Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of:	)	
	)	
	)	
Commission Staff Requests That Interested Parties Supplement the Record on Draft Interference Rules For Wireless Communications Service and Satellite Digital Audio Radio Service.	))))))	WT Docket No. 07-293 IB Docket No. 95-91 GEN Docket No. 90-357 RM No. 8610

SUPPLEMENTAL COMMENTS OF SIRIUS XM RADIO INC.

Sirius XM Radio Inc. ("Sirius XM") hereby submits these supplemental comments for the record in the above-captioned proceeding in order to provide additional technical information regarding the effect that the Commission's proposed Part 27 Wireless Communications Service ("WCS") rules[1] would have on satellite radio receivers.

Sirius XM has commissioned Dr. Theodore S. Rappaport, P.E., of the Telisite Corporation, who is the William and Bettye Nowlin Chair in Engineering at the University of Texas at Austin and the founding director of the Wireless Networking and Communications Group (WNCG) at the University's Austin campus, to assess the probabilities of interference to satellite radio service caused by WCS devices operating under the proposed rules that are contained in the Staff Public Notice. This analysis is contained in the attached report entitled "Technical Analysis of the Impact of Adjacent Service Interference to the Sirius XM Satellite Digital Audio Radio Services (SDARS)" and provides some of the clearest evidence yet that the

1 *Commission Staff Requests that Interested Parties Supplement the Record on Draft Interference Rules for Wireless Communications Service and Satellite Digital Audio Radio Service*, Public Notice, WT Docket No. 07-293, IB Docket No. 95-91, GEN Docket No. 90-357, RM No. 8610 (rel. Apr. 2, 2010) ("Staff Public Notice").

staff's proposed Part 27 rules would result in crippling interference to satellite radio operations in an unacceptable number of cases. Although retained by Sirius XM to conduct this study, Dr. Rappaport has undertaken this project under the express written conditions that the opinions provided in this study are his own.

In his study, Dr. Rappaport engages in a scientifically rigorous and transparent engineering analysis of the potential for mobile-to-mobile interference from WCS devices to satellite radio receivers. In addition to explaining how the proposed rules are inconsistent with the specific technical and operational needs of satellite broadcast systems, Dr. Rappaport also presents the results of a detailed and realistic "Monte Carlo" simulation of the interaction between these services. Dr. Rappaport's study demonstrates that the proposed Part 27 rules will unacceptably reduce the availability of satellite radio services, causing disruptive muting to a significant portion of satellite radio users. Dr. Rappaport's conclusions are consistent with the results of various studies Sirius XM has submitted in this proceeding.

Before revising the Part 27 service rules, the Commission should carefully consider Dr. Rappaport's well-reasoned analysis of the potential harm to over 35 million satellite radio listeners. Dr. Rappaport's analysis is founded upon reasonable, conservative assumptions and sound engineering. His findings confirm that there is a possible technical solution that will allow robust deployment of mobile broadband services in the WCS spectrum while also protecting satellite radio. Regrettably, Dr. Rappaport's findings also conclusively demonstrate that the proposed rules in the Staff Public Notice are not consistent with that optimum solution.

Respectfully submitted,

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April 29, 2010

Technical Analysis of the Impact of Adjacent Service Interference to the Sirius XM Satellite Digital Audio Radio Services (SDARS)

Dr. Theodore S. Rappaport, P.E.
TELISITE Corporation

April 29, 2010

STATEMENT OF DR. THEODORE S. RAPPAPORT

TELISITE Corporation

I, Dr. Theodore S. Rappaport, hereby state the following:

1. I received B.S., M.S., and Ph.D. degrees in electrical engineering from Purdue University in 1982, 1984, and 1987, respectively.

2. I am the William and Bettye Nowlin Chair in Engineering at the University of Texas at Austin (UT Austin) and am the founding director of the Wireless Networking and Communications Group (WNCG) at the university's Austin campus.

3. Prior to joining UT Austin, I was on the electrical and computer engineering faculty of Virginia Tech from 1988 to 2002, where I founded the Mobile and Portable Radio Research Group (MPRG), one of the world's first university research and teaching centers dedicated to the wireless communications field.

4. I have served on the Technological Advisory Council of the Federal Communications Commission, assisted the Governor and Secretary of Technology of Virginia in formulating rural broadband initiatives for internet access, and conducted research for the National Science Foundation, the Department of Defense (DOD), and dozens of global telecommunications companies.

5. I have provided objective technical analysis for the FCC and the listening public in the past. During the FCC proposed rulemaking for Low Power FM (LPFM), my work provided a thorough analysis of the technology and the regulations of existing and proposed FM broadcasting equipment. In the LPFM report, my company undertook a careful study of the state of FM receivers, the existing and proposed FCC regulations for LPFM, and used a database of actual FM broadcasting stations to conduct a computer simulation for coverage and interference levels. The results provided a meticulous, credible analysis which aided the FCC in making informed decisions regarding the LPFM interference regulations and protection to incumbent FM broadcasting stations.

6. I have testified before the United States Congress, served as a consultant for the International Telecommunication Union, consulted for over 30 major telecommunications firms, and have worked on many national committees pertaining to communications research and technology policy.

7. I am a technically qualified person and am familiar with the rulemaking proceeding related to interference rules for wireless communications service and satellite digital audio radio service.

8. The contents of this report were prepared by me or under my direct supervision and are complete and accurate to the best of my knowledge and belief.

Dr. Theodore S. Rappaport

Executed on 4/29/10

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Executive Summary

This study, prepared by Dr. Theodore S. Rappaport, P.E., of TELISITE Corporation, presents a scientific analysis of the impact on satellite radio services of the Part 27 Wireless Communications Service (WCS) rules proposed by Federal Communications Commission staff in an April 2, 2010 Public Notice.[1] The report discusses the background characteristics of these two services, the potential for interference to satellite radio posed by WCS due to their differing characteristics, and the results of a highly detailed "Monte Carlo" simulation based upon an application of the Commission's proposed rules. This analysis provides some of the clearest evidence yet, based on accepted and transparent engineering techniques, that the FCC's proposed Part 27 rules would result in crippling interference to satellite radio operations in an unacceptable number of cases.

Satellite systems have significantly different technical limitations and operational challenges than cellular systems. Satellite systems operate with very low link margins and thus are unable to tolerate even moderate sources of unplanned-for interference. Cellular systems, on the other hand have much larger received signal levels, which allow them to overcome both intrasystem and interservice interference. Moreover, systems operating on a broadcast business model strive for—and indeed their consumers will accept nothing less than—near constant availability over their entire service area. For Sirius XM, which has a service area covering the entire Continental United States (CONUS), this translates into a target of over 99% "worst case" availability in all locations within the CONUS, even in heavy local shadow fading conditions.

Interference from cellular Wireless Communication Systems (WCS) users to satellite radio receivers can be in one of the three forms; out-of-band emissions, overload, and intermodulation. Through the use of a detailed simulator, this paper characterizes the impact of out-of-band emission interference in reducing the quality of service of satellite radio broadcast receivers. In this context, this study analyzes the effect of the Commission's proposed rules on co-channel (*i.e.*, out of band emissions, - OOBE) experienced by satellite radio receivers for the realistic case of randomly placed WCS mobile transmitters and satellite radio receivers on highways. The paper also provides a brief analysis of the impact of overload interference that causes satellite receivers to become unusable due to desensitization.

As a point of reference, the legacy Sirius satellite system provides satellite link margin between 8 dB and 14 dB depending on the location of the satellite radio receiver. However, under the Commission's proposed rules, OOBE would end up eliminating the link margin, and creating desired to undesired signal ratios (D/U) of between -11 and -19 dB. The result would be to wipe out satellite radio in some cases, rendering the satellite radio service useless by allowing interferers to have an order of magnitude greater power than the protected signal. This study concludes that to obtain its original quality of service under the proposed rule, Sirius XM would have to increase the power of its satellite transmitters by about 33 dB, an impossible feat considering that Sirius XM is already using one of the highest power satellite designs in the industry.

This report also considers the performance of actual satellite radio receivers and provides an analysis to show that satellite radio receivers need to be protected from WCS mobile transmitters in greater fashion than has been proposed by the FCC. The overload or intermodulation interference conditions create incremental impact on satellite service availability. The analysis shows that adjacent channel transmit powers should not exceed 3 to 8 dBm from the C and D blocks, or 13 to 18 dBm from the lower B and upper A blocks—each of which would be produced by transmissions at less than 100 mW. Any greater transmitted signal level will overload and mute the satellite radio receiver at a three meter separation distance. However, the proposed rules would allow 250 mW transmissions. After taking into consideration the higher per megahertz signal strength in the C & D blocks, this would result in satellite radio receivers receiving between 9 and 24 dB more adjacent channel signal than the maximum amount an average receiver can withstand before experiencing overload.

To demonstrate the effect of the proposed rules in a comprehensive and realistic way, a detailed "Monte Carlo" software simulation of interactions between WCS and satellite radio that considered a variety of technical, environmental, and usage parameters was conducted. A series of reasonable assumptions were made regarding variables such as device market penetration, service usage, propagation path loss, power control, and highway traffic distribution, all of which are clearly explained in the analysis. The simulation also measured the impact of various OOBE masks applied to the WCS mobile transmitters.

[1] Although retained by Sirius XM to conduct this study, Dr. Rappaport has undertaken this project under the express written conditions that the opinions provided in this study are his own.

The study demonstrates the impact of WCS out of band emissions on satellite radio quality of service by simulating the interaction between the services in five geographically diverse cities, based on accurate traffic patterns. As an illustration of the findings, this report discusses in detail the results of the simulation for I-85 west of Charlotte, North Carolina. This data shows that under the proposed rules, 5.57% of the satellite radio receivers (1 in 18 listeners) would experience significant impairment and muting effects in normal highway busy hour conditions, using an accurate propagation path loss model between vehicles. Even when a more conservative, lossy propagation model between vehicles is assumed, 2.06% of the satellite radio receivers (1 in 50 listeners) would be rendered unusable. Indeed, the simulation demonstrates that even under somewhat more restrictive technical rules than those proposed by the Commission staff, satellite radio services might experience a decrease in availability that renders the service commercially unacceptable by broadcast consumer standards. Ultimately, a suitable spectrum mask should have between 70 and 85 dB of OOBE attenuation of WCS signals received in the satellite radio spectrum in order to assure satisfactory operation of satellite radio receivers.

Before adopting any changes to the Part 27 service rules, the Commission should carefully consider Dr. Rappaport's well-reasoned and transparent analysis of the potential harm to over 30 million satellite radio listeners. Dr. Rappaport's analysis is founded upon reasonable, conservative assumptions and sound engineering. This analysis confirms that there is a possible solution that will allow robust deployment of mobile broadband services in the WCS spectrum while also protecting satellite radio. Regrettably, Dr. Rappaport's findings also conclusively demonstrate that proposed rules of the staff's Public Notice do not use this solution.

1 Introduction

This technical report has been created to assist the FCC in understanding the impact of adjacent service interference to the Satellite Digital Audio Radio Service (SDARS), as the FCC staff has recently proposed.[2]

This report was commissioned by Sirius XM, Inc. and has been prepared in an objective, technically scientific manner to provide a fundamental understanding of the technical and regulatory nature of adjacent services and the impact that spectral masks provided by the FCC will have on the quality of service that Sirius XM is able to offer to its listening public. All assumptions, technical references, and source code used to develop the analysis presented here are offered for the public record, as attached in Appendices A, B, and C. While retained by Sirius XM to conduct this study, the author has undertaken this project under the express written conditions that the opinions provided in this study are his own.

Under the current proposal, the FCC seeks to relax the out-of-band interference protection limits provided to the SDARS service. In the March 1997 rulemaking (FCC-97-70) the FCC allocated six frequency slots in two contiguous bands (2305-2320 MHz and 2345-2360 MHz) to the WCS service, while providing spectrum for SDARS at 2320-2345 MHz between these bands as shown in Figure 1.

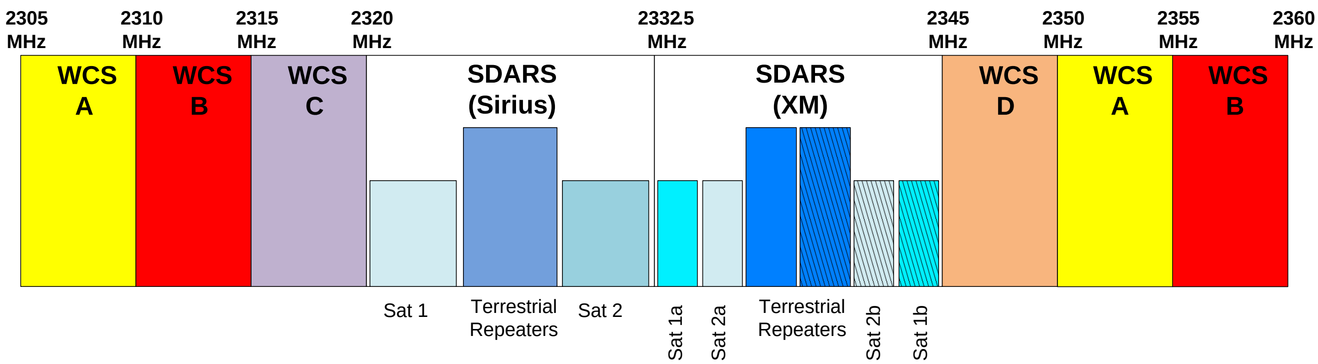

Figure 1: SDARS and WCS Spectrum Allocations

This report seeks to provide a fundamental understanding of the technical issues involving out-of-band interference for SDARS, and seeks to demonstrate what is practical, viable, and fair to all parties interested in using the 2300 MHz band of frequencies. Our goal in preparing this report is to provide technical data and analysis while providing reasonable and accurate simulations to understand the potential degradation of SDARS listening quality in the face of different FCC out of band emission (OOBE) rules for WCS. In taking an objective first-principles approach, the author strives to create an equal-footing from which technical arguments, tradeoffs, decisions and assessments may be made.

The report is organized in the following manner.

Section 2 of this report describes the fundamental differences between broadcast networks, satellite networks, and mobile networks. We point out that broadcast networks may be both satellite or terrestrial-based, and mobile networks are primarily terrestrial-based but can also be satellite-based (as in the case of Iridium). In the case of Sirius XM, we find that the service is primarily a satellite broadcast service which is augmented by terrestrial-based repeaters that provide coverage for when satellite signals are blocked (e.g. shadowed) primarily by buildings in dense urban areas.[3] Section 2 demonstrates the key design differences and operating characteristics of each of these types of networks, and shows how technical decisions, equipment choices, investments, and tradeoffs are made between noise-limited and interference-limited systems. Section 2

[2] *Commission Staff Requests that Interested Parties Supplement the Record on Draft Interference Rules for Wireless Communications service and Satellite Digital Audio Radio Service*, Public Notice, WT Docket No. 07-293, IB Docket No. 95-91, GEN Docket No. 09-357, RM No. 8610 (rel. Apr. 2, 2010) ("FCC Staff Proposal").

[3] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293 as "*Comments of Sirius Satellite Radio, Inc*.", February 14, 2008. See Page 17.

also demonstrates how these different systems must be planned and deployed, and we show the clear distinction between radio frequency (RF) planning techniques of these three types of radio services.

Section 3 provides a technical overview of the Sirius XM Radio SDARS satellite system, including received power levels and specific implementations that make the SDARS service novel. This section also provides a technical overview of cellular-based wireless systems, and provides an overview of how WCS carriers may perhaps implement a cellular-like wireless service using the WCS spectrum. Modern cellular system design principles are provided in this section, as well.

Section 4 of this report evaluates various existing FCC regulations that govern the interference protection afforded broadcast, satellite, and mobile radio services. By considering past and present FCC rules for the protection of adjacent radio services, we demonstrate how the FCC has handled the integration of new services at the band edge of existing broadcast and satellite services. Where applicable, we normalize many of the existing FCC out-of-band protection rules which afford protection to other radio services, and compare them to existing FCC rules and the FCC Staff Proposal.

Section 5 provides a simulation framework and analysis of WCS-SDARS interactions, with the goal of creating an extensive simulator that can be used to determine the level of quality degradation that the listening public will experience under the FCC's currently proposed out-of-band interference protection levels for SDARS. The simulation study, and resulting simulation software code, has been developed under the direction of the author and is based on fair and realistic assumptions to determine the amount of interference and the resulting degradation to the SDARS link margin. The simulator predicts interference levels and quality degradation for various market penetration rates, highway traffic rates, and various radio propagation models between vehicles on a highway. The simulation tool predicts the impact of different FCC interference masks, and allows the user to adjust propagation path-loss models between vehicles on a highway, to adjust assumptions on the use of power control, as well as the levels of the power control itself, to adjust the type of highway traveled by users of WCS and SDARS devices, and to consider users of the adjacent WCS bands. In addition, the simulator considers the satellite look angles and resulting sensitivities to shadowing and interference experienced by SDARS receivers over the US, so that realistic simulations may be carried out for cities across the US at varying latitudes and longitudes. The simulation code is provided as part of this report as a free public-domain resource[4], enabling one to predict interference levels and impact on quality for SDARS in a wide range of operating scenarios. In addition, simulation code has been developed to consider the effect of SDARS receiver front end overload –a condition that swamps the receiver due to closely located transmitters that are not under the control of the SDARS broadcast system.

Section 6 provides examples of simulator outputs, case studies of the impact of various simulation parameters, and an analysis of the extensive data provided by the simulator. Through Monte Carlo simulations[5], we demonstrate the impact that the currently proposed FCC spectrum out-of-band protection mask will have on the Sirius XM system. Specifically, by using realistic simulations of users in different cities across the USA[6], we show the percentage of users who would be impacted by WCS interference to such a degree that they would experience noticeable outages in service. We note that SDARS has been designed to eliminate audio outages for the listener, through a complex series of delay diversity paths, link margin design, and repeaters, and the simulator demonstrates how an increased level of interference directly translates to outages of the expected high service reception quality that is similar to other subscription based satellite broadcast services, including audio, video and data services.[7] In addition to considering the FCC Staff Proposal, we offer up several different metrics that may be used by the FCC to determine an appropriate OOBE mask for WCS subscribers, and evaluate different, more protective OOBE masks that would improve the FCC's recent proposal while allowing WCS systems to flourish.

[4] Code is published as attached to this text.

[5] See author's textbook, "Principles of Communication Systems Simulation with Wireless Applications" by W. H. Tranter, K. S. Shanmugan, T. S. Rappaport, and K. L. Kosbar, c. 2004, Pearson Prentice Hall, Chapter 9.

[6] Selected locations include examples from the northeast, mid-Atlantic coast and southeast.

[7] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293 as "Comments of Sirius Satellite Radio, Inc.", February 14, 2008.

2 Fundamental Differences between Broadcast and Cellular Services

For the current FCC Staff Proposal, the Office of Engineering Technology is analyzing the technical interference coordination aspects for the 2.3 GHz band interference issues, and drafting rules based on the facts and historical coordination techniques that apply to satellite and terrestrial systems. We note that the proposed 2.3 GHz rulemaking modification will directly impact at least four different radio services, including satellite radio, WCS, Mobile Aeronautical Telemetry, and amateur radio.

It is worthwhile to highlight some key technical differences between broadcast networks, satellite networks, and cellular/mobile radio networks. As can be seen, these differences are important to analyzing the interference from cellular or fixed WCS services to the satellite radio service.

2.1.1 Broadcast systems use one-way transmissions without feedback from listeners

Broadcast systems are designed to be simplex transmission systems. Broadcast signals are sent out for wide consumption over a geographic region, and no feedback is provided to the transmitting source with regards to quality of reception by the listening public. Because of this lack of feedback, the broadcaster is unable to adapt its transmission to ameliorate any sudden or gradual change in a listener's quality. The signal quality received by the listener is therefore highly susceptible to degradation if anything in the radio environment changes. New sources of interference, or new causes of signal propagation loss, can have immediate and dramatic deleterious effects on a listener. It is for this reason that the FCC has historically afforded broadcasters very strong co-channel and adjacent channel protection levels by other stations in the same service, and from adjacent services in adjacent spectrum bands. The FCC's clear-channel designation for AM broadcasters was an early example of the care that broadcasters are traditionally given to provide a reliable coverage region and quality. A broadcaster's inability to use feedback requires it to have more protection from interference than other systems that are dynamically adjustable.

2.1.2 Broadcast systems are licensed for particular power levels with little agility

Broadcasters are licensed based upon their fixed installation and placement of transmitters, and are given strict licensing requirements with their spectrum allocation. Thus, unlike cellular's dynamic control and ability to install new base stations within its own spectrum to support customer growth, broadcast systems typically provide stable coverage that doesn't vary in most cases. Because of the fixed and rigid requirements of transmitter power levels, antenna heights, and antenna placements, broadcast systems are operated in a "noise-limited" regime, where the coverage provided by the broadcaster is limited by the signal power that can be propagated to listeners, and the listener's noise level at her receiver. The lack of feedback, and the inability to adjust a broadcaster's transmission parameters, make the fixed broadcast transmissions much more sensitive to interference and noise than cellular networks (which are built to respond and adapt to dynamic signal changes from individual subscribers and are relatively unrestricted by their license from adding new base stations and adding more subscribers over time within a geographic area).

2.1.3 Since broadcast systems do not have feedback links to address outages, they must operate at a higher average quality of service than other systems

Because of the lack of feedback from the broadcast signal receivers, the lack of adaptability in their broadcasting equipment, and the inability to easily add new transmitting locations, broadcasters must design their coverage regions based on a "nominal" or "worst case" operating basis. In other words, broadcasters are forced to assume that the radio propagation environment and interference environment are static in nature, and their radio coverage zones are designed for the worst-case in that static situation. In designing a broadcast system, the FCC rules for interference protection are critical for determining the broadcaster's coverage and quality level. Once deployed, listeners to the broadcast network immediately come to expect a consistent, uninterrupted level of service, preferably of very high quality. Without real-time control or feedback of customer perceptibility, broadcasters are not able to flexibly reallocate spectrum or RF power resources to provide less power to those listeners with excellent coverage, and more power to those listeners with poor coverage. Because of the consistent expectations of listeners and lack of radio resource agility, broadcast systems must be designed to operate at a higher average quality level so that in the event unanticipated radio channel impairments (such as signal attenuation or interference) affect listeners, there is some built in safety margin to ensure that most listeners do not perceive a degradation in service. This safety margin is built into the link budget of every broadcaster's transmission scheme, and is implemented in concert with awareness of the geographical features of the RF coverage area, and with awareness of the interference levels and FCC protection rules for co-channel and adjacent channel interference coordination established during the spectrum licensing process.

2.1.4 Broadcast systems are designed to maximize coverage from just one or a few transmitters

Broadcast systems strive to use as little transmitting infrastructure as possible in order to provide coverage to its listeners at a reasonable cost. Most broadcast systems that use terrestrial or satellite radio frequencies typically have just one or a few major transmitting sites; e.g. the mobile TV broadcaster MediaFLO tries to cover large areas via single or a few tall UHF transmitters in dense urban markets.[8]

Unlike cellular systems, the addition of transmitting stations or repeaters is rare and not desired since additional transmitters are often not required to expand coverage, and in fact may create internal system interference.[9] Thus, broadcasters use the approach of building a strong main transmitting tower or satellite, and rely upon the upfront engineering analysis of the geographical RF coverage area and the FCC spectrum protections to determine coverage zones and listener quality. This is in contrast to cellular wireless systems that routinely install new cell sites and repeaters in order to accommodate subscriber growth and capacity needs, something that broadcasters strive not to do because of economic and technological reasons.

2.1.5 Broadcast receivers are much more susceptible to overload and adjacent channel interference than cellular handsets

Since broadcasters rely on only one or a few transmitters in a geographic region, the receivers used for broadcast reception are generally built to a much less rigorous specification than cellular subscriber equipment. Broadcast receivers are generally built to operate within the known specifications of the licensed broadcast service which, as shown in Sections 3 and 4, are highly protected from adjacent band interference. Thus, common terrestrial broadcast receivers are typically not built with the stringent front-end overload protections and tight band pass filtering of cellular subscriber equipment. The sensitivity to overload or adjacent channel interference in a broadcast receiver is much more acute than a typical cellular subscriber device or customer premises equipment (CPE), which are designed for the high co-channel and adjacent-channel interference levels of cellular systems.

2.1.6 Broadcast systems do not produce significant interference as they add listeners, and if repeaters are used, the FCC governs the placement of repeaters to protect other services and systems.

Because broadcast systems are one-way transmission systems, once their transmission regulations are established, they do not introduce additional interference as listeners are added. This is because all new listeners are simply receive-only – they do not transmit, and thus do not add to the spectral interference level of the system. In the event that the broadcaster uses repeaters to fill coverage holes, these repeater installations are generally governed by FCC rules that protect other services in the same or adjacent frequency bands. The fact that broadcast systems do not produce interference as listeners are added is in sharp contrast to wireless mobile systems which continually increase their total interference power levels and OOBE as more mobile subscribers are added to the network.

2.2 Fundamental Technical differences between Satellite and Cellular networks

This section highlights the primary technological differences between these two types of wireless communication systems.

2.2.1 Satellites operate with little link margin and have very weak received signal power levels on earth, thus making them hypersensitive to link impairments such as out-of-band interference.

Satellite engineers must limit the size, weight, and power drain of satellites in order to improve reliability in space, reduce degradation of the circuitry over time, and reduce satellite launch costs. A satellite is constructed to provide a specific amount of signal coverage on earth, without the ability to provide additional link margin.[10] Degradation of the link margin implies

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[8] http://en.wikipedia.org/wiki/MediaFLO

[9] http://en.wikipedia.org/wiki/Single-frequency_network

[10] Link margin, sometimes called fade margin, is the excess amount of power that is received at a receiver (in dBm) as compared to the minimum power level (in dBm) necessary for the receiver to provide acceptable reception.

that there is less excess power on the radio link to protect against fading and interference. In the event that the fading or interference losses exceed the link margin, the receiver's reception will fail. Satellite systems are typically designed to exceed 99.9% link continuity.[11] This is the case for Sirius XM, as well, although because of the severe fading experienced by mobile receivers in shadowed environments, the actual design target was to exceed 99% availability under worst case Extended Empirical Roadside Shadowing (EERS) model[12] assumptions.

2.2.2 *Sirius XM initially set its system performance design goal to ensure better than 99% availability under worst-case rural conditions for all of the contiguous United States[13].*

The Sirius XM system was designed and launched so that any SDARS listener in the US, at any time, would be assured of receiving a quality audio signal at least 99% of the time, no matter where they were in the US. Said another way, Sirius XM designed its system so that there would always be less than a 1% likelihood that any SDARS receiver would have a temporary or intermittent service outage. Achieving this design goal required the use of dual path satellite diversity and antenna beam shaping to increase the link margin in areas with lower elevation angles to the satellites.

Whether designing for a worst case availability of better than 99% or a typical average availability exceeding 99.9%, because of the huge losses due to foliage and the high expectations of radio listeners for uninterrupted service, mobile satellite systems such as the legacy XM and Sirius systems have only a thin safety margin compared to their design goals. Satellite systems operate in a noise-limited regime without a strong ability to overcome link impairments through any sort of adaptive behavior. Noise-limited regimes imply that a system's performance is limited by thermal noise, as the system is considered to already be protected against interference from adjacent users.

The antenna size of a satellite in space must be limited,[14] which is unfortunate since antenna size is directly proportional to antenna gain, which could be used to improve the link margin. Pratt and Bostian[15] show that in order to receive a 18-dB Carrier to Noise signal ratio in clear air from the INTELSAT IV-A's global beam, a ground station requires a massive 28-m diameter antenna and an extremely Low Noise Amplifier (LNA) with noise figure of about 0.1 dB. Chapter 4 of Pratt and Bostian demonstrates that typical commercial satellite links are designed for Carrier to Noise (C/N or CNR) ratios on the order of 10 dB to 20 dB for reception on earth, where the minimum acceptable C/N for acceptable reception is on the order of 4 dB to 8.5 dB. Thus, the safety margin (e.g. link margin) for a typical satellite link is 20 dB minus 8.5dB, or 11.5 dB. The safety margin offers protection for about only one order of magnitude variation of the received signal power at the satellite receiver. Any loss of signal due to foliage attenuation or building attenuation, or any increase in the receiver noise floor due to interference, shrinks the already-small link margin and leads directly to impaired reception quality as compared to the planned "worst case availability better than 99%" performance level. It is for this reason that the FCC and other governments historically provide satellite systems with very strong interference protection from out-of-band services. Without interference protection, out-of-band interference would increase the noise level of the satellite receivers, thereby eroding the fragile link margin of the satellite system.

2.2.3 *WCS and other cellular systems have substantial link margins and have much larger received signal levels in order to overcome their own interference.*

In contrast to satellite systems, cellular and fixed wireless systems are designed to operate in an *interference-limited*, rather than *noise-limited*, environment since many base stations and subscriber stations transmit on the same frequencies within a geographic region. The received signal levels at subscriber units within a cellular coverage area vary by several orders of

[11] Pratt and Bostian, "Satellite Communications"1986, Wiley, p. 119.

[12] Goldhirsh, Julius (Applied Physics Laboratory, The Johns Hopkins University) and Vogel , Wolfhard J. (Electrical Engineering Research Laboratory, The University of Texas at Austin) *Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems*, Chapter 3.3 available online at http://wwwhost.cc.utexas.edu/research/mopro

[13] *A Method for Jointly Optimizing Two Antennas in a Diversity Satellite System*, Richard Michalski and Duy Nguyen, AIAA-2002-1996 presented at the 20th AIAA International Satellite Systems Conference and Exhibit, Montreal Canada, May 12-15, 2002

[14] Ch. 4, "Satellite Communications" by T. Pratt and C. Bostian, c. 1986, John Wiley and Sons

[15] Page 125, "Satellite Communications" by T. Pratt and C. Bostian, c. 1986, John Wiley and Sons

magnitude, but are always at much stronger power levels than the signals received by satellites. This wide dynamic range of signals is due to the large proportional variations in distances between subscribers and a base station. As shown in Figure 2, the path loss (e.g., the amount of power lost in propagation from the base station to a subscriber unit) typically varies from 70 dB up to 140 dB (a signal dynamic range of over 70 dB, or 7 orders of magnitude in power) within a 10 km cell.

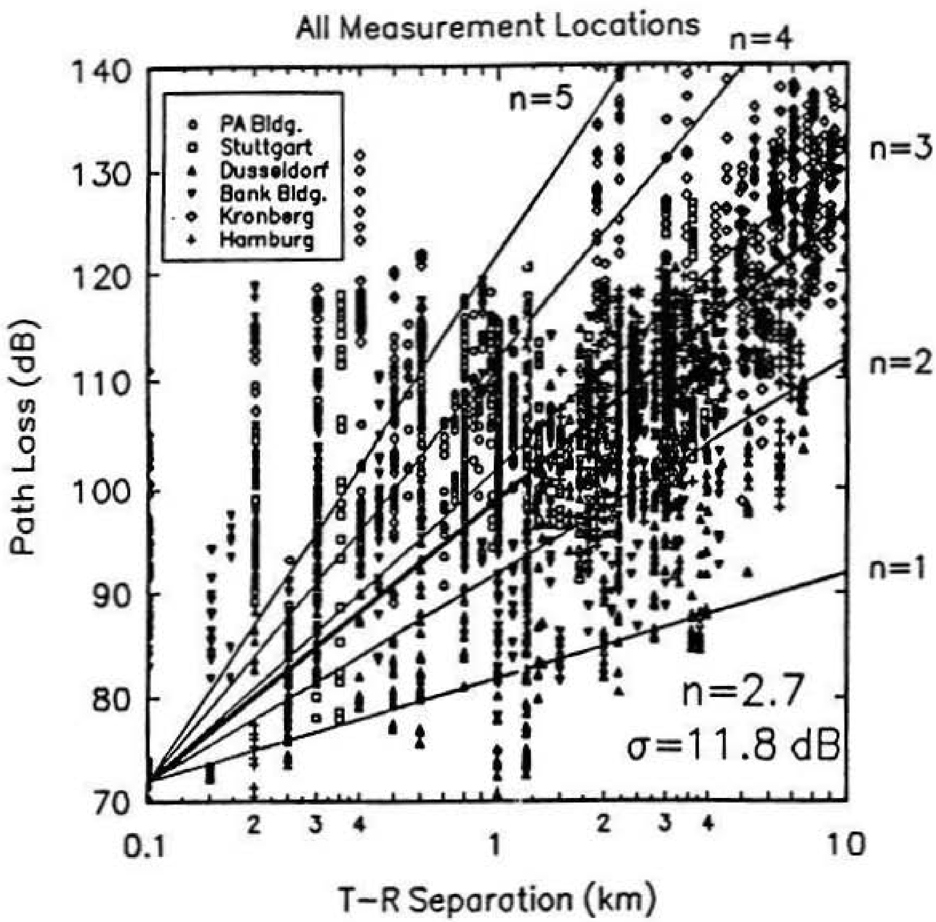

Figure 4.17 Scatter plot of measured data and corresponding MMSE path loss model for many cities in Germany. For this data, $n = 2.7$ and $\sigma = 11.8$ dB [from [Sei91] © IEEE].

Figure 2. Path Loss vs. Separation Data[16]

Even in-building cellular networks, with coverage distances of only several hundred meters, have large dynamic ranges as shown in Figure 4.27 of Rappaport (inserted here as Figure 3), where the propagation path loss over a distance of 40 meters inside a building drops from 30 dB to 100 dB (again, a 70 dB signal dynamic range).

[16] Figure 4.17 of T.S. Rappaport, "Wireless Communications: Principles and Practice, c. 2002, Pearson Prentice Hall

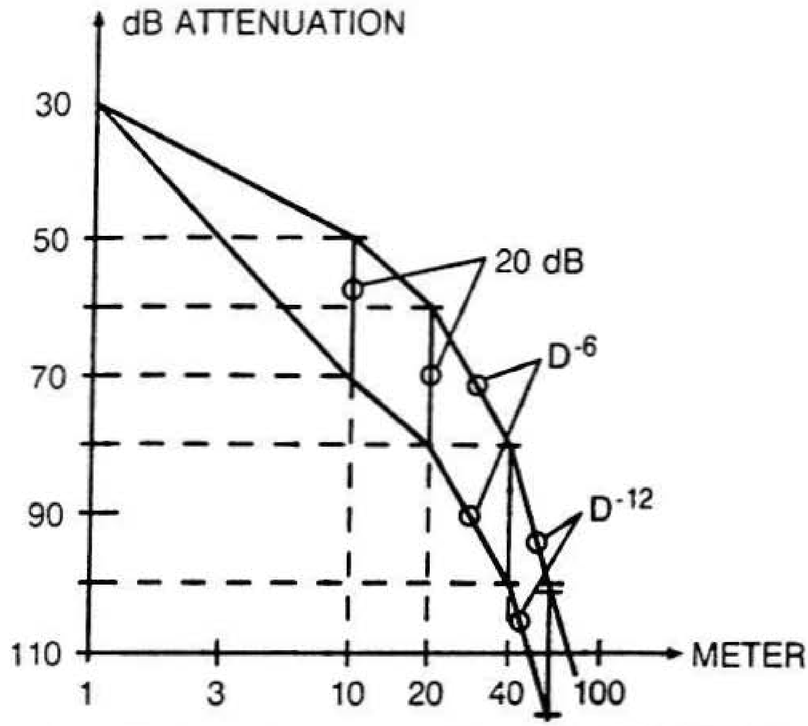

Figure 4.27 Ericsson in-building path loss model [from [Ake88] © IEEE].

Figure 3: In-building path loss Model

The robust signal variations tolerated by cellular systems allow cellular operators to install new base stations whenever link margins become saturated with interference or whenever new subscribers require more capacity. Given the large dynamic range of received signal levels in a cellular system, it is evident from Figure 2 and Figure 3 that many subscriber units can experience carrier to noise ratios of 30 dB to 50 dB or more from a serving base station, which is a much greater link margin than what is achievable by satellite systems. These tremendous link margins allow cellular systems to tolerate a great deal of interference.

3 The Sirius XM Satellite System and the WCS mobile radio service

The FCC Staff Proposal will impact the ongoing operation and performance quality of the incumbent satellite broadcaster. As discussed previously, the Sirius XM satellite system is a noise-limited satellite broadcast service that uses terrestrial repeaters to augment coverage. The WCS band will be used to provide broadband wireless services to fixed and mobile users and will operate in an interference-limited manner.

3.1 The Sirius XM Satellite System

The Sirius XM satellite system is designed to combat severe propagation experienced by mobile receivers in shadowed environments, and was deployed with a design target to exceed 99% availability in the worst case, as based upon the Extended Empirical Roadside Shadowing (EERS) propagation model[17]. In order to achieve this design goal of every receiver having less than a 1% chance of an intermittent outage, Sirius XM deploys dual path satellite diversity and antenna beam shaping to increase the link margin in areas with lower elevation angles to the satellites. In addition, terrestrial repeaters are used to augment the satellite coverage in dense urban areas where buildings or foliage provide coverage holes.

The modulation techniques of the Sirius XM satellites, types of satellites used, apportionment of content on the satellite uplinks, and use of redundancy are slightly different in the legacy XM and Sirius systems, yet both systems provide extremely similar signal level performance on earth, as both satellite systems were designed and deployed using state-of-the art satellite engineering concepts under similar FCC rules[18]. Unlike fixed satellite services that can increase margin with directional earth-based receive antennas, SDARS is a mobile service that requires an omni-directional reception capability on a vehicle installation.[19]

Both the legacy Sirius and XM satellite signal power levels are relatively weak as compared to modern terrestrial mobile and fixed wireless systems. For example,

- The XM satellite power level received before the receiver antenna in Miami, FL is -102.6 dBm over a 1 MHz bandwidth.[20] In the Northern Virginia/Washington DC area, the XM satellite provides a signal that is stronger than the Miami signal by about 8 dB, or -94.6 dBm over a 1 MHz bandwidth, in clear sky[21].
- The average[22] Sirius satellite power level received in Miami is -101 dBm per 4 MHz, and it is -99 dBm in clear sky in the Northern Virginia/DC area, which is equivalent to -107 dBm and -105 dBm over a 1 MHz bandwidth, respectively. [23]

The thermal noise level of the protected SDARS spectrum, without WCS interferers, was measured by Florida Atlantic University to be -113 dBm over a 4 MHz bandwidth.[24] Note that this -113 dBm satellite radio noise floor measured over a 4

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[17] Goldhirsh, Julius (Applied Physics Laboratory, The Johns Hopkins University) and Vogel , Wolfhard J. (Electrical Engineering Research Laboratory, The University of Texas at Austin) *Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems*, Chapter 3.3 available online at http://wwwhost.cc.utexas.edu/research/mopro

[18] Riza Akturan, "An overview of the Sirius satellite radio system", *International Journal of Satellite Communications and Networking*, Special Issue: Special issue on Mobile Satellite Radio, Volume 26 Issue 5, Pages 349 - 358, 9 Jul 2008.

[19] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008. See the gain patterns measured by Motorola.

[20] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, January 4, 2010. See Page A1 which shows that the satellite transmit power level for Miami is roughly 61 dBW. Subtracting the path loss of 191 dB attenuation for the 36.5 km of distance from the satellite to the ground, the satellite power on the ground would become -130 dBW or -100 dBm per 1.84 MHz satellite channel. As a result, it would become -102.6 dBm per MHz (-100dBm – 10log (1.84 MHz)).

[21] Comments filed by Robert Petit with FCC in Proc. 07-293, Notice of Ex Parte http://ecfsdocs.fcc.gov/filings/2010/01/22/6015531497.html

[22] Due to the satellite antenna gain pattern variations as a function of time of day in the highly elliptical satellite orbits.

[23] *Sirius Satellite Radio Inc. Application for Minor Modification of License to Construct, Launch and Operate a Non-Geostationary Satellite Digital Audio Radio Service System*, File No. SAT-MOD-19981211-00099, Dec. 11, 1998.

MHz bandwidth corresponds to -119 dBm noise floor level over a 1 MHz bandwidth.[25] Using standard satellite receiver analysis, this thermal noise level can be verified by considering an antenna sky noise temperature of 50 degrees Kelvin and a LNA noise figure of 0.65 dB (which yields a noise temperature of 47 degrees Kelvin). The derivation is shown here:

$$P_n = kTB$$

$$k = 1.38 \times 10^{-23} J/K$$

$$T = (T_{lna} \ of \ 47K + T_{antenna} \ of \ 50K)$$

$$B = 1 \, MHz = 1 \times 10^6 \, Hz$$

$$P_n = 1.38 \times 10^{-23}(47 + 50) \cdot (1 \times 10^6)$$

$$P_n = -149 \ dBW/MHz = -119 \ dBm/MHz$$

Consider a Sirius satellite as an example for further link budget analysis. After including the nominal 2 dB satellite radio vehicle antenna gain, the received satellite signal level for a Sirius satellite radio receiver located in Miami and the Northern Virginia /DC areas are, on average, -105 dBm and -103 dBm per MHz, respectively. Thus, the Sirius satellite operates with roughly a 14 dB[26] signal to noise ratio in Miami, and a 16 dB[27] signal to noise ratio in the Northern Virginia area. Based on a required 6 dB minimum signal to noise ratio needed to demodulate the SDARS signal[28], the Sirius satellite provides an average 8 dB link margin[29] in Miami and a 10 dB[30] link margin in Northern Virginia. Note that the link is even more sensitive, since there is an additional 1 to 2 dB loss in antenna pattern variation[31] (due to electromagnetic imperfections of a vehicle roof as compared to an ideal ground plane) which may be expected from the vehicle where the satellite radio receiver antenna is installed. These receiver antenna imperfections reduce the overall link margin even more.

The Sirius XM broadcasting system was designed and built using these relatively fragile link margins, and with the RF design foundations from the FCC's original 1997 decision establishing the satellite radio service.[32] Said another way, Sirius XM relied upon the FCC maintaining the 1997 interference protection rules so that its service could be operated as a noise-limited system without the need to compensate for the impact of future interference.

3.2 The WCS broadband mobile service

The WCS system will most likely be a cellular-like broadband wireless system to provide mobile and fixed broadband service using a cellular architecture, with technologies such as WiMAX, HSPA, or LTE. The WCS Spectrum was broken up into 4 frequency blocks:

- Block A – Two (paired) 5 MHz blocks allocated by markets
- Block B – Two (paired) 5 MHz blocks allocated by markets
- Block C – One 5 MHz block allocated by region (directly below SDARS)
- Block D – One 5 MHz block allocated by region (directly above SDARS)

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[24] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008.

[25] Subtract 6 dB from -113 dBm to convert from 4 MHz channel bandwidth to 1 MHz channel bandwidth, to yield -119 dBm per 1 MHz.

[26] (-105) - (-119) = 14

[27] (-103) - (-119) = 16

[28] Bruce R. Helbert, "Satellite Communications Applications Handbook", 2004 Artech House Inc. Page 270 where the minimum SNR of a satellite radio signal is listed as 6 dB. Also see Pratt and Bostian, Chapter 4, where minimum required SNR is between 4 and 8.5 dB.

[29] 14 – 6 = 8

[30] 16 – 6 = 10

[31] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008. See Motorola measurements.

[32] FCC MEMORANDUM OPINION AND ORDER, FCC 97-112, Adopted March 31 1997.

3.2.1 WCS A and B Blocks

For the WCS A and B blocks, coverage zones are calculated to have received power levels of between -71.1 dBm and -89.1 dBm over a 5 MHz bandwidth, depending on whether 64QAM or BPSK modulations are used.[33] For comparison purposes, the coverage zone of a satellite system is defined much closer to the thermal noise floor limit of -113 dBm over a 5 MHz band, and the strongest signals received on earth from the Sirius XM system are on the order of -94 dBm. This illustrates how cellular system designs rely on much higher link margins than satellite systems, as they are pre-designed to anticipate self-interference from more users over time, and typically operate with link margins that are 20dB to 30 dB (or more) above the thermal noise floor. In addition, terrestrial mobile and fixed systems such as WCS will allow for adaptive modulation on both the forward and reverse link, thereby providing agility in signaling data rates to adapt to changing interference and coverage levels.

3.2.2 WCS C AND D Blocks

The FCC proposes providing 2.5 MHz guard bands between the subscriber units in the C and D blocks and the SDARS service. For the reverse WCS link (subscriber-to-mobile link), the FCC Staff Proposal will reduce the potential capacity per user by half as compared to the A and B blocks. Since the forward link (base-to-subscriber link) will be able to use the originally licensed 5 MHz bands, the capacity offered in the C and D blocks, when measured on a per-user basis, will be identical to A and B blocks on the forward link, but half as great for subscribers on the reverse link. Therefore, WCS operators in the C and D bands will have to operate at half-rate links (but with better link margin) on the subscriber reverse link. Note WCS systems will be able to accommodate the same number of users on a per MHz basis in the A, B, C, and D blocks, but the reverse link capacity will be reduced by 50% in the C and D blocks, as compared to A and B blocks. On the other hand, by operating at half capacity, the C and D bands will be able to provide larger cell radii on a per user basis as compared to the A and B blocks, making the C and D blocks more suitable for large-cell coverage in suburban or rural markets, where high capacity is in less demand or where less expensive infrastructure investments are desired.

It is unclear whether a 2.5 MHz guard band will offer Sirius XM sufficient interference protection. From the SDARS standpoint, much more important than the guard band frequency gap is the particular OOBE mask that is required by the FCC for all WCS users. WCS systems, when operated as a cellular-like mobile or fixed system, can withstand much greater interference than receivers in the SDARS system. Thus, OOBE from an A or B block WCS subscriber terminal into the C or D block spectrum will have less system impact on WCS subscribers than would a C or D block subscriber transmitting out-of-band interference or overloading a nearby SDARS subscriber. Furthermore, for an impacted SDARS receiver, the OOBE emissions of an A or B block subscriber may or may not be worse than a C or D block subscriber, regardless of an established guard band, since the specific spectrum mask of each subscriber unit will dictate OOBE emissions. Regardless of the size of the guard band, the **power level** of out-of-band-interference allowed to come from WCS subscriber units will dictate the level of degradation to the SDARS listener. In summary, a wide guard band does not adequately define the protection of an adjacent service, but rather the OOBE spectral mask, and how it is defined as it falls off in frequency, defines the protection level. This OOBE mask must be determined for all WCS block users and should be defined to provide greater attenuation of OOBE as the frequency moves further away from a WCS subscriber’s transmission frequency.

3.2.3 WCS Cellular System Design

The coverage zones for each base station in a cellular system are generally limited in distance by the mobile–to–base (uplink, or reverse link) link budget, since the mobile and portable subscriber devices use smaller transmitter power levels than the base stations. Handoffs are provided between cell sites to allow subscribers to move throughout a geographic coverage region, and the forward link (from base station to mobile) and reverse link (mobile to base station) are designed with sufficient link margin to ensure handoffs are made gracefully and with as few of dropped calls as possible.

To ensure proper handoff, the coverage zones of each base station will be engineered to provide adequate link margin for mobile operation, and the WCS system will be designed to provide for sufficient overlap of adjacent base station coverage zones so as to avoid improper handoff situations. As shown in Figure 4, the WCS system will need to be designed to provide

[33] http://www.wimax360.com/forum/topics/610217:Topic:74358

sufficiently strong power levels at the boundaries of each of the base station coverage zones in order to ensure calls are handed off without dipping below a minimum acceptable signal level.

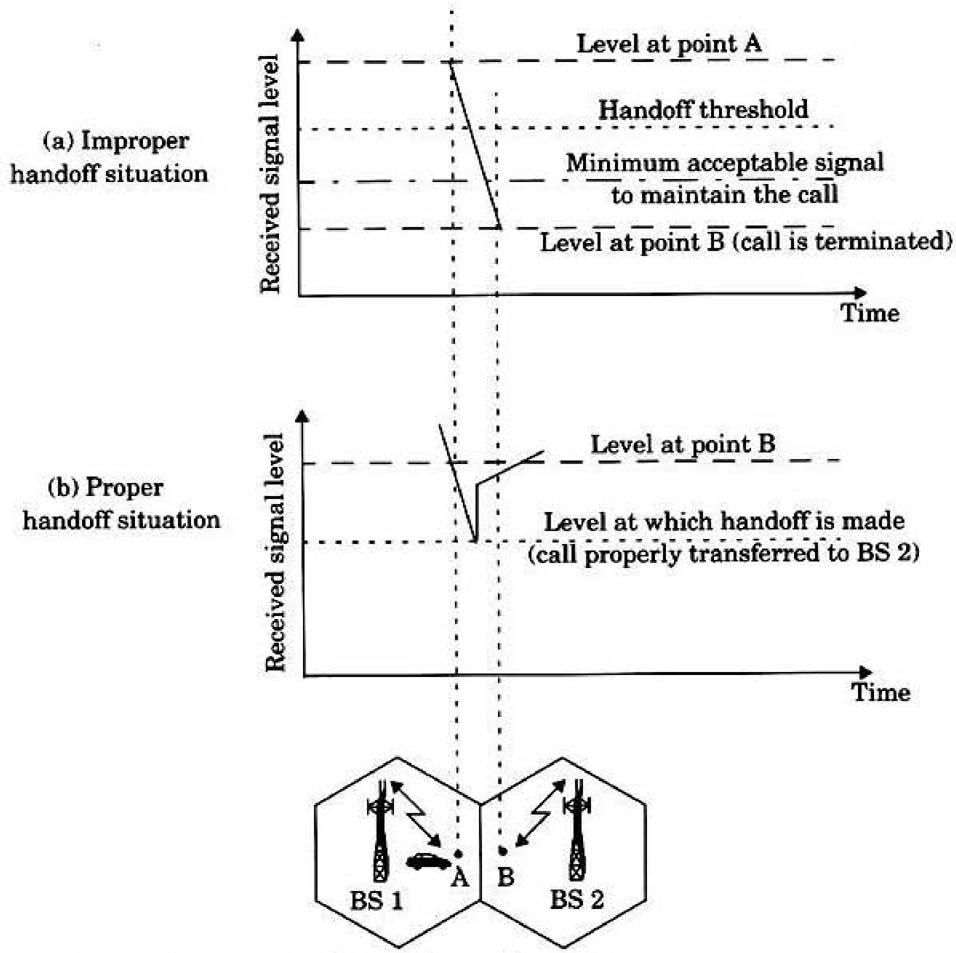

Figure 3.3 Illustration of a handoff scenario at cell boundary.

Figure 4: Cellular handoff scenario

To help limit the cellular system's own interference, and to retain as much battery life in each of the subscriber handset, the proposed rules require WCS systems to implement power control for each of its subscriber devices. Power control is required for proper management of co-channel interference within a cellular system[34] .With power control, the base station is able to dynamically cause the transmission power of each subscriber to be ratcheted up or down, depending on the particular location of the subscriber, the quality of the forward and reverse links, and the desired user data rate. This is typically done using proprietary algorithms. As a result, power output from WCS subscriber devices at the cell edge will be greatest in order to ensure link quality to the base station in the presence of other interfering devices.

[34] Ref: see T.S. Rappaport, "Wireless Communications: Principles and Practice, c. 2002, Pearson Prentice Hall; and J. Andrews, et. al., "Fundamentals of WiMAX: Understanding Broadband Wireless Networking, Pearson Prentice-Hall, c., 2007

4 Comparison of Existing FCC Interference Protection Rules for Broadcasters and adjacent services

This section compares different FCC rules aimed specifically at protecting incumbent broadcasters from out of band interference from new users or adjacent radio systems.

4.1 Overview of existing SDARS out of band interference protections:

4.1.1 FCC Interference Protect rules as they currently exist for SDARS

The existing WCS rules protect SDARS from out-of-band interference from WCS subscriber transmitters through the following formulas:

- for mobile transmitters, within the 1st MHz of the SDARS spectrum adjacent to the WCS spectrum:

$$OOBE\ Mask = 110 + 10\log_{10} P$$

- for fixed transmitters, within the 1st MHz of the SDARS spectrum adjacent to the WCS spectrum:

$$OOBE\ Mask = 80 + 10\log_{10} P$$

where P is the transmitter power level in Watts over a 1 MHz bandwidth.[35] The OOBE formula requires that the WCS subscriber out-of-band emissions within the 1st MHz of the SDARS band directly adjacent to the upper or lower WCS blocks shall not exceed -110 dBW per MHz[36] and -80 dBW per MHz[37] for mobile and fixed transmitters, respectively.

The WCS transmitters have the ability to overload the front end of the SDARS receivers if they are in close proximity, and the addition of interference powers from many different WCS transmitters sum up to desensitize the SDARS receivers by adding to the effective noise floor of each of the SDARS receiver. Intermodulation products from nearby WCS transmitters may show up as out of band interference signals, as well. Figure 5 illustrates how the Sirius XM noise floor increases, and compresses (e.g. reduces) the available link margin for SDARS receiver as WCS out-of-band emission levels rise and infiltrate the SDARS receivers. Section 4.1.5 describes the sensitivity to overload (D/U ratios) shown in Figure 5.

The current FCC rules require WCS to protect SDARS such that any out of band interference would only be allowed to raise the SDARS noise floor by 1 dB. This approach led to an OOBE protection mask requirement of 110+10log(P) dBW/MHz. The FCC Staff Proposal would reduce the Part 27 minimum suppression of out-of-band emissions from mobile WCS subscriber units by 55 dB (from 110 + 10 log (P) to 55 + 10 log (P) in the adjacent band). The WCS Coalition has stated that this change is aimed at facilitating mobile operations in the band. However, as demonstrated in Section 6, such out-of-band emission relief, if granted, would result in unacceptable degradation to SDARS listeners from the mobile-into-mobile interference, even when the victim SDARS receiver and interfering WCS subscriber devices are separated by many meters.

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[35] FCC MEMORANDUM OPINION AND ORDER, FCC 97-112, Adopted March 31 1997

[36] Where the mobile transmit power P per MHz has to be attenuated by a ratio of 110+10logP in order to yield -110 dBW/MHz within the 1st 1 MHz of the protected satellite radio band.

[37] Where the base station transmit power P per MHz has to be attenuated by a ratio of 80+10logP in order to yield -80 dBW/MHz within the 1st 1 MHz of the protected satellite radio band.

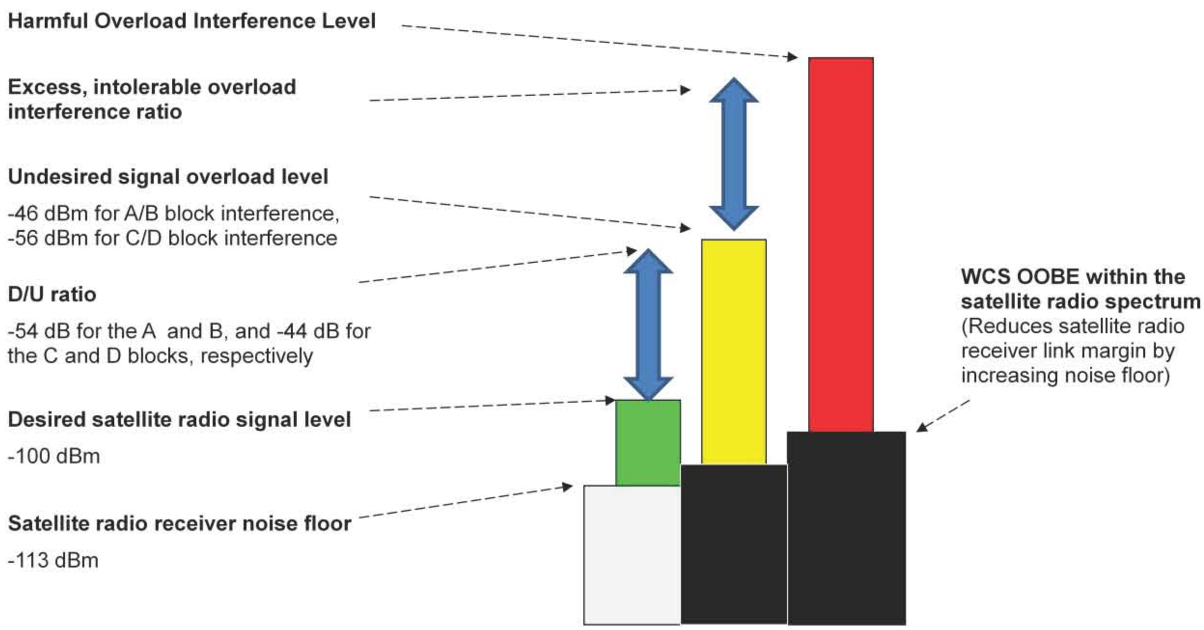

Figure 5: WCS Overload and OOBE Interference Definition

4.1.2 SDARS Protection When Considering A Simple Vehicle-To-Vehicle Interference Model

In order to ensure that the SDARS out of band interference protection is maintained under the 1997 rules which were based on generally accepted interference tolerance level definitions, the adjacent service users (in this case, WCS mobile and fixed stations) are required to ensure that their out-of-band transmissions remain at or below -125 dBm/MHz.[38] Consider that in a congested highway situation, a typical close-in distance between a WCS mobile phone user and a Sirius XM SDARS listener would be 3 meters, the length of a normal sized car, and roughly the width of a roadway lane. Given the free space propagation path loss of 49 dB at a three meter separation distance between a WCS subscriber transmitter and a satellite radio receiver, the WCS OOBE at the user terminal transmitter (just leaving the WCS subscriber antenna and before propagation) would be -125 dBm/MHz + 49 dB = -76 dBm/MHz, or -106 dBW/MHz at the transmitter. An additional increase in propagation path loss is possible due to attenuation of the WCS subscriber transmitter signal through the vehicle body, thus we assume an additional 10 dB of diffraction loss, yielding the maximum level of tolerable WCS subscriber OOBE to be -96 dBW/MHz within the SDARS band for these assumptions. In fact, measurements performed by several parties indicate that there can be some car body loss.[39]

The above example analysis translates to a WCS subscriber OOBE mask of 96+10logP, which is 14 dB less stringent than the FCC 1997 rules, but 41 dB more stringent than the OOBE mask in the FCC Staff Proposal[40]. Note that if the WCS antenna

[38] The -125 dBm/MHz limit results from the 1 dB noise floor criterion as applied to a satellite radio receiver who's interference-free noise floor is -113 dBm over 4 MHz, or -119 dBm/MHz. This 1 dB noise floor criterion was used by the FCC in establishing the 2.3 GHz coordination rules in 1997 and proposed by the WiMax Forum for coordination with satellite systems at 3.5 GHz. (see Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008). Note that a 1 dB increase in noise floor is a total noise power increase of 25%. Since 25% = ¼ = – 6 dB, it follows that -125 dBm/MHz = -119 dBm/MHz - 6 dB.

[39] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008; WCS Coallition Ex Parte Submitted to the FCC WT Docket No. 07-293, May 9, 2008; WCS Coaliltion Ex Parte Submitted to the FCC WT Docket No. 07-293, August 1, 2008.
[40] (1) For base and fixed stations: Not less than (75 + 10*log (P) dB) on all frequencies between 2320 and 2345 MHz.
(2.a) For fixed customer premises equipment: For fixed customer premises equipment (CPE) transmitting with more than 2 watts average EIRP, not less than (75 + 10*log (P) dB) on all frequencies between 2320 and 2345 MHz.
(2.b) For fixed CPE transmitting with 2 watts average EIRP or less: Not less than (55 + 10*log (P) dB) on all frequencies between 2320 and 2324 MHz and on all frequencies between 2341 and 2345 MHz, not less than (61 + 10*log (P) dB) on all frequencies between 2324

were integrated into the body of the vehicle, the "through the vehicle" diffraction loss might not apply and the WCS interference could be 10 dB greater, thus requiring a mask of 106+ 10logP to obey existing rules.

4.1.3 SDARS Protection When Compared To Typical FCC FM or TV Receiver D/U Guidelines

WCS OOBE presents itself to satellite radio receivers as co-channel interference. Radio manufacturers and the FCC typically define a Desired to Undesired (D/U) ratio for FM co-channel and adjacent-channel band users.[41] FM radio offers listeners a very high quality audio signal because of the capture effect, and Sirius XM strives to maintain a similar listener experience, so it is worthwhile to compare the performance of FM, Digital TV, and Sirius XM from a listener's standpoint. For SDARS, out- of-band emissions from the WCS service will appear as co-channel interference within the SDARS satellite receiver. This interference will raise the noise level (e.g. degrade the sensitivity) in today's Sirius XM receivers to a greater level than currently exists (this is shown in Figure 5). Because of the Gaussian Approximation [42], we can assume that a large number of interfering stations add up to produce Gaussian distributed noise, which is identical to the distribution of thermal noise that limits the sensitivity of all receivers, including SDARS receivers. Thus, the co-channel interference emitted by WCS mobile and fixed base stations will appear as higher levels of noise, which in turn will erode the link margin presently used in the Sirius XM satellite system.

FCC rules for the FM radio service demonstrate that most common broadcast receivers are required to design for co-channel interference levels (Desired-to-Undesired (D/U) power level ratio) of +17 dB to + 30 dB.[43] Also, as shown subsequently, Digital Television requires +23 dB D/U. If we apply a modest 17 dB D/U requirement for satellite radio receivers, and use the satellite radio signal level on the ground of -103 dBm/MHz (Miami), then the maximum allowable interference to provide a D/U of 17 dB at the SDARS receiver should be -120 dBm/MHz, or -150 dBW/MHz). To transfer this interference signal level back to the WCS subscriber transmitter, we again consider a WCS mobile terminal in a car 3 meters away, consider the free space path loss of 49 dB at three meters, and add 10 dB of car body path loss to find that the maximum WCS OOBE that should be tolerable to satellite radio receivers is -91 dBW/MHz within the SDARS band. Thus, applying a well-understood D/U ratio for standard broadcast receiver design requirements, the FCC should provide a OOBE mask of 91+10log P for WCS subscriber transmitters. This OOBE is 19 dB less stringent than the original 1997 rules but 36 dB more stringent than what the FCC staff has now proposed. Even if SDARS was expected to use its much stronger XM satellite signal in Northern Virginia to represent its entire CONUS coverage region as covered by all of its satellites, a modest D/U of 17 dB would provide a WCS subscriber OOBE requirement of 83 + 10 log P, which is 27 dB less stringent than the FCC's original 1997 rules, yet 28 dB more stringent than the newly proposed rules.

4.1.4 SDARS Protection as Related to the Physics of the Satellite Link

As demonstrated by the examples above, the current WCS rules provide a very high level of interference protection for SDARS, as required by a variety of factors, but the FCC Staff's proposed rules now allow too much OOBE. The previous two examples, and the following example, show that the FCC Staff Proposal would allow nearby WCS transmitters to harm SDARS service.

The Sirius XM system was designed and built using the 1997 rules. The various satellites deployed by Sirius XM provides roughly between 8 dB (-103 dBm/MHz earth signal in Miami) and 17 dB (-95 dBm/MHz earth signal in Northern Virginia) of link margin to mobile vehicles, depending on their location on earth and the quality of the car-mounted antenna. If one

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and 2328 MHz and on all frequencies between 2337 and 2341 MHz, not less than (67 + 10*log (P) dB) on all frequencies between 2328 and 2337 MHz.
(3) For mobile and portable stations: Not less than (55 + 10*log (P) dB) on all frequencies between 2320 and 2324 MHz and on all frequencies between 2341 and 2345 MHz, not less than (61 + 10*log (P) dB) on all frequencies between 2324 and 2328 MHz and on all frequencies between 2337 and 2341 MHz, not less than (67 + 10*log (P) dB) on all frequencies between 2328 and 2337 MHz.

[41] http://www.nrscstandards.org/Reports%20ref%20docs/USADR%20test%20data%20report/Appendixd.pdf

[42] Ref: see T.S. Rappaport, "Wireless Communications: Principles and Practice, c. 2002, Pearson Prentice Hall; and J. Andrews, et. al., "Fundamentals of WiMAX: Understanding Broadband Wireless Networking, Pearson Prentice-Hall, c., 2007.

[43] Unlicensed TV Band Devices/TV Broadcast Services (FCC No. 08-260)

considers the most recent FCC proposal for a WCS mobile subscriber to have an OOBE mask of 55 + log 10 P at the SDARS band edge, and if we again consider the resulting OOBE for a nearby WCS mobile terminal (3 m away from a SDARS receiver), we see that the SDARS receiver would receive an OOBE power of -84 dBm/MHz[44], which is more than 19 dB greater than the designed satellite signal level of -103 dBm/MHz in Miami, and more than 11 dB greater than the designed Northern Virginia -95 dBm/MHz[45] satellite signal level. In other words, if the FCC Staff Proposal were adopted, the FCC would essentially be *rendering the satellite radio service useless by allowing interferers to have an order of magnitude greater power than the protected signal*. By proposing a D/U ratio of -19 dB for a nearby WCS subscriber transmitter in Miami, and -11 dB in Northern Virginia, where other D/U values for co-channel signals are typically +20 dB for FM and Digital TV, the proposed rules would destroy the protection of SDARS signals within their own band.

If the proposed rules were in effect for a SDARS receiver in Miami, the 8 to 9 dB link margin demonstrated in Section 3 not only would be eliminated, but the interference from a single WCS mobile user in a neighboring car would be 19 dB stronger than the SDARS signal, thus completely covering up the weak satellite signal within the SDARS band. The SDARS broadcast system would be about two orders of magnitude *weaker* than the out-of-band interference the FCC was allowing. Even in a best case situation, where Sirius XM has a 17 dB link margin due to a -95 dBm/MHz signal level on the ground in Northern Virginia, the interference allowed by the FCC Staff Proposal for a WCS subscriber 3 meters away would cause the undesired in-band interference to be 11 dB stronger than the weak satellite signal. The FCC would be enacting a co-channel D/U ratio of -11 dB, which would be a best case scenario for SDARS coverage from its various satellites. Since SDARS requires a 6 dB CNR for proper demodulation[46], *the interference allowed under the proposed rules would mean that Sirius XM would have to increase its satellite transmitter power by 25 dB or 17 dB, respectively, just to get back to a thermal noise link without any protection for shadowing*. To obtain its original quality of service based on the current rules, *Sirius XM would have to increase power transmitter by about 33 dB*. Of course, increasing an already-launched satellite's transmit power by a factor of 50 or a factor of 450, or a factor of 2000 is impossible. This example shows the sensitivities of a noise-limited satellite system, and the impracticality of the FCC's proposed rule changes.

4.1.5 WCS Mobile Transmissions and Overload Conditions in Real World SDARS Receivers

The FCC staff proposes that the average EIRP of WCS mobile and portable transmitters must not exceed 250 mw for the 2305-2317.5 MHz band or the 2347.5-2360 MHz band. This section of the report investigates power levels and distances at which the SDARS receivers may experience overload. Overload is the condition when a nearby adjacent channel transmitter swamps out the receiver due to non-linearities in the victim receiver. Overload often results in blanking, since the front end of the victim receiver is completely swamped by the nearby transmitter.

WCS overload presents itself to satellite radio receivers as adjacent-channel interference. Using the common broadcast interference coordination criteria shown below, most FCC rules call for adjacent-channel interference (for FM, TV and Digital TV) D/U ratios of -20 to -30 dB. This means that the interferer's signal power at the protected receiver (as measured in the interferer's own adjacent operating band) should not be more than 20 dB to 30 dB greater than the signal that is intended for reception in its own protected band. Measurements reported by SWRI[47] show that a typical satellite radio receiver has a tolerance to overload interference from a WCS transmitter in the 1st adjacent WCS (C and D blocks) that is transmitting with a power level of -56 dBm as the receiver attempts to receive a desired signal level of -100 dBm. The tolerance of a typical satellite receiver to interference from the 2nd adjacent WCS band (B-lower and A-upper blocks) is -46 dBm for a desired satellite signal level of -100 dBm, as measured by SWRI. As a result, the satellite radio receiver's 1st and 2nd adjacent channel D/U ratios are 44 dB and 54 dB, respectively, at the point where overload interference completely mutes the receiver and renders it useless (See Figure 5). These measurements show that a typical satellite radio receiver is able to tolerate a much higher level of interference than typical consumer broadcast receiver designs used for FM or TV, and provide understanding as to when SDARS receivers would become overloaded by nearby WCS transmitters. It is important to note that when the SDARS receiver is in a linear operating range, interference from surrounding WCS transmitters will linearly

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[44] 55+10logP indicates -55 dBW/MHz or -25 dBm/MHz of WCS OOBE transmitter power within the SDARS band. For 49 dB path loss at a three meter distance, and allowing 10 dB of additional loss, -84 dBm/MHz WCS OOBE power level is received at the satellite radio receiver.

[45] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, January 22, 2010

[46] Bruce R. Helbert, "Satellite Communications Applications Handbook", 2004 Artech House Inc.

[47] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008

increase the noise floor, and thus linearly degrade the sensitivity of the receiver. However, as the SDARS receiver becomes overloaded by close-in WCS signals that create non-linearities throughout the analog and digital receiver circuitry, the additional noise floor caused by interference would be expected to reduce the adjacent channel D/U capabilities of the SDARS receivers.

Sirius XM requires robust SDARS receiver performance because of the fact that satellite mobile radio systems must operate in challenging propagation environments, due to shadow fading as well as nearby interferers on the highway. However, the following examples shows that even robust SDARS receivers will be unable to protect themselves from close-in WCS subscribers under the FCC's proposed rules.

Consider the example of an operational WCS transmitter located in a car that is three meters away from a SDARS-equipped vehicle, In order to receive a -56 dBm[48] adjacent channel WCS power level at a satellite radio receiver[49], we consider a 49 dB path loss at three meters of separation, and add an additional 10 dB path loss from car body blockage and other factors. Thus, no more than a 3 dBm WCS transmit power should be allowed within the C and D blocks if an SDARS receiver is going to be able to receive a -100 dBm/MHz satellite signal. For the best case Sirius XM satellite signal of -95 dBm/MHz in Northern Virginia[50], the WCS transmitter should transmit no more than 8 dBm. Any greater transmitted signal level will overload and mute the SDARS receiver at a three meter separation distance.

Similarly, if we consider the second adjacent channel to be the A and B WCS blocks, to obtain -46 dBm received power level at the SDARS receiver, we see that in the A and B bands, 13 dBm would need to be the maximum WCS transmit power allowed in order for the SDARS receiver to still be able to receive a satellite signal. For the case of the SDARS receiver receiving a best-case signal of -95 dBm, the WCS A and B block subscriber transmitter would need to be limited to transmit no more than 18 dBm, or 63 milliwatts. Any greater transmitted signal level will overload and mute the SDARS receiver at a three meter separation distance.

However, the FCC Staff Proposal would allow 250 mw, or 24 dBm, for WCS subscribers within the outer 2.5 MHz of the C and D blocks (this is similar to the first adjacent channel). The proposal provides a power level that is twice as large, on a per MHz basis, than in the A and B blocks. Given this situation, the FCC Staff's newly proposed transmission power offered by the C and D block subscribers, on a per MHz basis, is effectively double that from the OOBE mask originally proposed by the WCS coalition without a guard band.[51] That is, the FCC's proposed use of a guard band has produced an unintended consequence of doubling the power spectral density of C and D block users, and as a result, the proposal would allow WCS transmitters to operate at a 24 dB higher power level than the 3 dBm limit that a typical SDARS receiver can withstand when trying to demodulate a -100 dBm/MHz satellite radio signal[52]. Also, the FCC staff proposes to allow 250 mw, or 24 dBm, of transmit signals within the A and B blocks, which is 11 dB higher than the 13 dBm level determined to be the maximum allowed for typical SDARS reception of a -100 dBm/MHz satellite signal.

The above examples use the simple case of a single WCS transmitter located 3 m from an SDARS receiver, and makes simple assumptions on mobile-to-mobile propagation for a single-interferer case. In the real world, however, many WCS transmitters will operate at varying distances from SDARS receivers, and several WCS transmitters could be in very close

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[48] Satellite radio receivers were designed based on the FCC rules adopted 13 years ago but they still perform better than today's common broadcast receiver types considering their measured D/U ratios. They are typically installed in vehicles that have will be used for more than 10 years.

[49] Overload impacts on satellite radio receivers are further characterized in a recent FCC filing, where the overload and intermodulation interference effects of transmissions from one or two WCS blocks were examined. Significant overload interference occurred when the intermodulation interference further reduced the desensitization level to as low as -58 dBm. Reducing the frequency of the WCS transmission (i.e. transmitting every other frame instead of every WiMax frame) resulted in a clear improvement in the receiver's interference tolerance, in addition to reducing the uplink duty cycle from 31% to 12.5%.

[50] Northern Virginia represents the best position of the satellite orbit and receiver antenna gain for the Sirius satellites.

[51] WCS Coalition ExParte Submitted to the FCC WT Docket No. 07-293, October 7, 2009

[52] In calculating a 24 dB overload, 21 dB is due to subtracting 3 dBm from 24 dBm, to obtain the excessive interference level that blocks the SDARS receiver in the SWRI tests, and 3 dB is due to compressing the C and D transmit signal power into half of the "typical" WCS spectrum channel.

proximity to an SDARS receiver during slow rush hour traffic. The above examples are simple cases, and it should be clear that interference will occasionally be greater than what was presented above. There will also be many statistical variations that will impact real world performance, causing interference to occasionally be much less than as presented above. Furthermore, a sampling of many different Sirius XM receivers would likely perform differently than the ones measured in this study. Nevertheless, it should be clear from the above analysis that the proposed FCC guard bands and WCS transmitter power levels, when combined with the proposed OOBE mask of 55 dBW + 10 log P at the SDARS band edge, will be intolerable for SDARS in the case of even just one WCS subscriber transmitter in a car next to or behind/in front of a SDARS listener.

The only way to fully understand the impact and sensitivities of communication system performance is through a carefully designed Monte Carlo simulation, which is the subject of Sections 5 and 6. However, before describing the simulation methodology, we now consider how other broadcast services are protected from adjacent services by existing FCC rules.

4.2 Overview of FCC Protection Rules for Different existing Broadcast Services

4.2.1 Unlicensed TV Band Devices/TV Broadcast Services

The process for determining whether a TV channel is available for use by unlicensed TV Band devices is based on protecting the service contours of the primary services. Contours, based on propagation path loss models (often free space) allow each broadcast transmitter to define its coverage area. Table 1 shows the various equal E-field contour levels (E-field is used by the FCC to remove the dependency of receiver antennas). Note from Table 2 that the FCC protects Digital Television with a D/U of +23 dB for co-channel protection, whereas the proposed FCC OOBE mask would force SDARS to operate with a nearby WCS transmitter at an equivalent co-channel D/U ratio of between -11 dB and -19 dB.

Table 3 shows that the FCC provides a minimum distance of 6 km to protect the primary TV broadcaster from co-channel interference, and 0.1 km to protect the primary TV broadcaster from adjacent channel interference. A protection distance is used to ensure that protected receivers are not overloaded, or that the noise level is not artificially raised so as to weaken the link margin of the protected broadcast signal.

Table 1: Criterion for Definition of TV Station Protected Contours

Type of station	Protected contour		
	Channel	Contour (dBu)	Propagation curve
Analog TV	Low VHF (2-6)	47	F(50,50)
	High VHF (7-13)	56	F(50,50)
	UHF (14-69)	64	F(50,50)
Analog Class A, LPTV, translator and booster	Low VHF (2-6)	62	F(50,50)
	High VHF (7-13)	68	F(50,50)
	UHF (14-69)	74	F(50,50)
Digital TV	Low VHF (2-6)	28	F(50,90)
	High VHF (7-13)	36	F(50,90)
	UHF (14-51)	41	F(50,90)
Digital Class A	Low VHF (2-6)	43	F(50,90)
	High VHF (7-13)	48	F(50,90)
	UHF (14-51)	51	F(50,90)

Table 2: TV Interference Protection Criteria

Type of station	Protection ratios	
	Channel separation	D/U ratio (dB)
Analog TV, Class A,	Co-channel	+34

LPTV, translator and booster	Upper adjacent	-17
	Lower adjacent	-14
Digital TV and Class A	Co-channel	+23
	Upper adjacent	-26
	Lower adjacent	-28

Table 3: Minimum Required Separation Distances between Fixed Unlicensed TV Band Devices

Antenna Height of Unlicensed Device	Required Separation (kilometers) From Digital or Analog TV (Full Service or Low Power) Protected Contour	
	Co-channel	*Adjacent Channel*
Less than 3 meters	6.0 km	0.1 km
3 – Less than 10 meters	8.0 km	0.1 km
10 – 30 meters	14.4 km	0.74 km

4.2.2 700 MHz Wireless Communications Services and TV Broadcast

The FCC authorizes base stations, fixed stations, control stations, and mobile transmitters in the 698-763 MHz, 775-793 MHz, and 805-806 MHz frequency bands. Under Section 27.60 of the FCC rules, WCS devices must operate to reduce the potential for interference to existing TV and DTV broadcast stations transmitting on TV Channels 51 through 68. It is clear that the FCC provides protection to the existing TV and Digital TV broadcasters, even as new wireless systems are demanded by the public.

The FCC uses geographical spacing to ensure that the new WCS transmitters are far enough apart such that they do not impinge on the coverage of existing TV and DTV stations. While it is difficult to equate D/U ratios and geographic spacings directly to SDARS, since the broadcast equipment is located in space many thousands of km above the earth, the FCC Staff Proposal does not offer sufficient protection to SDARS from the OOBE of nearby WCS transmitters.

4.2.3 ITU and WiMAX Forum

Coexistence issues between adjacent services are well known, as described in the ITU's report on TDD/FDD coexistence and the WiMAX Forum's papers on coexistence.[53,] Both of these reports acknowledge the severity of "potentially crippling" mobile-to-mobile interference. In addition, the WiMAX Forum also identifies a 1 dB rise in the satellite receiver's noise floor [54] (the current FCC rules for WCS-SDARS) as a proposed coordination criteria for the interference that it creates to satellite receivers operating in the 3.5 GHz band.

The ITU Radiocommunications Study Groups[55] noted that some proposals aimed at protecting Fixed Service Satellites (FSS) would allow an interference noise contribution of only 1%. While the ITU supported this, it went further to suggest that in order to properly protect Fixed Satellite Systems from UWB transmissions, a maximum allowable UWB interference level would need to be determined, and that could only be done by specifically computing the Carrier to Interference plus Noise (C/I+N) needed to present unwanted interference to FSS reception.

[53] Report ITU-R M.2030, "Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2600 MHz operating in adjacent bands and in the same geographical area," 2003; "Service Recommendations to Support Technology Neutral Allocations – FDD/TDD Coexistence," WiMAX Forum (Apr. 10, 2007) ("FDD/TDD Coexistence").

[54] "COMPATIBILITY OF SERVICES USING WiMAX TECHNOLOGY WITH SATELLITE SERVICES IN THE 2.3 - 2.7 GHz AND 3.3 - 3.8 GHz BANDS", WiMAX Forum, 2007 Section 4.

[55] Document 4A/115-E 6 October 2004,"Response to Liaison Statement from TG 1/8 compatibility between ultra wideband UWB and FSS systems"

4.2.4 Comparison to previous FCC protection rules and the WCS-SDARS staff proposal

In the above cited instances of FCC and governmental protection rules, incumbent broadcasters are afforded protection from new in-band or adjacent services to a high degree. Some licensed services are granted protection through required separation distances. Other licensed services are assured protection through the use of D/U ratios that comport to installed receiver capabilities. Other protections limit the power of new interference sources. Yet, the FCC's staff recent proposal does not even protect SDARS for the case of just one nearby WCS subscriber transmitter in rush hour traffic.

5 Creation of a Simulator to understand WCS out-of-band interference to SDARS and impact on listening quality

To determine realistic interference levels and the resulting degradation to Sirius XM satellite receivers, we developed an extensive simulation environment based on Matlab software (Matlab is a popular and widely available engineering and scientific computing environment that is licensed by The Math Works, Inc[56].). Our simulator allows one to input important propagation parameters, traffic parameters, and transmitter and receiver parameters to determine real-world affects and resulting SDARS link deterioration and outages caused by WCS mobile stations that radiate out-of-band interference. The use of simulation is a highly-regarded engineering approach to develop understanding of the impact that randomly distributed wireless users have on a wireless communications system, and is a useful tool for determining the impact of OOBE on the listening public.

The author led the creation of the simulator presented here, building upon Sirius XM's existing traffic simulator originally presented in September of 2008[57]. The author directed an extensive modification of the simulator to model random locations of WCS subscriber stations, the likelihood of whether the WCS subscriber stations are transmitting, the duty cycle of a transmitting WCS subscriber, whether the WCS subscribers are from the A, B, or D blocks (as described subsequently, only high side WCS frequencies are considered), whether the WCS system is using mobile station power control, the maximum transmitter power of a WCS subscriber, and the particular power control level being implemented by a particular WCS subscriber station. The simulator also allows the user to specify different vehicle-to-vehicle path loss models that govern the propagation of out-of-band interference from the WCS mobile stations to the Sirius XM receivers over distance, and also considers the FCC's proposed interference protection mask, as well as other masks to allow comparisons of the impact of WCS OOBE on SDARS listeners. The simulator produces histograms of the received interference power from WCS subscriber transmitters under a wide range of possible operating scenarios, and uses the Sirius XM satellite look-angle data and link margin data to determine accurate outage probabilities for a wide range of different operating conditions as a function of location for a particular city in the United States. Source code for these simulators are given in Appendices A and B.

To properly model the impact of adjacent service out-of-band interference from mobile WCS users, and the resulting degradation to mobile SDARS listeners, it is necessary to first consider a realistic highway environment. Our simulator allows entering roadway length (in miles), the number of highway lanes on the road, the average speed of each vehicle, and the traffic volume of vehicular traffic as measured in cars per hour. Our simulator then generates the random locations of specific vehicles traveling throughout a highway. We assume interstate highways and freeways have lane widths of 3.5 meters in the simulation, which is standard for roadway construction. Local roads may have narrower lane widths. Our simulator allows the selection of either type of roadway.

In the simulation, we assume that each lane of the highway has a uniform distribution of highway traffic, so that users may randomly be in any of the highway lanes as found in typical urban and suburban highways. The selection of roadway length is a variable parameter and can be adjusted to describe the roadway being modeled. For the simulations, we chose five typical US cities with varying latitudes and longitudes (New York City, Jackson, MS, Denver, CO, Miami, FL and Charlotte, NC), and selected popular highways within each of those cities where Sirius XM relies upon satellite coverage, and not its terrestrial repeaters.

The simulator also provides inputs for the user density of SDARS listeners and WCS users. These data are entered in the Matlab script as a penetration rate, in terms of percentage of total vehicles, and dictates the user density of both WCS users and SDARS listeners on the simulated highway. First, the hourly traffic volume (cars per hour) is entered along with the traffic speed. Hourly traffic for rush hour can be estimated from public sources, such as Google and Mapquest, as described in Section 6. Traffic speed on highways varies throughout the day, with peak travel times typically accompanied by congestion and reduced flow, thereby reducing the average speed of travel. The average vehicle speed is determined from public sources and applied as an input to the simulator.

At any given time during the peak travel hours, the gross number of vehicles on a stretch of roadway is determined by multiplying the traffic volume (in cars/hour) by the roadway length (in miles), and then dividing by the speed of travel (miles/hour) as shown below.

[56] http://www.mathworks.com/

[57] Sirius XM Ex Parte Filing, September 8, 2008, Exhibit A.

$$\frac{Vehicle\ Volume}{Vehicle\ Speed} \times Roadway\ Length$$

Of the total number of vehicles on the roadway segment, a certain proportion will be satellite radio subscribers and another portion will be WCS service subscribers. For the simulations shown in this report, a satellite radio penetration rate of 34% was used, as this is believed to be a realistic customer penetration rate for the year 2015 – five years from now[58]. WCS market penetration was estimated to be a 5%, which we believe is a fair and conservative approximation for WCS subscriber penetration by 2015. Since the interference levels and degradation to the SDARS listeners increase in proportion to the WCS subscriber penetration rate, we intentionally chose a conservative estimate of 5% WCS penetration so as to not overstate the potential WCS interference in the simulations. The corresponding numbers of satellite radio and WCS equipped vehicles are found in the simulator by multiplying the total number of vehicles by the respective services' penetration rate.

As seen in Figure 1, Sirius XM offers satellite radio service on the lower and upper halves of its 25 MHz SDARS spectrum allocation. The WCS band is allocated frequency blocks that are both above and below the SDARS spectrum, and thus we make the assumption that there will be sufficient frequency spacing such that not all the WCS transmitters will affect all SDARS receivers. That is, we make the up-front assumption that WCS subscriber transmitters operating on frequencies below the SDARS spectrum will offer no interference to the Sirius XM listeners using the upper half of the SDARS spectrum, and we similarly assume that WCS subscriber transmitters operating on frequencies above the SDARS spectrum will not interfere with Sirius XM listeners using the lower half of the SDARS spectrum. This is a conservative approximation and produces simulation results that are more favorable to WCS service providers, as one would certainly expect occasional overload and OOBE to occur from nearby WCS transmitters on the highway, regardless of their particular frequency assignment. However, we intentionally chose to neglect this situation based on the high quality Sirius XM receivers that are employed, and in the interest of simulation simplicity,, with the intent of offering conservative simulation results. The simulator makes a reasonable assumption that there is an equal distributions of WCS users in the upper and lower blocks surrounding the SDARS spectrum, and an equal distribution of Sirius (low band) and XM (high band) vehicles.

To account for the various band allocations of WCS and SDARS users, our simulator specifically focuses on modeling the interference and link degradation that will be experienced by high band listeners in the SDARS spectrum allocation of 2332.5 – 2345 MHz (that is, listeners to the part of the SDARS spectrum originally allocated to XM), and we therefore consider potential interfering WCS subscriber transmitters that use only the upper portion of the WCS band (e.g. subscribers in the A, B, and D block allocations above 2345 MHz are the only potential interferers considered in the simulations presented here). Since the simulation results focus on the high band SDARS spectrum, we use the satellite link margin and satellite look-angle data to determine listener degradation for the high-band SDARS (legacy XM) system. Alternatively, the simulator may just as easily be used to model low-band SDARS listener degradation (that is, listeners to the part of the SDARS spectrum originally allocated to Sirius) and low-band WCS subscribers in the A, B, and C blocks below 2320 MHz. In the simulator, we specify a "band factor" which divides the total number of WCS-equipped vehicles and the total number of SDARS-equipped vehicles to determine the number of high-side users. Thus, the total number of WCS and satellite radio vehicles are divided by two in the simulations presented here. By using the band factor, and assuming equal distributions of WCS and SDARS vehicles throughout their respective spectrum allocations, we conduct simulations for SDARS link erosion and the degradation of availability likelihoods under the assumption that satellite radio receivers operating on the upper band are not affected by simulated transmitters in the lower WCS blocks. Thus, the simulation results presented here give interference and SDARS listener degradation statistics specifically for the Sirius XM high-band service listeners.

Once the customer penetration data and roadway conditions are entered, we assume that any car is equally likely to be a WCS user as any other car, and any car is equally likely to be a SDARS receiver-equipped car as any other user. With all power levels, highway factors, and locations determined, we activate the simulator to iteratively generate random positions for all SDARS-equipped vehicles and all WCS mobile-equipped vehicles within the bounds set by the roadway segment length, number of lanes, and lane widths. We can set the number of iterations in the simulator, and use a nominal value of 100 iterations per simulation run. Approximately 1000 different vehicle locations are generated for each iteration of the simulator, depending on the traffic density of the particular highway. These vehicle locations are randomly assigned to be

[58] Satellite Radio penetration rate is based on aftermarket and automotive industry projections on current and future production as well as historical scrappage rates for vehicles yielding 85 million satellite radio equipped vehicles of the 250 million total vehicle population on the road projected for 2015.All projected volumes have been provided by Sirius XM.

either a WCS or SDARS vehicle, based on the penetration rates, vehicle volume, vehicle speed, roadway length, and number of lanes of highway. Since there are 100 iterations for each simulation, each simulation run typically generates about 1,000,000 vehicle locations, from which WCS and SDARS users are randomly determined based on the specified penetration rates. Section 5.3 describes how we ensure that WCS stations are not counted as interferers within a vehicle if a vehicle location is randomly selected as being equipped with both WCS and SDARS equipment.

For each vehicle location, the vehicle is tagged as either having no WCS or SDARS equipment (the majority of the cases), or as having either WCS or SDARS equipment. If the vehicle location is randomly chosen to represent a WCS-equipped vehicle, the WCS activity factor is then used to determine which of those WCS vehicles actually have a transmitting WCS subscriber terminal. The activity factor is used to eliminate a majority of WCS-equipped vehicles from consideration, so that only those WCS-equipped vehicles that are transmitting at a particular point in time are considered for the interference analysis. For the simulations presented here, we assume that each WCS subscriber may randomly transmit for 13% of a busy hour, which means that at any instant of time, only 1 of 8 mobiles would be transmitting at a time, or thought of another way, each mobile would be in use for about 8 minutes per busy hour. The activity factor is also known as the holding time, or dwell time, and is typically computed based on statistics compiled during a cellular network's busiest hour. In recent years, smart phones and web browsing have led to more bursty transmissions but longer activity periods than conventional cell phone calls. This is discussed in detail in Section 5.3.

Similarly, the simulator allows the user to specify a SDARS listening factor that dictates the percentage of SDARS receivers that are on and being listened to. If a vehicle location is randomly chosen to represent a SDARS-equipped vehicle, the SDARS listening factor is then used to determine which of those SDARS vehicles actually have their receiver in use in the car. The activity factor is used to eliminate those Sirius XM satellite receivers that are not in use so that only SDARS-equipped vehicles that are being listened to are considered as being interfered with in the interference analysis. For the simulations presented here, we assume that 85% of the SDARS equipped vehicles are being listened to at any point in time. This is discussed in detail in Section 5.3.

Once the simulator has generated a large data set of WCS and SDARS equipped vehicles that are in operation, the software computes the straight-line (line-of-sight) distances between every operating WCS mobile transmitter and every operating SDARS vehicle, and applies a wide range of user-selectable distance-dependent -propagation models to determine the OOBE received by SDARS receivers due to WCS transmissions. The vehicle-to-vehicle propagation models used by the simulator are discussed in Section 5. 2.

Based upon the simulated levels of interference over a large number of iterations, the simulator produces statistics that allow us to see the overall SDARS listener quality degradation based on the reduction of the statistical availability of service to each user, as well as the statistical satellite link margin reduction to each user due to WCS interference.

To properly determine the power levels of each of the operational WCS transmitters within the simulator, it is necessary to consider power control, as this will help reduce the out of band interference to SDARS receivers and is required by the FCC proposed rules. Without the specific known base station locations of every WCS transmitter, it is impossible to predict the exact impact of power control, but a very good estimate may be determined by considering the coverage of a nominal WCS base station, and then determining the statistical proximity of a uniform distribution of users within the base station coverage region. This technique has been used successfully in the cellular industry to properly predict and design capacity estimates and outage probabilities[59]. The analysis and implementation of power control is discussed in detail in Section 5.1.

Using the concentric cell geometry of a typical WCS base station as shown in Figure 6, we can determine from analysis what the coverage of a typical WCS forward link would be. The forward link path loss may be used as a proxy for the reverse link path loss, as average path loss values (taken as either a spatial or temporal average) on the forward and reverse link are reciprocal on a large-scale basis (e.g. they will be approximately the same on average). Thus, without knowing the precise details of feedback used for power control, we may estimate the transmitting signal levels of WCS subscribers in a statistical sense by first considering the base-station to mobile radio channel, and applying statistical methods. While the WiMAX standard and other cellular systems specify power control typically in 3 dB steps ranging from 0 dB power attenuation (no

[59] T.S. Rappaport, "Wireless Communications: Principles and Practice, c. 2002, pp 141-145 and pp 477-484, see also equation 9.37.

power control) to 30 dB power attenuation (maximum power control), the following section shows that a close approximation may be found by using fewer step attenuations.

5.1 WCS Power Control Analysis

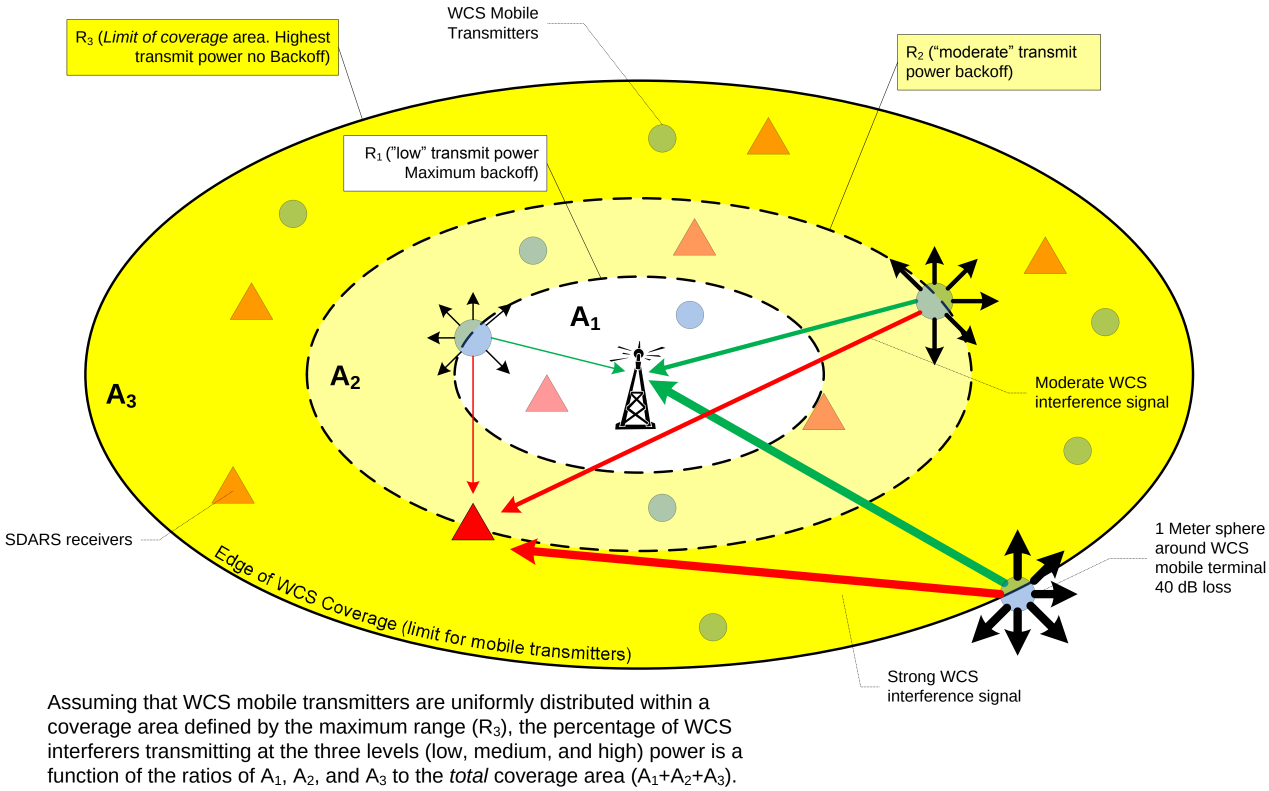

Figure 6: Cellular geometry and analysis of WCS transmit power distribution

Figure 6 shows three contours around a WCS base station:

- R_3 defines a boundary at the edge of the cell coverage, considered the practical maximum distance for a WCS mobile to be controlled by the serving base station. WCS subscribers that fall within the concentric circle zone between R_2 and the outer edge of the cell, R_3, will transmit with a power of = P_{HIGH}
- The area between R_1 and R_2 defines a concentric circle zone where WCS mobiles transmit with reduced power = P_{MED}
- The area between the base station and R_1 defines a concentric circle zone where WCS mobiles transmit with the most reduced power = P_{LOW} representing the maximum reduction in WCS transmitter power

The concentric circle zones defined by the radial boundaries defined by R_1, R_2 and R_3 define three regions as shown in Figure 6: A_1, A_2, and A_3

If we assume a uniform spatial distribution of WCS transmitters within the cell coverage region, the percentage of the WCS transmitters that operate at each of the three power levels (Pct_{HIGH}, Pct_{MED}, and Pct_{LOW}) can be given by the ratio of the areas of each of the three regions to the total coverage area as follows:

$$Pct_{HIGH} = \frac{A_3}{(A_1 + A_2 + A_3)} = \frac{\pi(R_3)^2 - \pi(R_2)^2}{\pi(R_3)^2} = 1 - \frac{(R_2)^2}{(R_3)^2}$$

$$Pct_{MED} = \frac{A_2}{(A_1 + A_2 + A_3)} = \frac{\pi(R_2)^2 - \pi(R_1)^2}{\pi(R_3)^2} = \frac{(R_2)^2 - (R_1)^2}{(R_3)^2}$$

$$Pct_{LOW} = \frac{A_1}{(A_1 + A_2 + A_3)} = \frac{\pi(R_1)^2}{\pi(R_3)^2} = \frac{(R_1)^2}{(R_3)^2}$$

If the simulation uses more than three concentric zones to determine power control levels, there is more complexity. Furthermore, expanding Figure 6 to consider a greater number of concentric circle zones for different power control levels, the concentric circle zone with mobiles having the greatest amount of power attenuation (e.g. the greatest degree of power control) will occur in the region closest to the serving base station (since the path loss is smallest in this zone). Figure 6 shows that in the concentric zone closest to the base station, the area is much smaller than the area of the zones that are further away from the base station. Thus, for a uniform spatial distribution of users, the percentage of WCS subscribers will be much smaller within the closest concentric zone than in the zones that are further away from the base station. Hence, the percentage of WCS subscribers that undergo maximum power attenuation will be much smaller than the percentage of subscribers that undergo moderate, or no, power control.

If we assume that the maximum coverage boundary of the cell site, R_3, is determined by the thermal noise floor (e.g. consider a new deployment at the very early stage of its growth, not yet in its interference-limited regime), we can solve for the cell site coverage distance by considering a realistic propagation path loss based on realistic urban and suburban cellular systems. As seen in Figure 2, a standard mean path loss exponent of n=2.7, or 27 dB loss per decade of distance, is often used in mobile cellular radio system designs.

Cellular systems are designed to provide adequate link margin to all of its mobile subscribers over a wide range of propagation environments. Since shadowing of buildings and terrain cause wide swings in the local average received signal levels (as shown in Figure 2), it is reasonable to assume a new WCS base station (a large coverage cell) would be designed for an average SNR of 30 dB or more at the cell edge, with the understanding that shadowing and obstructions would substantially reduce the average SNR at some locations. Assuming a green field WCS cellular system installation with a link budget that requires an average Signal to Noise ratio (S/N) of 30 dB above the thermal noise floor to be received by a WCS subscriber terminal at the edge of the cell, and a bandwidth of 2.5 MHz (D Block subscriber), a base station EIRP of 1000 W, λ of 0.128 m, and unity gain subscriber antennas, we can solve for the cell edge distance, R_3, under the constraint of having a received subscriber signal power level of

$$P_r = 1000 \cdot kT_0B = -80\ dBm$$

Note that this link calculation is for the initial installation of a mobile cellular service, before capacity demands require the cell coverage radius (e.g. base station power) to shrink. It can be readily shown that since our analysis is based on proportional areas related to propagation path loss, and is reciprocal between the base station and the mobile subscribers, our approach to modeling the effect of power control can be applied to *any* size cell, as determined by a particular base station power level, noise floor, and propagation path loss model that is dependent on distance. That is to say, this analysis is not limited to the particular power levels or SNR levels used to define a cell edge.

Using Chapter 4.9 of Rappaport's "Wireless Communications: Principles and Practice" book, c. 2002, we note that the average power received by a cellular subscriber is given by a log-distance path loss model:

$$P_r\ (dBm) = EIRP\ (dBm) - \left[Free\ Space\ Path\ Loss_{close\ in}\ (dB) + 10n\log_{10}\left(\frac{d}{d_{close\ in}}\right)\right]$$

where the close-in free space reference distance is typically $d_{close\ in}$ = 100 m for cellular systems. The free-space path loss for a transmitter at 2340 MHz is

$$L_{free-space} = \frac{\lambda^2}{[(4\,\pi\,d)^2]} = 39.8\ dB \cong 40\ dB$$

at a distance of 1 m from the radiating antenna, and is 79.6 dB at a distance of 100 m from the radiating antenna. To solve for d, we equate terms and let n=2.7.

$$10n\log_{10}\left(\frac{d}{d_{close\ in}}\right) = EIRP(dBm) - 79.6\ dB - P_r\ (dBm)$$

For the case of P_r (dBm) = -80 dBm at the cell edge, and given an EIRP =1000 W = 60 dBm, $d_{close\ in}$ = 100 m, and n=2.7, we find the coverage boundary of the cell to be,

$$\log_{10}(R_3/100\text{m}) = \frac{60.4}{27}$$

$$R_3 = 100 * 10^{\frac{60.4}{27}} m = 17{,}260\ m \cong 17.3\ km$$

If we make a reasonable assumption that WCS transmitters will support two power attenuation steps of 6 dB and 12 dB (discussed below), then subscribers may reduce their transmitted power according to:
$P_{MED} = P_{HIGH}$ - 6dB
$P_{LOW} = P_{HIGH}$ - 12dB

To determine the concentric zones in which subscribers radiate reduced transmission power levels under power control, we need to find the cell radii in Figure 6 that provide for stronger forward link received power levels of -80dBm + 6dB, and -80dB + 12 dB, so that power control may be used to ratchet down the closer subscriber's transmitted powers such that they have the same powers at the base station receiver as those operating in the farthest region from the cell. By using the link equation to solve for P_r (dBm) values of -74 dBm and -68 dBm, we find that R_2 and R_1 are calculated as follows:

$$R_2 = 100 * 10^{\frac{54.4}{27}} m = 10{,}347\ m \cong 10.4\ km$$
$$R_1 = 100 * 10^{\frac{48.4}{27}} m = 6{,}203\ m \cong 6.2\ km$$

Using these boundaries, and assuming a uniform distribution of WCS users within the coverage area, the percentage of WCS users that are transmitting at full power, 6 dB backoff, and 12 dB backoff are determined by the ratios of concentric circle coverage areas. Using the above values of R_1, R_2 and R_3 we can calculate the transmit power distribution of WCS users within a cell site (Pct_{HIGH}, Pct_{MED}, and Pct_{LOW}) to be:

$$Pct_{HIGH} = 1 - \frac{(10.4)^2}{(17.3)^2} = 64\%$$

$$Pct_{MED} = \frac{(10.4)^2 - (6.2)^2}{(17.3)^2} = 23\%$$

$$Pct_{LOW} = \frac{(6.2)^2}{(17.3)^2} = 13\%$$

The above analysis shows that only 13% of the total WCS subscribers would experience power attenuations of 12 dB from the maximum mobile transmit power, and that 64% of the total WCS subscribers would not have any attenuation due to power control. If the concentric geometry were expanded to include additional power control levels, of 15 to 30 dB backoff, the concentric circles closest to the base station would have much smaller areas and consequently much fewer WCS subscribers. For example, when one considers Figure 6 and solves for the case of a 30 dB power attenuation level, we see that we need to solve for the distance from the base station at which the subscriber's received power is -80 dBm + 30 dB, or -50 dBm. Following the analysis above, the 30 dB backoff cell coverage zone would have a radius of 133 meters. The number of subscribers within a 133 m radius from the base station would therefore be miniscule. This is shown by computing the percentage of users that would experience 30 dB backoff:

$$Pct_{30dB\ atten} = \frac{(0.133)^2}{(17.3)^2} = 0.006\%$$

Less than *one hundredth of one percent* of the WCS subscribers would be attenuated by 30 dB under power control.

The above analysis technique scales to any practical size of cell coverage, and has been used to accurately design wireless CDMA networks. Based on reports from the field and personal experience, the author believes it is fair to simulate power control settings for WCS mobile transmitters at levels of 0 dB, 6 dB, and 12 dB below maximum power. The author has not seen power reductions far below 12 dB in actual operating cellular systems. The author believes the data rates required for meaningful web browsing and voice quality required in WiMAX, LTE, or HSPA systems are such that one would rarely see power attenuations greater than 12 dB in an interference-limited environment. Thus, the choices of 0 dB, 6 dB, and 12 dB power backoff are believed to be fair and reasonable for an accurate representation of WCS power control. Nevertheless, the simulator has been built in a flexible manner so that other power control levels may be set. This can be done be performing the above analysis and inserting the percentage of users that would experience each of 3 different power control levels.

Since the locations of vehicles on the roadway are statistically generated, the percentage of WCS transmitters which undergo power control may also be statistically generated as if they were uniformly distributed throughout the coverage areas of many cell sites along the highway. When iterated over all of the locations of all WCS and SDARS vehicles along the highway, the impact of power control is properly accounted for, since a proportion of WCS transmitters are allocated their lower transmitter powers due to power control, based on the above analysis. Specifically, for the simulation results presented here, we assume that active WCS transmitters are proportioned such that 64% of the WCS transmitters are transmitting with full subscriber transmit power levels, 23% of the WCS transmitters are transmitting at 6 dB below their maximum power level, and 13% of the WCS transmitters are transmitting at 12 dB below their maximum power level. The step of implementing the effect of power control (e.g. adjusting the transmit power level of each subscriber transmitter) is performed only on the eligible WCS transmitters that remain after “turning off” the transmitters that are inactive based on the specified activity factor.

5.2 Vehicle – to – Vehicle Path Loss Modeling

In order for simulations to accurately account for WCS OOBE and the impact that interference has on SDARS receiver, it is important to consider the proper propagation model to describe propagation from a WCS transmitter to a SDARS receiver.

Based on published papers from the Netherlands, Carnegie Mellon University, and the Intelligent Vehicle Highway Systems community, as published in the references[60], many measurements and models have been proposed for vehicle – to –vehicle communication systems in the 900 MHz to 6 GHz range. Work at Carnegie Mellon proposed a path loss model having a log-distance path loss exponent of n=1.8, and a log-normal shadowing of 5.5 dB. Other propagation models propose a free space path loss model of n=2.0, and one study found that n=3.1 but indicated the higher value of n is likely due to a one-time car body loss factor. In previous comments to the FCC, Sirius XM and the WCS Coalition provided measurements in various vehicle environments, and the author has considered these data. We note that some measurements and models consider the impact of car body loss, and others do not. It is reasonable to expect that in some instances a WCS subscriber would use her cell phone within a vehicle, and as a result, there would likely be some car body loss and human body loss as the WCS signal was radiated from the vehicle. This body loss would cause the interference signal received at a SDARS receiver to be reduced when compared with models that do not consider any type of attenuation in addition to free space propagation. We note that this loss would be random due to a large number of specific variables, such as the orientation of people in a vehicle, the number of cars on the road, the orientation of antennas, etc. Thus, it is reasonable to assume that the car-to-car propagation loss would be log-normally distributed.

The author has reviewed the data provided by Sirius XM and the WCS Coalition, as well as the other papers referenced above. Based upon all the reviewed measurements and models, we propose several different vehicle-to-vehicle propagation

[60] Lin Cheng, et. al., “A Fully Mobile, GPS Enabled, Vehicle-to-Vehicle Measurement Platform for Characterization of the 5.9 GHz DSRC Channel”, ieeexplore.ieee.org/iel5/4395409/4395410/04395917.pdf: J. Turkka, et. al., “Path Loss Measurements for a Non-Line-of-Sight Mobile-to-Mobile Environment”, http://ieeexplore.ieee.org/Xplore/login.jsp?reload=true&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F4723929%2F4740207%2F04740270.pdf%3Farnumber%3D4740270&authDecision=-203; Vehicle to Vehicle RF Propagation Mreasurements, www.wirelesscommunication.nl/reference/pdfandps/ivhs2.pdf; Alexander Paier, et. al., “Characterization of Vehicle-to-Vehicle Radio Channels from Measurements at 5.2GHz”, ieeexplore.ieee.org/iel5/4395409/4395410/04395917.pdf/; “Statistical Charaterization of Rician Multipath Effects In a Mobile-Mobile Communication Channel”, www.springerlink.com/index/M648W47747M07123.pdf; Alexander Paier, et.al., “Car-to-car radio channel measurements at 5 GHz: Pathloss, power-delay profile, and delay-Doppler spectrum”, Wireless Communication Systems, 2007. ISWCS 2007. 4th International Symposium, Oct. 17, 2007; Vehicle to Vehicle RF Propagation Measurement”, wireless.per.nl/reference/chaptr03/ivhs2.htm

path loss models. Our proposed models are used in the simulator and appear to be in close agreement with the other observed vehicle-to-vehicle measurements over the 900 MHz to 6 GHz range over the past 20 years. Unlike most of the published peer-reviewed models, however, we employ the concept of a mean attenuation factor, a diffraction parameter that models the cumulative effects of car body loss, human body loss, and blockage between vehicles. Based on filings of SWRI[61], WCS Old[62] and WCS New[63], we assume loss factors of 10 dB and 16 dB, and consider path loss exponents of n=2.0 and 2.18. We also assume log-normal shadowing due to variations in the channel, and consider standard deviations of the shadowing to be 0 dB (no shadowing variation), 2 dB, and 4 dB. We note that the loss factors add attenuation to the distant-dependent path loss model, and the log-normal shadowing allows our simulator to generate realistic random effects that will impact interference levels received at SDARS receivers.

Even though most of the peer reviewed literature does not consider a car-body loss factor, but rather relies on a straight exponential decay of power over distance (e.g. strictly uses a path loss exponent without additional shadowing), the predicted signal strengths between measured car-to-car propagation reported by both Sirius XM and the WCS Coalition appear to be matched well by using our models.

The propagation path loss models used in the simulations are given by equation 4.69a in Rappaport's 2002 "Wireless Communications: Principles and Practice" text as:

$$PL\ (dB) = [\ \text{Free Space Loss at } 1\ m\ ]\ (dB) + 10{*}n \log (d) + X_\sigma$$

where X_σ represents a random shadowing loss that is assigned a mean value of either 10 dB or 16 dB, and is log-normally distributed, and the free space loss at 1 meter is 39.8 dB. Thus, in our simulations, X_σ is a Gaussian random variable having values in dB. The simulator allows the user to consider either a free space path loss exponent value of n =2.0, as well as a path loss exponent value of n = 2.18. Other values may also be used by anyone using the program. Standard deviations for the log-normal shadowing component are selected to be 0 dB (no shadowing), 2 dB, or 4 dB.

The simulation applies the path loss model to each of the WCS transmitters and generates a random path loss value for every WCS transmitter. Then, the simulator uses the distance between every WCS vehicle and SDARS vehicle, and computes the resulting total received interference power at each SDARS receiver, based on the particular FCC interference protection mask that is specified in the simulator. We make the fair assumption that each WCS transmitter is independent from one another, or at least uncorrelated and of zero mean, such that the interference powers (in watts, not dB) from multiple WCS transmitters are added together in a linear fashion at a particular SDARS receiver.

5.3 Usage and Activity Considerations

Since not all of the WCS or Sirius XM customers will have their equipment turned on while driving, we determine which of the vehicles have active equipment by randomly applying a listening factor[64] in the case of satellite radio, and an activity factor in the case of WCS devices. This is done across all of the locations of WCS and SDARS vehicles. These listening/activity factors may be entered by the user. In the simulation results presented here, we used a listening factor of 85%[65] for satellite radio, and an activity factor of 13% for WCS. For WCS users, this means that one out of every eight WCS equipped vehicles will contain an active transmitter, or, that every WCS equipped vehicle will use their transmitter for slightly less than 8 minutes out of every hour. We determined the WCS activity factor from Table 4 WiMAX Forum Busy

[61] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293, February 27, 2008

[62] WCS Coalition Ex Parte Submitted to the FCC WT Docket No. 07-293, May 9, 2008

[63] WCS Coalition Ex Parte Submitted to the FCC WT Docket No. 07-293, August 1, 2008

[64] A 2009 Sirius XM press release (http://www.prnewswire.com/news-releases/arbitron-study-of-satellite-radio-shows-more-than-35-million-premium-listeners-81475652.html) announced a 71% subscriber listening rate, based on the percentage of time that subscribers listen to Sirius XM audio services while in their cars. However, for purposes of this paper we are using "listening rate" to mean the percentage of time a Sirius XM radio is turned on and receiving Sirius XM's audio, video, or data services, including subscription and non-subscription services. While this number could actually be 100%, adding data services and additional growth in subscribers to the 71% audio listening figure, , it is reasonable to estimate a listening rate of 85% in 2015.

Hour Activity Factor Estimates, which was published in a WiMAX Forum study[66]. The last line of Table 4 shows the overall peak busy hour activity would be 1/ 7.9, or 13%.

Table 4 WiMAX Forum Busy Hour Activity Factor Estimates

Customer Type	Mature Customer Mix	Peak Busy Hour Activity: 1 of "N" active	DL Duty Cycle	Minimal per End-User DL Rate During PBH
Professional	50%	N = 5	25%	75 kilobytes/sec (600 kbps)
High-End Consumer	35%	N = 7	25%	60 kilobytes/sec (480 kbps)
Casual Consumer	15%	N = 20	25%	30 kilobytes/sec (240 kbps)
Overall Customer Average Over Metro Area		N = 7.9	25%	63 kilobytes/sec (504 kbps)

The simulator also allows specifying the duty cycle of each WCS transmitter. The duty cycle adjusts the total average radiated power of a WCS subscriber transmitter over a small time interval (typically on the order of milliseconds, as specified by the particular air interface standard). The duty cycle is specified in the simulator as a scaling factor that reduces the WCS transmitter power from its assigned transmission power. This is done to accurately account for the average interference power that will be reduced by duty cycle. Duty cycle values used in the simulations presented here range from 6.25% to 38%[67] .

The simulation avoided having a WCS transmitter within the same vehicle as a SDARS receiver, since the interference level would likely be very strong in such a case, and it is reasonable to assume that a WCS user would not be listening to the radio while making a WCS call. Nonetheless, it is certainly likely that in real world applications, WCS users and SDARS listeners would be in vehicles next to each other or behind each other on a highway. The simulation does not count the WCS transmitter as an active interferer when the simulator produces a location that has both an operational WCS station and an operating SDARS receiver station within 3 meters of one another. Instead, we adjust the effective WCS transmitter separation distance for that particular SDARS/WCS pairing by moving the WCS transmitter away from the SDARS receiver to a new location that is 3 meters away from the specific SDARS receiver, and then compute the interference based on a 3 meter separation. This ensures that proper customer penetration rates are considered for both services, while not penalizing the WCS service for the case when a WCS mobile user is also a Sirius XM radio listener. As shown in Section 6, the simulator measures the instances when this collocation occurs, and as shown subsequently, it is extremely rare (typically on the order of a couple hundredths of a percent).

5.4 WCS Block Allocations and OOBE Spectral Mask Considerations

The simulator allows the user to specify an OOBE spectral mask to be applied to the WCS transmitters. The spectral mask is specified in terms of an attenuation factor at three different frequency break points, each breakpoint being adjustable at 5 MHz intervals above the SDARS upper band edge. Thus, the simulator emulates the FCC's approach to specifying an OOBE mask as in the FCC Staff proposal. To distinguish between WCS transmissions from the various channel blocks in the simulator, the WCS transmitters are assumed to be randomly and uniformly distributed from the A, B, and D spectrum blocks, and the transmitted powers from each of the WCS transmitters are then attenuated based on the specific attenuation values for the user-specified OOBE mask. Thus, the simulator provides a powerful tool that allows proper simulation of the

[66] A Comparative Analysis of Mobile WiMAX™ Deployment Alternatives in the Access Network, The WiMAX Forum, May 2007, P.14, Table 3.

[67] The 38% duty cycle is based on the FCC's proposed rules, while the the 6.25% is the lowest duty cycle found in both the WCS Coalition and Sirius XM test reports.

proposed requirements for out of band transmissions for different WCS subscribers from different WCS spectrum blocks, and allows one to analyze the impact that different spectral emission masks will have on SDARS performance.

The simulator allows for the user to specify attenuation values that are applied to the WCS transmitter spectrum masks, in order to take into account the FCC's proposed rules that require WCS interference components at SDARS receivers to produce less interference as the frequency separation increases. Specifically, the model used in the simulator allows the user to select different levels of attenuation to be applied to the WCS transmitters at different frequencies away from the SDARS spectrum.

For example, to study the FCC's proposed rules, the simulator needs to implement the 55 + 10logP spectral mask for a 0.25W WCS subscriber transmitter using a 2.5 MHz channel in the D block. To do this, we compute the attenuation required by the mobile station as 55+10log(0.25W) dB. This equates to 55 db – 6 dB, = 49 dB of attenuation applied to all D block WCS transmitters. For all WCS transmitters assigned to be in the first adjacent channel (e.g. the A-upper block), the simulator implements 61 – 6, or 55 dB of attenuation level to implement the FCC's proposed 61 + 10 log P OOBE mask for the case of 0.25W transmitters. The simulator applies 67 – 6 = 61 dB of attenuation for the B-upper block WCS transmitters in order to implement the FCC's proposed 67 + 10 log P mask with 0.25 W transmitters. If all WCS carriers use subscriber equipment that have identical spectral mask characteristics, then it is reasonable to assume that identical equipment in the WCS upper band (A block) would cause less interference into the SDARS band as compared to D block transmitters, since the spectral emissions from WCS subscribers are further attenuated over the additional 5 MHz separation as required by the FCC OOBE mask (e.g., the FCC has proposed 61 + 10logP at 5 MHz above the SDARS upper band edge). Even less interference power will be received at SDARS receivers from the upper band B-block WCS transmissions, since the upper band B-block WCS transmitters are separated from the SDARS band edge by 10 MHz (where the FCC has proposed 67 + 10 log P).

The simulator allows the user to specify attenuation levels as settable parameters to implement the interference mask as proposed by the FCC, and also allows the user to specify other OOBE protection masks, as well. As mentioned earlier, the simulator only considers WCS subscribers above the SDARS spectrum, and only considers interference to the SDARS high-band (XM) spectrum. For the purposes of determining whether a WCS transmitter is from the D, A, or B block, the simulator randomly assigns one of the three required attenuation levels to each active transmitter, in essence assigning each transmitter a random, equally probable spectrum "channel" in one of the three blocks.

5.5 Path Loss and WCS Interference Power Received at Satellite Receivers

As discussed in Section 5.2, the simulator computes the distances between all WCS and SDARS vehicles, and then calculates the path loss for WCS signals at each SDARS receiver. The vehicle-to-vehicle path loss model is flexible, and multiple path loss parameters can be set and varied between runs. The basic structure of the path loss formula used in the simulation code is:

$$Pathloss(dB) = 39.8 + 10\, n\, logd(Range) + \; Blockage(mean(0), stdev)$$

Where 39.8 dB represents the path loss over the first meter of free space, and *n* is the path loss coefficient for the remainder of the distance and is settable to 2.0 or 2.18. The final term is a general blockage term, randomly generated as a Gaussian distributed variable, with a selectable mean of 10 or 16 dB, and a standard deviation selectable between 0 and 4 dB.

Once the path loss for each distance is found, the cumulative interference seen at each SDARS satellite receiver is calculated by summing up all interference levels from all WCS transmitters. The simulator limits the maximum distance of eligible interference sources to a settable maximum, nominally 200 meters. We do this to speed up the run-time of the simulator, since it is virtually impossible for any appreciable interference to be received from a 0.25W WCS transmitter that is 200 meters or more away from an SDARS receiver. As described in Section 5.3, the simulator does not allow any interference to be caused by WCS transmitters that are closer than 3 meters to an SDARS receiver. The received power from each transmitter is also reduced by the OOBE mask assignment as described in Section 5.4.

During each iteration, the simulator computes and stores the aggregate power from all of the WCS transmitters as seen at each SDARS receiver, as well as the aggregate WCS OOBE power which appears as interference to each of the SDARS receiver. The absolute (not dBm) interference power levels provided by each WCS transmitter, after passing through their respective OOBE masks and the propagation channel, are summed together, and this total interference power level is then summed with the SDARS receiver baseline noise floor of -113 dBm/4MHz, or -119dBm/1MHz. The result of the total interference plus noise is converted into dBm values, and is used to determine whether there is a corresponding reduction in available satellite link margin. This is done by using the noise plus interference level at each SDARS receiver as a new noise floor for that receiver, and then using that new (higher) noise floor to determine a new satellite link margin (which is therefore degraded by the amount of interference power based on a linear receiver assumption). The new link availability for each SDARS receiver within the simulator is computed using Sirius XM's original design procedure based on the EERS propagation model, and each SDARS receiver is evaluated for performance as compared to the existing baseline design. (The baseline design exists in today's Sirius XM system, and is based on the absence of any WCS interference). The statistics of WCS interference power levels and link degradations for hundreds of simulated receivers are computed over many iterations.

5.6 Interference and Outage Calculations at the Satellite Radio Receiver

5.6.1 Outage Due to WCS Out-of-Band Emission Interference (Linear receiver range)

The simulator uses the Sirius XM satellite look angles, satellite antenna patterns, and designed link margins in order to determine the signal levels at different locations on earth. The simulator incorporates the actual designs employed by Sirius XM to exceed 99% availability under worst case Extended Empirical Roadside Shadowing (EERS) model[68] assumptions.

The EERS model is used to determine the link outage performance and signal-to-noise ratios on earth for today's baseline case with no WCS transmitters present, and the same EERS model is used to quantify the degradation of each SDARS receiver in terms of how far each receiver is forced to dip below the baseline availability level as WCS interference is introduced. In other words, as described in Section 5.5, the WCS interference is treated as additive thermal noise, the SDARS receivers are assumed to be operating in their linear range (e.g. no non-linear overload is considered), and the satellite link margin is reduced by the additional WCS interference power that is received within the SDARS receiver band for every SDARS receiver in the simulation. The EERS model is then used by the simulator to determine the resulting link degradation in terms of erosion of the link availability statistics for every SDARS receiver, based on the particular interference level (e.g. the new satellite link margin) at each receiver. In addition to the statistics of outage likelihood for each affected receiver, the specific decrease (in dB) of the baseline link margin for each SDARS receiver, as caused by the increased receiver noise floor due to WCS interference, is also captured by the simulator.

The EERS model, pioneered by Goldhirsh and Vogel, is represented in the simulation code in 0.5 dB CNR steps. We note that before evaluating the interference at each SDARS receiver, only those receivers deemed to be "on", as specified by the listening factor, are considered by the simulator. A number of satellite receivers are randomly eliminated from consideration, as determined by the specified listening rate (specified here as 85%, which means that 15% of the SDARS receivers are not on and not considered). It is worth noting that the simulated outage statistics and link margin degradations produced by the simulation will not change appreciably for different SDARS listening rates, so long as there is a sufficiently large population of users, since the simulator uses the interference experienced by each active SDARS receiver to determine the availability likelihood and link margin degradation. If the SDARS listening rate is reduced from 85% to 42.5%, half as many SDARS receiver locations will be used by the simulator to determine outage statistics, but those active listeners will still be subjected to performance degradation based on the proximity of WCS interference sources for particular SDARS receiver locations, such that we would not expect the statistics to change greatly.

[68] Goldhirsh, Julius (Applied Physics Laboratory, The Johns Hopkins University) and Vogel , Wolfhard J. (Electrical Engineering Research Laboratory, The University of Texas at Austin) *Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems*, Chapter 3.3 available online at http://wwwhost.cc.utexas.edu/research/mopro

6 Simulation Results for WCS Out Of-Band-Emission Impact on SDARS Quality of Service

The simulator has been created to allow a determination of the outage and interference levels for SDARS receivers based on a wide range of complex inputs and situations. As described in Section 5, we have attempted to provide fair and reasonable assumptions in developing the simulation and analysis.

We now provide results for an extensive array of simulations that were carried out to determine the impact of adjacent service interference to the Sirius XM SDARS system.

6.1 Introduction to the Simulation Studies

6.1.1 Highways in Five Cities are considered with realistic traffic assumptions

In this report, we considered SDARS listening conditions across many markets in the USA. In order to ensure the simulations were realistic, we simulated highways where SDARS listeners rely solely on satellite coverage, and not terrestrial repeater coverage. We selected the following cities because of their distinctly different topographies, satellite link margins, look angles, traffic conditions, and customer penetration rates. The five cities were Charlotte, NC, Miami, FL, New York City/Newark, NJ, Jackson, MS, and Denver, CO. Within each of these five cities, we selected representative portions of roadways that are highly traveled and which do not have terrestrial SDARS repeater coverage, with the exception of the Miami, FL location where the selected roadway has weak repeater signal levels at some locations on the highway. We specifically sought to consider roadways that did not have repeaters since more than 98% of the Sirius XM CONUS coverage region is not served by repeaters.

Charlotte, NC is a mid-Atlantic eastern state that has mildly undulating terrain and an extremely strong satellite signal, close to the level received in Northern Virginia. We would expect the baseline outage levels to be among the best in the country in Charlotte. We considered an approximate 7 mile stretch of highway on Interstate 85, on the west side of Charlotte. Miami, FL is a southern state that has the poorest satellite link margin of all 5 cities considered, yet the terrain is quite flat and there is little highway shadowing. We considered a 7.5 mile stretch of Florida 836, west of the Miami core. The New York City/NJ Turnpike location is a major market for Sirius XM, and we simulated an 8 mile stretch of the New Jersey Turnpike between Exits 7A and 9. This is one of the busiest highways in the country. On the other hand, Jackson, MS is a smaller city located in the south central part of the US. The highway selected in Jackson, a three mile stretch of Interstate 55 and Interstate 20, has a much lighter traffic density than the New York/NJ market. The fifth city we considered is Denver, CO because of the surrounding mountains and the western longitude. We considered an 8 mile stretch of US 285 located south of the urban core.

The road segments selected for simulation were evaluated using the Google Maps traffic feature to determine accurate traffic volumes based on past conditions. Google is able to accurately predict traffic as a function of day and time on many major highways[69]. Peak-hour traffic times were determined, and road segments were identified in each of the five cities in order to determine typical peak-hour traffic speeds[70].The average daily traffic volume over the length of each highway segment was then determined from MapInfo Dynamap®/Traffic Counts[71]. The number of lanes and segment length of each of the five highways considered in our simulation was determined by measuring aerial photographs and maps in Google Earth Pro. All of the highway segments selected in the simulations presented here are meaningfully covered only by space-based satellite signals.

Each of the selected road segments has a corresponding daily traffic volume, distributed over a 24 hour period. To determine inputs for the simulator, we assumed that 60% of traffic occurs during the peak morning (7-9 am) and evening (4-6 pm) rush hours. Dividing the resultant by four yields the peak busy hour traffic volume (cars/hour) for entry into the simulator:

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[69] See http://maps.google.com

[70] Peak-hour speeds are shown on the maps as Green: more than 50 mph, Yellow: 25 – 50 mph, Red: less than 25 mph.

[71] Dynamap® /Traffic Counts, ©1992-2002 MapInfo Corporation, provides two-way Average Daily Traffic (ADT) count data on U.S. Interstates and highways nationwide and on major and residential roads in major metropolitan areas (where counts have been taken by government agencies). Enhanced coverage is provided in metropolitan areas using additional local city and county resources

$$Peak\ Hourly\ Traffic\ Volume = \frac{Average\ Daily\ Volume\ x\ 60\%}{4}$$

6.1.2 Consideration of Power Control by WCS service in adjacent spectrum

As described in Section 5.1, the power control distributions used in the simulation are based on a statistical distribution of WCS vehicle locations within a base station coverage area. The power control levels are settable, and for the simulation have been set to 0 dB (max power), -6 dB, and -12 dB from full power. Out of the total pool of WCS transmitters on the roadway segment, the simulator declares a portion of them inactive due to the specified WCS activity factor. The remaining eligible transmitters are then assigned a power level that is dictated by power control in the proportions derived in Section 5.1. Specifically for these simulations, we specified 64% at full power, 23% backed off by 6 dB, and 13% backed off 12 dB from full power. All the WCS transmitters, active and inactive, then receive a random power level assignment during each iteration, and the active transmitters are further scaled by the specified duty cycle and spectrum mask attenuation value when their powers are computed at a SDARS receiver.

6.1.3 Consideration of Propagation of Interference from WCS to SDARS

The received power at the SDARS receiver is calculated by subtracting the total path loss, per the propagation models in section 5.2, from the transmitted WCS power. Included in the total path loss is the log-normal (Gaussian in dB) random shadowing factor that has a selectable mean level in dB, and a standard deviation in dB that is adjustable between 0-4 dB. The mean attenuation for the shadowing is selected as either 10dB or 16 dB, and the shadowing factor is randomly assigned for each individual path loss calculation. Path loss parameters can be varied to assess performance using different vehicle-to-vehicle propagation assumptions.

6.1.4 Consideration of different markets and subscriber densities

Traffic volume, average vehicle speed, and roadway characteristics determine the total number of vehicles on the simulated roadway segment during the peak rush hour. A subset of the total vehicles will be satellite radio subscribers or WCS service subscribers. The number of subscribers to both services depends on how widely consumers adopt the respective services. This adoption factor is referred to as the penetration rate.

For the satellite radio service, it is likely that the penetration rate will grow to 34% of vehicles in the next few years.[72] The WCS penetration rate is more difficult to estimate as there is little or no current service available in the WCS spectrum. Therefore a modest penetration rate of 5% was assumed for the simulations. Penetration rates for both services are settable parameters in the model, and can be adjusted for future growth. As both services grow, the likelihood of their subscribers sharing the road in close proximity will increase.

6.1.5 Consideration of different satellite look angles and resulting link sensitivity

The final step in conducting the simulation is to evaluate the impact of interference received at the SDARS receivers in terms of link quality and signal availability.

Satellite radio performance depends heavily on two key factors: available link margin, and elevation angle between the receiver and the satellite. The elevation angle dictates how much shadowing (e.g. attenuation) will occur from roadside structures and foliage, while the link margin indicates the level of protection available to withstand such shadowing.

This relationship between link margin and elevation angle can be statistically estimated using a technique called the Extended Empirical Roadside Shadowing model[73]. This model allows the simulator to compute the outage probability (or the availability likelihood, where the availability likelihood is equal to 1.0 minus the outage probability) for different combinations of elevation angles and link margins. In short, given a specific link margin, there is a higher probability of suffering an outage if the elevation angle is low. Conversely, high elevation angles suffer fewer blockages.

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[72] See footnote 58.

[73] Goldhirsh, Julius (Applied Physics Laboratory, The Johns Hopkins University) and Vogel , Wolfhard J. (Electrical Engineering Research Laboratory, The University of Texas at Austin) *Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems*, Chapter 3.3 available online at http://wwwhost.cc.utexas.edu/research/mopro.

In the simulator, the baseline can be computed for today's Sirius XM satellite system, without the effects of any WCS OOBE. The baseline is set based on existing Sirius XM link margins and satellite data, in conjunction with the EERS model, and is corroborated by today's Sirius XM real world performance. The simulator is able to also determine the link margin degradation due to WCS interference, where the simulator sums up the interference effects of WCS transmitters, treats the interference as additive noise, and then recomputes the signal availability to each of the SDARS receivers using the reduced link margin. The outage likelihood for each SDARS receiver is then determined using the EERS model, and tallies are kept to compare overall availability statistics with the baseline performance. Thus, the simulator produces a new quality of service estimate (e.g. outage percentage or availability percentage) which can be used to compare SDARS listener performance under varying degrees of interference.

Similarly, the simulator also keeps tallies of the number of SDARS receivers that experience link margin degradations of greater than 1 dB, greater than 2 dB, and greater than 3 dB from the baseline. These receivers will therefore experience a corresponding decrease in their ability to mitigate propagation outages. That is to say, SDARS receivers, in the face of WCS OOBE, will suffer degradation in listening quality as compared to the baseline performance, since the SDARS receivers will lose some of their link margins to interference, and will be less effective in fighting off the challenges of mobile shadow fading conditions.

It is clear that Sirius XM designed its system by taking extraordinary measures to maintain adequate levels of broadcast quality throughout its satellite coverage area. As a reference point, when the output power of two of the Sirius XM's original satellites unexpectedly deteriorated to 3dB below the designed power level, the company decided to replace both satellites rather than attempt to offer service with a 3 dB loss in link margin. Thus, Sirius XM made a huge investment to maintain its target mobile quality of service (QoS) of better than 99% worst-case availability[74]. By its actions, Sirius XM made clear that any level of service below 99% availability is unacceptable for its broadcast listeners, and it also made clear that a link margin degradation of 3 dB is unacceptable, as well. It is worth noting that the simulations in this study show that if the FCC's Staff OOBE proposal is implemented, WCS interference can and will cause Sirius XM's QoS to drop below a 99% availability level for a large percentage of listeners, and that link margin destruction greater than 3 dB can and will occur in local usage conditions for many listeners throughout the U.S. Since this interference is out of the control of Sirius XM, and since Sirius XM will not be able to prevent the WCS OOBE by any practical means, (i.e. Sirius XM cannot practically replace or add satellites to repair the damage of adjacent service interference), the only practical solution is for the FCC to provide sufficient interference protection from the WCS adjacent service transmitters.

Another example of the pains one must go through to offer a high level of mobile satellite broadcast service is demonstrated through the use of satellite diversity. Sirius XM uses two satellites instead of one to deliver content to subscribers. In this approach, tradeoffs are required in terms of bandwidth, complexity and cost in order to deliver high quality service on earth. Obviously, it is less expensive to deploy a single satellite and to use ordinary encoding/decoding communication schemes rather than to add complementary signaling through a second satellite. Using the EERS model to calculate the resulting link availabilities, one can see in Table 5 that using a single satellite would only allow a level of availability in the 95% range. According to XM Satellite engineers, a 95% service availability range would result in shadowing that leads to about 3 seconds of muted audio during every minute of broadcasting – this is clearly not a commercially viable solution. To deliver a compelling subscription service, Sirius XM deploys an additional satellite and associated technology to bring the link availability level to above 99% within its satellite service area under most mobile fading conditions. The satellite diversity approach is described in "*A Method for Jointly Optimizing Two Antennas in a Diversity Satellite System,"* by Richard Michalski and Duy Nguyen, AIAA-2002-1996, as presented at the 20th AIAA International Satellite Systems Conference and Exhibit, Montreal Canada, May 12-15, 2002.

Table 5: Single vs. Dual Satellite Signal Availability

City	Single Satellite Availability-East	Dual Satellite Availability
New York	97%	99.5%
Miami	98.8%	99.8%
Charlotte	96.7%	99.7%
Denver	94.8%	99.6%
Jackson	94.2%	99.8%

[74] Sirius XM Ex Parte Submitted to the FCC in WT Docket No. 07-293 as "*Comments of Sirius Satellite Radio, Inc*.", February 14, 2008

6.2 Simulation Inputs and Outputs, and Results – An Overview

The inputs to the simulator are entered manually into the Matlab script, and both the input and output parameters are tabulated on an Excel spreadsheet for ease of analysis, as shown in Figure 7. The spreadsheet shown in the figure is for the Charlotte, NC simulation runs. The spreadsheets have yellow markings to help the reader see the various inputs that may be changed in the simulator, and the resulting simulation results that occur for each simulation run. This section is aimed at helping the reader understand the spreadsheets that are used to demonstrate the inputs and outputs of various simulation runs, and provides an overview of some of the key results that are presented for each of the five cities.

6.2.1 Baseline case – no interference from WCS subscribers

The spreadsheet in Figure 7 shows all of the simulation input parameters on the top half of the page, and all of the simulation output parameters on the lower half of the page. Spreadsheets such as Figure 7 have been created for each of the five cities studied in this report.

In Figure 7, each of the vertical columns represents a particular simulation run, also called a simulation *case*. Each column shows all of the simulator inputs and the resulting simulator outputs for a particular case of interest. The first vertical column (Case 1) shows the baseline simulation run for Charlotte, NC, where no WCS transmitters are operating (e.g. the no-interference case, or the *baseline case*). Line 1 of the figure shows the case number, and line 2 shows an abbreviation for the city that is being simulated. For Case 1, all WCS transmitters are turned off, since the input parameter for the WCS activity factor is set to zero (see the 11th line down, “WCS activity factor” highlighted in yellow has a value of 0). Entering a value of zero instructs the simulator to turn off all WCS transmitters. It can be seen on lines 3 through 8 of the input parameter section that the highway traffic statistics and penetration rates of SDARS receivers (34%) and WCS transmitters (5%) are used to calculate the appropriate number of randomly located users. For the Charlotte busy hour on I-85, there are 317 SDARS and 47 WCS vehicles placed randomly on the highway, as seen in lines 9 and 10 in the input section of the spreadsheet. Line 14 is the band factor, which is described in Section 5 and is set to 2 in order to instruct the simulator to only consider WCS transmitters and SDARS receivers on the high side of the spectrum band. The satellite look angles and designed satellite link margins are shown in lines 23-26 of the input parameter section, and the baseline outage availability for Charlotte, based on the satellite link margins and look angles, is computed by the simulator to be 99.74% as shown in the very last (bottom) line of the input parameter section.

The simulator output values shown below the center line of the spreadsheet allow one to readily observe the impact of WCS interference as compared to the baseline case. For the Case 1 column (baseline), there is no interference present, therefore none of the simulated SDARS receivers suffers any link degradation or reduced link availability from today’s baseline case. Furthermore, it can be seen from line 3 of the output section that only 0.02% of all simulated locations for WCS and SDARS receivers result in the WCS and SDARS equipment being collocated in the same vehicle. As mentioned in Section 5, WCS transmitters that are within 3 m of a SDARS receiver are moved to a distance 3 m away to prevent undue bias. Lines 1 and 2 of the output section of Case 1 show that only 262 points out of the total of 1,489,900 vehicle locations (points) land within 3 meters of one another. Each simulation run is computed by using many iterations to determine the interference and outages statistics, where vehicle locations are produced randomly during every one of the 100 iterations of the simulator. For all of the simulation cases, the total number of points (line 2 of the output section) can be computed by multiplying the number of satellite vehicles by the number of WCS vehicles by the number of iterations within a simulation run.

Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
City	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
Vehicle Volume	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900	6900
Vehicle Speed	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
WCS Penetration Rate	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDARS Penetration Rate	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Roadway Length	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Num_lanes	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# Sat	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317
# WCS	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
WCS Activity Factor	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
SDARS Listening Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Duty Cycle	0.38	0.38	0.38	0.38	0.38	0.125	0.0625	0.38	0.38	0.125	0.0625	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Band Factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C/D OOB Mask (X+10logP)	55	55	55	55	55	55	55	55	55	55	55	55	70	75	80	85	100	70	75	80	85
Bl, Au OOB Mask (X+10logP)	61	61	61	61	61	61	61	61	61	61	61	61	70	75	80	85	100	70	75	80	85
Bu, Al OOB Mask (X+10logP)	67	67	67	67	67	67	67	67	67	67	67	67	70	75	80	85	100	70	75	80	85
Max Tx	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Pwr Cntrl (0, -6, -12 back off)	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Path Loss exponent	2.00	2.00	2.00	2.18	2.18	2.18	2.18	2.18	2.00	2.00	2.00	2.00	2.00	2	2	2.00	2.00	2.18	2.18	2.18	2.18
Blockage Mean	10	10	10	16	16	16	16	16	10	10	10	10	10	10	10	10.00	10.00	16.00	16.00	16.00	16.00
Blockage Std Dev.	0	0	0	0	2	2	2	4	2	2	2	4	4	4	4	4.00	4.00	4.00	4.00	4.00	4.00
Sat1 Link Margin	12	12	12	12	12	12	12	12	12	12	12	12	12	11.5	11.5	11.50	11.50	11.50	11.50	11.50	11.50
Sa1 Elevation	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Sat2 Link Margin	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Sat2 Elevation	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
QoS Baseline	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%	99.74%
RESULTS																					
# Pts. < 3m Relocated to 3m	262.00	256.00	259.00	279.00	301.00	288.00	283.00	279.00	234.00	266.00	273.00	266.00	281.00	272.00	252.00	292.00	284.00	277.00	283.00	276.00	289.00
# Total Points	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900	1489900
% Relocated Pts.	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
% SDARS with Link Margin Reduced >1dB	0.00%	12.08%	10.00%	3.59%	3.72%	2.22%	1.54%	4.06%	9.88%	6.16%	4.27%	9.66%	3.41%	1.76%	0.91%	0.44%	0.00%	1.26%	0.71%	0.33%	0.07%
% SDARS with Link Margin Reduced >2dB	0.00%	8.30%	6.67%	2.41%	2.52%	1.44%	0.98%	2.73%	6.84%	4.10%	2.80%	7.17%	2.20%	1.09%	0.58%	0.20%	0.00%	0.82%	0.42%	0.15%	0.03%
% SDARS with Link Margin Reduced > 3dB	0.00%	6.37%	5.23%	1.80%	1.94%	1.07%	0.72%	2.06%	5.24%	3.17%	2.15%	5.57%	1.60%	0.79%	0.36%	0.09%	0.00%	0.60%	0.27%	0.07%	0.01%
% SDARS Availability Degraded <99%	0.00%	5.76%	4.71%	1.60%	1.79%	0.92%	0.64%	1.88%	4.74%	2.80%	1.91%	4.95%	1.43%	0.69%	0.30%	0.08%	0.00%	0.50%	0.24%	0.05%	0.01%
% SDARS Availability Degraded <98%	0.00%	3.96%	3.33%	1.12%	1.20%	0.63%	0.38%	1.32%	3.38%	1.95%	1.30%	3.38%	0.86%	0.40%	0.14%	0.03%	0.00%	0.31%	0.12%	0.02%	0.00%

Figure 7. Spreadsheet used to display the inputs and outputs for the Charlotte, NC simulation run

6.2.2 Impact of WCS interference on SDARS

Referring again to Figure 7, we consider Case 2 where the WCS transmitters are activated in the simulation run. As can be seen on the 11th line of the Case 2 column, the activation is obvious since the WCS activity factor is changed from 0 to 0.13. This implies that statistically 1 out of 7.9 WCS transmitters are transmitting during a simulation run. It can be seen in the Case 2 column that power control is turned off (see line 19), and all WCS subscribers are transmitting with a maximum power of 24 dBm (see line 18). The power levels of each transmitter are reduced in the simulator by the duty cycle factor (set to 0.38, see line 13). The propagation model used for vehicle-to-vehicle propagation is set in the simulator to have a free space path loss exponent of 2.0, a mean blockage attenuation factor of 10 dB, and 0 db standard deviation (e.g. no random shadowing). These inputs are seen on lines 20-22 of the figure. Lines 15-17 specify the OOBE mask break points implemented on all WCS transmitters. By specifying attenuation values on WCS transmitters at various break points as specified by the recent FCC proposed rules (adjacent 4 MHz channel spacings from the SDARS high band), the simulator allows one to compare and analyze the impact of various proposed spectral masks for a wide range of possible input parameters. In Case 2, the proposed FCC spectrum mask is used, as noted by the values of 55, 61, and 67 entered on lines 15, 16 and 17.

The values shown for attenuations in a particular spectrum mask in the spreadsheet, and values used to describe spectrum masks in the remainder of this report are often given as a shorthand notation. We wish to make clear that whenever there is a reference to a "55 dB mask" or “a mask that attenuates at 55 dB level”, this is actually a shorthand way of saying that the spectrum mask is defined as a 55 + 10 log P mask, where "P" is the transmit power, usually with a peak value of 0.25W. Likewise, references to a 70 or 75 dB OOBE mask correspond to a 70 + 10 log P mask or 75 + 10 log P mask, where "P" denotes the transmit power.

The outputs of Case 2 illustrate that with the proposed FCC OOBE mask and no power control, the interference levels suffered by the SDARS receiver are intolerable for SDARS. Line 4 of the output section of the spreadsheet shows that 12.08% of all SDARS receiver (1 in 8 listeners) suffers more than 1 dB of link degradation compared to today’s baseline design case, and Line 5 shows that 8.30% of the receivers (1 in 12 listeners) suffer more than 2 dB of link degradation due to WCS interference. Line 6 shows that 6.37% of all receivers (1 in 16 listeners) have their link degraded by more than 3 dB, which denotes that these users have their link margin cut in half from the original design. Recall that Sirius XM viewed their service unusable and replaced two satellites when the link margin was degraded by 3 dB. Thus, line 6 shows that *at least* 1out of every 16 listeners will have their service rendered unusable due to WCS interference, and most likely many more than this number of users will lose service when overload is considered. Line 7 shows another way to see how the interference levels impact SDARS receivers. Line 7 shows that 5.76% of all receivers (1 in 17 listeners) are no longer able to meet the original Sirius XM system design threshold of a 99% worst-case availability threshold, and Line 8 shows that 3.96% of all receivers (or 1 in 25 listeners) are unable to meet a much poorer 98% worst-case availability threshold. Recall that Sirius XM viewed their broadcast service as unusable whenever the service availability dropped below 99%.

It is important to put these simulator results in context. Sirius XM listeners expect to continue to receive service at the baseline quality levels shown in Case 1. Sirius XM designed and built its system with the goal of having better than 99% worst-case availability statistics. That is to say, the SDARS system should experience a worst-case coverage situation where no more than 1% of its listeners have an outage *at any time* – and the Sirius XM system has been implemented based on the assumption that the 1997 FCC rules would protect against adjacent service interference. Sirius XM has demonstrated by its replacement of satellites that a link erosion of 3 dB, or a drop below 99% worst-case service availability are not acceptable to any of its users, and renders its service as unusable.

The WCS interference clearly provides destruction of a listener’s link budget, which goes against the original Sirius XM design goal of having an interference-protected system designed for a worst-case 99% availability threshold due to building and foliage shadowing. A protected service would allow listeners to continue to experience reception QoS based on the original design goal over time. The simulation allows various parameters to be changed, so that the statistical QoS for the SDARS service may be predicted.

While Case 2 shows that over 5.76% of the SDARS receivers would be forced to dip below the 99% availability threshold (see line 7), consider if just *one percent* of the Sirius XM listeners experienced enough interference that their link margin dipped below the 99% availability threshold. The resulting interference would be detrimental to the service quality, since the allowed interference would undermine Sirius XM's goal of a worst-case outage likelihood of less than 1% for all of its

SDARS listeners -- instead, allowing such a level of adjacent service interference would *guarantee* that *more* than 1% of the SDARS listeners would fail to meet the worst-case 99% availability threshold, and possibly substantially more than 1%, depending on overload and intermodulation conditions. The adjacent WCS service essentially becomes an independent source of uncontrollable interference that increases the likelihood of random outages for SDARS listeners while removing the originally specified performance goal that listeners expect.

To have listeners dip below a 98% availability threshold would most likely be intolerable. A 98% availability threshold implies greater than a 2% outage/failure rate, which is double the number of worst-case expected outages as compared to today's SDARS system. A 2% failure rate is comparable to the grade of service that cellular systems use to establish call blocking levels for trunked systems (see Rappaport's Wireless Communications text, c. 2002, chapter 3, p. 77). We note that the SDARS system is a high quality subscription broadcast system --which competes with free terrestrial broadcast services that provide near-ubiquitous coverage -- not a cellular system or trunked radio system where users routinely tolerate dropped or blocked calls 2% of the time. To have availabilities approaching 98% would degrade the SDARS service in such a way that customers would likely view the service as unreliable or unusable. Line 8 of Case 2 for Charlotte, NC shows that 3.96% of the users, or 1 in 25 listeners, would suffer at least twice as many outages as today's listeners.

Figure 7 was produced from simulations described in Section 5.6.1 for linear receiver performance, and does not consider overload performance. One should bear in mind that overload is also an important consideration for determining degradation of SDARS performance from an adjacent service, as discussed in Section 4.

It can be seen that the Case 1 baseline demonstrates that the Charlotte, NC market has a worst-case outage of 99.74%, which is above the 99% worst-case design guideline. Thus, it is clear that there is some margin that may be yielded to accommodate additional interference from the WCS service. One viable solution would be to allow the adjacent WCS service to provide just enough interference such that the certain percentage of listeners that are forced to dip below the 99% availability threshold (e.g. line 7) would be set equal to the difference of the baseline outage probability and the 99% design goal. That is to say, for the Charlotte, NC case, the interference mask could be determined such that 99.74% - 99%, or 0.74% of the simulated users be allowed to experience an availability threshold that dips below 99%.

Another way to suitably protect the SDARS listeners would be to use the simulator to find the appropriate OOBE mask so that the WCS interference level would grow as large as possible without allowing any more than 0.5% of the SDARS receiver to either have their link margin reduced by 3 dB or have their receivers overloaded. Such a protection level would mean that SDARS would have to accept interference conditions so that one in two hundred customers would have their service rendered unusable. Note that the simulation results in Figure 7only show the SDARS degradation due to a linear decreasing link margin arising from out-of-band interference from WCS transmitters, and does not consider front end overload which also can render a SDARS receiver unusable.

Turning to the Case 2 results, we see that 5.76% of SDARS subscribers dip below the 99% threshold. This is drastically worse than having one-percent of the SDARS subscribers dip below the 99% design threshold, and drastically worse than having 0.74% of the SDARS subscribers dip below the 99% design threshold. Case 2 has 6.37% of the users with a link margin degraded by 3 dB (the unusable value of link margin attenuation), which is drastically worse than the case where 0.5% receivers have their link margin rendered unusable.

6.2.3 Impact of Power Control on SDARS

Referring again to Figure 7, the column for Case 3 shows simulation results for the case where power control is implemented in the simulator. Line 19 indicates that power control is turned "on." The same propagation model as used in Case 2 is again used in Case 3, as is the same proposed FCC OOBE mask. The simulator output indicates that the use of power control reduces the SDARS interference somewhat, but that the interference level is still untenable for SDARS. In particular, line 4 of the output section for Case 3 shows that 10% of the SDARS listeners have their link margins reduced by 1 dB due to interference, and 6.67% have their link margins reduced by 2 dB as shown in line 5. These values are a slight improvement compared to the no power control case of Case 2, where 12.08% and 8.30% had their link margins reduced, respectively, but are still not viable for reasonable SDARS service. Line 6 shows that 5.23%, or more than 1 in 20 listeners, have their link rendered unusable with a destruction of half the link margin or more (e.g. 5.23% of the receivers have their link reduced by 3 dB or more). This is before the consideration of overload or intermodulation effects.

Line 7 shows that 4.71% of the listeners, or 1 in 21 listeners, are degraded to below a 99% worst-case availability level, as compared to the baseline case where no users had their availability degraded below a 99% worst-case level. Line 8 shows that 3.33%, or one in 30 listeners, have their service availability degraded horribly to below a 98% threshold. While these values are untenable for SDARS operation, they are an improvement over the no power control case of Case 2, where service availability levels were degraded below 99% and 98% for 5.76% and 3.96% of the listeners, respectively. The simulator shows that the degradation to SDARS is substantial for the case of the FCC proposed OOBE mask, even when power control is used in the WCS service.

6.2.4 Impact of vehicle-to-vehicle path loss models on SDARS

Referring again to Figure 7, the column for Case 4 illustrates the effect of changing the propagation path loss model between vehicles, with the use of power control. In Case 4, the propagation model is changed to have a higher path loss exponent of 2.18, and a significantly larger mean blocking attenuation value of 16 dB. This is a very conservative path loss model, and favors WCS. Log-normal shadowing remains off, as line 22 is set to 0 dB. This propagation model induces more loss than the car-to-car propagation model used in Cases 2 and 3, and thus we would expect there to be less interference from WCS transmitters. The simulator produces results that match this expectation. While still untenable for SDARS operation, the interference levels are reduced as compared to Cases 2 and 3. Output line 4 for Case 4 shows that 3.59% of the SDARS receivers, or one in 27 listeners, have their link margin reduced by more than 1 dB. Although still a high number, it is a third of the number of users that experienced a > 1 dB link margin reduction for Case 3. Similarly, output line 5 shows that 2.41% of the SDARS receivers, or 1 in 40 listeners, have their link margin reduced by 2 dB. Line 6 shows that 1.8% of all SDARS receivers, or 1 in 55 listeners, have their link margin reduced to below a useable value of 3dB. Thus, even with a conservative propagation path loss model, and with power control, about 1 in 55 users would have unusable SDARS service even before overload outages are considered.

Note from line 7 that 1.6% of the listeners have their service availability reduced to below the 99% threshold, as compared to 4.71% in case 3. Line 8 shows that 1.12% of the SDARS listeners have their availability reduced to 98%, as compared to the case of 3.3% for Case 3. These results yield interference levels that still are too great, since 1.8% of the users are guaranteed to have an unusable link margin erosion of 3 dB, and 1.6% of the SDARS listeners will fail to meet the originally-intended 99% availability threshold.

The results of Case 4 illustrate how the vehicle-to-vehicle path loss model plays a major role in determining the impact of WCS OOBE on SDARS performance. Different propagation path loss models will yield significantly different interference results. Thus, it is critical to use an accurate path loss model for meaningful simulations. A propagation model with less loss will overestimate the impact of WCS interference and will provide extra protection to the SDARS spectrum owners where it may not be needed. On the other hand, a propagation model with more loss will underestimate the impact of WCS interference and will favor the WCS spectrum owners to the detriment of existing SDARS listeners. A balance must be reached as to the proper propagation model.

6.2.5 Impact of log-normal shadowing on SDARS

Referring again to Figure 7, the column for Case 5 illustrates the impact of log-normal shadowing in the propagation path loss computations performed by the simulator. Case 5 is identical to Case 4, except now we instruct the simulator to introduce a log-normal shadowing component with a 2 dB standard deviation about the mean attenuation factor. This can be seen by observing line 22, where the blocking standard deviation is set to 2 dB. Comparing the outputs of Case 5 with Case 4, we can see that interference levels increase slightly with the introduction of log-normal shadowing, as Case 5 reveals that 3.72% of the SDARS receivers have their link margin reduced by more than 1 dB (as compared to 3.59% without log-normal shadowing), and 2.52% of the receivers have their link margin reduced by more than 2 dB (as compared to 2.41% without log-normal shadowing). The percentage of receivers with 3 dB degraded link margin is 1.94%. The percentage of SDARS receivers that have their availability knocked down to below the 99% availability threshold is found to be 1.79% (as compared to 1.6% without log-normal shadowing), and the percentage of SDARS receivers that have their availability knocked down to below a 98% availability threshold is found to be 1.2% (as compared to 1.12% without log-normal shadowing). The simulator shows how SDARS is lightly impacted negatively as the car-to-car propagation model undergoes more shadowing.

Case 8 is identical to Case 5 except the car-to-car path loss simulation standard deviation is increased to 4 dB from 2 dB. Looking at the column for Case 8, it can be seen that the interference levels are increased yet again, by observing the output section lines in Figure7 for Cases 5 and 8 . Line 4 for Case 8 shows that 4.06% of the SDARS receivers have their link margin reduced by more than 1 dB, which is worse than the 3.72% found in Case5. Line 5, shows that the interference is worse for Case 8, as 2.73% of the SDARS receivers are found to have greater than 2 dB of link margin attenuation, which is greater than the 2.52% value found in Case 5. The percentage of SDARS receivers that have their availability knocked down to below the 99% availability threshold is found to be 1.88% for the case of 4 dB standard deviation, which is larger than the 1.79% found in Case 5 where 2 dB standard deviation was used.

In Cases 4, 5 and 8, the percentage of receivers with 3 dB or greater link margin loss was 1.8%, 1.94% and 2.06%, respectively. Thus, it can be seen by simulation that, in general, increased variation in log-normal shadowing slightly increases the level of interference and degradation of link margin. That is to say, the damage caused by WCS out of band interference increases slightly with increasing value of standard deviation for shadowing on the car-to-car propagation model.

6.2.6 Impact of WCS Duty Cycle on SDARS

Cases 5, 6, 7, 8, 9, 10, and 11 provide simulation runs to determine the combined effects of propagation path loss, shadowing, and WCS duty cycle. The FCC proposed OOBE mask is used in all of these cases. It can be seen that, in general, the level of interference decreases as the duty cycle is decreased, but the relationship is not linear. That is to say, a factor of six in reduction of the duty cycle (from 0.38 down to 0.0625) does not cause the percentage of users suffering from link availability or degraded link margins to also reduce by a factor of six.

This can be seen in the output columns of Cases 5, 6 and 7, where the conservative path loss model with the greatest attenuation (n=2.18 and 16 dB mean shadowing) is used. The link margin reduction percentages are seen to decrease with decreasing duty cycle, but the decrease is not nearly proportional to the reduction factor of the duty cycle. Even at a very meager 0.0625 duty cycle, the proposed FCC OOBE mask in Case 7 causes 1.54% of all SDARS receivers (1 in 65 listeners) to have their link margins degraded by more than 1 dB, and 0.98% of all SDARS receivers (1 in 102 listeners) have their link margins degraded by more than 2 dB. Furthermore, 0.64% of all SDARS users are knocked out of maintaining the design requirement of 99% worst-case link availability, and 0.38% of the SDARS receivers are knocked out of maintaining an abysmal 98% worst-case link availability. For the 0.0625 and .125 duty cycle cases, 0.72% and 1.07% of SDARS receivers have lost 3 dB of link loss, respectively. This number climbs to 1.94% for the .38 duty cycle case of Case 5, meaning that 1 in 50 users cannot receive SDARS signals due to WCS out of band interference.

Cases 9, 10 and 11 consider similar reduction factors of the duty cycle, and use a more realistic free space path loss model with 10 dB mean blockage factor. In these cases, the interference levels are worse than for Cases 5, 6, and 7. For the 0.38 duty cycle case, 5.24% of receivers lose 3 dB or more link margin, whereas 3.17% and 2.15% of receivers lose 3 dB or more of link margin for the 0.125 and 0.0625 duty cycle cases, respectively.

It is important to keep in mind that all of these results are strictly for the case of linear receivers. Non-linear effects such as receiver blocking due to overload are certain to increase the percentages of SDARS receivers that are impacted due to WCS OOBE.

6.3 Impact of FCC and Other Proposed Out of Band Emission Masks on SDARS in Charlotte, NC

Section 6.3 shows how the simulation data may be interpreted from the spreadsheets for Charlotte, NC, and provides analysis of the impact of different spectral masks on SDARS performance for Charlotte, NC.

6.3.1 Charlotte, North Carolina

Figure 7 shows all of the simulation runs for Charlotte, NC. We now provide details about the traffic environment, and explore suitable spectrum masks that would protect Charlotte, NC listeners from WCS OOBE, and continue with the analysis of Figure 7 to gain insights about suitable spectral masks that would protect SDARS receivers.

6.3.1.1 Traffic Environment

The following table shows the road type and traffic parameters obtained from Google and Mapquest.

Parameter	Value
Location	I85 West of Charlotte
Road Type	Interstate
Peak Traffic Time	5:45 PM Fridays
Road Segment Length	6.75 Miles
Average Speed	25 miles/hour
Number of Lanes	3
Average Daily Volume	45825

Table 6: Traffic Profile for Charlotte, NC

Using the traffic volume equation in Section 6.1.1, we calculate a peak hourly volume of 6900 vehicles, as shown in line 3 of Figure 7.

Figure 8: Road and Traffic View for Charlotte, NC

Table 6 shows the traffic profile of I-85 in Charlotte, during a rush hour period. Note that the traffic speed is 25 mph, meaning that cars are moving relatively slowly during the rush hour. Figure 8 shows an aerial view of the highway that was simulated in Charlotte.

6.3.1.2 Satellite Radio Service Environment for Charlotte, NC

The satellite geometry, link performance and overall QoS for Charlotte, NC is shown in Table 7. These data are shown on lines 23-26 in the spreadsheet of Figure 7.

Table 7: Satellite Parameters for Charlotte, NC

	Link Margin (dB)	Elevation Angle (degrees)	Baseline QoS
Sat1 (85E)	12	49	99.7%
Sat2 (115W)	12.5	36	

Referring again to the Figure 7 spreadsheet for Charlotte, NC, we see that Cases 12, 13, 14, 15, 16, and 17 consider identical simulation conditions, but the six simulations employ six different OOBE masks to determine and compare the effects that WCS OOBE masks have on SDARS receivers. Each of these six cases use a reasonable propagation model with n=2.0, a 10 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The six masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, a flat 85 dB attenuation mask, and a flat 100 dB attenuation mask. For comparison purposes, it is worth noting that existing rules require WCS transmitters to obey a flat 110 dB attenuation mask.

Cases 8, 18, 19, 20, and 21 consider identical simulation conditions, but the simulations employ five different OOBE masks and consider a much more conservative and lossy propagation model that has n=2.18, a 16 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The five OOBE masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, and a flat 85 dB attenuation mask.

6.3.1.3 Determining an appropriate OOBE mask for WCS mobile transmitters in Charlotte, NC

We now ask the most important question – how should the FCC determine a suitable WCS OOBE mask? This is akin to finding the proper amount of degradation the SDARS service should be required to accept as a protected broadcast service. Clearly, we have demonstrated through many analyses and simulations in Section 4 and Section 6 of this report that SDARS can give up some margin – that is to say, the current 110 dB adjacent channel protection mask offers too much protection and creates a hardship on the adjacent WCS service. We see this clearly from Case 1, as well as from Case 17 in Figure 7. However, as shown in Section 6.2, even with power control and reduced duty cycle, and even with a very conservative path loss model that favors WCS, a significant portion of SDARS listeners will have their satellite radio reception rendered useless if the FCC institutes its currently proposed 55 dB adjacent channel protection mask. Thus, the FCC Staff proposal is not acceptable, and has gone too far to harm the SDARS listeners.

Section 6.2.2 provided a rationale for three different acceptance criteria, where any one or a combination of all three could be reasonably used by the FCC to determine acceptable SDARS performance in the face of WCS out of band interference.

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%

3. Allow the greatest level of interference that still ensures that, at most, only 0.5% of all SDARS receivers suffer a 3dB or more link margin degradation due to WCS interference.

First consider Case 17, where the OOBE mask is set to 100 dB of attenuation (10 dB less stringent than the existing rules). Simulation shows this OOBE mask provides a large amount of interference protection as seen in lines 6 and 7 of the output section. Specifically, based on 1,489,900 simulation points, there is no erosion whatsoever of the 99% availability threshold for each of the SDARS receivers. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.0% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.0% is less than 1%, so criterion #2 is met. Finally, no SDARS receivers have lost 3 dB of link margin, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 100 dB of attenuation would meet all three acceptance criteria. Clearly, 100 dB is too great of a protection for SDARS.

Case 16 uses an OOBE mask set to 85 dB of attenuation (25 dB less stringent than the existing rules). We see that 0.44% of the SDARS receivers have their link margin reduced by 1 dB, but only 0. 08% of the listeners have their availability threshold knocked down to below 99% availability. Also, only 0.03% of SDARS receivers lost more than 3 dB of margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.08% SDARS receivers that suffer a degraded availability, which is less than 0.74%, so this mask would be acceptable based on criterion #1. Since 0.08% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since no receivers lost more than 3 dB of margin in the simulation.

Considering Case 15, where the OOBE mask is set to 80 dB of attenuation (30 dB less stringent than the existing rules), we see that 0.91% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.30% of the listeners have their availability threshold knocked down to below 99% availability. Also, only 0.36% of SDARS receivers lost 3 dB or more in link margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.3% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.74%, so this mask would be acceptable based on criterion #1. And since 0.3% is less than 1%, the second criterion would be passed. Finally, the third criterion is passed since less than 0.5% of receivers lost 3 dB or more of margin. Thus, Case 15 would pass all of the three different acceptance criteria.

Case 14 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). We see that 1.76% of the SDARS receivers have their link margin reduced by 1 dB, but 0.69% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.79% of receivers lost 3 dB or more in link margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.69% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.74%, so this mask would be acceptable based on criterion #1. Also note that .69% is less than 1%, so this mask meets the second criterion. Finally, this mask fails the third criterion since 0.79% of receivers lost 3 dB or more of their link margin. Thus, Case 14 would pass two of the three different acceptance criteria.

Case 13, where the OOBE mask is set to 70 dB of attenuation (40 dB less stringent than the existing rules), fails all three criteria, as it allows 1.43%, or 1 in 70 listeners, to have their availability degraded to below the 99% design target. Furthermore, 1.6% of SDARS receivers have their link margin degraded by more than 3 dB. Thus, 1.6% of the users experience unusable service, which is too many for a paid broadcast service in protected spectrum.

Case 12, the FCC Staff Proposal, is the worst performer as it would allow an unacceptably high 4.95% of SDARS receivers (1 in 20 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to 5.57% of SDARS receivers losing half their received power margin as they travel down the highway normal busy hour conditions.

It is clear from the above results that an OOBE mask greater than 75 dB and less than 80 dB would be appropriate for the Charlotte, NC case, and that the FCC Staff proposal mask is unsuitable and unfair to SDARS listeners. One must keep in mind that this simulation does not consider blocking/overload conditions from an adjacent interference-limited mobile system, so erring on the side of more protection for the existing SDARS would be fair and prudent from this simulation.

Now consider Cases 18 through 21, and Case 8, where we use a more conservative propagation model with greater loss, and again consider several different OOBE masks and their impact on SDARS performance.

Case 21 uses an OOBE mask of 85 dB of attenuation (25 dB less stringent than the existing rules). Simulation shows this mask provides a large amount of interference protection, as seen in lines 4 through 7 of the output section. Specifically, based on 1,489,900 simulation points, only 0.07% of the SDARS receivers experience more than a 1 dB link margin reduction, and there is virtually no erosion of the 99% availability threshold, as only 0.01% of the SDARS receivers breach this performance level. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.01% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.01% is less than 1%, so criterion #2 is met. Finally, only 0.01% of SDARS receivers suffer greater than 3 dB link margin loss and thus criterion #3 is met. Thus, a WCS OOBE mask requiring 85 dB of attenuation would meet all three acceptance criteria.

Case 20 uses an OOBE mask set to 80 dB of attenuation (30 dB less stringent than the existing rules). The simulation shows that 0.33% of the SDARS receivers have their link margin reduced by 1 dB, and only 0. 05% of the listeners have their availability threshold knocked down to below 99% availability. Also, only 0.07% of SDARS receivers lost 3 dB or more link margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.05% SDARS receivers that suffer a degraded availability to below 99%, which is less than 0.74%, so this mask would be acceptable based on criterion #1. Since 0.05% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers lose 3 dB link margin.

Case 19 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). The simulation shows that 0.71% of the SDARS receivers have their link margin reduced by 1 dB, but only 0. 24% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.27% or receivers lose 3 dB or more of link margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.24% SDARS receivers that suffer a degraded availability, which is less than 0.74%, so this mask would be acceptable based on criterion #1. Since 0.24% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since only 0.27% of the receivers lose 3 dB or more of margin, and this is less than the 0.5% threshold.

Case 18 uses an OOBE mask set to 70 dB of attenuation (40 dB less stringent than the existing rules). The simulation shows that 1.26% of the SDARS receivers have their link margin reduced by 1 dB, but 0.5% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.6% of receivers lose 3 dB or more of their link margin. Given a baseline quality of service of 99.74%, our first criterion would require that no more than 0.74% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.5% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.74%, so this mask would be acceptable based on criterion #1. Also note that 0.5% is less than 1%, so this mask meets the second criterion. Finally, this mask fails the third criterion since 0.6% of receivers are degraded by 3 dB or more, and 0.6% is greater than the 0.5% threshold. Thus, Case 18 passes two of the three different acceptance criteria.

Case 8 is the FCC-proposed OOBE mask, and the simulation shows it is the worst performer as it would allow 1.88% of SDARS receivers (1 in 53 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to about 2.06% of SDARS receivers (1 in 49 listeners) becoming unusable with 3 dB or more link margin loss as they travel down the highway in normal busy hour conditions.

The power of a simulator is readily seen by the above examples. Using realistic traffic conditions, propagation conditions, and satellite link design data, we are able to gain insight into the impact that different assumptions have on SDARS system performance. More importantly, we are able to identify the deleterious effects of different OOBE masks that would impact existing SDARS listeners. For the input parameters specified in Figure 7, we have applied three common-sense acceptance criteria for determining acceptable levels of SDARS system degradation.

Using a free space propagation model (n = 2.0) between vehicles with a 10 dB blockage factor, we found that the FCC-proposed mask failed all acceptance criteria by a very wide margin. The 70 dB and 75 dB masks also fail some or all of the three acceptance criteria. The 80 dB mask passed all three acceptance criteria, and the 100 dB masks provided too much interference protection.

Using a path loss model with n=2.18 and a 16 dB blockage factor, we found that the FCC-proposed mask again failed all acceptance criteria by a wide margin. The 70 dB mask also failed one of the three acceptance criteria. The 75 dB, 80 dB, and 85 dB masks each passed all three acceptance criteria.

Based on the two simulated propagation models, and the author's proposed acceptance criteria, the simulations demonstrate that the FCC-proposed mask will cause unacceptable performance degradation to SDARS listeners. It also is clear that a 70 dB OOBE mask will also fail to provide acceptable SDARS performance, since it failed under both propagation models. A suitable spectrum mask must have more than 70 dB of OOBE attenuation, but not more than 80 dB of OOBE attenuation. The simulator may be used to refine the assumptions and the models, but based on a cursory review of these simulation results, and under the proviso that a WCS penetration rate of only 5% is accurate, one would expect that a reasonable OOBE mask would have between 75 dB and 80 dB of attenuation. Given the fact that overload effects would degrade the SDARS service further, a spectral mask of 80 dB would be prudent. Note that the above results were determined for one particular highway in one particular city (Charlotte, NC), and more simulation runs are required in other cities to gain confidence about the selection of a suitable spectrum mask. Nevertheless, the above discussion should make clear how simulation may be used to gain insights into how to best compare OOBE masks and SDARS performance for various system settings. We now consider the four other cities to further investigate what would be a suitable OOBE mask to protect SDARS.

6.4 Impact of FCC and Other Proposed Out of Band Emission Masks on SDARS in Miami, FL

Section 6.4 shows simulation data for Miami, FL, and provides analysis of the impact of different spectral masks on SDARS performance in Miami.

6.4.1 Miami, Florida

Figure 9 shows the map of the roadway simulated in the Miami, FL area. We now provide details of the traffic environment.

6.4.1.1 Miami Traffic Environment

The following table, Table 8, shows the road type and traffic parameters obtained from Google and Mapquest.

Parameter	Value
Location	HWY 836 West of Miami
Road Type	Freeway
Peak Traffic Time	Mondays, 5:15PM
Road Segment Length	7.5 Miles
Average Speed	25 miles/hour
Number of Lanes	3
Average Daily Volume	91969

Table 8: Traffic Profile for Miami, FL

Using the traffic volume equation in Section 6.1.1 we calculate a peak hourly volume of 13795 vehicles, which is very heavy as compared to other major freeways. Figure 9 shows an aerial view of the roadway simulated in Miami during rush hour. Note that the average vehicle speed is 25 miles per hour.

Figure 9: Road and Traffic View of Miami, FL

6.4.1.2 Miami Satellite Radio Service Environment

The satellite geometry, link performance, and overall QoS for Miami, FL is shown in Table 9. These data are shown on lines 23-26 in the spreadsheet of Figure 10.

	Link Margin (dB)	Elevation Angle (degrees)	Baseline QoS
Sat1 (85E)	7.9	59.4	99.8%
Sat2 (115W)	10.2	41.2	

Table 9: Satellite Parameters and Baseline QoS for Miami FL

6.4.1.3 Determining an appropriate OOBE mask for WCS mobile transmitters in Miami, FL

Figure 10 shows the spreadsheet containing simulation inputs and outputs for the cases run for Miami, FL. Entries marked in yellow indicate parameters that changed from one case to the next. It is immediately apparent from the spreadsheet in Figure 10 that the Miami area has much more susceptibility to WCS interference than the Charlotte, NC area. This is plainly seen by considering any of the simulation cases. Recall that Case 2 is for the case of no power control, and we immediately see that for this simulation, Miami has 22.27% of all SDARS receivers suffering more than 1 dB of link margin due to WCS OOBE. This compares to 12.08% of all SDARS receivers suffering 1 dB degradation of link margin in Charlotte. Even with power control, and a very conservative path loss model, Case 8 shows that Miami has 7.13% of all SDARS users suffering more than 1 dB in link margin reduction, whereas Charlotte had 4.06% of its users undergo a 1 dB or more reduction in margin. We immediately see the affect of satellite look angle and link margin. Miami receives the weakest signals of all Sirius XM markets, and thus is much more susceptible to WCS out of band interference.

Consider Cases 12, 13, 14, 15, 16, and 17, where we have identical simulation conditions, but the six simulations employ six different OOBE masks to determine and compare the effects that WCS OOBE masks have on SDARS receivers in Miami. Each of these six cases use a free space propagation model with n=2.0, a 10 dB blockage factor, and log-normal shadowing

Configuration																					
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
City	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami	Miami
Vehicle Volume	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795	13795
Vehicle Speed	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
WCS Penetration Rate	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDARS Penetration Rate	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Roadway Length	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Num_lanes	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# Sat	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704	704
# WCS	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103
WCS Activity Factor	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
SDARS Listening Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Duty Cycle	0.38	0.38	0.38	0.38	0.38	0.125	0.0625	0.38	0.38	0.125	0.0625	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Band Factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C/D OOB Mask (X+10logP)	55	55	55	55	55	55	55	55	55	55	55	55	70	75	80	85	100	70	75	80	85
Bl, Au OOB Mask (X+10logP)	61	61	61	61	61	61	61	61	61	61	61	61	70	75	80	85	100	70	75	80	85
Bu, Al OOB Mask (X+10logP)	67	67	67	67	67	67	67	67	67	67	67	67	70	75	80	85	100	70	75	80	85
Max Tx	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Pwr Cntrl (0, -6, -12 back off)	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Path Loss exponent	2.00	2.00	2.00	2.18	2.18	2.18	2.18	2.18	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.18	2.18	2.18	2.18
Blockage Mean	10	10	10	16	16	16	16	16	10	10	10	10	10	10	10	10.00	10.00	16.00	16.00	16.00	16.00
Blockage Std Dev.	0	0	0	0	2	2	2	4	2	2	2	4	4	4	4	4.00	4.00	4.00	4.00	4.00	4.00
Sat1 Link Margin	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Sa1 Elevation	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4
Sat2 Link Margin	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Sat2 Elevation	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2
QoS Baseline	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%
Results																					
# Pts. < 3m Relocated to 3m	1182.00	1241.00	1217.00	1229.00	1162.00	1188.00	1174.00	1206.00	1150.00	1207.00	1235.00	1206.00	1239.00	1112.00	1216.00	1177.00	1193.00	1209.00	1173.00	1211.00	1176.00
# Total Points	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200	7251200
% Relocated Pts.	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
% SDARS with Link Margin Reduced >1dB	0.00%	22.27%	17.97%	7.13%	6.80%	4.04%	2.68%	7.13%	17.30%	10.66%	7.60%	17.85%	6.54%	3.42%	1.89%	0.80%	0.00%	2.37%	1.17%	0.50%	0.14%
% SDARS with Link Margin Reduced >2dB	0.00%	15.72%	12.50%	4.80%	4.63%	2.65%	1.67%	4.86%	12.41%	7.03%	5.01%	13.44%	4.38%	2.15%	1.12%	0.39%	0.00%	1.48%	0.65%	0.21%	0.04%
% SDARS with Link Margin Reduced > 3dB	0.00%	12.41%	9.68%	3.71%	3.59%	2.00%	1.24%	3.71%	9.56%	5.33%	3.76%	10.66%	3.27%	1.56%	0.72%	0.20%	0.00%	1.03%	0.40%	0.11%	0.01%
% SDARS Availability Degraded <99%	0.00%	12.41%	9.68%	3.71%	3.59%	2.00%	1.24%	3.71%	9.56%	5.33%	3.76%	10.66%	3.27%	1.56%	0.72%	0.20%	0.00%	1.03%	0.40%	0.11%	0.01%
% SDARS Availability Degraded <98%	0.00%	10.09%	8.01%	3.01%	2.89%	1.59%	0.95%	3.02%	7.73%	4.34%	3.00%	8.78%	2.52%	1.19%	0.50%	0.09%	0.00%	0.77%	0.28%	0.06%	0.01%

Figure 10: Simulation Results, Miami

with 4 dB of standard deviation. The six masks again include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, a flat 85 dB attenuation mask, and a flat 100 dB attenuation mask. For comparison purposes, it is worth noting that existing rules require WCS transmitters to obey a flat 110 dB attenuation mask.

Cases 8, 18, 19, 20, and 21 consider identical simulation conditions, but the simulations employ five different OOBE masks and consider a more conservative propagation model that has n=2.18, a 16 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The five OOBE masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, and a flat 85 dB attenuation mask.

We again apply the following three criteria for determining which OOBE mask is appropriate for Miami:

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%
3. Allow the greatest level of interference that still ensure that at most only 0.5% of all SDARS receivers suffer a 3dB link margin degradation due to WCS interference.

First consider Case 17, where the OOBE mask is set to 100 dB of attenuation (10 dB less stringent than the existing rules). Simulation shows this OOBE mask provides a large amount of interference protection as seen in lines 6 and 7 of the output section. Specifically, based on 7.25 million simulation points, there is no erosion whatsoever of the 99% availability threshold for each of the SDARS receivers. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.0% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.0% is less than 1%, so criterion #2 is met. Finally, no SDARS receivers experience greater than 3 dB link margin loss, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 100 dB of attenuation would meet all three acceptance criteria.

Case 16 uses an OOBE mask set to 85 dB of attenuation (25 dB less stringent than the existing rules). We see that 0.8% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.2% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.2% of SDARS users have lost greater than 3 dB of link margin. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.2% SDARS receivers that suffer a degraded availability, which is less than 0.78%, so this mask would be acceptable based on criterion #1. Since 0.2% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since only 0.2% of the receivers have greater than a 3 dB link erosion, which is less than the 0.5% threshold.

Considering Case 15, where the OOBE mask is set to 80 dB of attenuation (30 dB less stringent than the existing rules), we see that 1.89% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.72% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.72% of SDARS receivers have greater than 3 dB link loss. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.72% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.78%, so this mask would be acceptable based on criterion #1. And since 0.72% is less than 1%, the second criterion would be passed. The third criterion is not passed since more than 0.5% of receivers are degraded more than 3 dB. Thus, Case 15 would pass two of the three different acceptance criteria.

Case 14 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). We see that 3.42% of the SDARS receivers have their link margin reduced by 1 dB, but 1.56% of the listeners have their availability threshold knocked down to below 99% availability. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 1.56% SDARS receivers that suffer a degraded availability below 99% , which is greater than 0.78%, so this mask would not be acceptable based on criterion #1. Also note that 1.56% is greater than 1%, so this mask fails the second criterion. Finally, this mask fails the third criterion since 1.56% of receivers lose >3dB of link margin. Thus, Case 14 would not pass any of the three different acceptance criteria.

Case 13, where the OOBE mask is set to 70 dB of attenuation (40 dB less stringent than the existing rules), also fails all three criteria, as it allows 3.27%, or 1 in 30 listeners, to have their availability degraded to below the 99% design target.

Case 12, the FCC Staff Proposal, is the worst performer as it would allow an unacceptably high 10.66% of SDARS receivers (1 in 9 listeners) to suffer a breach of the required worst-case 99% link availability margin. It is clear that the FCC OOBE mask would devastate the Sirius XM service in Miami, knocking off 1 in 9 listeners, even before considering additional occasional outages due to overload.

Now consider Cases 18 through 21, and Case 8, where we use a propagation model with much greater loss and again consider several different OOBE masks and their impact on SDARS performance in Miami.

Case 21 uses an OOBE mask of 85 dB of attenuation (25 dB less stringent than the existing rules). Simulation shows this mask provides a large amount of interference protection, as seen in lines 4 through 7 of the output section. Specifically, based on 7.25 million simulation points, only 0.14% of the SDARS receivers experience more than a 1 dB link margin reduction, and there is very little erosion of the 99% availability threshold, as only 0.01% of the SDARS receivers breach this performance level. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.01% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.01% is less than 1%, so criterion #2 is met. Finally, less than 0.5% of receivers have lost 3dB of link margin, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 85 dB of attenuation would meet all three acceptance criteria.

Case 20 uses an OOBE mask set to 80 dB of attenuation (30 dB less stringent than the existing rules). The simulation shows that 0.5% of the SDARS receivers have their link margin reduced by 1 dB, and only 0. 11% of the listeners have their availability threshold knocked down to below 99% availability. Also, less than 0.5% of receivers have lost 3 dB or more of link margin. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.11% SDARS receivers that suffer a degraded availability to below 99%, which is less than 0.78%, so this mask would be acceptable based on criterion #1. Since 0.11% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than .5% have greater than 3 dB link margin loss.

Case 19 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). The simulation shows that 1.17% of the SDARS receivers have their link margin reduced by 1 dB, but only 0. 4% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.4% of SDARS receivers experience greater than 3 dB link loss. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.4% SDARS receivers that suffer a degraded availability, which is less than 0.78%, so this mask would be acceptable based on criterion #1. Since 0.4% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have lost 3 dB of link margin.

Case 18 uses an OOBE mask set to 70 dB of attenuation (40 dB less stringent than the existing rules). The simulation shows that 2.37% of the SDARS receivers have their link margin reduced by 1 dB, but 1.03% of the listeners have their availability threshold knocked down to below 99% availability. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 1.03% SDARS receivers that suffer a degraded availability below 99% , which is greater than 0.78%, so this mask would not be acceptable based on criterion #1. Also note that 1.03% is greater than 1%, so this mask fails the second criterion, but just barely. Finally, this mask fails the third criterion since 1.03% with 3 dB is greater than the 0.5% criterion. Thus, Case 18 would not pass any of the three different acceptance criteria.

Case 8 is the FCC-proposed OOBE mask, and the simulation shows it is the worst performer as it would allow 3.71% of SDARS receivers (1 in 27 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to the same percentage of SDARS receivers with 3 dB link margin reduction as they travel down the highway in normal busy hour conditions. Even with a very conservative path loss model between vehicles, the FCC's proposed mask would wipe out about 4% of Sirius XM's existing Miami customers, and that is before any overload considerations are given.

Using a free space propagation model (n = 2.0) between vehicles with a 10 dB blockage factor, we find that in Miami, the FCC-proposed mask failed all acceptance criteria by a very wide margin. The 70 dB and 75 dB masks also failed all three acceptance criteria. The 80 dB mask passed two of the three acceptance criteria, and the 100 dB masks provided too much interference protection. Thus, a Miami mask should offer greater than 80 dB of attenuation.

Using a path loss model with n=2.18 and a 16 dB blockage factor, we found that the FCC-proposed mask again failed all acceptance criteria by a wide margin. The 70 dB mask also failed all three acceptance criteria. The 75 dB, 80 dB, and 85 dB masks each passed all three acceptance criteria.

Based on the two simulated propagation models, and the author's proposed acceptance criteria, the simulations demonstrate that the FCC-proposed mask will cause unacceptable performance degradation to SDARS listeners. It also is clear that a 70 dB OOBE mask will also fail to provide acceptable SDARS performance, since it failed under both propagation models. A suitable spectrum mask in Miami should have more than 75 dB of OOBE attenuation, but not more than 85 dB of OOBE attenuation. The simulator may be used to refine the assumptions and the models, but based on a cursory review of these simulation results, and under the proviso that a WCS penetration rate of only 5% is accurate, one would expect that a reasonable OOBE mask would have 80 dB of attenuation for Miami.

6.5 Impact of FCC and Other Proposed Out of Band Emission Masks on SDARS in New York City/NJ

Section 6.5 shows the simulation data for the New York City/ New Jersey Turnpike area, one of the busier highways in the country.

6.5.1 New York City/New Jersey Turnpike

Figure 11 shows the map of the roadway simulated in the New York City market. The highway was a busy stretch of the New Jersey Turnpike near Rutgers University.

6.5.1.1 New York City/ New Jersey Turnpike Traffic Environment

The following table, Table 11, shows the road type and traffic parameters on the New Jersey Turnpike. Traffic parameters were obtained from Google and Mapquest.

Table 11: Traffic Profile for NYC/NJ

Parameter	Value
Location	NJ Turnpike between Exits 7A and 9
Road Type	Interstate
Peak Traffic Time	Fridays, 5:30 PM
Road Segment Length	8 Miles
Average Speed	25 miles/hour
Number of Lanes	3
Average Daily Volume	52000

Using the traffic volume equation in Section 6.1.1, we calculate a peak hourly volume of 7900 vehicles. Note that the average speed of each vehicle is again 25 mph.

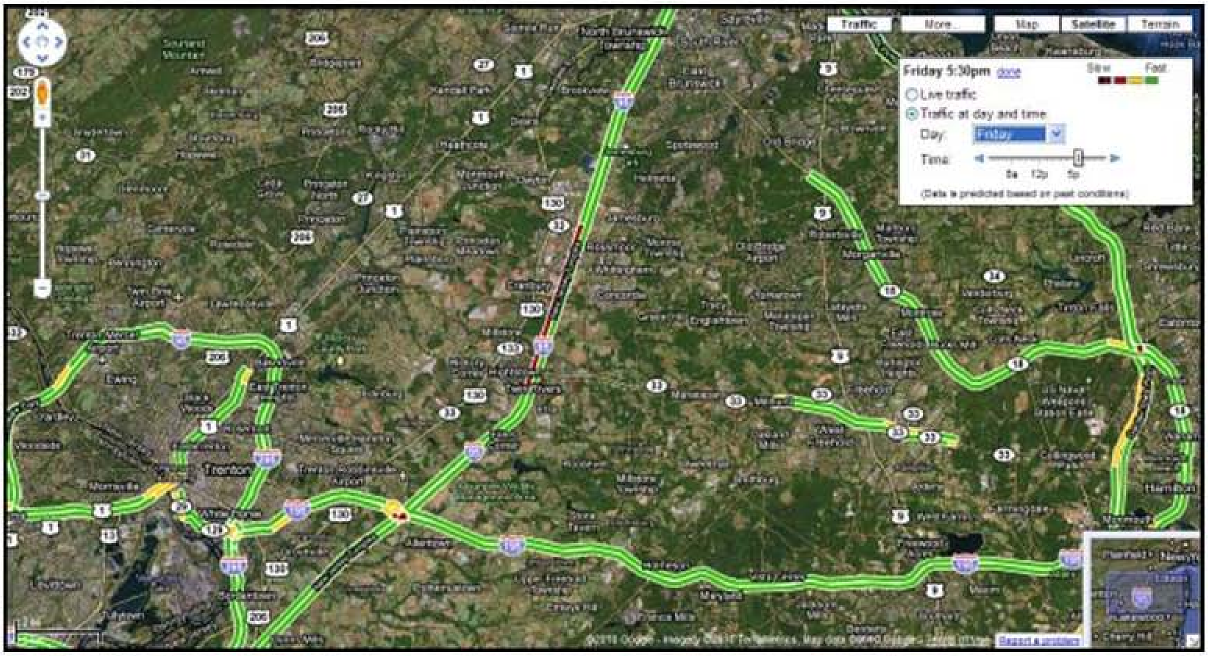

Figure 11: Road and Traffic View

6.5.1.2 New York City/ New Jersey Turnpike Satellite Radio Service Environment

The satellite geometry, link performance, and overall QoS for the New Jersey Turnpike is shown in Table 12. These data are shown on lines 23-26 of the New York City/NJ spreadsheet, which is shown in Figure 12.

Table 12: Satellite Parameters and Baseline QoS for NYC

	Link Margin (dB)	Elevation Angle (degrees)	Baseline QoS
Sat1 (85E)	15.5	41.3	99.5%
Sat2 (115W)	12.0	27.1	

6.5.1.3 Determining an appropriate OOBE mask for WCS mobile transmitters in NYC/NJ Turnpike

Figure 12 shows the spreadsheet containing simulation inputs and outputs for the simulation cases run in NYC/NJ. Entries marked in yellow indicate important parameters that changed from one case to the next. One can see from the spreadsheet in Figure 12 that the NYC area has a tremendous number of simulated points and a strong link budget as compared to Miami. It is important to note that simulations presented here are only based on linear OOBE, and do not consider overload or intermodulation effects, which would likely be much greater in NYC than in other markets because of the greater traffic volumes.

The outputs of Case 2 in NYC, using the proposed FCC OOBE mask and no power control, show that the interference levels suffered by the SDARS receiver are intolerable. Line 4 of the output section of Case 2 shows that 13.6% of all SDARS receiver (1 in 7 listeners) suffers more than 1 dB of link degradation compared to today's baseline design case, and Line 5 shows that 9.4% of the receivers (1 in 10 listeners) suffer more than 2 dB of link degradation due to WCS interference. Line 6 shows that 7.24% of all receivers (1 in 14 listeners) have their link degraded by more than 3 dB, which denotes that these users have their link margin cut in half from the original design. Recall that Sirius XM viewed their service unusable and replaced two satellites when the link margin was degraded by 3 dB. Thus, line 6 shows that *at least* 1out of every 16 listeners will have their service rendered unusable due to WCS interference, and most likely many more than this number of users when overload is considered.

Configuration																					
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
City	New York	NY1	NY2	NY3	NY4	NY5	NY6	NY7	NY8	NY9	NY10	NY11	NY12	NY13	NY14	NY15	NY16	NY17	NY18	NY19	NY20
Vehicle Volume	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900	7900
Vehicle Speed	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
WCS Penetration Rate	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDARS Penetration Rate	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Roadway Length	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Num_lanes	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# Sat	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430	430
# WCS	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
WCS Activity Factor	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
SDARS Listening Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Duty Cycle	0.38	0.38	0.38	0.38	0.38	0.125	0.0625	0.38	0.38	0.125	0.0625	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Band Factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C/D OOB Mask (X+10logP)	55	55	55	55	55	55	55	55	55	55	55	55	70	75	80	85	100	70	75	80	85
Bl, Au OOB Mask (X+10logP)	61	61	61	61	61	61	61	61	61	61	61	61	70	75	80	85	100	70	75	80	85
Bu, Al OOB Mask (X+10logP)	67	67	67	67	67	67	67	67	67	67	67	67	70	75	80	85	100	70	75	80	85
Max Tx	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Pwr Cntrl (0, -6, -12 back off)	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Path Loss exponent	2.00	2.00	2.00	2.18	2.18	2.18	2.18	2.18	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.18	2.18	2.18	2.18
Blockage Mean	10	10	10	16	16	16	16	16	10	10	10	10	10	10	10	10.00	10.00	16.00	16.00	16.00	16.00
Blockage Std Dev.	0	0	0	0	2	2	2	4	2	2	2	4	4	4	4	4.00	4.00	4.00	4.00	4.00	4.00
Sat1 Link Margin	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Sa1 Elevation	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3
Sat2 Link Margin	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Sat2 Elevation	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
QoS Baseline	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%	99.50%
RESULTS																					
# Pts. < 3m Relocated to 3m	424.00	431.00	453.00	403.00	416.00	441.00	445.00	444.00	417.00	416.00	439.00	401.00	383.00	402.00	450.00	417.00	434.00	409.00	433.00	443.00	404.00
# Total Points	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000	2709000
% Relocated Pts.	0.02%	0.02%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%
% SDARS with Link Margin Reduced >1dB	0.00%	13.60%	10.75%	3.87%	3.95%	2.50%	1.65%	4.51%	10.59%	6.49%	4.53%	10.62%	3.72%	2.03%	0.97%	0.47%	0.00%	1.43%	0.73%	0.31%	0.10%
% SDARS with Link Margin Reduced >2dB	0.00%	9.40%	7.26%	2.53%	2.72%	1.67%	1.09%	3.06%	7.54%	4.30%	3.03%	7.72%	2.51%	1.29%	0.57%	0.23%	0.00%	0.90%	0.43%	0.12%	0.02%
% SDARS with Link Margin Reduced > 3dB	0.00%	7.24%	5.60%	1.96%	2.11%	1.22%	0.84%	2.33%	5.93%	3.28%	2.31%	6.23%	1.92%	0.95%	0.36%	0.11%	0.00%	0.64%	0.29%	0.06%	0.00%
% SDARS Availability Degraded <99%	0.00%	9.40%	7.26%	2.53%	2.72%	1.67%	1.09%	3.06%	7.54%	4.30%	3.03%	7.72%	2.51%	1.29%	0.57%	0.23%	0.00%	0.90%	0.43%	0.12%	0.02%
% SDARS Availability Degraded <98%	0.00%	5.29%	4.18%	1.41%	1.55%	0.88%	0.58%	1.70%	4.45%	2.41%	1.66%	4.64%	1.34%	0.63%	0.18%	0.04%	0.00%	0.38%	0.16%	0.03%	0.00%

Figure 12: Simulation Results, NY/NJ

Referring again to the NYC/NJ simulation data in Figure 12, inspection of Case 3 shows that power control is turned on, and the same path loss model and FCC proposed mask are used. We see that the simulator indicates that the use of power control reduces the impact of WCS OOBE interference somewhat, but that the interference level is still untenable for SDARS. In particular, line 4 of the output section for Case 3 shows that 10.75% of the SDARS listeners have their link margins reduced by 1 dB due to interference, and 7.26% have their link margins reduced by 2 dB as shown in line 5. These values are a slight improvement compared to the no power control case of Case 2, where 13.6% and 9.4% had their link margins reduced, respectively. Line 6 shows that 5.6%, or 1 in 18 listeners, have their link rendered unusable with a destruction of half the link margin. Furthermore, line 7 of the output section shows that 7.26%, or 1 in 14 users, have their availability knocked down to less than 99%.

Cases 12, 13, 14, 15, 16, and 17 consider identical simulation conditions, but the six simulations employ six different OOBE masks to determine and compare the effects that WCS OOBE masks have on SDARS receivers. Each of these six cases use a free space propagation model with n=2.0, a 10 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The six masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, a flat 85 dB attenuation mask, and a flat 100 dB attenuation mask. For comparison purposes, it is worth noting that existing rules require WCS transmitters to obey a flat 110 dB attenuation mask.

Cases 8, 18, 19, 20, and 21 consider identical simulation conditions, but the simulations employ five different OOBE masks and consider a more conservative and lossy propagation model that has n=2.18, a 16 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The five OOBE masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, and a flat 85 dB attenuation mask.

Again, we apply three proposed acceptance criteria for a suitable spectral mask, where any one or a combination of all three could be reasonably used to determine acceptable SDARS performance in the face of interference:

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%
3. Allow the greatest level of interference that still ensure that at most only 0.5% of all SDARS receivers suffer a 3dB link margin degradation due to WCS interference.

First consider Case 17, where the OOBE mask is set to 100 dB of attenuation (10 dB less stringent than the existing rules). Simulation shows this OOBE mask provides a large amount of interference protection as seen in lines 6 and 7 of the output section. Specifically, based on 27 million simulation points, there is no erosion whatsoever of the 99% availability threshold for each of the SDARS receivers. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.0% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.0% is less than 1%, so criterion #2 is met. Finally, no SDARS receivers experience greater than 3 dB link margin loss, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 100 dB of attenuation would meet all three acceptance criteria. It is also very clear that 100 dB is an excessive amount of protection, even in the NYC/NJ area. However, we again point out that overload issues will be strongest in a region such as NYC/NJ where there is such a high density of RF interference due to the massive traffic volumes.

Case 16 uses an OOBE mask set to 85 dB of attenuation (25 dB less stringent than the existing rules). We see that 0.47% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.23% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.11% of SDARS users have lost greater than 3 dB of link margin. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.23% SDARS receivers that suffer a degraded availability, which is less than 0.5%, so this mask would be acceptable based on criterion #1. Since 0.23% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have more than 3 dB link loss.

Considering Case 15, where the OOBE mask is set to 80 dB of attenuation (30 dB less stringent than the existing rules), we see that 0.97% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.57% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.36% of SDARS receivers have greater than 3 dB link loss. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.57% SDARS receivers that suffer a degraded availability below 99% , which is more than 0.5%, so this mask would not be acceptable based on criterion #1. And since 0.57% is less than 1%, the second criterion would be passed. The third criterion is passed since less than 0 .36% of receivers are degraded more than 3 dB. Thus, Case 15 would pass two of the three different acceptance criteria.

Case 14 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). We see that 2.03% of the SDARS receivers have their link margin reduced by 1 dB, but 1.29% of the listeners have their availability threshold knocked down to below 99% availability. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 1.29% SDARS receivers that suffer a degraded availability below 99% , which is greater than 0.5%, so this mask would not be acceptable based on criterion #1. Also note that 1.29% is greater than 1%, so this mask fails the second criterion. Finally, this mask fails the third criterion since 0.95% of receivers lose >3dB of link margin. Thus, Case 14 would not pass any of the three different acceptance criteria.

Case 13, where the OOBE mask is set to 70 dB of attenuation (40 dB less stringent than the existing rules), also fails all three criteria, as it allows 2.51%, or 1 in 40 listeners, to have their availability degraded to below the 99% design target. Furthermore, 1.92% of SDARS receivers lose <3dB of link margin.

Case 12, the FCC Staff Proposal, is the worst performer as it would allow an unacceptably high 10.62% of SDARS receivers (1 in 10 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leaves 6.23% of receivers with greater than 3 dB link margin loss. Thus, the FCC OOBE mask would cause 1 in 16 Sirius XM customers in NYC/NJ to lose their service, and this is before any overload conditions are considered.

Now consider Cases 18 through 21, and Case 8, where we use a conservative propagation model with greater loss and once again consider several different OOBE masks and their impact on SDARS performance.

Case 21 uses an OOBE mask of 85 dB of attenuation (25 dB less stringent than the existing rules). Simulation shows this mask provides a large amount of interference protection, as seen in lines 4 through 7 of the output section. Specifically, based on 7.25 million simulation points, only 0.14% of the SDARS receivers experience more than a 1 dB link margin reduction, and there is very little erosion of the 99% availability threshold, as only 0.01% of the SDARS receivers breach this performance level. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.01% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.01% is less than 1%, so criterion #2 is met. Finally, less than 0.5% of receivers have lost 3dB of link margin, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 85 dB of attenuation would meet all three acceptance criteria.

Case 20 uses an OOBE mask set to 80 dB of attenuation (30 dB less stringent than the existing rules). The simulation shows that 0.31% of the SDARS receivers have their link margin reduced by 1 dB, and only 0. 12% of the listeners have their availability threshold knocked down to below 99% availability. Also, less than 0.5% of receivers have lost 3 dB or more of link margin. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.12% SDARS receivers that suffer a degraded availability to below 99%, which is less than 0.5%, so this mask would be acceptable based on criterion #1. Since 0.12% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% have greater than 3 dB link margin loss.

Case 19 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). The simulation shows that 0.73% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.43% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.29% of SDARS receivers experience greater than 3 dB link loss. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.43% SDARS receivers that suffer a degraded availability, which is less than 0.5%, so this mask would be acceptable based on criterion #1. Since 0.43% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have lost 3 dB of link margin.

Case 18 uses an OOBE mask set to 70 dB of attenuation (40 dB less stringent than the existing rules). The simulation shows that 1.43% of the SDARS receivers have their link margin reduced by 1 dB, but 0.90% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.64% of users have lost 3 dB of link margin. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.9% SDARS receivers that suffer a degraded availability below 99% , which is greater than 0.5%, so this mask would not be acceptable based on criterion #1. Also note that 0.9% is less than 1%, so this mask passes the second criterion, but just barely. Finally, this mask fails the third criterion since 0.64% with 3 dB is greater than the 0.5% criterion. Thus, Case 18 would barely pass one of the three different acceptance criteria.

Case 8 is the FCC-proposed OOBE mask, and the simulation shows it is the worst performer as it would allow 3.06% of SDARS receivers (1 in 32 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to the 2.33% of SDARS receivers with 3 dB link margin reduction as they travel down the NJ Turnpike in normal busy hour conditions.

Using a free space propagation model (n = 2.0) between vehicles with a 10 dB blockage factor, we found that on the NJ Turnpike, the FCC-proposed mask failed all acceptance criteria by a very wide margin. The 70 dB and 75 dB masks also failed all three acceptance criteria. The 80 dB mask passed two of the three acceptance criteria, and the 100 dB mask passed and provided too much interference protection.

Using a path loss model with n=2.18 and a 16 dB blockage factor, we found that the FCC-proposed mask again failed all acceptance criteria by a wide margin. The 70 dB mask passed only one of the three criteria, and the 75, 80, and 85 dB masks each passed all three acceptance criteria.

Based on the two simulated propagation models, and the author's proposed acceptance criteria, the simulations demonstrate that the FCC-proposed mask will cause unacceptable performance degradation to SDARS listeners in NYC. The proper mask should be greater than 75dB and perhaps set to 80 dB in anticipation of overload interference due to the high congestion on the NJ Turnpike.

6.6 Impact of FCC and Other Proposed Out of Band Emission Masks on SDARS in Jackson, MS

Section 6.6 provides simulation data for Jackson, MS and provides analysis of the impact of different spectral masks on Sirius XM satellite radio receivers in Jackson, MS.

6.6.1 Jackson, MS

Figure 13 shows the map of the Interstate highway simulated in the Jackson, MS area. The highway was I55-I20 just south of the Jackson city center. We now provide details of the traffic environment.

6.6.1.1 Jackson, MS Traffic Environment

The following Table, Table 14, shows the road type and traffic parameters obtained from Google and Mapquest. Note that the traffic volume is approximately half that of the New Jersey Turnpike.

Table 13: Traffic Profile for Jackson, MS

Parameter	Value
Location	I55-I20 Interchange, South of Jackson
Road Type	Interstate
Peak Traffic Time	Mondays, 7:45 AM
Road Segment Length	3 Miles
Average Speed	35
Number of Lanes	3
Average Daily Volume	39167

Using the traffic equation in Section 6.1.1, we calculate a peak hourly volume of 5900 vehicles. Figure 13 shows an aerial view of the Interstate highway that was simulated in the Jackson area.

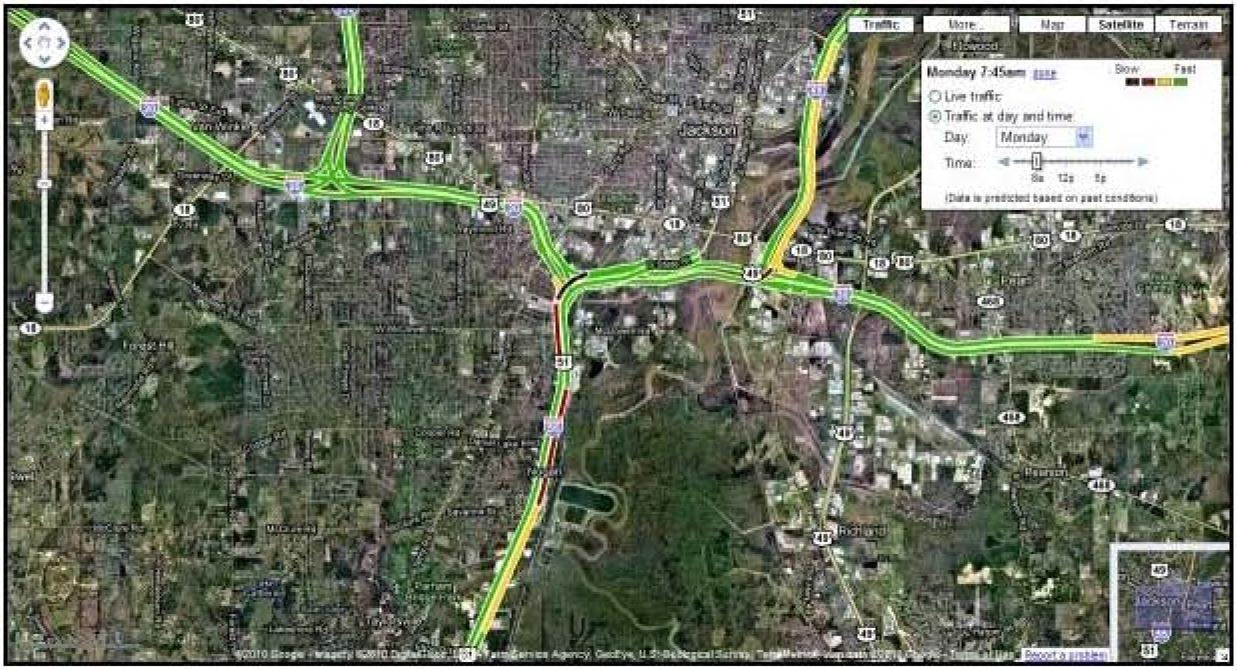

Figure 12: Road and Traffic View in Jackson, MS

6.6.1.2 *Jackson, MS Satellite Radio Service Environment*

The satellite geometry, link performance, and overall QoS for Jackson, MS is shown in Table 15. These data are shown on lines 23-26 of the Jackson, MS simulation spreadsheet given in Figure 14.

Table 14:Satellite Parameters and Baseline QoS for Jackson, MS

	Link Margin (dB)	Elevation Angle (degrees)	Baseline QoS
Sat1 (85E)	8.0	52.0	99.8%
Sat2 (115W)	12.9	43.8	

6.6.1.3 *Determining an appropriate OOBE mask for WCS mobile transmitters in Jackson, MS*

Figure 14 shows the spreadsheet containing inputs and outputs for the cases run in Jackson, MS. Entries marked in yellow indicate parameters that changed from one case to the next. It can be seen from the spreadsheet that the interference levels in Jackson are much more benign than in the larger cities presented earlier. For example, consider the use of power control and an accurate propagation model in Case 3, where the proposed FCC OOBE mask is used. The simulator output on Line 6 indicates that 2.71%, or nearly 1 in 37 listeners, have their link rendered unusable with a destruction of 3 dB or more of the satellite link margin. While 2.71% is an intolerable number of users to have knocked off of a protected for-pay broadcast system, this result is better than results given for the same case in the larger cities (NYC and Miami), where the number of destroyed users was two or three times greater.

Configuration																					
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
City	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
Vehicle Volume	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900	5900
Vehicle Speed	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
WCS Penetration Rate	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDARS Penetration Rate	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Roadway Length	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Num_lanes	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# Sat	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
# WCS	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
WCS Activity Factor	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
SDARS Listening Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Duty Cycle	0.38	0.38	0.38	0.38	0.38	0.125	0.0625	0.38	0.38	0.125	0.0625	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Band Factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C/D OOB Mask (X+10logP)	55	55	55	55	55	55	55	55	55	55	55	55	70	75	80	85	100	70	75	80	85
Bl, Au OOB Mask (X+10logP)	61	61	61	61	61	61	61	61	61	61	61	61	70	75	80	85	100	70	75	80	85
Bu, Al OOB Mask (X+10logP)	67	67	67	67	67	67	67	67	67	67	67	67	70	75	80	85	100	70	75	80	85
Max Tx	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Pwr Cntrl (0, -6, -12 back off)	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Path Loss exponent	2.00	2.00	2.00	2.18	2.18	2.18	2.18	2.18	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.18	2.18	2.18	2.18
Blockage Mean	10	10	10	16	16	16	16	16	10	10	10	10	10	10	10	10.00	10.00	16.00	16.00	16.00	16.00
Blockage Std Dev.	0	0	0	0	2	2	2	4	2	2	2	4	4	4	4	4.00	4.00	4.00	4.00	4.00	4.00
Sat1 Link Margin	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8.00	8.00	8.00	8.00	8.00	8.00
Sa1 Elevation	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52.00	52.00	52.00	52.00	52.00	52.00
Sat2 Link Margin	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13.00	13.00	13.00	13.00	13.00	13.00
Sat2 Elevation	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44.00	44.00	44.00	44.00	44.00	44.00
QoS Baseline	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%	99.78%
RESULTS																					
# Pts. < 3m Relocated to 3m	41.00	34.00	42.00	48.00	43.00	40.00	49.00	42.00	69.00	50.00	55.00	46.00	42.00	35.00	36.00	50.00	47.00	46.00	49.00	46.00	45.00
# Total Points	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800	111800
% Relocated Pts.	0.04%	0.03%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.06%	0.04%	0.05%	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
% SDARS with Link Margin Reduced >1dB	0.00%	8.32%	5.99%	1.79%	2.30%	1.27%	0.89%	2.53%	5.79%	3.09%	2.09%	5.94%	2.28%	1.12%	0.59%	0.23%	0.00%	0.81%	0.33%	0.12%	0.05%
% SDARS with Link Margin Reduced >2dB	0.00%	5.61%	3.72%	1.12%	1.67%	0.90%	0.56%	1.68%	3.97%	1.94%	1.35%	4.12%	1.55%	0.71%	0.31%	0.10%	0.00%	0.51%	0.21%	0.08%	0.04%
% SDARS with Link Margin Reduced > 3dB	0.00%	4.10%	2.71%	0.88%	1.19%	0.66%	0.37%	1.48%	2.82%	1.56%	1.08%	3.05%	1.08%	0.51%	0.23%	0.04%	0.00%	0.34%	0.12%	0.05%	0.03%
% SDARS Availability Degraded <99%	0.00%	3.65%	2.49%	0.75%	0.96%	0.57%	0.34%	1.33%	2.57%	1.37%	0.98%	2.67%	0.93%	0.37%	0.19%	0.04%	0.00%	0.29%	0.07%	0.05%	0.01%
% SDARS Availability Degraded <98%	0.00%	2.78%	1.86%	0.51%	0.68%	0.33%	0.21%	0.89%	1.89%	1.05%	0.71%	1.96%	0.63%	0.21%	0.11%	0.03%	0.00%	0.21%	0.03%	0.01%	0.00%

Figure 14: Simulation Results, Jackson, MS

We again consider the three different proposed acceptance criteria for determining suitable OOBE masks for WCS transmitters in Jackson, MS, realizing that any one or a combination of all three could be reasonably used to determine acceptable SDARS performance in the face of interference. These proposed criteria are:

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%
3. Allow the greatest level of interference that still ensure that at most only 0.5% of all SDARS receivers suffer a 3dB link margin degradation due to WCS interference.

First consider Case 17, where the OOBE mask is set to 100 dB of attenuation (10 dB less stringent than the existing rules). Simulation shows this OOBE mask provides a large amount of interference protection as seen in lines 6 and 7 of the output section. Specifically, based on 7.25 million simulation points, there is no erosion whatsoever of the 99% availability threshold for each of the SDARS receivers. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.0% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.0% is less than 1%, so criterion #2 is met. Finally, no SDARS receivers experience greater than 3 dB link margin loss, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 100 dB of attenuation would meet all three acceptance criteria. It is clear that 100 dB is too protective and too stringent of a mask for WCS subscribers.

Case 16 in Jackson, MS uses an OOBE mask set to 85 dB of attenuation (25 dB less stringent than the existing rules). We see that 0.23% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.04% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.04% of SDARS users have lost greater than 3 dB of link margin. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are again no SDARS receivers that suffer a degraded availability, so this mask would be acceptable based on criterion #1. Since 0.04% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have more than 3 dB link loss.

Considering Case 15, where the OOBE mask is set to 80 dB of attenuation (30 dB less stringent than the existing rules), we see that 0.31% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.19% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.23% of SDARS receivers have greater than 3 dB link loss. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.19% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.78%, so this mask would be acceptable based on criterion #1. And since 0.19% is less than 1%, the second criterion would be passed. The third criterion is passed since fewer than 0.5% of receivers are degraded more than 3 dB. Thus, Case 15 would pass all three different acceptance criteria.

Case 14 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). We see that 0.71% of the SDARS receivers have their link margin reduced by 1 dB, but 0.37% of the listeners have their availability threshold knocked down to below 99% availability. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.37% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.78%, so this mask would be acceptable based on criterion #1. Also note that 0.37% is less than 1%, so this mask passes the second criterion. Finally, this mask fails the third criterion by the slimmest of margins, since 0.51% of receivers lose >3dB of link margin. Thus, Case 14 would pass two of the three different acceptance criteria.

Case 13, where the OOBE mask is set to 70 dB of attenuation (40 dB less stringent than the existing rules), fails the first criteria, as 0.93% of receivers fall below the 99% design target. Furthermore, 1.08% of SDARS receivers lose <3dB of link margin. Therefore, Case 13 fails all three acceptance criteria.

Case 12, the FCC Staff Proposal, is the worst performer as it would allow an unacceptably high 2.67% of SDARS receivers (1 in 37 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leaves 3.05% of receivers, 1 in 30 receivers, with greater than 3 dB link margin loss.

Now consider Cases 18 through 21, and Case 8, where we use a conservative propagation model with greater loss and again consider several different OOBE masks and their impact on SDARS performance.

Case 21 uses an OOBE mask of 85 dB of attenuation (25 dB less stringent than the existing rules). Simulation shows this mask provides a large amount of interference protection, as seen in lines 4 through 7 of the output section. Specifically, based on 1.1 million simulation points, only 0.05% of the SDARS receivers experience more than a 1 dB link margin reduction, and there is very little erosion of the 99% availability threshold, as only 0.01% of the SDARS receivers breach this performance level. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% SDARS receivers have their availability degraded to below 99%. In this case, there are 0.01% SDARS receivers with degraded availability, so this criterion is met. Furthermore, 0.01% is less than 1%, so criterion #2 is met. Finally, less than 0.5% of receivers have lost 3dB of link margin, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 85 dB of attenuation would meet all three acceptance criteria.

Case 20 uses an OOBE mask set to 80 dB of attenuation (30 dB less stringent than the existing rules). The simulation shows that 0.12% of the SDARS receivers have their link margin reduced by 1 dB, and only 0. 05% of the listeners have their availability threshold knocked down to below 99% availability. Also, less than 0.5% of receivers have lost 3 dB or more of link margin. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.05% SDARS receivers that suffer a degraded availability to below 99%, which is less than 0.78%, so this mask would be acceptable based on criterion #1. Since 0.05% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% have greater than 3 dB link margin loss.

Case 19 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). The simulation shows that 0.33% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.07% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.12% of SDARS receivers experience greater than 3 dB link loss. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.07% SDARS receivers that suffer a degraded availability, which is less than 0.78%, so this mask would be acceptable based on criterion #1. Since 0.07% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have lost 3 dB of link margin.

Case 18 uses an OOBE mask set to 70 dB of attenuation (40 dB less stringent than the existing rules). The simulation shows that 0.81% of the SDARS receivers have their link margin reduced by 1 dB, but 0.29% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.34% of users have lost 3 dB or more of link margin. Given a baseline quality of service of 99.78%, our first criterion would require that no more than 0.78% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.29% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.78%, so this mask would be acceptable based on criterion #1. Also note that 0.29% is less than 1%, so this mask meets the second criterion. Finally, this mask meets the third criterion since 0.34% with 3 dB is less than the 0.5% criterion. Thus, Case 18 would pass all three different acceptance criteria.

Case 8 is the FCC-proposed OOBE mask, and the simulation shows it is the worst performer as it would allow 1.33% of SDARS receivers (1 in 75 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to 1.48% of SDARS receivers with 3 dB link margin reduction as they travel down the highway in normal busy hour conditions. Thus, the FCC fails all three criteria handily, and allows over 1% of existing SDARS radios to be rendered unusable in the face of WCS OOBE in Jackson, MS.

Using a free space propagation model (n = 2.0) between vehicles with a 10 dB blockage factor, we found that the FCC-proposed mask failed all acceptance criteria in Jackson, MS by a wide margin. The 70 dB and 75 dB masks also failed one or more of the three acceptance criteria. The 80 dB mask passed all three acceptance criteria, and the 100 dB masks provided too much interference protection.

Using a more conservative path loss model with n=2.18 and a 16 dB blockage factor, we found that the FCC-proposed mask again failed all acceptance criteria by a wide margin. The 70 dB, 75 dB, 80 dB, and 85 dB masks each passed all three acceptance criteria.

Based on the two simulated propagation models, and the author's proposed acceptance criteria, the simulations demonstrate that the FCC-proposed mask will cause unacceptable performance degradation to SDARS listeners. It also is clear that a suitable spectrum mask should have 75dB or more of OOBE attenuation for Jackson, MS, but not more than 80 dB of OOBE attenuation. These conclusions are made under the assumptions that the WCS penetration rate is only 5% and overload is not a critical degrading factor to SDARS receivers in Jackson, MS.

6.7 Impact of FCC and Other Proposed Out of Band Emission Masks on SDARS in Denver, CO

Section 6.7 shows how the simulation data may be interpreted for simulations performed for the Denver, CO area, and provides analysis of the simulation results for determining suitable OOBE spectrum masks for WCS users in the Denver, CO area.

6.7.1 Denver, Colorado

Figure 15 shows the aerial view of US 285, a freeway that is located south of downtown Denver. Mapquest and Google were used to obtain traffic statistics and average vehicle speeds during rush hour.

6.7.1.1 Denver, CO Traffic Environment

Table 15: Traffic Profile for Denver, CO

Parameter	Value
Location	US285 South of Denver
Road Type	Freeway
Peak Traffic Time	Mondays, 8:00 AM
Road Segment Length	8 Miles
Average Speed	35
Number of Lanes	2
Average Daily Volume	26163

Using the traffic volume equation in Section 6.1.1, we calculate a peak hourly volume of 3950 vehicles, as shown in line 3 of Figure 16. We note that this highway has less rush hour traffic than the other cities considered, and thus has a higher rush hour average speed of 35 mph.

Figure 15: Road and Traffic View for Denver, CO

6.7.1.2 Denver, Colorado Satellite Radio Service Environment

The satellite geometry, link performance, and overall QoS for Denver, CO is shown in Table 18. These data are shown on lines 23 – 26 in the spreadsheet of Figure 16.

Table 16: Satellite Parameters and Baseline QoS for Denver, CO

	Link Margin (dB)	Elevation Angle (degrees)	Baseline QoS
Sat1 (85E)	12.8	39.6	99.6%
Sat2 (115W)	9.3	42.8	

6.7.1.3 Determining an appropriate OOBE mask for WCS mobile transmitters in Denver, CO

The following table shows the simulation inputs and outputs for the cases run. Entries marked in yellow indicate parameters that changed from one case to the next.

Configuration																					
Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
City	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver	Denver
Vehicle Volume	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950	3950
Vehicle Speed	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
WCS Penetration Rate	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDARS Penetration Rate	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Roadway Length	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Num_lanes	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
# Sat	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154
# WCS	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
WCS Activity Factor	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
SDARS Listening Factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Duty Cycle	0.38	0.38	0.38	0.38	0.38	0.125	0.0625	0.38	0.38	0.125	0.0625	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Band Factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C/D OOB Mask (X+10logP)	55	55	55	55	55	55	55	55	55	55	55	55	70	75	80	85	100	70	75	80	85
Bl, Au OOB Mask (X+10logP)	61	61	61	61	61	61	61	61	61	61	61	61	70	75	80	85	100	70	75	80	85
Bu, Al OOB Mask (X+10logP)	67	67	67	67	67	67	67	67	67	67	67	67	70	75	80	85	100	70	75	80	85
Max Tx	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Pwr Cntrl (0, -6, -12 back off)	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Path Loss exponent	2.00	2.00	2.00	2.18	2.18	2.18	2.18	2.18	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.18	2.18	2.18	2.18
Blockage Mean	10	10	10	16	16	16	16	16	10	10	10	10	10	10	10	10.00	10.00	16.00	16.00	16.00	16.00
Blockage Std Dev.	0	0	0	0	2	2	2	4	2	2	2	4	4	4	4	4.00	4.00	4.00	4.00	4.00	4.00
Sat1 Link Margin	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Sa1 Elevation	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Sat2 Link Margin	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Sat2 Elevation	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
QoS Baseline	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%	99.57%
# Pts. < 3m Relocated to 3m	72.00	81.00	83.00	77.00	94.00	74.00	89.00	100.00	85.00	97.00	73.00	98.00	81.00	98.00	85.00	83.00	84.00	87.00	81.00	87.00	87.00
# Total Points	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200	354200
% Relocated Pts.	0.02%	0.02%	0.02%	0.02%	0.03%	0.02%	0.03%	0.03%	0.02%	0.03%	0.02%	0.03%	0.02%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
% SDARS with Link Margin Reduced >1dB	0.00%	5.36%	4.57%	1.87%	1.53%	1.02%	0.80%	1.77%	4.56%	2.51%	1.65%	4.51%	1.40%	0.80%	0.47%	0.28%	0.00%	0.61%	0.31%	0.14%	0.01%
% SDARS with Link Margin Reduced >2dB	0.00%	3.56%	3.06%	1.27%	1.08%	0.70%	0.60%	1.17%	3.19%	1.74%	1.11%	3.25%	0.95%	0.54%	0.22%	0.10%	0.00%	0.41%	0.19%	0.08%	0.00%
% SDARS with Link Margin Reduced > 3dB	0.00%	2.78%	2.40%	0.94%	0.83%	0.55%	0.43%	0.96%	2.55%	1.31%	0.83%	2.49%	0.79%	0.40%	0.16%	0.06%	0.00%	0.33%	0.11%	0.02%	0.00%
% SDARS Availability Degraded <99%	0.00%	3.07%	2.67%	1.08%	0.91%	0.60%	0.52%	1.07%	2.83%	1.47%	0.96%	2.83%	0.83%	0.44%	0.18%	0.08%	0.00%	0.37%	0.15%	0.03%	0.00%
% SDARS Availability Degraded <98%	0.00%	2.25%	1.81%	0.81%	0.73%	0.43%	0.34%	0.79%	2.11%	1.04%	0.64%	1.99%	0.56%	0.34%	0.11%	0.04%	0.00%	0.24%	0.08%	0.01%	0.00%

Figure 16: Simulation Results, Denver

In Denver, CO, Case 3 shows simulation results for the case where power control and the FCC proposed mask is implemented in the simulator. The simulator output indicates untenable WCS OOBE for SDARS. In particular, line 4 of the output section for Case 3 shows that 4.57% of the SDARS listeners have their link margins reduced by 1 dB due to interference, and 3.06% have their link margins reduced by 2 dB as shown in line 5. These values are a slight improvement compared to the no power control case of Case 2, where 5.36% and 3.56% had their link margins reduced, respectively. Line 6 shows that 2.4%, or 1 in 42 listeners, have their link rendered unusable with a destruction of more than half the satellite link margin.

Line 7 for the Denver Case 3 situation shows that 2.67% of the listeners, or 1 in 37 listeners, are degraded to below a 99% worst-case availability level, as compared to the baseline case where no users had their availability degraded below a 99% worst-case level. Line 8 shows that 1.81%, or 1 in 55 listeners, have their service availability degraded horribly to below a 98% threshold. While these values are untenable for SDARS operation, they are an improvement over the no power control case of Case 2, where service availability levels were degraded below 99% and 98% for 3.07% and 2.25% of the listeners, respectively. The simulator shows that the degradation to SDARS is substantial when the FCC proposed mask is considered.

For Denver, CO, Cases 12, 13, 14, 15, 16, and 17 consider identical simulation conditions, but the six simulations employ six different OOBE masks to determine and compare the effects that WCS OOBE masks have on SDARS receivers. Each of these six cases use a free space propagation model with n=2.0, a 10 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The six masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, a flat 85 dB attenuation mask, and a flat 100 dB attenuation mask. For comparison purposes, it is worth again noting that existing rules require WCS transmitters to obey a flat 110 dB attenuation mask.

Cases 8, 18, 19, 20, and 21 consider identical simulation conditions, but the simulations employ five different OOBE masks and consider a more conservative and lossy propagation model that has n=2.18, a 16 dB blockage factor, and log-normal shadowing with 4 dB of standard deviation. The five OOBE masks include the FCC-proposed mask, a flat 70 dB OOBE attenuation mask, a flat 75 dB attenuation mask, a flat 80 dB attenuation mask, and a flat 85 dB attenuation mask.

Again we consider the proposed three different acceptance criteria, where any one or a combination of all three could be reasonably used to determine an acceptable OOBE mask to ensure SDARS performance in the face of interference:

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%
3. Allow the greatest level of interference that still ensure that at most only 0.5% of all SDARS receivers suffer a 3dB link margin degradation due to WCS interference.

First consider Case 17 in Denver, where the OOBE mask is set to 100 dB of attenuation (10 dB less stringent than the existing rules). Simulation shows this OOBE mask provides a large amount of interference protection as seen in lines 6 and 7 of the output section. Specifically, based on 3.5 million simulation points, there is no erosion whatsoever of the 99% availability threshold for each of the SDARS receivers. It is clear that 100 dB is too protective of the SDARS service, under the assumption of 0.25W WCS subscribers..

Case 16 uses an OOBE mask set to 85 dB of attenuation (25 dB less stringent than the existing rules). We see that 0.28% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.08% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.06% of SDARS users have lost greater than 3 dB of link margin. Given a baseline quality of service of 99.57%, our first criterion would require that no more than 0.5% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.08% SDARS receivers that suffer a degraded availability below 99%, which is less than 0.5%, so this mask would be acceptable based on criterion #1. Since 0.08% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have more than 3 dB link loss.

Considering Case 15, where the OOBE mask is set to 80 dB of attenuation (30 dB less stringent than the existing rules), we see that 0.47% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.18% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.16% of SDARS receivers have greater than 3 dB link loss. Given a baseline quality of service of 99.57%, our first criterion would require that no more than 0.57% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.18% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.5%, so this mask would be acceptable based on criterion #1. And since 0.18% is less than 1%, the second criterion would be passed. The third criterion is passed since less than 0.16% of receivers are degraded more than 3 dB. Thus, Case 15 would pass all three different acceptance criteria.

Case 14 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). We see that 0.8% of the SDARS receivers have their link margin reduced by 1 dB, and 0.44% of the listeners have their availability threshold knocked down to below 99% availability. Given a baseline quality of service of 99.57%, our first criterion would require that no more than 0.57% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.44% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.5%, so this mask would be acceptable based on criterion #1. Also note that 0.44% is less than 1%, so this mask meets the second criterion. Finally, this mask meets the third criterion since 0.4% of receivers lose >3dB of link margin. Thus, Case 14 would pass all of the three different acceptance criteria.

Case 13, where the OOBE mask is set to 70 dB of attenuation (40 dB less stringent than the existing rules), fails all three criteria, as it allows 0.83%, or 1 in 120 listeners, to have their availability degraded to below the 99% design target. Furthermore, 0.79% of SDARS receivers lose <3dB of link margin.

Case 12, the FCC Staff Proposal, is the worst performer as it would allow an unacceptably high 2.83% of SDARS receivers (1 in 35 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leaves 2.49% of receivers, 1 in 40 listeners, with greater than 3 dB link margin loss. This is unacceptable for a broadcasting pay-service in a protected band.

Now consider Denver Cases 18 through 21, and Case 8, where we use a conservative propagation model with greater loss and again consider several different OOBE masks and their impact on SDARS performance.

Case 21 uses an OOBE mask of 85 dB of attenuation (25 dB less stringent than the existing rules). Simulation shows this mask provides a large amount of interference protection, as seen in lines 4 through 7 of the output section. Specifically, only 0.01% of the SDARS receivers experience more than a 1 dB link margin reduction, and there is no erosion of the 99% availability threshold, as none of the SDARS receivers breach this performance level. Given a baseline quality of service of 99.57%, our first criterion would require that no more than 0.57% SDARS receivers have their availability degraded to below 99%. In this case, there are no SDARS receivers with degraded availability, so this criterion is met, as is criterion #2. Finally, less than 0.5% of receivers have lost 3dB of link margin, thus criterion #3 is met. Thus, a WCS OOBE mask requiring 85 dB of attenuation would meet all three acceptance criteria.

Case 20 uses an OOBE mask set to 80 dB of attenuation (30 dB less stringent than the existing rules). The simulation shows that 0.14% of the SDARS receivers have their link margin reduced by 1 dB, and only 0. 03% of the listeners have their availability threshold knocked down to below 99% availability. Also, less than 0.5% of receivers have lost 3 dB or more of link margin. It is clear that 80 dB of attenuation easily passes all three acceptance tests.

Case 19 uses an OOBE mask set to 75 dB of attenuation (35 dB less stringent than the existing rules). The simulation shows that 0.31% of the SDARS receivers have their link margin reduced by 1 dB, but only 0.15% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.11% of SDARS receivers experience greater than 3 dB link loss. Given a baseline quality of service of 99.5%, our first criterion would require that no more than 0.57% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.15% SDARS receivers that suffer a degraded availability, which is less than 0.5%, so this mask would be acceptable based on criterion #1. Since 0.15% is less than 1%, the second criterion is also passed. Finally, the third criterion is passed since less than 0.5% of receivers have lost 3 dB of link margin.

Case 18 uses an OOBE mask set to 70 dB of attenuation (40 dB less stringent than the existing rules). The simulation shows that 0.61% of the SDARS receivers have their link margin reduced by 1 dB, but 0.37% of the listeners have their availability threshold knocked down to below 99% availability. Also, 0.33% of users have lost 3 dB or more of link margin. Given a baseline quality of service of 99.57%, our first criterion would require that no more than 0.57% of SDARS receivers have their availability degraded to below 99%. In this case, there are 0.37% SDARS receivers that suffer a degraded availability below 99% , which is less than 0.5%, so this mask would be acceptable based on criterion #1. Also note that 0.37% is less than 1%, so this mask passes the second criterion. Finally, this mask meets the third criterion since 0.33% with 3 dB is less than the 0.5% criterion. Thus, Case 18 would pass all of the three different acceptance criteria.

Case 8 is the FCC-proposed OOBE mask, and the simulation shows it is the worst performer as it would allow 1.77% of SDARS receivers (1 in 56 listeners) to suffer a breach of the required worst-case 99% link availability margin. The FCC OOBE mask also leads to the 0.96% of SDARS receivers (1 out of 100) that have 3 dB or more link margin reduction as they travel down the Denver highway in normal busy hour conditions.

Using a free space propagation model (n = 2.0) between vehicles with a 10 dB blockage factor, we found that the FCC-proposed mask failed all acceptance criteria by a very wide margin. The 70 dB mask also failed all three acceptance criteria. The 75 and 80 dB mask passed all three acceptance criteria, and the 100 dB masks provided too much interference protection.

Using a path loss model with n=2.18 and a 16 dB blockage factor, we found that the FCC-proposed mask again failed all acceptance criteria. The 70 dB, 75 dB, 80 dB, and 85 dB masks each passed all three acceptance criteria.

Based on the two simulated propagation models, and the author's proposed acceptance criteria, the simulations demonstrate that the FCC-proposed mask will cause unacceptable performance degradation to SDARS listeners. It also is clear that a 70 dB OOBE mask will also fail to provide acceptable SDARS performance, since it failed under the first propagation model. models. A suitable spectrum mask should have more than 70 dB of OOBE attenuation, but not more than 75 dB of OOBE attenuation for the Denver case. This conclusion is made based on an assumption of 0.25 W transmit powers, and a WCS penetration rate of only 5%.

6.8 Key observations regarding WCS interference and its impact on SDARS subscribers in 5 Cities.

The simulations show very clearly that the effect of many WCS transmitters leads to an increase in SDARS receiver noise floor. The simulation statistics provide insights into the exact degree of this phenomenon by counting the noise floor levels for each of the SDARS receivers as the noise floors are raised by 1, 2, and 3 dB or more. As discussed earlier, an increase of 3 dB in the noise floor is the equivalent of cutting the satellite transmitter power by 3 dB, making the Sirius XM satellite service unusable.

We saw that certain cities, like Denver or Jackson, had lower levels of interference as compared to Miami, NYC/NJ, and Charlotte. This is because of the particular satellite look angles (that overcome building and foliage shadowing) and particular satellite beam patterns that provide variable signal strengths to different places on earth.

Using the proposed WCS transmitter power levels of 0.25W, the simulator shows that in cities where the satellite link is less robust (such as Miami or New York, where there are more buildings or foliage, or where the satellite power is weaker), the impact of WCS OOBE is much more severe, thus requiring spectral masks on WCS subscribers that provide 80 dB or more of out-of-band attenuation, regardless of the car-to-car propagation model. In cities where the satellite coverage is strong, and high in the sky, less OOBE protection is needed, but in all cases, at least a 70 dB mask was required to satisfy the two different car-to-car propagation models. In no cases did the FCC Staff proposed spectral mask provide reasonable protection to the SDARS service.

In heavy traffic environments, the impact of overload is likely to be non-trivial as we showed in Section 4, and this should cause the FCC to err on the side of caution to protect broadcast receivers from non-linear overload.

7 Summary

This report has provided a careful inspection of the proposed rules to allow the coexistence of SDARS and WCS in the 2300 MHz band. We have analyzed various sources of potential interference to SDARS receivers, and have made fair and reasonable engineering judgments in order to deduce the levels of OOBE that would be seen from adjacent service WCS subscribers in the SDARS band. In doing this work, we sought to determine reasonable guidelines from which suitable spectrum masks could be developed.

To determine the levels of interference, and to determine appropriate approaches, we studied how the FCC and other governments have protected both satellite and terrestrial broadcast services in the past. We also provided some simple analysis by assuming that a single WCS transmitter was located one car length away from a single SDARS receiver, and we considered measured data on SDARS receiver overload performance. This analysis provided insights into reasonable interference and power levels in the face of the recently proposed FCC OOBE mask and proposed transmit power levels. We also noted that overload could be an important issue to understand, and that the FCC should err on the side of safety, as rush hour highway traffic could be expected to place many WCS transmitters in close range with many SDARS receivers over time.

We created a simulator that models a wide range of real-world parameters so that realistic interference levels could be deduced in realistic operating conditions in 5 cities. The simulations allowed us to see the wide range of outages and link margin degradations that occur, and allowed us to compare the FCC Staff proposed OOBE mask with other OOBE masks. We developed three test criteria for accepting a spectral mask, and these test criteria were based on Sirius XM's historic design and implementation activities of their system. For example, Sirius XM designed their protected pay-broadcast system for a worst case availability of 99%, and in the past had replaced satellites whenever their transmitter power was degraded by 3dB. From these observations, and from inspection of the simulation outputs, we proposed three acceptance criteria for a WCS spectral mask, given a WCS transmitter power level of 0.25W:.

1. If the baseline availability is greater than 99% as determined by the EERS design methodology, subtract 99% from the baseline availability to find the percentage of users that may be allowed to experience a worst-case availability threshold that is less than 99% (this value will be less than 1%).
2. Interference shall be tolerated so long as not more than 1 % of all SDARS users shall have their worst-case availability threshold reduced to below 99%
3. Allow the greatest level of interference that still ensure that at most only 0.5% of all SDARS receivers suffer a 3dB link margin degradation due to WCS interference.

The simulations showed that for WCS subscribers under power control and for a wide range of traffic conditions, locations on earth, and path loss models between vehicles, the proposed FCC OOBE masks failed to work in every case. Instead, spectrum masks ranging between 70dB and 85 dB were required in all instances, to meet the proposed acceptance criteria. We noted that the simulations did not consider receiver blocking due to overload, although we demonstrated by a simple analysis that overload will be a problem for a WCS transmitter located 3 m away from a SDARS receiver.

7.1 SDARS is a satellite broadcast service operating with razor-thin link margins

The Sirius XM satellite radio system is a pay-service that was designed to provide high quality service to mobile subscribers throughout the USA. The system was designed based on 1997 rules provided by the FCC, which offered protection from interference. Satellite systems rely on the ability to operate in a noise-limited regime, and are unable to compensate for the fragile link margins that dictate the received signal on earth. The simulator provided in this report allows a user to vary various parameters, including satellite link parameters, to further understand the delicate link margin relationship, and the required protections from noise and interference sources in order to achieve a target availability goal in the face of adjacent service WCS mobile users.

7.2 Our simulations strive to make fair, real world assumptions, and demonstrate how the FCC proposed rules for SDARS protection would decay today's 99%+ Sirius XM performance

The simulations in this report show that with reasonable and fair assumptions, WCS out of band interference under the recently proposed FCC Staff rules would cause 7.72% of NY/NJ SDARS receivers and 10.66% of Miami receivers to fall below the originally-designed 99% availability. These data are before any overload outages are considered. These statistics were shown by Case 12 simulations for several markets in Section 6. Even in lightly traveled highways such as Jackson, MS, 2.67% of SDARS receivers would be knocked out of the original 99% availability design goal. Section 6 provides a wide range of simulations that demonstrate link margin erosion and degradation of availability to SDARS receivers.

7.3 Recommendations of the author

Based on my analysis of the simulation outputs, and the analysis of SDARS receiver performance, I recommend that the FCC stipulate a stronger out of band protection mask for WCS subscribers, to a level of 75 + 10log (P), and that the maximum transmitter power of WCS subscribers be limited to 100 mW with a 2.5 MHz guardband. Such a rule would be a compromise between both parties, but would provide sufficient protection to SDARS while allowing WCS to build out a viable terrestrial mobile network.

APPENDIX A Simulator Code FCC Probability Function

```
function [Distances PL Ptx num_WCS num_Sat Iter_cnt Int_dist min_dist_count Vehicle_volume Vehicle_speed
WCS_pen_rate  Sat_pen_rate Roadway_len]=FCC_Probability7
% This function performs  analysis of vehicle locations, as filed in
% exparte.
%
%  Technical Analysis of the Impact of Adjacent Service Interference to the Sirius XM Satellite Digital Audio Radio
%Services (SDARS) Simulator. Developed and tested under direction of Dr. Ted Rappaport


clear;

global cases q
global activity duty_cycle band_factor d L_1meter blocking_enable block_mean
global stdev pwr_cntrl max_pwr Phi Pmid Plo Poff
global Distances num_lanes
global lane_width Vehicle_volume Vehicle_speed WCS_pen_rate Sat_pen_rate
global Roadway_len Iter_cnt num_WCS num_Sat

%%%%% ADJUST INPUT PARAMETERS HERE
%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%

band_factor=2; % Divide WCS vehicles to adjust for SDARS high/low band users being affected - Leave =2


% %Interference distances to bucket results into (meters)
% %Reference, Overload, A,B Block, C,D block
% %Int_measures=[3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 100 200];
Int_measures=[6 19 40 60];
% xlswrite('vehiclestats.xls',Int_measures,'Sheet1','B4');
%Quantities of WCS transmitters to assess within a given distance of a
%Satellite radio
WCS_tx_count_bins=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15];
% xlswrite('vehiclestats.xls',WCS_tx_count_bins','Sheet1','A5');
%Distance Units     Conversion Factor
miles_to_meters=1609.344;
% Roadway Characteristics
num_lanes=cases(q,7);
lane_width=3.5; % meters
% Traffic Volume in Vehicles per Hour
Vehicle_volume=cases(q,2);
%Vehicle speed in mph
Vehicle_speed=cases(q,3);
%Assumed Service Penetration Rates in percent
%WCS Transmitters
WCS_pen_rate=cases(q,5);
% Satellite radios
Sat_pen_rate=cases(q,4);
% Length of roadway segment in miles
Roadway_len=cases(q,6);
```

```
%Number of iterations
Iter_cnt=100;%500;
% Calculate number of vehicles of each type
% Number of vehicles on roadway segment
num_vehicles=round(Vehicle_volume*Roadway_len/Vehicle_speed);
% Number of WCS transmitters on roadway segment
num_WCS=round(num_vehicles*WCS_pen_rate/100/band_factor);
%Number of Satellite receivers on roadway segment
num_Sat=round(num_vehicles*Sat_pen_rate/100/band_factor);
% Road segment coordinate limit



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% END INPUT PARAMETER ENTRY
%%%%%%%%%%%%%%%%%%%%

% Find number of transmitters to set at each activity level
if pwr_cntrl==1
   Loff=round(num_WCS*Poff);
   L1=round((num_WCS-Loff)*Phi);
   L2=round((num_WCS-Loff)*Pmid);
   L3=round((num_WCS-Loff)*Plo);
else
      Loff=round(num_WCS*Poff);
      L1=round((num_WCS-Loff));
end


Ptx(1:num_WCS,Iter_cnt)=0;

if Loff>0
Ptx123(1:Loff)=-99;  % if "off" set to -99 dBm, does not contribute
end
if pwr_cntrl==1
   Ptx123(Loff+1:Loff+L1)=24;    % full power
   Ptx123(Loff+L1+1:Loff+L1+L2)=18;  %  6 dB backoff
   Ptx123(Loff+L1+L2+1:num_WCS)=12;     % 12 dB backoff
else
   Ptx123(Loff+1:num_WCS)=max_pwr;
end

% Pre-allocate
Distances=0;

Distances(1:num_Sat,1:num_WCS,1:Iter_cnt)=0;
blockage(1:num_Sat,1:num_WCS,1:Iter_cnt)=0;


lambda=3e8/2.3e9; % Wavelength at 2.3 GHz


Y_min=0;
Y_max=Roadway_len*miles_to_meters;
```

```
% Write basic parameters to spreadsheet
% Headings={'Volume','Speed','WCS_Pen','Sat_Pen','Iter_cnt','n_Satvehicles'};
% xlswrite('vehiclestats.xls',Headings,'Sheet1','A1');
% Heading_values=[Vehicle_volume Vehicle_speed WCS_pen_rate Sat_pen_rate Iter_cnt num_Sat];
% xlswrite('vehiclestats.xls',Heading_values,'Sheet1','A2');
%
n_WCS_bins=length(WCS_tx_count_bins);
n_Int_measures=length(Int_measures);
% Predefine array for speed of execution
WCS_count_2=zeros(n_WCS_bins,n_Int_measures,Iter_cnt);


min_dist_count=0;  % initialize counter for WCS transmitters <3m removed from analysis


for n=1:Iter_cnt
%+++++++++++++++++++++++++++++++++++++++++++
% Random position loop for WCS Transmitters
% Pre-allocation for speed

Ptx(:,n)=Ptx123(randperm(num_WCS));  % randomize transmitter subscript assignments

WCS_Pos=zeros(2,num_WCS);
%
   for j=1:num_WCS
      WCS_Pos(1,j)=Lane(num_lanes);
      WCS_Pos(2,j)=Y_min+(Y_max-Y_min)*rand;
   end
% Random position loop for Satellite receivers
%rand('state',sum(100*clock));
SAT_Pos=zeros(2,num_Sat);
   for i=1:num_Sat
   SAT_Pos(1,i)=Lane(num_lanes);
   SAT_Pos(2,i)=Y_min+(Y_max-Y_min)*rand;
   end

  %plot positions of SAt users and WCS users
%   figure(11)
%   plot(SAT_Pos(1,:),SAT_Pos(2,:),'*')
%   hold
%   plot(WCS_Pos(1,:),WCS_Pos(2,:),'ro')
%   hold
%

% Create Separation matrix
%Pre-allocation for speed
dist_X=zeros(num_Sat,num_WCS);
dist_Y=zeros(num_Sat,num_WCS);
%Distances=zeros(num_Sat,num_WCS,Iter_cnt);
%
   for i=1:num_Sat
         dist_X(i,:)=WCS_Pos(1,:)-SAT_Pos(1,i);
         dist_Y(i,:)=WCS_Pos(2,:)-SAT_Pos(2,i);
   end
```

```
Int_dist=sqrt(dist_X.^2+dist_Y.^2);


% Stop listening to interference after 200m
 dd=find(Int_dist>200);
 Int_dist(dd)=9999999;  %  Assign extremely large distance - makes interference negligible


% Limit min distance to 3m meters from SDARS cars
dd=find(Int_dist<3);
 % If <3m, then relocate the WCS transmitter away from the victim SDARS and
 % efectively ignore impact to victim
 %  Assign extremely large distance - makes interference negligible
%Int_dist(dd)=9999999;%;
Int_dist(dd)=3;

% accumulate counter every iteration for number of points within 3m
    min_dist_count=min_dist_count+length(dd);

%  Store interference distances for this interation into Distances
Distances(:,:,n)=Int_dist;
%  Calculate a Gaussian, zero mean, stdev dB term for inclusion in pathloss
if blocking_enable==1
   blockage(:,:,n)=block_mean + randn(num_Sat,num_WCS)*stdev;
end



% Free up some memory by dumping position matrix

clear SAT_Pos;
clear WCS_Pos;
clear dist_X;
clear dist_Y;
%
%{
Create Statistics based on each satellite radio. For each satellite radio
on the highway, index i determine how many WCS transmitters are within a
distance indexed by q
%}

   for i=1:num_Sat
      for q=1:length(Int_measures)
        % I added this if to look at binning between distance values
        % if q==1
            bin=[0 Int_measures(q)];
         %else
          %   bin=[Int_measures(q-1) Int_measures(q)];
         %end
         %
         ni=histc(Int_dist(i,:),bin,2);
         WCS_count_1(i,q)=ni(1,1);
      end
   end
```

```
 %{
Produce count of how many sat radios have, within a given distance, a certain number of
WCS transmitters. WCS_count_2 is a three dimensional (third is the iteration count) matrix whose elements
contain the
number of satellite radios that have the number of wcs transmitters denoted by the
row index value within a distance indexed by the column index value.
%}

WCS_count_2(:,:,n)=histc(WCS_count_1,WCS_tx_count_bins,1);

%
end  % of master iteration loop
%




% % Form average and std of all the iterations
for l=1:length(WCS_tx_count_bins)
   for m=1:length(Int_measures)
      Average_count(l,m)=round(mean(WCS_count_2(l,m,:)));
      Std_dev_count(l,m)=std(WCS_count_2(l,m,:));
   end
end
xlswrite('vehiclestats.xls',Average_count,'Sheet1','B5');




PL=-(L_1meter+10*d*log10(Distances)+ blockage);

clear WCS_Count_2 WCS_Count_1;



% "Lane" Returns a random lane assignment coordinate
function L=Lane(num_lanes)
global lane_width
snap=rand;
switch num_lanes
   case 1
      L=lane_width/2;
   case 2
      if snap <0.5
         L=lane_width/2;
      else
         L=(3/2)*lane_width;
      end
   case 3
      if snap<(1/3)
         L=lane_width/2;
      elseif (snap>(1/3)) && (snap <(2/3))
         L=(3/2)*lane_width;
```

```
    else
       L=(5/2)*lane_width;
    end

end
```

APPENDIX B WCS Interference Code

```
   %  Main script for executing WCS interference simulation
   %  Technical Analysis of the Impact of Adjacent Service Interference to the Sirius XM Satellite Digital Audio
Radio %Services (SDARS) Simulator. Developed and tested under direction of Dr. Ted Rappaport


clear all;  % clear all memory




global cases
global q

% %  Cases contains all the test case parameters
  cases=[1 13795   25  34  5   7.5 3   0   0.85    0.38    49  55  61  0   2   1   10  0   8   60  10  41  ;
2   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  0   2   1   10  0   8   60  10  41  ;
3   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2   1   10  0   8   60  10  41  ;
4   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2.18    1   16  0   8   60  10  41  ;
5   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2.18    1   16  2   8   60  10  41  ;
6   13795   25  34  5   7.5 3   0.13    0.85    0.125   49  55  61  1   2.18    1   16  2   8   60  10  41  ;
7   13795   25  34  5   7.5 3   0.13    0.85    0.0625  49  55  61  1   2.18    1   16  2   8   60  10  41  ;
8   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2.18    1   16  4   8   60  10  41  ;
9   13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2   1   10  2   8   60  10  41  ;
10  13795   25  34  5   7.5 3   0.13    0.85    0.125   49  55  61  1   2   1   10  2   8   60  10  41  ;
11  13795   25  34  5   7.5 3   0.13    0.85    0.0625  49  55  61  1   2   1   10  2   8   60  10  41  ;
12  13795   25  34  5   7.5 3   0.13    0.85    0.38    49  55  61  1   2   1   10  4   8   60  10  41  ;
13  13795   25  34  5   7.5 3   0.13    0.85    0.38    64  64  64  1   2   1   10  4   8   60  10  41  ;
14  13795   25  34  5   7.5 3   0.13    0.85    0.38    69  69  69  1   2   1   10  4   8   60  10  41  ;
15  13795   25  34  5   7.5 3   0.13    0.85    0.38    74  74  74  1   2   1   10  4   8   60  10  41  ;
16  13795   25  34  5   7.5 3   0.13    0.85    0.38    79  79  79  1   2   1   10  4   8   60  10  41  ;
17  13795   25  34  5   7.5 3   0.13    0.85    0.38    94  94  94  1   2   1   10  4   8   60  10  41  ;
18  13795   25  34  5   7.5 3   0.13    0.85    0.38    64  64  64  1   2.18    1   16  4   8   60  10  41  ;
19  13795   25  34  5   7.5 3   0.13    0.85    0.38    69  69  69  1   2.18    1   16  4   8   60  10  41  ;
20  13795   25  34  5   7.5 3   0.13    0.85    0.38    74  74  74  1   2.18    1   16  4   8   60  10  41  ;
21  13795   25  34  5   7.5 3   0.13    0.85    0.38    79  79  79  1   2.18    1   16  4   8   60  10  41

];

%cases= [1  13795   25  34  5   7.5 3   0   0.85    0.38    45  48  54  0   2   1   10  0   8   60  10  41  ;
%2  13795   25  34  5   7.5 3   0.13    0.85    0.38    45  48  54  0   2   1   10  0   8   60  10  41  ;
%];

copyfile('Simulation_results_blank.xml','Simulation_results.xml');

for q=1:length(cases(:,1))  % steps through test cases

   % %%%%%%%%%%%%%%%%%%%SET CITY NAME FOR TEST RUNS
%%%%%%%%%%%%%%%%%%%%%%%%
city='Miami';
fname=char(city);
fnum=num2str(q);
```

```
fname=([fname fnum]);

global activity duty_cycle
global Distances
global activity duty_cycle band_factor d L_1meter blocking_enable block_mean
global stdev pwr_cntrl max_pwr Phi Pmid Plo Poff
global Distances num_lanes
global lane_width Vehicle_volume Vehicle_speed WCS_pen_rate Sat_pen_rate
global Roadway_len Iter_cnt num_WCS num_Sat


%%%%%%%%%% ADJUST INPUT PARAMETERS HERE AND IN FCC_PROBABILITY.M FUNCTION

listen_prob=cases(q,9); % Probability of SDARS subscriber listening to radio
activity=cases(q,8); % WCS Activity Factor
duty_cycle=cases(q,10);  % WCS 0n-time duty cycle (portion of frame)
dc_db=10*log10(duty_cycle); % duty cycle in db
% Enter required OOB attenuation (Transmitter mask) IN dB
OOB_mask1=cases(q,11); % 42 dB for 55+10logP, 48 dB for 61+10logP, 54 for 67+10logP
OOB_mask2=cases(q,12);
OOB_mask3=cases(q,13);

% Path Loss Coeffients
d=cases(q,15);
L_1meter=39.7; % Loss at 1 meter - varies with model assumptions.
blocking_enable=cases(q,16);  % 0= no blockage, 1=normally distributed blockage in dB
block_mean=cases(q,17); % mean of car blockage attenuation
stdev=cases(q,18);  % standard deviation of blockage in addition to path loss

% Transmit Parameters
pwr_cntrl=cases(q,14);  % 1 for on, 0 for off
max_pwr=24; % 24 dBm
%  Assign Power Control 63.2 @ full power, 23.4% at -6, 13.4% at -12 dB
Poff=1-activity;  % Transmitter Activity factor
Phi=.64;
Pmid=.23;
Plo=.13;



% Nominal Link Margins and Elevation angles for city:  Sat1 (S1) and Sat2
% (S2)
% Estimate for High-band, NYC
% ROUND LM TO NEAREST .5 dB, AND ELEVATION TO NEAREST DEGREE
LM_S1=cases(q,19); % dB;
EL_S1=cases(q,20); % Degrees
LM_S2=cases(q,21); % dB;
EL_S2=cases(q,22);  % Degrees


%%%%%%%%%%% END INPUT VARIABLES (CHECK FCC_PROBABILITY FUNCTION) %%%%%%
[Distances PL Ptx num_WCS num_Sat Iter_cnt Int_dist min_dist_count Vehicle_volume Vehicle_speed
WCS_pen_rate  Sat_pen_rate Roadway_len ]=FCC_Probability7;  %  Call main function generate random
placement
```

```
filenameo=strcat(fname,'.xml');

% Indexes
% n= Iteration counter
% i=Sat radio index
% j=WCS transmitter index

%%%%%%%%%%%%% Calculate Received Power  %%%%%%%%%%%%%
% Mask off SDARS receivers not listening
Listening=round(num_Sat*listen_prob);  % find # of SDARS receivers listening
Listen(1:Listening)=1;         % if listening, assign as "1"
Listen(Listening+1:num_Sat)=0;   % if not, assign as "0"



for n=1:Iter_cnt
   r=randperm(num_Sat); % generate a random ordering of SDARS receiver (row subscripts)
   r=r.*Listen(r);    % enter zeros in entries where sat radio is off
   sub=find(r==0);   % find the zeros
   %tx_rand=randperm(num_WCS);  % randomize transmitter subscript assignments

   for i=1:num_Sat
      Prx(i,:,n)=PL(i,:,n)+Ptx(:,n)';  % Calculate received power at each SDARS receiver
   end

   Prx(sub,:,n)=-999;  % minimize Prx for inactive SDARS receivers using subscripts "sub"
end

% Assign received WCS power to A/B/C/D bands (1/3)
rand_band=randperm(num_WCS);  % random subscripts for WCS band
band_allot=round(num_WCS/3);
mask_array(1:band_allot)=OOB_mask1;
mask_array(band_allot+1:2*band_allot)=OOB_mask2;
mask_array(2*band_allot+1:num_WCS)=OOB_mask3;
 for n=1:Iter_cnt
   OOB_mask=mask_array(rand_band); % random band assignment
%     % Track which WCS block transmitter assigned to:
    A=find(OOB_mask==OOB_mask3);
   B=find(OOB_mask==OOB_mask2);
   D=find(OOB_mask==OOB_mask1);
   % Sum overload at satellite receiver by WCS block assignment, one
   % column per iteration
   pa=(10.^(Prx(:,A,n)/10));
   PrxA(:,n)=10*log10(sum(pa,2));
   pb=10.^(Prx(:,B,n)/10);
   PrxB(:,n)=10*log10(sum(pb,2));
   pd=(10.^(Prx(:,D,n)/10));
   PrxD(:,n)=10*log10(sum(pd,2));


   for i=1:num_Sat

      Prx_oob(i,:,n)=Prx(i,:,n)-OOB_mask; % adjust for OOB mask.  Can also add a second step for stepped mask
```

```
    end

 end % n


% Calculate cumulative interference at each receiver

 Lin_noise=0;  % Linear interference initialize
for n=1:Iter_cnt

    for i=1:num_Sat
    noise_sum=0;  % initialize interfernece  summation


    for j=1:num_WCS

        % calculate linear interference component from WCS OOB and sum up for each satellite receiver
        Lin_noise=10^(Prx_oob(i,j,n)/10);
        noise_sum= noise_sum+Lin_noise ;
    end

    Interference_lin(i,n)=(noise_sum); % Store linear noise for each receiver/iteration

    Int_cum(i,n)=10*log10(Interference_lin(i,n));  % cumulative OOB noise at receiver in dB

    end

end

% Adjust interference component for Duty Cycle

if activity>0
compensated_int_cum=Int_cum + dc_db;
else
    compensated_int_cum=Int_cum;
end

%  %%%% Determine QoS impact %%%%%

% Define Probability Matrix
load('Prob.mat');
Prob=a1;

%  Link Margins and Elevations for NY
% Uses EERS model

LM=[LM_S1 LM_S2];
el=[EL_S1 EL_S2];

        % Find availability by looking up probability in table "Prob"
        for k=1:2
```

```
    y_lookup=LM(k);
    x_lookup=(el(k));
    y_value=1;
    LM_lookup = Prob(y_value,1);
    while y_lookup > LM_lookup
        y_value = y_value +1;
        LM_lookup = Prob(y_value,1);
    end % while y_lookup
    x_value = 1;
    el_lookup = Prob(1,x_value);
    while x_lookup > el_lookup
        x_value = x_value +1;
        el_lookup = Prob(1,x_value);
    end% while x_lookup
     QProb(k)=Prob(y_value,x_value);  % resulting prob of outage, @ TDM
    end % for k

    % Nominal QoS with no interference
    Q_base=100-(QProb(1)*QProb(2)*.01);

   % Find availability for Interference Case
% Convert noise floor in 4MHz channel to dBm per 1 MHz, Sirius XM noise
% floor = 113 dBm/4MHz
N_base=-113-6;

 compensated_int_lin=10.^(compensated_int_cum/10);  % lin interference

N_I(num_Sat,Iter_cnt)=0;
NI_db(num_Sat,Iter_cnt)=0;
NI_delta(num_Sat,Iter_cnt)=0;
LM_OOB(num_Sat,2,Iter_cnt)=0;



 for n= 1:Iter_cnt

   for i=1:num_Sat

   % Calculate Noise + Interference term for @ receiver
   N_I(i,n)=compensated_int_lin(i,n) +10^(N_base/10);
   NI_db(i,n)=10*log10(N_I(i,n));  % convert N+I to dB
   NI_delta(i,n)=NI_db(i,n)-N_base;  % find N+I delta from baseline noise

   if NI_delta(i,n) <0
       NI_delta(i,n)=0;
    end


   LM_OOB(i,1:2,n)=LM-NI_delta(i,n);   %  Link margin degradation for each receiver/iteration

   end

   % find negative link margins and set to zero
```

```
    f=find(LM_OOB(:,:,:)<0);
    LM_OOB(f)=0;

%      Avg_Noise_Impact(i)=mean(NI_delta);

      % Find availability for interference case (same process as baseline,
      % using margin degraded by N+I
    for h=1:num_Sat
      for k=1:2
       y_lookup=LM_OOB(h,k,n);
       x_lookup=(el(k));
       y_value=1;
       LM_lookup = Prob(y_value,1);
       while y_lookup > LM_lookup
           y_value = y_value +1;
           LM_lookup = Prob(y_value,1);
       end % while y_lookup
       x_value = 1;
       el_lookup = Prob(1,x_value);
       while x_lookup > el_lookup
           x_value = x_value +1;
           el_lookup = Prob(1,x_value);
       end% while x_lookup
       Q_int(h,k)=Prob(y_value,x_value); % Qos for receiver w/Interference
      end % for k
    end

   % Calculate signal availability with interference
    Qos_int=100-(Q_int(:,1).*Q_int(:,2)*.01);

   % Store Qos for each satellite receiver and iteration
   % #sat rows, # iterations columns
    Qos_WCS(:,n)=Qos_int;

end %n

% Average Qos for each iteration
% #sat rows by one column
for i=1:num_Sat
   Avg_Qos_WCS(i)=mean(Qos_WCS(i,:));
%    out=find (Qos_WCS(i,:)<=89);
%    Qos_WCS(i,out)=0;
end

%%%%%%%%%%%%%%%% Plots %%%%%%%%%%%%%%%%%%
% Show distribution of received interference power compensated for duty
% cycleQ_bins=[50 60 70 80 90 95 99 100];

%N_base-12 is the noisefloor, minus 6 dB for 1 MHz, then 6 dB more for the
%1dB impact point.
pwr_bins=[N_base-12 -120 -115 -110 -105 -100 -95 -90 -85 -80 -75 -70 -65 -60 -55 -50];
```

```
% Show distribution of received interference power compensated for duty
% cycle.  Each column is cumulative noise by iteration
rhist=histc(compensated_int_cum,pwr_bins);
% figure(1)
% bar(pwr_bins,100*mean(rhist')/num_Sat)
% rhist=histc(compensated_int_cum,pwr_bins);
%
% xlabel('Received Power (dBm)','FontSize',12);
% ylabel('% of SDARS Receiver Affected','FontSize',12);
% title('Distribution of WCS received OOB at SDARS Receivers on Roadway, Compensated for Activity')



% Show distribution of received interference power compensated for duty
% cycle.  Each column is cumulative noise by iteration
rhist2=histc(compensated_int_cum,pwr_bins);
figure(2)
h=bar(pwr_bins,100*mean(rhist2')/(num_Sat*listen_prob))
%bar(pwr_bins,sum(rhist2')/Iter_cnt)
figname=[fname 'a'];

xlabel('Received Power (dBm)','FontSize',12);
ylabel('% of SDARS Receiver Affected','FontSize',12);
title([figname,', Distribution of WCS received OOB at SDARS Receivers on Roadway, Compensated for Activity'])
saveas(h,figname,'jpg');

% Show distribution of QoS with interference
figure(3)

Q_bins=[60 80 90 95 96 97 98 99 100];

qhist=histc(Qos_WCS,Q_bins);
h=bar(Q_bins,mean(qhist'))

xlabel('Signal Availability (%)','FontSize',12);
ylabel('# of SDARS Receiver @QoS Level','FontSize',12);
figname=[fname 'b'];
title([figname,', Distribution of SDARS QoS Levels with Interference'])
saveas(h,figname,'jpg');

% Qos Delta from baseline distribution
figure(4)
Q_delta_bins=[0 .5 1 1.5 2 2.5 3 3.5 4 4.5 5 6 7 8 9 10 20 30];
Q_delta=Q_base-Qos_WCS;
qdelta=histc(Q_delta,Q_delta_bins);
%  bar(Q_delta_bins,qdelta)

h=bar(Q_delta_bins,mean(qdelta'))
figname=[fname 'c'];

xlabel('Signal Availability (%) Difference','FontSize',12);
ylabel('# of SDARS Receiver @QoS Delta Level','FontSize',12);
title([figname,', Distribution of SDARS QoS Deltas with Interference'])
saveas(h,figname,'jpg');
```

```
% Plot Link margin impact due to noise floor rise from OOB
N_delta_bins=[ 0 .25 .5 1 2 3 4 5 6 7 8 9 10 12 14 16 20 30];

figure(5)
Deltahist=histc(NI_delta,N_delta_bins)
h=bar(N_delta_bins,mean(100*Deltahist'/(num_Sat*listen_prob)))
xlabel('Link Margin Impact from Nominal (dB)','FontSize',12);
ylabel('% of SDARS Users with Link Margin Distribution','FontSize',12);
figname=[fname 'd'];
title([figname,', Distribution of SDARS Link Margin Degradation with Interference'])
saveas(h,figname,'jpg');
% Percentage of users affected by LM degradation in "N_delta_bins"
percent=100*Deltahist/(num_Sat*listen_prob);
%WCS_results.rhist2=rhist2

%  figure(6)
%  dbins=[0 3 6 9 12 15 20 30 40 50 100 150 200 250];
%  dd=find(Distances(:,:,2)<=200);
%  dhist=histc(Distances(:,:,2),dbins);
% % dd=find(Distances<9999999);
% % dhist=histc(Distances(dd),dbins);
% %bar(dbins,mean(dhist'))
%  bar(dbins,dhist)
%  xlabel('Separation Distance (m)');
%  ylabel('% of SDARS Population');
%  title('Distribution of SDARS - WCS Separation');



% figure(8)
% Distances2=Distances;
% nnn=find(Distances==9999999);
% Distances2(nnn)=0;
% mesh(Distances2(:,:,1))
% ylabel('SDARS Vehicles');
% xlabel('WCS Vehicles');
% zlabel('Distance (m)');
% title('Distance (m), NOT CORRECTED FOR CLOSE-IN VEHICLES');

% LM_bins=[-inf 0.1 5 10 15 20];
% h=histc(LM_OOB(:,:),LM_bins);
% mutes=round(mean(h(1,:)));


% Calculate the mean mutes (no remaining link margin) by summing all
% conditions where LM=0 on both links, and the dividing by the # of
% iterations.
mutes=round(length(find(LM_OOB(:,1,:)==0 & LM_OOB(:,2,:)==0))/Iter_cnt);
```

```
disp('Total Satellite Radio Receivers = ')
    disp(num_Sat)

    disp('Total WCS Vehicles= ')
    disp(num_WCS)

    disp('Baseline Quality of Service with No Interference (%) = ')
    disp(Q_base)

    disp('Mean percentage of SDARS receivers suffering link margin degradation >1dB= ')
    %disp(mean(sum(percent(3:length(N_delta_bins),:))))
    percent_floor_degraded=length(find(NI_delta>=1))/Iter_cnt/(num_Sat*listen_prob)*100;
    disp(percent_floor_degraded)

    disp('Mean percentage of SDARS receivers suffering link margin degradation >2dB = ')
    %disp(mean(sum(percent(3:length(N_delta_bins),:))))
    percent_2db=length(find(NI_delta> 2))/Iter_cnt/(num_Sat*listen_prob)*100;
    disp(percent_2db)

    disp('Mean percentage of SDARS receivers suffering link margin degradation >3dB = ')
    %disp(mean(sum(percent(3:length(N_delta_bins),:))))
    percent_3db=length(find(NI_delta> 3))/Iter_cnt/(num_Sat*listen_prob)*100;
    disp(percent_3db)


    %       disp('Mean number of SDARS receivers likely muted <90% Availability) due to WCS OOB = ')
     likely_mute=round(mean(sum(qhist(1:2,:))));
%       disp(likely_mute)

     disp('Mean percentage of SDARS receivers degraded to <99% Availability) due to WCS OOB = ')
     int99=100*((length(find(Qos_WCS(:,:)<99))/Iter_cnt)/(listen_prob*length(Qos_WCS(:,1))));
     disp(int99)


     disp('Mean percentage of SDARS receivers degraded to <98% Availability) due to WCS OOB = ')
     int98=100*((length(find(Qos_WCS(:,:)<98))/Iter_cnt)/(listen_prob*length(Qos_WCS(:,1))));
     disp(int98)


     disp('Mean number of SDARS receivers muted (0 dB Link Margin on Both Sats) =')
    disp(mutes)

    disp('Percentage of SDARS receivers muted due to WCS OOBE = ' )
%      mean_muted=100*mean(sum(qhist(1:2,:)))/num_Sat;
    mean_muted=100*mutes/(num_Sat*listen_prob);
%       disp(100*mean(sum(qhist(1:2,:)))/num_Sat)
    disp(mean_muted)

    disp('Number of points removed <3 meters from SDARS = ')
```

```
    disp(min_dist_count)

    disp('Total number of points computed = ')
    pts=size(Distances,1)*size(Distances,2)*size(Distances,3);
    disp(pts)

    disp('Percentage of removed points <3m= ')
    removed=100*min_dist_count/pts;%(size(Distances,1)*size(Distances,2)*size(Distances,3));
    disp(removed)




%Begin writing to file and storing session
  %summary=[Vehicle_volume,
Vehicle_speed,WCS_pen_rate,Sat_pen_rate,Roadway_len,num_Sat,num_WCS,activity, band_factor, d,
L_1meter, blocking_enable, block_mean, stdev,pwr_cntrl,max_pwr,
Poff,Phi,Pmid,Plo,percent_floor_degraded,likely_mute, mutes, min_dist_count,pts,removed]'


time=clock;
filenameo=filenameo(1:end-3);
filenameo=strcat(filenameo,'D',num2str(time(1)),'-',num2str(time(2)),'-
',num2str(floor(time(3))),'T',num2str(time(4)),'-',num2str(time(5)),'-',num2str(time(6)),'.xml');
fid2 = fopen( filenameo,'w');
fprintf(fid2,'<?xml version="1.0"?>\n');
fprintf(fid2,'<?mso-application progid="Excel.Sheet"?>\n');
fprintf(fid2,'<Workbook xmlns="urn:schemas-microsoft-com:office:spreadsheet"\n');
fprintf(fid2,'xmlns:o="urn:schemas-microsoft-com:office:office"\n');
fprintf(fid2,'xmlns:x="urn:schemas-microsoft-com:office:excel"\n');
fprintf(fid2,'xmlns:ss="urn:schemas-microsoft-com:office:spreadsheet"\n');
fprintf(fid2,'xmlns:html="http://www.w3.org/TR/REC-html40">\n');
fprintf(fid2,'<DocumentProperties xmlns="urn:schemas-microsoft-com:office:office">\n');
fprintf(fid2,'  <Author>Public</Author>\n');
fprintf(fid2,'  <LastAuthor>Public</LastAuthor>\n');
fprintf(fid2,'  <Created>2010-04-16T14:19:58Z</Created>\n');
fprintf(fid2,'  <LastSaved>2010-04-16T14:26:36Z</LastSaved>\n');
fprintf(fid2,'  <Company>Public</Company>\n');
fprintf(fid2,'  <Version>12.00</Version>\n');
fprintf(fid2,' </DocumentProperties>\n');
fprintf(fid2,' <ExcelWorkbook xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'  <WindowHeight>11640</WindowHeight>\n');
fprintf(fid2,'  <WindowWidth>18060</WindowWidth>\n');
fprintf(fid2,'  <WindowTopX>480</WindowTopX>\n');
fprintf(fid2,'  <WindowTopY>15</WindowTopY>\n');
fprintf(fid2,'  <ProtectStructure>False</ProtectStructure>\n');
fprintf(fid2,'  <ProtectWindows>False</ProtectWindows>\n');
fprintf(fid2,' </ExcelWorkbook>\n');
fprintf(fid2,'<Styles>\n');
fprintf(fid2,'  <Style ss:ID="Default" ss:Name="Normal">\n');
fprintf(fid2,'   <Alignment ss:Vertical="Bottom"/>\n');
fprintf(fid2,'   <Borders/>\n');
fprintf(fid2,'  <Font ss:FontName="Calibri" x:Family="Swiss" ss:Size="11" ss:Color="#000000"/>\n');
```

```
fprintf(fid2,'  <Interior/>\n');
fprintf(fid2,'  <NumberFormat/>\n');
fprintf(fid2,'   <Protection/>\n');
fprintf(fid2,'  </Style>\n');
fprintf(fid2,'  <Style ss:ID="s74">\n');
fprintf(fid2,'   <NumberFormat ss:Format="0%%"/>\n');
fprintf(fid2,'  </Style>\n');
fprintf(fid2,'  <Style ss:ID="s75">\n');
fprintf(fid2,'   <NumberFormat ss:Format="Fixed"/>\n');
fprintf(fid2,'  </Style>\n');
fprintf(fid2,' </Styles>\n');

%start first worksheet
fprintf(fid2,' <Worksheet ss:Name="Summary results">\n');
fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(2),'" ss:ExpandedRowCount="',num2str(13),'"
x:FullColumns="1"\n'));
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Total Satellite Radio Receivers </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(num_Sat),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Total WCS Vehicles </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(num_WCS),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Baseline Quality of Service with No Interference (%%)
</Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(Q_base),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean percentage of SDARS receivers suffering link margin
degradation greater than 1dB </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(percent_floor_degraded),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean percentage of SDARS receivers suffering link margin
degradation greater than 2dB </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(percent_2db),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean percentage of SDARS receivers suffering link margin
degradation greater than 3dB </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(percent_3db),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean percentage of SDARS receivers degraded to less than 99%%
Availability) due to WCS OOB </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(int99),'</Data></Cell>\n');
```

```
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean percentage of SDARS receivers degraded to less than 99%%
Availability) due to WCS OOB </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(int98),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Mean number of SDARS receivers muted (0 dB Link Margin on Both
Sats) </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(mutes),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Percentage of SDARS receivers muted due to WCS OOBE
</Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(mean_muted),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Number of points removed less than 3 meters from SDARS
</Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(min_dist_count),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Total number of points computed </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(pts),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">"Percentage of removed points less than 3m </Data></Cell>\n');
xmlline=strcat('    <Cell ss:StyleID="s74"><Data ss:Type="Number">',num2str(removed/100),'</Data></Cell>\n');
fprintf(fid2,xmlline);
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'  </Table>\n');
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
fprintf(fid2,'   <Selected/>\n');
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');

fprintf(fid2,' <Worksheet ss:Name="S1">\n');
fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(length(pwr_bins)+1),'"
ss:ExpandedRowCount="',num2str((Iter_cnt)+2),'" x:FullColumns="1"\n'));
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
```

```
fprintf(fid2,'    <Cell><Data ss:Type="String">Distribution of WCS received OOB at SDARS Receivers on
Roadway</Data></Cell>\n');
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,strcat('    <Cell><Data ss:Type="String">Received Power (dBm)</Data></Cell>\n'));
for i=1:length(pwr_bins)
   xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(pwr_bins(i)),'</Data></Cell>\n');
   fprintf(fid2,xmlline);
end
fprintf(fid2,'   </Row>\n');
for j=1:Iter_cnt
   fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
   fprintf(fid2,strcat('    <Cell><Data ss:Type="String"># of SDARS Receiver Affected
iter',num2str(j),'</Data></Cell>\n'));
   for i=1:length(pwr_bins)
      xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(rhist(i,j)),'</Data></Cell>\n');
      fprintf(fid2,xmlline);
   end
   fprintf(fid2,'   </Row>\n');
end
%end worksheet
fprintf(fid2,'  </Table>\n');
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
fprintf(fid2,'   <Selected/>\n');
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');

fprintf(fid2,' <Worksheet ss:Name="S2">\n');
fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(length(pwr_bins)+1),'"
ss:ExpandedRowCount="',num2str((Iter_cnt)+2),'" x:FullColumns="1"\n'));
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Distribution of WCS received OOB at SDARS Receivers on
Roadway, Compensated for Activity</Data></Cell>\n');
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Received Power (dBm)</Data></Cell>\n');
for i=1:length(pwr_bins)
   xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(pwr_bins(i)),'</Data></Cell>\n');
   fprintf(fid2,xmlline);
end
fprintf(fid2,'   </Row>\n');
for j=1:Iter_cnt
   fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
   fprintf(fid2,strcat('    <Cell><Data ss:Type="String"># of SDARS Receiver Affected
iter',num2str(j),'</Data></Cell>\n'));
   for i=1:length(pwr_bins)
      xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(rhist2(i,j)),'</Data></Cell>\n');
```

```
        fprintf(fid2,xmlline);
    end
    fprintf(fid2,'   </Row>\n');
end

%end worksheet
fprintf(fid2,'  </Table>\n');
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
fprintf(fid2,'   <Selected/>\n');
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');

fprintf(fid2,' <Worksheet ss:Name="S3">\n');
fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(length(Q_bins)+1),'"
ss:ExpandedRowCount="',num2str(Iter_cnt+2),'" x:FullColumns="1"\n'));
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Distribution of SDARS QoS Levels with
Interference</Data></Cell>\n');
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Signal Availability (%%)</Data></Cell>\n');
for i=1:length(Q_bins)
    xmlline=strcat('    <Cell ss:StyleID="s74"><Data
ss:Type="Number">',num2str(Q_bins(i)/100),'</Data></Cell>\n');
    fprintf(fid2,xmlline);
end
fprintf(fid2,'   </Row>\n');
for j=1:Iter_cnt
    fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
    fprintf(fid2,strcat('    <Cell><Data ss:Type="String"># of SDARS Receiver @QoS Level
iter',num2str(j),'</Data></Cell>\n'));
    for i=1:length(Q_bins)
        xmlline=strcat('    <Cell ss:StyleID="s75"><Data ss:Type="Number">',num2str(qhist(i,j)),'</Data></Cell>\n');
        fprintf(fid2,xmlline);
    end
    fprintf(fid2,'   </Row>\n');
end

fprintf(fid2,'  </Table>\n');
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
```

```
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');



fprintf(fid2,' <Worksheet ss:Name="S4">\n');
if(length(qdelta(:,1))~=1) fprintf(fid2,strcat('  <Table
ss:ExpandedColumnCount="',num2str(length(Q_delta_bins)+1),'" ss:ExpandedRowCount="',
num2str(Iter_cnt+2),'" x:FullColumns="1"\n'));
else fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(length(Q_delta_bins)+1),'"
ss:ExpandedRowCount="3" x:FullColumns="1"\n'));
end
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');



fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Distribution of SDARS QoS Deltas with
Interference</Data></Cell>\n');
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Signal Availability (%%) Difference)</Data></Cell>\n');
for i=1:length(Q_delta_bins)
    xmlline=strcat('<Cell ss:StyleID="s74"><Data
ss:Type="Number">',num2str(Q_delta_bins(i)/100),'</Data></Cell>\n');
    fprintf(fid2,xmlline);
end

fprintf(fid2,'   </Row>\n');

if(length(qdelta(:,1))~=1)
   for j=1:length(qdelta(1,:))
        fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
        fprintf(fid2,strcat('    <Cell><Data ss:Type="String"># of SDARS Receiver @QoS Delta Level
iter',num2str(j),'</Data></Cell>\n'));
        for i=1:length(Q_delta_bins)
            xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(qdelta(i,j)),'</Data></Cell>\n');
            fprintf(fid2,xmlline);
        end
        fprintf(fid2,'   </Row>\n');
    end
else
    fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
    for i=1:length(Q_delta_bins)
            xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(qdelta(i)),'</Data></Cell>\n');
            fprintf(fid2,xmlline);
    end
     fprintf(fid2,'   </Row>\n');
end

%end worksheet
fprintf(fid2,'  </Table>\n');
```

```
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');



fprintf(fid2,' <Worksheet ss:Name="S5">\n');
fprintf(fid2,strcat('  <Table ss:ExpandedColumnCount="',num2str(length(N_delta_bins)+1),'"
ss:ExpandedRowCount="', num2str(Iter_cnt+2),'" x:FullColumns="1"\n'));
fprintf(fid2,'   x:FullRows="1" ss:DefaultRowHeight="15">\n');


fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Distribution of SDARS Link Margin Degradation with
Interference</Data></Cell>\n');
fprintf(fid2,'   </Row>\n');
fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
fprintf(fid2,'    <Cell><Data ss:Type="String">Link Margin Impact from Nominal (dB)</Data></Cell>\n');
for i=1:length(N_delta_bins)
    xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(N_delta_bins(i)),'</Data></Cell>\n');
    fprintf(fid2,xmlline);
end

fprintf(fid2,'   </Row>\n');

for j=1:Iter_cnt
    fprintf(fid2,'   <Row ss:AutoFitHeight="0">\n');
    fprintf(fid2,strcat('    <Cell><Data ss:Type="String">Link Margin Delta Distribution
iter',num2str(j),'</Data></Cell>\n'));
    for i=1:length(N_delta_bins)
        xmlline=strcat('    <Cell ss:StyleID="s75"><Data
ss:Type="Number">',num2str(Deltahist(i,j)),'</Data></Cell>\n');
        fprintf(fid2,xmlline);
    end
    fprintf(fid2,'   </Row>\n');
end


%end worksheet
fprintf(fid2,'  </Table>\n');
fprintf(fid2,'  <WorksheetOptions xmlns="urn:schemas-microsoft-com:office:excel">\n');
fprintf(fid2,'   <PageSetup>\n');
fprintf(fid2,'    <Header x:Margin="0.3"/>\n');
fprintf(fid2,'    <Footer x:Margin="0.3"/>\n');
fprintf(fid2,'    <PageMargins x:Bottom="0.75" x:Left="0.7" x:Right="0.7" x:Top="0.75"/>\n');
```

```
fprintf(fid2,'   </PageSetup>\n');
fprintf(fid2,'   <Unsynced/>\n');
fprintf(fid2,'   <ProtectObjects>False</ProtectObjects>\n');
fprintf(fid2,'   <ProtectScenarios>False</ProtectScenarios>\n');
fprintf(fid2,'  </WorksheetOptions>\n');
fprintf(fid2,' </Worksheet>\n');

fprintf(fid2,'</Workbook>\n');
fclose(fid2);

fid = fopen('Simulation_results.xml','r');
fid3 = fopen('dummy.xml','w');
for i=1:174
   xmlline=fgetl(fid);
   fprintf(fid3,'%s\n',xmlline);
end
xmlline=fgetl(fid);
if(xmlline(35)=='"')
   col=str2num(xmlline(34));
   xmlline=strcat(xmlline(1:33),num2str(col+1),xmlline(35:end));
elseif(xmlline(36)=='"')
   col=str2num(xmlline(34:35));
   xmlline=strcat(xmlline(1:33),num2str(col+1),xmlline(36:end));
elseif(xmlline(37)=='"')
   col=str2num(xmlline(34:36));
   xmlline=strcat(xmlline(1:33),num2str(col+1),xmlline(37:end));
end
fprintf(fid3,'%s\n',xmlline);
xmlline=fgetl(fid);
fprintf(fid3,'%s\n',xmlline);
xmlline=fgetl(fid);
fprintf(fid3,'%s\n',xmlline);
for i=1:38
   for j=1:col
      xmlline=fgetl(fid);
      fprintf(fid3,'%s\n',xmlline);
   end
   xmlline=fgetl(fid);
   switch i
      case {1}
         xmlline2=xmlline;%do nothing
      case {2}
%           if(col<10)
%              xmlline2=strcat(xmlline(1:50),num2str(col-1),xmlline(52:end));
%           elseif(col<100)
%              xmlline2=strcat(xmlline(1:50),num2str(col-1),xmlline(53:end));
%           else
%              xmlline2=strcat(xmlline(1:50),num2str(col-1),xmlline(54:end));
%           end
         xmlline2=strcat(xmlline(1:50),num2str(col-1),xmlline(52:end));
      case {3}
         xmlline2=strcat(xmlline(1:50),city,xmlline(52:end));
      case {4}
         xmlline2=strcat(xmlline(1:50),num2str(Vehicle_volume),xmlline(52:end));
      case {5}
```

```
        xmlline2=strcat(xmlline(1:50),num2str(Vehicle_speed),xmlline(52:end));
    case {6}
        xmlline2=strcat(xmlline(1:50),num2str(WCS_pen_rate),xmlline(52:end));
    case {7}
        xmlline2=strcat(xmlline(1:50),num2str(Sat_pen_rate),xmlline(52:end));
    case {8}
        xmlline2=strcat(xmlline(1:50),num2str(Roadway_len),xmlline(52:end));
    case {9}
        xmlline2=strcat(xmlline(1:50),num2str(num_lanes),xmlline(52:end));
    case {10}
        xmlline2=strcat(xmlline(1:50),num2str(num_Sat),xmlline(52:end));
    case {11}
        xmlline2=strcat(xmlline(1:50),num2str(num_WCS),xmlline(52:end));
    case {12}
        xmlline2=strcat(xmlline(1:50),num2str(activity),xmlline(52:end));
    case {13}
        xmlline2=strcat(xmlline(1:50),num2str(listen_prob),xmlline(52:end));
    case {14}
        xmlline2=strcat(xmlline(1:50),num2str(duty_cycle),xmlline(52:end));
    case {15}
        xmlline2=strcat(xmlline(1:50),num2str(band_factor),xmlline(52:end));
    case {16}
        xmlline2=strcat(xmlline(1:50),num2str(OOB_mask1+13),xmlline(52:end));
    case {17}
        xmlline2=strcat(xmlline(1:50),num2str(OOB_mask2+13),xmlline(52:end));
    case {18}
        xmlline2=strcat(xmlline(1:50),num2str(OOB_mask3+13),xmlline(52:end));
    case {19}
        xmlline2=strcat(xmlline(1:50),num2str(max_pwr),xmlline(52:end));
    case {20}
        if(pwr_cntrl==0)
            xmlline2=strcat(xmlline(1:50),'OFF',xmlline(54:end));
        else
            xmlline2=strcat(xmlline(1:50),'ON',xmlline(54:end));
        end
    case {21}
        xmlline2=strcat(xmlline(1:50),num2str(d),xmlline(52:end));
    case {22}
        xmlline2=strcat(xmlline(1:50),num2str(block_mean),xmlline(52:end));
    case {23}
        xmlline2=strcat(xmlline(1:50),num2str(stdev),xmlline(52:end));
    case {24}
        xmlline2=strcat(xmlline(1:50),num2str(LM_S1),xmlline(52:end));
    case {25}
        xmlline2=strcat(xmlline(1:50),num2str(EL_S1),xmlline(52:end));
    case {26}
        xmlline2=strcat(xmlline(1:50),num2str(LM_S2),xmlline(52:end));
    case {27}
        xmlline2=strcat(xmlline(1:50),num2str(EL_S2),xmlline(52:end));
    case {28}
        xmlline2=strcat(xmlline(1:50),num2str(Q_base/100),xmlline(52:end));
    case {29}
        xmlline2=strcat(xmlline(1:50),num2str(min_dist_count),xmlline(52:end));
    case {30}
        xmlline2=strcat(xmlline(1:50),num2str(pts),xmlline(52:end));
    case {31}
```

```
            xmlline2=strcat(xmlline(1:50),num2str(removed/100),xmlline(52:end));
        case {32}
            xmlline2=strcat(xmlline(1:50),num2str(percent_floor_degraded/100),xmlline(52:end));
        case {33}
            xmlline2=strcat(xmlline(1:50),num2str(percent_2db/100),xmlline(52:end));
        case {34}
            xmlline2=strcat(xmlline(1:50),num2str(percent_3db/100),xmlline(52:end));
        case {35}
            xmlline2=strcat(xmlline(1:50),num2str(int99/100),xmlline(52:end));
        case {36}
            xmlline2=strcat(xmlline(1:50),num2str(int98/100),xmlline(52:end));
        case {37}
            xmlline2=strcat(xmlline(1:50),num2str(mutes),xmlline(52:end));
        case {38}
            xmlline2=strcat(xmlline(1:50),num2str(mean_muted/100),xmlline(52:end));

%    case {'linear','bilinear'}
%       disp('Method is linear')
%    case 'cubic'
%       disp('Method is cubic')
%    case 'nearest'
%       disp('Method is nearest')
%    otherwise
%       disp('Unknown method.')
    end

    fprintf(fid3,'%s\n',xmlline2);
    fprintf(fid3,'%s\n',xmlline);
    xmlline=fgetl(fid);
    fprintf(fid3,'%s\n',xmlline);
end

for i=1:19
    xmlline=fgetl(fid);
    fprintf(fid3,'%s\n',xmlline);
end
fclose(fid);
delete('Simulation_results.xml');
%delete('summary_page_test.xml');
fclose(fid3);
copyfile('dummy.xml','Simulation_results.xml');
pause(5);
delete('dummy.xml');

filenameo=filenameo(1:end-3);
%save(strcat(filenameo,'.mat'));

save(fname);

pause(10);
end % q
copyfile('Simulation_results.xml',strcat(city,'_Summary_Simulation_results.xml'));
delete('Simulation_results.xml');
pause(5);
```