Radio Access and Devices – Wireless Technology Strategies

Date: **September 18, 2014**

Subject: **Joint AT&T/SiriusXM Interference Testing Results**

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Abstract

As a requirement for the joint signing of the AT&T/Sirius XM Coordination Agreement for the WCS C&D Blocks (Coordination Agreement), testing of AT&T's Air-to-Ground (ATG) Avionics Stations and ATG Base Stations to determine the potential for harmful interference to Sirius XM's Satellite Digital Audio Radio Systems (SDARS) receivers was stipulated by the parties. This document presents the results of that testing.

For the ten use cases specified in the Test Plan the following results were obtained:

(1) The power and altitude requirements specified in the Joint Agreement for AT&T's Avionics Station both with and without WCS A&B Block devices met requirements above 10Kft but did not meet the requirements by 6 to 19 dB at and below 1000 feet and at power levels of 1 and ¼ of a watt. (It was proposed because of these missed objectives that the altitude demarcation point of the two lower power levels be increased by an amount that would result in the Avionics Station meeting the specified requirements. In addition with power control, clutter and the proposed airplane operational conditions, the interference potential lowers such that ¼ watt power max at ground level is still acceptable to both AT&T and Sirius XM for the proposed avionics service.
(2) The power specified in the FCC Rules at the SiriusXM receiver from a WCS D Block Base Station met requirements.
(3) The power at the SiriusXM receiver from the WCS D Block and the WCS A & B Blocks at equal power levels missed the requirement by 2 dB. (It was generally felt that this difference could be overcome by prudent network design.
(4) Reducing the out-of-band signal (OOBE) 10 and 18 dB without changing the inband signal level showed that reducing the out-of-band signal level had no appreciable effect on testing results for the Sirius TDM1 band .
(5) Reducing the power at the SiriusXM receiver in the A and B Blocks Stations from -42 dBm/10 MHz to a – 45 dBm/10 MHz while having a simultaneously transmitting C-block station in the lower WCS band had no appreciable effect on testing results for interference into the Sirius TDM1 band.
(6) Under established test conditions with a 5 dB increase in the satellite power (repeater power) at the SiriusXM receiver, the muting interference power level at the receiver could be 7 dB higher. (It was generally felt that a one to one increase would be appropriate.).

1. Introduction

As a requirement for the joint signing of the AT&T/Sirius XM Coordination Agreement for the WCS C&D Blocks (Coordination Agreement), testing stipulated by the parties in the Coordination Agreement at the SiriusXM labs in New Jersey was completed. A Joint Test Plan, included in the Appendix, was developed by both parties which defined the testing procedures followed during the testing. This testing was performed to determine the potential for harmful interference between AT&T's Air-to-Ground (ATG) Avionics Stations and ATG Base Stations to Sirius XM's Satellite Digital Audio Radio Systems (SDARS) receivers. This document presents the results of that testing.

1. Testing Methodology

The objectives of testing AT&T's ATG operations was to assure SiriusXM that in-band emissions and Out-Of-Band Emissions (OOBE) originating from the proposed ATG operations will not impact SiriusXM receiver operations regardless of the operational condition. To meet these testing objectives ten use cases were tested. These 10 use cases can be divided into four categories: (1) testing of various inband and out of band WCS C Block only receive power levels at the SiriusXM receiver, (2) testing of various inband and out of band WCS C Block receive power levels at the SiriusXM receiver with a WCS A and B Block receive power level at the SiriusXM receiver of a – 42 dBm across the two blocks, (3) testing of a single inband and out of band WCS D Block only receive power levels at the SiriusXM receiver of a – 55 dBm and (4) testing of a single inband and out of band WCS D Block receive power levels at the SiriusXM receiver of a – 55 dBm with WCS A and B Block receive power levels of a – 55 dBm in each of the two blocks at the SiriusXM receiver. The first category includes use cases 1 through 4. Each one of these cases tests a different C Block transmit power level (1/4, 1, 8 and 16 watts). The second category includes use cases 5 through 8. Each one of these cases also tests a different C Block transmit power level (1/4, 1, 8 and 16 watts).The third category includes use case 9 and the fourth category includes use case 10.

In each case the satellite receive level at the SiriusXM receiver was set to the specified satellite receive level (- 100 dBm for the Sirius system adjacent to the C Block and a – 103 dBm for the XM system adjacent to the D Block) and the WCS receive level was adjusted until audio distortion occurred. The level recorded was one dB above the distortion level. This level was compared to the target receive level (a calculated power level that took into account transmit power, path loss and equipment capabilities for the various aircraft altitudes) to determine if harmful interference existed.

2. Study Results

Testing results for the ten use cases are shown below.

Table 1. WCS C Block Only Testing Results

TDM1 = -100dBm	WCS	Power	Radio	Satellite	Target Pwr. (dbm) from Path Loss	Highest WCS-C Block Power (5MHz) not Causing a Mute	Note
Case #1	C-Block	0.25W	G2.5	TDM1	-50	-67.5	Remove 10 dB OOBE: -66 dBm
	0 ft ground level						Remove 18 dB OOBE: -66 dBm
Case #2	C-Block	1W	G2.5	TDM1	-59.5	-66.5	Remove 10 dB OOBE: -65.8 dBm
	1k ft						Remove 18 dB OOBE: -65.8 dBm
Case #3	C-Block	8W	G2.5	TDM1	-71	-71	Meets Target
	10k ft						
Case #4	C-Block	16W	G2.5	TDM1	-73.5	-73.5	Meets Target
	20k ft						

Table 2. WCS C Block With A & B Blocks Testing Results

TDM1 = -100dBm	WCS	Power	Radio	Satellite	Target Pwr. (dbm) from Path Loss	Highest WCS-C block Power (5MHz) not Causing a Mute	Note
Case #5	C-Block	0.25W	G2.5	TDM1	-50	-69.5	
	A/B-L (-42 dBm/10MHz)					-68.5	at A/B = -45 dBm
	0 ft ground level					-61.8	at TDM1=-95 dBm
Case #6	C-Block	1W	G2.5	TDM1	-59.5	-68.5	
	A/B-L (-42 dBm/10MHz)					-67.5	at A/B = -45 dBm
	1k ft						
Case #7	C-Block	8W	G2.5	TDM1	-71	-71	Meets Target
	A/B-L (-42 dBm/10MHz)						
	10k ft						
Case #8	C-Block	16W	G2.5	TDM1	-73.5	-73.5	Meets Target
	A/B-L (-42 dBm/10MHz)						
	20k ft						

Table 3. WCS D Block Only Testing Results

SAT1B = -103dBm	WCS		Radio	Satellite	Target Pwr. (dbm) from Path Loss	Highest WCS-D Block Power (5MHz) not Causing a Mute	Note
Case #9	D-Block		Roady XT	SAT1B	-55	-55	Meets Target

Table 4. WCS D Block With A & B Blocks Testing Results

SAT1B = -103dBm	WCS		Radio	Satellite	Target Pwr. (dbm) from Path Loss	Highest WCS-D Block Power (5MHz) not Causing a Mute	Note
Case #10	D-Block		Roady XT	SAT1B	-55	-57	D/Au/Bu (in 5MHz)
	Au/Bu equal power to D						

3. Conclusions

In the first category of testing (Use cases 1 through 4), the test results show that the requirements on the ATG Avionics Station operating in the WCS C Block at and above 20 Kft and from 20 Kft to 10 Kft were met. The test results also show that from 1 Kft to the ground the ATG Avionics Station operating in the WCS C Block did not meet the requirements. The requirements at 1 Kft and a transmit power level of 1 watt missed the objective by 6 dB. The requirement on the ground and at a transmit power level of 1/4 watt missed the objective by 17 dB. It was proposed because of these missed objectives that the altitude demarcation point of the two lower power levels be increased by an amount that would result in the Avionics Station meeting the specified requirements. In addition with power control, clutter and the proposed airplane operational conditions, the interference potential lowers such that ¼ watt power max at ground level is still acceptable to both AT&T and Sirius XM for the proposed avionics service.

Additional testing was done during Case 1 testing that included reducing the out-of-band signal (OOBE) 10 and 18 dB without changing the inband signal level. These tests were done to determine if the out-of-band or inband signal was causing the harmful interference condition. The results of the testing showed that reducing the out-of-band signal level had no appreciable effect on the testing results for the Sirius TDM1 band.
In the second category of testing (Use cases 5 through 8), the test results showed that the requirements on the ATG Avionics Station operating in the WCS C Block with the A and B Blocks Stations at a power level of a – 42 dBm across 10 MHz at and above 20 Kft and from 20 Kft to 10 Kft were met. The test results also showed that from 1 Kft to the ground the ATG Avionics Station operating in the WCS C Block with the A and B Blocks Stations at a power level of a – 42 dBm across 10 MHz did not meet the requirements. The requirements at 1 Kft and a transmit power level of 1 watt missed the objective by 9 dB. The requirement on the ground and at a transmit power level of 1/4 watt missed the objective by 19 dB. It was proposed because of these missed objectives that the altitude demarcation point of the two lower power levels be increased by an amount that would result in the Avionics Station meeting the specified requirements. In addition with power control, clutter and the proposed airplane operational conditions, the interference potential lowers such that ¼ watt power max at ground level is still acceptable to both AT&T and Sirius XM for the proposed avionics service.

Additional testing was done during Case 5 testing that included reducing the power at the SiriusXM receiver in the A and B Blocks Stations from -42 dBm/10 MHz to a – 45 dBm/10 MHz while having a simultaneously transmitting C Block station in the lower WCS band. This test was done to determine if the power from the A and B Block Stations was causing the harmful interference condition. The results of the test showed that reducing the A and B Blocks Station's signal level had no appreciable effect on testing results for interference into the Sirius TDM1 band. Another additional test that was done during Case 5 testing that was not officially documented in the Test Plan but was documented in the results was a test under Case 5 conditions but with a Sirius satellite signal level 5 dB higher. The results of this test showed that with a 5 dB increase in the satellite power at the SiriusXM receiver, the muting point of the receiver could be 7 dB higher. It was generally felt that a one to one increase would be appropriate.

In the third category of testing (Use cases 9), the test results show that the power at the SiriusXM receiver from the WCS D Block met requirements. For the fourth category of testing (Use case 10), the test result shows that the power at the SiriusXM receiver from the WCS D Block and the WCS A & B Blocks at a power level equal to the D Block's power level missed the requirement by 2 dB. It was generally felt that this difference could be overcome by prudent network design.

APPENDIX

Date: **July 15, 2014**

Subject: **ATG LTE/SDARS Interference Test Plan**

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4. 1. Introduction

As a requirement for the joint signing of the AT&T/Sirius XM Coordination Agreement for the WCS C&D Blocks (Coordination Agreement), testing of AT&T's Air-to-Ground (ATG) Avionics Stations and ATG Base Stations to determine the potential for harmful interference to Sirius XM's Satellite Digital Audio Radio Systems (SDARS) receivers was stipulated by the parties. This document defines the testing procedures.

5. 2. Test Objectives

The purpose of testing AT&T's ATG operations is to assure Sirius XM that in-band emissions and Out-Of-Band Emissions (OOBE) originating from the proposed ATG operations will not impact Sirius XM receiver operations regardless of the operational condition.

6. 3. Methodology

The testing will be performed in a conducted setup at the Sirius XM Engineering Labs in Lawrenceville, New Jersey by qualified personnel from AT&T and Sirius XM.

3.1 Test Setup

The setup is shown in Figure 1. SDARS and the simulated ATG interference signals will be generated from their respective signal generators. The ATG interference signal shall be generated from two signal generators, one simulating the simulating in-band and the other one simulating the OOBE part of the ATG signal according to the levels specified in the Coordination Agreement.

The simulated ATG WCS C- and D- block in-band signal will be generated with the LTE Device Simulator 2 and represent an FDD LTE signal at full burst rate (100%) and channel resource block utilization (5 MHz). This signal will be filtered with Band Filter 2 to remove any excess OOBE generated internally from the LTE device simulator.

For the respective test cases, the simulated ATG WCS A- and B- block in-band signal will be generated with the LTE Device Simulator 1 and represent an FDD LTE signal at full burst rate (100%) and channel resource block utilization (5 MHz) for each of those bands. This signal will be filtered with Band Filter 1 to remove any excess OOBE generated internally from the LTE device simulator.

The ATG aircraft OOBE test signal will be a simulated physical realization of the 5 MHz LTE Device emissions within the SDARS band representing AT&T's proposed OOBE mask for the WCS C block ATG operations. LTE Device Simulator 3 will generate the simulated WCS C-block OOBE test signal at the aircraft. The tested WCS C block OOBE mask is depicted in Figure 2. This mask will be created using multi-tone carriers and resembling and scaling them as closely as possible to the tested OOBE mask. Any other tested WCS OOBE profiles will comply with the current rules.

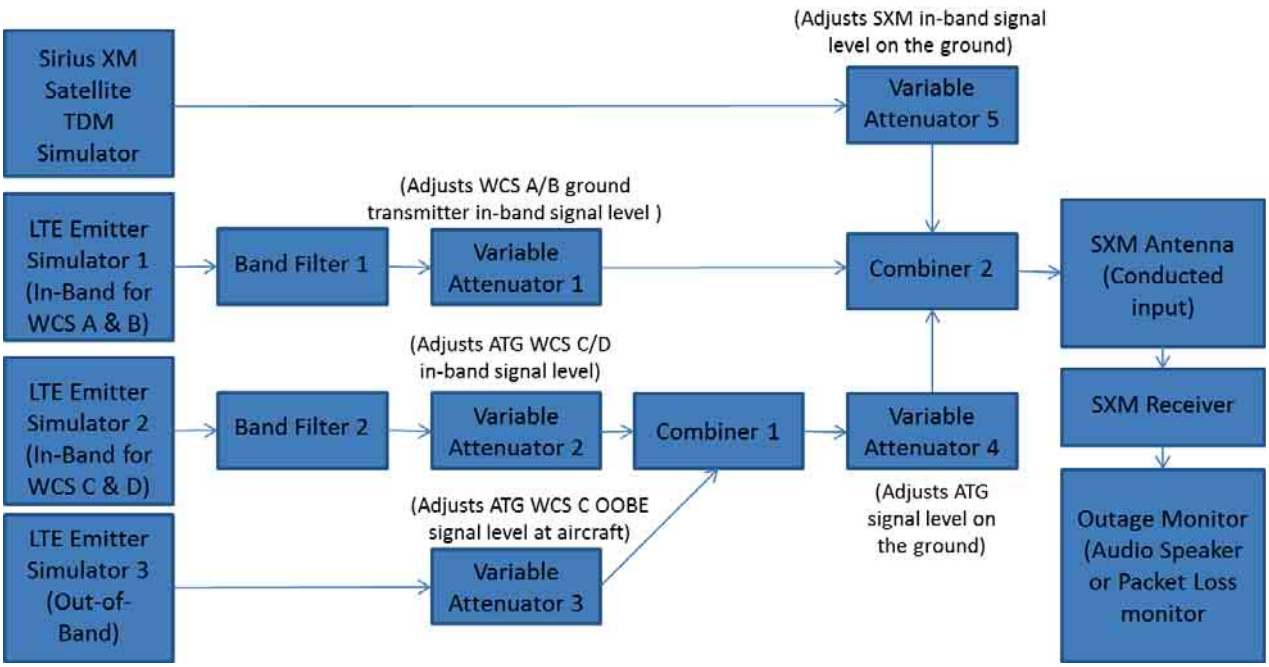

FIGURE 1. High Level Test Setup

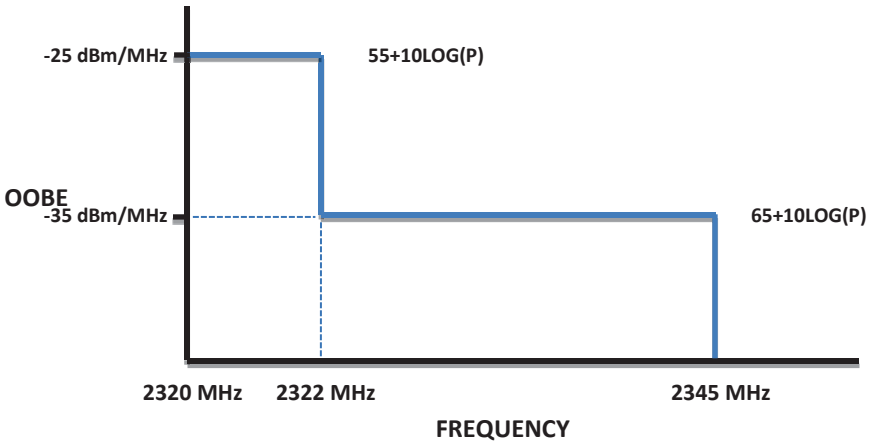

FIGURE 2. Tested OOBE Mask

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Variable Attenuators 2 and 3 will be used to adjust the respective simulated WCS in-band and OOBE signal levels at the output of Combiner 1 at the ATG transmitter level according to the Coordination Agreement.

Variable Attenuator 4 will be used to adjust for Free Space Path Loss (FSPL)[1] to result in the proper WCS signal levels on the ground, after combining with the generated SDARS signals at the output of Combiner 2.

Variable Attenuator 1 will be used to adjust for the level of the generated WCS signals representing ground emitters from the A and B blocks at the output of the Combiner 2.

Variable Attenuator 5 will be used to adjust for the ground level of the generated SDARS signal at the output of Combiner 2 as well.

The resulting composite signal (SDARS and WCS ATG interference) at the output of Combiner 2 shall be fed to the Sirius XM antenna/receiver setup with audio muting and code word error monitoring capability.

During the test, while keeping the SDARS signal stable, the levels of the generated WCS signals will be varied with the respective attenuators in order to test the impact to the SDARS receiver technical parameters specified in the Coordination Agreement. These steps are specified below.

3.2 Test Procedure

1. Set the Sirius XM Satellite Transmitter Simulator to TDM1 at – 101 dBm ground power level of by adjusting the Attenuator 5 and measure this level at the output of Combiner 2.
2. With the WCS LTE Simulator turned off, verify proper operation of the Sirius XM receiver.
3. Turn on the WCS LTE Simulators 1, 2 and 3 with their respective the test waveforms.
4. Repeat the following steps for the tested ATG technical operation parameters as specified in Coordination Agreement. A detailed test case matrix is shown in the appendix.
    a. Adjust the Attenuator 2 and 3 to result in the proper WCS interference signal (i.e. set the relationship between the WCS ATG in-band and OOBE emissions) at aircraft level at the output of Combiner 1.

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[1] The FSPL equals $\left(\frac{4\pi df}{c}\right)^2$ where: λ is the signal wavelength (in meters), f is the signal frequency (in hertz), d is the distance from the transmitter (in meters), c is the speed of light in a vacuum (2.99792458×10^8 meters per second).

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b. For the multicarrier WCS interference test cases, adjust the Attenuator 1 to result in the proper WCS A/B interference signal at ground level at the output of Combiner 2.
c. Starting from an interference level that would typically not cause a service event condition for the Sirius XM receiver (i.e. WCS ground signal level <-70 dBm as measured at the output of Combiner 2), vary the Variable Attenuator 4 to increase the WCS interference signal level up to the corresponding ground power levels according to the aircraft transmit power at various altitudes as specified Coordination Agreement and observe whether an error event condition occurs at the Sirius XM receiver.
    i. An event condition occurs if the interference causes the SDARS receiver to produce an audio mute or a code word error within a 2 minute observation window. During each Variable Attenuator step change, allow time for the SDARS receiver to empty the initial buffer.
d. Once an event condition is detected, reduce the WCS interference signal level in order to determine the highest WCS interference signal level that does not cause an event condition. While reducing the interference level after a muting event, allow proper time for the receiver to reacquire the signal.
e. Document the test information
    i. Document the test case:
        1. Tested WCS signal profile (power levels, spectrum analyzer pictures)
        2. SDARS signal level at ground level
    ii. Document test results:
        1. Tested WCS signal levels and the observed event conditions
        2. Using 1) the highest WCS signal level measured above and 2) the path loss calculation in Reference 1, calculate and report the corresponding power level at the tested ATG transmitter distance.

7. 4. Testing Schedule and resources

The test will be implemented in the week of September 8, 2014. All test resources will be provided by AT&T and Sirius XM.

8. 5. Summary

Completing these tests will provide data on possible harmful interference conditions from the proposed AT&T operations to Sirius XM receivers and will assist in the evaluation of AT&T's rule waiver (or rule making) request submitted to the FCC.

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Appendix - Test cases

There will be a total of 10 test cases as defined below.

All test cases will use the following OOBE mask settings:

- The OOBE from the airplane shall not exceed 55+10LogP between 2320 and 2322 MHz, and 65+10LogP between 2322 and 2345 MHz
- The OOBE from the ATG base station shall not exceed 75+10logP
- All the other tested combinations of WCS signals from the A and B blocks shall be assumed to comply with the current FCC specifications, while the OOBE will be simulated in the test using the single C-block and D-block case levels, respectively.

There will be five test cases to determine impact to SDARS in single carrier ATG interference conditions:

1. WCS C-block airplane to ATG base station transmission
   a) 0.25 W below 1,000 feet and Above Ground Level (AGL), and on the ground,
   b) 1 W below 10,000 feet and above 1,000 feet AGL
   c) 8 W below 20,000 feet and above 10,000 feet AGL
   d) 16 W above 20,000 feet

2. WCS D-block ATG base station to airplane transmission
   a) 2,000 W Average with 13 dB PAR

There will be five test cases to determine impact to SDARS in multicarrier (ATG and ground cellular) interference conditions, where A and B block interference would occur at the impacted SDARS terminals while ATG interference also creates impact. These are the following:

3. WCS C-block airplane to ATG base station transmission with simultaneous ground interference from the lower WCS A and B blocks at 0.25 w per 5 MHz transmit power level for each of the A and B blocks.
   a) 0.25 W below 1,000 feet and Above Ground Level (AGL), and on the ground,
   b) 1 W below 10,000 feet and above 1,000 feet AGL
   c) 8 W below 20,000 feet and above 10,000 feet AGL
   d) 16 W above 20,000 feet

4. WCS D-block ATG base station to airplane transmission test cases with simultaneous ground interference from the upper WCS A and B blocks at 2000 w per 5 MHz transmit power level
   a) 2,000 W Average with 13 dB PAR

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