DATE: August 13, 2007

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SUBJECT: Peer Review of a Report Relied Upon in the draft *Second Report and Order* (WT Docket No. 04-344)

On August 3, 2007, the Wireless Telecommunications Bureau (WTB) requested that the Office of Engineering and Technology convene a review panel to conduct a peer review of an ITU-R, Working Party 8B, Draft New Report: "*Satellite Detection of Automatic Identification System Messages*", produced by the Department of Defense Joint Spectrum Center (JSC) and relied upon in the subject draft Order in Docket No. 04-344. The review panel welcomes the opportunity to perform a peer review of the JSC Report relied upon by WTB. Our review is below:

On July 20, 2006, the Commission adopted a *Report and Order and Further Notice of Proposed Rule Making and Fourth Memorandum Opinion and Order* in WT Docket No. 04-344.[1] In the *Further Notice*, the Commission requested comment, *inter alia*, on whether VHF maritime Channel 87B (161.975 MHz) should be designated exclusively for Automatic Identification Systems (AIS)[2] in inland VHF Public Coast (VPC) service areas (VPCSAs).[3] The Commission noted that the National Telecommunications and Information Administration (NTIA) had argued that Channel 87B should be designated for exclusive AIS use in the inland VPCSAs in order to accommodate satellite AIS operations.[4] The Commission further noted, however, that the subject

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[1] *See* Amendment of the Commission's Rules Regarding Maritime Automatic Identification Systems, *Report and Order and Further Notice of Proposed Rule Making and Fourth Memorandum Opinion and Order*, WT Docket No. 04-344 & PR Docket No. 92-257, 21 FCC Rcd 8892 (2006) (*Report and Order*, *Further Notice*, and *Fourth MO&O*).

[2] AIS is a "maritime navigation safety communications system standardized by the International Telecommunication Union (ITU) and adopted by the International Maritime Organization (IMO) that provides vessel information, including the vessel's identity, type, position, course, speed, navigational status and other safety-related information automatically to appropriately equipped shore stations, other ships, and aircraft; receives automatically such information from similarly fitted ships; monitors and tracks ships; and exchanges data with shore-based facilities." *See* 47 C.F.R. § 80.5.

[3] In the *Report and Order*, the Commission determined that Channel 87B should be designated for exclusive AIS use in the *maritime* VPCSAs. *See Report and Order*, 21 FCC Rcd at 8904 ¶ 18. For purposes of geographic area licensing in the VPC service, the Commission established nine licensing regions near major waterways, *i.e.*, the maritime VPCSAs, and thirty-three inland licensing regions. *See* Amendment of the Commission's Rules Concerning Maritime Communications, *Third Report and Order and Memorandum Opinion and Order*, PR Docket No. 92-257, 13 FCC Rcd 19853, 19861-63 ¶¶ 14-16 (1998); codified at 47 C.F.R. § 80.371(c)(1)(ii).

[4] *See Report and Order*, 21 FCC Rcd at 8929 ¶ 51. ORBCOMM, Inc., the satellite service provider that has contracted with the Coast Guard to develop satellite AIS capabilities, filed reply comments concurring in

of satellite AIS had been raised for the first time in NTIA's comments to the *Notice of Proposed Rule Making* in this proceeding and that, as a consequence, the record "provide[d] almost no information regarding the technical feasibility, effectiveness or potential benefits of satellite AIS, and no studies or analysis of potential interference to or from satellite AIS."[5]

The Commission therefore requested in the *Further Notice* that commenters provide information regarding satellite AIS and address whether Channel 87B should be designated for exclusive AIS use in the inland VPCSAs in order to accommodate satellite AIS.[6] In response to the *Further Notice*, NTIA and the majority of the other commenters indicated that they favored the designation of Channel 87B for AIS in inland VPCSAs both as an accommodation to satellite AIS and for independent reasons. With the exception of MariTEL, Inc. (MariTEL), all of the commenters addressing this issue argued that satellite AIS would offer significant advantages over terrestrial AIS by expanding vessel tracking capabilities to encompass areas of the high seas well beyond the reach of non-satellite AIS.[7] NTIA and the other commenters also argued that the Commission should prohibit non-AIS transmissions on Channel 87B, even in inland areas, in order to avoid disruption to satellite reception of AIS signals. MariTEL disputed both the public interest benefits to be derived from satellite AIS, and the contention that non-AIS transmissions on Channel 87B in inland VPCSAs would cause harmful interference to satellite AIS communications.

In support of its argument that the integrity of satellite AIS operations would be impaired unless Channel 87B is designated for exclusive AIS use nationwide, in the inland VPCSAs as well as the maritime VPCSAs, NTIA submitted a report by the Department of Defense Joint Spectrum Center (JSC) analyzing technical issues relating to satellite AIS (JSC Report).[8] According to NTIA, the JSC Report demonstrates that non-AIS co-channel signals "cause degradation in AIS signal detection … that is both unpredictable and unmanageable,"[9] and that

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NTIA's assessment of the need for a nationwide designation to accommodate satellite AIS. *Id*. at 8929 n.264.

[5] *Id*. at 8930 ¶ 52.

[6] *See Further Notice*, 21 FCC Rcd at 8933-34 ¶ 58. The Commission also invited further comment on the broader issue of whether a nationwide designation of Channel 87B for exclusive AIS use would benefit the public interest, offering commenters an additional opportunity to provide information regarding, for example, "the extent to which vessels on navigable waterways in the inland VPCSAs may benefit from AIS on the one hand, and VPC services, including maritime public correspondence services, on the other." *Id*. at 8934 ¶ 59.

[7] NTIA explained that land-based AIS facilities provide only limited line-of-sight coverage and that the Department of Homeland Security and the United States Coast Guard Research Development Center have demonstrated the under certain conditions it is possible for land base systems to reliably receive AIS signals from approximately 350 nautical miles. However, the Maritime Transportation and Security Act of 2002, 46 U.S.C. § 70115, requires the Coast Guard to develop long-range tracking capabilities, and the Coast Guard's goal in furtherance of that mandate is to extend AIS coverage to two thousand nautical miles from the United States shoreline. *See* U.S. General Accountability Office, Maritime Security: Partnering Could Reduce Federal Costs and Facilitate Implementation of Automatic Vessel Identification System, Report to the Committee of Commerce, Science, and Transportation, U.S. Senate, at n.16 (GAO-04-868 July 2004) (viewable at http://www.gao.gov/new.items/d04868.pdf).

[8] *See* "Satellite Detection of Automatic Identification System Messages," Joint Spectrum Center, Department of Defense (Sept. 19, 2006) (JSC Report). The JSC Report is attached to NTIA's comments as Exhibit A.

[9] *See* NTIA Comments at 6.

this signal degradation "will significantly decrease the effectiveness of the AIS system" to the point of defeating the purpose of using satellite AIS to expand long-range vessel tracking capabilities.[10] In the draft *Second Report and Order,* the Commission would rely in part on the JSC Report in support of its determination that a nationwide designation of Channel 87B for AIS is needed to prevent interference to satellite AIS communications, and its decision that the public interest benefits of accommodating satellite AIS provide a rationale, but not the sole rationale, for adopting a nationwide AIS designation of the channel.

The review panel discussed the assumptions, calculations, and methodology in the JSC Report referenced in the draft *Second Report and Order* in WT Docket 04-344. Specifically, as requested in the WTB memo, the review panel discussed the following:

1. Do the assumptions contained in the JSC Report conform to generally accepted standards in the radio engineering field?
2. Do the calculations in the JSC Report conform to generally accepted standards in the radio engineering field?
    a. Are the results accurate?
    b. If statistical methods are used, are the techniques appropriate for the problem?
    c. If software is used, is the software appropriate for the problem and current?
3. Does the methodology contained in the JSC Report conform to generally accepted standards in the radio engineering field?
4. Do the conclusions contained in the JSC Report conform to generally accepted standards in the radio engineering field?
5. Are there any revisions, improvements, or extensions the reviewer recommends to ensure that the JSC Report conforms to generally accepted standards in the radio engineering field?

The response of the review panel is presented below for each question shown above:

The report addresses several technical models/issues in different sections and subsections, so we consider these as they are asserted in each section/subsection.

1. Do the assumptions contained in the JSC Report conform to generally accepted standards in the radio engineering field?

Section 2 (pages 2-4): Operational and technical characteristics of shipborne AIS

- In the section on technical feasibility of satellite detection of AIS the operational and technical characteristics of shipborne AIS taken from Recommendation ITU-R M.1371 are summarized. AIS parameters not included in the ITU-R Recommendation, two antenna types and line loss are presented. On the conservative side, it is assumed that the half-wave dipole antenna has a maximum gain of approximately 2 dBi, a minimum gain of -10 dBi, and a cosine-squared

[10] *Id*. NTIA explains that the JSC Report "finds that several key technical factors distinguish satellite AIS detection from conventional ship-to-ship and ship-to-shore AIS detection, specifically receiver sensitivity, antenna gain pattern, and reliability requirements. Unlike conventional terrestrial AIS operations that may be able to co-exist with other co-channel transmitters through geographical separation, because the satellite beam covers a very large geographical area, the satellite antenna receives not only AIS ship transmissions, but also non-AIS signals transmitted on the AIS frequency." *Id*.

elevation gain pattern; and that the total transmission line loss – representing all lengths of line – is 3 dB. These assumed values are generally accepted standards for these parameters.

Section 3 (pages 5-6): Satellite detection of AIS

- In the section on Satellite detection of AIS many assumptions are needed since a functioning satellite AIS detection system is not in place and such parameters have not been defined. Table 5 in the report summarizes all of the assumed characteristics of the AIS satellite link. The assumptions in the table related to LEO satellite configurations are well within generally accepted norms[11] and the parameters for the AIS satellite receiver are considered reasonable and technically achievable.

Section 5 (page 9-17): Intra-system interference analysis (class A only)[12]

Three methodologies are developed which use assumptions appropriate to the individual methodologies:

Analytic Approach (pages 9-14)

- The first methodology develops a simple probability model assuming a uniform distribution of ships in the satellite footprint, initially two ships and one message, the probability of timeslot collision and probability of successful detection without collision, based on simple combinatorial principles using the basic parameters of message transmission: average transmission period, message length, the duty cycle of the undesired transmitted messages, and a weighting factor based on the zone (area in the satellite footprint) from which the message was transmitted. The assumption of independence for transmitted messages is invoked and the standard probabilistic expansion to N ships and M messages are produced. These types of assumptions are basic, hence standard in the development of simple combinatorial probability models to quantify the probability parameters.

Simulation Method (page 15)

- The second methodology uses Monte Carlo simulation methods. The assumptions include: ships are uniformly distributed in a circular geographic area with a 3,281 km radius centered on the sub-satellite point, ships randomly transmit on AIS channel 1 or 2, and on one of the 2250 time slots, and each Class A ship transmits at the power and average time slot interval described in the report. This is a slight refinement of the analytic approach. The assumed parameters are essentially the same as in the analytic approach.

Stochastic Method (pages 16-17)

- The third methodology develops statistics for detection of Class A ships using a random variable approach known as Poisson Arrivals to characterize the message arrivals at the satellite receiver. The assumptions in this methodology are essentially the same as for the first methodology, since the random function characterizing the message arrivals can be approximated by factors which can be directly equated to the variables in the first methodology.

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[11] "Satellite Communications", 2nd Edition, by T. Pratt, C. Bostian, and J. Allnutt, John Wiley and Sons, 2003, p. 388.

[12] Class A AIS equipment is required for ships meeting the requirements of the IMO carriage requirements. These transmitters operate at 12 watts.

All of the assumptions involved in these seemingly different approaches are standard principles associated with quantifying the probabilities involved while working within the normal constraints of the physical model. It is our opinion that they conform to standard radio engineering judgments appropriate to provide answers to the questions posed in the analysis.

Section 6 (page 17-18): Intra-system interference analysis (mixed Class A and Class B)[13]

- The assumption is made that the Class B ships can be accommodated in the analysis (using any one of the three methodologies presented earlier) by adjusting the factor which accounts for the basic probability of time slot collision. The factor becomes the sum of the probability of interference from the Class A units and the Class B units (each considered as if it were acting separately). Unfortunately, a constant (k_A) in this probability expression which for Class A units is well defined, since overlap of time slots for Class A always produces a collision, is not well defined for Class B units (k_B), since only a smaller portion of time slot overlaps produce a collision because of the lower power of Class B units. The argument is made that an estimate of this constant for Class B units can be derived from the simulation model (second methodology discussed earlier). This produces a value for use in the analysis that is at least commensurate with the constant chosen for Class A and reflects the smaller probability of interference due to message collisions. This assumption appears to be the weakest in the analysis since the results (figures 9 – 11) show large variations with the percentage of Class B ships which is interrelated to the determination of the Class B constant and the effect of the smaller Class B power level which allows fewer time slot collisions. However, given the lack of information on Class B units, the assumptions here are considered to be reasonable and generally accepted to combine both of these AIS emitter types into the three methodologies.

Section 7 (page 19-22): Intra-system interference analysis (non-uniform ship distribution)

In this section, a number of new assumptions are introduced to specify four additional variables added to this portion of the analysis.

- An estimate was derived for the total number of AIS-equipped ships in the world. Data was examined from several sources which estimated the range at between 50,000 to 80,000. An estimate of 70,000 Class A equipped ships in the world (as of year 2005) was used.

- The location of a desired target ship had to be selected. The selection was made considering the consequence that is would have a large influence on the probability of detection, *e.g.* a ship located far from a heavily-used shipping route could be detected with about 100% certainty. For this study, a target ship located at four locations was used: 1,000 km off the coast of New York and Los Angeles, one near the center of the Gulf of Mexico, and one in the mid-Atlantic.

- A geographic distribution of Class A ships (latitude and longitude) was needed. An available set of data for the month Oct 2004 containing over 80,000 weather observation reports from 800 ships was selected. The absence of data for Class B ships was a reason for excluding them from this analysis.

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[13] Ships not meeting the IMO carriage requirements for Class A equipment may use Class B equipment. Class B equipment operates at lower power (2 watts maximum) and has different features and nature of design from class A equipment.

These assumptions are clearly stated with the rationale used for the particular selections. We believe that these assumptions are reasonable given the discussion in the report, and that they are indicative of general situations. However, we caution that, even as the report recognizes, there were geographic distributions of ships with clusters of ships large enough to cause the satellite detection to fail for ships in those clusters.

Section 8 (page 23): Candidate technique to enhance satellite capacity:

In this section, the report discusses four techniques (*i.e.*, Satellite Antenna, Doppler Tracking, and Correlation Processing) for improving satellite capacity. There is a whole body of knowledge behind the four techniques and their potential impact on satellite capacity. These methods (and their corresponding assumptions) do indeed conform to the generally accepted standards in the radio engineering field.

Section 9 (pages 29-30): Compatibility with other incumbent fixed and mobile systems:

Co-channel mobile systems – simple scenario

Assumptions were included in Table 9 listing the typical VPCS and LMR technical parameters. They assume a "simplified" methodology involving two satellite overpasses for a representative LMR transmitter in the central US and an AIS equipped ship in the Atlantic Ocean. They assume that mobile EIRP was constant at 50 dBm over the upper hemisphere, ship AIS EIRP was constant at 44 dBm over the upper hemisphere, the satellite antenna had constant gain towards the Earth, no polarization discrimination, and free space propagation was used during periods of satellite visibility. They also make a statement that if in addition to these assumptions they assume a 100% duty cycle for mobile devices it would have dramatic implication for AIS satellite detection.
These assumptions are greatly simplified to get trends and average operational information on mobile system effects on AIS satellite detection and they are considered appropriate for that purpose.

Co-channel mobile systems – refined scenario (to include mobile system duty cycle)

Assumptions are placed on the operational duty cycle of the mobile systems. The report considers three categories of mobile transmitters: high duty cycle (30-100%), medium duty cycle (10-30%), and low duty cycle (10%). It is assumed that mobile systems have an EIRP of 50 dBm, vertical polarized antennas with a cosine squared antenna elevation pattern, and that the AIS parameters defined early in the report (Table 5) are employed. They also assume the mobiles are operating on one of the AIS frequencies, but allow for different percentages of mobiles to appear on both AIS frequencies. These assumptions are considered appropriate to evaluate the effect of duty cycle on AIS satellite performance. It is also noted that the same type of assumptions used for the AIS transmit are used for the mobile transmit (*e.g.* vertically polarized and cosine squared antenna patterns). That antenna polarization and pattern are generic to a host of mobile transmit devices.

Adjacent Channel Mobile Compatibility

It is assumed here that adjacent channel rejection values of 30 dB, 40 dB, and 50 dB will occur. It was also assumed that mobiles would be operating on three, rather than five adjacent channels, and that the number of mobile systems operating within the satellite antenna footprint was assumed to be the same on all three channels, and that a maximum number of 240 per individual channel would be considered. A uniform distribution of 1000 Class A AIS equipped ships, and mobile transmit duty cycles of 5%, 10%, and a maximum of 30% would be considered.

2. Do the calculations in the JSC Report conform to generally accepted standards in the radio engineering field?
    a. Are the results accurate?
    b. If statistical methods are used, are the techniques appropriate for the problem?
    c. If software is used, is the software appropriate for the problem and current?

- The first calculation of significance in the technical feasibility section involves an estimate of the long term average transmission interval for class A ships. Weighting and summing the times indicated in Table 4 provides a value of 6.95 seconds which they report as 7 seconds as the average for all ships.

- The link budget for basic ship to satellite AIS operation at maximum range is presented in Table 6. This is a standard calculation of power gains and losses which demonstrates that successful operation is achievable.

- The section on the link budget explores the propagation loss appropriate to very low take-off angles from the ship antennas over water. They use a software program available from ITS, the IF-77 Electromagnetic Wave Propagation Model (DOT/FAA/ES-83/3), September 1983, by G.D. Gierhart and M.E. Johnson. This is particularly appropriate for earth to satellite propagation loss predictions and their results show that nominal free space propagation conditions apply within a couple of dB all the way to the optical horizon. Thus applying free space propagation conditions the parameters in the link budget for the Class B devices is shown to be the same as for Class A, except for reduced power of Class B devices. Hence, these results and the software used to generate them are considered appropriate and generally accepted for this type of analysis.

- In the section on intra-system interference analysis (class A only), three methodologies are described that perform different calculations appropriate to that methodology.

- The calculations in the analytic approach are basic analysis with the exception of the use of the commercially available satellite analysis program which is not identified. This type of calculation - satellite visibility periods as a function of orbit inclination and latitude of an earth location - are the essential basic outputs from this type of software. The exact results are not critical, since a specific satellite system does not exist, but approximate results are required to demonstrate feasibility for the system and the parameters chosen are for the analysis are reasonable for LEO satellite systems.

- The calculations in the Monte Carlo simulation method are straight forward using a set of assumptions that allows specific randomized parameters for the transmit parameters of each AIS unit and essentially repeatedly recalculating (essentially using a link budget) the resulting *aggregate* power received at the satellite in a given time slot. This section also notes that it was necessary to compute the propagation time delay for each simulated ship to properly define the time slot collision factor. This requirement led to dividing up the time slots into sub-time slots and comparing the aggregate power in a set of the sub-time to the D/U ratio as the criteria for interference.

- The calculations in the stochastic method reduce, after the approximation of the random function for small arguments, to similar calculations involved in the analytic approach.

The statistical methods used in these three approaches are considered to be appropriate for this problem, and the results from these calculations are easily seen to be accurate. In fact, near identical results are obtained from the three different analysis approaches. However, it is our opinion that there are in fact only two essentially different approaches used in this section of the report since the stochastic method is essentially identical to the analytic method.

- The section on intra-system interference analysis (mixed Class A and Class B) used the same calculations as the previous section for Class A alone, but with slightly different parameters. No specifics of the derivation of the probability constant for the Class B ships is provided and there is no statement made about the sensitivity of the result to small changes in parameters. It is not clear therefore how the smaller probability constant used for Class B ships influences the result (*i.e*. to what degree when compared to the lower power of Class B devices which allows for fewer slot collisions).

- The section on intra-system interference analysis (non-uniform ship distribution) used a refined version of the second methodology (Monte Carlo simulation analysis) discussed above. The calculations still involve the repeated recalculation (essentially a link budget) for the resulting aggregate power received at the satellite in a given time slot. The features discussed earlier are augmented by more detail, for instance calculating in steps the path loss based on the assumed ship location and the satellite location over the visible period for all of the randomly selected ship locations taken from an assumed location database and selected satellite paths taken from satellite ground track information. The results appear to be accurate (commensurate with the more course earlier model), and the Monte Carlo simulation methodology is judged to be one of the best approaches for a problem with this complexity and level of assumptions.

- The sections on co-channel and adj-channel mobile compatibility are believed to use the Monte Carlo simulation technology developed earlier for the uniform ship distribution, where the modifications for instance to account for adjacent channel rejection involve changing the parameters in this existing model. For instance to account for adjacent channel power rejection, the transmit power of the mobiles is reduced dB for dB by the adj-channel rejection ratio. Hence, there are no new types of calculations to be considered for these report sections.

3. Does the methodology contained in the JSC Report conform to generally accepted standards in the radio engineering field?

- In the section on technical feasibility of satellite detection of AIS, the table of Shipboard AIS Technical Parameters shows a required D/U protection ratio at 10 dB per 20% packet error rate (PER) stated as specified in IEC 61993-2. We were not able to verify this value from the IEC standard, however the ITU-R Recommendation does specify a 10 dB value for the RF carrier sense level to the noise level but there is no discussion of PER. The use of a D/U ratio for determining interference is a well accepted standard in the radio engineering field.

- The section on intra-system interference analysis (class A only) describes three methodologies for quantifying the limitations on AIS satellite system performance due to intra-system interference.

An analytic approach is presented which employs a geographical representation of the satellite footprint to identify zones in which different types of RF interference occurs (slot collisions), and a basic probability model is generated. From an initial scenario involving a uniform distribution of ships in the satellite footprint, a single message being received at the satellite, the probability of packet collision and the probability of packet detection is determined depending on the average transmission period, message length, the duty cycle of the undesired transmitted messages, and a weighting factor based on the zone from which the message was transmitted. The probability for a timeslot collision and for at least one successful detection without collision is determined in terms of these parameters. This basic model is then expanded to include independent transmissions from N ships, and M messages (transmitted during the period of satellite visibility).

The satellite visibility time period is then defined for a single satellite using a "commercially available satellite analysis model" which is not identified in the report. That model took into account that most satellite overpasses will occur at some low elevation angle, depending on the satellite specific orbit and the latitude of the ship location. Average visibility periods are presented for a single overhead pass, as well as average values over extended observation periods (4 and 12 hours, consistent with earlier assumptions) are presented.

Finally, the analytic methodology and the visibility statistics are combined (the delta T parameter is changed to the various visibility times) to provide the results for the percentage of ships detected and the probability of detecting all ships.

- A simulation approach using Monte Carlo methods was also applied. This methodology relies on developing specific randomized parameters for the transmit factors of each AIS unit and essentially repeatedly recalculating (essentially using a link budget) the resulting *aggregate* power received at the satellite in a given time slot. The time slots were divided into sub-time slots for the purpose of accounting for the propagation time delay to use to determine the time slot collision factor. The aggregate power in a portion of the time slot was compared to the D/U ratio as the criteria for interference (time slot collision).

- The third methodology, called the stochastic method (essentially known as Poisson Arrivals), assumed a specific probability distribution (Poisson distribution) for the arrival of messages to the satellite receiver from the ship borne AIS units. This methodology collapses into the same form as the first methodology when a mathematical expansion is applied to the exponential function for small argument.[14]

The methodologies presented here are generally accepted radio engineering practices for this type of statistic/probability problem. Near identical results are obtained from the application of these methodologies.

- The section on intra-system interference analysis (mixed Class A and Class B) used the same methodology (methodology three) as the previous section for Class A alone, but with slightly different parameters.

- The section on intra-system interference analysis (non-uniform ship distribution) introduces variations on the Monte Carlo simulation model discussed earlier. To introduce a non-uniform ship distribution more typical of the actual environment, the report introduces additional variables: the total number of AIS ships in the world, the geographic location of the desired target ship (latitude and longtitude), the world-wide geographic distribution of AIS-equipped ships, and satellite ground track information. When appropriate assumptions are made to make specific the values of these additional variables (only Class A is considered), the former Monte Carlo simulation model is employed with the following additional changes: a random sub-set of ship

[14] Dr. J.K.E. Tunaley, *A Stochastic Model for Space-Borne AIS*, Undated

locations is chosen, the satellite location is stepped along a representative satellite orbit passing over the target ship. As before, this methodology repeatedly recalculates (essentially using a link budget) the resulting *aggregate* power received at the satellite in a given time slot. The time slots were divided into sub-time slots for the purpose of accounting for the propagation time delay to use to determine the time slot collision factor. The aggregate power in a portion of the time slot was compared to the D/U ratio as the criteria for interference (time slot collision). This type of methodology – generalizing from a simplified model containing all of the basic elements and refining the manner in which the individual elements are incorporated to provide for a more realistic representation – and then examining large numbers of examples is universally applied to get realistic estimates to solve complex problems. The accuracy of the model then primarily relies on the ability of the analyst to determine when enough realistic representations have been examined (how many Monte Carlo iterations to include). The results presented in figures 13-16 appear to be consistent with the earlier more restrictive Monte Carlo model while incorporating the details that provide the most realistic representation of the expected performance of AIS satellite detection.

- In the section on compatibility with other incumbent fixed and mobile systems, the co-channel system simple scenario, a simplified methodology was used to infer generalized results and trends. The methodology included: Mobile EIRP was constant at 50 dBm over the upper hemisphere, Ship AIS EIRP was constant at 44 dBm over the upper hemisphere, the satellite antenna had constant gain towards the Earth, no polarization discrimination, and free space propagation was used during periods of satellite visibility. For the purpose of a quick identification of trends and average parameters, this methodology is fully acceptable.

- In the section on compatibility with other incumbent fixed and mobile systems, the co-channel system refined the Monte Carlo simulation methodology and reemployed it with the assumption of the uniform distribution of ships, and we infer a uniform distribution of mobile devices. It is not clear from the report exactly how the mobile devices were distributed, but if a uniform distribution of devices was considered it should have been restricted to places where these types of devices would be found namely in the land areas in the satellite footprint.

4. Do the conclusions contained in the JSC Report conform to generally accepted standards in the radio engineering field?

- The first conclusion in the technical section on ship-to-satellite operation is that adequate link margin exists to detect and decode both Class A and Class B AIS signals at most ship locations within the satellite footprint. This follows directly from the assumptions on the satellite link and the NIST propagation software program.

- In the section on intra-system interference analysis (class A only), three types of statistics are reported from the first methodology in that section: the probability of detecting a ship during a specified satellite visibility period, the percentage of ships detected, and the probability that, during a given visibility period, all the ships in the satellite footprint are detected (under the primary assumption of a uniform distribution of ships in the satellite footprint). The conclusion drawn from these results are that "many transmitted messages can be corrupted and lost by time slot collisions and still achieve the desired goal of updating ship locations during a given satellite visibility period." This conclusion is consistent with and based on the results of the first methodology.

- The conclusions drawn from the three methodologies in the section on intra-system interference analysis (Class A only) are all identical (*i.e.*, they do not depend on the methodology used).

- The conclusions drawn from the section on intra-system interference analysis (mixed Class A and Class B) and presented by means of figures 9-11, definitely show the influence of the lower power of Class B devices and the effect they have on the probability of detection versus the total number of ships in the satellite footprint. The conclusions confirm the expected results based on the difference in power between Class A and Class B devices.

- The conclusions drawn from the section on intra-system interference analysis (non-uniform ship distribution) and presented by means of figures 13-16 are the last refinements provided in the report on the detection capability of worldwide Class A ships. They appear to follow from levels of model refinement using a generally accepted and appropriate methodology (Monte Carlo simulation analysis) in radio engineering.

- The conclusion in the section on Long Term Studies/Solutions that the use of a shorter message length and longer transmit period will dramatically increase satellite detection is strongly confirmed by the analysis of Class B AIS units in the report.

- The conclusions in the section on compatibility with other incumbent fixed and mobile systems, the co-channel system simple scenario are very simplified: The D/U values during the line-of-sight periods could possibly vary form -17 dB to +5 dB with an average of -6 dB. The average D/U value of -6 dB is consistent with the 6 dB higher EIRP used for the mobile system transmitter as compared to an AIS ship transmitter. If these co-channel mobile service transmitters were to be operated on a 100% duty cycle basis, it would follow that satellite detection of AIS is not compatible with other co-channel mobile service applications. This last comment on "compatible operation" of AIS with co-channel systems is inappropriate since this analysis will be much farther refined in their next section.

- The conclusions in the section on compatibility with other incumbent fixed and mobile systems, the co-channel system refined scenario (to include mobile system duty cycle) are summarized in figures 24-27. It is recognized that the multidimensional elements selected in these analyses cannot cover all possible conditions but that they may provide limiting cases for the selection of parameters presented here. These conclusions do follow from the assumptions and models proposed and they are considered useful in their sphere of applicability

5. Are there any revisions, improvements, or extensions the reviewer recommends to ensure that the JSC Report conforms to generally accepted standards in the radio engineering field?

The report presents a technical structure of an AIS satellite system that can potentially be used to track ships over large distances from the US borders. The assumptions contained in the report are considered to conform to generally accepted standards in the radio engineering field. The calculations in the report are considered to be accurate for the level of detail that was presented. In instances where statistical methods are used, the techniques are considered appropriate for the systems being modeled and the software used in the modeling is considered appropriate and current. The methodologies contained in the report are generally accepted and are appropriate for the types of radio engineering problem addressed. The conclusions in the report are considered to follow from the assumptions, calculations and methodologies employed based on the level of detail that was discernable from the presentation in the document. Specifics referring to this evaluation are presented above, organized by appropriate sections in this peer review.

Our strongest criticism of this report is that many of the assumed parameters and associated values used in the analysis are assumed to be as generic as possible in nature so that the resulting conclusions will be valid for a wide variety of potential future AIS satellite systems. For instance, it is recognized in the report that the conclusions drawn on AIS satellite detection can depend strongly on certain elements such as the assumed distribution (e.g., non uniform) of class A ships. As stated in the report, if this distribution contains large clustering of ships at various locations, AIS satellite detection will fail. One method to account for this potential problem is to perform sensitivity analyses for such critical system variable – this important issue is not addressed in the report. Further, this raises questions as to how specific values and parameters are selected in the sections related to Co-channel and adjacent channel mobile operations compatibility. In that section of the report, it is stated, for instance, that “it was beyond the scope of this study to examine differing mobile system usage on the three adjacent channels”. This example is typical of a weakness in the analysis in this entire section of the report. The information on mobile usage exists but wasn’t considered in order to determine mobile system parameters. Instead, generic assumptions were made, possibly, to simplify the analyses rather than determining parameters that would lead to more accurate results commensurate with the refined level of simulation model used in that section. We recommend that if this study is revised or extended in the future that the section on mobile system compatibility be more fully developed.

Respectfully submitted,

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