September 18, 2008

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

R**e: GE Healthcare *Ex Parte***
ET Docket No. 08-59

Dear Ms. Dortch:

GE Healthcare ("GEHC") hereby provides additional information regarding its Medical Body Area Networks Service ("MBANS") proposal in the above-referenced proceeding and responds to comments and *ex parte* statements made by the Aerospace & Flight Test Radio Coordinating Council ("AFTRCC") in response to the proposal.

On December 27, 2007, GEHC submitted a comprehensive MBANS proposal, which included preliminary suggestions for detailed changes to the Part 95 rules.[1] While the proposal was comprehensive and generally well conceived, GEHC nevertheless viewed it as a starting point and fully expected that it would be further vetted and refined via the rulemaking process and through constructive cooperation with incumbents and other interested parties. Moreover, as GEHC has learned more about the concerns of aeronautical mobile telemetry ("AMT") operators, it has signaled a willingness to adopt reasonable modifications to its initially proposed rules to accommodate legitimate incumbent concerns and produce more-effective service rules for MBANS.

GEHC is deeply disappointed that its good-faith efforts to understand and accommodate technical concerns raised by AMT incumbents are now being used by those same incumbents to argue for a premature dismissal of the MBANS proposal. AFTRCC, in stark contrast to other incumbents such as Amateur Radio, has clearly decided to take a "Dog in the Manger" position with respect to the MBANS proposal, presenting many unrealistic and misleading arguments that do not withstand scrutiny. As a result, GEHC takes this opportunity to address AFTRCC's statements in detail.

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[1] *Ex Parte* filing by GE Healthcare, ET Docket No. 06-135 (filed Dec. 27, 2007).

1. GEHC Expects that the Most Widespread Use of MBANS Devices will be in Hospitals and Healthcare Facilities.

In its July 28 ex parte comments, AFTRCC questioned the scope of the MBANS proposal and the use of body sensor networks ("BSNs"):

> [S]eemingly, [GEH's] deployment plan is changing: Consistently to this point, GEH has maintained that it intends its devices to be cheap enough to be disposable, and used wherever patients need monitoring: At home, at work, at school, etc. This still seems to be the case.
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> Yet, in the Reply GEH also seems to suggest that BSN use be confined to hospitals or other health care facilities. For example, at page 14 GEH states that "[w]hile GEHC initially proposed that [BSN] device use not be restricted to health care facilities, the most important, safety critical and highest density uses of the devices would be in hospitals." Neither AFTRCC, other interested parties, nor the Commission itself, can be certain just what it is for which GEH seeks a major spectrum allocation.[2]

To erase any doubt about the need for and benefit of an MBANS allocation, GEHC emphasizes, once again, that the most important, immediate, and widespread use of MBANS devices would be in hospitals and healthcare facilities (*e.g.*, managed care facilities, clinics).[3] The need for MBANS devices in those locations – and the tremendous public benefits that would accrue – is more than sufficient to warrant creation of the MBANS service.

2. An Additional Spectrum Allocation for MBANS is in the Public Interest.

AFTRCC questions whether there is a need for additional spectrum for MBANS devices:

> While the Proponent argues for the benefits of BSNs, substitute technologies are available such as Wireless Medical Telemetry Service ("WMTS") monitors and legacy Part 15 devices. Likewise, Holter and other direct-wired, but portable monitors allow for patient mobility and recording.
>
> By contrast, there is no substitute for real-time flight test telemetry. The aeronautical mobile telemetry ("AMT") enabled by the S-band allocation at issue here has been and will remain in the critical path for aircraft development and production, as well as for demonstrating compliance with certification

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[2] *Ex Parte* filing by AFTRCC, ET Docket No. 08-59, 1-2 (filed Jul. 28, 2008) ("AFTRCC July *Ex Parte*").

[3] GEHC's initially proposed rules actually anticipated a two-tier allocation with an inner and outer channel set the former being limited to hospital use. This would provide additional bandwidth to help ensure adequate capacity for hospitals where MBANS usage density will without a doubt be highest and would lend itself to geographic and frequency coordination with primary users like AMT and radio astronomy, much like WMTS is coordinated with government radar and radio astronomy today.

> requirements imposed by other agencies of the Federal Government including the Federal Aviation Administration and Department of Defense.[4]

GEHC has previously explained in detail the reasons why there is currently no suitable spectrum available for the next generation of low-power, short-range medical devices such as the devices that would be made possible under the proposed MBANS rules.[5] Moreover, Holter and other direct-wired, portable monitors are not a substitute for wireless BSNs or the other short range wireless medical devices that would be enabled by MBANS. Such monitors do not offer benefits (such as monitoring parameter flexibility, increased care efficiency, patient comfort and safety, and infection control, among other benefits) that are associated with wireless monitoring.

Despite having tens of thousands of users, special purpose medical spectrum (WMTS and Medical Implant Communications Service, or "MICS") currently totals only 19 MHz scattered over four disjointed spectrum bands from 400-1432 MHz, all of which is not available in any one location. By contrast, despite having only a tiny fraction of the users, AMT has a total of 150 MHz allocated to it[6]—most of it on an exclusive primary basis. This is a truly remarkable amount of spectrum to be exclusively allocated for a handful of part-time users that are tightly clustered in a few select areas of the United States. It is not in the public interest for this much spectrum to be left lying fallow in the majority of the United States at any time (and, in fact, 100 percent of the time over much of the U.S) when a compelling and compatible use such as MBANS exists.

GEHC also emphasizes further that MBANS – and its accompanying devices and applications – is distinct from wireless medical telemetry. Thus, contrary to AFTRCC's statements,[7] there is no conflict between GEHC's MBANS proposal and its statements regarding the WMTS that no additional secondary WMTS designations are necessary at this time. While it may seem natural to characterize BSNs and other short-range wireless medical devices that would be allowed by MBANS as "medical telemetry," they in fact, represent wholly separate applications. "Medical telemetry" is a specific term of art in the health care field referring to the acquisition devices and associated infrastructures used to allow patient physiological parameters (typically ECG) to be monitored

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[4] AFTRCC July *Ex Parte* at 2.

[5] *See* Comments of GE Healthcare, ET Docket No. 06-135, at 7-11 (filed Oct. 31, 2006).

[6] In addition to the 35 MHz primary 2360-2395 MHz allocation at issue here, Part 87 provides AMT an additional primary allocation of 90 MHz at 1435-1525 MHz as well as a secondary allocation of 25 MHz within 2130-2320 and 2345-2360 MHz. AMT will also benefit from WRC-07's allocation of an additional 1374 MHz of additional bandwidth within 4400-4940 MHz, 5091-5150 MHz and 5925-6700 MHz band, as described by http://www.telemetryspectrum.org/docs/Extract_Final_Acts_Prov.pdf (last accessed Sept. 3, 2008).

[7] AFTRCC July *Ex Parte* at 4-6.

wirelessly over a predetermined, fixed and relatively large "coverage area" throughout a medical facility. The Commission has acknowledged this distinction by issuing the MedRadio NPRM/NOI that proposed to expand the current Part 95 MICS rules to allow short-range, body-worn devices (including physiological monitoring devices), proposing to allocate 2 MHz of additional spectrum for such devices, and seeking comment on additional body-worn applications that may require the creation of further service rules and spectrum allocations, all while reaffirming the Commission's policy against allocating additional spectrum for traditional medical telemetry applications:

> "...the medical community also uses basic telemetry transmission for many other communications purposes, but these uses are distinct in their needs and means of accommodation. We do not seek comment here on operations permitted by the wireless medical telemetry service (WMTS) under Part 95 of our Rules."[8]

In addition, traditional medical telemetry typically employs unidirectional FDMA channelized technology, and GEHC does not believe that a secondary allocation is appropriate for such legacy technology. By contrast, bidirectional, frequency-agile technology, which would be required for MBANS devices under the proposed rules, makes a secondary allocation extremely viable.[9]

3. The MBANS Proposal Continues to Gain Support From Interested Parties.

GEHC is very pleased that its MBANS proposal has recently gained the support of the IEEE 802.15 Task Group 6, Body Area Networks, reflecting the broad industry interest in developing standards and products that would take advantage of the MBANS allocation. GEHC is also pleased that the proposal currently under development by ETSI ERM TG30 – Medical Devices (TR102 655) has independently identified the 2360 to 2400 MHz band as a candidate band. Coupled with the availability of low-cost 2.4 GHz radiofrequency components, this decision bodes very well for international harmonization and economies of scale that will make MBANS a success. Although AFTRCC (referring to Nordic Semiconductor) is quick to point out that "the maker of one of the chips GEH has proposed to rely upon recommends against its use in applications like this,"[10] GEHC looks forward to components being offered from

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[8] *Investigation of the Spectrum Requirements for Advanced Medical Technologies, Notice of Proposed Rulemaking*, Notice of Inquiry and Order, 21 FCC Rcd 8164 ¶ 5 (rel. Jul. 18, 2006).

[9] GEHC also disputes AFTRCC's characterization that "[GEHC] argues that technological developments (such as diversity, frequency agility, and contention-based protocols) render the policy not to allocate additional spectrum for medical telemetry, overly restrictive." AFTRCC July *Ex Parte* at 6. GEHC has not made any statements regarding the Commission's policy against additional allocations for medical telemetry.

[10] *Ex Parte* filing by AFTRCC, ET Docket No. 08-59, slide 7 (filed Aug. 15, 2008) ("AFTRCC August 15 *Ex Parte*").

multiple vendors, including Texas Instruments,[11] which supports the MBANS proposal.

4. The AMT Spectrum is Sparsely Utilized, and MBANS and AMT Operations can Coexist Easily.

The AMT Spectrum is Sparsely Utilized. By any objective measure, the spectrum currently allocated to AMT in the 2360-2395 MHz band is extremely sparsely utilized over time, frequency and geography. A 2004-2005 study by the Shared Spectrum Company ("SSC") conducted for the National Science Foundation, for example, found that the 2360-2390 MHz band was largely fallow.[12]

Although GEHC does not question the value of AMT to its users, it has pointed out several references in open literature demonstrating that, contrary to the stark picture painted by AFTRCC, alternatives do exist that augment, complement and mitigate the failures of AMT.[13] In fact, alternatives such as on-board recording seem to be *preferred* to telemetry for a significant amount of critical data on aircrafts large enough to accommodate the logging equipment, which is undoubtedly shrinking in cost, size and power consumption over time.[14] In addition, AFTRCC itself has admitted that more reliable and spectrally efficient two-way technologies are on the horizon[15] and that the very sparse licensing of S-band spectrum (only 32 of 157 AMT sites hold any S-band licenses, and 30 of those 32 sites use an average of only 2.5 out of 34 available S-band channels) belies AFTRCC's argument that the existing S-band is already being used to capacity and thus these emerging technologies will be used only to telemeter more data and not to improve AMT link reliability or enable use of less spectrum.[16]

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[11] *See* Comments of Texas Instruments, ET Docket No. 08-59, 1 (filed May 27, 2008) ("TI supports the allocation of additional spectrum for medical devices. In particular, TI supports allocation of the 2360–2400 MHz band for innovative medical applications, including body sensor networks (BSNs).").

[12] *See* Spectrum Occupancy Measurements, Shared Spectrum Company, *at* http://www.sharedspectrum.com/measurements/ and http://www.sharedspectrum.com/measurements/download/NSF_Chicago_2005-11_measurements_v12.pdf. The study, which considered seven locations across the United States, found that the 2360-2390 MHz band was only 6.31% and 0.02% utilized in two locations and 0% utilized in the other five locations, amounting to only a 2.5% observation-time-weighted average utilization for the seven locations overall. *Id.*

[13] *See, e.g.*, Reply Comments of GE Healthcare, ET Docket No. 08-59, at 16-17 (filed Jun. 11, 2008) ("GEHC Reply Comments").

[14] *See id.*

[15] AFTRCC July *Ex Parte* at 7.

[16] *See id.* at 2, 4, 7.

AFTRCC also has not refuted GEHC's statements that military flight test applications (occurring on remote military sites) are the primary demand driver for aeronautical telemetry spectrum.[17] Furthermore, AFTRCC's comments regarding the proximity of some government test sites to populated areas[18] are misleading, given comments made by the aeronautical telemetry community to the ITU Radiocommunication Study Group 8B:

> Testing of aircraft in the US is conducted at remote inland sites (Nevada, the California deserts, Washington State, and Montana, to name a few), as well as offshore, over the Atlantic and Pacific Oceans as well as the Gulf of Mexico . . . even though flight tests are typically conducted over sparsely populated areas, flights originate from flight test centers such as Panama City, Florida; Wichita, Kansas; Seattle, Washington; and St. Louis, Missouri.
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> Flight tests are already conducted subject to numerous "keep-out" zones. This is true, for example, at Atlantic Coast ranges that are not far from metropolitan areas such as Washington, D.C. or Baltimore, Maryland. Flight testing at these ranges is conducted towards the east, over the Ocean. For ranges in the Southwestern United States, flight tests are conducted away from populated areas like Los Angeles. [19]

These comments demonstrate that the overwhelming amount of AMT operations occur away from densely populated areas.

AFTRCC is also incorrect when it states that "[t]he combination of flight testing and BSNs in proximity will mean no vacant spectrum – especially for hospital use where BSN density would be highest."[20] In addition to the sparse utilization of S-band frequencies among the minority of AMT sites that conduct S-band operations, and the fact that many AMT operations are being conducted at remote locations or otherwise away from population centers, spectrum is available for sharing due to AMT's recommended practices of channel separation and edge of band separation. In its Telemetry Standard,[21] the Range Commanders Council ("RCC") defines a minimum frequency separation between AMT operations as a function of the bit rate and modulation type employed. Examples are given showing frequency separation between AMT operations of 6 to 11 MHz. In addition, the RCC Telemetry Standard addresses the amount of separation

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[17] *See* GEHC Reply Comments at 16-17.

[18] *See* AFTRCC July *Ex Parte* at 3 ("The Reply asserts that Government test sites are 'located at some distance from populated areas.' However, a number of Government receive sites are proximate to population centers. These include places like Eglin and Tyndall Air Force Bases in the Florida Panhandle; Patuxent River Naval Air Test Center near Baltimore and Washington; and Point Magu Naval Air Test Center at Oxnard, CA in the densely populated area just north of Los Angeles, to name a few.").

[19] Response to the Liaison Statement From WP-8D Concerning Sharing Between Aeronautical Mobile Telemetry and GSO MSS Systems, United States of America, Document 8B/283-E, International Telecommunications Union Radiocommunication Study Groups (Sept. 6, 2002).

[20] AFTRCC August 15 *Ex Parte* at slide 7.

[21] Telemetry Standard RCC Document 106-07, Appendix A, page A-4 (September 2007).

required between the center frequency of AMT signals and the band edges.[22] Example calculations for 1 Mbps telemetry operation show 1 to 2.5 MHz spacing between AMT carrier frequencies and the 2360-2395 MHz band edges. These frequency separations represent fallow AMT spectrum that could be utilized by MBANS devices.[23]

MBANS and AMT Operations Can Coexist Easily. AFTRCC's technical concerns significantly exaggerate the potential for harmful interference to AMT operations from MBANS devices, particularly when spectrum-efficient technologies, such as unrestricted, contention-based protocols, are used in conjunction with MBANS. In addition, to further ensure that MBANS devices do not cause harmful interference to AMT operations, GEHC supports the use of geographic exclusion zones, coordination, and registration around existing AMT test sites within which MBANS devices would be prohibited from operating.

AMT to MBANS Interference Concerns**.** AFTRCC asserts that a 10 kilometer separation distance would be required between a flight test aircraft and an MBANS device in order to avoid interference to the MBANS device.[24] Again, these comments by AFTRCC reveal a fundamental lack of understanding of how MBANS devices would function. The 10 kilometer separation cited from GEHC's comments is the distance at which an AMT transmitter might preclude *co-channel* operation by an MBANS device. However, AMT operations at less than a 10 kilometer-separation from MBANS devices would still not cause harmful interference to the MBANS operations because the opportunistic, frequency agile MBANS devices would be designed to autonomously select a different, clear frequency from within the 40 MHz allocation. Again, there is ample precedent for such devices operating robustly on an autonomous, opportunistic basis, including operations in the 5 GHz U-NII and MICS bands.[25]

AFTRCC also mentions that "technologies are being developed that will enable flight test operators to make even more efficient use of [AMT] spectrum resources by dynamically controlling test bandwidth from the ground,"[26] and that these technologies contemplate the use of high-power transmissions that "will cause destructive co-channel interference for any BSN within line of sight of the AMT omnidirectional transmit antenna, whether the BSN is located indoors or outdoors**."**[27] As an initial matter, GEHC points out that no AMT uplink

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[22] *Id.* at page A-28.

[23] Frequency coordination of MBANS operations would further enable the utilization of AMT channel separation gaps.

[24] *Ex Parte* filing by AFTRCC, ET Docket No. 08-59, 8 (filed Jun. 11, 2008) ("AFTRCC June 11 *Ex Parte*").

[25] *See* 47 C.F.R. §§ 15.407; 95.628.

[26] AFTRCC July *Ex Parte* at 7.

[27] *Id*.

operations are currently occurring and no concrete timetable has been established for such operations. More importantly, however, GEHC notes that the same mechanisms, including contention-based protocols and frequency agility, that would make MBANS devices robust to interference from downlink AMT and other incumbent services would enable MBANS devices to operate reliably in the proximity of AMT uplink transmissions such as the "iNet" transmissions described by AFTRCC. Since these transmissions would occupy only a portion of the AMT/MBANS spectrum, remaining spectrum would still be available in which the opportunistic, frequency-agile MBANS devices could operate (including the 5 MHz block of spectrum in the 2395-2400 MHz band in which AMT is not authorized). In fact, if these uplink signals become universal, they might even serve as a useful beacon that could be exploited by MBANS devices as another method of ensuring coexistence with AMT.[28]

Geographic Exclusion Zones, Coordination, and Registration. GEHC does not believe that MBANS devices operating under the proposed rules would pose a risk of harmful interference to AMT operations. In a good-faith attempt to advance the MBANS proposal, however, GEHC proposes the use of limited geographic exclusion zones around the 157 existing AMT test sites.[29] The exclusion zones would pertain to the 2360-2390 MHz band, where GEHC understands that, with the exception of the Wichita, Kansas area, all S-Band AMT operations occur. Under this approach, MBANS devices would have secondary access to the 2360-2390 MHz band outside of the exclusion zones[30] and would have secondary access to the 2390-2400 MHz band nationwide.[31]

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[28] GEHC also observes that omnidirectional transmission of hundreds of watts or more would seem to be strikingly incompatible with the stringent PFD standards AFTRCC seeks to apply to MBANS devices to arrive at the conclusion that a single 1mW MBANS device outdoors would interfere with AMT receive operations at a distance of over 60 km.

[29] GEHC notes that only a small minority of AMT test sites currently operate using S-Band spectrum. Nevertheless, for simplicity's sake and to make provisions for AMT sites that may wish to operate over S-Band frequencies in the future, GEHC proposes that the exclusion zones apply to all AMT test sites.

[30] In its comments AFTRCC pointed out that GEHC's proposed footnote to the Table of Allocations, NG 186, could be construed to prohibit currently-permitted AMT operations in the 2370-2390 MHz band. To be clear, the proposed NG 186 language was intended merely to prohibit aeronautical mobile use of MBANS devices in order to protect radio astronomy operations in that band. It was not intended to apply to existing AMT operations. To clarify this, and to reflect the exclusion zones, GEHC proposes the following revised text for NG 186:

NG186: The 2360-2400 MHz band is allocated on a secondary basis for non-Federal mobile use for Medical Body Area Network Service (MBANS) operations. MBANS mobile and MBANS aeronautical mobile uses are prohibited in the 2360-2390 MHz band. MBANS stations are authorized by rule on the condition that they do not cause harmful interference to, and must accept interference from, stations authorized to operate on a primary basis.

[31] If necessary, the Commission also could adopt a geographic exclusion zone for the Witchita AMT test site that extends to the 2390-2400 MHz band.

As a further means of narrowing the issues in dispute in this proceeding, GEHC also supports limiting the use of MBANS devices operating in the 2360-2390 MHz band to certain fixed locations (*e.g.*, health care facilities, managed care facilities). Thus, although MBANS operations would be licensed by rule, the Commission could require frequency coordination and device registration for 2360-2390 MHz MBANS operations akin to that used successfully in WMTS.[32] Such coordination could involve, for example, a query of a database that included all AMT sites and frequencies in use by AMT along with a data submission similar to that used for WMTS registration (*e.g.*, location of the health care facility, a point of contact, number of transmitters in use). Under this approach, AMT operators and the Commission would be able to identify the source of any harmful interference from MBANS operations, in the unlikely event that any occur.

Contention-Based Protocols**.** AFTRCC's concerns over the proposed contention-based protocols for MBANS devices are meritless.[33] GEHC has long-recognized that interference to wireless medical devices and other mission-critical wireless devices (especially Part 15 devices in hospitals) is a significant issue. For this reason, GEHC has taken a strong leadership role representing the interests of medical telemetry users and manufacturers in the Commission's TV White Spaces proceeding.[34]

In the TV White Spaces proceeding, spectrum sensing was proposed by some proponents as the sole and sufficient mechanism to prevent interference to incumbent services, including medical telemetry. However, unlike the proposed MBANS devices, the proposed white spaces devices would operate over long ranges with radiated transmit powers up to 36 dBm – thousands of times higher than the relatively low-power, short-range medical telemetry devices with which they would have to avoid interfering. Because of this power discrepancy, the separation distance at which the white spaces devices would interfere with medical telemetry operations was much larger than the distance at which they could reliably detect such medical telemetry operations. Because of these factors, the implementation of spectrum sensing alone is not sufficient to protect medical telemetry devices from harmful interference caused by much higher-power white spaces devices.[35]

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[32] 47 C.F.R. § 95.1111.

[33] *See* AFTRCC July *Ex Parte* at 6-7.

[34] *See, e.g.*, Comments of GE Healthcare, ET Docket No. 04-186 (filed Jan. 31, 2007); of GE Healthcare, ET Docket No. 04-186 (filed Jan. 31, 2007); *Ex Parte* filing by GE Healthcare, ET Docket No. 04-186 (filed Aug. 27, 2007); *Ex Parte* filing by GE Healthcare, ET Docket No. 04-186 (filed Sept. 17, 2007); *Ex Parte* filing by GE Healthcare, ET Docket No. 04-186 (filed May 6, 2008).

[35] AFTRCC also confuses legacy unidirectional FDMA channelized medical telemetry with the proposed MBANS devices. It states that "[m]ost medical telemetry systems employ distributed antenna systems that combine received signals from many antennas distributed throughout the entire coverage area – typically hundreds of thousands of square feet. In such systems, a single

In the case of the MBANS proposal, however, GEHC has proposed contention-based protocols (including but not limited to spectrum sensing) primarily to promote coexistence among MBANS devices and to protect MBANS devices from interference from primary incumbents such as AMT – not as the primary method of protecting AMT receivers. While GEHC has observed that contention-based protocols would add a measure of protection for many incumbent devices in many scenarios, it has also stated consistently since proposing the detailed MBANS service rules that the primary method of protecting AMT receivers would be by maintaining sufficient physical separation between MBANS operations and AMT receivers and by limiting MBANS power spectral density. Therefore, while AFTRCC has correctly pointed out that under some circumstances a transmitting aircraft could be so far away that a sensing MBANS device would fail to detect it and transmit on the same frequency as the aircraft,[36] under GEHC's proposal, that MBANS device would nevertheless still be sufficiently separated from the AMT receiver to prevent harmful interference to AMT operations.

Other Technical Issues**.** To the extent AFTRCC raises valid technical concerns, GEHC notes that the proposed MBANS devices and service rules are designed to address such concerns. Moreover, the geographic exclusion zones, fixed location use, and coordination and registration applicable to MBANS device use will further eliminate the potential for harmful interference.

Signal Drop-out. For example, AFTRCC claims that GHEC "fails to account for the fact that even a short duration interfering signal can entail a long-duration drop-out in the received telemetry signal."[37] While this effect is certainly possible and will depend on the specific AMT protocol (*e.g.*, packet structure and error control schemes), to the extent it is true for a given protocol it will also exacerbate the baseline AMT outages due to intrinsic receiver noise in the absence of interference. Therefore, whatever this amplifying effect may be for a given AMT system, since it applies equally to the baseline AMT outages and the interference-caused outages, it falls out of the analysis in the approach taken in Appendix A. The analysis in Appendix A proposes to limit the AMT outage rate in the presence of interference to a maximum value proportional to the baseline noise-limited outage rate.

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interferer can cause loss of monitoring to all patients, regardless of their location within the coverage area." AFTRCC July *Ex Parte* at 8. It also repeats GEHC's statement that "[d]ue to the very low power of medical telemetry, [the cochannel] interference distance [from TV white space devices] is substantial – tens of kilometers under conservative analysis . . . ." *Id.* Unlike WMTS operations, the proposed MBANS devices would be specifically designed to be opportunistic, frequency agile devices that are able to communicate reliably as long as sufficient spectrum is available somewhere within the 40 MHz proposed allocation.

[36] AFTRCC July *Ex Parte* at 7.

[37] *Id.* at 10.

Interference Probability. AFTRCC also erroneously states that "the probabilit[y] for interference to AMT ground stations from BSNs" will be more than 80%"[38] and that the consequences of interference to aircraft manufacturers, their employees, and persons on the ground are potentially severe."[39] Although the bold assertions of AFTRCC and other AMT advocates attempt to convey a sense of pervasive interference, upon close examination they are based on unrealistic, static, worst-case analyses and flawed tests representing (at best) non-typical, and in many cases completely unrealistic, scenarios. GEHC's initial probability calculations, contained in its June 11 Reply Comments, were intended merely to provide a simple (but more realistic) first-order estimate of the interference likelihood and to illustrate the proper probability-based approach to the analysis. By comparison, AFTRCC's analysis to this point has been even more simple and less realistic. To try and demonstrate that MBANS would interfere with AMT, AFTRCC offered only a static, worst-case minimum coupling loss analysis that upon closer inspection must be flawed—it yields absurd results when applied to the many interference sources already present in the band.[40]

Thus, instead of offering a proper statistical or probability-based analysis, the AMT incumbents base their claims of pervasive interference on their flawed, worst-case analyses (and the flawed Learjet field test). GEHC has never denied that some interference could occur with its MBANS proposal, but it is confident that such interference would be rare, infrequent, and certainly not harmful.

It is important to note that, from both a practical and legal standpoint, the Commission should be concerned with assessing the probability of *harmful* interference. Of course, what actually constitutes harmful interference is service-dependent. Received interference energy that is theoretically measurable but yet is insufficient to cause actual outages (*e.g.*, a marginal increase in the noise floor of a victim receiver when the victim link still has ample margin to operate reliably) cannot by definition be harmful and therefore should not be of interest to the Commission. In addition, it is certainly true that in many cases actual outages will not be harmful if they are sufficiently brief and/or infrequent. Thus, the intrinsic link performance in the absence of interference gives a very good indication of what level of interference-induced outages, if any, can be tolerated without harm.

In Appendices A and B attached hereto, GEHC provides a rigorous Monte Carlo analysis convincingly demonstrating that the probability of MBANS-caused AMT outages becomes negligible at modest and practical separation distances less than 10 km for practical worst cases, including a hospital with many MBANS

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[38] *Id*. AFTRCC assumed a worst-case scenario in which 20 BSNs simultaneously are transmitting in the same AMT channel while AMT operations are being conducted.

[39] *Id*.

[40] *See, e.g.*, GEHC Reply Comments at 23-24.

systems lying directly in the main beam of the AMT directional antenna. The separation distances resulting from this analysis should serve as the basis for defining the geographic exclusion zones around AMT test sites that would apply to 2360-2390 MHz MBANS operations.[41]

Bolstering GEHC's latest results, the recent ECC Draft Report 121, which considers the coexistence of AMT and Professional Wireless Microphone Systems ("PWMS"), strongly supports GEHC's conclusions regarding MBANS and AMT coexistence.[42] PWMS devices operate at L-band with a 50 mW/200 kHz emissions limit, yet despite the lower operating frequency, narrower bandwidth and substantially higher power of PWMS versus MBANS devices – corresponding to more than 28 dB higher power flux density per Hertz at the AMT receiver for the same separation distance – the ECC Draft Report 121 concludes that PWMS devices can coexist with co-channel aeronautical telemetry *unconditionally* in urban environments.[43] For suburban and rural environments, the Report concludes that indoor PWMS devices can coexist with aeronautical telemetry given only relatively modest separation distances of as little as 1.5 km and 6 km, respectively.[44]

Potential Interference Levels. In disputing GEHC's statement that interference from microwave ovens and related devices operating in the S-band already exceeds Rec. M.1459 levels, AFTRCC asserts that "recent test range measurements indicate that environmental noise due to microwave ovens and out-of-band emissions from unlicensed devices is generally not a problem and when it is, it is at the band edges."[45] In fact, the limited test range measurements from the Jablonski analysis cited by AFTRCC conclusively establish nothing of the kind. Simply being able to measure a 0.1 mW source at a single random location corresponding to 2 km distance cannot prove in general the absence of interference from spurious emissions at all times, frequencies, and azimuth angles—the standard to which AFTRCC apparently seeks to hold MBANS. To prove that would require a much more detailed study that employs a directional

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[41] GEHC notes that the final analysis contained in the attached Appendices reflects corrections and refinements that yielded slightly smaller separation distances than the preliminary results shown on slide 25 of GEHC's September 10th ex parte filing. See Ex Parte filing by GE Healthcare, ET Docket No. 08-59, Slide 25 (filed Sept. 10, 2008).

[42] *See* Draft ECC Report on Compatibility Studies Between Professional Wireless Microphone Systems (PWMS) and Other Services/Systems in the L Band, Electronic Communications Committee within the European Conference of Postal and Telecommunications Administrations, Report 121, *at* http://194.182.137.12/367C8D90-8C23-4A16-8B8D-349C5B086E5D?frames=no&.

[43] *Id.* at 31.

[44] *Id.*

[45] AFTRCC July *Ex Parte* at 9.

antenna and very low noise amplifier and that considers all frequencies and azimuth angles for long periods of time.[46]

In addition, the telemetry system cited by Mr. Jabolski (with a 750k noise temperature) would have a noise floor of –169.9 dBm/Hz, which is 9 dB *above* the received power spectral density of interference at the –180 dBW/m^2/4kHz M.1459 PFD limit (assuming 36 dBi gain for the 15 foot dish antenna cited). Therefore, it would be virtually impossible for such a system to detect the many potential interference sources that significantly exceed the M.1459 PFD limit.

* * *

The creation of WMTS took a grossly underutilized spectrum block (*i.e.*, 16 MHz previously used only by a handful of radio astronomy and government radar sites) and made it available at substantial public benefit with few if any problems occurring in the eight years since. Notably too, WMTS has achieved this success largely without the aid of recent technological developments, such as bi-directionality and frequency agility, that would be leveraged by MBANS devices. In sum, although AFTRCC attempts to downplay the opportunity for more efficient spectrum use presented by the inherently intermittent nature of AMT operations – in addition to the tremendous opportunity presented by the sparseness of incumbent operations in spatial and frequency domains – the fact remains that opportunistic, frequency-agile MBANS devices would be able to coexist easily with AMT operations—especially when geographic exclusion zones, fixed location use, and registration are employed.

5. AFTRCC'S Defense of the Learjet Test Overlooks the Crucial Flaws in the Test.

As GEHC has previously stated, the Learjet test, purportedly designed to evaluate MBANS and AMT compatibility, does not properly represent MBANS operations.[47] Moreover, the measurements reported by Learjet are highly suspect in that they exceed both the theoretically expected and maximum possible free-space values by substantial margins. In sum, the implausibility of these measurements certainly calls into question the overall validity of the Learjet test.

AFTRCC's defense of the Learjet field tests[48] contains several factual and technical errors and completely neglects to address several key concerns raised by GEHC. First, as GEHC observed in its Reply Comments and as acknowledged in Learjet's own test report, the failure mode that resulted from Learjet's unrealistic test involved the AMT tracking antenna locking onto the strong, continuous, and

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[46] Moreover, the study would have to be repeated at multiple AMT receive locations because some may turn out be subject to more interference than others.

[47] *See* GEHC Reply Comments at 17-19.

[48] AFTRCC July *Ex Parte* at 8-9.

narrowband interfering signal used by Learjet instead of the desired aircraft signal. It stands to reason that a test signal representative of actual MBANS devices – non-continuous (*i.e.*, duty-cycled and/or frequency hopping) and/or having a lower power spectral density – would have been much less likely to cause this interference effect.

In addition, AFTRCC's assertion that these continuous narrowband signals were equivalent to MBANS signals because both signals fit into the AMT receiver bandwidth is technically incorrect.[49] AFTRCC considers only the gross C/I interference mechanism and not the actual behavior of the tracking antenna, automatic gain control ("AGC"), or demodulator. (For many practical real-world receivers, a narrow-band signal often produces a worse jamming effect than a wider-band more noise-like signal of the same received power.[50])

Despite AFTRCC's assertion that GEHC has not provided detailed specifications for MBANS devices, GEHC has, in fact, provided detailed rules, including quantitative power spectral density limits and a contention-based protocol requirement, as well as clear details in terms of the expected MBANS duty cycle and contention-based protocol techniques (*e.g.*, listen-before-talk, frequency-hopping). In light of this fact, there simply is no legitimate justification for Learjet's choice of test signals. In fact, the choice of test signals appears to have been selected solely to produce a desired test result unfavorable to MBANS. In Appendix C, attached hereto, GEHC provides a comparison of the Learjet test signals with typical MBANS signals.

In his engineering statement attached to AFTRCC's July *Ex Parte*, Daniel Jablonski dismisses GEHC's observation that Learjet's reported signal measurements greatly exceed what would be expected even with free space ($1/r^2$) path loss with the statement: "With respect to the claim that the interference source used in the Learjet tests fails to obey the inverse r-squared law, [GEHC] in its own analysis asserts that such behavior is to be expected."[51] However, the expected phenomena cited in GEHC's analysis, and later agreed to by AFTRCC, is *greater* than $1/r^2$ path loss, whereas the Learjet results seem to indicate significantly *less* than $1/r^2$ path loss, which is not physically plausible. Although AFTRCC seeks to explain this discrepancy by admonishing GEHC for neglecting the low noise amplifier gain, the fact is that Learjet's test report completely failed to disclose any such gain. Rather, it simply stated "[t]he following measurements were made and recorded using a spectrum analyzer connected to one of the two

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[49] *See id.* at 9.

[50] "These notes are presented to point out a severe problem in systems involving preamplifiers. Intermodulation products are produced whenever the signal strength is sufficient to cause the amplifier (or receiver) to operate in the nonlinear portion of the characteristics of the unit. A major cause of intermodulation is gain compression." Range Commanders Council Document 118-02, Test Methods for Telemetry Systems and Subsystems, Volume 2, page A-2 (Jun. 2002).

[51] AFTRCC July *Ex Parte*, Exhibit A at 1.

RF feeds of the tracking antenna system,"[52] implying that the dramatically high levels were the actual received signal levels from the "MBANS" test transmitter without any additional amplification besides the reported 31 dBi AMT receive antenna gain.

AFTRCC's recent filing goes on to claim that "[t]he tests conducted by Learjet revealed that interference to the AMT receiver increased as the interference source was moved further away,"[53] and that "the fact that the interference was stronger at 3.2 miles (the maximum distance for the test) than it was at 0.7 miles should not be surprising."[54] This is a completely erroneous account of the Learjet measurements. In reality, the *highest* of the measurements (-61 dBm) occurred at 0.7 miles and the three measurements made at the greater distances were all significantly *lower* (-71, -67, and –68 dBm respectively for 1.2, 2.2, and 3.2 miles). This mischaracterization or misinterpretation of their own measurements calls into serious question AFTRCC's attempt to address GEHC's well-founded criticism that the only portion of the test involving an actual aircraft was conducted with the interference source at the fixed distance of 0.7 miles, which produced the highest measured level at the receiver. Moreover, AFTRCC has not addressed GEHC's observation that the Learjet measurements failed to continue dropping from 1.2 to 3.2 miles, which raises the question of whether some other source in the environment might have been producing a relatively fixed measurement floor in the range of –71 to –68 dBm below which the test signal was not actually being measured at the greater distances.

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[52] AFTRCC Comments, ET Docket No. 08-59, Exhibit G at 2 (filed May 27, 2008).

[53] AFTRCC July *Ex Parte* at 9.

[54] *Id*.

Conclusion

As discussed in detail herein, GEHC's MBANS proposal will produce widespread healthcare benefits and increased spectrum efficiency without causing harmful interference to incumbent operations such as AMT. For these reasons, the Commission should issue a Notice of Proposed Rulemaking proposing MBANS rules so that it can place itself in a favorable position to expeditiously adopt final MBANS rules.

Respectfully submitted,

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APPENDIX A

Analysis of Interference to Aeronautical Mobile Telemetry from the Medical Body Area Network Service

I. INTRODUCTION

GEHC has offered a detailed proposal[1] for creating a new Medical Body Area Network Service (MBANS) that would include a secondary allocation of the 2360-2400 MHz band, of which 2360-2395 MHz contains allocations for the Aeronautical Mobile Telemetry (AMT) service. As the proposed MBANS devices would be low power / short range and the incumbent services (including AMT) operate at much higher power, GEHC has, prior to this point, offered only a relatively rudimentary engineering analysis to explain how MBANS devices would coexist without causing harmful interference to higher power incumbent services. At the same time, AFTRCC, representing AMT incumbents opposed to the proposed MBANS allocation, has offered an even more simplistic analysis of its own purporting to show that MBANS devices could not coexist with AMT without very large separation distances. With the present analysis, GEHC seeks to provide a more comprehensive, sophisticated and realistic analysis that gives a much more accurate assessment of the potential for MBANS operations to interfere with AMT operations.

II. AFTRCC's ANALYSIS

AFTRCC's analysis is flawed in several respects. To begin with, it applies a minimum coupling loss (MCL) approach. Although safe and simple to apply, the MCL technique is a static worst-case approach that is well-known[2] to often produce overly pessimistic conclusions about coexistence (*e.g.*, yielding unrealistically large separation distances) at the cost of spectrum efficiency. Specifically, the AFTRCC analysis fails to take into account probabilistic variations of many key factors, including:

- Actual MBANS device locations with respect to AMT receivers
- MBANS device to AMT receiver propagation path loss
- AMT transmitter to AMT receiver propagation path loss

<u>Essentially, AFTRCC's MCL analysis is based on the unrealistic assumption that the MBANS device lies in the main beam of the highly-directional, parabolic AMT receive antenna, that the non-line-of-sight MBANS signal is unfaded and that the line-of-sight AMT signal is deeply faded – all simultaneously.</u> Based on this highly improbable scenario, the AFTRCC analysis

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[1] *See* Ex Parte Comments of GE Healthcare, ET Docket No. 06-135 (filed Dec. 27, 2007).

[2] *See, e.g.*, ERC Report 101 "A Comparison Of The Minimum Coupling Loss Method, Enhanced Minimum Coupling Loss Method, And Monte Carlo Simulation," May 1999.

concludes that a 1mW device at 62 km separation having non-line-of-sight propagation will interfere with a 10W AMT transmitter at 320 km having line-of-sight propagation.

AFTRCC's analysis does not directly consider important details of the AMT link, such as the statistical distribution of received signal strength, minimum required signal strength, etc. Rather, it simply invokes without justification an absolute power flux density (PFD) limit for the interfering signal at the AMT receiver (taken from ITU-R M.1459) and then wrongfully equates any violation of this absolute PFD limit with an interference event. That something is wrong with this approach becomes obvious when it is applied[3] to existing services already coexisting with AMT and results in the absurd results for separation distances summarized as follows:

- Fundamental emissions of a typical 10 Watt EIRP amateur radio transmission would interfere with aeronautical telemetry operations at a radius of 1,370 km line-of-sight, and the spurious OOBE of such operation, even assuming excellent 60 dB suppression, would interfere with AMT operations at a radius of 4.4 km.
- The allowable, spurious OOBE from a single, 2.4 GHz, Part 15 unlicensed, intentional radiator would interfere with aeronautical telemetry operations at a radius of 1.2 km. Moreover, due to the ubiquity of these devices, aggregation effects would greatly compound this effect.
- The allowable spurious OOBE from a single, 2.4 GHz, Part 18 ISM device (*e.g.*, microwave oven, plasma discharge light, etc.) would interfere with aeronautical telemetry operations at a radius of 4.5 km.
- The allowable spurious OOBE from a single WCS device would interfere with aeronautical telemetry operations at a radius of 17.8 km.

AFTRCC's simplistic and highly conservative approach is particularly undesirable for assessing the merits of the MBANS proposal, given that the spectrum at issue is grossly underutilized by the AMT service and that the MBANS proposal represents an opportunity to put the residual, currently fallow, spectrum to use for substantial public benefit throughout at least 99% of the geography of the United States.

III. MONTE CARLO ANALYSIS

Because of the complexity and inherently random nature of both the coexistence scenarios (*i.e.*, number of MBANS devices and their physical locations with respect to the AMT receiver) and underlying physical phenomena (*e.g.*, RF propagation effects), providing a more thorough, reasonable and accurate treatment through a purely analytical approach is virtually impossible. However, a well-known alternative tool for such problems is Monte Carlo modeling and simulation. In particular, the Monte Carlo technique has recently gained widespread acceptance (*e.g.*, by FCC, Ofcom, CEPT, ITU, IEEE,) over simple MCL-based analysis for assessing radio

[3] *See* Reply Comments of GE Healthcare, ET Docket No. 08-59 (filed June 11, 2008) at B-1.

system coexistence.[4] The increasing adoption of the Monte Carlo approach has been driven by the extreme scarcity of spectrum and the necessity to utilize it ever more efficiently.

GEHC has performed a detailed, Monte Carlo analysis to assess the actual probability of interference from the proposed MBANS to AMT.

Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT), version 3.1.43, was used for this probabilistic analysis. SEAMCAT is a software tool based on the Monte Carlo simulation method, which was developed within the frame of European Conference of Postal and Telecommunication administrations (CEPT). This tool permits statistical modeling of different radio interference scenarios for performing sharing and compatibility studies between radio communications systems in the same or adjacent frequency bands.[5]

This analysis considers numerous factors, including:

- Separation distance of MBANS transmitter to AMT receiver
- Extended Hata propagation model environments – suburban and rural
- Extended Hata propagation model environments – MBANS transmitter out/indoors
- Duty cycle of MBANS transmitter, 25% or 100%
- Frequency-hopping of MBANS transmitters
- Number of MBANS transmitters
- MBANS transmitter location relative to mainlobe of AMT receive antenna

SEAMCAT works by running a large number of random trials, according to a given scenario, and predicting for each trial the desired received signal, (dRSS), and aggregate received interfering signal (iRSS), at the victim receiver. In this analysis, dRSS represents the received AMT signal and iRSS represents the aggregate received interference due to one or more MBANS systems. The number of trials for which the specified interference limit is violated is reported as a percentage of trials for which dRSS met or exceeded receiver sensitivity (*i.e.*, those for which the AMT link would have been closed in the absence of interference).

A more-detailed description of the AMT link is presented in Appendix B. Table 1 summarizes how the SEAMCAT parameters and simulation variables discussed in this analysis correspond to the notation used in Appendix B.

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[4] *See e.g.,* Appendix 1 of M2Z Aug 11, 2008 Reply Comments in WT Docket No. 07-195; IEEE 1900.2, "IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems," at 36.

[5] SEAMCAT is available from the European Radio Office, http://www.ero.dk/seamcat.

Table 1 - Victim Link, AMT System

SEAMCAT	AMT link model in Appendix B
$C = 10^{dRSS/10}$	$10\log_{10}(P_{RX})$
$dRSS = 10\log_{10}(C)$	P_{RX}
$I = 10^{iRSS/10}$	$10\log_{10}(P_I)$
$iRSS = 10\log_{10}(I)$	P_I
N	$10\log_{10}(P_N)$
N+I	$10\log_{10}(P_{N+I})$
C/N	$10\log_{10}(P_{RX} - P_N)$
C/(N+I)	$10\log_{10}(P_{RX} - P_{N+I})$
I/N	$10\log_{10}(P_I - P_N)$
$VR_{sensitivity}$	$P_N + SINR_{min}$

IV. SCENARIOS CONSIDERED

SEAMCAT was used to analyze the following cases with the MBANS to AMT receiver separation distance, D_s, manually varied in order to tabulate the interference probability for various separation distances. Details of the input parameters used for each case are listed in Section V.

Case 0 AMT receiver and transmitter only with AMT transmitter at maximum distance of 320 km.

Case 1 A single, continually transmitting MBANS system located uniformly in azimuth about the AMT receiver, AMT transmitter at max distance, co-channel. Use Extended Hata model with suburban and rural general environments, outdoor transmitter and outdoor receiver environments and above roof condition.

Case 2 Repeat Case 1 with Extended Hata model using indoor transmitter to outdoor receiver environments.

Case 3 Repeat Case 2 with 10 continually transmitting MBANS systems located uniformly about AMT receiver.

Case 4 Repeat Case 3 using 25% duty cycle for each individual MBANS system. An MBANS system consists of a gateway plus one or more sensor nodes.

Case 5 Repeat Case 4 with frequency hopping, allowing each MBANS system to transmit across 2361 to 2399 MHz band in 1 MHz steps with equal probability.

Case 6 Repeat Case 5 with 50 MBANS systems located uniformly in azimuth about AMT receiver

Case 7 Repeat Case 6 with AMT system at a fixed azimuth and 50 MBANS transmitters located uniformly , +/- 1 degree about this azimuth (*i.e.*, in AMT mainlobe).

Case 8 Repeat Case 0 using 31 dBi AMT receive antenna.

Case 9 Repeat Case 6 using 31 dBi AMT receive antenna.

Case 10 Repeat Case 7 using 31 dBi AMT receive antenna.

The 100% duty cycle used in cases 1 through 3 is worse than any practical MBANS system would exhibit, but these cases are presented for more direct comparison with the AFTRCC analysis. Cases 4 through 10 assume a 25% MBANS duty cycle, which represents a realistic worst-case scenario for a fully loaded body sensor network ("BSN"). In reality, many BSNs (usually, in fact, the *majority* of BSNs) that will be monitoring the lower-acuity patients who represent the majority of patients in a health care facility, will comprise only one or two sensors resulting in a less than 10% duty cycle. Therefore, the analysis is quite conservative in this respect.

Cases 7 and 10 are representative of the worst-case scenario raised by AFTRCC of a hospital with many MBANS systems falling directly into the mainlobe of an AMT antenna. It is important to note that while a large hospital might have more than 50 MBANS systems, 50 is nevertheless a conservative figure to be used in the analysis, since the only MBANS systems contributing significantly to the interference seen by the AMT receiver will be those located near the face of the building that is oriented towards the receiver, as illustrated by the red bubbles in Figure 1. This must be the case because, in order for a larger number of MBANS devices to reuse spectrum in the same hospital, they must have significant RF isolation from each other. This necessary isolation will arise principally from interior building structures such as walls and floors and these additional interior building structures will also be present in the path between the majority of the MBANS devices in the hospital, depicted by the blue bubbles in Figure 1, and the AMT receiver.

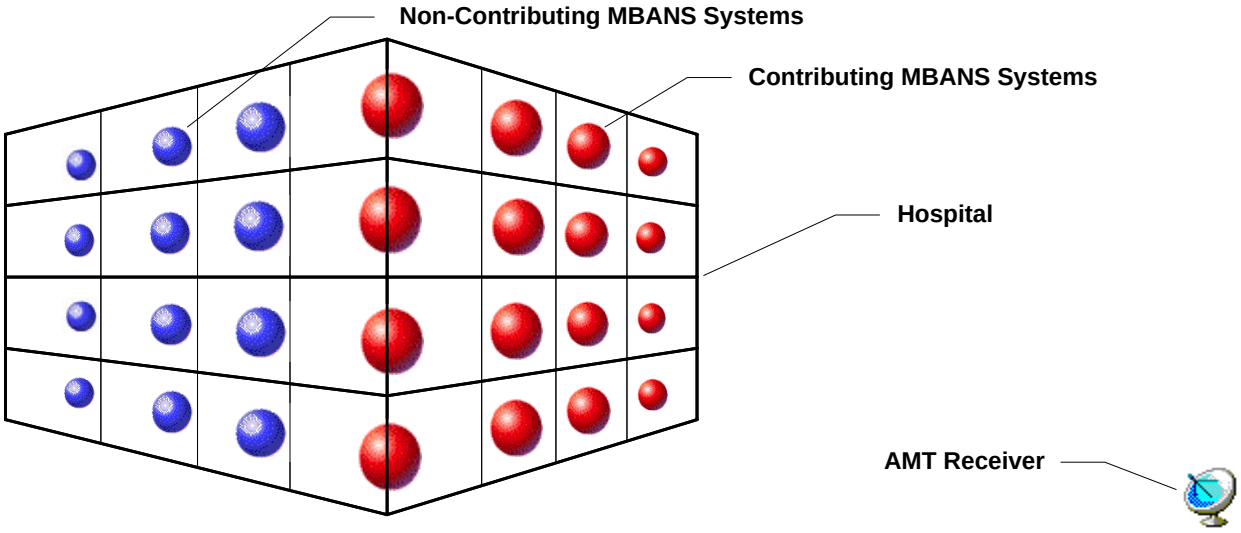


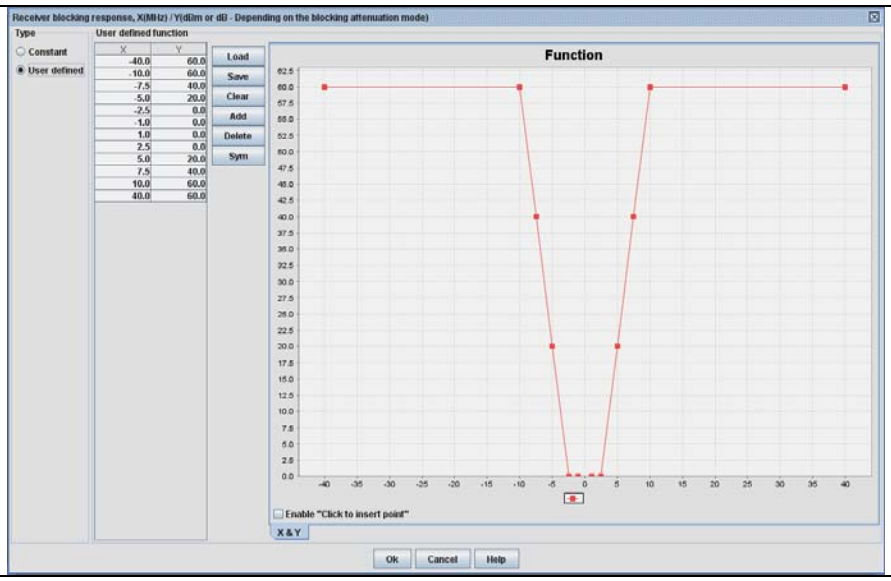
Figure 1 – Subset of MBANS Systems in a Hospital Contributing to Interference at AMT Receiver

V. SEAMCAT SIMULATION SETTINGS

Table 2 and Table 3 summarize the detailed inputs and assumptions used in the interference analysis for AMT and MBANS systems respectively. Selected screen shots from SEAMCAT have been included for clarity. Values are taken from previous AFTRCC comments, Range Commander Council Telemetry Handbook, ITU M.1459 recommendation and GE Healthcare's MBANS proposal of December 27, 2007.

Table 2 - Victim Link, AMT System

Description	AMT Receiver
Frequency	2377.5 MHz, fixed
Bandwidth	5 MHz
Noise Floor	-108.6 dBm based on N_o = kTB with T = 200 K
Sensitivity	-96 dBm. $VR_{sensitivity}$ = N_o + $SINR_{min}$ (–108.6 + 12 = -96.6 dBm). For Cases 0 and 8 a constant value of –108.6 dBm is used to allow SEAMCAT to calculate probability of C/(N+I) < 12 dB as link failure.
Interference Criteria	I/N ≤ -3 dB; C/(N+I) ≥ 12 dB given desired signal > victim receiver sensitivity; from which C/I = 16.8 dB and (N+I)/N = 1.8 dB
Blocking Response	User defined mode. 20 dB/octave per Range Commander Council text on RLC filters. This response is used by SEAMCAT to calculate $iRSS_{blocking}$ signal.



Antenna

19.8 meters height (65 feet) constant.
Azimuth offset = 0 degrees.
Elevation offset = 0.984 degrees for aircraft at 320 km distance and 5520 meter height. Note that SEAMCAT version 3.1.43 does not automatically track the elevation pattern of the receive antenna to point at the wanted transmitter. This offset accomplishes antenna elevation steering for the fixed altitude and maximum distance case.

Cases 0 to 7 use peak gain of 41.2 dBi and M.1459 EQUATION (1) pattern for both azimuth and elevation.

Vertical

Elevation	dBi
-90	-49.2
-80	-49.2
-70	-49.2
-60	-49.2
-50	-49.2
-49	-49.2
-48	-49.18
-47	-48.95
-46	-48.72
-45	-48.48
-44	-48.24
-43	-47.99
-42	-47.73
-41	-47.47
-40	-47.2
-39	-46.93
-38	-46.64
-37	-46.36
-36	-46.06
-35	-45.75
-34	-45.44
-33	-45.11
-32	-44.78
-31	-44.43
-30	-44.08
-29	-43.71
-28	-43.33
-27	-42.93
-26	-42.52
-25	-42.1

Elevation	dBi
-24	-41.66
-23	-41.19
-22	-40.71
-21	-40.21
-20	-39.68
-19	-39.12
-18	-38.53
-17	-37.91
-16	-37.25
-15	-36.55
-14	-35.8
-13	-35
-12	-34.16
-11	-33.46
-10	-32.68
-9	-31.82
-8	-30.86
-7	-29.78
-6	-28.52
-5	-23.15
-4	-18.38
-3	-15.64
-2	-12.12
-1	-6.1
0	0
1	-6.1
2	-12.12
3	-15.64
4	-18.38
5	-23.15

Elevation	dBi
6	-28.52
7	-29.78
8	-30.86
9	-31.82
10	-32.68
11	-33.46
12	-34.16
13	-35
14	-35.8
15	-36.55
16	-37.25
17	-37.91
18	-38.53
19	-39.12
20	-39.68
21	-40.21
22	-40.71
23	-41.19
24	-41.66
25	-42.1
26	-42.52
27	-42.93
28	-43.33
29	-43.71
30	-44.08
31	-44.43
32	-44.78
33	-45.11
34	-45.44
35	-45.75

Elevation	dBi
36	-46.06
37	-46.36
38	-46.64
39	-46.93
40	-47.2
41	-47.47
42	-47.73
43	-47.99
44	-48.24
45	-48.48
46	-48.72
47	-48.95
48	-49.18
49	-49.2
50	-49.2
60	-49.2
70	-49.2
80	-49.2
90	-49.2

Horizontal

Azimuth	dBi
0	0
1	-6.1
2	-12.12
3	-15.64
4	-18.38
5	-23.15
6	-28.52
7	-29.78
8	-30.86
9	-31.82
10	-32.68
11	-33.46
12	-34.16
13	-35
14	-35.8
15	-36.55
16	-37.25
17	-37.91
18	-38.53
19	-39.12
20	-39.68
21	-40.21
22	-40.71
23	-41.19
24	-41.66
25	-42.1
26	-42.52
27	-42.93
28	-43.33
29	-43.71
30	-44.08
31	-44.43

Azimuth	dBi
32	-44.78
33	-45.11
34	-45.44
35	-45.75
36	-46.06
37	-46.36
38	-46.64
39	-46.93
40	-47.2
41	-47.47
42	-47.73
43	-47.99
44	-48.24
45	-48.48
46	-48.72
47	-48.95
48	-49.18
49	-49.2
50	-49.2
60	-49.2
70	-49.2
80	-49.2
90	-49.2
100	-49.2
110	-49.2
120	-49.2
130	-49.2
140	-49.2
150	-49.2
160	-49.2
170	-49.2
180	-49.2

Azimuth	dBi
190	-49.2
200	-49.2
210	-49.2
220	-49.2
230	-49.2
240	-49.2
250	-49.2
260	-49.2
270	-49.2
280	-49.2
290	-49.2
300	-49.2
310	-49.2
311	-49.2
312	-49.18
313	-48.95
314	-48.72
315	-48.48
316	-48.24
317	-47.99
318	-47.73
319	-47.47
320	-47.2
321	-46.93
322	-46.64
323	-46.36
324	-46.06
325	-45.75
326	-45.44
327	-45.11
328	-44.78
329	-44.43

Azimuth
330
331
332
333
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360

Cases 8 to 10 use peak gain of 31 dBi and the measured 2.44 meter diameter antenna pattern shown in M.1459 FIGURE 1. This pattern is applied to both azimuth and elevation.

Vertical

Elevation	dBi
-90	-39
-40	-39
-39	-30
-38	-31
-36	-46
-35	-31
-33.5	-28
-32	-31
-30	-46
-29	-31
-27	-26
-25	-31
-24	-46
-22	-26
-21	-24
-20	-26
-19	-31
-18	-46
-17	-26
-15	-21
-13	-26

Elevation	dBi
-12	-46
-11	-21
-9	-16
-8	-21
-6	-46
-5	-16
-1.9	-3
0	0
1.9	-3
5	-16
6	-46
8	-21
9	-16
11	-21
12	-46
13	-26
15	-21
17	-26
18	-46
19	-31
20	-26

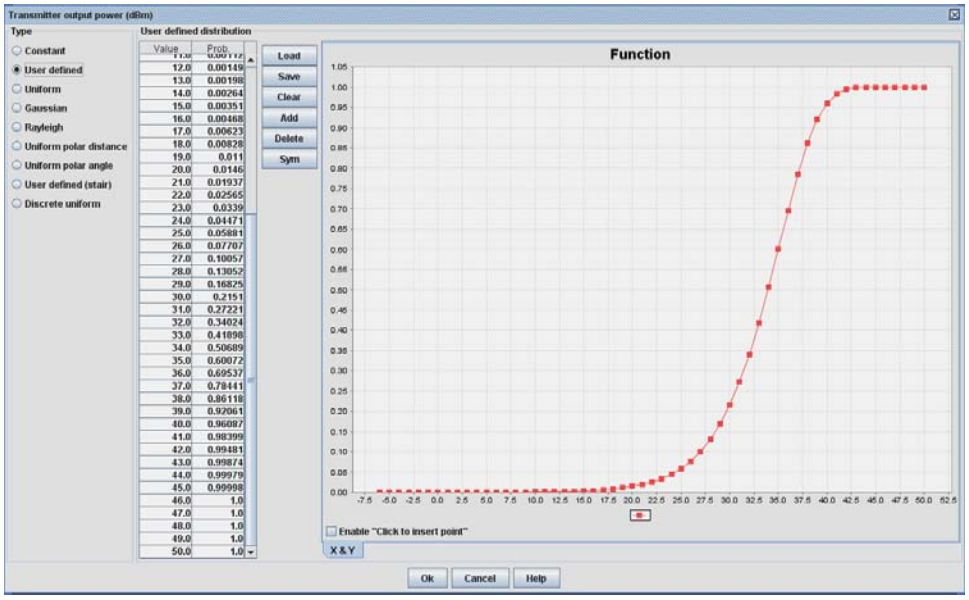
Elevation	dBi
21	-24
22	-26
24	-46
25	-31
27	-26
29	-31
30	-46
32	-31
33.5	-28
35	-31
36	-46
38	-31
39	-30
40	-39
90	-39

Horizontal

Azimuth	dBi
0	0
1.9	-3
5	-16
6	-46
8	-21
9	-16
11	-21
12	-46
13	-26
15	-21
17	-26
18	-46
19	-31
20	-26
21	-24
22	-26
24	-46
25	-31
27	-26
29	-31
30	-46

Azimuth	dBi
32	-31
33.5	-28
35	-31
36	-46
38	-31
39	-30
40	-39
90	-39
135	-39
180	-39
225	-39
270	-39
320	-39
321	-30
322	-31
324	-46
325	-31
326.5	-28
328	-31
330	-46
331	-31

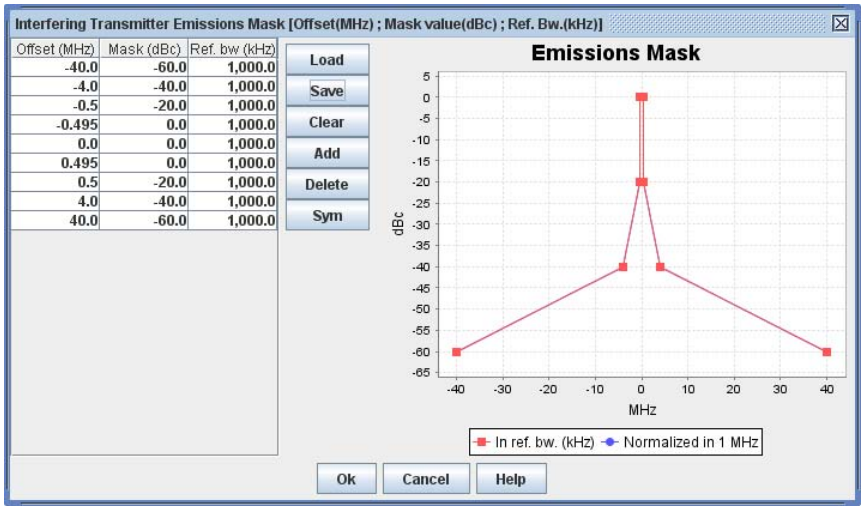
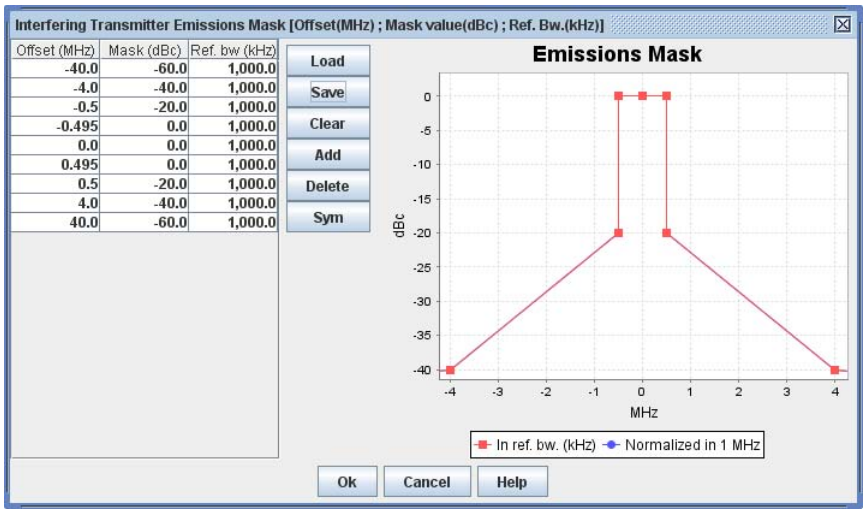
Azimuth	dBi
333	-26
335	-31
336	-46
338	-26
339	-24
340	-26
341	-31
342	-46
343	-26
345	-21
347	-26
348	-46
349	-21
351	-16
352	-21
354	-46
355	-16
358.1	-3
360	0

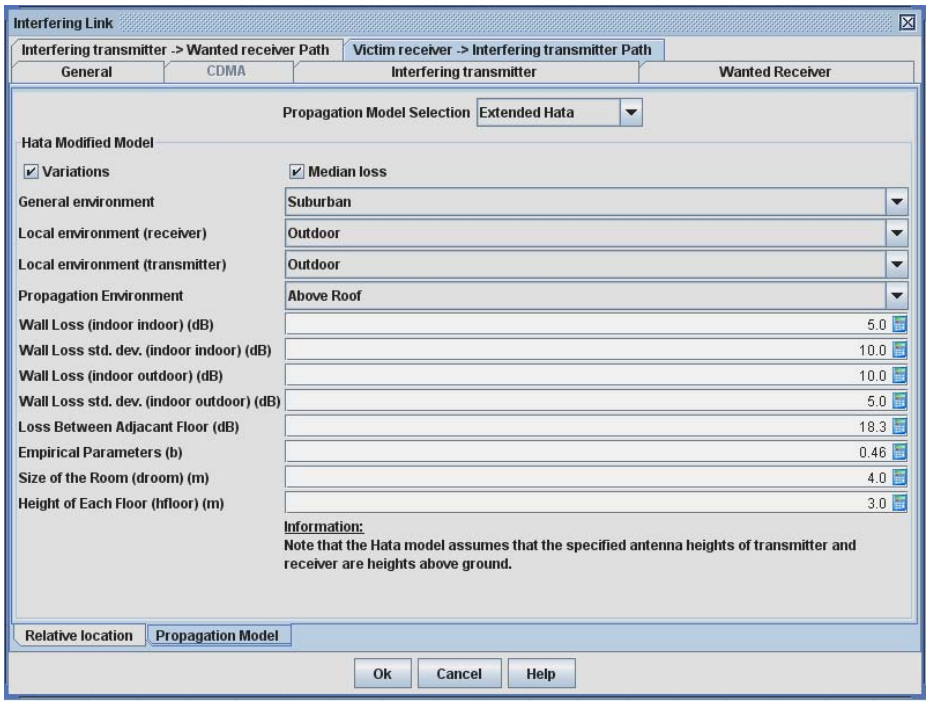
Description	**AMT Transmitter**
Antenna	Omnidirectional pattern with 0 dBi (see Power entry below). Azimuth = elevation = 0 degrees. Antenna height = aircraft height = 5520 meter (18,110 feet) constant.
Power	Represents EIRP via user-defined distribution. Apply M.1459 FIGURE 2 transmit antenna cumulative distribution function (1-exp(-3.46G1)^1.25, with 40 dBm conducted TX power. 
Propagation Model	Wanted Transmitter to Victim Receiver propagation using free space loss without shadowing variation.
Relative Location	Path azimuth taken as uniform random variable over 0 to 360 degrees. For Case 7, path azimuth will be assigned a constant value of 45 degrees.

	Path distance factor taken as a constant value of 1.0. User-defined coverage radius of 320 km.

Table 3 – Interfering Link, MBANS System

Description	MBANS Transmitter
Frequency	2377.5 MHz, fixed or discrete uniform distribution over 2361 to 2399 MHz in 1 MHz steps with equal probability.
Power	0 dBm constant level for 100% duty cycle cases or User defined stair distribution with P(0 dBm) = 0.25 and P(-200 dBm) = 0.75 to represent 25% duty cycle of an individual MBANS system.
Antenna	Constant height of 1.5 meters. Azimuth and elevation = 0 degrees. Omnidirectional pattern with peak gain of 0 dBi.

Emissions Mask	User defined reflecting proposed MBANS 1 MHz (-20 dB) bandwidth.  close-up view of +/- 4 MHz follows: 

Propagation Model	Victim Receiver to Interfering Transmitter path loss calculated using Extended Hata model. Median loss and variations enabled. Results generated for Suburban and Rural environments. Above roof propagation environment selected. Local environment (AMT receiver) is outdoors. Local environment (MBANS transmitter) is outdoors or indoors depending upon the test case. 
Relative Location	Victim Receiver to Interfering Transmitter locations using “None” mode. Path azimuth taken as uniform random variable over 0 to 360 degree range. Path distance factor taken as constant equal to 1. For Case 7, path azimuth will be taken as a uniform random variable over 224 to 226 degrees, to force the MBANS transmitters to occupy the mainlobe of the AMT receive antenna.
Number of Active Transmitters	Constant value of 1, 10 or 50 used to represent the number of active MBANS systems. Only one node transmits at a time within any given MBANS network.
Simulation Radius	Control parameter, manually set to find probability of interference.

VI. VALIDATION TEST CASE

A simplified scenario was performed to validate SEAMCAT's calculation of $iRSS_{blocking}$ using the values shown in the tables above. For this validation case, the AMT transmitter and receiver were placed at a fixed relative location of (–320 km, 0). The MBANS interfering transmitter was placed at a fixed, relative location of (-10 km, 0) with respect to the AMT receiver. All antenna heights were set to zero. Figure 2 illustrates the geometry of this validation case.

Given 10 km separation, 0 dBm EIRP and 41.2 dBi receive antenna gain and free space path loss, a constant received power (iRSS) of –78.76 dBm is expected at 2377.5 MHz. SEAMCAT calculated a value of –78.76 for $iRSS_{blocking}$ (see Figure 2). This result matches the expected level.

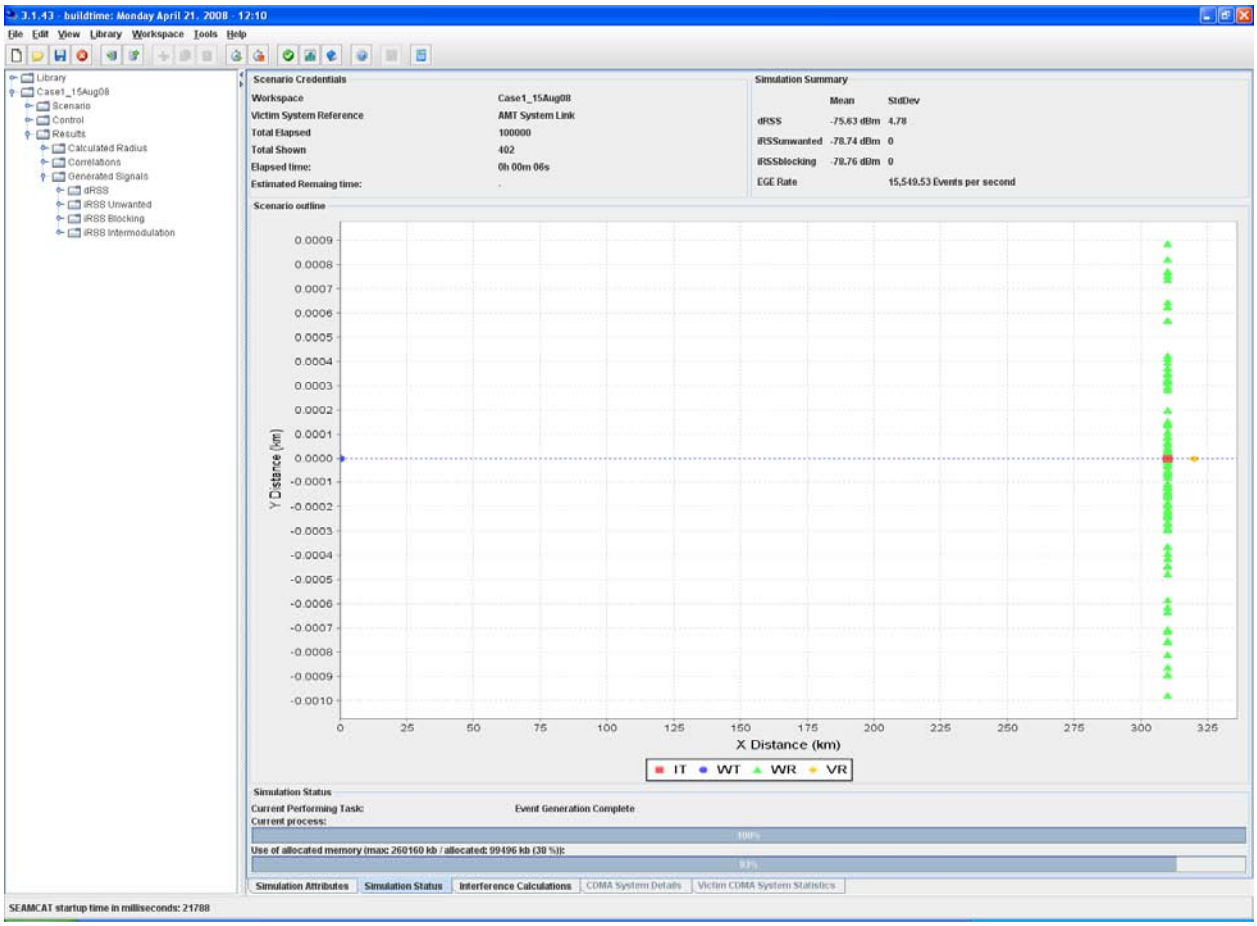


Figure 2 – Validation Case Spatial Arrangement

VII. DETAILED ANALYSIS RESULTS

The following sub-sections present detailed results from SEAMCAT for all scenarios. For each case, a brief description is followed by a table listing the probability of violating the I/N and C/(N+I) criteria of –3 dB and –12 dB for various MBANS to AMT separation distances. These probabilities are based on SEAMCAT's $iRSS_{blocking}$ variable, which represents the aggregate interference from all MBANS transmissions and is calculated by applying the defined AMT receiver selectivity mask to each interfering MBANS signal, considering its frequency separation from the AMT channel center.

A screen shot of the SEAMCAT simulation status window is included to show the mean and standard deviation statistics of the desired and interfering signals, as well as the spatial layout of AMT and MBANS devices for a representation of each case.

Case 0

SEAMCAT needs to have an interference source defined in its scenario workspace. As a result, the MBANS interfering system was retained in the simulation workspace. However, the MBANS transmit power level was set to a constant value of -200 dBm and test radius to 25 km, so that its contribution to I/N would be insignificant.

For the desired AMT signal an average value of –74.9 dBm is expected given 40 dBm transmit power, -6 dBi average transmit antenna gain, 41.2 dBi receive antenna gain and 150.1 dB free space path loss at 2377.5 MHz and 320 km separation. It was discovered that while SEAMCAT treats the victim receiver to wanted transmitter path as zero azimuth for index into the horizontal antenna gain pattern, the calculated elevation is used as an index into the vertical antenna gain pattern. SEAMCAT effectively steers the victim receiver's antenna beam in azimuth but not in elevation. Since this case considers a fixed aircraft distance and height, a constant 0.984 degree elevation tilt angle was specified in the victim receiver parameters.

Figure 3 summarizes the results of two million trials and shows an average AMT received signal of –75.64 dBm. This agrees well with the calculated value of –74.9 dBm listed above. Figure 4 and Figure 5 show the desired AMT received signal's cumulative distribution function and histogram, respectively. The probability of failure to close the link given victim receiver sensitivity equal to the noise floor, –108.6 dBm, was calculated by SEAMCAT to be 0.00155 = 1.55E-3. This value represents the probability that the AMT link at maximum distance fails to satisfy a C/N > 12 dB threshold. Review of the cumulative distribution function of the two million trial samples shows P(dRSS < -96.6 dBm) = 0.00159.

The positions of the victim receiver (VR) and wanted transmitter (WT), as well as interfering transmitter (IT) and wanted receiver (WR) in Figure 3, correspond to AMT and MBANS systems, respectively. SEAMCAT displays only a subset of the actual trials considered and places the wanted transmitter at the origin.

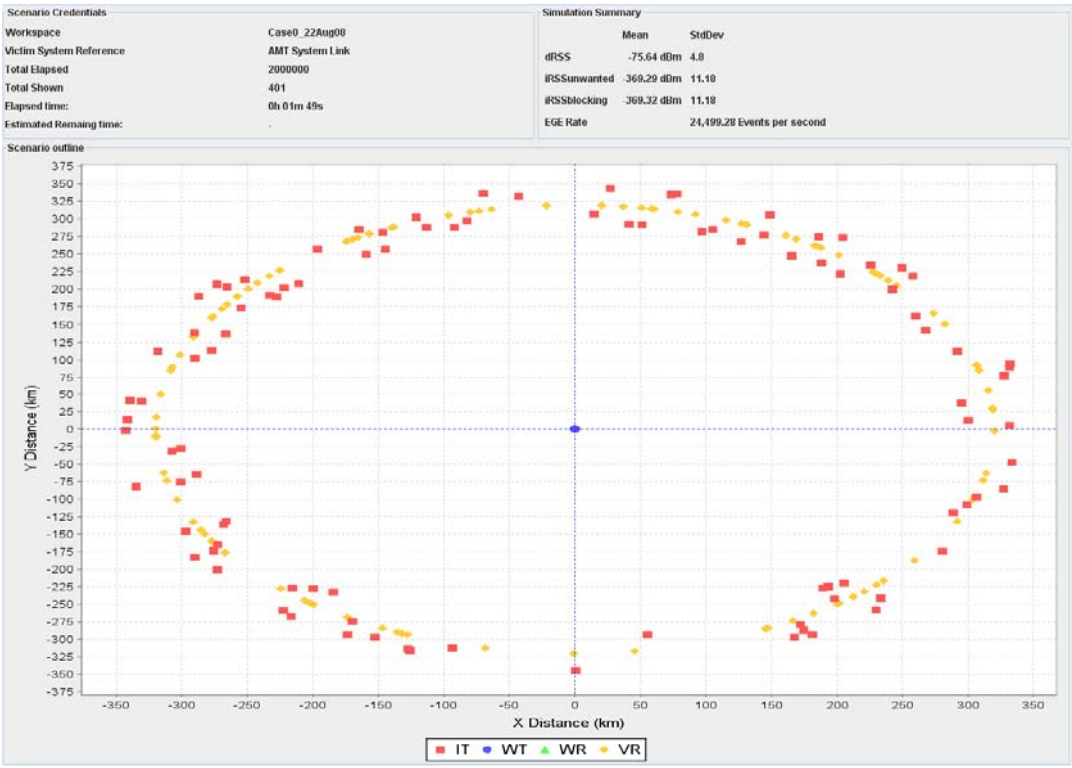


Figure 3 - Case 0 Simulation Status

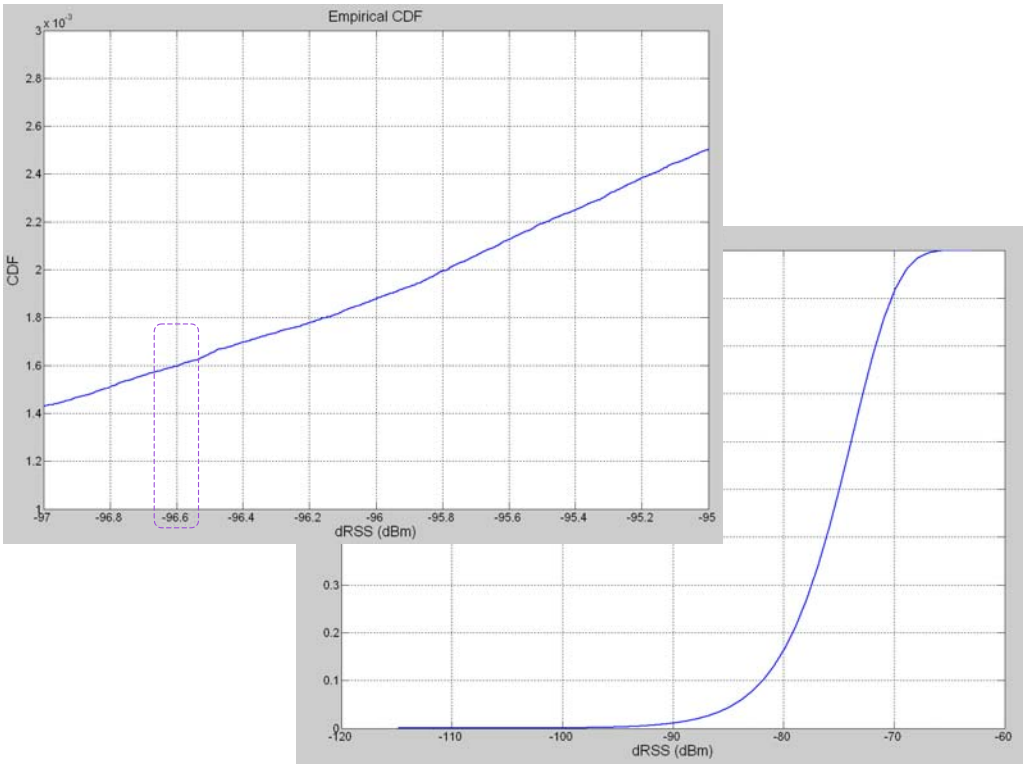


Figure 4 - AMT Received Signal Cumulative Distribution Function

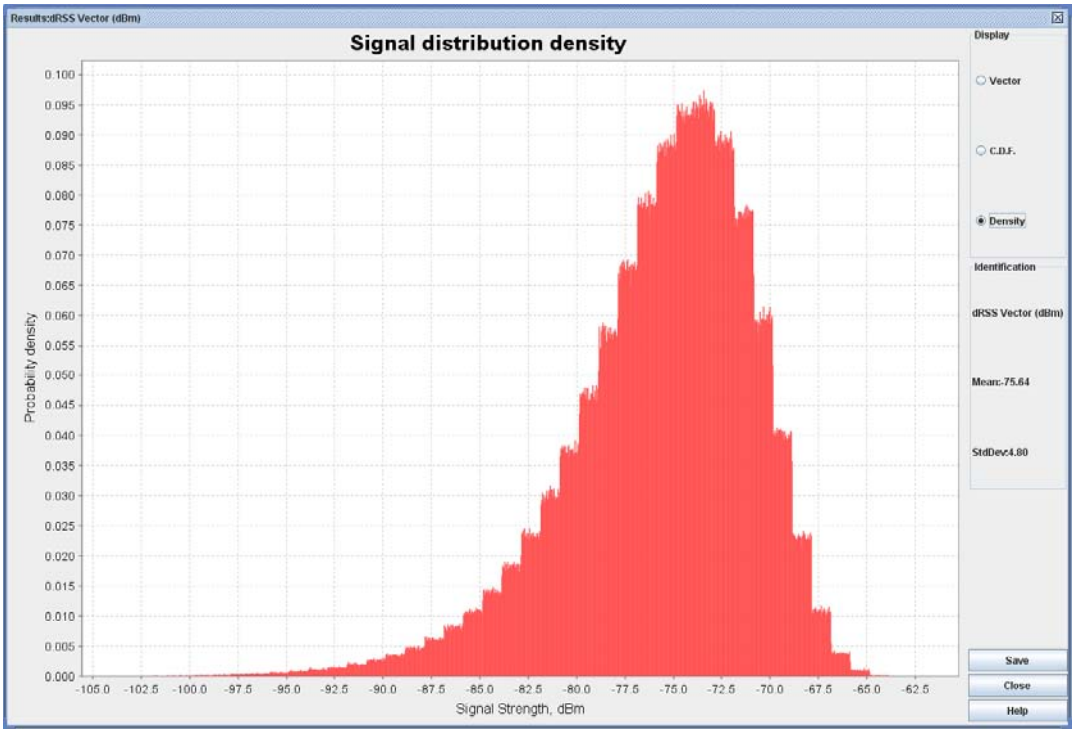
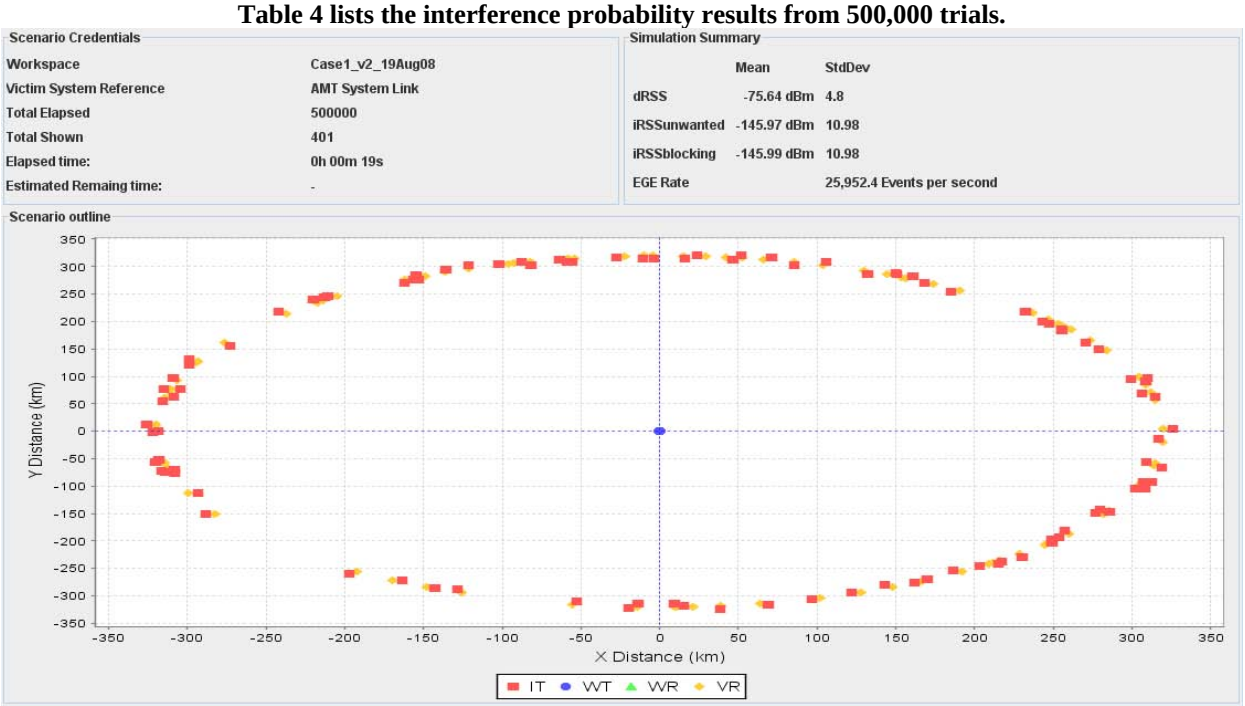


Figure 5 – AMT Received Signal Probability Density Function

Case 1

A single MBANS system is located uniformly in azimuth about the AMT receiver with the AMT transmitter at maximum 320 km distance and co-channel. The Extended Hata model is used with suburban and rural general environments, outdoor transmitter and outdoor receiver environments and above roof condition. Table 4 lists the interference probability results from 500,000 trials.



Scenario Credentials

Workspace	Case1_v2_19Aug08
Victim System Reference	AMT System Link
Total Elapsed	500000
Total Shown	401
Elapsed time:	0h 00m 19s
Estimated Remaing time:	-

Simulation Summary

	Mean	StdDev
dRSS	-75.64 dBm	4.8
iRSSunwanted	-145.97 dBm	10.98
iRSSblocking	-145.99 dBm	10.98
EGE Rate		25,952.4 Events per second

Figure 6 and Figure 7 show simulation status windows for selected conditions evaluated within Case 1.

Table 4 - Case 1 Interference Probability Results

Probability of Interference	Extended Hata Model Outdoor to Outdoor					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
50	0		0	0		0
20	7.98E-4		6.01E-6	0		0
10	0.00436		7.81E-5	4.41E-5		0
6	0.0102		3.69E-4	4.11E-4		4.01E-6
1.5	0.0865		0.0062	0.0083		2.12E-4
1.25				0.0100		3.37E-4
1	0.1713		0.0104	0.0131		4.67E-4

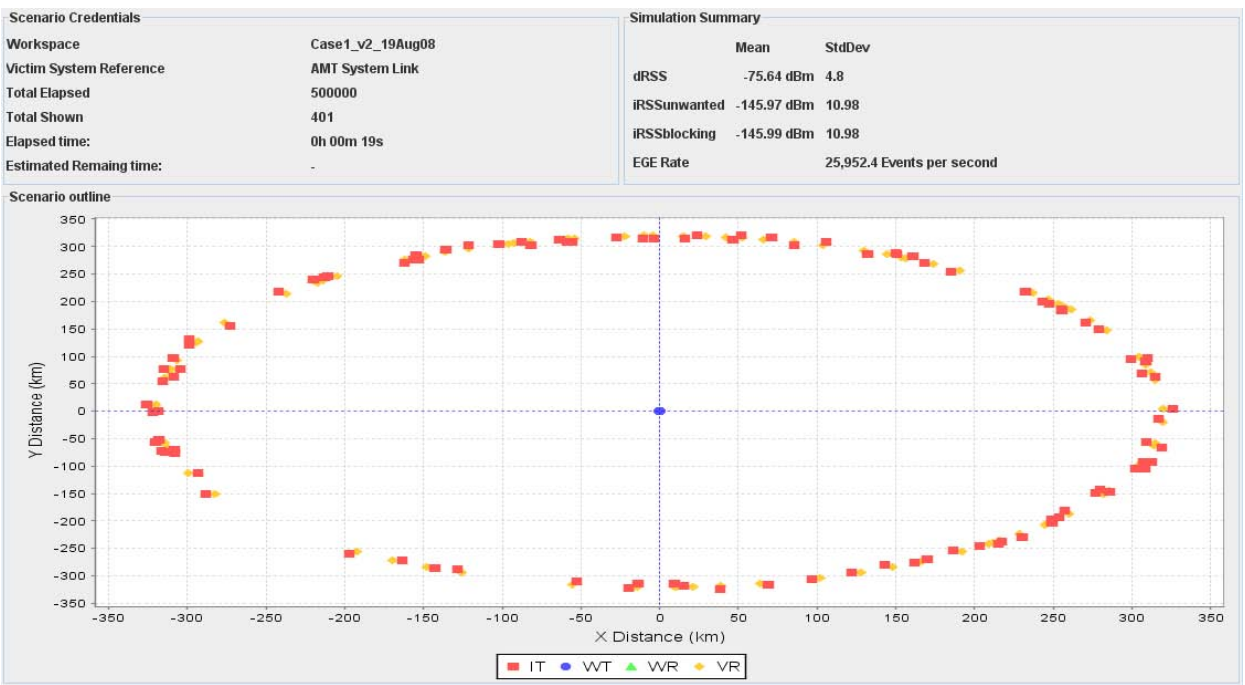


Figure 6 - Case 1 Simulation Status Window, 6 km, Extended Hata Model, Rural, Outdoor/Outdoor

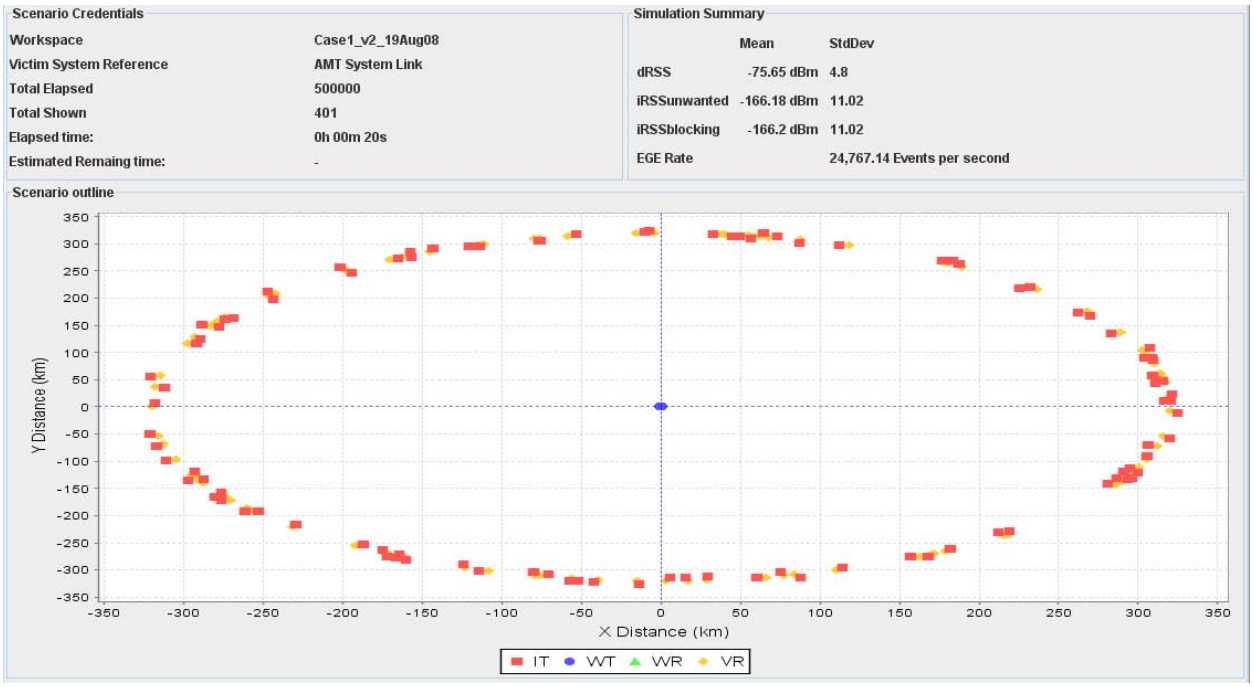


Figure 7 - Case 1 Simulation Status Window, 6 km, Extended Hata Model, Suburban, Outdoor/Outdoor

Case 2

Building upon Case 1, the Extended Hata propagation model configuration includes indoor transmitter and outdoor receiver environments. Table 5 lists the interference probability results from 500,000 trials. Figure 8 shows a representative simulation status window for comparison with Figure 7.

Table 5 - Case 2 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
20	1.22E-4		2.00E-6	0		0
10	0.0012		8.02E-6	1.00E-5		0
6	0.0036		5.81E-5	7.21E-5		2.00E-6
3.25	0.0099		4.05E-4	4.99E-4		2.00E-6
1.5	0.0292		0.0018	0.0026		3.01E-5
1	0.0538		0.0035	0.0046		9.42E-5
0.5				0.0109		4.99E-4

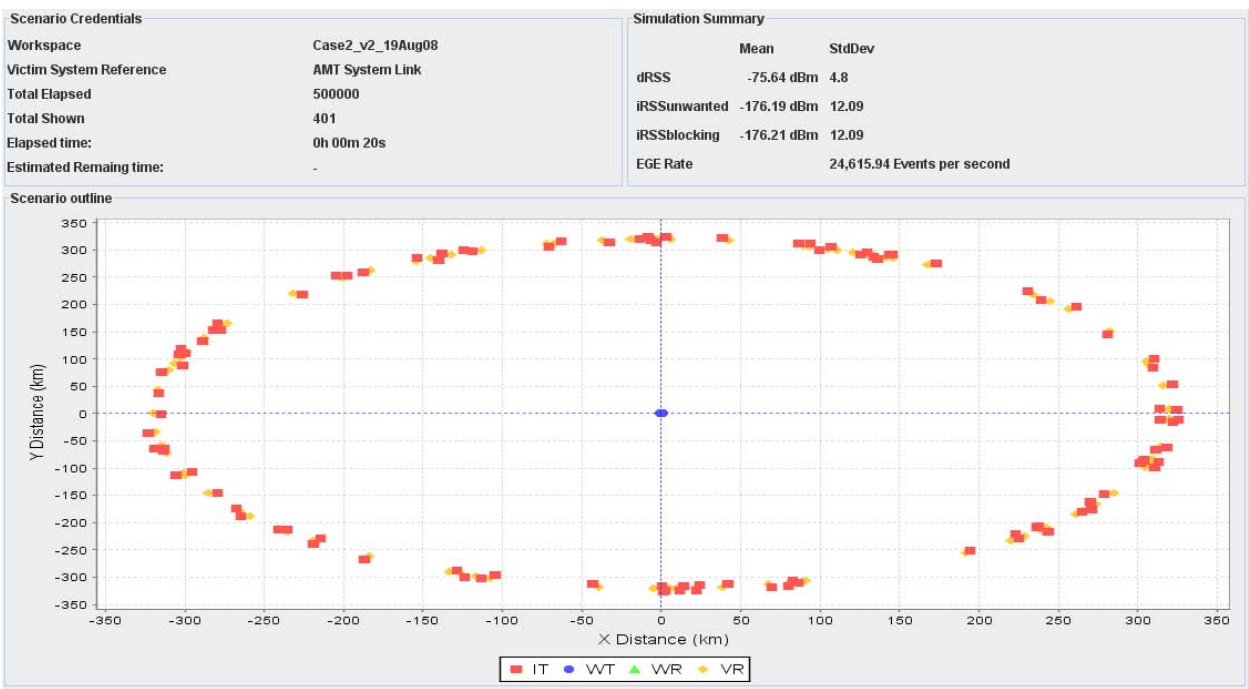


Figure 8 - Case 2 Simulation Status Window, 6 km, Extended Hata Model, Suburban, Indoor/Outdoor

Case 3

Case 3 introduces ten MBANS systems located at a fixed distance and distributed uniformly in azimuth about the AMT receiver. Table 6 lists the interference probability results from 500,000 trials. Figure 9 shows a representative simulation status.

Table 6 - Case 3 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 10 MBANS					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
20	0.0013		0	6.01E-6		0
10.5	0.0100		8.82E-5	5.01E-5		0
10	0.0112		1.04E-4	7.42E-5		0
6	0.0359		6.29E-4	6.01E-4		2.00E-6
2.5	0.1390		0.0071	0.0095		9.02E-5
1.5	0.2944		0.0192	0.0261		4.01E-4

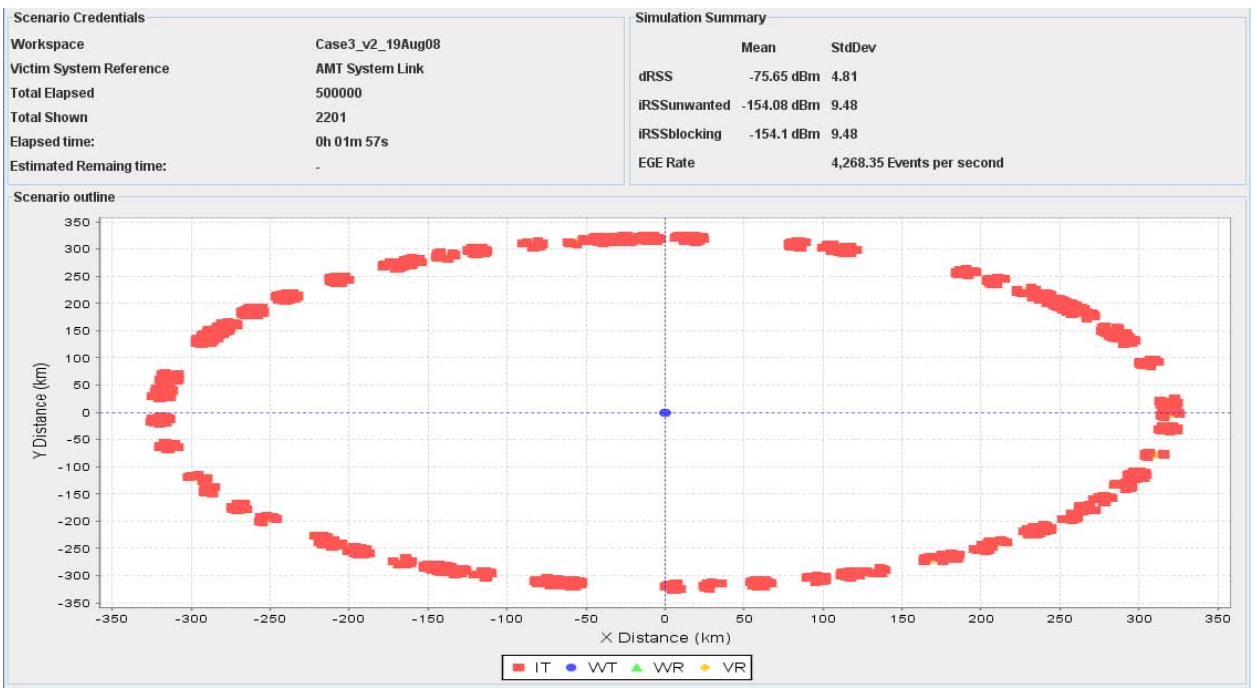


Figure 9 - Case 3 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 10 MBANS

Case 4

Case 4 applies a 25% duty cycle factor on each of the ten MBANS systems. Table 7 summarizes the interference probability results from 500,000 trials. Figure 10 shows a representative simulation status.

Table 7 - Case 4 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 10 MBANS, 25% Duty Cycle					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
20	3.31E-4		6.01E-6	2.00E-6		0
10	0.0029		3.01E-5	1.60E-5		0
6	0.0089		1.36E-4	1.42E-4		2.00E-6
5.75	0.0095		1.72E-4	1.92E-4		0
1.15	0.1130		0.0073	0.0096		1.40E-4
1.10				0.0104		1.98E-4
1	0.1376		0.0089	0.0119		2.69E-4

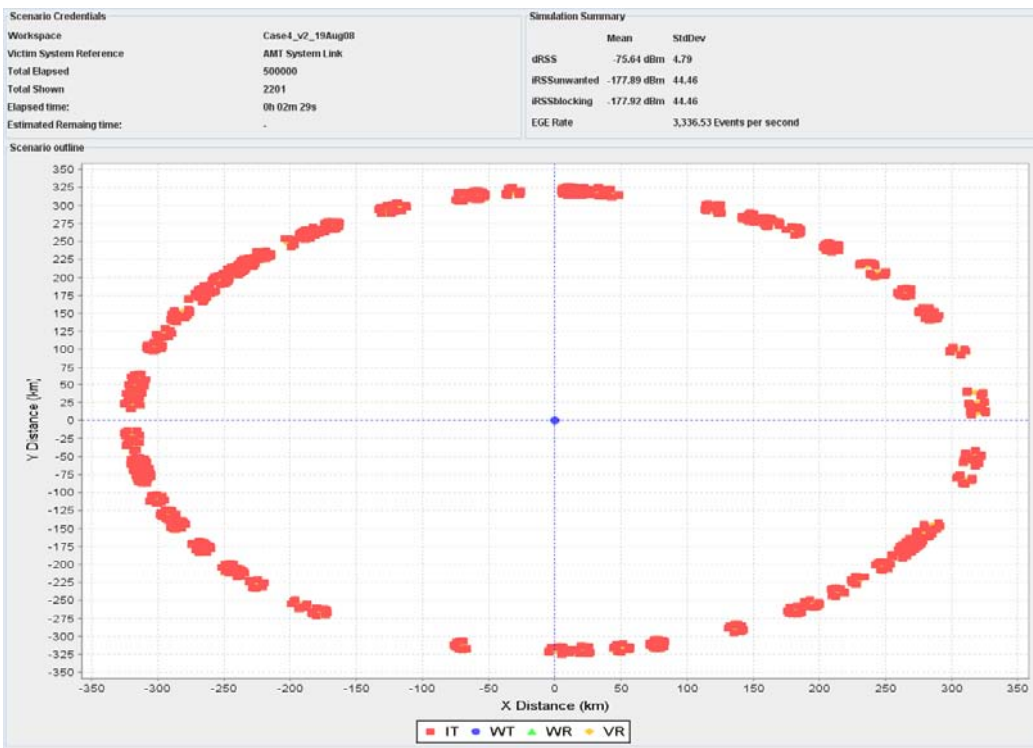


Figure 10 - Case 4 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 10 MBANS, 25% Duty Cycle

Case 5

Case 5 introduces frequency hopping to the MBANS systems. Each MBANS system transmits on a frequency across the 2361 to 2399 MHz band in 1 MHz steps with equal probability. Table 8 summarizes the interference probability results from 500,000 trials for each of various distances. Figure 11 shows a representative simulation status.

Table 8 - Case 5 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 10 MBANS, 25% Duty Cycle, Frequency Diversity Across 2361 to 2389 MHz					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
10	4.65E-4		2.00E-6			
6	0.0015		3.81E-5			
2.2	0.0079		3.63E-4			
1.8	0.0101		5.91E-4			
1.2	0.0191		0.0013			
0.35				0.0078		4.53E-4
0.2				0.0080		4.27E-4
0.15				0.0091		6.15E-4
0.1				0.0125		8.98E-4

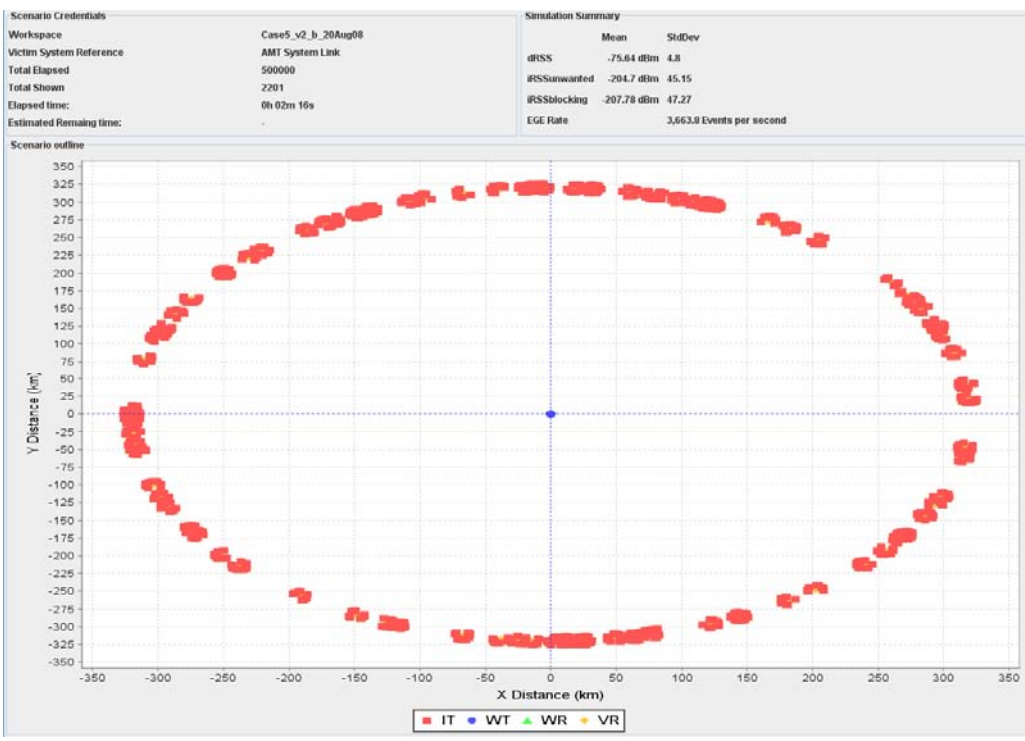


Figure 11 - Case 5 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 10 MBANS, 25% Duty Cycle, Frequency Diversity

Case 6

Case 6 builds upon Case 5, including a total of 50 MBANS systems uniformly distributed about the AMT receiver. Table 9 summarizes the interference probability results from 500,000 trials for each of various distances. Figure 12 shows a representative simulation status.

Table 9 - Case 6 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity Across 2361 to 2389 MHz					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
5	0.0106		2.12E-4			
3	0.0250		8.68E-4			
2.95	0.0257		9.66E-4			
2.9	0.0263		0.0010			
2.8	0.0278		0.0012			
1.1				0.0087		1.76E-4
1				0.0101		2.22E-4
0.75				0.0150		3.63E-4
0.7				0.0163		4.59E-4
0.6				0.0195		6.21E-4
0.55				0.0218		7.95E-4
0.52				0.0239		9.64E-4
0.5				0.0252		0.0010
0.4				0.0339		0.0018

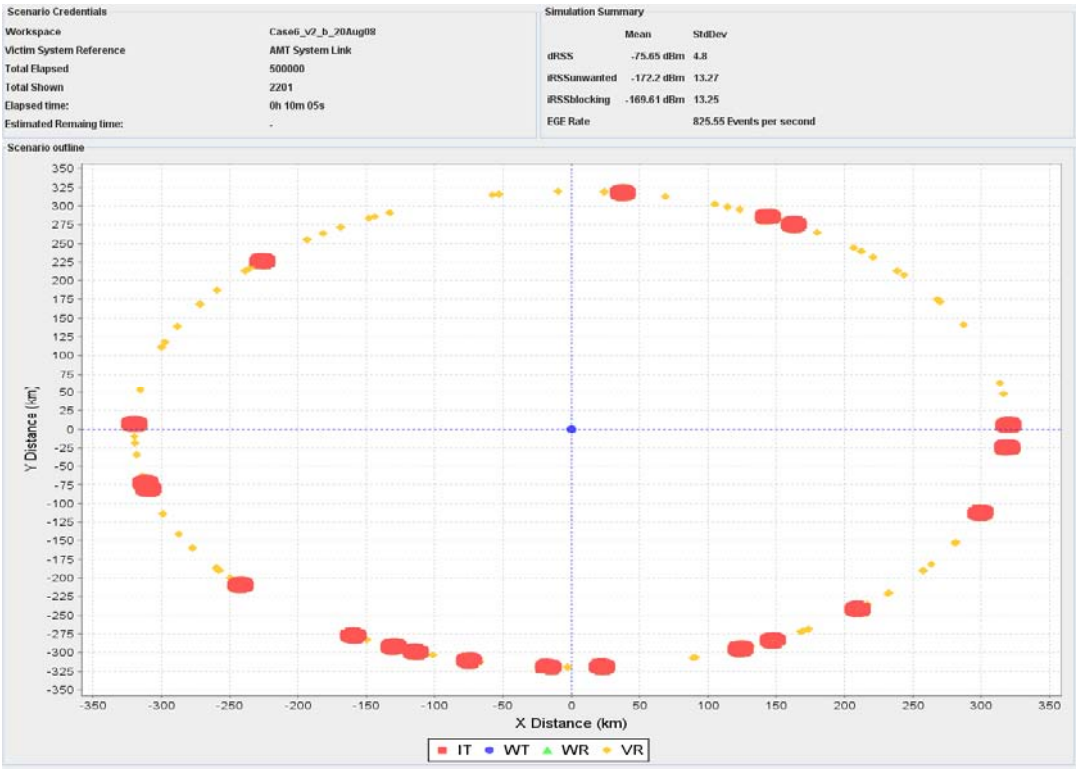


Figure 12 - Case 6 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity

Case 7

Case 7 locates the 50 MBANS transmitters from Case 6 uniformly, +/- 1 degree about the AMT receive antenna mainlobe. Table 10 summarizes the interference probability results from 500,000 trials for each of various distances. Figure 13 shows a representative simulation status.

Table 10 - Case 7 Interference Probability Results

Probability of Interference	**Extended Hata Model Indoor to Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity Across 2361 to 2389 MHz, +/- 1 degree about AMT Receive Antenna Mainlobe**					
	Rural			**Suburban**		
Separation Radius (km)	**I/N > -3 dB**		**C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$**	**I/N > -3 dB**		**C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$**
27.5	0.0050		1.40E-5			
25.2	0.0094		3.81E-5			
25	0.0098		3.21E-5			
24.6	0.0111		5.01E-5			
24.5	0.0112		6.01E-5			
24.4	0.0116		5.41E-5			
23.9	0.0133		5.61E-5			
23.8	0.0132		6.41E-5			
23.5	0.0145		6.61E-5			
16.3	0.0750		4.45E-4			
14	0.1188		8.56E-4			
13.6	0.1299		9.16E-4			
13.5	0.1323		9.74E-4			
13.4	0.1349		9.90E-4			
13.3	0.1330		0.0010			
7.1				0.0098		3.61E-5
3.6				0.1029		7.07E-4
3.5				0.1103		7.57E-4
3.4				0.1192		8.48E-4
3.3				0.1276		9.34E-4
3				0.1638		0.0013
2.7				0.2059		0.0019
2.5				0.2400		0.0024

Figure 13 - Case 7 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 50 MBANS about AMT Receive Antenna Mainlobe, 25% Duty Cycle, Frequency Diversity

Case 8

This case is the same as Case 0, except that the AMT receive antenna is changed to a 31 dBi gain pattern. The pattern was taken from Figure 1 of ITU-R M.1459 documentation and represents measured data from a 2.44 meter diameter antenna.

Figure 14 summarizes the results of two million trials and shows an average AMT received signal of –85.84 dBm. This agrees well with expected free space loss of –85.1 dBm. Figure 15 shows the desired AMT received signal's cumulative distribution function. The probability of failure to close the link, given victim receiver sensitivity equal to the noise floor, –108.6 dBm, was calculated by SEAMCAT to be 0.0285 = 2.85%. This value represents the probability that the AMT link at maximum distance fails to satisfy a C/N > 12 dB threshold. Review of the cumulative distribution function of the two million trial samples shows P(dRSS < -96.6 dBm) = 0.0295.

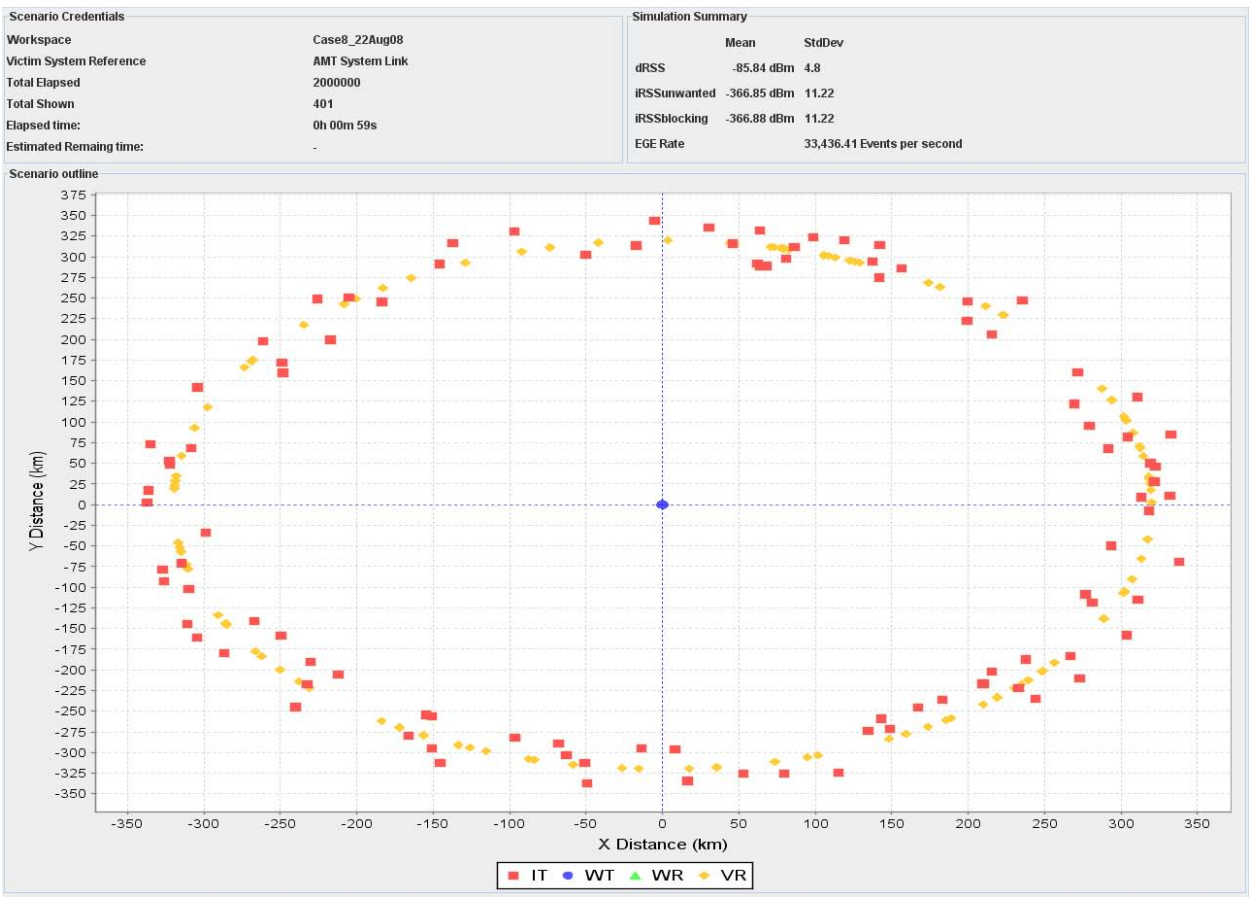


Figure 14 - Case 8 Simulation Status

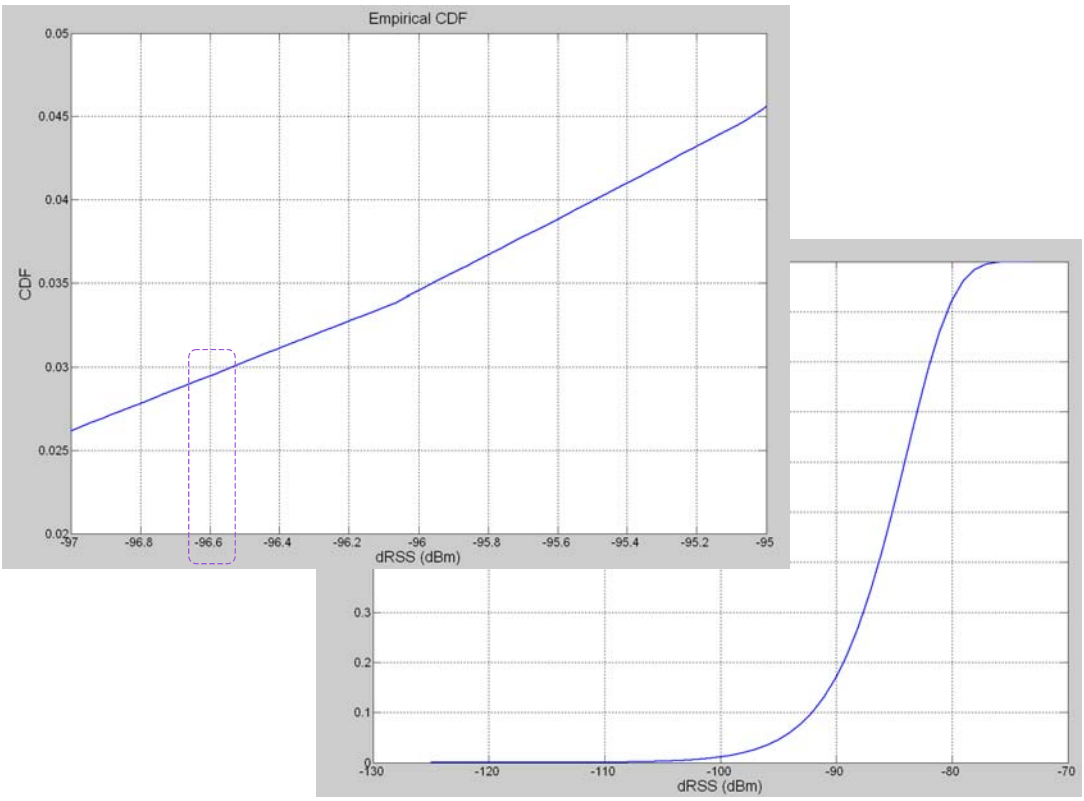


Figure 15 - AMT Received Signal Cumulative Distribution Function

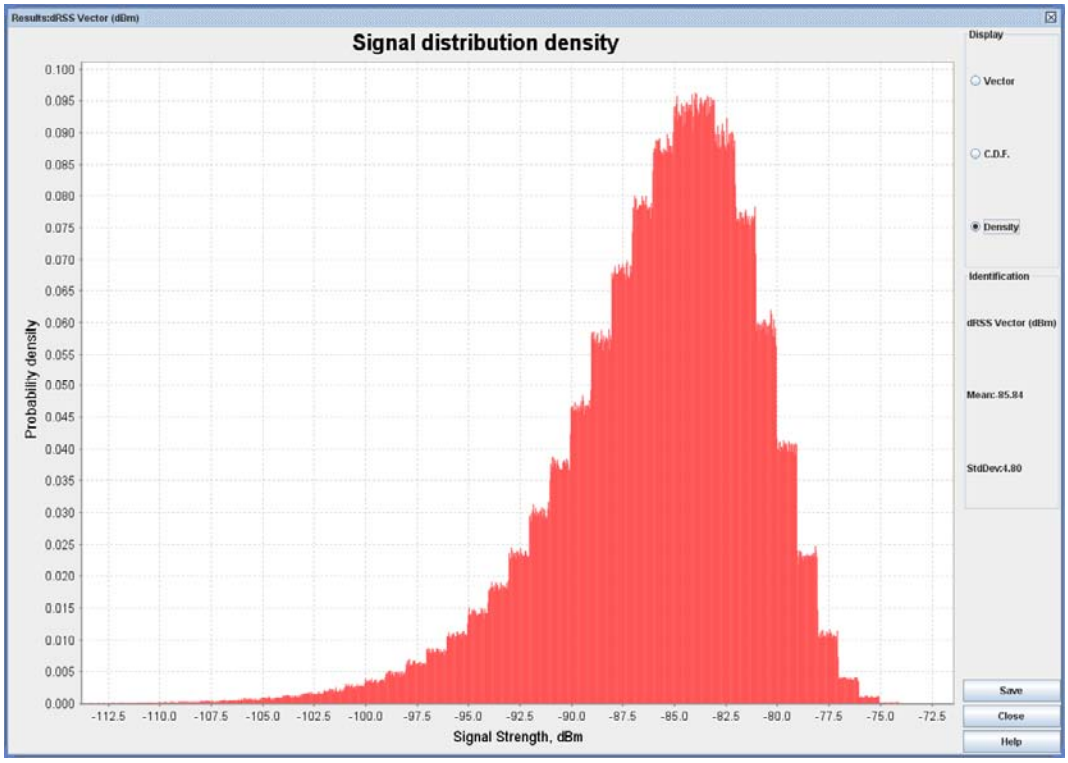


Figure 16 – AMT Received Signal Probability Density Function

Case 9

This case is the same as Case 6, except that the AMT receive antenna is changed to a 31 dBi gain pattern. The pattern was taken from Figure 1 of ITU-R M.1459 documentation and represents measured data from a 2.44 meter diameter antenna. Table 11 summarizes the interference probability results from at least 100,000 trials for each of various distances. Figure 17 shows a representative simulation status.

Table 11 - Case 9 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity Across 2361 to 2389 MHz, 31 dBi Antenna					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
20	2.07E-4		1.04E-5			
15	4.43E-4		2.48E-5			
10	0.0022		9.32E-5	4.14E-6		
8	0.0043		3.42E-4			
6	0.0079		8.90E-4			
5.5	0.0103		0.0012			
5	0.0124		0.0015	1.82E-4		6.22E-6
4.5	0.0148		0.0021			
4	0.0202		0.0030	4.20E-4		3.94E-5
3	0.0339		0.0062	0.0012		1.10E-4
2.5	0.0465		0.0094			
2	0.0692		0.0150	0.0042		3.96E-4
1.9	0.0755		0.0172			
1.8	0.0805		0.0187	0.0056		5.80E-4
1.5	0.1120		0.0262	0.0082		9.63E-4
1.4				0.0098		0.0012
1.3				0.0112		0.0014
1				0.0182		0.0028
0.85				0.0230		0.0038
0.7				0.0300		0.0054
0.5				0.0480		0.0093
0.3				0.0859		0.0168

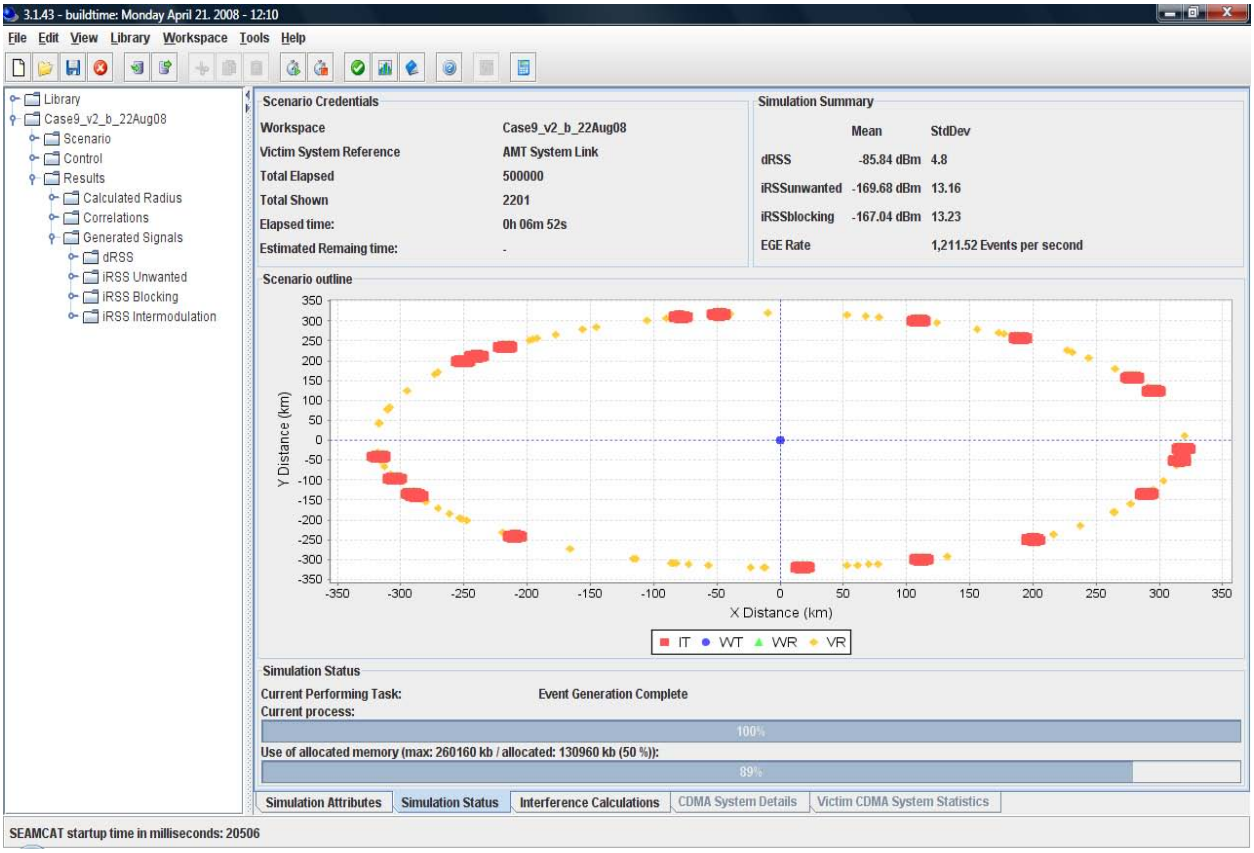


Figure 17 - Case 9 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity, 31 dBi Antenna

Case 10

This case is the same as Case 7 except that the AMT receive antenna is changed to a 31 dBi gain pattern. The pattern was taken from Figure 1 of ITU-R M.1459 documentation and represents measured data from a 2.44 meter diameter antenna. Table 12 summarizes the interference probability results from at least 100,000 trials for each of various distances. Figure 18 shows a representative simulation status.

Table 12 - Case 10 Interference Probability Results

Probability of Interference	Extended Hata Model Indoor to Outdoor, 50 MBANS, 25% Duty Cycle, Frequency Diversity Across 2361 to 2389 MHz, 31 dBi Antenna +/- 1 degree about AMT Receive Antenna Mainlobe					
	Rural			Suburban		
Separation Radius (km)	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$	I/N > -3 dB		C/(N+I) < 12 dB | dRSS > $VR_{sensitivity}$
24	0.0043		2.80E-4			
22	0.0085		5.28E-4			
21	0.0104		6.73E-4			
20	0.0146		0.0011			
15	0.0449		0.0033			
11.5	0.1108		0.0090			
10	0.1641		0.0153	0.0005		2.07E-5
9.7	0.1800		0.0169			
9.6	0.1856		0.0182			
9.5	0.1902		0.0187			
9	0.2165		0.0214	0.0010		5.18E-5
8	0.2826		0.0325	0.0020		1.35E-4
7				0.0039		2.69E-4
6				0.0083		5.59E-4
5.5				0.0102		0.0014
5				0.0125		0.0017
4.5				0.0262		0.0020
4				0.0417		0.0031
3				0.1070		0.0097
2.5				0.1790		0.0174
2				0.2970		0.0350

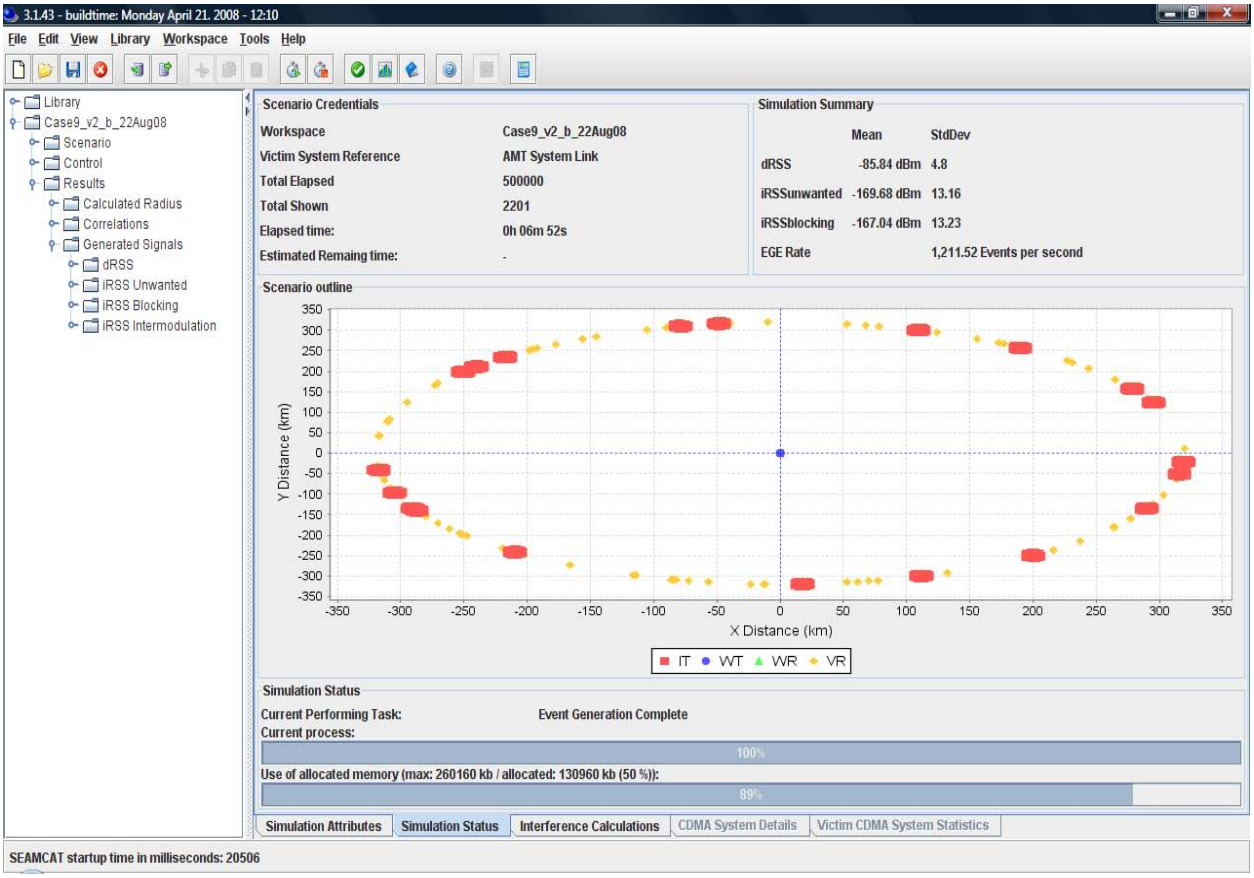


Figure 18 - Case 10 Simulation Status Window, 6 km, Extended Hata Model, Suburban, In/Outdoor, 50 MBANS about AMT Receive Antenna Mainlobe, 25% Duty Cycle, Frequency Diversity, 31 dBi Antenna

VIII. SUMMARY OF RESULTS AND CONCLUSIONS

The probabilistic interference analysis results are initially considered with respect to the ITU-R M.1459 recommendation, which defines I/N "maximum practical value is considered to be approximately 0.5 (-3 dB) with smaller values desired."[6] Such an approach, however, affords no insight as to the actual probability of *harmful* interference from MBANS to AMT. As a result, the probabilistic interference analysis results are considered with respect to an increase in AMT link outage from the best-case, purely noise-limited scenario.[7] Such a focus on the impact of MBANS to AMT link outage provides more relevant and meaningful insight into the separation distance sufficient to prevent harmful interference to AMT.

An outage threshold of 1.6 times the noise-limited AMT link is applied for the determination of separation distance to prevent harmful interference. This 60% value is based upon examination of the AMT link budget (Cases 0 and 8) with I/N = -3 dB. With this interference-to-noise ratio, the AMT link budget for a 320 km target and 41.2 dB receive antenna gain yields a 67% increase in link outage with respect to its noise-limited case. When a 31 dBi AMT receive antenna pattern is applied, I/N = -3 dB yields a 61% increase in noise-limited AMT link outage probability. Therefore, our limit for acceptable increase in outages is drawn from the recommended –3dB I/N level of ITU-R M.1459.[8]

Separation Distance to Satisfy I/N < -3 dB

Table 13 summarizes the minimum separation distance at which the probability of exceeding –3 dB I/N equals 1%. This table also shows the corresponding probability of failing to meet the C/(N+I) > 12 dB objective at the same separation distance. The results show that the maximum, practical I/N threshold put forth by ITU-R M.1459 can, in fact, be met with very high (> 99%) certainty for modest separation distances of 5.5 km and 1.4 km for rural and suburban propagation environments, respectively (Cases 6 and 9).

Even when 50 MBANS systems are forced to lie within the narrow, main beam of the AMT receive antenna with 41.2 dBi gain, the I/N threshold will still be met with 99% likelihood for separation distances of 7.1 and 25 km for suburban and rural RF propagation environments, respectively (Case 7). When a more realistic, 31 dBi AMT receive antenna pattern is considered, similar to that reportedly used for the Learjet testing, 50 MBANS systems within the main beam need separation of 5.5 and 21 km to satisfy I/N < -3 dB with 99% certainty (Case 10). Note that

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6 *Protection Criteria for Telemetry Systems in the Aeronautical Mobile Service and Mitigation Techniques to Facilitate Sharing with Geostationary Broadcasting-Satellite and Mobile-satellite Services in the Frequency Bands 1452-1525 MHz and 2310-2360 MHz*, Recommendation ITU-R M.1459, 2000, Section 2.2.3. *available at* www.itu.int.

7 The actual baseline outage rate can be expected to be higher than the conservative noise-limited case considered because of the significant interference often expected in the S-band due to sources such as ubiquitous Part 15 and Part 18 devices operating in the adjacent band.

8 ITU-R M.1459 also recommends –8.13 dB I/N for terrestrial interference sources but this is in addition to –4.15 dB from BSS satellites, which are not present in the 2360-2395 MHz band at issue here. The combined ITU-R M.1459 –8.13 dB and –4.15 dB I/N limits correspond to an effective composite interference limit of –2.68 dB, slightly higher than its separately-stated –3 dB "maximum practical value." We use the slightly more stringent value of –3 dB here.

at these separation distances, the probability of AMT link outage increases by only a factor of ~1.02 to 1.05 from the noise-limited condition, well below the 1.6 factor representing harmful interference.

Separation Distance to Avoid Harmful Interference

Table 14 lists the minimum separation distance to ensure an increase in AMT link outage rate for the most sensitive 200K AMT receiver by no more than a factor of 1.6 (*i.e.*, from 3.0% to 4.8% for the 31 dBi receive antenna and from 0.16 % to 0.26% for the 41.2 dB RX antenna). Figure 19 and Figure 20 plot the increase in AMT link outage over the range of separation distances considered.

A separation distance of less than 0.3 or 1.9 km prevents harmful interference from 50 MBANS systems to an AMT link with a 31 dBi receive antenna gain in suburban or rural propagation environments, respectively (Case 9). If the 50 MBANS systems are forced to lie within the main beam of the 31 dBi AMT receive antenna, a separation of 2.5 or 9.7 km is sufficient for suburban or rural environments, respectively (Case 10). At these separation distances, the increase in AMT link outage relative to the noise limited case is less than 1.6 times, as shown by the probability of C/(N+I) < 12 dB given desired AMT signal above the receiver sensitivity threshold.

When the ITU-R M.1459 peak gain of 41.2 dBi is considered, a separation distance of 0.55 or 3.0 km prevents harmful interference from 50 MBANS systems to an AMT link in suburban or rural propagation environments, respectively (Case 6). If the 50 MBANS systems are placed within the main beam of the 41 dBi AMT receive antenna, a separation of 3.3 or 13.6 km is sufficient for suburban or rural environments, respectively (Case 7). These separation distances support an increase in AMT link outage relative to the noise limited case is less than 1.6 times, as shown by the probability of C/(N+I) < 12 dB given desired AMT signal above the receiver sensitivity threshold.

Conclusions

Figure 21 maps hospitals and AMT receive sites in the continental United States using latitude and longitude data provided by Verispan and AFTRCC, respectively.[9] A radius of 9.7 km[10] is drawn about each AMT site to reflect the larger result of Case 10. A conservative calculation that ignores overlap of exclusion zones indicates 99.5% of the continental United States area lies outside a 9.7 km separation radius from all AMT sites. It is clear from this map that there is a tremendous opportunity to realize the benefit of MBANS for the majority of the United States.

These simulations include MBANS transmitter frequency-hopping across the 2360 to 2400 MHz band. The separation distances listed above could be dramatically reduced if geographic and frequency coordination is implemented between AMT and MBANS deployments. Such coordination could ensure that MBANS systems implement frequency hopping or agility using

[9] Comments of GE Healthcare, ET Docket 08-59 (filed 11 June 2008), Appendix A.

[10] The 9.7 km separation corresponds to the 31 dB receive antenna (an 8 foot parabolic dish) that should be much more common than the 41.2 dB antenna, which is a huge 10 meter parabolic dish.

only channels outside the AMT receive bandwidth or between AMT channels. A previous analysis of frequencies listed in AMT S-band licenses reveals ample bandwidth for MBANS operation.[11]

Perhaps the most important outcome of these simulations is that the AMT outage rate remained very low, even for substantially smaller separation distances than those given above for which the ITU-R M.1459 I/N is satisfied with 99% certainty. This result is a consequence of the significant, excess, average margin in the AMT link. This result was missed entirely by AFTRCC's minimum coupling loss analysis, since it neglected to directly consider the AMT link at all, but rather focused only on violations of an absolute power flux density limit suggested by ITU-R M.1459. The fact that the present Monte Carlo study demonstrates that I/N levels corresponding to much higher power flux densities still result in negligible increases in AMT outages confirms the prior conclusion by GEHC that the various ITU-R M.1459 limits are overly conservative.

It is important to note that the separation distances obtained from this analysis should be conservative upper bounds for several reasons. First, the 25% MBANS duty cycle used represents a fully-loaded body sensor network. In the more common case with only one or two sensors the duty-cycle would be significantly lower. Second, although all MBANS emissions are assumed to be at the maximum permitted level; in reality many actual MBANS devices may employ lower transmit powers. Third, the baseline AMT outage rate assumes the most sensitive possible AMT system (*i.e.*, 200K noise temperature) operating in the absence of interference, whereas in reality most AMT systems will have worse intrinsic sensitivity and/or be expected to receive significant ambient interference from sources such as ubiquitous Part 15 and Part 18 devices. Finally, the conditional probability $P[C/(N+I) < 12\text{ dB} \mid dRSS \geq VR_{sensitivity}]$ reported by SEAMCAT will always exceed the joint probability $P[C/(N+I) < 12\text{ dB} \cap dRSS \geq VR_{sensitivity}]$ that represents the actual incremental outage probability with respect to the baseline noise-limited AMT outage rate.

[11] *See* Comments of GE Healthcare, ET Docket 08-59 (filed 11 June 2008), Appendix A, Figure 3, at page A-4.

Table 13 - Separation Distance Summary for 99% Certainty of I/N < -3 dB

		Rural		Suburban	
Case	**Description**	**Separation Distance, Ds, [km] for P[I/N > -3 dB] = 1%**	**P[C/(N+I < 12 dB | dRSS > $VR_{sensitivity}$] at Ds**	**Separation Distance, Ds, [km] for P[I/N > -3 dB] = 1%**	**P[C/(N+I < 12 dB | dRSS > $VR_{sensitivity}$] at Ds**
0	AMT max distance link without MBANS	Free Space Loss with Aircraft Antenna Fading Characteristic : P[C/N < 12 dB] = **1.55E-3**			
1	1 MBANS, out/out	6.0	3.69E-4	1.25	3.37E-4
2	1 MBANS, in/out	3.25	4.05E-4	0.5	4.99E-4
3	10 MBANS, in/out	10.5	8.82E-5	2.5	9.02E-5
4	10 MBANS, in/out, 25% duty cycle	5.75	1.72E-4	1.10	1.98E-4
5	10 MBANS, in/out, 25% duty cycle, frequency hopping	1.8	5.91E-4	0.15	6.15E-4
6	50 MBANS, in/out, 25% duty cycle, frequency hopping	5	2.12E-4	1	2.22E-4
7	50 MBANS, in/out, 25% duty cycle, frequency hopping, in 41.2 dBi mainlobe	25	3.21E-5	7.1	3.61E-5
8	AMT max distance link without MBANS, 31 dBi antenna	Free Space Loss with Aircraft Antenna Fading Characteristic : P[C/N < 12 dB] = **0.0295**			
9	50 MBANS, in/out, 25% duty cycle, frequency hopping, 31 dBi antenna	5.5	0.0012	1.4	0.0012
10	50 MBANS, in/out, 25% duty cycle, frequency hopping, in 31 dBi mainlobe	21	6.73E-4	5.5	0.0014

Table 14 - Separation Distance for Factor of 1.6 Increase in AMT Noise-Limited Link Outage

		Rural		Suburban	
Case	**Description**	**Separation Distance, Ds [km]**	**P[C/(N+I < 12 dB | dRSS > $VR_{sensitivity}$] at Ds**	**Separation Distance, Ds [km]**	**P[C/(N+I < 12 dB | dRSS > $VR_{sensitivity}$] at Ds**
0	AMT max distance link without MBANS	Free Space Loss with Aircraft Antenna Fading Characteristic: P[C/N < 12 dB] = **1.55E-3** 60% = 9.3E-4			
6	50 MBANS, in/out, 25% duty cycle, frequency hopping	3	8.68E-4	0.55	7.95E-4
7	50 MBANS, in/out, 25% duty cycle, frequency hopping, in 41.2 dBi mainlobe	13.6	9.16E-4	3.3	9.34E-4
8	AMT max distance link without MBANS, 31 dBi antenna	Free Space Loss with Aircraft Antenna Fading Characteristic: P[C/N < 12 dB] **= 0.0295** 60% = 0.0177			
9	50 MBANS, in/out, 25% duty cycle, frequency hopping, 31 dBi antenna	1.9	0.0172	< 0.3 km	0.0168
10	50 MBANS, in/out, 25% duty cycle, frequency hopping, in 31 dBi mainlobe	9.7	0.0169	2.5	0.0174

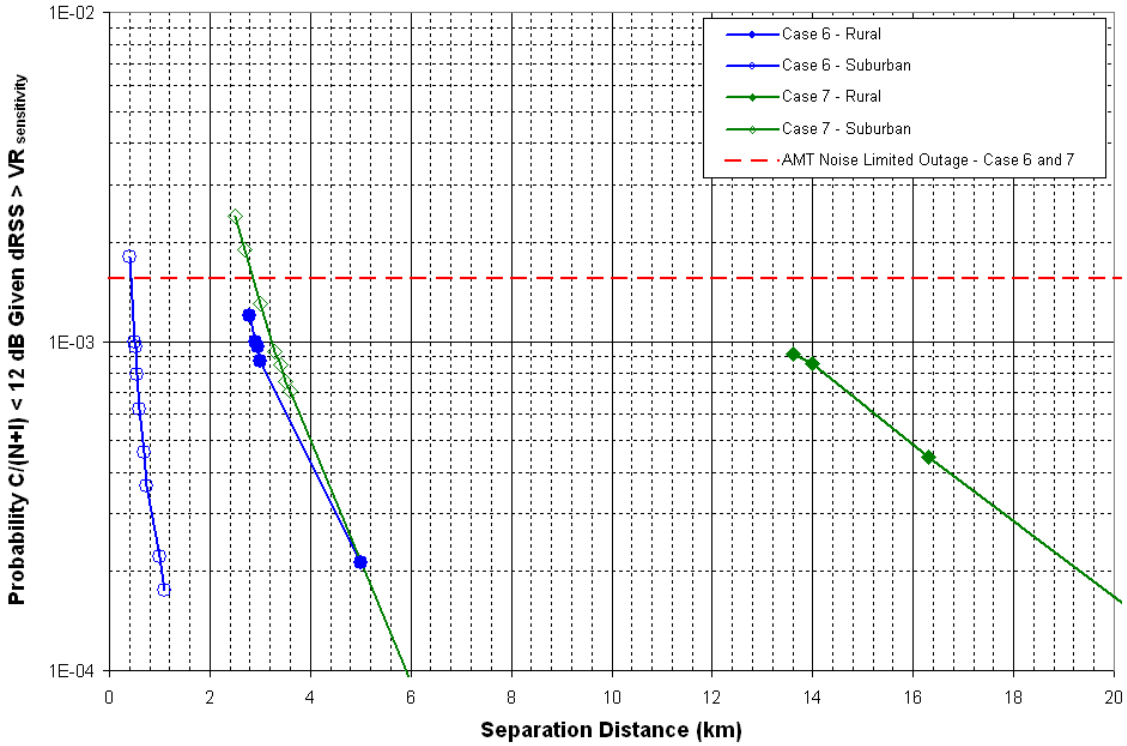

Figure 19 - Increase Above AMT Noise-Limited Link Outage Versus Separation Distance, Cases 6 and 7

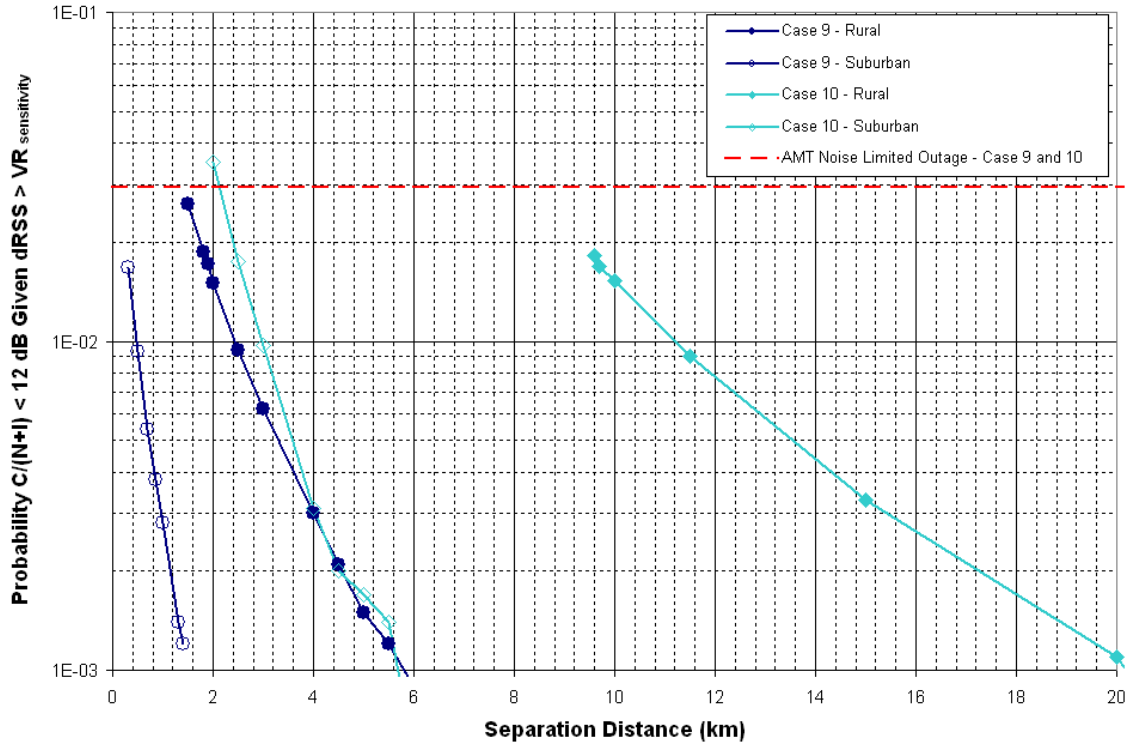

Figure 20 - Increase Above AMT Noise-Limited Link Outage Versus Separation Distance, Cases 9 and 10

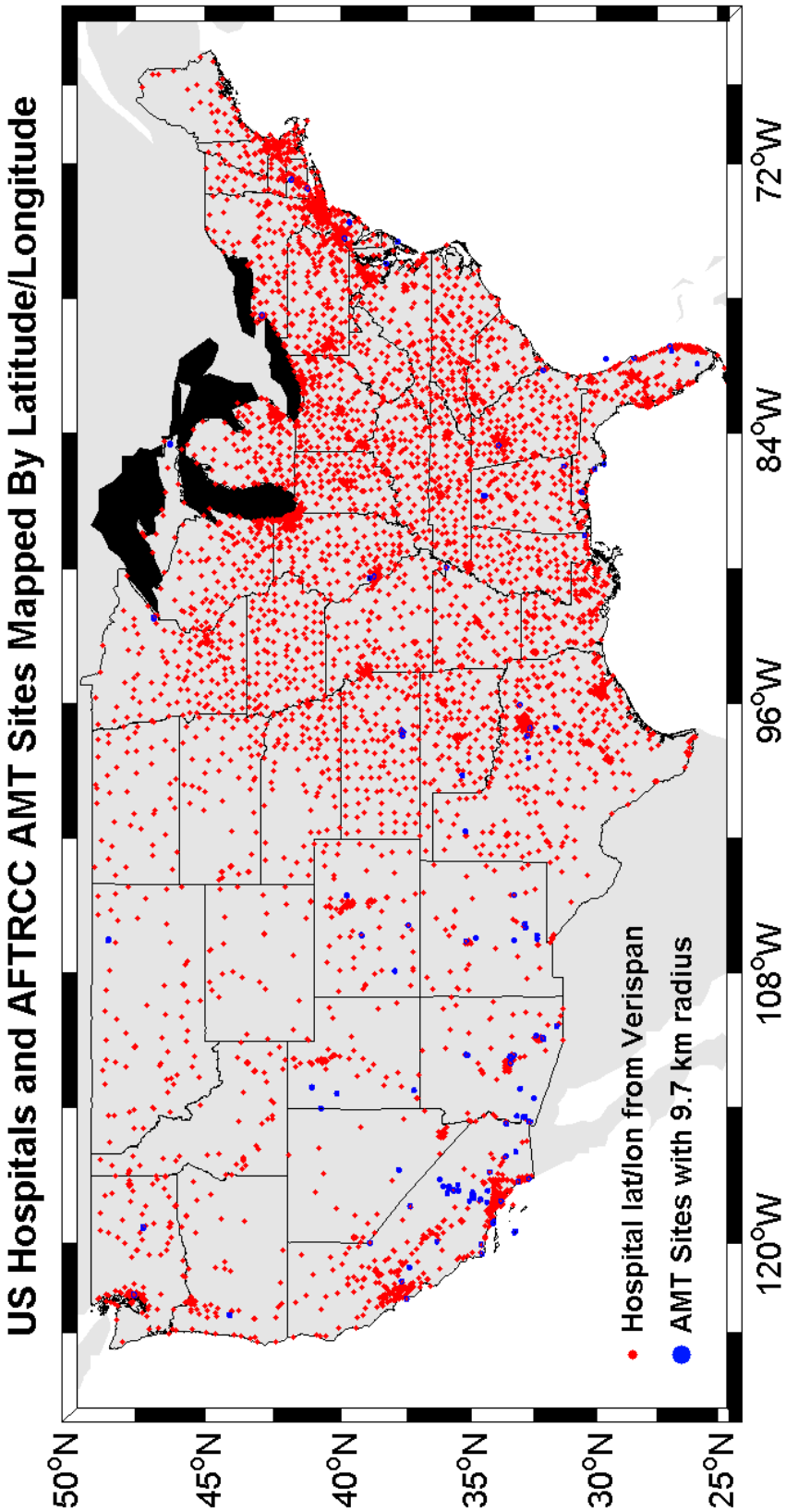

Figure 21 - US Hospitals and AMT Receive Sites With 9.7 km Radius, Plotted by Latitude and Longitude

APPENDIX B

Modeling and Characterization of Aeronautical Mobile Telemetry Link

I. INTRODUCTION

In order to perform Monte Carlo interference analysis, it is necessary to have a model of the victim link. In addition, it is helpful to characterize the victim link performance under "baseline" conditions (*i.e.*, in the absence of interference) in order to interpret the results of the interference analysis.

This Appendix presents a general model for the aeronautical mobile telemetry (AMT) link based on information provided or cited by AFTRCC, including ITU-R M.1459. A baseline characterization of the AMT link is also performed for the best possible case of a highly sensitive AMT receiver operating in the absence of interference (*i.e.*, the noise-limited case).

II. GENERAL MODEL OF THE AMT LINK

The AMT link budget can be generalized as follows:

$$P_{RX} - P_{N+I} \geq SINR_{\min} \tag{1}$$

or alternately as

$$Margin = P_{RX} - P_{N+I} - SINR_{\min} \geq 0 \tag{2}$$

where P_{RX} is the received desired AMT signal power in dBm, $SINR_{\min}$ is the minimum permissible signal-to-noise-plus-interference ratio in dB, which according to ITU-R M.1459 may be in the range 9-15 dB, and P_{N+I} is the combined power of noise and interference at the AMT receiver in dBm given by

$$P_{N+I} = 10\log_{10}\left[10^{P_N/10} + 10^{P_I/10}\right] \tag{3}$$

In equation 3 P_I is the received interference power in dBm, which is a random variable that is a function of several (many also random) factors, such as the emission power spectrum, path loss and AMT antenna gain associated with each interference source, AMT receiver selectivity mask, etc. and P_N is the AMT receiver's intrinsic thermal noise in dBm, which is given by

$$P_N = 10\log_{10}(kTB) + 30 \tag{4}$$

where k is the Boltzmann constant, 1.38 x 10^{-23} Joules/Kelvin, and where T and B respectively are system noise temperature in Kelvin and bandwidth in Hertz of the AMT receiver.

When the inequalities in equations (1) and (2) are satisfied, the AMT symbol or packet error rate will be below the maximum acceptable level and, by definition, the AMT link is "closed" or

"available". When these inequalities are not satisfied the symbol or packet error rates will exceed the maximum acceptable level and this by definition will constitute an "outage" event.

The received desired signal power P_{RX} may be expressed as:

$$P_{RX} = P_{in} + G_{TXant} - L_{path} + G_{RXant} \tag{5}$$

Where P_{in} is the conducted input power to the AMT transmit antenna in dBm which according to M.1459 may be in the range 33-44 dBm, G_{TXant} is the effective gain of the AMT transmit antenna in dBi, L_{path} is the path loss in dB, and G_{RXant} is the main beam gain of the tracking directional AMT receive antenna in dBi.

According to ITU-R M.1459, G_{RXant} may be in the range of 20 to 41.2 dBi. Because the AMT link is line-of-sight, the path loss L_{path} is simply the free space loss given by:

$$L_{path} = 20\log_{10}(d) + 20\log_{10}(f) + 32.44 \tag{6}$$

Where f is frequency in MHz, nominally 2380 MHz for the center of the proposed band, and d is the line-of-sight distance in km, which according to ITU-R M.1459 may be as far as 320 km.

Finally, the effective transmit antenna gain G_{TXant} is a random variable that takes into account fading effects due to reflections and blockages from the aircraft with its potentially rapidly-varying physical orientation. According to ITU-R M.1459, the effective gain of the AMT transmit antenna in linear units, $g_{TXant} = 10^{G_{TXant}/10}$, has the following empirical cumulative distribution function[12] :

$$P[g_{TXant} \le x] = \left(1 - e^{-3.46x}\right)^{1.25} \tag{7}$$

III. CHARACTERIZATION OF AMT LINK

Within the framework above, we can consider a couple of conservative baseline cases of the AMT link in a purely noise-limited scenario (*i.e.*, in the absence of any interference) where $P_{N+I} = P_N$. First, we shall consider the nature of the AMT link for the case cited by AFTRCC of an aircraft operating at the maximum specified distance of d=320 km, using $P_{in} = 40$ dBm (10W) with a bandwidth of 5 MHz and with receiver noise temp of 200K and receive antenna gain G_{RXant} of 31 dBi, which corresponds to a typical 2.4 meter diameter parabolic dish. Monte Carlo simulation of this scenario, in which the only random variable is G_{TXant}, yields the result in Figure 1.

[12] The M.1459 empirical CDF was found to be very closely approximated by the Gamma distribution with parameters a=1.2446 and b=0.268111.

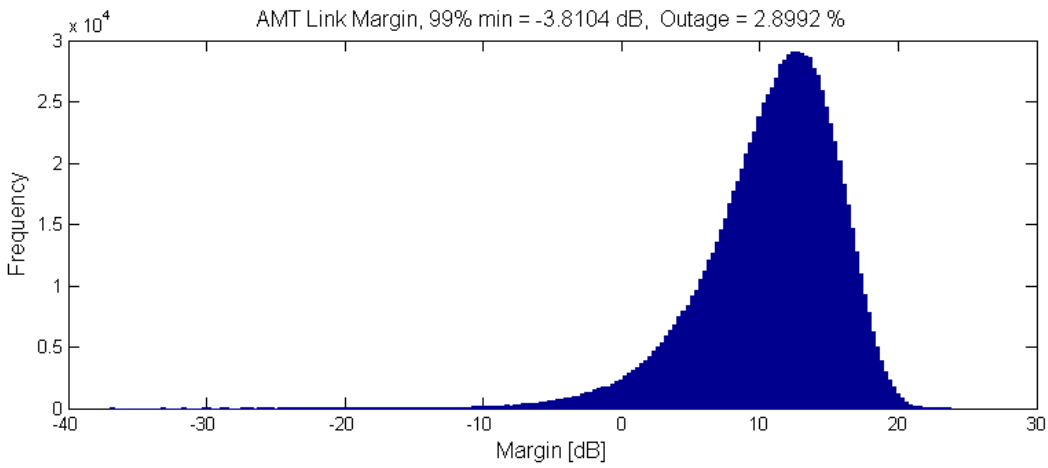

Figure 1: Simulated AMT link margin for G_{RXant} = 31 dBi

It is clear from Figure 1 that the AMT link is generally quite robust because, at most instants in time, it has copious excess margin. Nevertheless, <u>even in the absence of interference, the AMT link is imperfect in that some outages will occur.</u> For this first conservative noise limited baseline case the outage probability is approximately 3%. Furthermore, since the AMT outages are driven by long "tail" of the G_{TXant} fading distribution, they cannot be eliminated simply by modest increases in transmit power or antenna gain. For example, consider the limiting case of G_{RXant} = 41.2 dBi, which corresponds to a huge 10-meter diameter receive antenna, simulation results for which are shown in Figure 2. Even the addition of over 10 dB of link margin has not eliminated outages – they will still occur with 0.17% frequency.

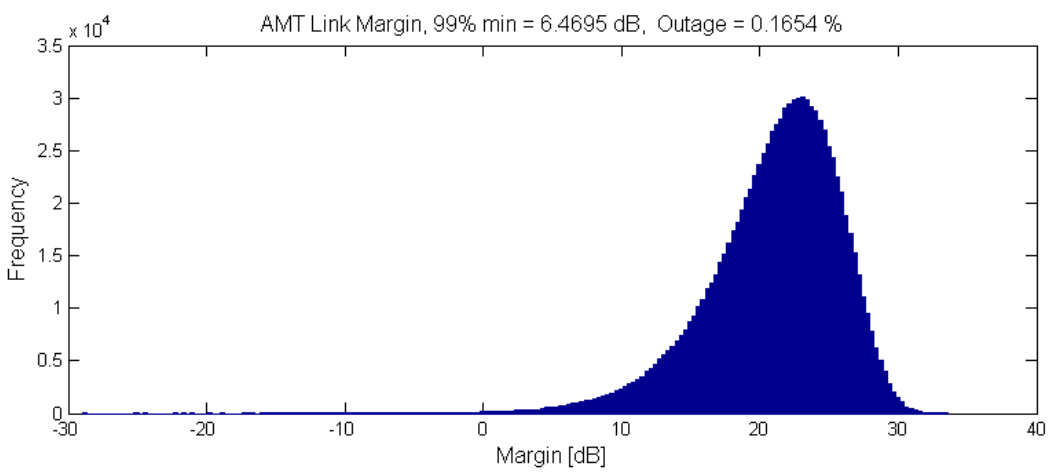

Figure 2: Simulated AMT link margin for G_{RXant} **= 41.2 dBi**

Clearly, for any case where a perfectly reliable AMT link really is required, it would best be achieved through techniques like coding or diversity, which can exploit the (on average) considerable excess link margin and not by striving to preserve fractional dBs of link margin by

imposing overly-stringent interference limits such as the –8.13 dB I/N recommendation in ITU-R M.1459.

The most important conclusion from these baseline AMT link simulations is that AMT outage rates on the order of several percent are apparently being tolerated already and must therefore be acceptable – at least for the typical link parameters offered by AFTRCC.[13] Having established this fact, it is now possible to define a reasonable quantitative harmful interference threshold for the allowable increase in outage rate due to interference. If we consider the effect of the –3 dB I/N ratio provided by ITU-R M.1459 as the "maximum practical value" on outage rate for both of the previous AMT link examples with link distances ranging from 0-320 km, we obtain the results shown in the following Figure 3 and Figure 4.

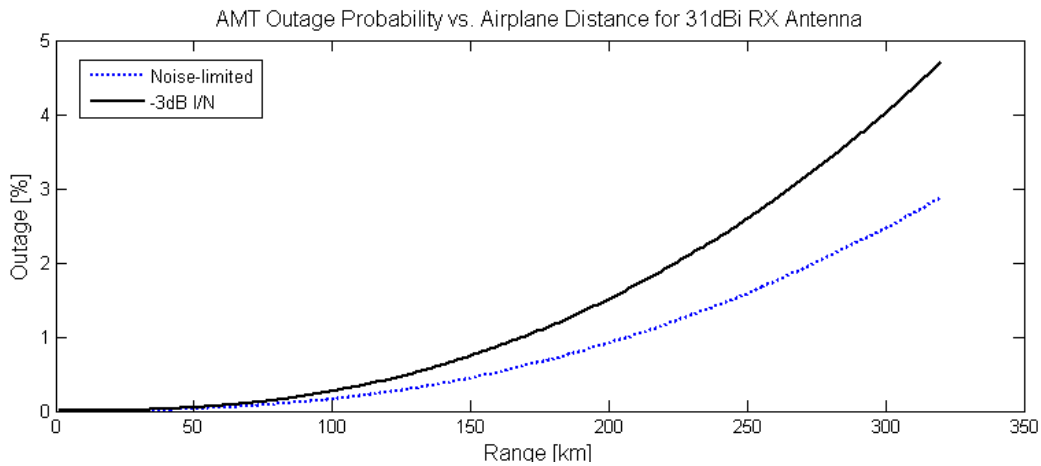

Figure 3: AMT Outage Probability vs. Airplane Distance for G_{RXant} = 31 dBi

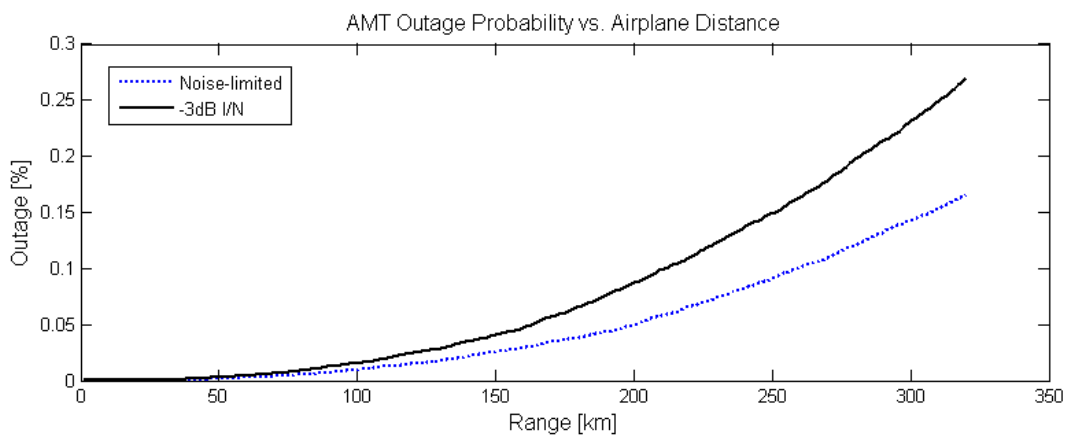

Figure 4: AMT Outage Probability vs. Airplane Distance for G_{RXant} = 41.2 dBi

[13] If this is in fact not the case, then clearly there are other mitigating factors that have not been disclosed by AFTRCC such as AMT employing substantially higher transmit power than the claimed 2-25 W, not operating nearly out to the full 320 km stated radius or incorporating other beneficial techniques (*e.g.*, TX/RX diversity, coding gain).

From these results we can relate the –3 dB I/N limit from ITU-R M.1459 to a factor of 1.6 in outage rate from the baseline noise-limited outage rate. Therefore, we will consider an increase factor greater of 1.6 or less to be non-harmful to AMT operations. This threshold is certainly reasonable from the common-sense perspective as well, since the existing, naturally occurring outage rate of AMT operations cannot be too near the limit of acceptability. Otherwise, it would be expected to frequently violate the limit due to unavoidable small perturbations in system parameters.

APPENDIX C

Comparison of Learjet Test Signals with MBANS Signals

AFTRCC has submitted a field test performed by Learjet that purports to show that MBANS operations will interfere with AMT operations. However, the test had several serious flaws, including the use of surrogate MBANS test signals that were not representative of actual MBANS signals.

Figures 1 to 3 depict the power spectra of three signals with equal fundamental emissions power of 0 dBm (1mW). The spectrum in Figure 1 corresponds to a typical FSK digitally modulated signal that might be expected from an actual MBANS transmitter. Figure 2 and Figure 3 show the spectra of the two test signals used in the LearJet test – an unmodulated CW tone and an FM signal resulting from a 1 kHz modulating tone and 50 kHz FM deviation. The peak power spectral density of both Learjet test signals significantly exceeds that of the MBANS test signals.

Comparing the transmit power spectra in Figure 1 through Figure 3 tells only part of the story, however. An additional key difference, making Learjet's test signals more problematic to the AMT receiver than actual MBANS signals, is that the Learjet signals were continuous, whereas actual MBANS signals would be bursty, with typical duty cycles less than 10%. In addition, MBANS devices may likely also employ frequency hopping so that the actual transmit duty cycle observed with respect to a single AMT channel is far lower still. This difference is illustrated by examining the spectrograms of the signals, as illustrated in Figure 4 to Figure 6. These spectrograms show power density (color) in 5 MHz (horizontal axis) of the proposed MBANS allocation, which contains five 1 MHz wide MBANS channels, over time (vertical axis). The Learjet signals are continuous in time with high power spectral density concentrated in a narrow bandwidth, while the MBANS signal is non-continuous in both frequency and time and its peak power spectral density is much less than that of the Learjet test signals.

It is expected that, for the same transmit power and separation distance, actual bursty wideband MBANS signals will be substantially less likely to cause harmful interference to the AMT system than the test signals employed by Learjet.

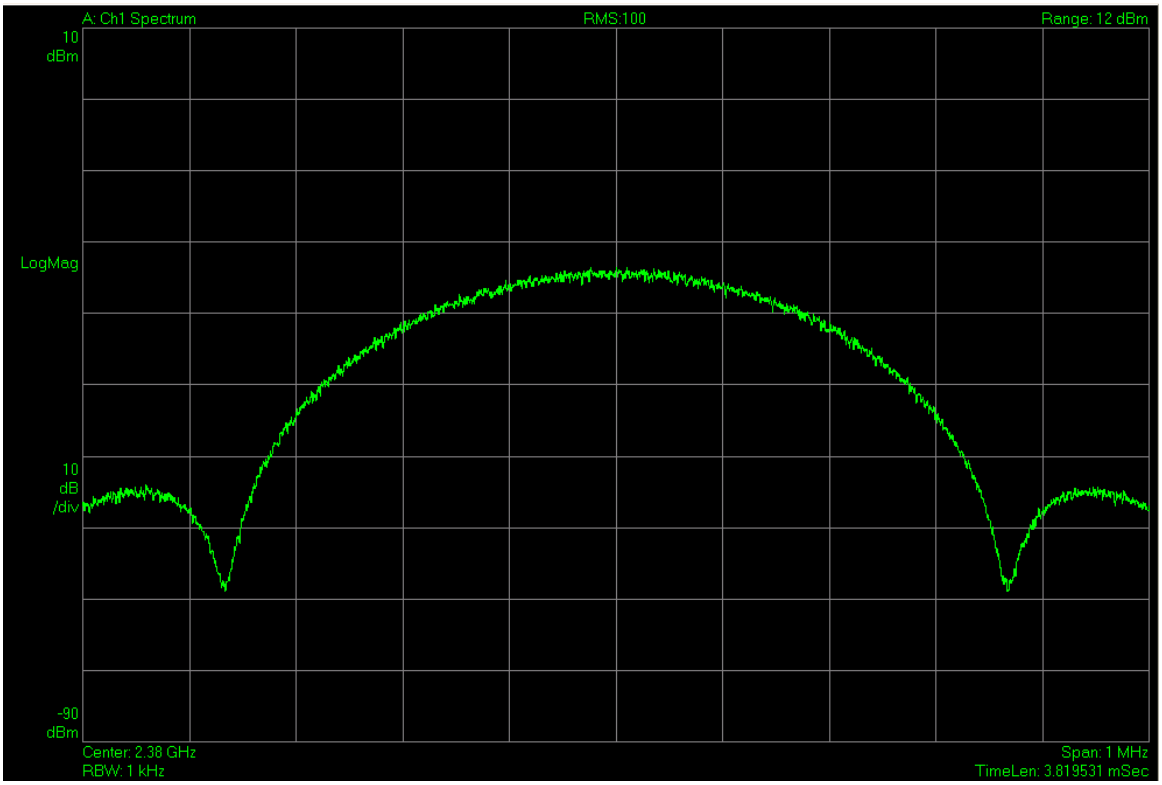

Figure 1 - Typical MBANS Signal Spectrum

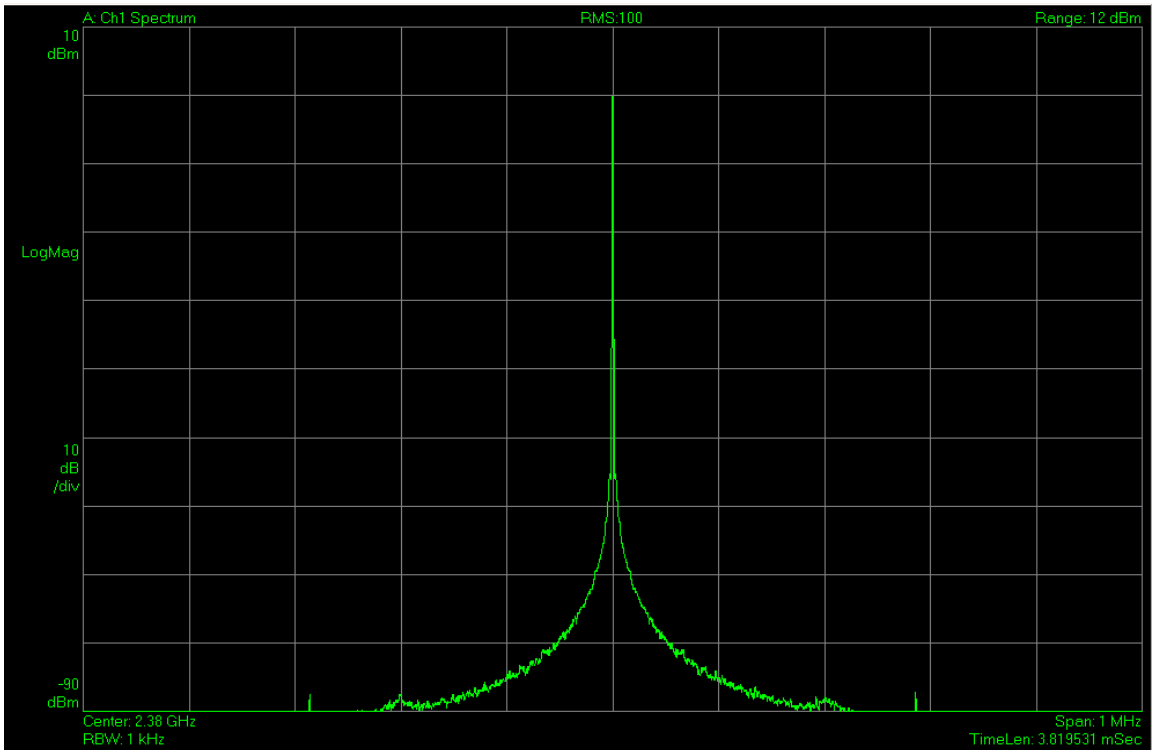

Figure 2 - Learjet's CW Test Signal Spectrum

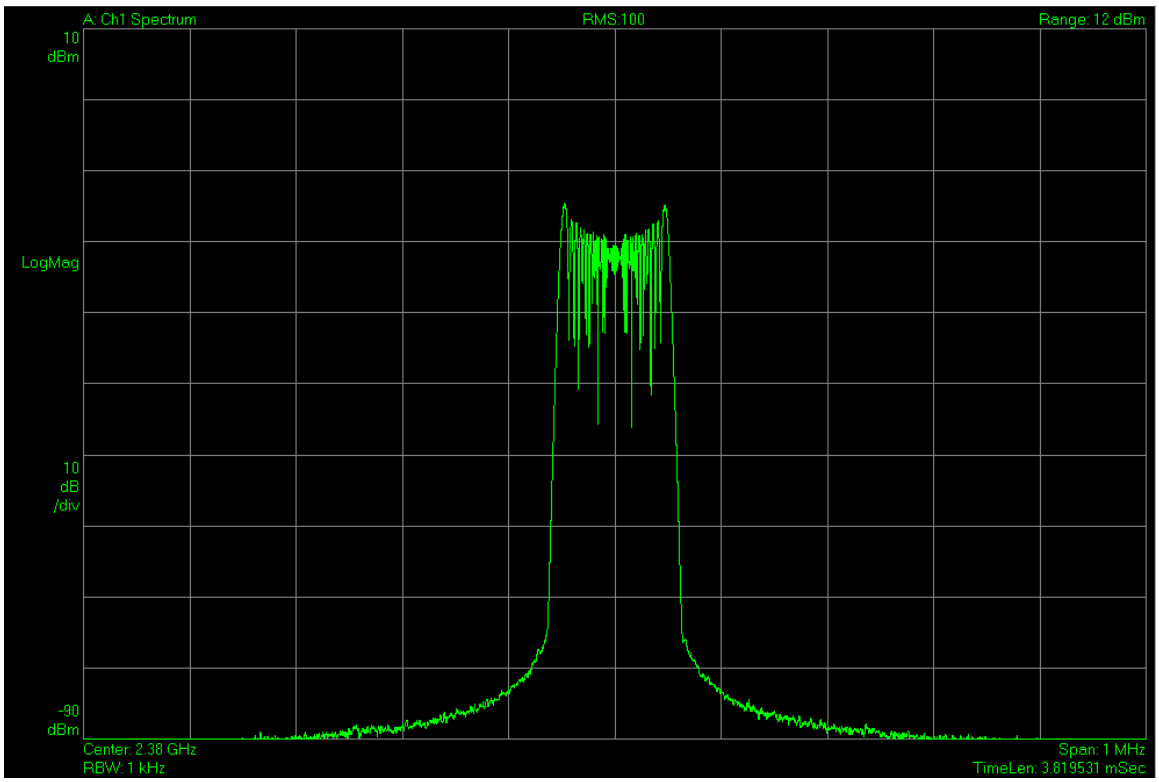

Figure 3 - Learjet's FM Test Signal Spectrum

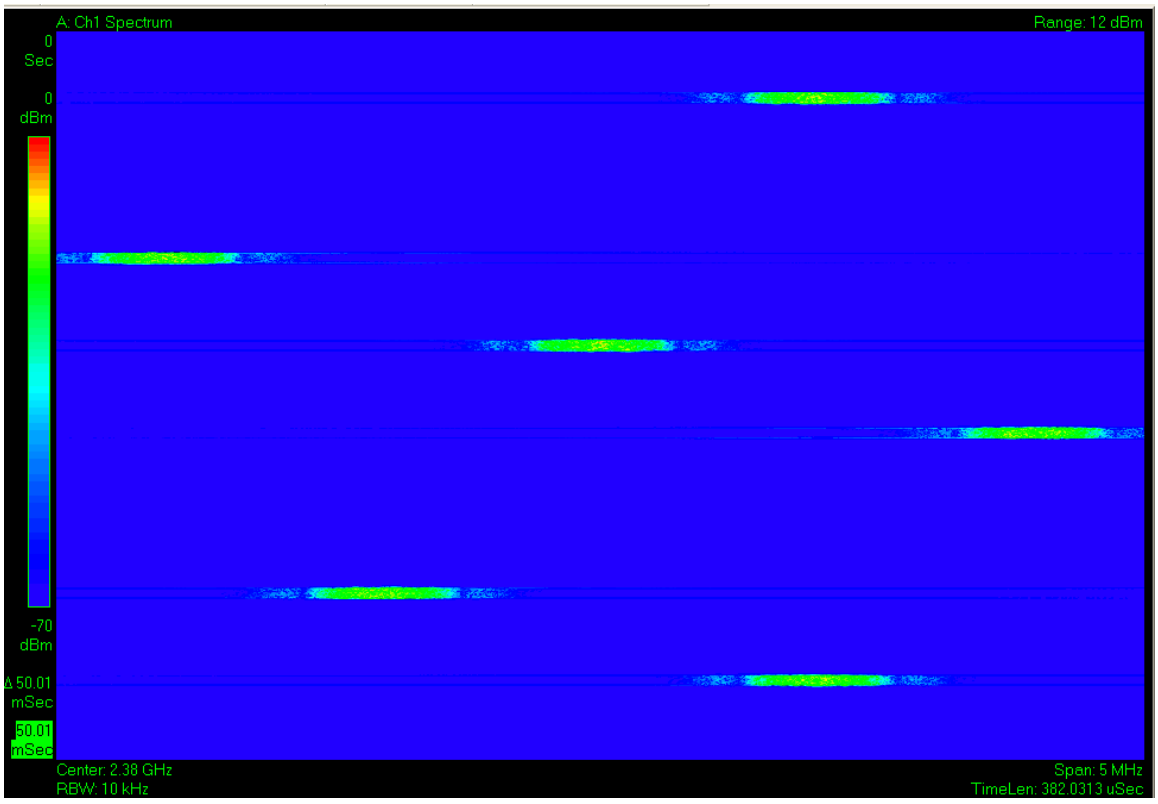

Figure 4 - Typical MBANS Signal Spectrogram

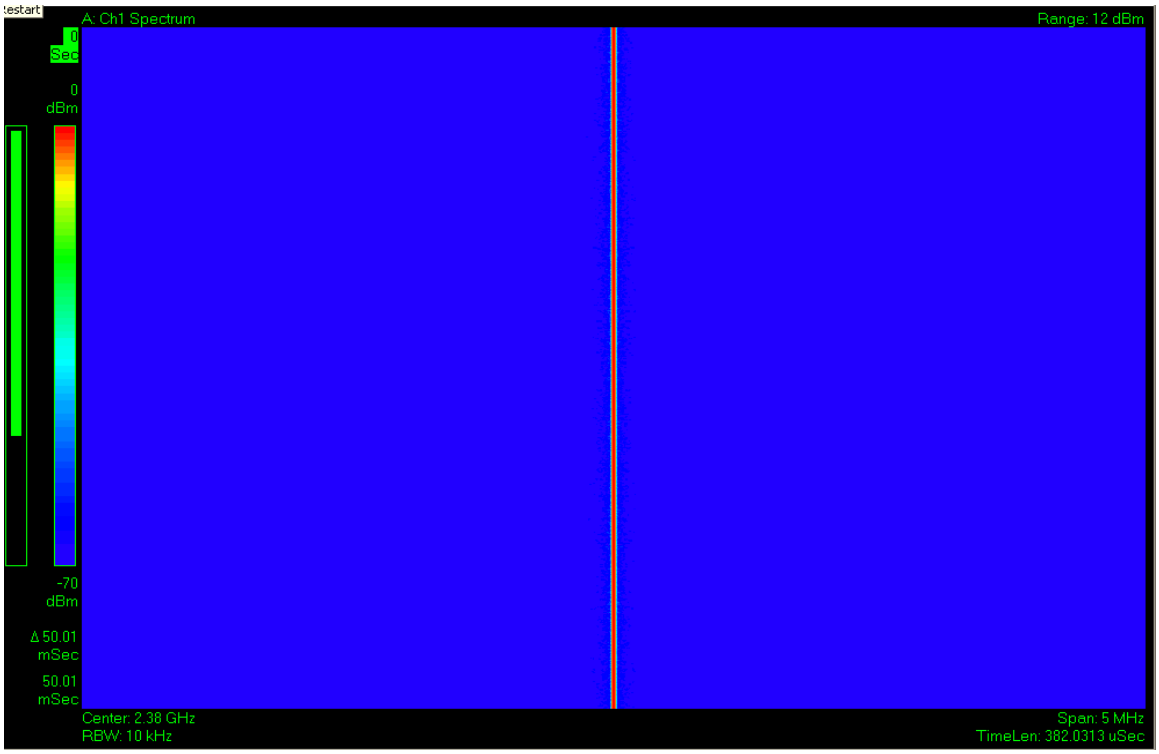

Figure 5 - Learjet's CW Test Signal Spectrogram

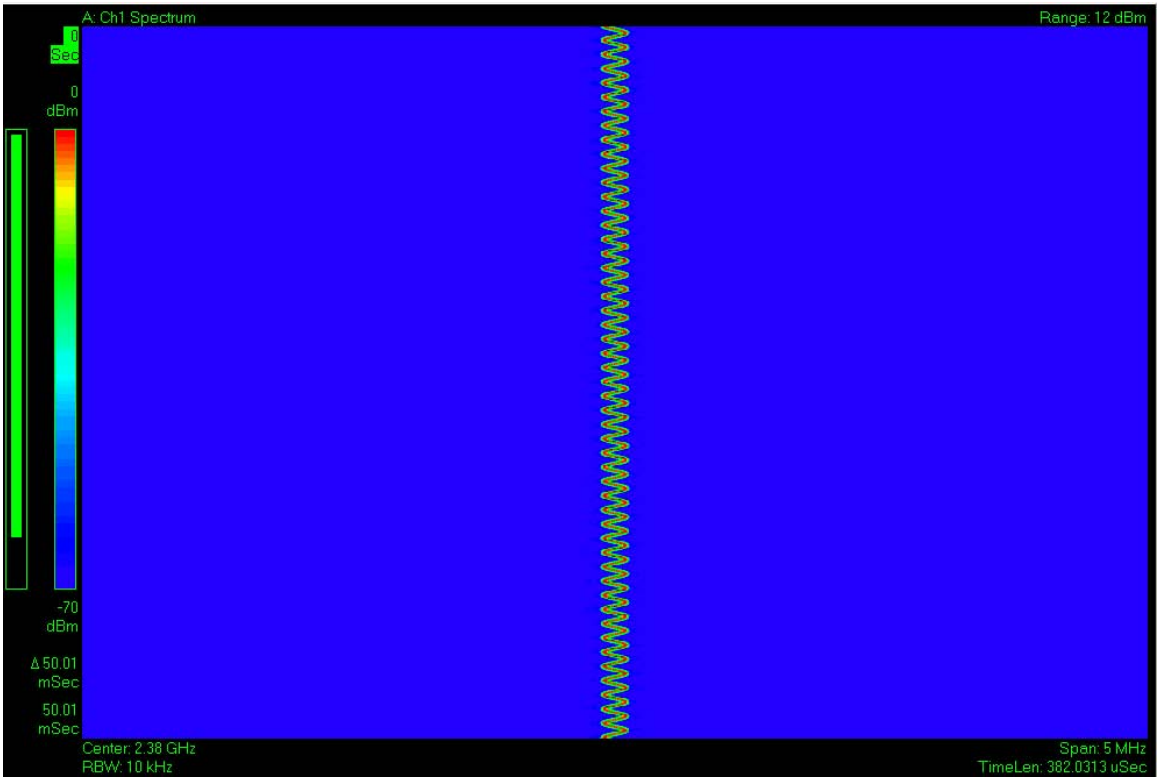

Figure 6 - Learjet's FM Test Signal Spectrogram