reasons. First, a calibrated test antenna was used as the receive antenna. The antenna calibration information assumes measurements performed in the main-beam (no other pattern information was available). Therefore, had we oriented the receive antenna off-axis from the broadcast tower, we would not have been able to quantify the actual DTV signal level within an acceptable degree of certainty. Secondly, in our initial experiments utilizing this technique, the maximum signal attenuation we were able to obtain, and still avoid close-in signal blockage, was 3-4 dB. A 4-dB reduction in the desired signal level would still result in a scenario where the desired signal is well above the threshold of visibility. Therefore, we decided to go with the most convenient test orientation under the premise that detuning the desired signal through antenna azimuth orientation did not represent a significant enough improvement (relative to worst-case) to the interaction scenario to compensate for the associated issues.

In general, the review panel feels that, the scope of the wireless microphone interference testing was appropriate to provide a basic understanding of susceptibility of wireless microphones to interference. The review panel feels that a few over-the-air tests conducted with the wireless microphones would have helped to verify the direct-coupled results.

First it should be noted that only Prototype A had transmission capability and it had to be shared with the very time consuming DTV testing. Second the Prototype A system was not very portable. It required computer control, external filters, power supplies, etc. Also, the microphones required an audio signal generator and interconnecting coax cables for the audio analyzer between the microphone location and the receiver location. Time constraints and other practical considerations precluded over-the-air testing.

4) Whether the various tests performed were properly conducted consistent with the selected methodologies.

The review panel notes that the information contained in Table 3-13, Summary of Field Test Data with Prototype A Version 2, for "Site 2" NTSC observations is inconsistent with what is described in the text. The table indicates that a NTSC signal was viewable on the TV for Site 2, but the text indicates that the converter box at Site 2 did not include an NTSC tuner and thus it was not possible to verify whether an analog TV signal could be viewed.

The subject table has been modified to correct for this oversight.

Also, in the OTA interference test (Section 5.1), the report describes that "receiver #I1" from a previous study was selected to be used in the test. The review panel questions the basis for the selection. The review panel believes that it would be useful to know if receiver #I1 selected randomly; if it was selected because it was in the median range of performance in the previous study; or if it was selected for another reason.

The basis for the selection of this receiver for the tests was partly random in that it was one of the few available receivers small enough to accommodate moving it around a test site on a lab cart. However, it also represents a near-median performer in the previous study as can be discerned from Figure 5-1 of the report documenting the results of that effort (OET 07-TR-1003) which presents measured D/U ratios for eight receivers (including the one used in this test and identified as I1) at a desired signal level of -68 dBm.

OET expresses gratitude to the reviewers for conducting a thoughtful review on a rigid schedule and for providing comments that have served to both improve the quality of the subject report and to stimulate additional technical consideration with respect to similar test programs that might be undertaken in the future.

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