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

In the Matter of	)	
	)	
Amendment of the Commission's Rules to Provide Spectrum for the Operation of Medical Body Area Networks	)	ET Docket No. 08-59
	)	
	)	
To: The Commission	)	

REPLY COMMENTS OF AEROSPACE AND FLIGHT TEST RADIO COORDINATING COUNCIL

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SUMMARY

As noted in AFTRCC's initial Comments, the Commission has long recognized and protected the 2360-2390 MHz band for flight testing due to its safety-related purposes and the fact that interference would adversely affect the US aerospace industry, the US taxpayer, and the flying public.

The record to date does not provide assurance that the Commission can safely mix two safety-related services, Aeronautical Mobile Telemetry ("AMT") and Medical Body Area Networks Service ("MBANS"), in the same band. By allocating MBANS to alternative spectrum, the Commission can avoid harmful interference to either service.

The Commission has several options, including the use of 2300-2305 MHz paired with 2390-2400 MHz, or other bands. MBANS proponents fail to explain why such options are inadequate compared to a co-allocation with AMT. Indeed, at earlier stages of this proceeding proponents themselves contemplated use of 2300-2305 MHz, together with other bands far removed.

The MBANS interference analyses remain deficient. The Philips analysis produces misleading results for reasons similar to those previously noted with respect to GEH. Additionally, some commenters, including GEH, claim that the 2360-2390 MHz band is subject to extensive out-of-band interference -- without any real-world tests to back up such a claim. In fact, 2360-2390 MHz is remarkably free of such interference as confirmed by recent third-party field tests.

Not surprisingly given the flaws in its probability analyses, the exclusion zone proposed by Philips, 11.5 km, does not nearly protect AMT sites. Recent tests conducted by AFTRCC Members Bombardier and Cessna show that MBANS devices will cause

significant and intolerable degradation in the bit error rate, and material drop-outs, at line-of-sight distances to AMT transmissions. The same tests also show that there is a risk of interference from AMT to MBANS; assertions to the contrary by MBANS proponents are untested and untried in this context.

If, despite this, the Commission were to consider further the notion of a co-band allocation with AMT, the proposal offered by Philips would warrant further examination. Philips suggests the use of an "electronic key," coupled with a beacon signal, which might be used to ensure that hospitals within exclusion zones operate only on permitted frequencies, and that patients at such hospitals could not wander outside transmitting on prohibited frequencies. The proposal would allow MBANS use in the 2360-2390 MHz spectrum at hospitals outside exclusion zones, but would default to 2390-2400 MHz within exclusion zones. The proposal represents, theoretically at least, an option possibly worth further investigation. However, the details of this proposal would need to be further developed and additional conditions considered before any conclusions could be drawn.

AT&T's proposals to convert MBANS into some kind of anywhere, anytime voice and data service are not only miles beyond the scope of this proceeding, but effectively ignore the effects of the resulting interference on incumbent, primary AMT systems.

For these and the other reasons set forth in these Comments, an MBANS allocation in 2360-2390 MHz should not be pursued.

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Aerospace and Flight Test Radio Coordinating Council ("AFTRCC") hereby replies to certain of the opening comments filed in this proceeding. As explained below, the record does not provide sufficient assurance that the two safety-related services, Aeronautical Mobile Telemetry ("AMT," or flight test telemetry) and Medical Body Area Networks (or "MBANS") can reliably share the 2360-2390 MHz band. However, Philips Healthcare Systems ("Philips") has offered an interesting proposal which bears further examination. Details concerning this and other points made in opening comments of other parties are set forth below.

I. BACKGROUND

In its opening Comments, AFTRCC stressed the importance of real-time telemetry afforded by the S-band (i.e., 2360–2390 MHz) to flight test safety. Johns Hopkins University Applied Physics Laboratory analyzed the probability study presented by GE Healthcare ("GEH"), and pointed out the deficiencies in that study, e.g., the fact that the study presumed outage rates ranging from 1.7 to as much as 20 percent - - all of which would be harmful to flight test operations. AFTRCC underscored its concerns with the practicality and enforceability of exclusion zones. It reminded the Commission that, while MBANS would nominally be

"secondary," the Commission has treated secondary medical telemetry devices in other bands as super-primary, even to the point of requiring primary users in those bands to shut down their operations to protect medical telemetry. AFTRCC pointed out that this threatens to make a hash of the agency's spectrum regulatory regime. Accordingly, AFTRCC urged that the agency proscribe "life-critical" applications for MBANS devices - - in effect, taking MBANS proponents at their word when they say they want "secondary" status. Finally, AFTRCC reiterated, in light of the points noted above, that alternative bands would be much more suitable for MBANS devices, enabling the Commission to avoid intermixture of two incompatible safety services.

The Comments of the Boeing Company underscore the importance of 2360–2390 MHz for the aerospace industry. As Boeing observes, real-time telemetry provided via the S-band has been, and remains, critical to the safety of flight testing, as well as Boeing's productivity and global competitiveness. For example, Boeing notes that "during an initial airworthiness test, the [aircraft] analysts and engineers rely on the real-time data received via the AMT data link to determine the aircraft's current status and whether the aircraft is safe to continue the flight and initiate a subsequent test."[1] If the AMT signal receives interference, the "ground crew may not be able to alert the flight crew in time to avoid or correct a dangerous situation that could result in significant aircraft structural damage to the hull, wing, tail, or other critical components," such as was the case with the E-6 depicted in the photograph provided by Boeing.[2]

Furthermore, Boeing stresses that manufacturers must have the flexibility to conduct flight tests at new and temporary test locations in order to respond to changing weather conditions, scheduling conflicts, and other program-specific requirements. Boeing highlights the

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[1] Boeing Comments filed October 5, 2009 in ET Docket No. 08-59 at 3.
[2] *Id*. at 3-4.

public safety benefits of flight test operations, which the Notice failed to appropriately factor into its discussion.

AFTRCC's concerns about exclusion zones and the prospect of interference likewise are underscored by the Telecommunications Industry Association ("TIA") which shares the aerospace industry's concerns that exclusion zones would need to be large in order to avoid interference.[3]

Comments offered by MBANS proponents rehash previous arguments, are often misguided, and should not be accorded decisional weight.

II. DISCUSSION

A. Alternative Spectrum Remains Viable for MBANS

AFTRCC has urged consideration of a split band approach, i.e., 2300 – 2305 MHz paired with 2390–2400 MHz.[4] GEH and Philips focus much of their comments only on 2395–2400 MHz, leaving out of the mix the additional five MHz represented by 2390–2395 MHz.[5] In any event, both parties, supported by Texas Instruments ("TI"), argue that the split-band approach would be too costly and result in effectively less than a 15 MHz allocation because of additional band edges and need for guard bands.[6] Indeed, GEH goes so far as to say that it "is not aware of any current radio frequency transmission chips that operate in the 2300–2305 MHz band and expects that, even if this block were allocated to the MBANS service, chip vendors would decide to omit support for it from future chips due to technical challenges."[7]

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[3] Comments at 4.
[4] *Id*. at 20 vs 22.
[5] Philips at 13; GEH at 10-11.
[6] *Ibid*; TI at 3-4.
[7] GEH at 10-11.

As AFTRCC has advised previously, the very Nordic semiconductor chips proposed by GEH are tunable over the entire range 2300 to 2425 MHz.[8] Thus, there is no merit to GEH's assertion, least of all the unsupported speculation that vendors would elect not to "support" the band: If the Commission sees fit to allocate the band for MBANS, they (the vendors) will come.

Insofar as additional band edges and associated guard bands are concerned, MBANS would be subject to Commission Rules just as are all other licensees. The key consideration is whether sufficient spectrum would still be available for MBANS operations. GEH itself has said that it would need no more than "5-10 megahertz of spectrum ... to be available for BSN communications at any given location, *after* taking into account spectrum that may be in use by incumbent spectrum users at any point in time . . . ."[9] That being the case, whatever capacity might be required for guard bands should be considered immaterial if 15 MHz is allocated for MBANS use.

But most important, GEH itself has proposed use of a variety of bands -- and one of the five "candidates" was 2300-2305 MHz.[10] Moreover, as AFTRCC has noted before, GEH is on record stating that it could use a combination of bands as long as they were "separated by no more than 150 megahertz in order to reduce the cost of component parts and overall manufacturing costs."[11]

Moreover, it is clear from the Comments of the Advanced Medical Technology Association ("AdvaMed") that MBANS need not have an exclusive allocation, but simply an

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8 *See* AFTRCC Opening Comments, Exhibit B at 13.

9 Reply Comments filed December 4, 2006 in ET Docket No. 06-135 at 6. More recent comments have claimed a need for 10-20 MHz (GEH at 9), or perhaps 15-20 MHz in "most high-density deployment cases" (Philips at A-9). This reflects the spectral requirement equivalent of "mission creep."

10 GEH ex parte of July 25, 2007 in ET Docket No. 06-135, at 21 and 24 ("propos[ing]" five bands, including 2300-2305 MHz, and discussing "BSN coexistence mechanisms" for each). Significantly, too, that proposal would appear to have contemplated use of "disjointed" bands (in TI's words, Comments at 3).

11 AFTRCC Comments filed October 5, 2009 at 22 quoting from GEH Reply Comments filed December 4, 2006 in ET Docket No. 06-135 at 6.

allocation that is not "shared with AMT."[12] While AdvaMed suggests that 20 MHz is the preferred total size of the bands required for MBANS, its preference for the extra five megahertz is based more on the desire to support additional business opportunities for its members, i.e., the notion that 15 MHz "would make it harder for multi-vendor deployment in a hospital site; this would tend to drive up cost by limiting competition."[13] Even if there were merit to AdvaMed's premise, the desire for a particular business model is hardly grounds for allocating more spectrum, especially when there has been no showing - - or even claim for that matter - - that a 15 MHz allocation cannot be made to work.[14] Whether there is one vendor or three or some other number, the MBANS devices of multiple-providers should be required to efficiently share spectrum, allocated to MBANS, at any location.

ARRL, The National Association for Amateur Radio ("ARRL") argues, on the other hand, that high-power transmissions associated with amateur weak signal operations pose an unacceptable risk to MBANS operations in the 2300-2305 MHz band.[15] Interestingly, however, not a single one of the MBANS proponents have raised this as a concern. On the contrary, if they are to be believed, contention-based protocols can easily deal with any amateur transmissions to eliminate or satisfactorily mitigate the potential for receipt of harmful interference.[16]

ARRL contends that GE, itself, has conceded that "MBAN operation is absolutely incompatible with amateur operation at 2300 – 2305 MHz."[17] To the contrary, and as noted

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[12] AdvaMed at 3 of 13.

[13] *Id*.

[14] Indeed, it could just as easily be argued that hospitals would prefer a common telemetry product as simplifying maintenance, training, and the like, instead of systems from more than one vendor. Plenty of price competition would remain when vendors appreciate that it's a winner-take-all proposition for each MBANS sale.

[15] Comments of ARRL at 3.

[16] *See*, e.g., Comments of AdvaMed, at 3 of 13 ("MBANS devices will be able to tolerate interference from amateur users").

[17] *Id*. at 7.

above,[18] GEH has in fact proposed use of 2300-2305 MHz notwithstanding the presence of high-power, long range Amateur transmissions such as the operations referenced by ARRL.

ARRL cites to language from the Commission's Seventh Report and Order, FCC 04-246, in ET Docket No. 00.-258, 19 FCC Rcd 21350 (2004) for the proposition that coordination with amateurs is not feasible.[19] That may be so, but it is also irrelevant: MBANS proponents have not claimed a need to coordinate with amateurs in order to avoid causing amateurs interference, or avoid receiving interference from them.

ARRL's suggestion that the agency's rationale from the above Report and Order supports the notion that AMT would not receive interference from MBANS, is also unfounded. The 2004 Order references the "high altitudes of aeronautical mobile flight testing transmitters, and the correspondingly high elevation and off-axis attenuation of high gain [AMT receive] antennas …" together with "the remoteness of flight testing facilities …"[20]

However, MBANS is likely to cause AMT operations harmful interference. As AFTRCC has pointed out previously in this proceeding,[21] while test flight maneuvers are usually conducted over remote or sparsely populated areas for safety reasons, the AMT receive dishes at issue are frequently located in or near urban areas.[22] Moreover, telemetry dishes are not typically oriented at high elevation angles, but rather at low angles, even below the horizontal, in order to maintain tracking with far-distant aircraft. These factors produce vulnerability to co-channel interference from MBANS. These same factors have prompted AFTRCC members to generally avoid use of 2390–2395 MHz due to the risk of interference from amateurs.

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18 *See* note 10, *supra*.
19 *Id*. at 10. See also GEH at 18-19.
20 Seventh Report and Order, ¶47. *See* also GEH at 12-13.
21 AFTRCC Reply Comments filed June 11, 2008 at 5-6.
22 *Ibid.*

ARRL raises the concern that MBANS might interfere with amateurs. In this respect, however, it offers no more than the thought that GEH may not have taken into account the different types of amateur uses, now and tomorrow, suggesting that such usage is subject to local variation.[23] However, it is not enough for ARRL to advance unspecified uses that GEH has not taken into account: It is the incumbent's job to specify those uses, or take the risk that the record will be incomplete on its needs. In any event, ARRL has already discounted the likelihood of interference from MBANS in its earlier comment to the effect that it "does not, frankly, expect a significant amount of harmful interference to amateur operators at 2390–2400."[24]

An allocation to MBANS in the 5 GHz band presents different issues, but nothing in the opening Comments should lead the Commission to rule the band out at this juncture. Comments by MBANS proponents have asserted that the higher propagation losses at 5150–5250 MHz will require higher power, and thus reduce battery life, and that propagation losses due to the human body are also a factor.[25]

However, if MBANS devices are truly intended for very short-range, e.g., on the order of 10-20 feet, an allocation below 3 GHz does not make sense as a matter of physics. As ARRL cogently observes, 2 GHz bands have "exceptionally long-distance propagation characteristics."[26] Spectrum above 3 GHz, particularly 5150-5250 MHz, would be more suitable for short-range MBANS devices. At a minimum, a much more complete record is required on the pros and cons of 5 GHz for MBANS before the Commission could make an informed decision on the issue.

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[23] *Id*. at 8.
[24] Comments of ARRL filed May 27, 2008 at 2.
[25] Philips at 11 to 12; GEH at 7; TI at 4 (power consumption would increase by a factor of four).
[26] ARRL at 12.

MBANS proponents also misstate the facts in arguing that bands other than 2360-2390 MHz should be dismissed because any such allocation would frustrate international harmonization. They reference the European Telecommunications Standards Institute which is said to be considering the 2360-2390 MHz band, and that a common allocation would reduce prices of MBANS devices.[27] However, this kind of argument built on hope is refuted by Zarlink Semiconductor which observes that "[t]he use of frequencies below 2400 MHz is unlikely to meet with European approval, as they are heavily used, amongst other requirements, for security purposes."[28]

B. MBANS Interference Analyses Remain Deficient

The interference probability analyses proffered by MBANS advocates continue to suffer from serious deficiencies. Among these is the notion that certain percentages of interference from MBANS devices to flight testing should not, by definition, be considered harmful.[29] In effect, MBANS proponents are asking the Commission to require AMT operations to assume, with respect to MBANS, one of the two touchstones of secondary status, namely that AMT operations accept whatever interference they receive from MBANS devices.

This argument is not only contrary to AMT's priority status and the proposed secondary allocation, but it ignores the long line of Commission decisions affirming and protecting flight test telemetry due to the important safety-of-life functions it performs. Those decisions are set forth in AFTRCC's Opening Comments at 5-6.

Moreover, as discussed in AFTRCC's opening Comments, the probability analyses presented by GEH thus far are able to reach rosy conclusions on sharing only because the

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[27] GEH at 8-9; TI at 3.

[28] Comments at 1. While proponents' preoccupation with their costs is understandable (e.g., GEH at 7-8), there has been very little recognition of the potential costs their interference would inflict on AMT -- costs that can run six-figures for a single flight, not to speak of the threat to human life.

[29] GEH at 14-15.

assumptions upon which those analyses are based are so flawed: One, they fail to use the U.S.-sponsored, internationally-endorsed Recommendation for evaluating the risk of interference to AMT. Two, they fail to recognize that the nature of flight testing is such that fades on the order of 30 dB are commonplace. Three, they fail to acknowledge that their proposed standard of "harmful interference" means that aerospace and Government flight test agencies must tolerate outage rates as high as 20 percent![30] This is absurd.

Implicit in the MBANS no-harmful-interference-argument is an invitation to the Commission to place greater weight on the theoretical and untested assertions of prospective new entrants, than the expert judgment of the aerospace companies and Military Departments which are accountable for the safety of their own personnel and bystanders during flight testing. The Commission should decline any such invitation, and defer to the reasonable, good faith judgment of experts as to just how much interference they should tolerate.

Philips, for its part, proffers a new analysis, the gist of which is that AMT would suffer a data outage rate of less than 0.0026 percent based on the Extended HATA propagation model.[31] Indeed, Philips's analysis claims that AMT already tolerates "some SINR [signal-to-interference-plus noise] outage during normal operations."[32]

However, as discussed in the attached Engineering Statement (Exhibit A), the extended HATA model produces misleading results in the AMT context. The assumptions underlying the individual Philips case studies also betray many of the same deficiencies discussed in AFTRCC's opening Comments regarding the utilization of probability analyses for this safety-of-life application. For example, the simulation results are sensitive to small changes in

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[30] *See* AFTRCC opening Comments, at Exhibit B at 10-11.
[31] Philips at 8 and Appendix E-9 to11.
[32] *Id*. at E-11.

parameters such as building attenuation, and the required signal-to-noise ratio at the AMT receiver.

The Engineering Statement also demonstrates that, contrary to the Philips document, the presence of MBANS devices will, indeed "present an increase in the AMT link data loss;"[33] and that the notion that "AMT systems can tolerate [up to] 0.0026 SINR outage probability,"[34] is erroneous. For example, Bombardier has conducted an in-depth technical assessment of its telemetry system performance. It has achieved 99.9% link availability with the acceptable bit error rate of 10^{-6} or better. Bombardier's telemetry system performance is typical of both government and commercial aircraft telemetry operations. An additional outage rate of 0.0026 would represent a 260 percent increase above the .0001 link unavailability currently realized by Bombardier and others.

GEH persists in claiming - - without any real-world tests to back it up - - that the band 2360-2390 MHz is subject to extensive interference from out-of-band sources.[35] There simply is no such widespread interference. In fact, this Restricted band is remarkably free of extraneous noise, a result confirmed by the laborious field tests conducted by Boeing and by Textron, Inc., both of which have been submitted for the record.

This conclusion is confirmed by the attached report prepared for AFTRCC by SAT Corporation, a world leader in RF Spectrum monitoring and interference detection systems for satellite and terrestrial communications (Exhibit B). Based on measurements recently conducted at Sunnyvale, CA, in the heart of the heavily populated San Francisco-Palo Alto corridor, out-of-band noise is so low as to be characteristic of extraneous noise into radio astronomy bands. In

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33 *Ibid* at 8.
34 *Id*. at E-11.
35 GEH at 15-16.

other words, contrary to MBANS claims, the aerospace industry and its Government counterparts are not experiencing the alleged noise pollution in 2360-2390 MHz band.

AFTRCC has previously demonstrated without rebuttal that interference from MBANS devices will impact AMT receive sites within line-of-sight. More recent testing conducted using the same Nordic semiconductor transceiver chips proposed by GEH, operating at a 34% duty cycle and placed in the upper stories of modern buildings produce signals at a level 5 – 7 dB above the noise floor of the end-to-end telemetry receive system, including external environmental noise, noise created in the system's low noise amplifier, noise due to cable loss, and the inherent noise of the flight test telemetry receiver. The measurement techniques and details are set forth in the Engineering Statement. But this is not all.

AFTRCC Member Companies Bombardier and Cessna recently conducted additional tests using the same MBANS devices and deployment referenced above, and a Canadair Regional Jet. The purpose of these tests was to dispel the notion that exclusion zones of only 11.5 (much less 9.7 km) are adequate. Those tests demonstrated in compelling terms that MBANS devices cause significant and intolerable increases in the bit error rate, and material drop-outs at line-of-sight distances, in the received telemetry signal. These results confirm what AFTRCC has been saying all along: Co-channel operation of medical devices within line of sight of AMT receivers will cause harmful interference.

GEH questions whether the high-power AMT uplink technologies being developed for the band will cause interference to current co-band AMT systems. These systems will make extensive use of the S-band but will not cause the interference alleged. Rather, it is envisioned that these technologies will utilize TDMA architectures in wide-bandwidth channels so as to achieve additional efficiencies in use of the spectrum resource. Such systems represent the next

generation evolution in AMT spectrum utilization -- rather than displacing or interfering with current uses.[36]

GEH argues there is no risk of interference from AMT to MBANS. It quotes filings where AFTRCC discounted the likelihood of interference from AMT downlinks to SDARS reception.[37] While some of the factors mitigating the risk of interference to SDARS might also be present here, there is a major difference between evaluating the risk of interference from AMT to an entertainment service, on the one hand, versus evaluating the risk of interference from AMT to a "life-critical" medical telemetry service, on the other hand. In the latter case, the analysis must, of necessity, be more exacting than what GEH offers.

Moreover, as AFTRCC has explained previously,[38] the issue addressed in AFTRCC's earlier filing concerned a request by XM and Sirius for the imposition of tighter out-of-band emission limits on AMT transmitters given an anticipated influx of Government fixed and mobile systems migrating from the 1710-1755 MHz band to 2360-2390 MHz. AFTRCC observed that there was little likelihood of aircraft interference to DARS when at high altitude (where a no-gain DARS antenna would be unable to detect the telemetry signal), or at low altitude (where ground attenuation and geographic separation between aircraft and the general public minimize the risk). GEH argues that the same factors preclude interference to BSNs.

GEH fails to account for clear distinctions between the AMT-DARS scenario and an AMT-MBANS scenario: As an initial matter, the MBANS devices would be <u>co-channel to AMT</u> -- not separated by a 15 MHz guard band (2345-2360 MHz).[39] Moreover, by GEH's own earlier

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[36] The fact that the current Rule limits transmitter power to 25 watts (GEH at 21) is immaterial: The ultimate power utilized, whether it be 25 watts or 100, would be consistent with the then-current Commission Rules and policies.

[37] *Id*. at 17-23.

[38] Reply Comments filed June 11, 2008 at 7-8.

[39] SDARS operates at 2320-2345 MHz.

calculations, at least a 10 kilometer separation would be required between a test aircraft and a BSN in order to avoid interference to the BSN.[40] This is a far cry from the 1400 foot separation deemed acceptable (0.42 km) in the DARS case. Finally, while attenuation is a factor in both scenarios, it is much less so for BSNs, being co-channel, than in the DARS case.

Even still, GEH argues, it "would not be proposing secondary status for MBAN operations in the 2360-2400 MHz band unless it was confident that MBAN devices could be designed to operate safely and effectively on a secondary basis."[41] This misses the point: The issue is that the consequences of interference to MBANS are incurred as much, if not more, by AMT -- which would be subject to FCC Orders to shut down despite its primary status -- than by MBANS. As the theoretically secondary, but practically primary, service, it is incumbent on MBANS proponents to carry the burden of persuasion on this issue. To this point, they have not done so -- particularly given the interference potential described in the Engineering Statement.[42]

In this regard, it should be underscored that it is unclear what sort of spectrum protocol would be adopted to protect MBANS. While the Notice references the protocol adopted for the 3.5 GHz allocation as one possibility, and asks for comment, AFTRCC and other parties are left to guess at this very important issue. In AFTRCC's view the variety of protocols suggested by MBANS proponents, if implemented, could increase the risk of interference to MBANS systems. Among other things, a detailed algorithm should be defined, including the power level the devices would be required to sense, how fast the devices must detect operation on a channel, and how quickly the devices must stop operating on a channel, among other specifications. Without a more specific proposal in this regard, commenters cannot provide an opinion on the potential

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40 *See* GEH Reply Comments filed December 4, 2006 in ET Docket No. 06-135 at 9 and Appendix A at page 1 (assuming free space propagation). The distance is much greater as calculated by AFTRCC's consulting engineer, Dan Jablonski, namely at least 17.8 to 71 km (depending on attenuation assumptions).

41 *Id*. at 8.

42 *See* also AFTRCC Comments, Exhibit B at 11-12.

effectiveness of the 3.5 GHz-type protocol, or any other, to prevent MBANS devices from receiving interference from AMT operations. Indeed, consideration of such a protocol based on the generalities in the NPRM would deprive interested parties of notice and a meaningful opportunity for comment in contravention of their rights under the Administrative Procedures Act.[43] Accordingly, before any report and order could be considered here, it is imperative that there be greater specificity relative to the type of protocol and related technical/operational requirements for MBANS devices that the Commission might adopt, and opportunity provided for comment thereon.

Notwithstanding everything said to this point in time, and in particular AFTRCC's position that alternative spectrum is better suited for MBANS, the following comments are offered in an effort to narrow differences between the parties.

C. <u>Philips Proposal</u>

Philips proposes the use of an "electronic key" which might be used to ensure that hospitals within exclusion zones operate only on permitted frequencies. In particular, Philips proposes that such hospitals be limited to 2390-2400 MHz (with up to 20 mW power) where the electronic keys are not activated. Philips urges that exclusion zones be established in order to protect fixed, mobile, or new AMT facilities, and notes that any hospital initially operating MBANS devices in the 2360-2390 MHz band be defaulted to 2390-2400 MHz if it subsequently finds itself within a mobile or a new, fixed AMT receive site. Philips proposes that, in any instance where a hospital is located, now or later, within an exclusion zone, it could seek to

[43] 5 U.S.C. Section 553(b). See *Am. Radio Relay League, Inc. v. FCC*, 524 F.3d 227, 236 (D.C. Cir. 2008) (stating that an agency must publish "notice of either the terms or substance of the proposed rule or a description of the subjects and issues involved, in order to give interested persons an opportunity to participate in the rule making through submission of written data, views, or arguments" (internal quotation marks removed)).

coordinate use of discrete frequencies or segments in the band with AFTRCC.[44] According to the commenter, a key system "could be implemented manually or automatically implemented through software" with control of the keys residing with a coordinator such as the American Society for Healthcare Engineering ("ASHE");[45] and that via a "hospital site registration process," a beacon signal from the coordinator "would be utilized to protect against unintentional movement of a MBAN device from an authorized hospital site.[46] Philips' proposal is supported by AdvaMed.[47]

Philips has offered an interesting theoretical proposal to overcome the problems inherent with MBANS devices trying to share the 2360-2390 MHz band with primary AMT operations. The electronic key idea, in concept at least, would appear to offer a means of enforcing exclusion zones, such that patients do not wander around transmitting on Restricted frequencies.

However, much remains unsaid about the proposal and the all-important specifics of implementation. AFTRCC is prepared to engage with Philips representatives, GEH, and the Commission on this issue. Among the points requiring further exploration are the following:

AFTRCC would oppose coordination for use of specific AMT frequencies within an exclusion zone in order to minimize burdens and keep the process simple. In AFTRCC's view exclusion zones should be treated as a go/no-go proposition, i.e., either the hospital is, now or later, within an exclusion zone, in which case operation is limited to 2390-2400 MHz; or it is outside an exclusion zone, in which case it would, according to Philips, be able to use 2360-2400 MHz subject to prompt relocation to 2390-2400 MHz in the circumstances referenced above. As long as implementation of the key were mandated by FCC rules, transparent and timely, and

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44 Philips at 6 to 8.
45 *Id*.
46 *Id*. at C-1.
47 AdvaMed at 2 of 13, 5 of 13.

AFTRCC has the ability to inform and cause prompt action by ASHE and its hospital customers relative thereto, an electronic key would seem workable in theory. Of course, tests would be required to prove out the concept, and further conditions possibly required to protect the primary service.

AdvaMed proposes that MBANS sites once registered be grandfathered as against installation of any new AMT sites.[48] Since AMT sites, even mobile facilities, are generally at airports, most hospital registrants within exclusion zone distance of an airport would have reason to know that its MBANS could be restricted to 2390-2400 MHz. In any event, the Notice contemplates a secondary allocation only: Efforts by AdvaMed even now to bootstrap MBANS into co-equal status with temporary, mobile and new, permanent AMT stations, not only confirms the wisdom of limiting MBANS usage to non-life critical applications,[49] but are completely at odds with the secondary status MBANS proponents purport to seek. Hence, AFTRCC strongly opposes AdvaMed's proposal.

D. <u>Other Comments</u>

GEH argues that the S-band is lightly used on a time-weighted average basis.[50] However, as AFTRCC has pointed out previously, flight testing is typically not conducted at night, or in bad weather, for safety reasons.[51] This was the case when spectrum was first allocated for AMT, and it remains the case today. Policy-makers have understood this. The opportunity cost that may be associated with the exclusive allocation has been viewed as more than offset by the societal benefits accruing from an interference-free, flexible spectrum allocation dedicated for flight safety and the Nation's most important export industry.

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[48] AdvaMed at 9 of 13.

[49] AFTRCC Comments at 17-20 (reminding the Commission that medical telemetry has assumed super-primary status when it suffered interference notwithstanding its secondary status).

[50] GEH at 12.

[51] *See* AFTRCC ex parte filed July 28, 2008 at 3.

Moreover, prior assertions by GEH as to the amount of spectrum licensed for AMT are seriously erroneous.[52] According to GEH, "only a small portion of the 2360 to 2395 MHz band is licensed for AMT usage at each test location."[53] However, in making this argument GEH only credited the center 1 MHz of each license. In fact, many if not most AMT licenses are for wideband systems on the order of 12 and even 20 MHz. When credit is given for the actual amount licensed, the picture is dramatically different: Actual spectrum is as much 2000 percent more in the case of a 20 MHz license. The difference is illustrated by a comparison of the graphs in Exhibit C, page C-1 being the chart supplied previously by GEH, and C-2 being the accurate depiction. This data is material for a correct resolution of this proceeding.

AT&T offers comments which urge no exclusion zones, no limitation on outdoor use, would allow voice use, and would have no limits on the manner of interconnection with the monitoring stations.[54] At the same time AT&T's comments offer only the most generalized of notions as to how AMT might be protected, e.g., by frequency coordination, "alternate band[s]," etc.[55]

AT&T's proposals should be dismissed out of hand. It fails to recognize the basis of the proceeding or the consequences to its aerospace customers. It also goes far beyond the scope of the Notice of Proposed Rulemaking which does not even begin to contemplate voice communications or AT&T's notion of "alternate band[s]" -- except for MBANS. Such proposals have not been suggested by the MBANS proponents. Furthermore, AT&T offers no analysis for the dramatically increased risk or consequences of interference that its proposals would entail for

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52 Reply Comments of GE Healthcare filed June 11, 2008 at 9 and Figure 3.
53 *Id.*
54 Comments at 1.
55 Id. at 3.

the aerospace industry as the primary service. Perhaps the Commission should consider utilizing AT&T's WCS spectrum for MBANS operations.

For all these reasons, AT&T's proposed rules lack probative weight.[56]

The Notice asks for comment on appropriate out-of-band emission limits for MBANS devices.[57] Given the potential for a proliferation of devices at 2390-2400 MHz, including devices radiating at 20 mW, the Commission should take great care to ensure that AMT systems operating close to the band edge are fully-protected. Hence, the Commission should require that aggregate MBANS emissions into the AMT band be below the noise floor in 2360-2390 MHz, and that MBANS systems be designed to comply with whatever means are necessary to accomplish this.

AdvaMed suggests no limitation on the relay of MBANS data to receivers not a part of the system.[58] To the extent such an architecture increases the likelihood of longer transmission paths and ranges in the 2360-2390 MHz band, such operations would necessarily require high powers and larger gain, and AFTRCC would oppose the proposal given the increased risk of interference.

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[56] AT&T does offer one comment worth consideration, and that is its emphasis on patient mobility -- but not for the reason proffered by the Commenter. Id at 4-5. Rather, AT&T's comments underscore the imperative need for a fail-safe, technologically-based means of enforcing any exclusion zones if they are to be considered.

[57] Id. at para. 68.

[58] Id. at 7 of 13; see also TI at 5 (external control transmitters should be allowed to "coordinate communications" for multiple patients); GEH at 24 (referencing "MBAN control transmitters").

III. CONCLUSION

Accordingly, for the foregoing reasons and those set forth in AFTRCC's filings in this proceeding, the Commission should not mix two safety operations in 2360-2390 MHz, but should allocate spectrum for MBANS in 2300-2305/2390-2400 MHz or another suitable band.

Respectfully submitted,

AEROSPACE AND FLIGHT TEST RADIO COORDINATING COUNCIL

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Its Counsel

November 4, 2009

Exhibit A

Engineering Statement

Reply Comments re:

The Impact of Medical Body Area Networks on Aircraft Testing in the Band 2360 MHz – 2390 MHz.

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4 November 2009

This Engineering Statement replies to statements put forth by the comments of proponents of Medical Body Area Networks (MBANs) in response to the Notice of Proposed Rulemaking (NPRM).

I. Introduction

In the pages that follow, we identify significant technical errors in the comments filed by MBANs proponents.

This is followed by further comments about the validity of Monte Carlo techniques, and the use of the SEAMCAT software and the extended-HATA model. We note that the validity of the extended-HATA model (as opposed to its non-extended predecessor) is questioned by many. We further note that SEAMCAT results are very sensitive to small changes in input parameters, and that the proponents of Monte Carlo

have failed to include a sensitivity analysis in their contributions. This has a dramatic impact on the size of the small exclusion zones proposed by MBANs parties.

We then describe, in detail, the results of a recent flight test conducted at the Bombardier Flight Test Center in Wichita, Kansas.

II. Correction of Technical Errors in the Comments submitted by healthcare proponents in response to the NPRM

It should be stressed that there are several errors of fact in the documents submitted by advocates of a new allocation for MBANs networks. These are addressed in turn.

General Electric Healthcare (GEH) repeatedly cites the need to leverage existing COTs devices designed for 2.4 GHz operation when implementing BSNs.[1] This suggests that GEH recognizes the ease with which these devices can be "re-crystalled" to operate at lower frequencies, as AFTRCC has done for tests that were conducted almost a year ago. It is puzzling why GEH then asserts that these same devices will not work at 2300 – 2305 MHz.

Next, there is a general consensus that appropriate device technology for implementation of MBANs networks in the 5 GHz bands does not exist.[2] Shown in Figure 1 is a picture of a dual-band 802.11 wireless transceiver. It works at both S and C bands.[3]

The adapter draws a considerable amount of power under worst case conditions. However, when adjustments are made for lowering the transmit power from 40 mW to 1 mW, lowering the data rate from 54 MBPS to 1 MBPS, and reducing the duty cycle to 3%, the power consumption will fall dramatically. Until these factors are taken into account, a sensible comparison between the use of S and C band for MBANs networks cannot be completed. Furthermore, the power requirements of the microprocessor and sensor portions of a BSN device will be the same regardless of which band is used.

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[1] GEHC states, "Indeed, unlike for 2360-2400 MHz, GEHC is not aware of any current radio frequency transceiver chips that operate in the 2300-2305 MHz band and expects that, even if this block were allocated to the MBAN service, chip vendors would decide to omit support for it from future chips due to technical challenges," General Electric Healthcare comments of October 5, 2009 in ET Docket 08-59.

[2] AdvaMed, GEH, Philips, and Texas Instruments' comments of October 6, 2009 in Docket 08-59.

[3] http://www.linksysbycisco.com/US/en/products/WUSB600N

Figure 1. A Linksys Dual-Band Wireless-N USB Network Adapter. It features IEEE 802.11a/b/g, and IEEE802.11n draft

Related to this, Texas Instruments asserts that operation of MBANs devices at 5 GHz will require precisely four times as much power as operation of these devices at 2360 – 2400 MHz.[4] This seems to be based on the assumption that the gain of the receive antenna G_{rec} is constant, and that the power received at the AMT ground station antenna is given by the Friis equation:

$$P_{rec} = \frac{P_{transmit} G_{transmit} c^2 G_{rec}}{(4\pi r)^2 f^2} \qquad (1)$$

where c is the speed of light and f is the frequency of the transmitted signal.

However, when the frequency of a signal is changed, and the length of the antenna remains unchanged, G_{rec} increases by a factor of f^2, and equation 1 becomes independent of frequency. In this limit, the assertion that an increase in frequency automatically requires an increase in transmitter power is not correct.

A portion of the data sheet for the Cisco/Linksys 802.11 adapter shown in Figure 1 is presented in Figure 2.[5] Note that at 5 GHz, the gain of the internal antenna is *4 dBi*, not *2 dBi*, and that the transmit power of the device, 40 mW, is the same for each of its two bands.

[4] Comments of Texas Instruments, ET Docket No. 08-59, October 5, 2009.
[5] Ibid, reference 3.

Tech Specs

- **Model:** WUSB600N
- **Standards:** IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, Draft IEEE 802.11n
- **LEDs:** Link/Act
- **No. of Antennas:** 2 Internal Antennas
- **Transmitted Power:**
  2.4 GHz Wireless-N @ < 16 dBm (typical)
  5 GHz Wireless-N @ < 16 dBm (typical)
- **Receive Sensitivity :**
  2.4 GHz Wireless-N @ < -91 dBm (typical)
  5 GHz Wireless-N @ < -91 dBm (typical)
- **Antenna Gain in dBi :**
  2.4 GHz Wireless @ ± (typical): 2 dB +/- 1 dB
  5 GHz Wireless @ ± (typical): 4 dB +/- 1 dB
- **Power Consumption:**
  TX < 480mA (maximum)
  RX < 300mA (maximum)
- **Security Features:** WEP, WPA, and WPA2
- **Security Key Bits:** Up to 256-Bit Encryption

Key Features

- High-speed, Dual-Band Wireless-N (draft 802.11n) networking for your desktop or notebook PC
- MIMO technology uses multiple radios to create a robust signal that travels farther and reduces dead spots
- Much faster than Wireless-G, but can also connect to Wireless-G, -B and -A networks
- Performance investment protection: compatibility with Wireless-B (802.11b) and Wireless-G (802.11g) standards
- Supports up to 256-bit encryption (WEP, WPA and WPA2)
- USB 2.0 interface
- Easy-to-use setup wizard
- Compatible with Microsoft Windows 2000, XP, and Vista

Figure 2. Technical specifications for the wireless adapter shown in Figure 1. Note that the antenna gain is 4 dBi at 5 GHz, a factor of 2 dB higher than the gain of the antenna for 2.4 GHz. This suggests that the length l of the antenna is the same for each band, and that the gain is proportional to l/λ, thus eliminating the factor of f^2 component of the frequency dependence. The sensitivity of -91 dBm is comparable to that of the Nordic chips. The output power is 40 mW. (from http://www.linksysbycisco.com/US/en/products/WUSB600N)

Philips expresses concern about the large cross-body attenuation of up to 56 dB that is expected at C-band, which is larger than the corresponding value at S-band.[6] This is a serious concern, at all of the bands in question. Indeed, the first proposal for MBANs assumed a required power level of 0.1 mW, which has since been raised by a factor of 10 to 1 mW.[7]

Thus, until a full, side-by-side analysis of all aspects of the MBANs architecture implemented in both frequency bands is considered, including the specifics of antenna design, it is premature to discount the possibility of a C-band solution.

[6] Comments of Philips healthcare Systems, Docket 08-59, FCC.gov.
[7] See GEH filings in ET 08-59 at FCC.gov.

III. Validity of the Monte-Carlo simulations based on the Extended-HATA Model.

The original HATA model was designed to predict propagation parameters of electromagnetic signals at frequencies up to 1 GHz. The extended-HATA model purports to enable these predictions to 3 GHz. The SEAMCAT software uses the extended-HATA model for Monte Carlo simulations.

Of interest here is that the validity of the model at these higher frequencies is questionable. This point is addressed in recent submission to the ITU of a Report that details concerns about whether the extended-HATA model is accurate.[8] The Report notes several apparent inconsistencies in the current SEAMCAT implementation, and explains clearly why additional studies, validated by experiment, are needed in order for SEAMCAT simulations to be trusted for simulations above 1 GHz.

For example, one of the issues discussed in the paper is the possibility that the software includes a parameter or phenomenon in its models twice. For link budget analyses, double-counting such as this is always a concern. For example, the gain G of an antenna is often re-defined as the directivity D, which sometimes, but not always, includes the efficiency of the antenna, which ranges from ~0.6 to .8 for an AMT parabolic dish.

Even if one were to accept the validity of the extended-HATA model, the conclusions drawn far exceed the capability of the analysis to produce precise results. Philips, for example, uses the software to justify an 11.5 km exclusion zone. Specification of an exclusion radius to this precision of 0.5 km, or 500 meters, is questionable.

This is especially true given the assumptions about building attenuation, BSN height, and the signal to noise ratio required at the AMT receiver for proper operation.

Figure 3 shows why this is a concern. The Figure is a generic plot of Bit Error Probability (BEP) versus received signal-to-noise (or signal-to-noise-plus-interference) ratio. In the Figure, the horizontal axis is scaled in units of 1 dB, but without the specific values specified. This is deliberate, as the purpose here is to highlight the extreme sensitivity of the bit error probability to small changes in the signal-to-noise-plus-interference ratio. A 3 dB decrease in this ratio caused, for example, by an increase in interference or a decrease in building attenuation, can cause a factor of 1000 increase in the number of errors per second that occur.

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[8] United Kingdom contribution to the ITU, "Comments Relating to the Use of the Extended HATA Model SEAMCAT for Sharing Studies, Document 3K/62-E, 24 April 2009, *www.itu.int*. This report was filed in connection with the possible use of SEAMCAT in sharing studies submitted to the ITU.

Put differently, once interference begins to affect an AMT system, slight increases in interference above this threshold level will have severe consequences. This is why Rec. M.1459 stipulates such large fade margins.

Thus, small parameter changes may have a profound impact on the Monte Carlo simulation results presented by GEH and Philips. In their simulations, these parties assume that an AMT receiver requires a *C/(N+I)* ratio of 12 dB for proper operation. This is a compromise between the minimum value of 9 dB, and the maximum value of 15 dB, both specified in Rec. M.1459.

Laboratory measurements indicate that for modern AMT receivers built since Rec. M.1459 was published, 15 dB, rather than 12 dB, is the appropriate value to be used. And, for advanced modulation techniques with improved spectrum efficiency, even higher values may be needed. However, since the Monte Carlo simulations performed by GEH and Philips do not include a sensitivity analysis, it is not possible to tell what impact such changes will have on the simulation results.

Thus, the underlying propagation model used in the Monte Carlo simulations is suspect, as is the SEAMCAT software that implements this model. But, the key assumption upon which any C/(I+N) analysis depends, namely the assumed value for this parameter, is also in question.

In any case, note that a 3 dB difference in *C/N* causes a 30 dB, or factor of 1000, increase in BEP. That is, a factor of 3 dB change in the *C/(N+I)* can cause a factor of 1000 increase in the predicted Bit Error Probability.

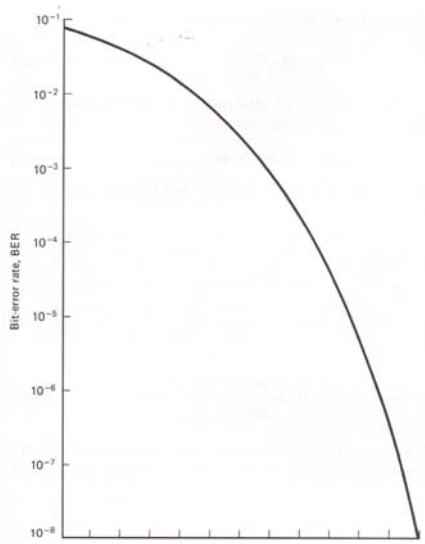

Figure 3. Generic chart of Bit Error Probability (BEP) versus *C/(N+I)* . The horizontal axis is scaled in relative units of 1 dB. The specific values are not specified, as they depend on the particulars of the system being analyzed.

Hence, the decision by GEH and Philips to use 12 dB, rather than 15 dB, for the required *C/(N+I)*, and their assumption of average building attenuation factors of 10 dB, instead of a more conservative value of 6 dB, likely understates the impact of their interference signals on AMT telemetry link performance.

Unless this is taken into consideration, and until the concerns about the extended-HATA model and the SEAMCAT software are resolved, the Monte Carlo simulations must be viewed as understating the impact of interference from MBANs networks to AMT operations.

Put differently, what is the point of specifying a 11.5 km proposed exclusion zone with a precision of 500 meters if there is a 10 km uncertainty in this value to begin with?

As shown below, AMT receivers in Wichita have no difficulty seeing MBANs (also known as Body Sensor Network (BSN)) signals, even using a lower-gain 5-foot diameter AMT antenna,[9] from BSNs located 10 miles (16 km) away inside a building. This is in contrast to the predictions of the SEAMCAT analyses.

Finally, the Monte Carlo simulations incorrectly use the probability function provided in ITU-R Recommendation M.1459 to describe fading due to aircraft maneuvers and ground multipath. The function is shown in Figure 4, excerpted from the Recommendation, and shows the cumulative probability of a fade (vertical axis) that exceeds a particular level (in dB, on the horizontal axis). Both the GEH and Philips Monte Carlo results depend on the data in this plot; it is one of several probability distributions used in the simulations.

The Monte Carlo simulations perform "coin tosses" at each of the thousands to millions of iterations that decide which data point, from each of the probability distributions in the simulation, is to be used for that iteration.

Because of this, data points from the graph are chosen at random with no consideration of the kinematics (i.e., the motion) of the aircraft. The flight characteristics of the aircraft are completely ignored in the SEAMCAT simulations. In SEAMCAT, fades due to maneuvers can vary instantly, from one SEAMCAT iteration to the next, from 0 dB to -40 dB in an instant. However, this does not happen for an airplane in flight; the airplane cannot discontinuously encounter a deep fade without going through all of the intermediate values first, as fades are not instantaneous. Thus, SEAMCAT ignores an essential feature of aircraft operations: The motion of the aircraft is not random, but follows the laws of aerodynamics.

[9] Versus, for example, a higher gain 15 foot diameter dish.

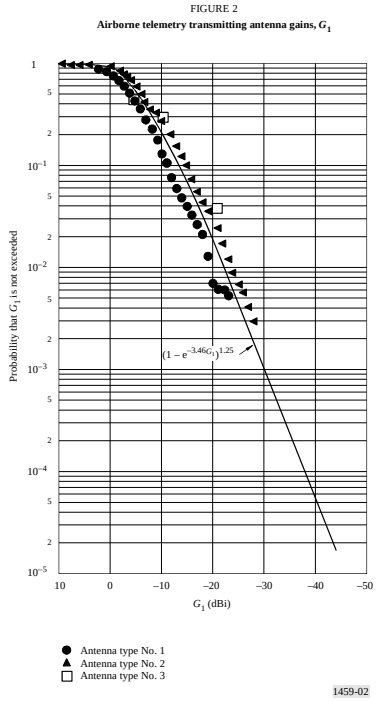

Figure 4. Fade Characteristics from Aircraft as shown in Figure 2 of ITU-R Recommendation M.1459.

This matters greatly, inasmuch as a "momentary dropout" predicted by Monte Carlo simulations will often be an extended dropout. Such a dropout will entail significant data loss, or complete loss of the data link, or even capture of the ground station tracking antenna control loop by the BSN. Any of these scenarios will require a repeat of the test maneuver, at a minimum, or the entire test flight.

The importance of properly considering the dynamics of fading in the aviation environment was recognized by the authors of Rec. M.1459, and by the United States and the ITU-R when the Recommendation was formally approved. In the Recommendation, the authors present the distribution shown in Figure 4, and then explain that proper inclusion of Markov effects (in which the behavior of a system at instant t is governed by the behavior of the system at the previous instant, $t - \Delta t$), precludes the use of the random assumptions that are at the essence of Monte Carlo simulations. By taking the probability distribution out of context, the Monte Carlo results presented by GEH and Philips are inherently flawed -- independent of whether the extended-HATA propagation model is valid.

Indeed, the graph in Figure 4 was included in the Recommendation not because it is needed for deriving protection levels for AMT operations. To the contrary, it was included in order to demonstrate why statistical techniques cannot be used to derive these protection levels.

Finally, it is worth noting that the fades due to aircraft maneuvers are greatly influenced by the fact that aircraft structures are large compared to the telemetry signal wavelength of ~.125 meters. Thus, short-path-delay multipath due to aircraft structures, and antenna-to-antenna interference issues, make deep fades an inevitable consequence of aircraft flight test operations.

IV. Flight Testing at the Bombardier Flight Test Facility in Wichita, Kansas

Philips has proposed exclusion zones of only 11.5 km, not dissimilar to those proposed by GEH (9.7 km). In order to demonstrate the inadequacy of such radii, AFTRCC member companies, Bombardier and Cessna, undertook additional testing on the effects of BSN interference on the flight test telemetry stream. This test was undertaken using the same Nordic chip proposed by GEH.

The results of these tests are provided below. First, however, it is important to address details concerning flight test operations that must be understood for an informed resolution of this matter.

Safety Considerations

The aircraft used in the test, shown in Figure 5, is a Bombardier Canadair Regional Jet, CRJ-700. It has two features that are not typically associated with commercial aircraft. The first is an escape hatch, shown in Figure 6, in the floor of the fuselage just aft of the cockpit. This provides the crew members the possibility (not the promise) of leaving the aircraft safely during a flight emergency. For high-risk flights, the aircrew wear parachutes, helmets, and an assortment of survival gear, which they are fully trained to use.

Figure 5. The test aircraft, with its crew of four.

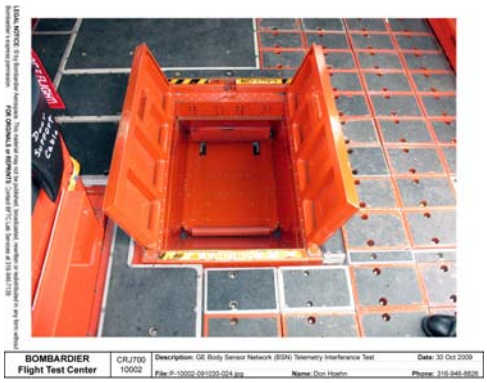

Figure 6. The escape hatch, located in the fuselage floor just aft of the cockpit.

The chief pilot for this test was a former shuttle astronaut, whose flights to space include trips on the ill-fated Columbia. The co-pilot and flight test engineers have comparable, if perhaps less exotic, experience.

In the aft section of the aircraft is a winch assembly for the spin-recovery parachute. For stall testing, in which loss of the aircraft is a distinct possibility, the emergency deployment of a large parachute through the tail-cone provides a high-risk, last-ditch possibility for saving the aircraft. If deployed successfully, it slows the airplane and gets the nose down, such that control can be regained and a recovery made possible.

Details of the Flight Test

The test was accomplished by placing BSN devices inside two buildings. The first, the 18-story Hyatt Regency Hotel in downtown Wichita, is 5.7 miles from the Bombardier AMT Ground Station at Midcontinent Airport (referred to by its FAA abbreviation, ICT).[10] The second is an 11-story apartment building for elderly residents called Highland House. It is located 10 miles from the ground station.

This is shown on the map in Figure 7. Note that Wichita is surrounded by airfields. There are flight test ground stations at Midcontinent Airport, at McConnell Air Force Base, and at the Hawker-Beechcraft facility. Clearly, all three of these sites, each being several miles apart, would require protection.[11]

Figure 8 shows the approximate path flown during the outbound phase of the flight test. During the inbound phase, the aircraft returned directly to Wichita. It then re-

[10] The letter W for Wichita is supposedly not used in order, per FCC requirements, to not confuse the airport with a radio station.

[11] As an aside, the official tourist guide for Kansas lists two industries for the State, *aviation* and *agriculture*. Coincidentally, these are two of the leading industries in the United States in terms of mitigating the enormous trade deficit.

flew the outbound leg, from West of the airport to east of the Highland House, to repeat the measurements.

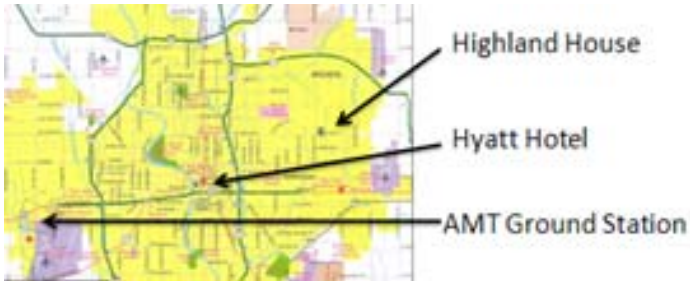

Figure 7. Wichita and its surroundings

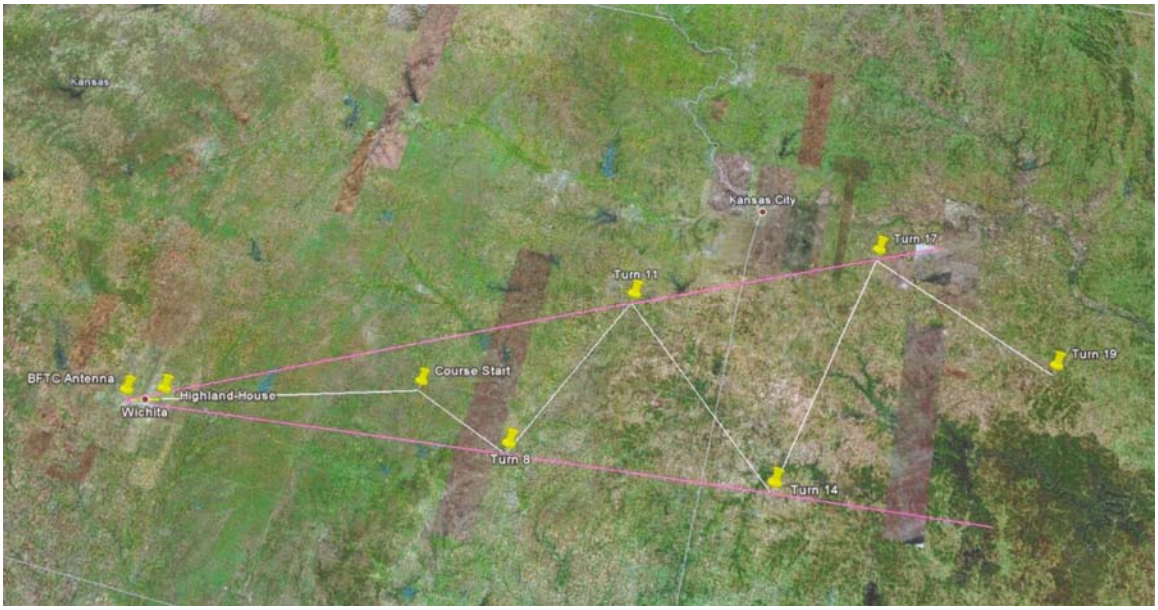

Figure 8. Flight Path of the CRJ-700.

The view from the Highland House to the West toward the Bombardier plant is shown in Figure 9. Note that the airport and the Bombardier site are another 5 miles beyond the skyline.

Figure 9. View to the West from the Highland House. The Wichita Skyline can be seen in the distance. The airport is an additional five miles west of the City.

For the test, the aircraft was instrumented with data links operating at two frequencies using two antennas. The data links transmitted identical data streams at 2.5 MBPS. The data stream for the antenna on the bottom of the fuselage was transmitted at a center of 2361.5 MHz, with a receiver IF bandwidth of 3.3 MHz. It was received on the ground using a tracking antenna 5 feet in diameter. The data stream for the antenna on the top of the fuselage was transmitted at 2374.5 MHz, and received by an 8-foot diameter tracking antenna, also with a receiver IF bandwidth of 3.3 MHz.

The configuration is similar to that used for the earlier test performed by Bombardier, using a signal generator having low values of FM deviation as the interference source.

The BSN devices used for the test were prototyped using the Nordic nRF2401 transceiver chip. They were operated under a special temporary authorization (STA) from the Commission. Two additional devices, also authorized under the STA, used the Nordic nRF24L01. These were placed in the Highland House, and communicated from one to the other the following test message, transmitted repeatedly: “AMT to BSN Interference Test 09.”

The separation between the nRF24L01 devices was several feet, emulating the expected attenuation between a BSN transmitter and its companion receiver on a patient’s

body, or that for a transmission from a patient to a nearby base station (another application contemplated by proponents of MBANs).

Three nRF2401 chips were operated as transmitters at the Highland House, in an 11th floor room, at the frequencies 2360.5, 2361.5, and 2362.5 MHz. The latter was measured to be slightly higher in frequency (2362.7 MHz), likely due to an issue with its low-cost, un-temperature compensated crystal oscillator. (BSN operators can expect to see similar variations as they deploy large numbers of these devices.)

Finally, a fourth nRF2401 device, configured as a transmitter, was operated at 2361.5 MHz in a room on the 16th floor of the Hyatt.[12]

The use of BSNs beyond radio horizon from an AMT ground station, or that are in compliance with the pfd limits specified in Recommendation ITU-R M.1459, are not material from an interference standpoint.

The BSN devices were operated at duty cycles of 34%, with on-times of 3.4 mS. Their nominal bandwidth, as configured, was 640 kHz. Further details are provided in AFTRCC's earlier filings.[13] Thus, each device could represent the transmissions to be expected from a single patient's body-mounted hub to a base-station located inside a hospital.

Alternatively, one can regard each device as representing the aggregate emissions from a patient wearing ten individual BSNs, communicating to a patient-located hub, using a TDMA protocol with a per-receive duty cycle of 3%. Note that 1 mW represents the EIRP, which is the proposed BSN transmitter power <u>after</u> it is attenuated by body absorption and blockage effects.[14]

Test Results – Interference to AMT Ground Stations from BSNs

Figure 10 shows signals received at the AMT ground station from the four devices. As stated, the devices are located indoors. Note that the signal in the middle is the superposition of co-frequency BSNs, one at the Highland House and one from the Hyatt Hotel.

When the AMT receive antenna is pointed, in manual mode, so that the BSN signals are offset from the center of the antenna beam, the received signal power decreases, as expected. However, pressing the "Autotrack" button on the Antenna

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[12] With respect to the widespread deployment of BSN devices, data previously presented by AFTRCC (see ex parte of February 23, 2009) include measurements of devices located outdoors at ground level, 15 feet above ground level, and on a bridge 30 feet above ground level. It can be said with confidence that line of sight propagation from BSN devices at even moderate heights above ground level to a tower-located AMT antenna is generally superb.

[13] See Test Report attached to AFTRCC's February 23, 2009 ex parte.

[14] GEH's November 2008 and other filings, docket 08-59.

Control Unit causes the conical scan tracking system to locate, and steer the antenna to, the centroid of the interference source, thus maximizing the received signal amplitude.

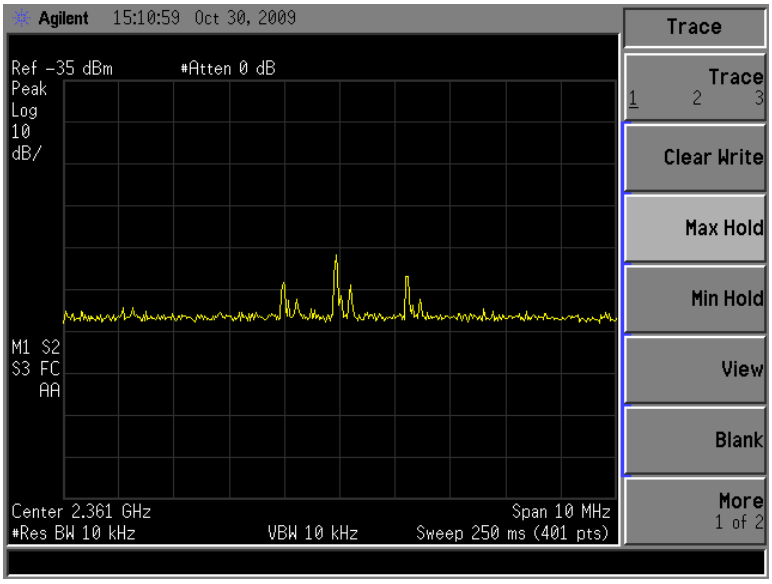


Figure 10. Time-averaged spectrum analyzer plot of the signals from BSNs, as received at the Bombardier Flight Test Center at Wichita Midcontinent Airport. As the BSNs are operating at a 34% duty cycle, the max-hold feature of the spectrum analyzer was used to capture the data. Otherwise, a single 250 mS sweep of the analyzer might catch all four of the devices turned on simultaneously, or any subset of 0, 1, 2, or 3 of the devices turned on. However, the operation of the AMT telemetry receiver, with its AGC time constant of 100 mS, is affected by both the average-aggregate power of the devices (which sets the AGC level), and the instantaneous values of interference (which affects whether a given set of bits in the data stream are corrupted).

Figure 11 shows the AGC output of the AMT ground station telemetry receiver, with the AGC time constant set to 0.1 mS. The vertical scale is logarithmic, so that a doubling of power due to simultaneous operation of two BSNs makes only a small increase in the apparent amplitude of the combined signals. This behavior was first observed and reported in the Test Report submitted earlier this year.[15] The unsynchronized, limited duty-cycle behavior of the individual devices is easily discerned.

[15] *See* Note 13.

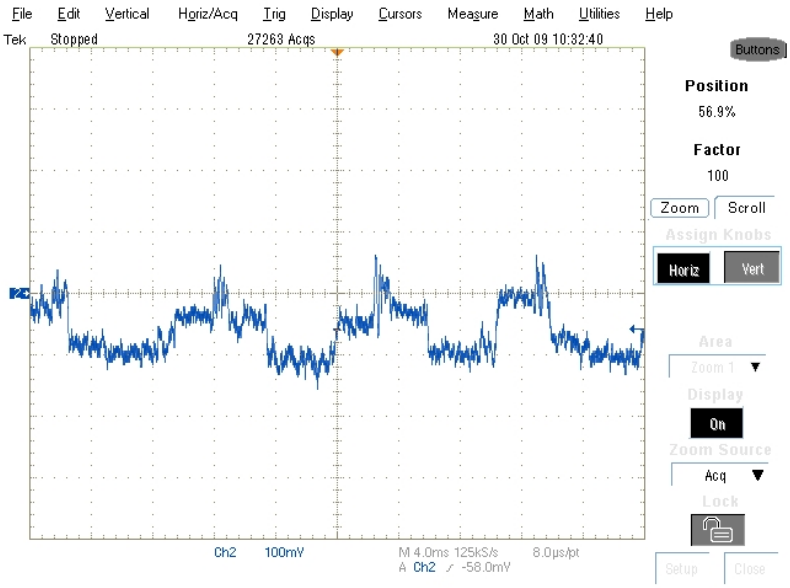


Figure 11. Signal strength (AGC) output of the AMT ground station telemetry receiver. The vertical scale is logarithmic. The trace shows the various BSN devices, each turning on, asynchronously, for approximately, 3.4 mS and off for 6.6 mS.

As noted in the earlier Test Report, the Nordic devices do not exhibit the theoretical *sinx/x* profile, as GEH has claimed in an earlier filing.[16] This is likely because the plastic packing and single-chip design of the nRF2401 permit re-modulation of the radiated signal as it couples from the transmit antenna back into the device. (It is also an indication that the proposals for MBANs networks are still immature.)

Figure 12 shows a view of the test aircraft from the Hyatt as it leaves Wichita headed in the general direction of Kansas City at an altitude of 2000 above ground level.

Figure 12. The CRJ-700 passing over the Hyatt en route to the test area in Eastern Kansas.

[16] GEH submission of February 9, 2008 at page 28..

Figure 13 shows the aircraft telemetry signal, transmitted from the CRJ-700 at a range of well over 150 nautical miles. Note that all four BSNs are visible above the aircraft's TM signal. The beamwidth of the tracking antenna is approximately 6 degrees. Thus, the aircraft and BSNs, at this range, are simultaneously in view over an angular distance of twice the antenna beamwidth, which is 12 degrees. At climb-out and speeds of 180 knots, an aircraft traveling at right angles to the line defined by the ground station and the interfering devices takes 4 minutes to pass through this interference region. At a cruise speed of 400 knots, the possible duration of an outage is approximately 2 minutes.

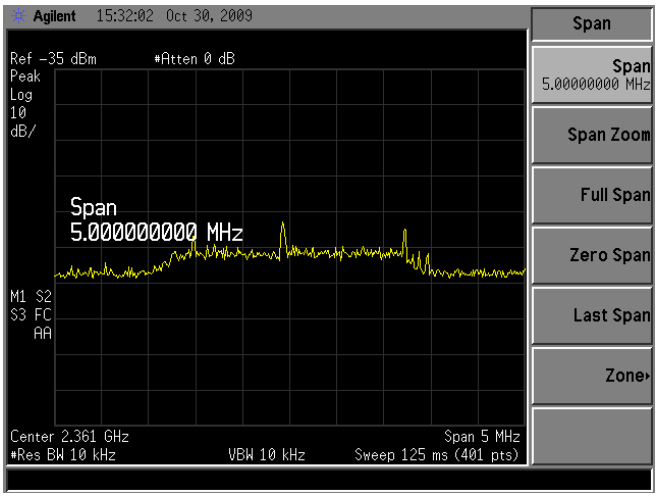


Figure 13. Interference from BSNs visible through an aircraft telemetry signal

At a distance of 150 nautical miles, an aircraft at an altitude of 30,000 feet is only two degrees above the horizon. For the ground antenna beamwidth of 6 degrees, the BSNs and the aircraft are thus in simultaneous view. The notion that the antenna points above the interference devices is only true very close to the airport.

The geometry of this is captured in Rec. M.1459, in which the pfd levels for protecting the AMT ground station depend on the elevation angle of the tracking antenna.

The next several Figures provide the reader a flavor of what flight test operations are all about, and will show just how complicating and insidious even small amounts of interference can be. The four transmitting devices used in this test represent only four people wearing the devices that GEH and others hope to make ubiquitous among the patient population. If even a tiny percentage of these users stands near a window on a high floor (e.g, above the 4th floor) of a building that is within line of sight of an AMT ground station, harmful interference will occur when the AMT antenna points within a beamwidth of the facility.

A single patient who chooses to step outside will create interference that is not attenuated by buildings or windows. Under line of sight conditions, as would occur on a balcony at the Highland House (all of the apartments have outdoor balconies), stepping

outdoors would have the same effect as reducing the distance to the AMT ground station by a factor of 2. The notion that patients are mobile transmitters that operate autonomously without coordination, as proposed by AT&T, is thus completely unworkable.[17] The notion that Monte Carlo simulations can be used to dismiss the likelihood of this happening is also baseless.

Returning to the discussion of test data, Figure 14 shows a perfectly good telemetry signal, except for the BSN signals poking through the top. The aircraft is about 170 nautical miles (about 192 statute miles) from the AMT ground station. The aircraft is flying wings-level at an altitude of 23,000 feet above sea level at a ground speed of about 400 knots.

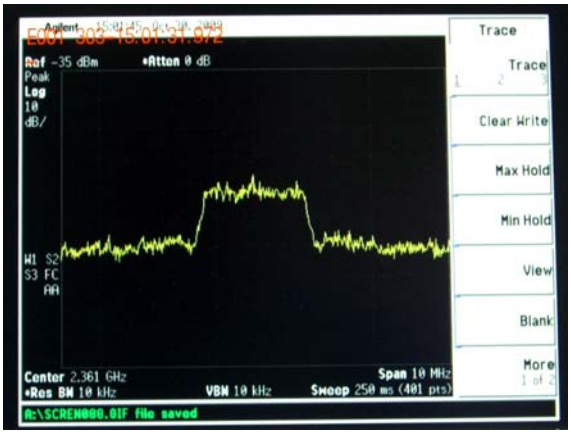


Figure 14. A high quality telemetry signal, with slight BSN interference "poking through".

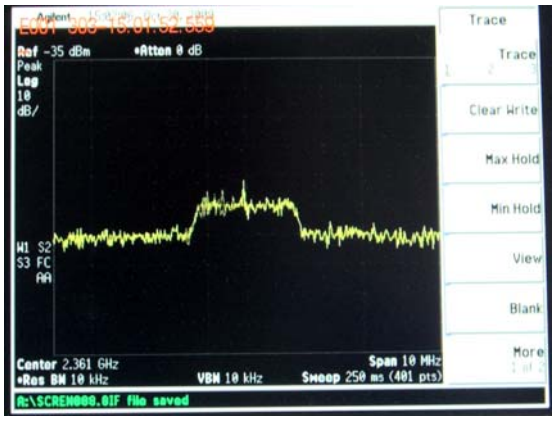


Figure 15. Variation in AMT signal strength showing interference from BSNs.

[17] AT&T filing of October 5, 2009 in Docket 08-59.

Figure 15, from several seconds later in the flight, shows the typical variation of received signal strength as the aircraft is, in this case, buffeted by “heavy chop”. The BSNs are more noticeable, but the quality of the received telemetry is within that required for an acceptable bit error rate of 10^{-6}.[18]

The next Figures show the antenna control unit display, which indicates that the parabolic dish antenna at the AMT ground station is automatically tracking the aircraft at an azimuth angle of ~75 degrees, which places the BSNs firmly in view of the AMT ground station antenna. The relative signal strength is 13, with the auto-track alarm threshold set to 5. When the receive signal strength falls below 5, an alert is triggered. At this point, the antenna operator will typically switch from autotrack to manual track. This is in anticipation of failure of the antenna’s servo-control tracking loops, and with the hope that manual intervention can maintain lock.

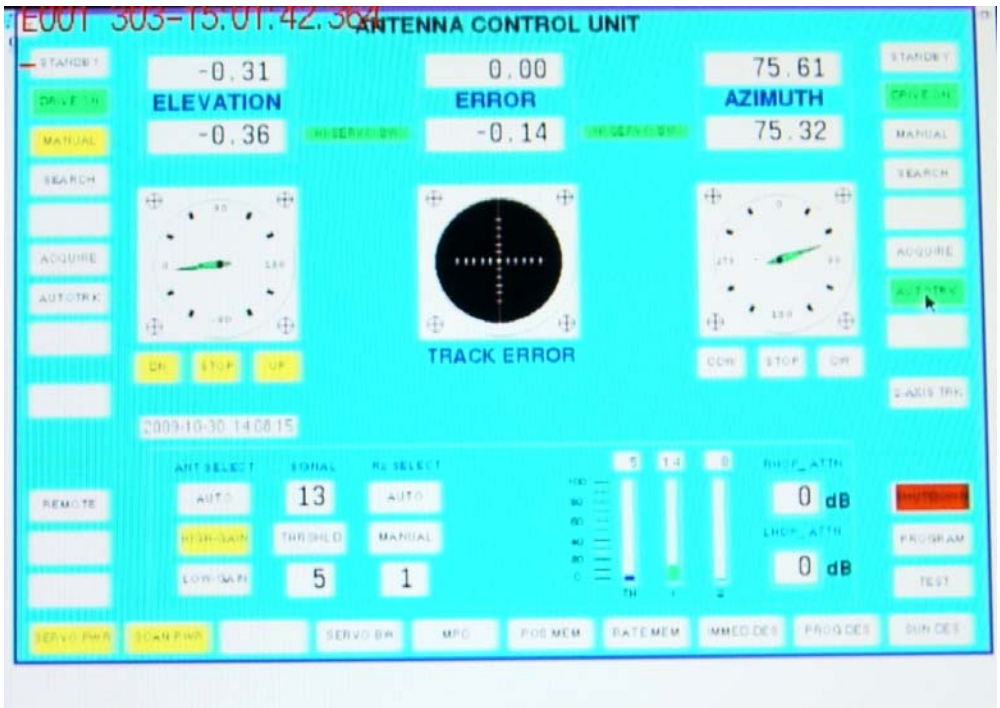


Figure 16. Antenna Control Unit display at 15:01:42:364.

Figure 17 shows the real time display of a small portion of the flight test data extracted, in real time, from the downlinked telemetry stream. The aircraft attitude and heading are illustrated graphically, as is the aircraft’s in-cockpit artificial horizon. The range to the AMT ground station is displayed (167 nm), as are barometric altitude (feet, based on barometric pressure referenced to 29.92 inches of mercury), radar altitude (a

[18] Bombardier has conducted studies of the performance of their AMT systems, and have observed, over a one year performance period, performance at or better than the acceptable bit error rate of 10^{-6} for 99.9% link availability.

direct measurement of the height above ground), airspeed (knots), and bearing to the ground station.

Less obvious, but equally important, is the horizontal strip chart showing the status of the bit synchronizer and data decommutator. The single flat line, located at the top of the stripchart, indicates that all is well. However, when data dropouts occur, the telemetry stream has already become corrupted; since the header bits that are used to determine bit-sync status comprise only a tiny fraction of the bits in the overall data stream, there will be significant bit errors long before header bits are affected.

Note that a running clock, based on an independent time standard, is displayed at the top of each data display. This permits accurate synchronization of the spectrum analyzer, antenna control unit, and flight data information. Although the ground station instruments also have internal clocks, no special effort is made to calibrate these to sub-second accuracy.

In parallel with the displays shown here, the data from each of the two telemetry streams (2374.5 MHz from the aircraft's top antenna and 2361.5 MHz from the bottom antenna) are recorded at the ground control station for subsequent analysis. These files, which are available in real time to flight test engineers, contain the several megabits per second of real-time data that is the reason for performing the flight test in the first place.

For this particular test, paper strip chart recorders were used to plot, in real-time, the strength of the received signal from each aircraft. This permitted the behavior of the TM link that was exposed to interference to be conveniently compared, on a second-by-second basis, with the data from the control channel.

Figure 17. Flight test data display under "nominal" conditions at 15:01:16.591.

The next Figure shows how quickly things can happen during a flight test. Unlike view-graph engineering and the use of computer simulations, one cannot hit the pause button, or fix problems by changing the simulation parameters or performing additional computer runs. An aircraft, with people on board, is using the flight test ground station as a safety net.

For the period from 15:01:00 to 15:03:00 on 30 October, this "net" turned out to be rather fragile. During this period, the aircraft passes behind the BSNs at both the Hyatt and the Highland House. Figure 18 shows how the resulting telemetry failure begins to evolve.

The aircraft is known to be flying straight and level, but the artificial horizon shown in the Figure indicates a pitch-up attitude. The strip chart, which moves from right to left, shows that bit synch has been lost (the dark vertical line). Readings such as these can reflect a dropout due to interference or due to an in-flight emergency. The resulting confusion is dangerous and unacceptable.

Figure 18. First sign that bit sync has been lost, at 15:01:50.591. Note the change in the artificial horizon (pitch-up, even though the aircraft is thought to be level), and that bit synch has been lost (the dark vertical line at the right hand side of the strip chart, which moves from right to left).

A few seconds later, at 15:01:52, the Antenna Control Unit indicates (Figure 19) that signal strength has fallen to a level of 6, just above the warning threshold value of 5.

The azimuth indicates, to the informed operator, that the aircraft is in direct line with the (in this case known) interfering devices.

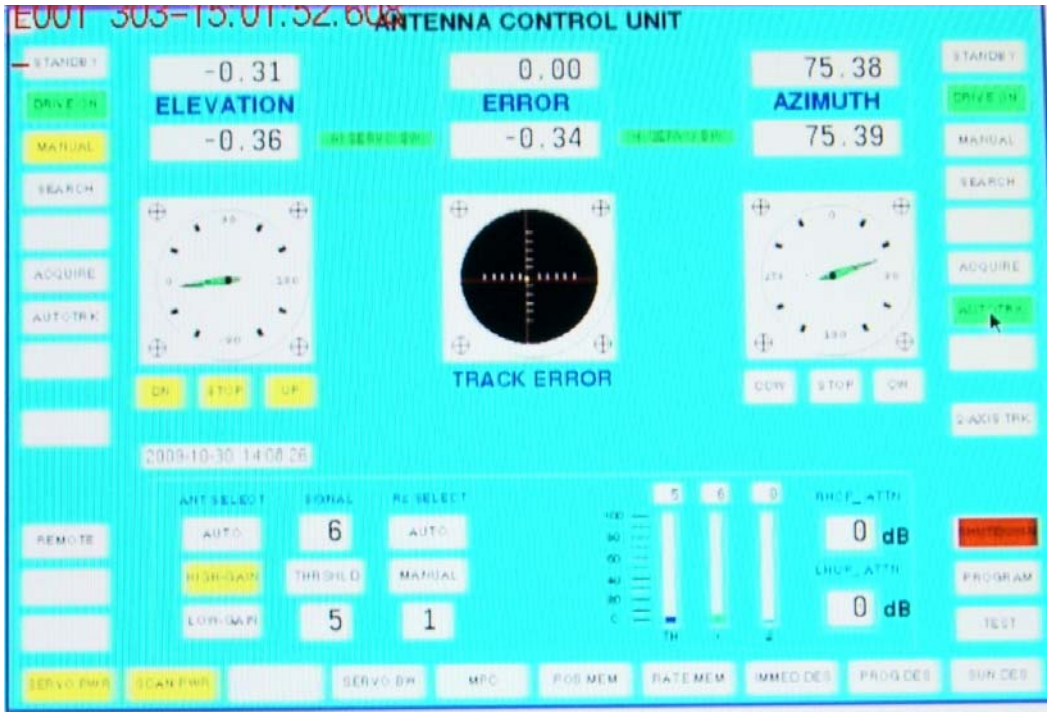


Figure 19. Antenna Control Unit (ACU) display showing signs of signal dropout (the signal strength has fallen to a value of 6).

At 15:01:58, six seconds after the first sign of trouble, the flight data display shown in Figure 20 indicates that bit sync is still lost and that the aircraft is flying directly towards the ground. The artificial horizon shows the aircraft in a spiral. It is not possible to tell from these readings whether it is the aircraft or the telemetry link that is failing. Since the purpose of the telemetry, if this were a regular flight test, is to enable ground engineers to detect problems which may not be evident to the pilots, voice communication with the aircrew would not necessarily resolve the issue: Serious problems aboard the aircraft could be masked by BSN interference, or all could be normal on board. This is the very essence of “harmful interference.”

Likewise, if the problem is a telemetry dropout due to a fade caused by, for example, an aircraft maneuver, the telemetry stream would typically recover quickly (within a second), as opposed to becoming progressively worse over a period of several seconds.

However, the CRJ-700 was known to be flying wings-level at constant speed, heading, and altitude. (The latter was because of an air traffic control instruction to maintain constant altitude, thus postponing a planned climb at this point in the flight.)

Thus, one would not expect a fade due to a maneuver. And, at 23,000 feet at a distance of 160 nautical miles, ground multipath is unlikely to be an issue.

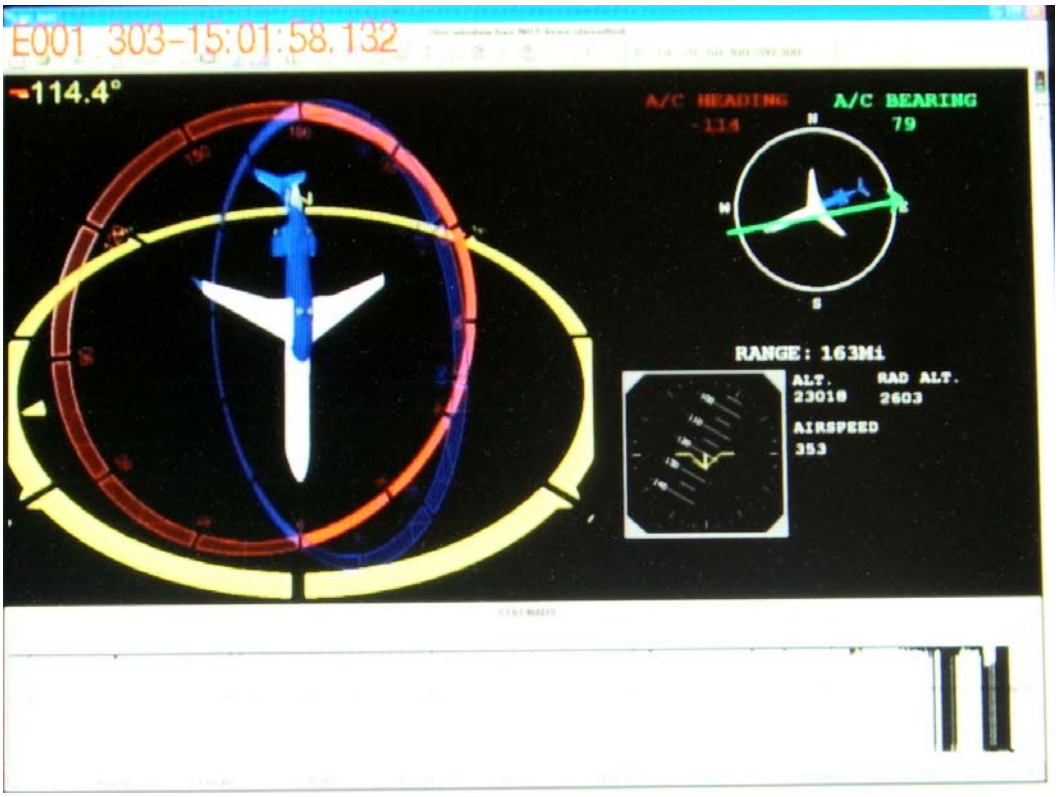


Figure 20. Flight Data Display after loss of the Telemetry link. The aircraft is shown to be in a dive towards the ground in the general direction of Wichita.

Figures 21 and 22 below show the received signal strength from each of the two aircraft transmitters. The first trace shows that the signal from the transmitter at 2361.5 MHz has totally flat-lined. This behavior, preceded by rapid oscillations of the signal strength, is not typical of signal fading that the authors have observed during their combined decades of observing, participating in, designing, and/or leading flight tests. The second, control trace implemented specifically for this test, is unaffected.

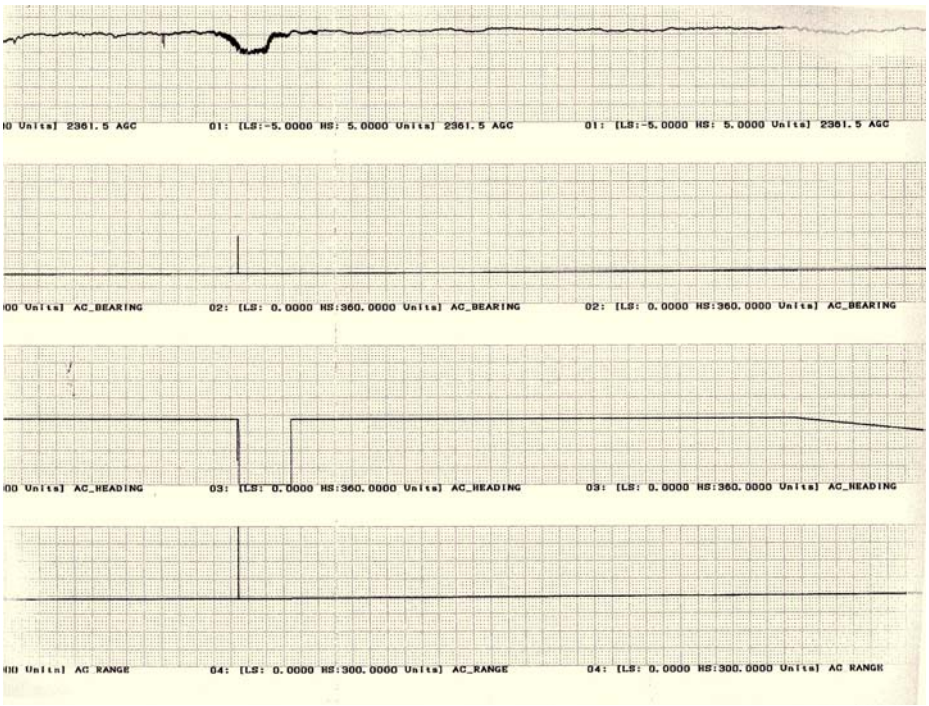


Figure 21. Complete telemetry dropout of the signal from the aircraft at 2361.5 MHz (top trace). The other plots are aircraft attitude parameters.

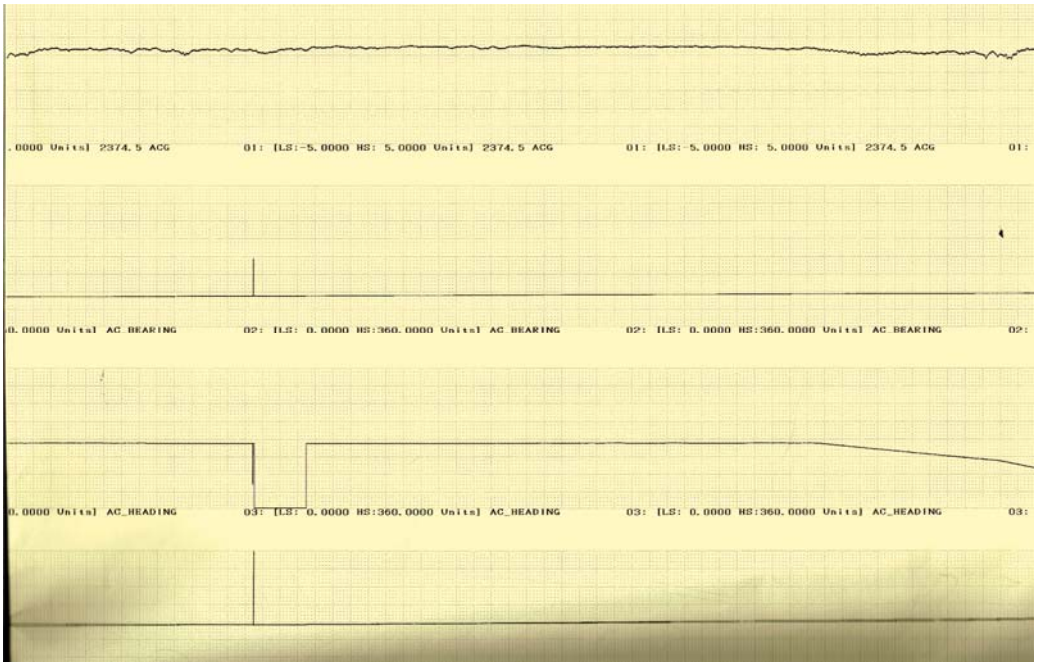


Figure 22. The received signal strength for the aircraft telemetry link operating at 2374.5 MHz. Note that the received signal strength (top line) is well-behaved, with no evidence of

dropouts. The other three lines are identical to those in Figure 21. This permits accurate alignment of the two charts.

Figure 23 shows the spectrum analyzer, at 15:01:56.597. The signal from the bottom antenna telemetry signal is almost completely gone. What remains in its place are signals from the BSNs. Note that the BSNs turn on and off at 3.4 millisecond intervals, but that it takes the spectrum analyzer 250 mS to complete a single sweep. Thus, the interference to the AMT receiver is considerably more severe than that indicated in the Figure by this real-time, non-averaged spectrum measurement.

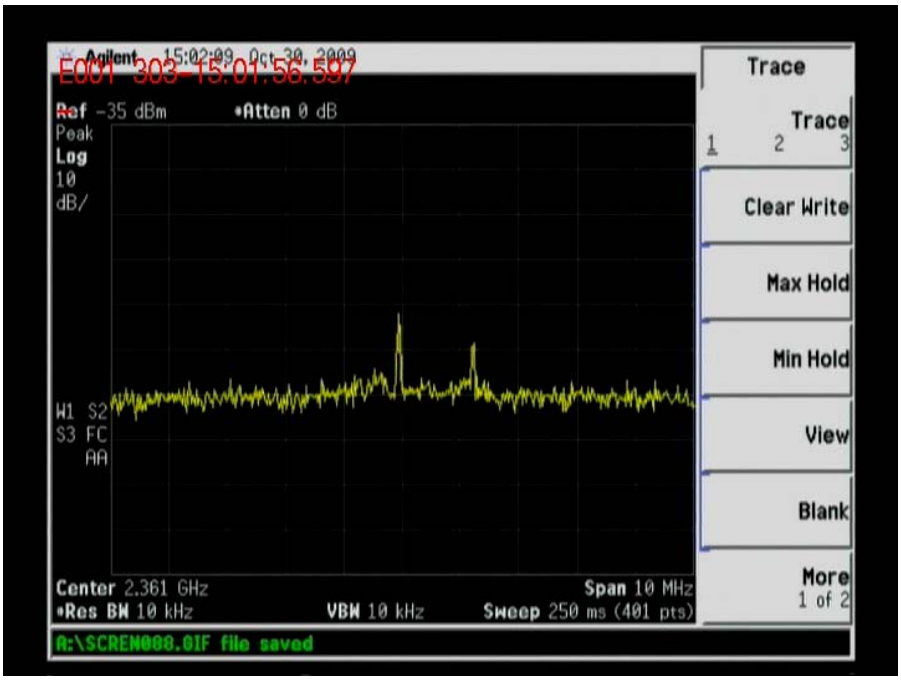


Figure 23. BSN signals dominating the remnants of the telemetry signal from the bottom aircraft antenna at 2361.5 MHz after the data link is lost.

Given that the telemetry signal from the top antenna remained operational, and that it was received by a different ground station antenna with its own antenna control unit, the question is whether the antenna control loop for the signal at 2361.5 MHz has been hijacked by the interfering signals.

This is the most plausible reason for the observed behavior. The interfering signals, with a cumulative bandwidth of 4 MHz, and with received power levels higher than that of the AMT signal, contribute to the composite signal used by the Antenna Control Unit to steer the AMT receive antenna.

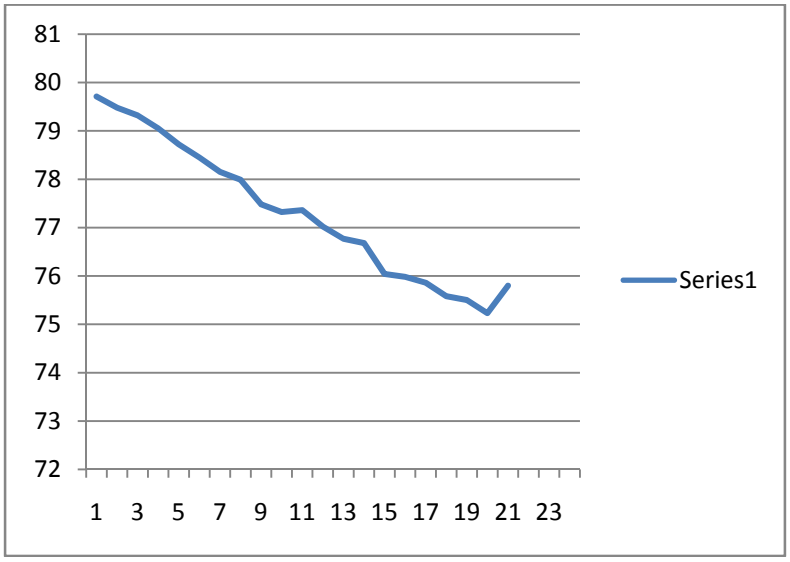
Figure 24 is a plot of the azimuth angle indicated by the Antenna Control Unit, at 5 second intervals, until just before the point at which the operator switched the system

into manual mode. In manual mode, the operator then steers the antenna in the direction where the aircraft is thought to be. Re-acquisition can be quite difficult to accomplish.

This preliminary analysis shows a slight increase in the antenna slew rate as the first BSN, at an azimuth angle of 77 degrees comes into view, and its signal begins to influence the antenna tracking loop.[19]

The signal at this azimuth angle is the BSN at the Hyatt. The other three BSNs, located at the Highland House, are at an azimuth angle of 74 degrees with respect to the AMT ground station.

Note that the link has completely failed while the antenna azimuth remains between 77 and 74 in the region where BSNs at both locations are in view. The graph extends to 15:02:00. Two seconds later, the antenna operator switched to manual control, and began the signal recovery process.



Vertical: AMT ground station antenna azimuth angle in degrees
Horizontal: time, in increments of 5 seconds.

Figure 24. Antenna slew angle as a function of time. The BSN at the Hyatt Hotel is located at 77 degrees, and the multiple BSNs at the Highland House are located at 74 degrees. The aircraft is flying slightly east of north at a heading of 347 degrees. It crosses behind the Hyatt, and then behind the Highland House. The half-power beamwidth of the AMT ground station antenna

[19] As stated earlier, static tests show that AMT ground stations can successfully autotrack signals from the BSNs.

is approximately 6 degrees, so that the BSNs from both locations are in view when antenna track is lost.

In summary, BSNs that are operating in line of sight to an AMT ground station will cause harmful interference, even if located indoors. The impact of such interference goes well beyond intermittent and brief dropouts.

Finally, the Commission should note that in addition to the four member aircrew, about a dozen test engineers staffed the ground station during the test. This number doesn't include the pre-flight support by aircraft maintenance engineers and Bombardier management.

Air Traffic Control services were provided by the staff at the three control towers involved, Midcontinent Airport, McConnell AFB, and Hawker-Beechcraft Airport, as well as by the Kansas City Air Route Traffic Control Center (ARTCC).

Much of the test flight was conducted under instrument conditions and with air traffic control restrictions at higher altitudes. During the return to Wichita, the aircraft encountered severe icing conditions.

Test Results – Interference to BSNs from Flight Test Aircraft

In the previous section, interference from BSNs to flight test aircraft was discussed. In this section, we address the opposite situation: Interference from flight test aircraft to BSN devices.

As described previously, two nRF24L01 devices were configured as a transmitter and a receiver, and an ASCII test message was broadcast continuously from one unit to the other. The devices were located in the Highland House. The devices operated at 2360.5 MHz. During this portion of the flight test, the nRF2401 device operating at the same frequency at the Highland House was turned off.

Interference from the flight test aircraft was measured, as evidenced by data errors, and then complete dropout, of the ASCII data. Example data obtained during the flyover of the Highland House are shown in Figure 25.

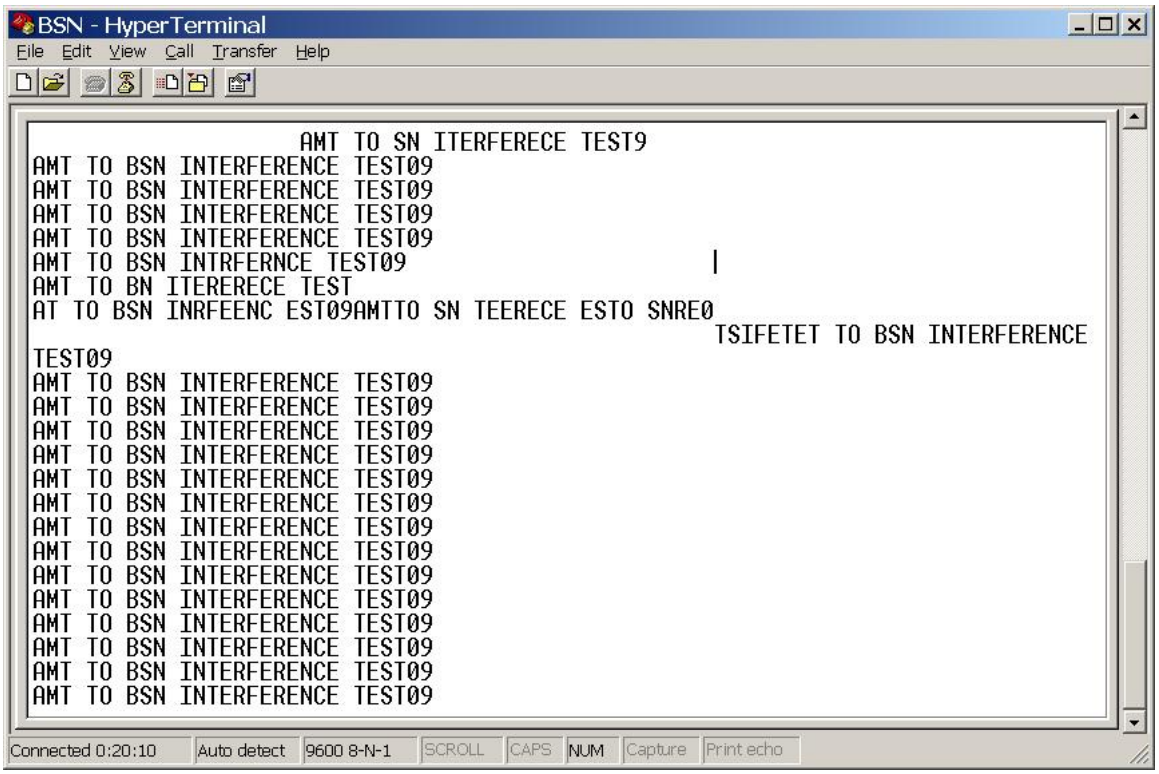


Figure 25. Screen capture of the ASCII data message being communicated wirelessly from one nRF24L01 to another at 2360.5 MHz in the Highland House. Interference is demonstrated by dropouts of letters, skipped spaces, incorrect letters and numbers, and freezing of the screen until the interference goes away.

At the beginning of the test, the aircraft flew directly away from the airport towards Kansas City, MO, on a path that took it in close proximity to the Hyatt (cf. Figure 12), to the Highland House. The aircraft was 2000 feet above ground level as it crossed the Wichita skyline, and climbed gradually to 30,000 beyond Kansas City.

There were sporadic dropouts in the nRF24L01 data link caused by the presence of wireless and cellphone antennas on the roof of the Highland House. Under similar operating conditions, but not near these sources, the dropouts were not present.

During the test flight, data errors and intermittent dropouts were seen when the aircraft was several miles (e.g., over a minute of flight time) away. It is noteworthy that this occurred even during the inbound flight, when the aircraft was east of the building, and hence not within direct line of sight; the interfering signal was sufficiently large to pass through the roof of the building.

For periods of 1 to 2 minutes during the three flyovers that were conducted, the data link was completely shut down. The aircraft was flying at approximately 200 knots

in a climb (from) or descent (to) the airport for two of the tests, and in straight and level flight for the third. In each case, the aircraft crossed the building at an altitude of 2000 feet above ground level.

Thus, at slant ranges of approximately 5 statute miles, BSN transmissions were shut down for devices operating indoors. This again underscores that notion that being indoors provides little protection for BSNs.

For outdoor operation, the BSN's would be shut down at distances that are twice as large --10 miles and more. A flight test aircraft at an altitude of 30,000 feet (~6 statute miles) can thus cause interference to BSNs in this situation.

In other words, an aircraft operating from Wichita could jam BSNs operating in Kansas City. In this case, a BSN switching to another frequency would not interfere with the AMT ground station 200 miles away.

However, this is completely consistent with the statement, made repeatedly, that while the operation of BSNs over the radio horizon from an AMT ground station may be immaterial to the problem of interference from BSNs to AMT, it is not immaterial to the problem of interference <u>from</u> AMT <u>to</u> BSNs. This is an issue that requires further, careful consideration, with a better understanding of what specific protocols MBANs might actually implement.

V. Final comments

Philips has expressed the need for a high power (e.g., 20 mW) option for the backhaul of data from a patient hub to a building-located base station. However, the use of 802.11 protocols in the existing 2.4 GHz band is ideal for this application, both in hospitals and in residential locations. It is straightforward to set up additional, proprietary networks within this band that would be restricted to MBANs devices identified to the network by their MAC address or through use of the Wireless Encryption Protocol (WEP).

AFTRCC's concern is that the use of the band 2390 – 2400 for medium power backhaul purposes devices would introduce out-of-band emissions into the AMT frequencies just below 2390 MHz.

Finally, hospital administrators have essentially complete control over the use of ISM spectrum within their facilities. Before the Commission draws the conclusion that the 2.4 GHz band is not usable by BSNs, it should investigate the extent to which hospital Information Technology (IT) staff can apply discipline to, and impose efficiency on, the use of this spectrum.

VI. Conclusions

In the preceding discussion, we have established the following technical conclusions:

- There is no apparent reason why Nordic devices cannot be made to work economically at 2300 MHz.
- Devices that operate in the 5 GHz ISM band do not necessarily require four times as much battery power as S band devices, and their potential use for MBANs should be further investigated.
- The use of the extended HATA model and the SEAMCAT software for modeling interference to AMT networks is flawed.
- Flight test measurements demonstrate that interference to AMT ground stations will occur at distances that are considerably larger -- to line of sight -- than those proposed by GEH and Philips for exclusion zones.
- The purpose of real-time telemetry afforded via the S-band is so that engineers on the ground can be alerted to a problem. A "glitch" in the data that indicates a problem can easily be misinterpreted as a mere telemetry dropout.
- Likewise, a loss of telemetry due to interference can be misinterpreted as an in-flight emergency.
- Interference from flight test aircraft to MBANs networks will occur at slant ranges of ~5 or more statute miles.
- Contention-based protocols, listen-before-talk protocols, and other cognitive radio techniques do not work for resolving interference to passive receive stations, such as AMT ground stations, that use high gain antennas and low-noise amplifiers to detect weak signals.

Operation of a flight test aircraft costs tens, and even hundreds, of thousands of dollars per flight, not including the cost of preparation, which can involve tens to hundreds of people spending 10 – 40 hours each.

The Boeing 787 Dreamliner will be the first aircraft to have an all-composite fuselage, which will be a leap forward in aircraft technology, and which will lower the operating cost of aircraft in a manner that will benefit all air travelers, in the United States and throughout the world. The 787 will use S-band spectrum.

Likewise, the Bombardier CRJ-1000, the significantly larger follow-on to the CRJ-700 used in the flight test described above, will enter commercial service in December 2009. Like the CRJ-700, it has been tested using the 2360 MHz to 2390 MHz AMT spectrum allocation.

On the military side, the Engineering and Manufacturing Development (EMD) program for the F/A-18 E/F Superhornet involved the flight testing of 7 aircraft by a joint

government/industry team at the Naval Air Warfare Center at Patuxent River, Maryland. The EMD program cost about $7 billion, or $1 billion per aircraft.

The Superhornet program has produced what is perhaps the most successful fighter aircraft, and attack aircraft, of all time. Sales of this aircraft to other nations, and its use in defending the United States, bear this out. A follow-on aircraft, the EA-18 G, also called the "Growler", is currently in development to replace the venerable EA-6B "Prowler". Electronic warfare aircraft are used to support essentially all air combat missions by the United States. All of the F/A-18 E/F/G flight tests have been conducted using S-band spectrum.

In short, the S-band is a vital resource for the aerospace industry. Resolution of this proceeding mandates appreciation of this fact.

We have read and are familiar with the attached Reply Comments. The statements made therein are true and correct to the best of our knowledge and belief.

Daniel G. Jablonski
Johns Hopkins University
Applied Physics Laboratory

Don Hoehn
Bombardier

Danny B. Hankins
Cessna

November 4, 2009

Exhibit B

SAT CORPORATION

S-Band Noise Floor Study

A Noise Floor Measurement Study in Sunnyvale, California
Frequency Range 2360-2390 MHz

FINAL REPORT

SAT CORPORATION

"An Integral Systems Company"

INTEGRAL SYSTEMS

SAT PROJECT #46336

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1 Introduction

1.1 Summary

This report documents measurements of the noise floor in the 2360-2390 MHz band. The band 2360-2390 MHz is a restricted band allocated exclusively for Aeronautical Mobile Telemetry (AMT). 2390-2395 MHz is also allocated for amateur use. The measurements were taken at SAT Corporation facilities located at 931 Benecia Ave, Sunnyvale, California, in early October, 2009.

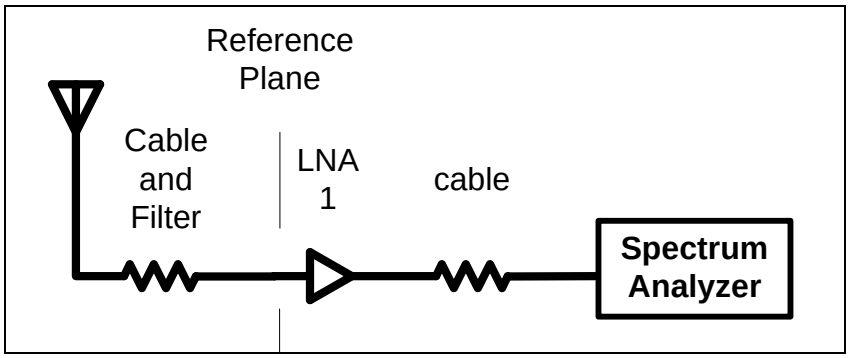
The noise floor was measured to be below -173 dBm/Hz across the band of interest. This extremely low level of extraneous noise is remarkable, particularly given the location of the test in the congested San Francisco – Palo Alto corridor. This is characteristic of the out-of-band and spurious emission levels in bands used for radio astronomy research.

1.2 Measurement Goals

SAT performed these measurements under contract to Aerospace and Flight Test Radio Coordinating Council (AFTRCC). The goal was to measure extraneous noise, with incidental information to be collected about any coherent signals detected. The site was selected as a typical populated area including civilian and military airports, satellite uplink signals and light industry.

2 Measurement Equipment Description

The measurement equipment consisted of a vertically polarized Omni antenna, pre-selector filter, LNA, short shielded cables, spectrum analyzer and a PC performing automated spectrum analyzer control and data logging. The monitoring equipment configuration is shown below.



2.1 Noise Floor Measuring Equipment List

- Antenna
  - JEM omni antenna, 2-18 GHz, gain at 2360 MHz very close to zero dBi. Model 901-0022-001.
- Spectrum Analyzer
  - Agilent E4440A, 9 Hz – 26.5 GHz
- Filter
  - Micro-tronics BPC10159, pass band 1435 – 2400 MHz, 0.5 dB insertion loss, SN-028
- Low Noise Amplifier (LNA)
  - Miteq, AMF-3F-014024-04-10P-GF, 1.4 – 2.4 GHz, 35-40 dB gain, Gain Flatness 0.5 dB max, 0.4 dB Noise Figure, SN 986783 (LNA #1).
- System Controller Hardware, Software & Data Logger
  - Dell Laptop, XP Pro OS
  - SigMon 4000 software by SAT Corporation, with integrated Microsoft SQL Server running on Windows XP Pro

To optimize the measurements by using the shortest practical cables, the antenna was mounted on a tripod on the roof of the building and all the equipment was simply laid out on the roof as shown at right. The antenna is elevated above other structures on the roof and has a clear view of the horizon on all sides with the exception of a few trees.

2.2 Antenna Description

The Omni antenna has roughly 0 dBi gain at 2360 MHz. The gain patterns at 2 GHz are shown in the diagrams below. The gain at 4 GHz is roughly the same near and just above the horizon but lower at higher elevations.

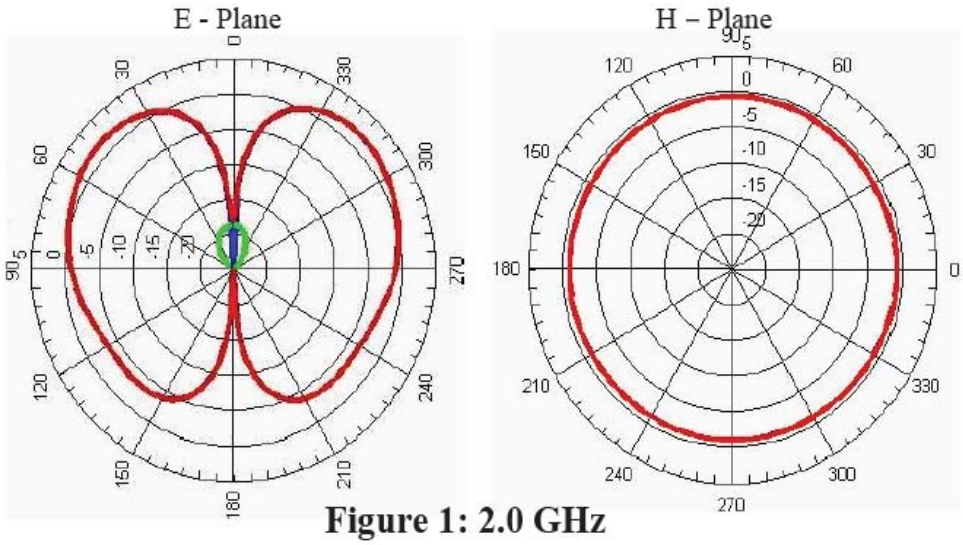


Figure 1: 2.0 GHz

Top and side views of antenna:

Dimensions:	4 cm H x 15 cm diameter (1.3 x 6 inches)
Weight:	100 g (3.5 oz. without magnetic mount)

It should be noted that the measurement data will be presented without compensation for antenna gain to avoid a bias on measurements of the natural noise floor which can be introduced by the gain compensation process. This is consistent with other well-regarded noise floor studies such as the NASA UWB & Noise Floor Study of 2004, section 2.2.1.

> *"The directional horn antennas amplify the man-made signals from sources near the horizon when they come under the main lobe of the antenna gain pattern. However, the*

natural noise will not be amplified if the noise background has a uniform noise temperature, and thus the measurement results by a directional antenna and ones by an omni-directional antenna are same in this case."

This report will follow the methodology used by NASA for calculating the noise floor, i.e., no antenna gain will be used in the noise floor calculations.

3 Equipment Gain and Noise Floor Measurements

3.1 Calibration

The gain/loss of the RF path components was measured with CW signals from a signal generator, an Agilent calibrated power meter and manually calibrated pads.

3.2 Filter & LNA

These components were measured in two pieces: Losses prior to the LNA, and LNA onward to the spectrum analyzer. The component measurements are indicated in the table below.

	Freq (MHz)				
	2360	2370	2380	2390	Avg
Ant cable + filter loss	1.70	1.70	1.72	1.75	1.72
LNA + cable to SA	34.22	34.26	34.28	34.29	34.26
Full Path gain	32.52	32.56	32.56	32.54	32.55

Tests on this amplifier showed linear operation (no drop in gain) when input power to the assembly was less than -20 dBm.

3.3 System Noise Floor

A commonly accepted method for measuring the Noise Figure of a high gain system is explained in the following manner:

There are two primary sources of noise in the measuring system. The first is the noise power associated with all matter that cannot be filtered out. It is represented by the term kTB where:

k = Boltzmann's Constant (1.38×10^{-23} Joules/°K)

T = Temperature in Kelvin (293°K is standard)

B = Bandwidth in Hz (1 Hz for our spectrum analyzer measurements)

$kTB = (1.38 \times 10^{-23}\ \text{Joules/°K})(293\text{°K})(1\ \text{Hz}) = 4.0434 \times 10^{-21}\ \text{Joules}\cdot\text{Hz}$

Converting this value to dBm/Hz is done as follows:

$10\log_{10}(4.0434 \times 10^{-21}) = -203.9\ \text{dBW/Hz} = -173.9\ \text{dBm/Hz}$

The value most commonly used by RF designers is -174 dBm/Hz.

The second noise source is the system Noise Figure (NF_{SYS}) measured in dB.

NF_{SYS} can be derived by measuring the thermal noise power at the output of the measuring system while the input is terminated.

The system Noise Figure can then be calculated using the following equation:

NF_{SYS} = Output Power – Total System Gain – Thermal Noise Power

$= P_{SA} - (G_{LNA} - L_{SYS}) - kTB$

Where:

NF_{SYS} = Noise Figure of all system components from 50 ohm load to analyzer

P_{SA} = Power measured by the spectrum analyzer

G_{LNA} = Gain of the Filter & LNA assembly

L_{SYS} = Total losses of the shielded cables and jumper assembly

kTB = -174 dBm/Hz

The Noise Floor of the spectrum analyzer was verified to be slightly less than the -153 dBm/Hz as is typical of this model. This was measured at zero span at 2375 MHz with a 1 Hz RBW and 1Hz VBW, average detector type, averaged over 10 sweeps. No internal pre-amp was installed or used in the SA. However, the LNA assembly lowers this system noise floor, and is described below.

Using a signal generator through manually calibrated pads, a CW signal of -162.35 dBm was injected into the cable + filter + LNA + cable assembly. Using a span of 100 Hz, RBW and VBW of 1 Hz and average detector type, the displayed noise floor was -140.68 dBm/Hz and the CW signal was measured at -126.89 dBm for an SNR of 13.79

dBm. Therefore, confidence was established that noise "signals" from the antenna stronger than -170 dBm/Hz would be detected and measured. This was verified later when ambient signals less than -172 dBm were shown to disappear into the noise floor when the antenna was disconnected, and reappeared when the antenna was connected.

Also, the thermal noise floor of -174 dBm/Hz amplified by 34 dB would be roughly -140 dBm/Hz at the SA, which is near the displayed value.

4 Measurement Site

4.1 Location

The roof of the SAT Corporation building was used for this study and was selected to represent a typical populated area with military and civilian airports nearby as well as military satellite uplink facilities and light industry. The building is one story with the roof roughly 30 feet in elevation. The address is:

SAT Corporation
931 Benecia Ave
Sunnyvale, CA 94085

37.394833N, 122.037848W

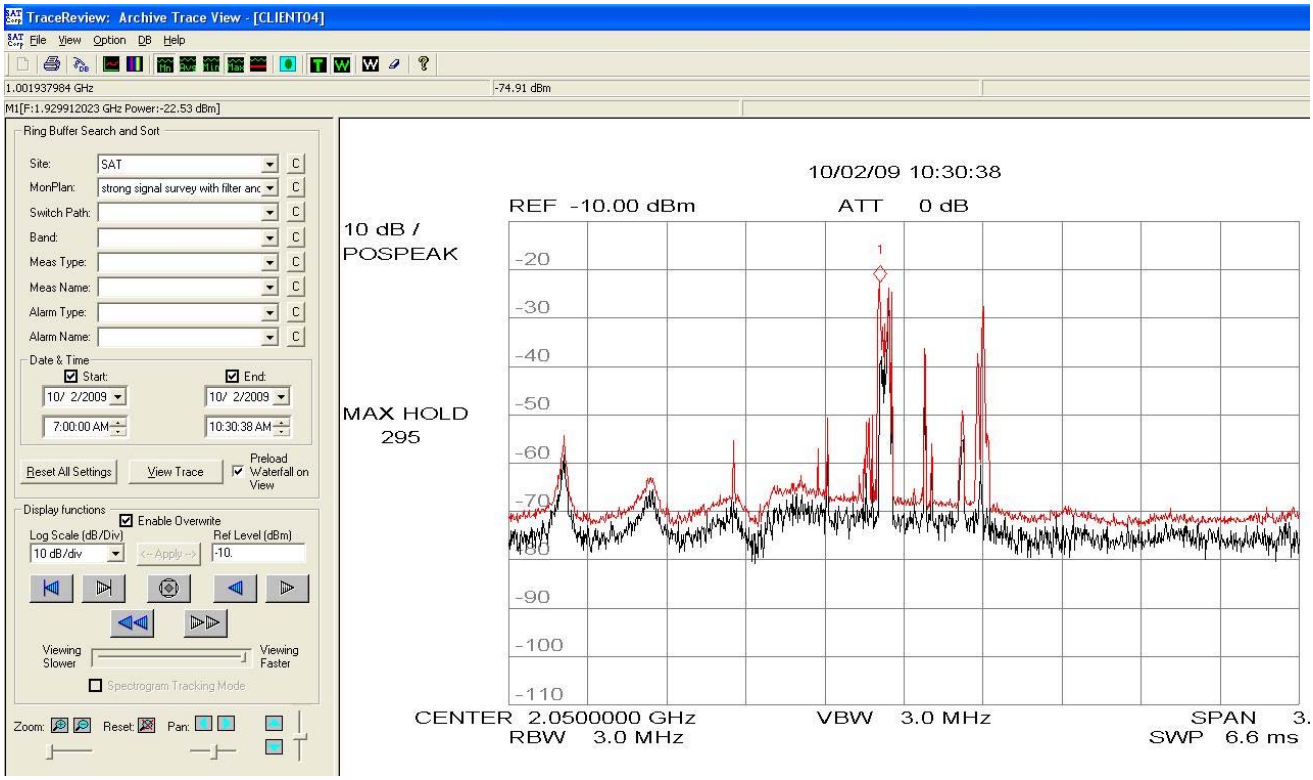
The antenna was mounted on a 4 foot tripod, above obstructions on the roof.

4.2 Strong Signal Survey

With the pre-selector filter and LNA in place, a strong signal survey was conducted. The strongest signal was measured at -22.53 dBm (Marker 1 in red) into the spectrum analyzer as shown by the marker in the max hold trace below. This is approximately 30 dB below the 1 dB compression point of the LNA, therefore the LNA is operating well within its linear region and spurious signals generated within the LNA are not expected to be measureable.

Unlike the rest of the of the trace displays in this document, these traces were recorded without the 32 dB correction for the LNA gain, and so reflect the measurement at the spectrum analyzer input.

The span is 3.9 GHz. Maximum span sweeps displayed no other significant signals getting through the filter to the LNA.



5 Measurement Band Considerations

5.1 Monitoring Plan

A SigMon Monitoring Plan was set up dividing the 30 MHz span of interest into 1 MHz Bands. The spectrum analyzer was set to 4096 points per sweep and Resolution Bandwidth to 1 Hz. The shape of the RBW filter is not a perfect square, so more than just 1 Hz of bandwidth around each point is sampled. These settings result in a pseudo-random sampling of the noise floor every 244 Hz. While it is possible to miss some CW signals, this technique of sampling 123k frequencies provides a statistically accurate measurement of the background noise, and will catch almost any information-carrying signal.

The Video Bandwidth (VBW) was set to 1 Hz making it easier to directly measure the noise at any particular frequency. The detector type was set to Average, since the goal was to measure random noise instead of hunt for brief signals with low SNR. This resulted in each 1 MHz sweep requiring a little over 7 minutes each.

For reporting purposes, the bandwidth was arbitrarily divided into 200 kHz channels. The received power within each channel was totaled and reported in units of dBm/Hz. For those bands that were sampled more than once, the min, max and average power was computed. This technique provides statistically accurate noise measurements for

those channels that do not have signals in them. Channels containing artificial signals report higher power and are discarded from the noise floor calculation. Channel power measurements were recorded in the SigMon database and were later extracted into a spreadsheet for reporting and graphing.

All spectrum traces were recorded, and are available for additional manual measurements. Users may "zoom" into recorded traces to see additional detail of the 4096 point traces, as seen in the displays below.

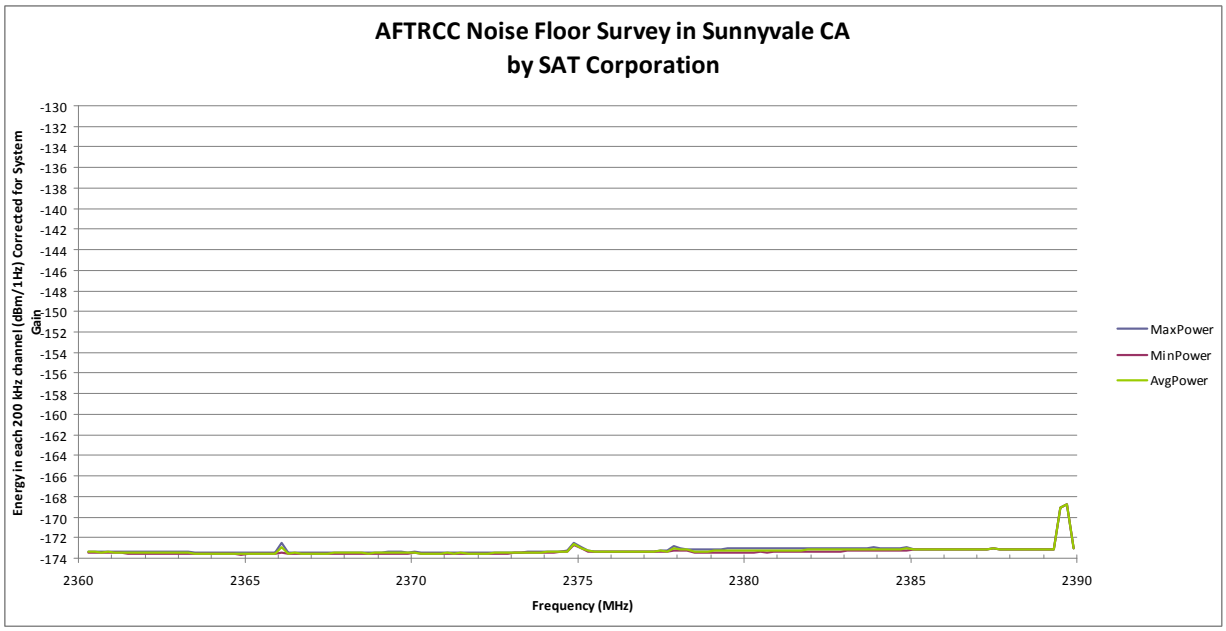
5.2 Gain Adjustment

The Full Path Gain of 32.55 dBm was entered into SigMon software so the spectrum traces are adjusted to display the power levels received from the antenna, not the level measured at the spectrum analyzer.

6 Spectrum Measurements

6.1 Power vs Frequency

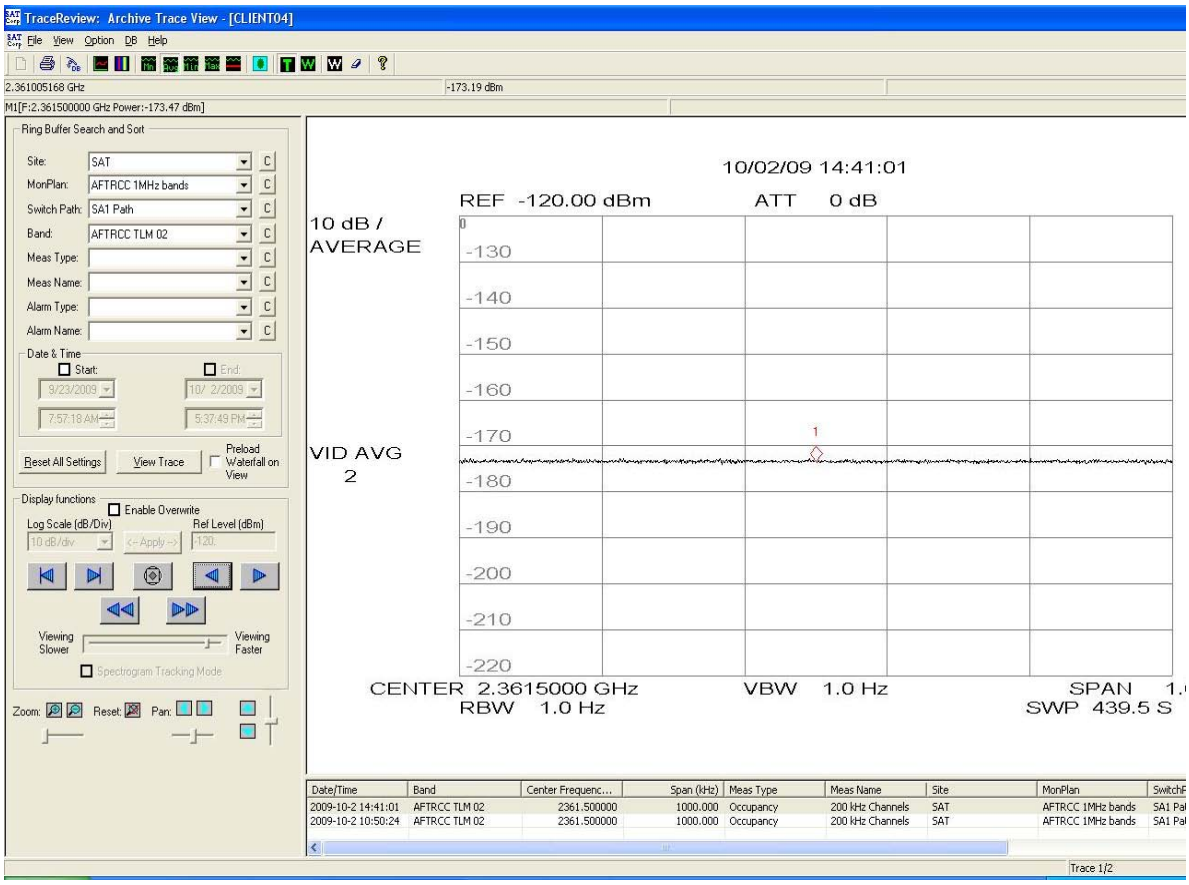
The following chart shows the minimum, average and maximum power measured within the 200 kHz wide channels. To measure noise floor, those few channels that contain measureable signals should be ignored. Thus the measured noise floor across the band is -173 dBm/Hz or less.



Some of the slight variation in noise floor across the bandwidth may be due to variations in either the incoming noise signal, or variations in the noise floor of the amplifier, since the LNA was not controlled for temperature variations during the day-long measurement

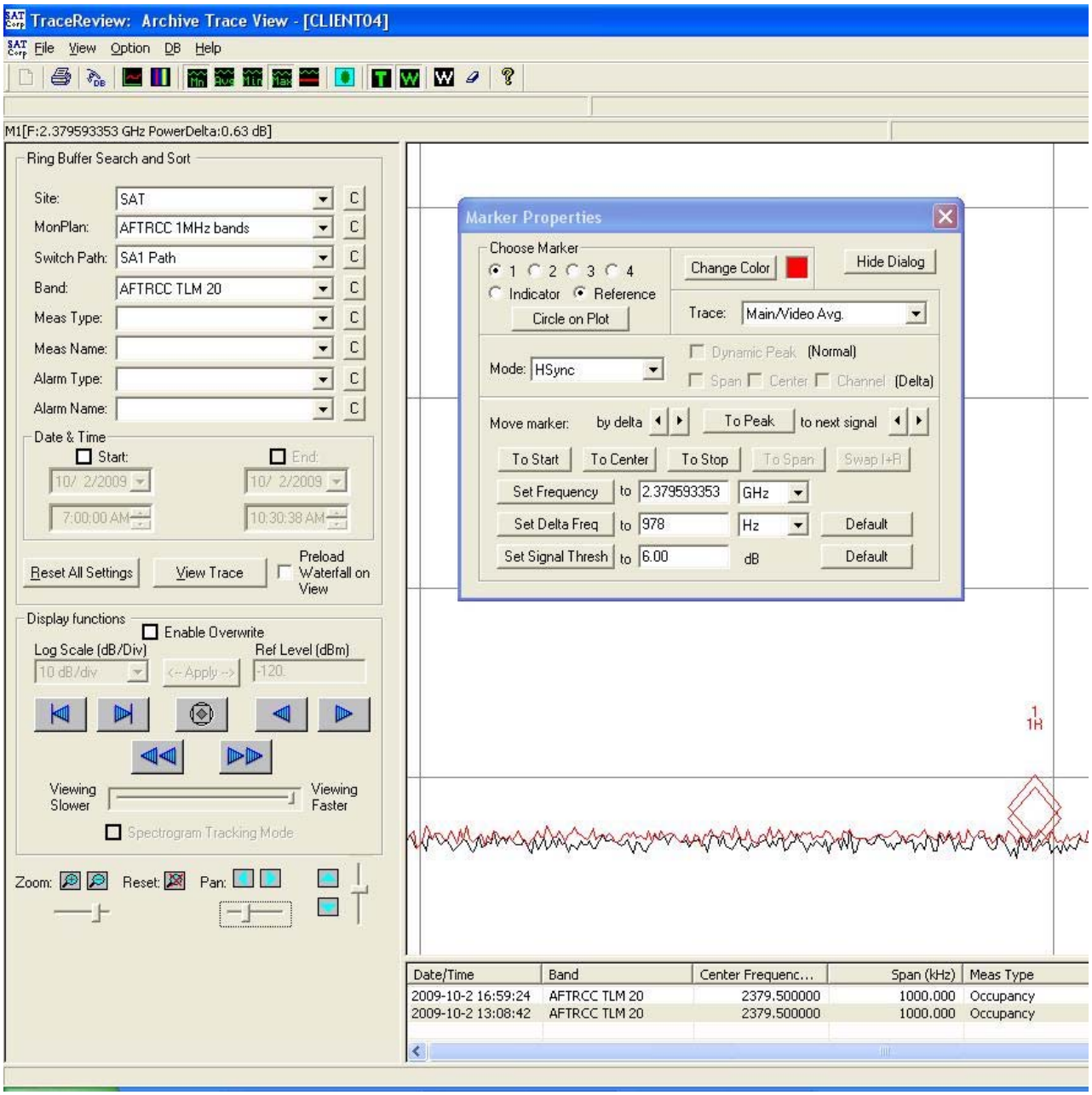
period. An indication of this variability is near 2380 MHz where the min and max have some visible separation between sweeps over 4 hours apart.

A complete spectrum trace of a typical quiet channel is shown below for reference.



Note at the bottom of the display that 2 sweeps were taken 4 hours apart and the average of these two traces is displayed. The span is 1 MHz.

The following display shows two traces (red and black) recorded 4 hours apart, in a typical non-signal portion of the band, showing how consistent the measurements are over time. The marker shows the small power difference (0.63 dB) between the traces at the same frequency.

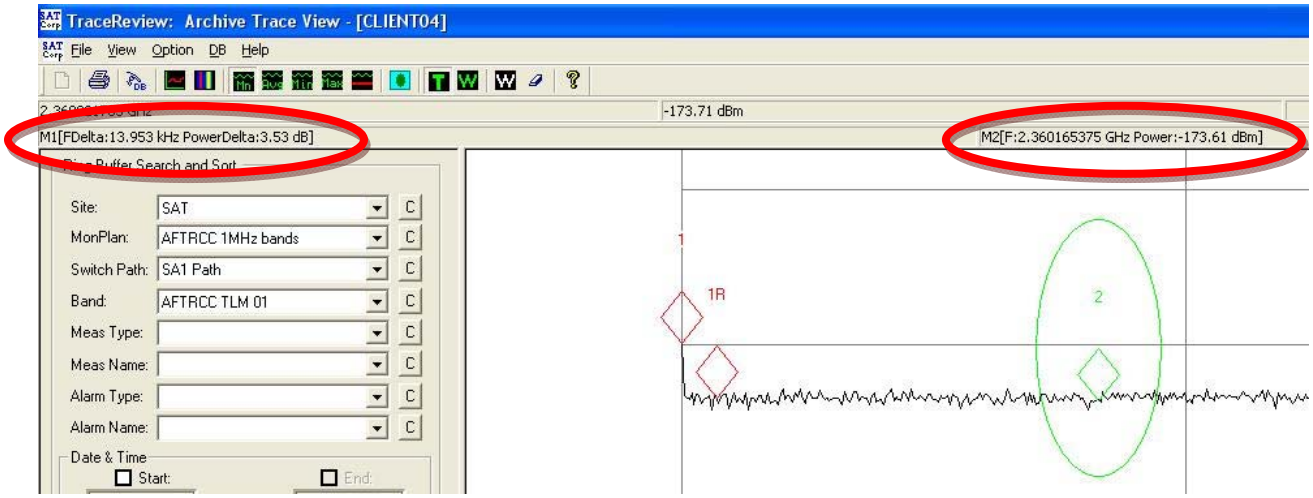


6.2 Signals Detected

A few signals were detected, but determining their origin was beyond the scope of the study. However, the signals were so few and so weak as to have no material effect on the noise floor, which remains so low as to resemble the noise floor in bands reserved for radio astronomy. Details of each detected signal are shown below.

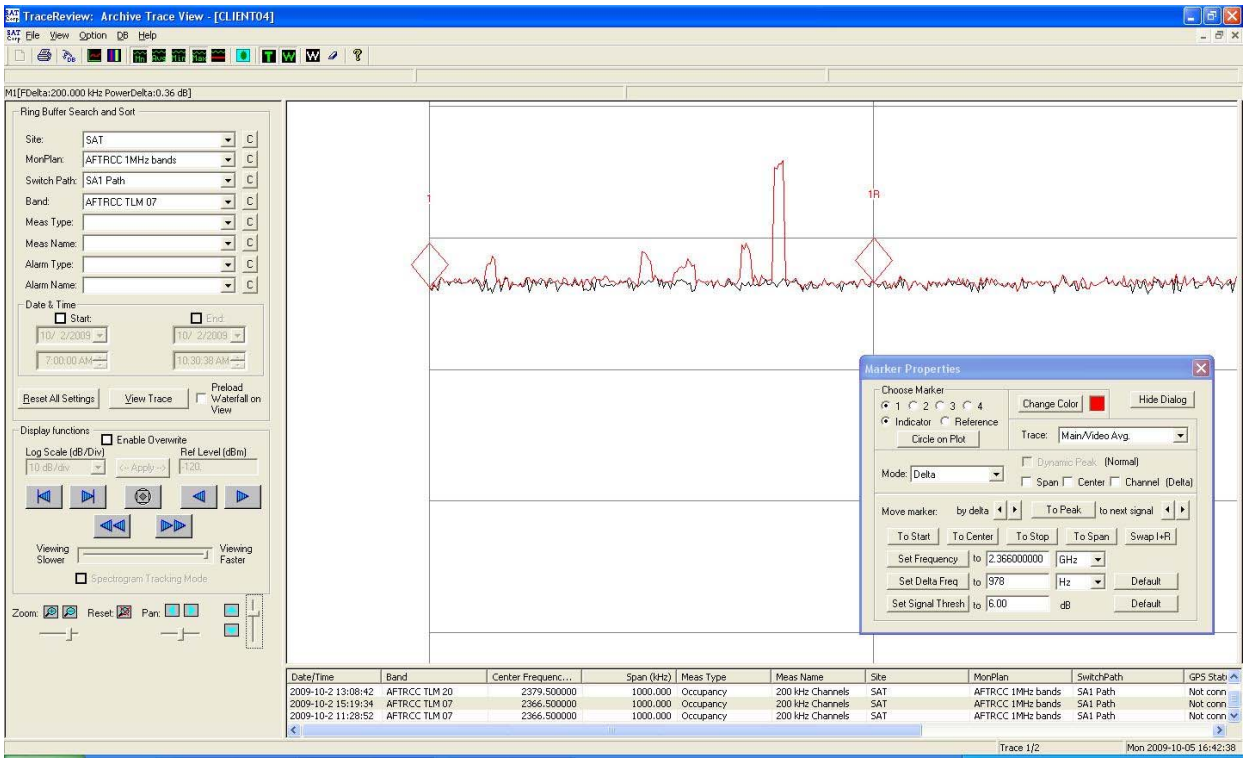
6.2.1 CW at 2360 MHz

A small un-modulated (Continuous Wave or CW) signal was present constantly at 2360.000 MHz (Marker 1 with an SNR of 3.53 dB) but had no material effect on the noise floor measurement. The noise at other frequencies is shown by Marker 2 in green at -173.61 dBm. The SigMon Marker information is shown circled in red in the picture below. The power scale is 10dB/division.



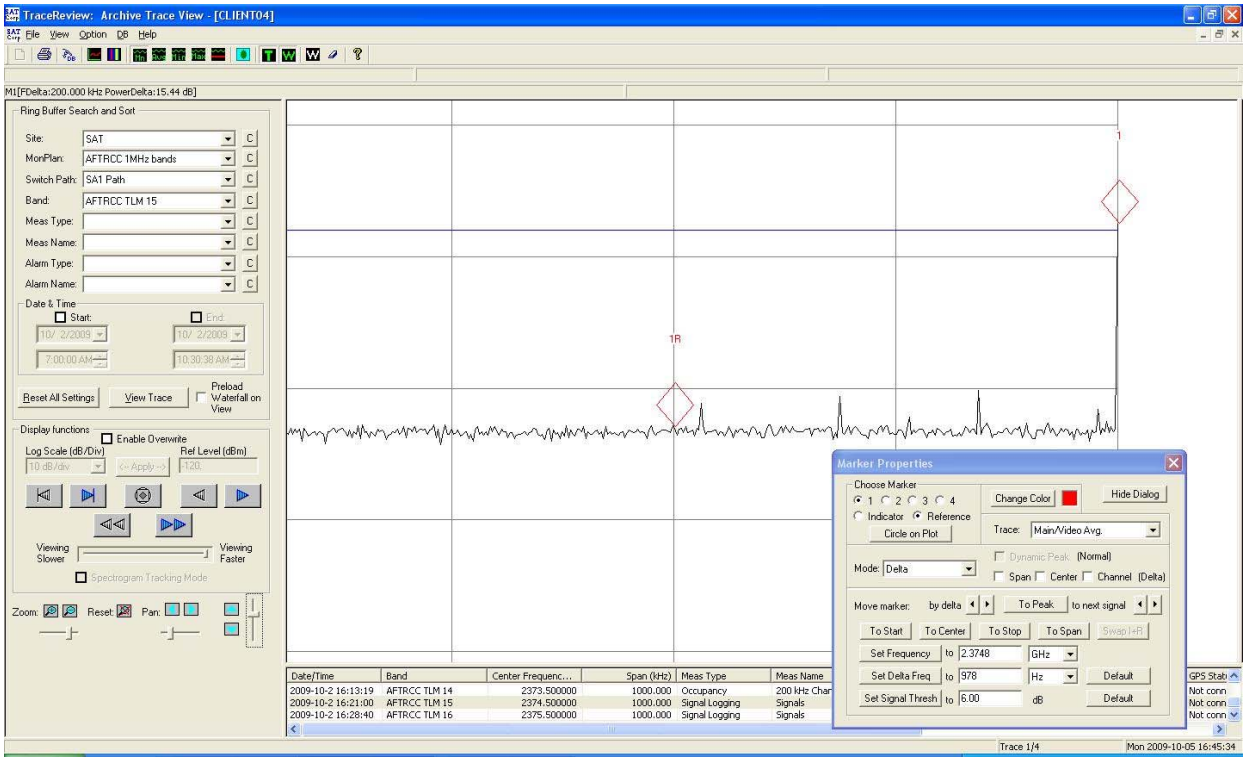
6.2.2 Transient Signal at 2366.1 MHz

The following signal was detected in one trace but not the other 4 hours apart. Portions of the signal span nearly 200 kHz. Given the slow sweep rate and low SNR, it is likely that only a portion of this transient signal was captured. The power scale is 10dB/division and the noise floor is approximately -173 dBm/Hz, consistent with the other bands measured.



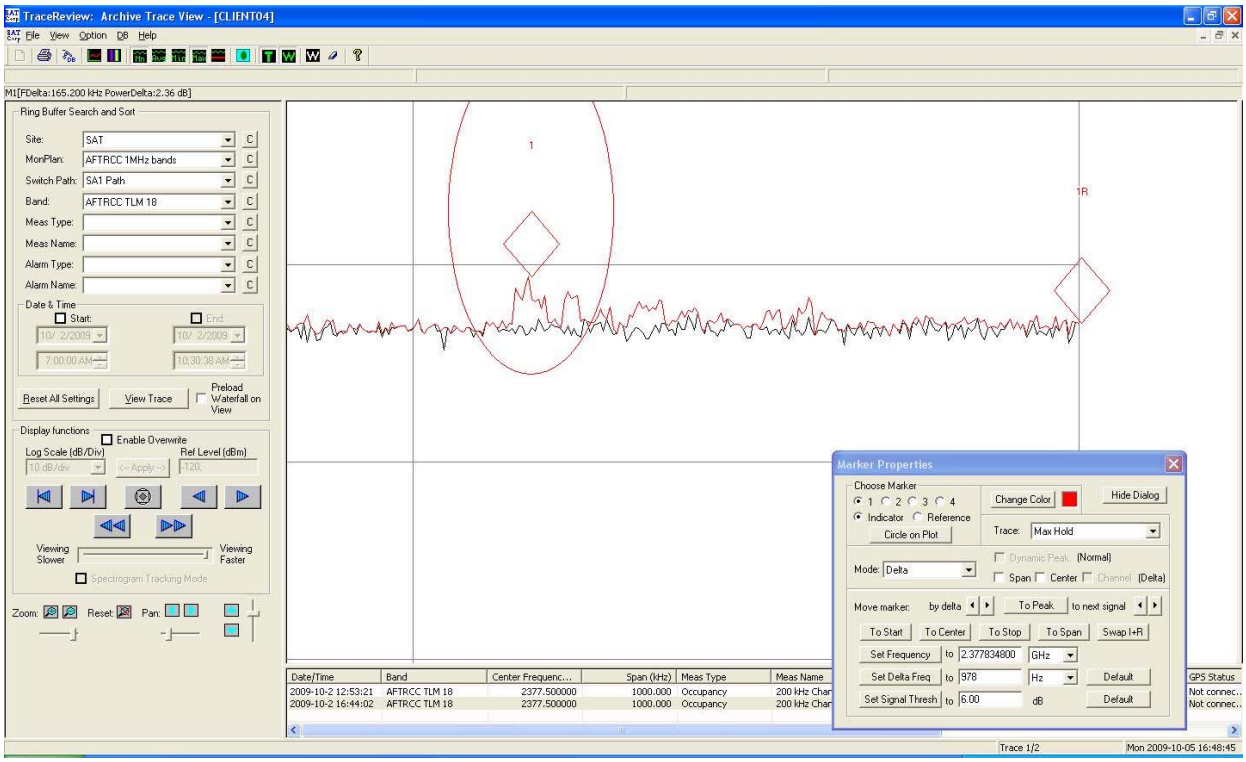
6.2.3 CW at 2375 MHz

This signal was present throughout the test and is visible in this trace as a spike on the far right of the trace. The regularly spaced spurs were observed above and below the signal and are likely products of another oscillator or data rate with the primary signal. It was found to drift somewhat in frequency and so may be an accidental spur emitted from a nearby receiver. The power scale is 10dB/division and the noise floor is approximately -173 dBm/Hz, consistent with the other bands measured.



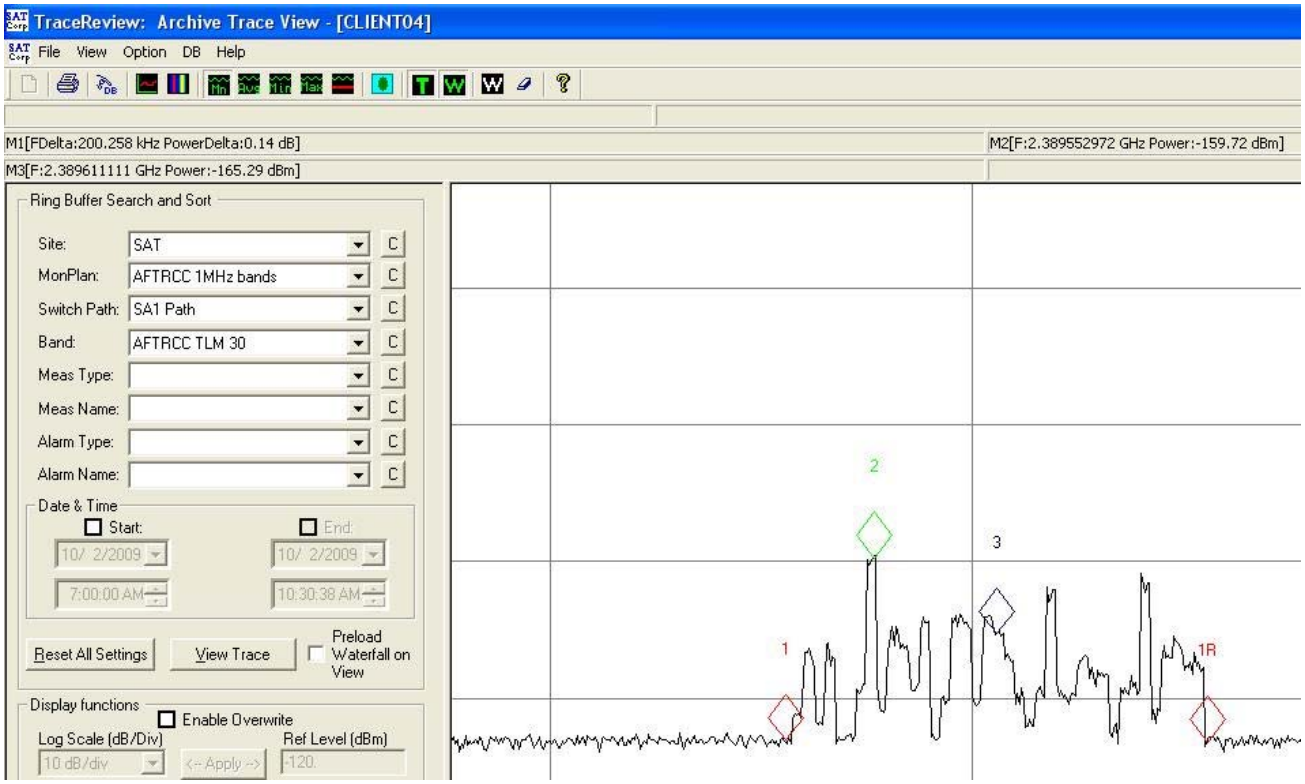
6.2.4 Transient at 2377.8 MHz

The following signal was detected on one trace but not on another trace spaced 4 hours apart. The SNR is so low that little information about the signal is available beyond an indication that it occupies more bandwidth than a CW signal. The power scale is 10dB/division and the noise floor is approximately -173 dBm/Hz, consistent with the other bands measured.



6.2.5 Transmission at 2389 MHz

The following signal was the most significant signal detected, but the peak power was only -159 dBm as shown by Marker 2. The occupied bandwidth was 200 kHz as shown by Marker 1 and Reference. The center frequency is 2389.611 MHz as shown by Marker 3. Additional study of this signal and efforts to locate the source using Direction-Finding techniques might identify the source. The power scale is 10dB/division and the noise floor is approximately -173 dBm/Hz, consistent with the other bands measured.



7 Conclusions

Careful measurements showed the noise floor is less than -173 dBm/Hz across the band of 2360 – 2390 MHz in a typical populated location in Sunnyvale CA. This is very near the theoretical thermal noise floor of the room temperature equipment used. A few low-level signals were detected, with one spanning 200 kHz of bandwidth which may warrant additional study and emitter location.

8 Declaration

8.1 Signed Statement

This report is true and correct to the best of my knowledge and belief.

Mark Rasor 10/30/2009

Mark A. Rasor

SAT Corporation

Exhibit C

Licensed AMT Frequencies Per FCC ULS Search of June 5, 2008

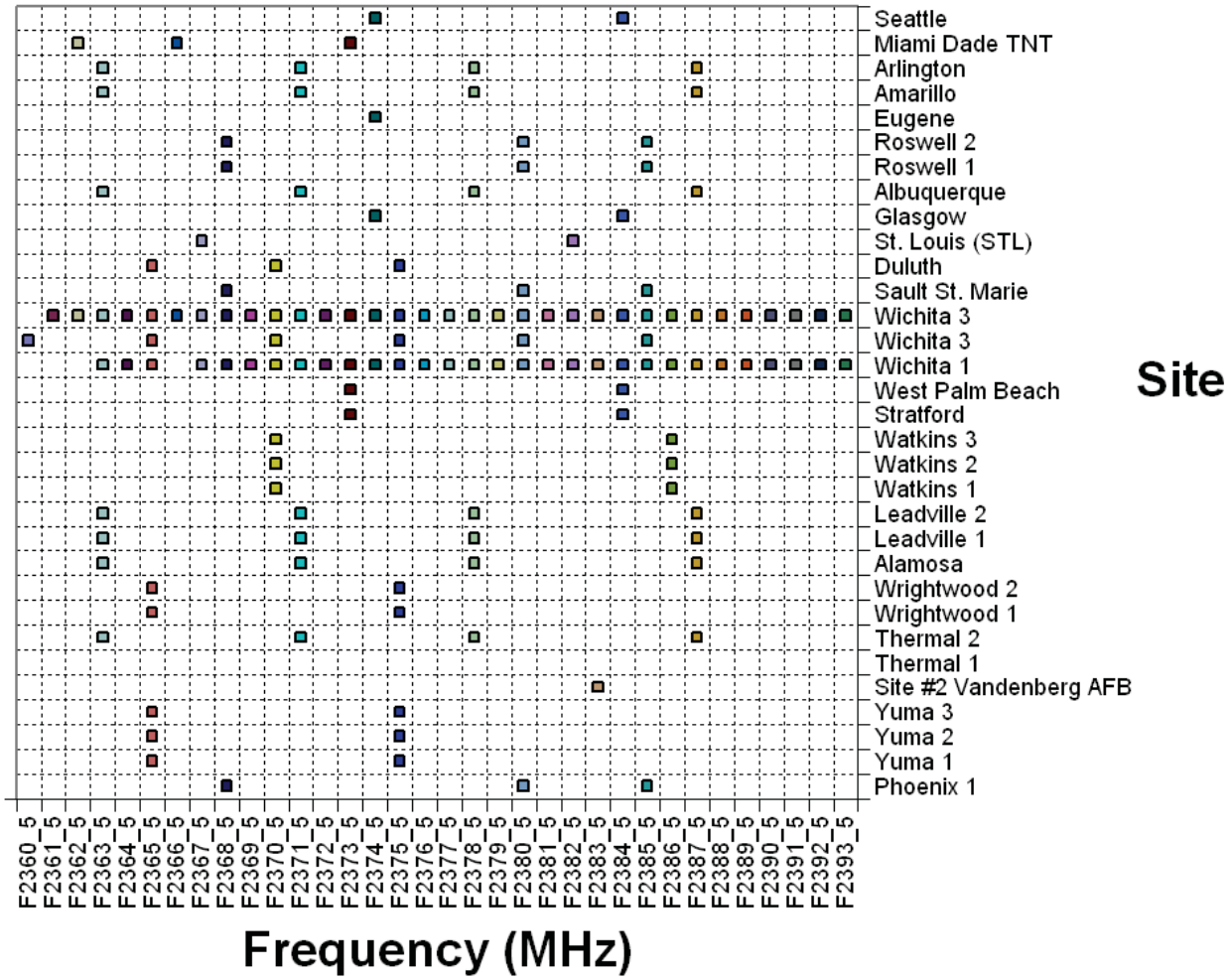
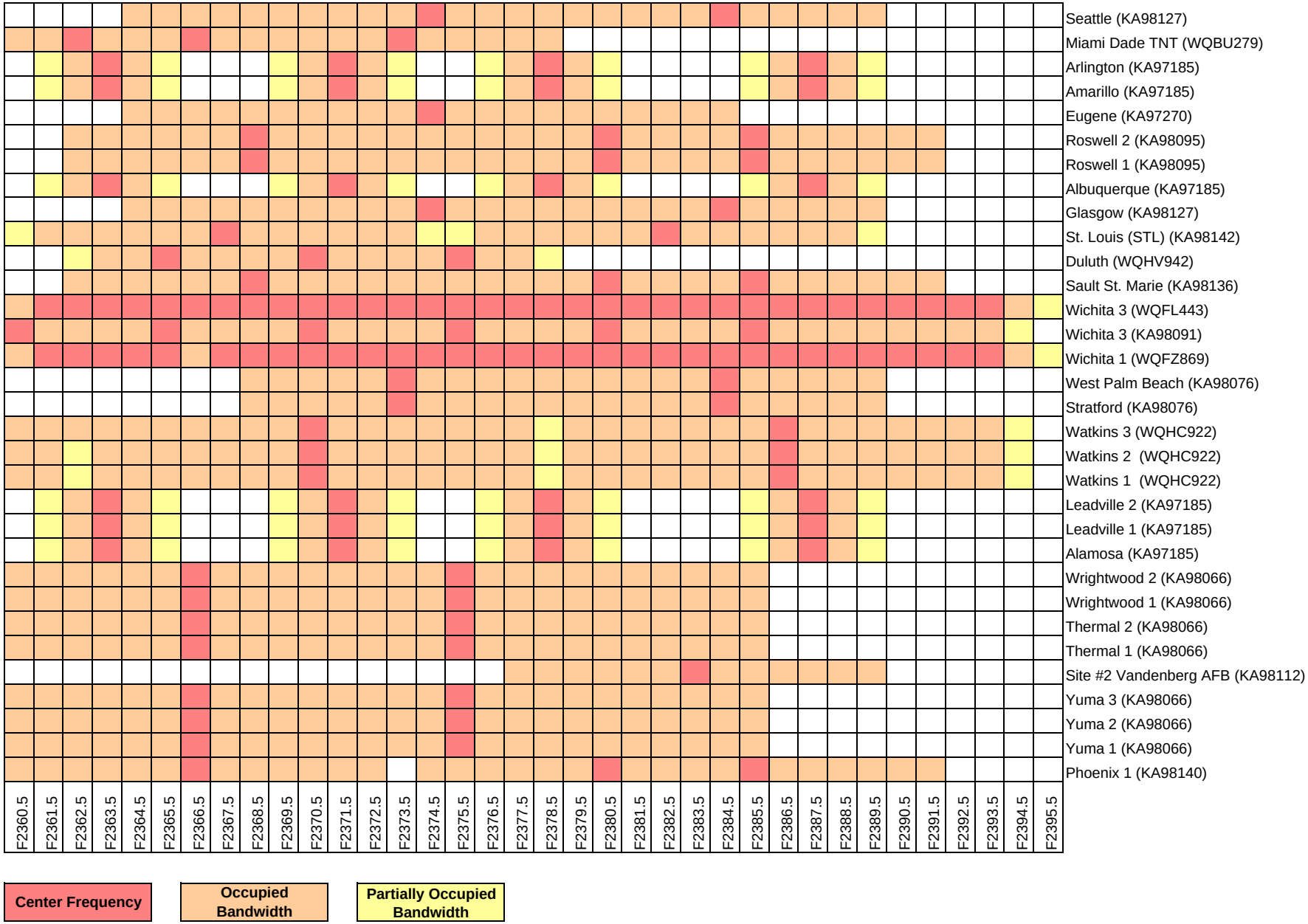


Figure 3



Center Frequency | **Occupied Bandwidth** | **Partially Occupied Bandwidth**