Electromagnetic Interference and Electromagnetic Compatibility Testing for White Sands Complex Software Defined Radio

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Abstract - *Communication systems or electronics have the ability of emitting or picking up unwanted electromagnetic energy which can impair their operation, or the operation of other equipment in the environment. The White Sands Complex-Software Defined Radio (WSC-SDR), developed by Goddard Space Flight Center (GSFC) will be installed at WSC to provide a ground radio to support Space Communication and Navigation (SCaN) Testbed experiments and provide a platform for experimenters to create a matched modulator and demodulator for the waveforms loaded onto SCaN Testbed's space segment. This paper summarizes the Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) testing and test results for the White Sands Complex (WSC) Software Defined Radio (SDR).*

Keywords: *Software Defined Radio, Electromagnetic Compatibility (EMC), Electromagnetic Interference (EMI), Space Communication and Navigation (SCaN), Conducted Emissions (CE), Conducted Susceptibility (CS), Radiated Emissions (RE), Radiated Susceptibility (RS)*

1 Introduction

This paper discusses White Sands Complex Software Defined Radio (WSC-SDR) EMI/EMC testing. The WSC-SDR will provide a programmable hardware platform for experiments flown on the SCAN Testbed as part of the SCaN Testbed project. SCaN Testbed experimenters will load and execute waveforms on the WSC-SDR that match the particular experiment running aboard the space platform. The WSC-SDR provides an over-allocated Digital Signal Processing (DSP) capability through the combination of Field-Programmable Gate Arrays (FPGA), multiple multi-core Central Processing Units (CPU), and one or more Graphical Processing Units (GPU). Experimenters will access these hardware capabilities by writing a set of Very High Speed Integrated Circuits (VHSIC) Hardware Description Language (VHDL) and/or higher-level software scripts in order to implement their unique designs.

2 WSC-SDR Functional Overview

The WSC-SDR consists of three parts: the Radio Frequency Module (RFM), Signal Processing Module (SPM), and General-Purpose Processing Module. The RFM provides an interface between either a 370 or 1200 MHz Intermediate Frequency (IF) and the SPM. The SPM Converts signals to and from analog/digital form for data transmission or reception. Finally, the GPM performs modem operations to receive or transmit data.

An S or Ka band signal is transmitted from the SCaN Testbed on the International Space Station (ISS). The signal is relayed through the Tracking and Data Relay Satellite System (TDRSS), downlinked to the WSC and routed through one of the SGLTs. A 370 MHz IF is passed on from the SGLT to the WSC-SDR which performs frequency translation, data conversion, and demodulation. Data from the WSC-SDR is passed on to its destination through a Virtual Private Network (VPN). An operator at Glenn Research Center (GRC) will remotely logon and control the WSC-SDR. Data may be routed to a Bit Error Rate Tester (BERT) for analysis

3 EMI/EMC Testing Requirements

Each device under test shall comply with requirements contained in the following parts of the Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, MIL-STD-461C and MIL-STD-461F.

4 EMI and EMC Tests

The following tests will be performed:

a. Power line emission and susceptibility requirements *CE03*, *CE07*, *CS01*, *CS02*, and *CS06* applied at the equipment power entry connector.

b. Electric Field radiated emission and susceptibility requirements RE02 and RS03 are applicable at the specified test distance of 1 meter from the equipment as defined in MIL-STD-461C.

c. Magnetic and Electric Field radiated susceptibility requirement *RS02* applies to the equipment and interconnecting cables.

4.1 Radiated Emissions

The only radiated emissions test performed was RE02. The purpose of this test was to verify that radiated electromagnetic emissions from the Device Under Test (DUT) would not exceed the specified requirements, over the frequency range of 14 kHz to 10 GHz. For this test, the antenna was polarized vertically from 14 kHz to 30 MHz. The antenna was also polarized horizontally and vertically from 30 MHz to 10 GHz. The DUT and test equipment were configured using the figures below. The antenna was placed 1m away from the DUT.

Figure 1: RE02 14kHz to 30 MHz

For radiated emissions tests antennas are used to measure the emissions from the DUT across a certain frequency range. In figure 1, the antenna is placed one meter away from the DUT. It sweeps the DUT from 14kHz to 30 MHz. For the next frequency range, a different antenna was used. This antenna swept the DUT from 30 MHz to 200 MHz. As shown in figures 2 and 3, the antenna was polarized horizontally and vertically. The same was done for the next two antennas. Figures 5 and 6 show the horizontal and vertical polarity of the antenna as it sweeps the DUT from 200 MHz to 1 GHz and figures 7 and 8 show the horizontal and vertical polarity of the antenna as it sweeps the DUT from 1GHz to 10 GHz.

Figure 2: RE02 30 MHz to 200 MHz Horizontal Polarity

Figure 3: RE02 30 MHz to 200 MHz Vertical Polarity

Figure 4: RE02 200 MHz to 1 GHz Horizontal Polarity

Figure 5: RE02 200 MHz to 1 GHz Vertical Polarity

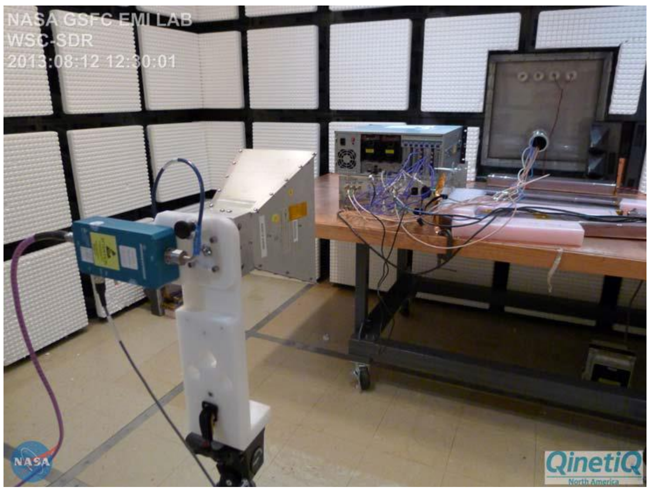

Figure 6: RE02 1 GHz to 10 GHz Horizontal Polarity

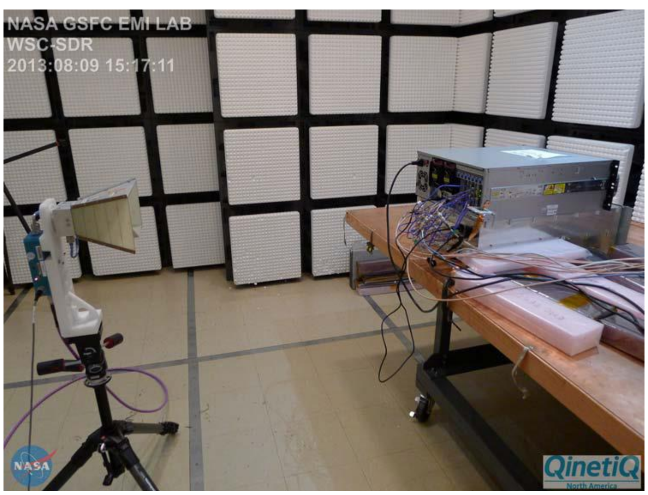

Figure 7: RE02 1 GHz to 10 GHz Vertical Polarity

4.2 Radiated Susceptibility

The first Radiated Susceptibility test performed was RS02. The purpose of this test method was to verify the ability of the DUT to withstand the effects of voltage spike interference applied to its input power leads.

The second RS test performed was RS03. The purpose of this test was to verify the ability of the DUT to withstand radiated electromagnetic fields over the frequency range of 14 kHz to 10 GHz.

Figure 8: RS03 14 kHz to 30 MHz

Figure 9: RS03 30 MHz to 200 MHz Horizontal Polarity

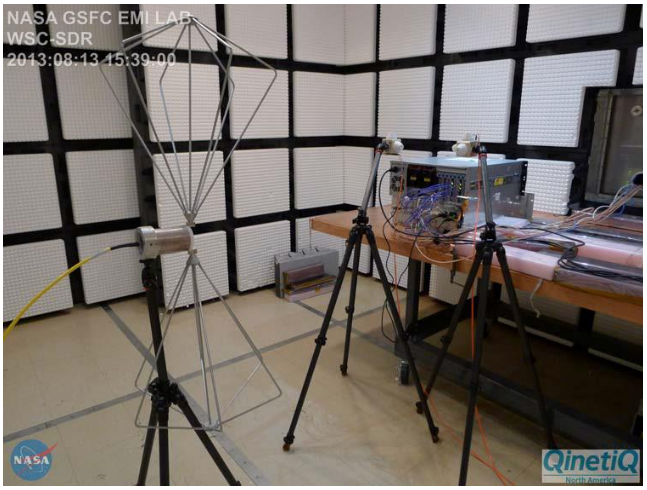

Figure 10: RS03 30 MHz to 200 MHz Vertical Polarity

For radiated susceptibility tests antennas are used to blast the DUT with radiation in order to determine the sensitivity of the device. In figure 8, the antenna is blasting the DUT with radiation from 14 kHz to 30 MHz. Figures 9 and 10 show the horizontal and vertical polarization of the antennas as they blast the DUT with radiation from 30 MHz to 200 MHz.

4.3 Conducted Emissions

The first conducted emissions test performed on the WSC-SDR was CE03. The purpose of this test was to verify that electromagnetic emissions from the Device Under Test (DUT) would not exceed the specified requirements for the power input leads, including returns, over the frequency range of 150 kHz to 30 MHz. The DUT and test equipment was configured using the figure below.

Figure 11: CE03 Equipment Setup

For conducted emissions tests, radiation is measured through powerlines. In figure 11, the powerlines of the DUT are connected to a Line Impedance Stabilization Network (LISN). The LISN is used to predict conducted emissions for testing.

The second conducted test performed was CE07. The purpose of this test was to verify that on/off switching transient emissions of the DUT does not exceed the specified requirements. Conducted Spike Emissions (transients of duration less than 50 µsec) will be measured on the DUT 120 VAC, 60 Hz power input. The test equipment was configured using the figure below.

4.4 Conducted Susceptibility

The first Conducted Susceptibility test performed on the WSC-SDR was CS01. The purpose of this test was to verify the ability of the DUT to withstand audio frequency energy coupled onto its input power leads over the frequency range of 30 Hz to 50 kHz. The test equipment and DUT were configured using the figure below.

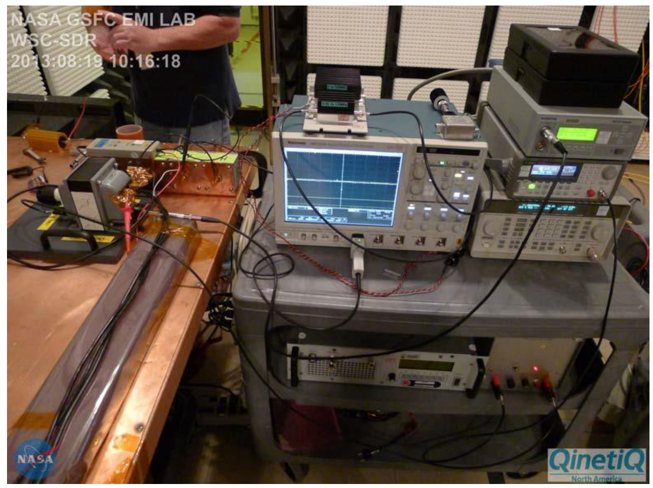

Figure 12: CS01 Equipment Setup

For conducted susceptibility tests, equipment is connected to the DUT, radiation is injected into the DUT's powerlines, and the sinsitivity of the device is measured. Figure 12 shows the equipment setup that was just explained.

The second test performed was CS02. The purpose of this test was to verify the ability of the DUT to withstand radio frequency energy coupled onto its input power leads over the frequency range of 50 kHz to 400 MHz.

The third CS test that was performed was CS06. The purpose of this test was to verify the ability of the DUT to withstand the effects of voltage spike interference applied to its input power leads. The calibration for this test was the same as RS02. (See figure 9 as a reference).

5 Test Results, Changes and variants

Based on the Test Plan, it was assumed that this test was going to be moderately complex, which suggested that the test could be performed within a manageable, 10-day period. However, the test took twice as long to run due to the time taken to investigate significant Radiated Emissions anomalies.

Though there were no significant issues in CE, CS, and RS testing, there were major concerns revealed in RE testing. Noise issues were present throughout the entire electromagnetic spectrum from 14 kHz to 10 GHz, even in the very sensitive S-band and Ka-band communications notches. This is clearly seen in the following example (Test Run 038 on Page 50 of the Data)

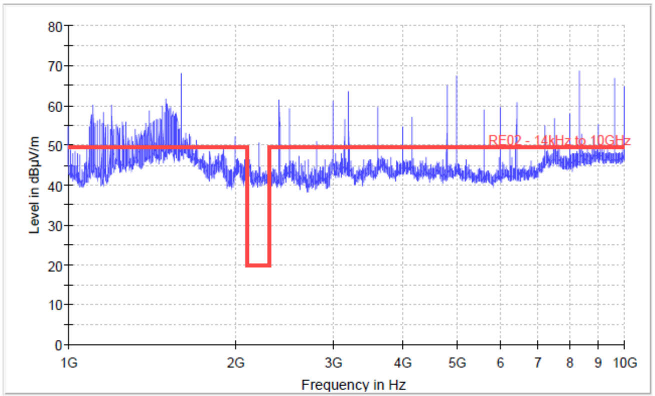

Figure 13: RE02 Test Results 1 GHz to 10 GHz

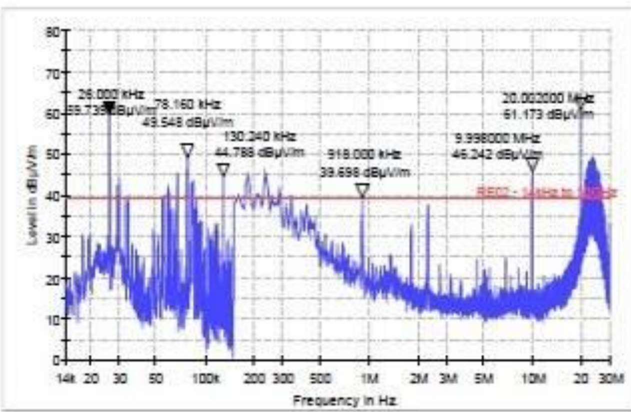

Figure 14: RE02 Test Results 14 kHz to 30 MHz

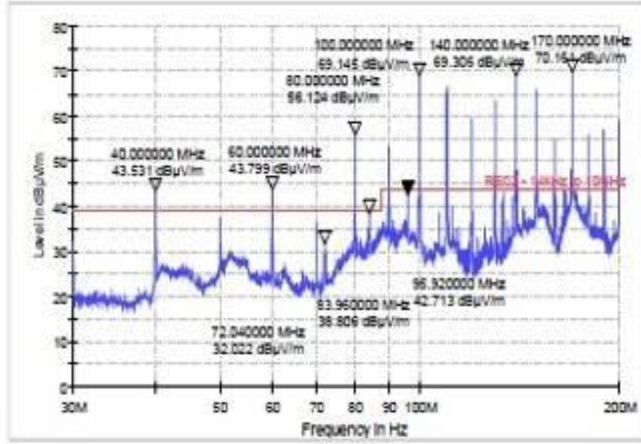

Figure 15: RE02 Test Results 30 MHz to 200 MHz

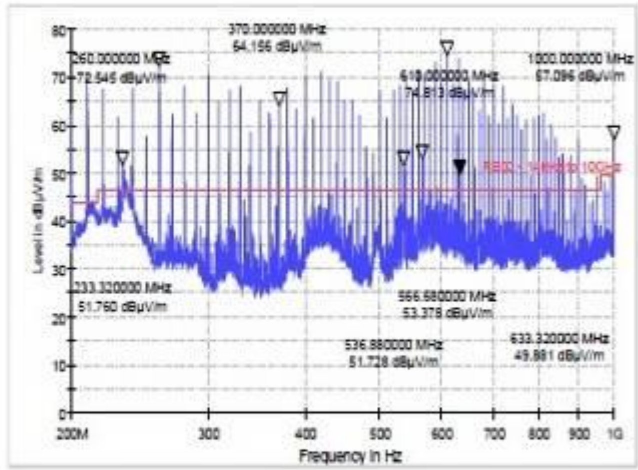

Figure 16: RE02 Test Results 200 MHz to 1 GHz

More than one full week was used to investigate the RE anomalies. These investigations revealed that both the Device Under Test (DUT) and its associated Ground Support Equipment (GSE) had inherent noise issues. Various shielding techniques were employed in attempts to reduce the level of radiated noise emanating from the DUT. However, none proved to be effective. Thus, the test concluded with major RE noise issues still present in the DUT.

6 Conclusions

One of the most important lessons to be taken away from this test is the need to be aware of EMI issues early in the development of an electronic system. When one waits until a system is fully developed to think about EMI issues, it is already too late. As in the case of the WSC-SDR, it may be both time-consuming and costly to eliminate or even mitigate emissions or susceptibility anomalies after a system has been developed.

Coincidentally, engineers at GSFC have proven the effectiveness of early intervention to reduce EMI anomalies with the development of the Magnetospheric Multi-scale (MMS) mission. The EMC Test Group at GSFC within Code 549 developed a mobile system that is used in a project's design labs to stomp out EMI issues at the card level. So, as a system is built up from the card level, EMI issues are either eliminated or significantly mitigated throughout the entire component, subsystem, and system development phases. This approach could have been quite beneficial in the development of the WSC SDR.

The RE concern revealed in this test does not mean that the system can't be used effectively at the WSC. As the field strength of an electromagnetic transmitter falls off with respect to distance, the WSC SDR may be placed in an environment/location where it is not in close proximity to another device that may be susceptible to the levels be radiated by the SDR. So, an assessment of the WSC SDR's intended working environment must be made to ensure that this device will work as envisioned without impairing the operation of other devices working within the same environment.

7 Acknowledgments

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8 References

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