

# LATHAM & WATKINS LLP

February 3, 2005

Marlene H. Dortch  
Secretary  
Federal Communications Commission  
445 12th Street, S.W.  
Washington, D.C. 20554

Re: *Ex Parte* Presentation  
IB Docket No. 01-185  
File No. SAT-MOD-20031118-00333  
File No. SAT-AMD-20031118-00332  
File No. SES-MOD-20031118-01879

Dear Ms. Dortch:

Enclosed on behalf of Inmarsat are the following papers:

1. ATC and Overloading of the I4 Satellites;
2. Protection of Inmarsat Terminals Operating in Airports and on Navigable Waterways;
3. ATC Interference Into Inmarsat Aeronautical Terminals;
4. Effect of MT Antenna Gain Pattern on Uplink Interference;
5. Analysis of MSV's Proposed Method to Ensure Sharp Signal Cut-Off at Edge-of-Coverage;
6. Distribution of MSV ATC Base Stations and Co-Frequency Reuse Limit Within the United States;
7. Memorandum from Honeywell regarding Interference Signal Levels for Inmarsat Aero H and S64.

These papers elaborate on matters raised at yesterday's meeting among representatives of the Department of Defense, the National Telecommunications and Information Administration, the FCC, MSV and Inmarsat. They also respond to the following MSV *ex parte* presentations: (i) Technical Response to Inmarsat's January 5, 2005 filing (filed January 14, 2005); (ii) Additional Protection for Terminals Operating in Open Areas of Airports and Navigable Waterways (filed January 7, 2005); and (iii) Affidavit of LCC International Inc. (filed January 7, 2005).

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LATHAM & WATKINS<sup>LLP</sup>

In our meeting yesterday, MSV expressed its current intention to deploy ATC base stations in densely populated areas covering a small percentage of the U.S. land mass ---perhaps only 2-3 percent of the land mass. There are two responses to this. First, as the attached U.S. Census Bureau data shows, that network would cover almost the entire US population: 79% of the US population lives in the 2.6% of the land area of the US that is defined as "urban." MSV's statement thus is consistent with the deployment of a very large-scale terrestrial network. For this reason, the "swiss cheese holes" in Inmarsat's coverage area that would be created by ATC base station interference from that type of a deployment could well constrain the ability to provide MSS service to a significant percentage of the US population. Second, there is nothing in the ATC rules that constrains the geographic areas where ATC can be deployed, and absent such limits, the Commission can have no assurance where MSV or any successor to MSV's license actually will deploy ATC.

MSV also encouraged FCC staff to view an alleged "study" that is posted on the MSV web site, but which has not been submitted in the record of this proceeding. That document purports to address the potential for ATC interference into the Inmarsat network. As an initial matter, there is no basis for the Commission to consider such an extraneous reference, particularly when the merits of that document were not open to public comment in this proceeding. Moreover, that document does not address the measurement of data from an ATC network, there is no indication whether MSV's ATC network would be similar to the architecture of the network referenced in that document, and the work described in that document did not involve measuring the interfering signal levels emitted toward the geostationary arc. Thus, that reference is not probative in the least of the interference threat of ATC into the Inmarsat network.

The Commission must not make unfounded assumptions about the deployment of MSV's ATC network. Rather, it is imperative that the Commission adopt appropriate constraints on ATC deployment to ensure that ATC interference, coupled with the interference from the supporting MSS system, does not produce harmful interference into other MSS networks.

Sincerely yours,



John P. Janka

cc: Richard Engelman  
Howard Griboff  
Bruce Jacobs



**GCT-PH1. Population, Housing Units, Area, and Density: 2000**

Data Set: Census 2000 Summary File 1 (SF 1) 100-Percent Data

Geographic Area: **United States -- Urban/Rural and Inside/Outside Metropolitan Area**

NOTE: For information on confidentiality protection, nonsampling error, and definitions, see <http://factfinder.census.gov/home/en/datanotes/expsf1u.htm>.

Geographic area	Population	Housing units	Area in square miles			Density per square mile of land area	
			Total area	Water area	Land area	Population	Housing units
<b>United States</b>	281,421,906	115,904,641	3,794,083.06	256,644.62	3,537,438.44	79.6	32.8
<b>URBAN AND RURAL</b>							
Urban	222,360,539	89,965,943	93,321.42	813.64	92,507.78	2,403.7	972.5
In urbanized area	192,323,824	77,289,882	72,683.25	661.36	72,021.90	2,670.4	1,073.1
In central place	109,705,763	44,486,262	27,072.13	206.19	26,865.95	4,083.5	1,655.9
Not in central place	82,618,061	32,803,620	45,611.12	455.17	45,155.95	1,829.6	726.5
In urban cluster	30,036,715	12,676,061	20,638.17	152.28	20,485.88	1,466.2	618.8
In central place	22,844,647	9,732,506	11,699.55	70.58	11,628.97	1,964.5	836.9
Not in central place	7,192,068	2,943,555	8,938.61	81.70	8,856.91	812.0	332.3
Rural	59,061,367	25,938,698	3,700,761.65	255,830.98	3,444,930.67	17.1	7.5
Place of 2,500 or more	4,089,599	1,762,875	55,582.40	9,247.20	46,335.19	88.3	38.0
Place of 1,000 to 2,499	4,989,152	2,246,309	18,392.68	840.66	17,552.02	284.2	128.0
Place of less than 1,000	3,821,336	1,810,929	35,239.31	2,260.60	32,978.71	115.9	54.9
Not in place	46,161,280	20,118,585	3,591,547.25	243,482.51	3,348,064.74	13.8	6.0
<b>INSIDE AND OUTSIDE METROPOLITAN AREA</b>							
In metropolitan area	225,981,679	90,812,960	764,595.13	58,805.54	705,789.59	320.2	128.7
In central city	85,401,127	35,414,873	35,021.06	3,580.57	31,440.49	2,716.3	1,126.4
Not in central city	140,580,552	55,398,087	729,574.07	55,224.97	674,349.09	208.5	82.2
Urban	114,885,009	45,039,822	56,829.72	565.67	56,264.05	2,041.9	800.5
In urbanized area	105,628,220	41,312,646	50,041.12	511.68	49,529.44	2,132.6	834.1
In urban cluster	9,256,789	3,727,176	6,788.61	53.99	6,734.62	1,374.5	553.4
Rural	25,695,543	10,358,265	672,744.34	54,659.30	618,085.04	41.6	16.8
Not in metropolitan area	55,440,227	25,091,681	3,029,487.94	197,839.08	2,831,648.86	19.6	8.9
Urban	22,695,347	9,770,144	15,302.08	108.27	15,193.82	1,493.7	643.0
In urbanized area	2,708,887	1,142,591	1,793.15	11.01	1,782.14	1,520.0	641.1
In urban cluster	19,986,460	8,627,553	13,508.93	97.26	13,411.67	1,490.2	643.3
Rural	32,744,880	15,321,537	3,014,185.86	197,730.81	2,816,455.04	11.6	5.4

(X) Not applicable

Source: U.S. Census Bureau, Census 2000 Summary File 1

## **ATC AND OVERLOADING OF THE I4 SATELLITES**

### **ATC OVERVIEW**

The ATC concept introduced by Mobile Satellite Ventures (MSV) has its origins in the approach used by the Satellite-Digital Audio Broadcast (SDAB) systems, whereby satellite coverage in areas with poor propagation conditions, like urban canyons, is enhanced by the use of terrestrial repeaters. However, there are crucial differences between the two approaches.

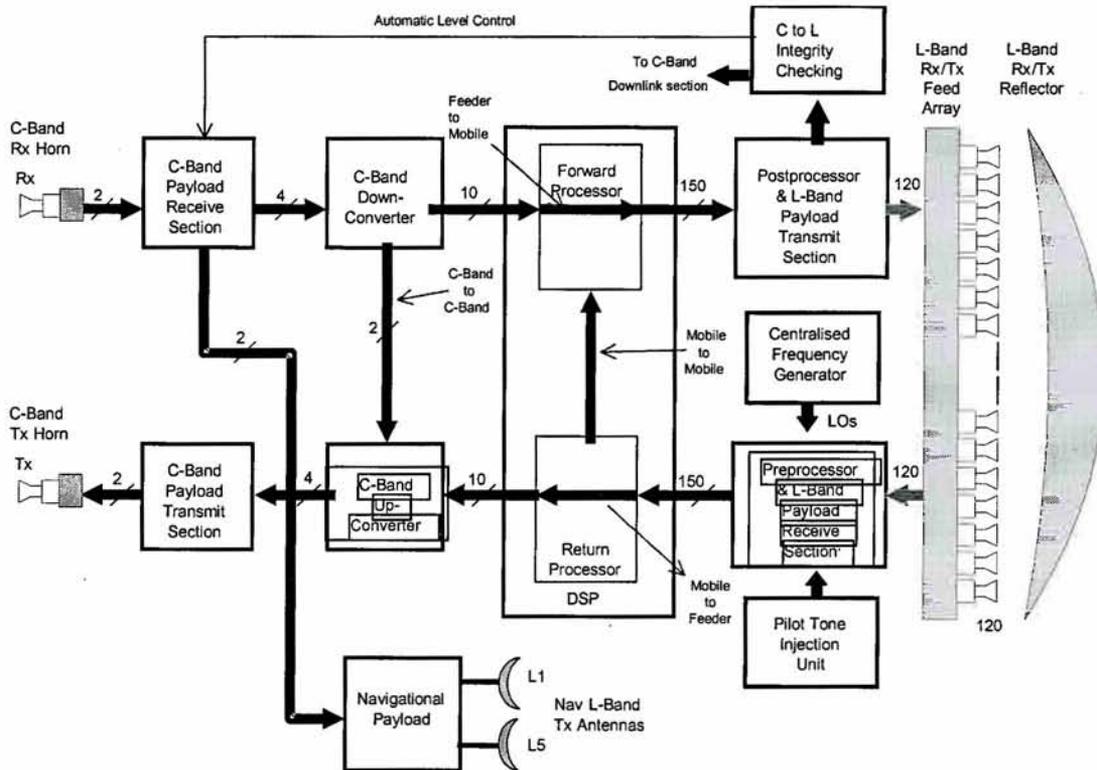
In the case of SDAB the User Terminals (UT) are receive-only, and the terrestrial and space components truly complement each other, with the terrestrial repeaters enhancing the coverage in urban areas, and the satellite covering the rural and remote areas. The UT's are designed to utilise the best signal they can get, and will cause no interference to the space component, nor limit its capacity. Furthermore, neither the UT's nor the terrestrial repeaters, independently of their numbers, will have any negative impact on, or cause interference to, other SDAB systems operating on adjacent segments of the spectrum.

When we apply the ATC concept to MSS, we now have UT's that receive and transmit signals, instead of terrestrial repeaters we have cellular base stations. When communicating with a terrestrial base station, the UT's will be producing interference into the satellite, as their transmissions to both the satellite and the terrestrial base stations use the same frequency bands. The UT's will also be interfering into any other MSS systems with satellites visible from that geographical area. Contrary to the SDAB case, increasing the number of UT's will have the effect of increasing the interference into the satellite component of that system, and into any other MSS system for that matter. The end effect is that the terrestrial and space components of an MSS/ATC system are not complementary, and in fact compete for the same scarce resource.

### **ATC IMPACT ON THE OVERLOADING OF THE INMARSAT 4 DSP**

Figure 1 presents a simplified block diagram for the payload of the Inmarsat 4 satellites. For this particular issue, the relevant area to concentrate is the L band receive section.

We verify from Figure 1, at the right hand side, that the I4 L-band antenna comprises a large reflector and a feed array comprising 120 elements. On the L band uplink side, signals received by each of those 120 feed elements are wide-band filtered at the individual diplexers and independently amplified by one of 120 dedicated Low Noise Amplifiers (LNA). The signals are then down-converted at the L Band Pre-processor, before being fed to the Digital Signal Processor (DSP). At the input of the DSP, we have Analog/Digital Converters (ADC) that convert the analog signal originating from each feed element to a digital signal to be processed by the DSP.

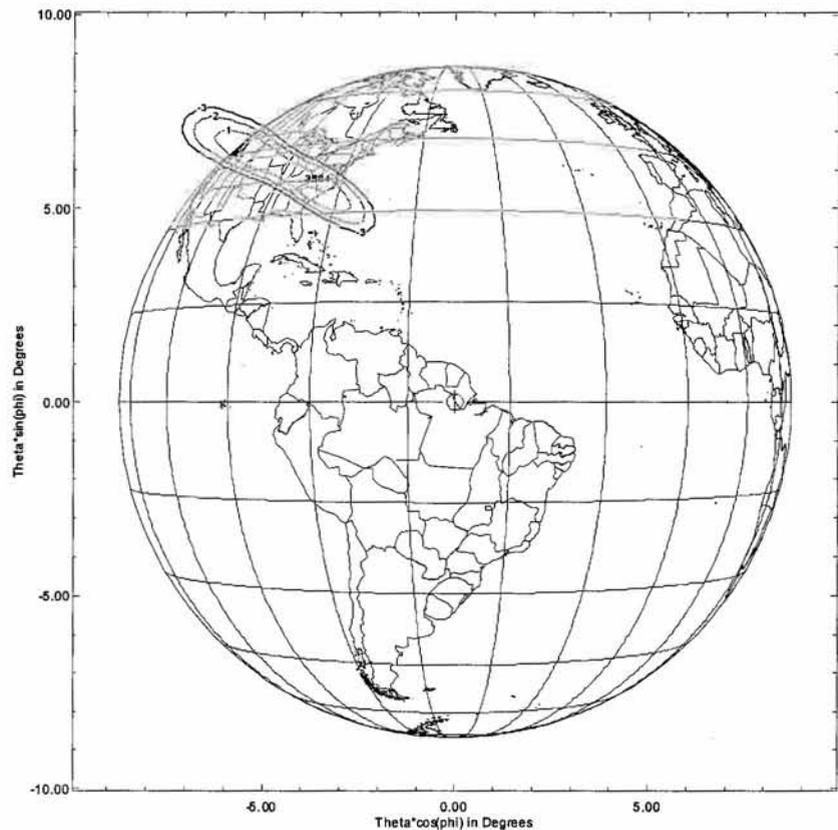


**Figure 1 – The Inmarsat 4 Payload**

The MSV ATC system would certainly operate outside Inmarsat's frequency assignments for that region. However, even operating outside Inmarsat's frequency assignments, the interfering signals produced by a large number of handsets would degrade the performance of the ADC's at the DSP input. The ADC's are wide band devices, as narrow band channelisation is performed downstream from the ADC, within the DSP proper. High interference levels would take those devices into compression, even if the interfering signals were outside the segment of spectrum allocated to Inmarsat. The payload has been designed assuming that the total out-of-band interference signals correspond to an aggregate 40 dBW of uplink EIRP (referred to the element -3dB contour). Considering that the EIRP of a User Terminal (UT) for the new Broadband Global Area Network (BGAN) service can be as low as 10 dBW, we can conclude that the 40 dBW allocation is in fact very substantial.

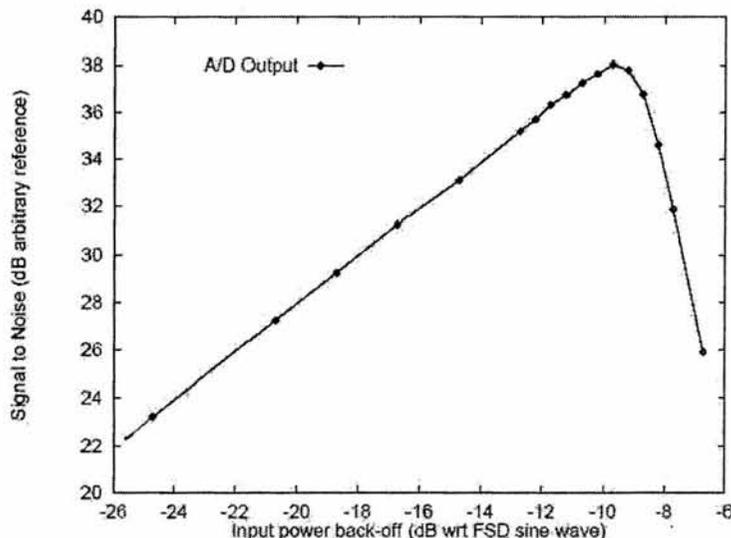
The 40 dBW allocation encompasses both interfering signals from Inmarsat terminals, which have been allocated 37 dBW, and interference from other MSS systems (including MSV's current generation spacecraft), which have also been allocated 37 dBW. There were no specific allocations for ATC systems, as the Inmarsat 4 satellite was specified in 1999, with the request for proposals being issued in December 1999, and the contract signed in May 2000. ATC interference would have to be dealt with within the allocation for other MSS systems. The problem would have a geographical characteristic, impacting the area covered by specific feed elements, and would depend on

the number of interfering ATC users. A typical feed element coverage area is shown in Figure 2.



**Figure 2 – Typical I4 Feed Element Coverage Pattern (Element 89)**

The net effect on the system performance could range from degradation in the link C/N, due to deterioration in the available S/N, to the total jamming of signals originating in the area covered by the affected feed element. Although the performance of the ADC's is well known and characterised, with a typical S/N response being shown in Figure 3, the problem is assessing the total level of interference reaching the ADC.



**Figure 3 – Typical ADC S/N Performance**

The problem is further compounded by the response of ADC's under overload, with the S/N performance degrading at ratio of 4/1 with respect to the increase in the overloading signal power, as can be observed from the right hand side of Figure 3. This steep ratio, combined with the effect of the exact user locations and uncertainties in the gain from the feed element output to the ADC input, due to diurnal temperature variations and aging, make it difficult to accurately assess the impact of ATC.

Even taking into account those factors, Inmarsat believed that the interference situation was manageable if the ATC implementation adhered to the February 2003 ATC rulemaking Order, as the number of simultaneously transmitting ATC users within the coverage of one feed element would be limited. However, taking into account the impact of the IB November 04 ATC license grant order, the number of interfering ATC transmissions within the coverage area of one feed element could increase dramatically. On a simple calculation, if we assume that 1/8 of the total interference allowance was allocated to ATC, totalling 31 dBW, and assume a -20 dBW average handset EIRP towards the satellite combined with an average gain of 1 dB below the element peak gain, we conclude that the limit for the number of users within the pattern of one beam would be just under 80,000. Even if we allow for, yet to be proven, interference reduction factors like polarisation isolation (1.4 dB), obstruction (0.5 dB for an Inmarsat satellite at 98W), voice activation (1.0 dB) and vocoder implementation (0.97 dB), we have a maximum number of users of 190,000.

The original ATC order allowed for 1,725 frequency re-uses, which would result in a potential 86,250 simultaneous users across CONUS if ATC is deployed in 10 MHz of spectrum (50 GSM channels). This just meets the 80,000 limits derived above. Considering that this is a CONUS-wide limit and there are a few I4 antenna feed elements covering CONUS, this can be considered acceptable. With the IB order, the re-use number was raised to 2,415, implying a maximum of 120,750 users, which would allow very little

margin given the uncertainties about the distribution of ATC terminals and other interference sources. The approximately 30,000 re-uses sought by MSV would allow up to 1,500,000 users and would certainly have severe impact on the Inmarsat-4 satellite.

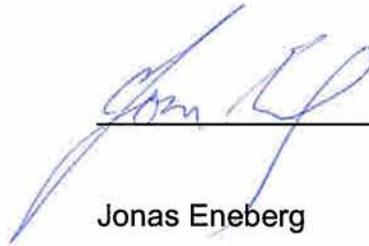
It is worthwhile to compare the above figures to the limit of 90,000 simultaneous ATC MTs in para 188 of the ATC Order. Firstly, these simple calculations show that the licence Order would permit MSV to operate more than the prescribed 90,000 simultaneous MTs, even if MSV is assumed to operate ATC in only 10 MHz of spectrum (less than what was made available under the terms of the last Operators' Agreement under the Mexico City MOU). Secondly, the 90,000 limit corresponds very closely to what is required to protect the Inmarsat-4 satellites from overloading due to ATC interference. This demonstrates the relevance of this limit and Inmarsat repeats its plea for the Commission to enforce this limit.

## **CONCLUSION**

The Inmarsat 4 satellites were designed and procured before the ATC concept was dreamed of. The satellites are all fully integrated and the first launch is expected by March. There are numerous unknowns on the impact that ATC may have on the overloading of the Inmarsat DSP. However it is clear that if the number of users in the system reaches a few millions, the aggregate interference caused by the ATC handsets, combined with the interference from other MSS systems and from Inmarsat users on other satellites, would add to the levels produced by the Inmarsat 4 users to drive the ADC well beyond their design point. The net effect would depend on the number and location of the users, but it could range from degradation in the user link to total jamming of users in specific areas. The potential impact and consequences demand the cautious approach to the ATC implementation that was achieved with the February 2003 ATC rulemaking Order.

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



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Dated: February 3, 2005

### **Protection of Inmarsat Terminals Operating in Airports and on Navigable Waterways**

In a January 7, 2005, ex parte, MSV presents results of measurements purporting to show that, when MSV ATC carriers are judiciously placed at a limited number of selected frequencies, Inmarsat terminals would be less sensitive to overload interference than assumed by the FCC. Based on these measurements and assumptions regarding Inmarsat's use of L-band, MSV proposes relaxations of the pfd limits and site restrictions on ATC base stations {§ 25.253 (d) (3-5)}. In making these proposals, MSV has failed to explain or account for the following important issues.

1. MSV has not described the measurement setup and methodology and without this information the proposal cannot be assessed on its merit. Inmarsat has pointed out shortcomings in MSV's previous measurements of Inmarsat terminals [e.g. Inmarsat March 25, 2004 Opposition to MSV ATC Application]. MSV gives no indication that these shortcomings have been corrected in its latest measurements.

2. It appears from MSV's description that a single Inmarsat GAN terminal has been tested. This is inappropriate for two reasons:

- a) GAN is neither a maritime nor an aeronautical terminal type and can therefore not form the basis for determining the interference susceptibility of maritime or aero terminals.
- b) A single terminal from one particular supplier and one particular Inmarsat standard can not be assumed to be representative of the wide range of products and services that Inmarsat offers.

3. MSV has based its proposals on the assumption that Inmarsat GMDSS terminals only operate below 1540 MHz. This is incorrect. No. 5.353A gives frequency coordination priority to GMDSS in the band 1530-1544 MHz. However, nothing prevents Inmarsat from operating GMDSS terminals in coordinated spectrum outside this range and Inmarsat does operate GMDSS terminals throughout its coordinated spectrum.

4. MSV's measurements are based on limiting the number of carriers to two or three at select frequencies. MSV states that the frequencies have been chosen to optimally protect Inmarsat terminals. MSV also states that selecting frequencies in this manner protects Inmarsat to a much greater extent than a deployment that uses all available frequencies. However, MSV has not explained how in practice it will be able to select operational ATC frequencies that provide this optimum protection of Inmarsat terminals. The choice of optimum ATC frequencies would depend on what frequencies are used by the potentially affected Inmarsat terminals. Inmarsat's frequency plans change frequently in response to traffic requirements and to improve spectrum efficiency. It would be unrealistic to assume that MSV would be able to dynamically accommodate these changes in Inmarsat spectrum use. Inmarsat has addressed other concerns with site-by-site coordination requirements in its December 8, 2004 Application for Review.

5. MSV argues that Inmarsat terminals should use their power control capabilities to overcome interference from MSV's ATC base stations and requests a relaxation of the base station constraints on the basis of Inmarsat assuming this responsibility. First,

there is no basis to require that Inmarsat bear the burden of MSV's waiver request. Moreover, as a technical matter, it is contrary with the primary reason for the introduction of power control mechanism in MSS systems and the way in which the downlink power control operates. Downlink power control is used to minimize satellite power to the level actually required depending on link characteristics. It cannot be used to overcome the high levels of ATC interference, including receiver saturation, that would occur in the vicinity of ATC base stations, because this would defeat its purpose of saving satellite power and would have no effect whatsoever in situations where METs are already receiving maximum power.

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



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Dated: February 3, 2005

**ATC Interference Into Inmarsat Aeronautical Terminals**

In this technical annex we respond to the technical points raised in MSV’s January 14, 2005 *Ex Parte* in which MSV attempts to explain its incorrect calculations of interference into Inmarsat aeronautical terminals.<sup>1</sup>

Inmarsat showed conclusively in its January 5, 2005 pleading that MSV had made considerable errors in its calculation of interference from a single ATC base station to an Inmarsat aeronautical terminal.<sup>2</sup> MSV had claimed a positive margin of more than 6 dB for an aircraft flying at an altitude of 65 meters on a trajectory that passed directly over an ATC base station. Inmarsat showed, with full back up of every step of the calculation, that in fact the margin, given the very same set of assumptions, was negative 6 dB at zenith, and worsening to negative 9 dB at a horizontal distance of around 430 meters.<sup>3</sup> In addition and more importantly, MSV’s analysis is based on the -50 dBm receiver threshold derived from the voluntary ARINC Characteristics 741.

Rather than admitting its errors, MSV attempts, unconvincingly, to extract itself from this embarrassing situation by making a set of claims that are contrived and just plain wrong. The excuses MSV makes are summarized as follows:

- (a) MSV claims that it was not trying to indicate the margin when the aircraft was immediately overhead the ATC base station, but just a little bit either side of the zenith position. This is surprising considering the way that MSV presented its results in tabular form, which are repeated again below. Considering the structure of this table, was the reader really meant to assume that he should not interpolate between the different columns of the table, such as with an X and Y value of 0, right in the middle of the table? The most positive way to interpret MSV’s table, and MSV’s subsequent explanation, is that MSV was attempting to deliberately conceal the worst case interference margin when it originally presented this table.

**MSV’s Analysis of AMS(R)S Receiver Trajectory over one ATC Base Station Emitting 32 dBW EIRP per Sector and using the Relaxed Overhead Gain Suppression Pattern (AMS(R)S Receiver at 65 Meters Altitude; Base Station Located at X, Y = 0, 0 km)**

X	-4	-3.4	-2.8	-2.2	-1.5	-0.9	-0.3	0.3	0.9	1.5	2.2	2.8	3.4	4
Y	-4	-3.4	-2.8	-2.2	-1.5	-0.9	-0.3	0.3	0.9	1.5	2.2	2.8	3.4	4
Over. Level (dBm)	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50
Agg. Rec. Sig. (dBm)	-68.5	-67.2	-65.7	-63.9	-61.6	-58.7	-56.9	-56.9	-58.7	-61.6	-63.9	-65.7	-67.2	-68.5
Margin (dB)	18.51	17.22	15.71	13.89	11.63	8.73	6.87	6.87	8.73	11.63	13.89	15.71	17.22	18.51

<sup>1</sup> MSV Technical Response to Inmarsat’s January 5, 2005 Filing, IB Docket No. 01-185 (filed January 14, 2005).

<sup>2</sup> Appendix A to January 5, 2005 Reply of Inmarsat in the Application for Review of DA 04-3553 (included as Attachment A to Inmarsat’s January 21, 2005 *ex parte* submission in IB Docket 01-185).

<sup>3</sup> Note that Inmarsat believes the assumptions used by MSV are incorrect, and therefore that the interference situation is in fact much worse than this calculation suggests. This was fully explained in Inmarsat’s January 5 pleading.

- (b) MSV asserts that the aircraft antenna gain towards the ATC base station, when the aircraft is at positions in the sky corresponding to an elevation angle of greater than 30° as seen from the base station, should be reduced to -10 dBi, rather than using the value used by the FCC in its ATC Order, which is 0 dBi. Note that MSV clearly stated in footnote 4 of its December 23, 2004 pleading that "... the AMS(R)S terminal antenna gain in the direction of the base station is set to 0 dBi ...".

MSV cites an RTCA document to support the assertion that airborne low gain antennas used in the AMSS have similar characteristics to GPS airborne antennas. This assertion is completely incorrect because:

- a) The gain of an AMSS Low Gain Antenna is optimized for situations in which the satellite is at lower elevation angle relative to the aircraft horizon, which is when the path loss is greater between a geostationary satellite and an aeronautical terminal, and also when the effects of multipath are more significant and need to be mitigated. When the geostationary satellite is overhead the aircraft ('zenith' direction), the path loss to the satellite is reduced and the AMSS Low Gain Antenna specifications have been carefully designed to sacrifice gain in the overhead/zenith direction so that the gain towards low elevation angles can be increased. These considerations do not apply to airborne GPS antennas in view of the fact that the GPS system is composed of 24 satellites constantly moving in medium Earth orbit (MEO) in which the non-obstructed view of the sky from the GPS antenna on the aircraft will allow the GPS system at any given time to receive signals from a number of GPS satellite, well in excess of the minimum requirement, allowing the GPS system not to be dependent on receiving signals from GPS satellites that are at low elevation angles with respect to the aircraft horizon.
- b) MSV cites the GPS antenna gain values of RTCA/DO235A, Appendix G, as representative of AMS(R)S Low Gain Antennas. An antenna with such characteristics would not satisfy the AMSS antenna gain requirements as outlined in RTCA MOPS 210D
- c) The electrical and physical characteristics of an airborne GPS antenna and an AMS(R)S Low Gain Antenna are markedly different as can be seen on the product specification in Attachments A and B. Inside the blade AMSS antenna there is vertical helix antenna which will create a 'doughnut' shaped antenna pattern optimized in gain towards lower elevation angles. Once mounted on top of the aircraft fuselage, the antenna will allow greater visibility of signals coming from the side or below the aircraft horizon as opposed to the GPS antenna in which visibility of signals coming from below the aircraft horizon will be very limited. The antenna gain for the two different antennas is outlined in the attached product specifications and the considerable difference in gain performance speaks for itself.
- d) The potential for shielding of the antenna by the aircraft is fully recognized by Inmarsat and the performance of all AMS(R)S Low Gain Antennas are tested mounted on a metallic ground plane 'electrically' representative of the worst case shielding effect that is encountered, which is typically that of a Boeing 747 aircraft. To obtain Inmarsat type approval, AMSS antenna manufacturers have to submit their

antennas to the renowned David Florida Laboratory, a division of the Canadian Space Agency. See Attachment C

- e) Furthermore, MSV does not seem aware of the fact that a great majority of the Inmarsat AMSS installations are fitted with High Gain Antennas instead of the Low Gain Antennas, which are primarily used as back-up antennas. A significant proportion of these High Gain Antennas on commercial airliners are side mounted antennas. For this type of antenna, one side-mounted antenna panel is mounted on each side of the aircraft at a 45 degree angle towards the aircraft horizon. The reason for using these antennas is the ability to maintain connectivity when the satellite is at low elevation angles to the aircraft horizon. Attachment D provides data from one of the manufacturers of such antennas in which it indicates full antenna performance at look angles of -15 degrees. In addition, a large proportion of corporate aircraft are fitted with mechanical High Gain Antennas mounted at the top of the aircraft tail, thereby having excellent look angles in all directions (see Attachment E).

In conclusion, MSV's assertion that a gain of -10dBic is a valid assumption for elevation angles between -30 and -90 degrees is derived from GPS performance analysis that is wholly irrelevant to the characteristics of AMSS antennas and associated installation environments. The figure of 0 dBi for the antenna gain at antenna elevation angles ranging from -30 to -90 degrees is fully supported by the fact that Inmarsat High Gain Antennas tightly meet the RTCA MOPS 210D antenna discrimination requirement of '13 dB for angles higher than 45 degrees from boresight'. This antenna requirement has proven to be the most difficult one to meet and in general is met with not much margin. Considering that the antenna gain is normally in the range of 12dBi to 15dBi for elevation angles (with respect to the aircraft horizon) from -15 degrees or more (in particular for side- and tail-mounted antennas), it can be derived that one can only be certain that the gain has dropped by 13 dB from maximum (i.e. resulting in -1dBi to +2dBi of antenna gain) for elevation angles of -60 degrees or lower. Regarding the antenna gain within the remaining range of -60 to -90 degrees of elevation, one needs to take into account that there will be antenna sidelobes on a random basis with gain peaking close to 13 dB below boresight gain, Furthermore aircraft very often carry out banking maneuvers of up 30 degrees. Therefore, the assumption of 0dBi in the ATC Order for elevation angles of -30 degrees to -90 degrees remains sound and is fully justified by the actual antenna data.

MSV then goes on to make further incorrect claims about the analysis by stating that "For a horizontal distance that is greater than approximately 100 meters from the base station zenith, the overload margin increases to over 4 dB." MSV's analysis is completely at odds with Inmarsat's analysis, as presented in its January 5, 2005 pleading, which shows that the margin reaches a level of negative 9 dB at a horizontal distance of around 430 meters for -50 dBm receiver threshold. Note that, at such a horizontal distance, the elevation angle to the aircraft (under the given assumptions used for this analysis) is significantly below 30°, and therefore even MSV would agree that the correct aircraft antenna gain to use is 0 dBi. All the assumptions relevant to this analysis are therefore identical between MSV and Inmarsat, yet MSV still has an error, in its favor, in excess of 13 dB in its results. The details of Inmarsat's analysis of this situation, including all the assumptions, are provided below:

Assumptions:

- (a) ATC base station antenna height is 30 meters above the ground, and aircraft altitude is 65 meters above the ground;
- (b) 4 dB interference reduction due to voice activity;
- (c) 5.2 dB interference reduction due to power control;
- (d) AMS(R)S antenna gain is 0 dBi;
- (e) ATC base station down-tilt angle is 5°;
- (f) shielding due to aircraft body already accounted on antenna gain in (d);
- (g) 0 dB polarization discrimination.

Analysis for the case of aircraft at horizontal distance of 430 meters:

ATC base station peak EIRP per sector

$$= +32 \text{ dBW (i.e., 8 dB increase over the value in the ATC rules)}$$

Elevation angle to aircraft at horizontal position of 430 meters from the base station

$$= \text{ATAN}(35/430) = 4.65^\circ$$

Gain suppression towards aircraft (at elevation angle of 4.65°, corresponding to off-axis angle of 9.65°)

$$= 5 \text{ dB (i.e., } G_{\text{max}} - 5, \text{ according to gain suppression mask)}$$

ATC base station EIRP per sector towards aircraft

$$= +27 \text{ dBW}$$

Distance between ATC base station antenna and aircraft at horizontal distance of 430 meters

$$= \text{SQRT}(430^2 + 35^2) = 431.4 \text{ meters}$$

Spreading loss from ATC base station antenna to aircraft (for distance of 431.4 meters)

$$= 10 \log (4 \pi 431.4^2) = 63.7 \text{ dB}$$

Effective aperture of 0 dBi receive antenna at 1.5 GHz

$$= G \lambda^2 / 4 \pi = 0.003183 \text{ m}^2$$

$$= -25.0 \text{ dB-m}^2$$

Interfering signal power at Inmarsat receiver

$$\begin{aligned} &= +27 - 63.7 - 25.0 - 4 - 5.2 = -70.9 \text{ dBW} = -40.9 \text{ dBm} \\ &= \underline{9.1 \text{ dB above assumed threshold of } -50 \text{ dBm and not } 4 \text{ dB below as claimed by MSV}^4 \end{aligned}$$

The interference impact would be even greater than shown above if the power control reduction (5.2 dB) and voice activity (4 dB) factors assumed are not valid. The Commission included these factors in its analysis when assessing the impact of a large number (1000) of ATC base stations, based on the statistical effect of these mechanisms over a large number of channels. As the interference calculated above is from a single base station, and these factors rely on averaging over a large number sources, Inmarsat believes that these factors are not applicable. Furthermore, the voice activity factor would be approximately zero for data communications, which is a growing type of traffic on mobile communications systems, and could well occupy an entire GSM channel. Similarly, when a base station is communicating with a disadvantaged ATC user, there will be no power control reduction, and again this could be the case for an entire GSM channel.

In conclusion, the ATC Order and the MSV ATC license grant already underestimate the interference impact on aeronautical terminals by using an incorrect figure of -50 dBm for receiver threshold. This needs to be corrected, without reference to incorrect assumptions on antenna gain that MSV posits. MSV's January 14, 2005 analysis should be disregarded because MSV has made errors in its calculations, demonstrated a lack of understanding of the operation of AMSS, and has selectively presented its results in a way that hides the worst case aeronautical interference situations.

---

<sup>4</sup> Note that Inmarsat believes the assumptions used in this analysis are incorrect, and they are used here solely to illustrate the errors in MSV's analysis. The interference situation is in fact much worse than this calculation suggests. This was fully explained in Inmarsat's January 5 pleading.

**Attachment A**

GPS Passive Antenna

# GPS S67-1575-Series

ARINC 743A



## SPECIFICATIONS

	GPS		
	S67-1575-16	S67-1575-52	S67-1575-82
<b>ELECTRICAL</b>			
Frequency .....	1575.42 MHz	1575.42 MHz	1575.42 MHz
VSWR .....	1.5:1	2.0:1	2.0:1
Polarization .....	RHCP	RHCP	RHCP
Impedance .....	50 ohms	50 ohms	50 ohms
Antenna Gain (Typ) .....	3 dBic @ Zenith		
Gain Coverage (min) .....	-1.0 dBic	0° ≤ θ ≤ 75°	
	-2.5 dBic	75° < θ ≤ 80°	
	-4.5 dBic	80° < θ ≤ 85°	
	-7.5 dBic	θ = 90° @ Horizon	
Gain (preamp) .....		26.0 dB	40.0 dB
Noise Figure .....		2.5 dB	2.5 dB
Power Handling .....	1 watt	1 watt	1 watt
Voltage .....		+4 to 24 VDC	+4 to 24 VDC
Current .....		25 mA	45 mA
Lightning Protection .....		DC grounded	

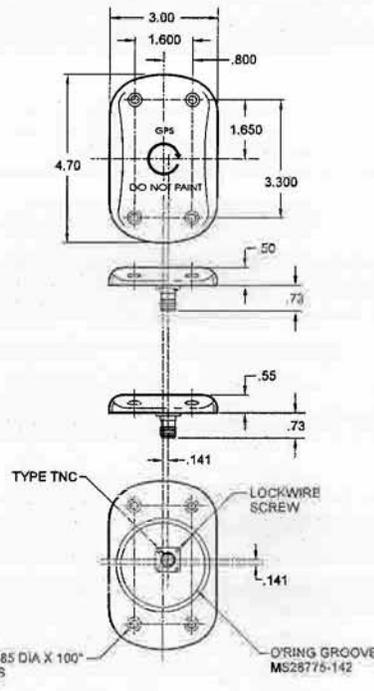
## MECHANICAL

Weight .....	5 oz.	6 oz.	6 oz.
Height .....	.50 in.	.55 in.	.55 in.
Width .....		3.0 in.	
Length .....		4.70 in.	
Material .....	6061-T6 aluminum / thermoset plastic		
Finish .....	Skydrol resistant enamel		
Connector .....	TNC		

## ENVIRONMENTAL

Temperature .....	-67°F to +185°F		
Vibration .....	10 G's		
Altitude .....	55,000 ft.		

## OUTLINE DRAWING



S67-1575-16

S

S67-1575-52

S67-1575-82

S67-1575-82

## DESCRIPTION

**S67-1575-16:** ARINC 743A passive GPS antenna. Low profile, with advanced radome design and material, offers enhanced protection against rain, ice and lightning strikes. Hermetically sealed. ARINC applications.

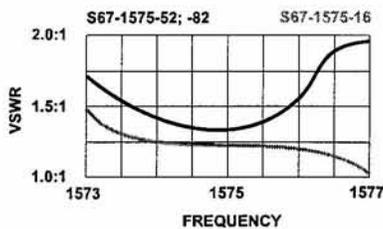
**S67-1575-52:** Same as (-16) except 26 dB gain internal amplifier with special filtering for airline applications. Requires +4 to +24 VDC with internal voltage regulator. D.C. bias is provided through the coax connector. Height .55 inches.

**S67-1575-82:** Same as (-52) except 40.0 dB gain amplifier.

**S67-1575-38:** Same as (-52) except covers GPS/ Glonass frequency Band.

**FEDERAL & MILITARY SPECS:** FAA TSO C115a and C129, DO-160, MIL-STD-810, ARINC 743A, MIL-C-5541, MIL-E-5400.

## PERFORMANCE



1575 MHz  
L1



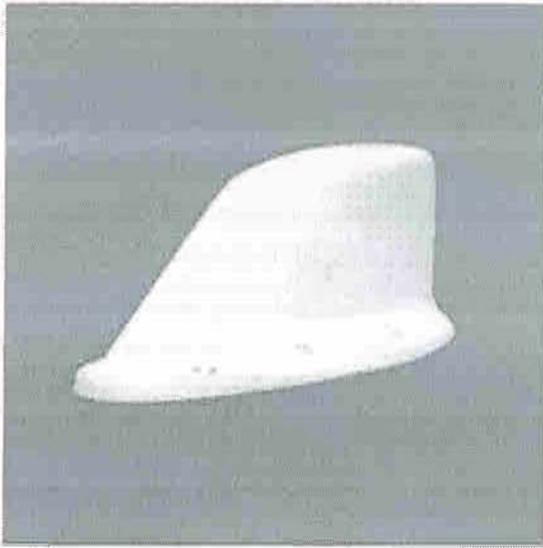
RADIATION PATTERN

**Sensor Systems Inc.**  
8929 Fullbright Avenue  
Chatsworth, CA 91311 USA  
818-341-5366 fax: 818-341-9059  
email: info@sensorantennas.com  
www.sensorantennas.com

**Attachment B**

Inmarsat Low Gain Aeronautical Antenna

# S Satcom S65-8282-101; -201



## DESCRIPTION

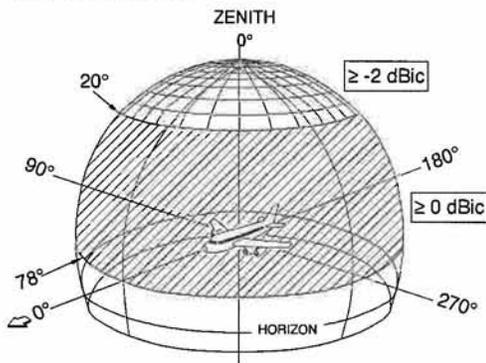
**S65-8282-101:** Low-gain INMARSAT Satcom antenna provides 93% sky coverage and is approved for both Aero-L and Aero-C applications. May be used to back up the high-gain antenna ARINC 741 Aero-H communications should the high-gain antenna lose its satellite link. Reliable link for both Aero-C (store and forward) and Aero-L system. Small size, low drag profile radome.

INMARSAT approved under Letter of Assessment Number 960909TC.RO4. FAA PMA.

**S65-8282-201:** Identical to above except LHCP. May be used for Geostar applications requiring Left Hand Circular Polarization (LHCP). Continuously covers the frequency range of 1530-1660.5 MHz. Provides 93% sky coverage.

**FEDERAL & MILITARY SPECS:** ARINC 741, DO-160C, FAA PMA, MIL-HDBK-5400T, MIL-STD-810D, MIL-C-5541, MIL-E-5400.

## PERFORMANCE



## SPECIFICATIONS

ELECTRICAL	SATCOM	
	S65-8282-101	S65-8282-201
Frequency .....	1530-1559 MHz	1530-1559 MHz
	1626.5-1660.5 MHz	1626.5-1660.5 MHz
VSWR .....	1.5:1	1.5:1
Polarization .....	RHCP	LHCP
Impedance .....	50 ohms	50 ohms
Power Handling .....	60 watts CW	60 watts CW
Gain .....	$\geq -2$ dBic @ $-20^\circ \leq \theta \leq +20^\circ$ $\geq 0$ dBic @ $+20^\circ < \theta \leq +78^\circ$ $\geq 0$ dBic @ $-20^\circ > \theta \geq -78^\circ$ 0° = Zenith	
Lightning Protection .....	DC grounded .....	

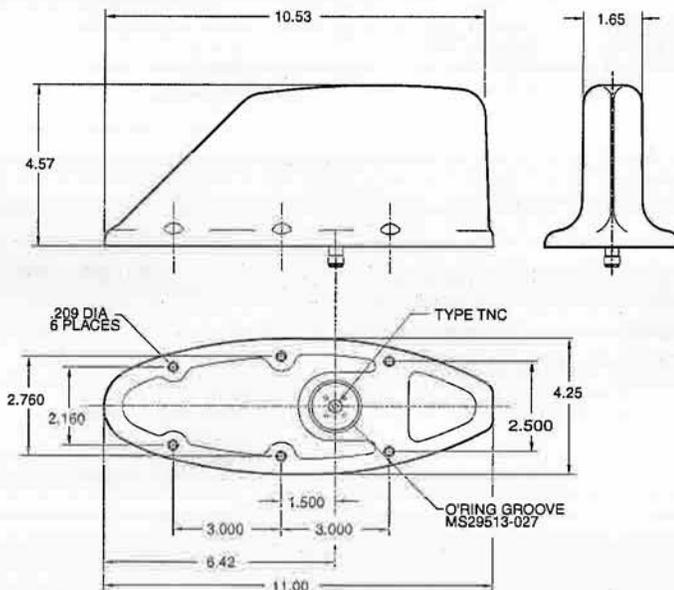
## MECHANICAL

Weight .....	1.5 lbs. ....
Height .....	4.57 in. ....
Length .....	11 in. ....
Width .....	4.25 in. ....
Material .....	6061-T6 aluminum / thermoset plastic .....
Finish .....	Skydrol resistant enamel .....
Connector .....	TNC .....
Drag .....	1.1 lbs. Mach .85 @ 35,000 ft. ....

## ENVIRONMENTAL

Temperature .....	-65°F to +185°F .....
Vibration .....	10 G's .....
Altitude .....	70,000 ft. ....

## OUTLINE DRAWING



**Sensor Systems Inc.**  
 8929 Fullbright Avenue  
 Chatsworth, CA 91311 USA  
 818-341-5366 fax: 818-341-9059  
 email: info@sensorantennas.com  
 www.sensorantennas.com

S67-8282-201

**Attachment C**

Canadian Space Agency---David Florida Laboratory

Canadian Space  
AgencyAgence spatiale  
canadienne

Canada

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**CSA Sectors*****David Florida Laboratory*****INMARSAT Aeronautical Antenna Testing**

The CSA and INMARSAT agreement designates the DFL as its sole authorized antenna test house. The DFL supports RF and environmental measurements on Aeronautical Earth Station (AES) Low, High, and Intermediate gain installations to verify compatibility with INMARSAT satellite communication access approval requirements.

The AES Assessment Software System Service Coverage package processes raw data into suitable formats for quantitative and qualitative analysis.

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Updated: 2002/12/31

Important Notices

**Attachment D**

Inmarsat High Gain, Side-Mounted Aeronautical Antenna



## AIRLINK® High-gain Antenna System

[home](#) | [programs](#) | [products](#) | [profile](#) | [careers](#) | [news](#) | [contact us](#)



**Ball Aerospace's AIRLINK® High-gain Antenna System (HGAS) provides worldwide voice and data transmission using Inmarsat's Aero H system.**

The AIRLINK® system consists of two conformal antenna assemblies, two beam steering units (BSU), two diplexers/low noise amplifiers (DIP/LNA), signal combiner and high power relay, and associated wiring. The AIRLINK® HGAS is operating on more than 30 different aircraft types, including government VIP/SAM aircraft.

The AIRLINK® high-gain antennas are side-mounted, conformal, electronically steered phased arrays. The HGAS is comprised of two antenna assemblies located on the aircraft exterior at nominally 45 degrees on either side of the aircraft, providing a coverage area of 360 degrees around, and 210 degrees above the aircraft. This ensures high reliability, and provides superior coverage for all latitudes and aircraft maneuvers.

The antenna footprint is 16 in. (406.4 mm) by 32 in. (812.8 mm), and 0.375 in. (9.5 mm) thick; the antenna's aerodynamically efficient design produces the lowest drag of any SATCOM antenna system.

### Features and Benefits

- Lowest drag of any SATCOM antenna resulting in significant fuel savings.
- Lower installed weight (103 lb) than top-mount antenna system (113 lb.).
- Dual phased-array antennas for lowest "look angle" (-15 degrees) provide the most reliable satellite acquisition available, even at high latitude.
- Exceedingly robust antenna construction with no delamination failures in its 10-year history.
- Successfully integrated with avionics from Rockwell-Collins, Honeywell/Racal, Sextant and Toshiba.
- Fully compliant with the ARINC 741 Specification for SATCOM systems.

[AIRLINK® High-gain Specifications](#)

Other AIRLINK® Products:

AIRLINK® High-gain Antenna System

- [AIRLINK® Low-gain Antenna System](#)
- [Secure AIRLINK® Systems](#)
- [AIRLINK® Software](#)

[Contact us](#) for more information about this specific product.

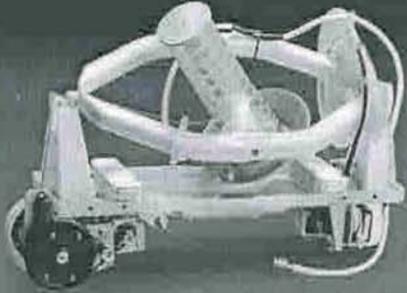
*Copyright © 2004 by Ball Aerospace & Technologies Corp.*

**Attachment E**

Inmarsat High Gain, Tail-Mounted Aeronautical Antenna

# eNfusion AMT-50

Inmarsat high gain antenna



**eNfusion AMT-50: the world's most reliable, multi-channel Aero-H/H+ antenna.**

The eNfusion AMT-50 continues to set the aviation standard for tail-mounted Inmarsat multi-channel Aero-H/H+ antenna. The AMT-50 has proven reliability in a form factor design to minimize weight when installed in a tail-tip radome on a wide variety of aircraft.

## features

The eNfusion AMT-50 is the antenna of choice for aircraft OEMs and Business Jet Owners.

- Multi-channel capability
- Hemispherical coverage (no key holes or gaps)
- Lightweight: 18.4 lbs./8.3 kg total
- No holes in aircraft fuselage
- Compatible with ARINC 741 AVIONICS
- 28VDC power
- OEM installed
- Best retrofit solution
- Over 1,000 systems in service
- Optimal position for view of Inmarsat satellites
- Ku Band transparent for co-installation with DBS Systems

**EMS**  
SATCOM

## installed, approved and operating on:

### Fixed Wing – Commercial

- G-IIB
- G-III
- G-IV/G-IVSP
- G-V/G-IVSP
- G-400/450/500/550
- CL-600/601/604
- Global Express, G-5000, XRS
- Falcon 50/50EX
- F-900/900EX
- F-2000/F-2000EX
- Falcon 7X
- Cessna Citation X
- BBJ/BBJ2

### Fixed Wing – Military

- C-40B
- C-37A
- C-40
- C-20
- C-130

### Rotary Wing – Commercial

- Sikorsky S-92

### Rotary Wing – Military

- Sikorsky H-53, H-60 "Blackhawk"
- Boeing B234/CH-47

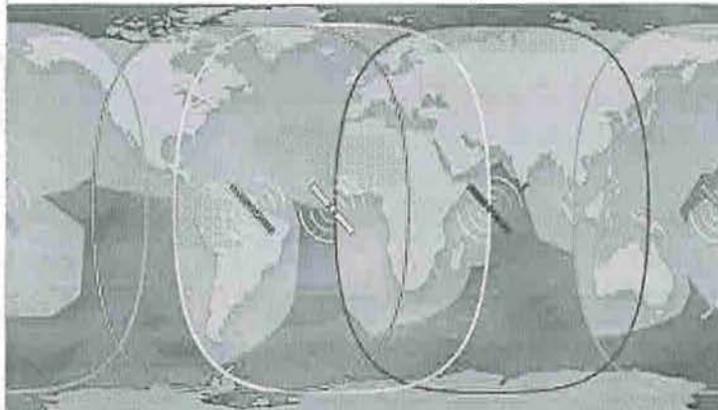
## specifications

<b>Frequency</b>	1530.0 MHz to 1660.5 MHz
<b>Coverage</b>	seamless hemispherical coverage >95%
<b>High Gain Antenna</b>	171"L x 13.5"H x 10.0"W 5.1 lbs.
<b>Antenna Driver Assembly</b>	14.0"L x 2.5"H x 4.6"W 6.8 lbs.
<b>Diplexer/LNA</b>	11.1"L x 2.0"H x 7.8"W 6.5 lbs.
<b>Operating Temperature</b>	-63°C to +71°C

These specifications are subject to change without notice. Printed in Canada 10/04

## coverage map

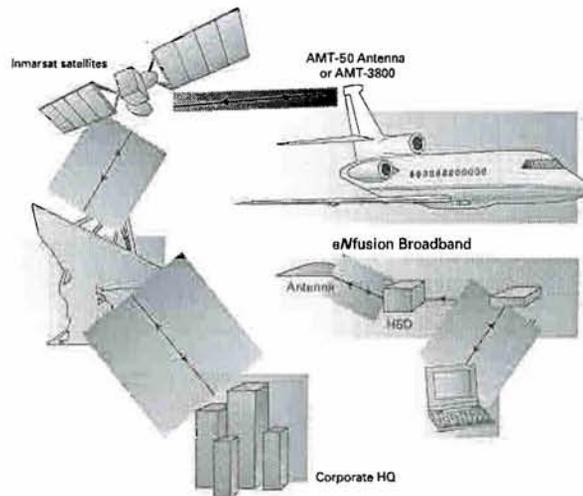
eNfusion Broadband, partnered with Inmarsat, serves customers across most of the continental world and within most major flight paths.



Limit of global beam coverage for Inmarsat Aeronautical Services

- Pacific Ocean region
- Atlantic Ocean region-east
- Atlantic Ocean region-west
- Indian Ocean region
- Inmarsat Swift64

## how it works



**EMS**  
SATCOM



EMS Satcom  
1725 Woodward Drive  
Ottawa, Ontario  
K2C 0P9

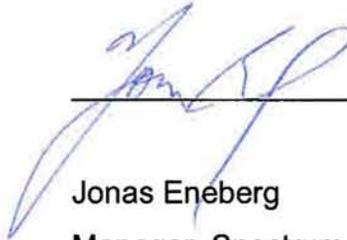
1 800 600-9759 (North America)  
1 613 727-1034 (Worldwide)

info@emssatcom.com

www.emssatcom.com

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



---

Jonas Eneberg  
Manager, Spectrum  
Inmarsat Limited  
99 City Road  
London EC1Y 1AX  
United Kingdom

Dated: February 3, 2005

**Effect of MT Antenna Gain Pattern on Uplink Interference**

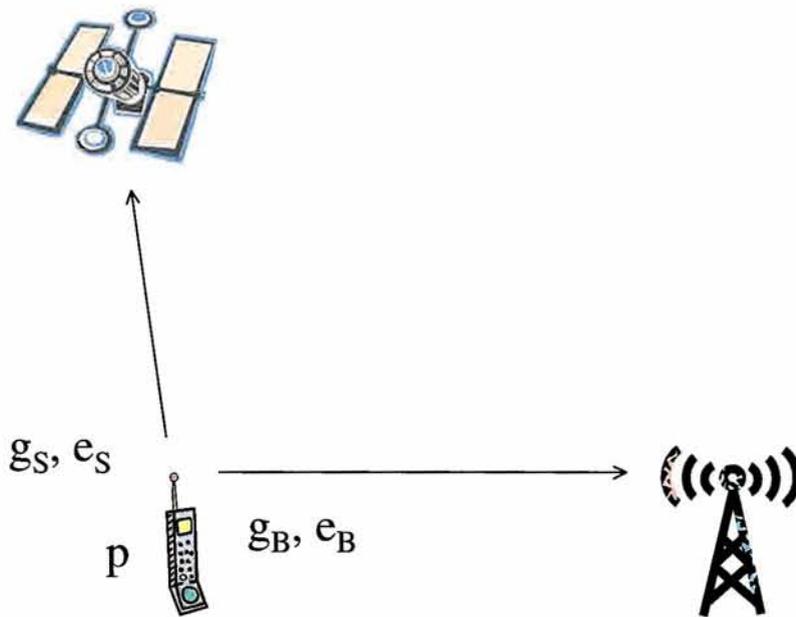
1. Introduction

In the MSV ATC Application, Appendix H, MSV presented an analysis of the average antenna gain of L-band ATC mobile terminals. Based on measured and theoretical antennas, MSV demonstrated that the average gain of MSV’s planned ATC MTs is -4 dBi. Based in part on this data, the Bureau allowed a 40% increase in the number of ATC co-channel reuses and a relaxation of the ATC vocoder constraints, when it granted MSV’s ATC licence.

This paper demonstrates that the effect of the MSV MT antenna gain pattern is that the *average MT EIRP towards the Inmarsat satellite is greater than the average MT EIRP towards the ATC base station*. As a result, the 4 dB relaxation in the ATC limits granted by the Bureau is not justified.<sup>1</sup>

2. Description of the interference scenario

The interference scenario is depicted in Figure 1, showing the wanted and interfering signal paths towards the ATC base station and the Inmarsat satellite respectively.



**Figure 1: Interference scenario**

The following equations apply:

$$e_B = p \cdot g_B \tag{equation 1};$$

$$e_S = p \cdot g_S \tag{equation 2}.$$

<sup>1</sup> Inmarsat has previously pointed out that many other factors in the FCC interference analysis are uncertain and that several FCC assumptions may underestimate the actual interference impact on Inmarsat satellites.

where

- $e_B$  (W) is the MT EIRP in the direction of the ATC base station;
- $e_S$  (W) is the MT EIRP in the direction of the Inmarsat satellite;
- $g_B$  (#) is the MT antenna gain towards the ATC base station;
- $g_S$  (#) is the MT antenna gain towards the Inmarsat satellite; and
- $p$  (W) is the transmit power of the ATC mobile terminal.

The MT EIRP and antenna gain towards the base station,  $e_B$  and  $g_B$ , are determined by the location of the user and the MT antenna alignment relative to the base station. Given these two parameters, the transmit power of the MT,  $p$ , is set by automatic power control to the appropriate level, determined by *equation 1*. Note that the MT transmit power,  $p$ , is inversely proportional to the antenna gain,  $g_B$ , so that  $p$  is high when  $g_B$  is low and vice versa.

However, in the direction of the satellite, there is no correlation between the MT antenna gain and transmit power. Hence, whereas high transmit powers are associated with low antenna gains in the direction of the base station, the same high transmit powers are, on average, associated with average antenna gains towards the satellite. In other words, when the transmit power is high, the antenna gain (and hence EIRP) will tend to be higher towards the satellite than towards the base station. Similarly, when the transmit power is low, the antenna gain (and EIRP) will tend to be lower towards the satellite than towards the base station. Another way to look at this is that the distribution of EIRP values in the direction of the satellite will contain more extreme cases (high and low) than the EIRP values towards the base station. This will typically result in a higher average EIRP towards the satellite than towards the base station.

### 3. Statistical analysis

In accordance with the above, we have

$$e_B = p \cdot g_B$$

$$e_S = p \cdot g_S = \frac{e_B}{g_B} \cdot g_S$$

where all parameters are now random variables. As mentioned above, the distribution of  $e_B$  is determined by the location of the user and the characteristics of the ATC cell;  $g_B$  and  $g_S$  have the same distribution according to the MSV antenna pattern.

The mean EIRP towards the Inmarsat satellite is determined by

$$E\{e_S\} = E\{e_B\} \cdot E\{g_S\} \cdot E\left\{\frac{1}{g_B}\right\} = E\{e_B\} \cdot E\{g_B\} \cdot E\left\{\frac{1}{g_B}\right\}$$

Hence, the factor  $\Delta E = E\{g_B\} \cdot E\left\{\frac{1}{g_B}\right\}$  determines the difference in EIRP towards the ATC base station and the Inmarsat satellite. In the ATC Application, MSV specified two measured antenna patterns: one for a 'patch' antenna and one for a 'stubby'

antenna. Using these patterns and also using the interpolation methods used by MSV, but with nulls limited to -15 dBi, Inmarsat has calculated the following values.

Antenna	MSV mean gain	Mean gain calculated by Inmarsat	Mean inverse gain calculated by Inmarsat
'Patch'	-4.5 dBi	-4.2 dBi	6.1 dBi
'Stubby'	-4.7 dBi	-4.2 dBi	8.3 dBi

Hence, Inmarsat's calculations show that in the case of the 'patch' antenna,  $\Delta E$  is 1.9 dB and in the case of the 'stubby' antenna  $\Delta E$  is 4.1 dB.

It should be noted that this calculation assumes that there is 15 dB headroom in power control. Therefore the results apply to outdoor and vehicle powers. A smaller difference would occur in-buildings.

Practical measurements of MT antennas, such as those reported in [1], and MSV's reported measurements of the stubby antenna suggest that depths of 20-30 dB are measurable. Inmarsat calculated the mean gain and mean inverse gain for the stubby antenna assuming a null depth of 20 dB – the average antenna gain over all orientations was then -4.4 dBi and the average inverse antenna gain was 10.1 dB. Thus in this case, the power difference would be 5.7 dB.

#### 4. Conclusion

From the rationale above, validated by industry experts with extensive experience in the terrestrial cellular arena, it is clear that the 4 dB relaxation in the ATC limits requested by MSV cannot be justified. It has been demonstrated that, due to the MT antenna pattern presented by MSV, the average EIRP in the direction of the Inmarsat satellite will be greater than the average EIRP in the direction of ATC base stations. It is of utmost importance that this effect is taken into account in the interference analysis. Inmarsat strongly urges the FCC to reconsider the relaxations in ATC limits granted for MSV based on the use of the average MT antenna gain.

#### References

- [1] Jorn Toftgard, Sten Hornsleth, Jorgen Bach Andersen, "Effects on Portable Antennas of the Presence of a Person", IEEE Transactions on Antennas and Propagation, Vol. 41, No. 6, June 1993, pp. 739-746

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



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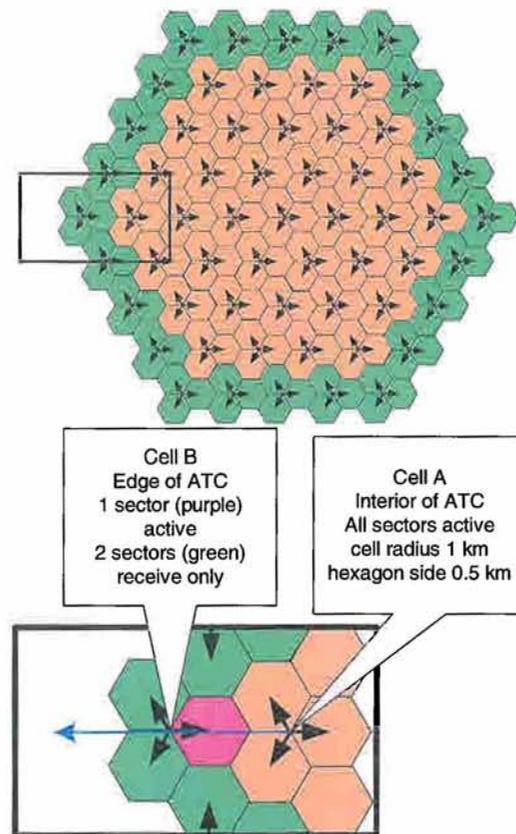
Dated: February 3, 2005

David Thompson  
Principal Engineer  
Multiple Access Communications Ltd.  
Delta House  
Chilworth Science Park  
Southampton SO16 7NS  
United Kingdom

### Analysis of MSV's proposed method to ensure sharp signal cut-off at edge-of-coverage

In its ATC Application, Appendix E, MSV describes a method to ensure that mobile terminals will not operate outside the edge of coverage of ATC areas at high EIRP levels. MSV proposes to use receive-only sectors at the edge to achieve this. This paper demonstrates that the method proposed by MSV will not ensure that MTs do not operate at high power levels outside the intended ATC coverage area and a different strategy to the one proposed by MSV is required.

Figure 1 shows the ATC area surrounded by edge cells<sup>1</sup>. We will examine what happens in the area of the rectangle.

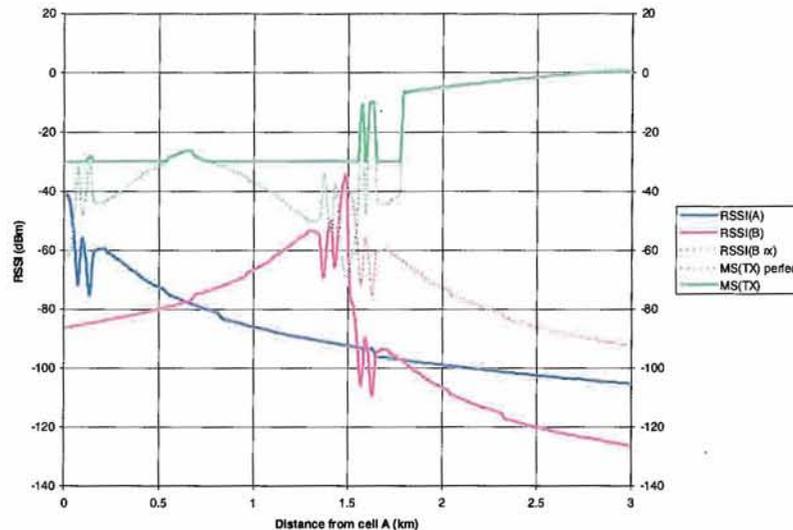


**Figure 1: Example ATC area surrounded by edge cells**

In the blown-up part of the ATC area shown in the rectangle in Figure 1, the green sectors are receive-only, whereas all other sectors transmit. The base station antennas are assumed to be at 5 degree downtilt and have 85 degree horizontal width. A mobile terminal is assumed to travel along the route shown in blue starting in cell A on the right and passing cell B and out of the network.

<sup>1</sup> It should be noted that actual ATC network coverage areas are likely to be much less regular than the circular shape shown in Figure 1. This will have the effect of increasing the length of the boundary and hence the proportion of mobile terminals that are likely to operate outside the intended network coverage area.

Figure 2 shows the received signal strength identification (RSSI) for cells A and B and the MT EIRP.



**Figure 2: Illustration of cell handovers**

From Figure 2 it can be seen that between 0 and 1.5 km, the MS TX power shows the effects we would expect. Handover from cell A to B occurs at about 600 m. After 1.5 km, we see handover again occurring between cell B and A because the RSSI from cell A is stronger than cell B, as the edge sectors are receive-only.

When cell B is stronger than cell A, we see the benefit of the receive-only sectors which produce low MT EIRPs. As the distance from the ATC coverage area increases, the MS hands back to cell A and transmits very high powers. As a result of this, MSV's strategy will not work as intended.

The terrain outside the intended ATC coverage area will affect the magnitude of the problem highlighted above. Open terrain or high elevations will exacerbate the problem.

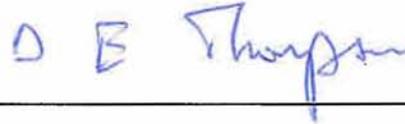
In conclusion, the Commission needs to require MSV to employ a different strategy than the one proposed to ensure that MTs are not able to operate at high power levels outside the intended ATC coverage. In the absence of an improved strategy, Inmarsat's satellite system will not be protected.

### **Effect of handover hysteresis and fast moving mobile terminals**

When an MT moves from one cell to another in a cellular network, handover will not occur at the ideal cell boundary. Hysteresis is introduced to avoid MTs switching rapidly back and forth between cells. The amount of hysteresis applied is a network parameter, which can be changed even after the network has been deployed. MTs that have passed the ideal handover point but have not yet met the hysteresis requirement will have higher transmit power than inferred from the simplistic network arrangement shown in Figure 1. This applies throughout the network (not just at the edge of coverage) and will have the effect of increasing the average MT EIRP.

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



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Dated: February 3, 2005

## **Distribution of MSV ATC base stations and co-frequency reuse limit within the United States**

### **1. Introduction**

In a January 7, 2005, ex parte, MSV presents an affidavit from LCC International Inc, to the effect that MSV will be able to determine the number of ATC base stations and the traffic operating on its licensed frequencies both within and outside the US at any given time. MSV claims that this affidavit demonstrates that the Commission can allow MSV to use over 50% of its "authorized system-wide co-channel reuse" in the US while ensuring that MSV does not exceed a system-wide co-channel reuse allowance.

MSV is wrong. The Commission has previously considered this issue and denied MSV's requests for increase co-channel reuse on this basis. The Commission's position on this remains entirely appropriate, as discussed in the following sections.

### **2. The FCC never authorized a system-wide reuse for MSV**

First, MSV is wrong in how it characterizes the base station limit adopted in the February 2003 ATC Order. In its Petition for Reconsideration and ATC Application, MSV claimed that it would deploy 80% of its ATC base stations in the U.S., and only 20% in Canada, and that this provides a basis for the Commission to waive its rules and increase for MSV the limit on the permitted number of co-channel ATC reuses from 1,725. MSV argues that the Commission calculated a total allowable system wide co-channel reuse of 3,450 ATC and apportioned 50% of them to the U.S. Thus, by MSV promising not to deploy more than 20% of its base stations in Canada, MSV argues that it should be able to increase the 1,725 reuse limit to 2,760 within the U.S.

As Inmarsat pointed out in its Opposition to the MSV ATC Application, the Commission did not conclude in the ATC Order that a total of 3,450 co-frequency ATC base stations is an appropriate limit on the total number of ATC base stations inside and outside the U.S. Such a conclusion would be meaningless as the Commission has no authority to enforce such a limit in Canada, Mexico, or anywhere else outside the U.S. Instead, the Commission determined that a limit of 1,725 reuses within the U.S. is necessary to contain MSV's self-interference and correspondingly would adequately protect Inmarsat co-channel uplinks. The Commission also noted that an additional 1,725 co-frequency ATC carriers outside the U.S. could be deployed without appearing to cause undue harm to Inmarsat co-channel uplinks.

### **2. Increasing the permitted co-channel reuse in the U.S. would raise MSV's satellite noise floor above 6% $\Delta T/T$**

The co-channel reuse limit was derived to limit the interference caused by ATC into MSV's own satellite to a level of 6%  $\Delta T/T$ . The Commission calculated (see Table 1.14.A of App. C2 of the ATC Order) that 173 co-channel reuses within the vicinity of one MSV satellite beam would create a 6% noise increase in the MSV satellite. The FCC then made the unstated assumption that MSV's ATC stations would be essentially uniformly distributed and hence imposed a U.S.-wide reuse limit of 1,725. It can be noted that if MSV's ATC usage is non-uniformly distributed across the U.S.

(as is likely) the noise increase will be greater than 6% into some MSV beams. MSV's proposal to deploy more than 1,725 reuses in the US would result in even higher densities of MTs than contemplated by the Commission and accordingly greater uplink interference into MSV. Thus, MSV's proposal, if adopted, would undermine a critical underpinning of the ATC Order – *constraining self-interference into MSV is essential in order to protect Inmarsat from harmful interference.*<sup>1</sup>

### 3. Inmarsat would also receive higher interference

The Commission's analysis of interference into Inmarsat satellites (see Table 2.1.1.C of App. C2 of the ATC Order) is based on an average Inmarsat satellite antenna isolation towards CONUS of 25 dB. However, this gain is not constant across CONUS. For example, a satellite beam that is pointed to an area that is closer to CONUS than to Canada would have a higher average gain over the U.S. than over Canada. Hence, if the density of ATC base stations is greater over the U.S. than over Canada, such a beam would receive more interference than in the case of a uniform distribution of base stations.

### 4. ATC in other countries

The Commission's limits appropriately take into consideration the potential actions of non-U.S. administrations. As the Commission acknowledged, Inmarsat is susceptible to the aggregate affects of ATC uplink interference over a large portion of the Americas. The Commission has no authority to limit the deployment of ATC base stations that are authorized by the regulatory authorities in Canada, Mexico, Central America, the Caribbean or South America. MSV refers to the fact that it is currently only licensed in the U.S. and Canada. However, MSV's coverage map (see for example MSV Application, Fig 1-2) includes many other countries, e.g. Mexico, the Caribbean and countries in Central and South America. There is no guarantee that MSV will not subsequently be authorized to operate ATC also in these countries. Even if MSV itself decides not to deploy ATC outside the U.S. and Canada, other non-U.S. administrations could authorize operators to deploy ATC systems or other secondary applications that would cause uplink interference into Inmarsat's and MSV's MSS systems. Such systems would obviously be completely out of MSV's control.

### 5. Conclusion

The Commission's interference analysis appropriately leaves a margin for the possibility of additional interference from ATC or other secondary uses of the L-band spectrum outside the U.S. To reduce this margin, as proposed by MSV, would significantly increase the impact of ATC uplink interference into Inmarsat. The Commission had a rational basis for establishing the limits set forth in the ATC Order based on its interference analysis, the desire to protect Inmarsat from ATC

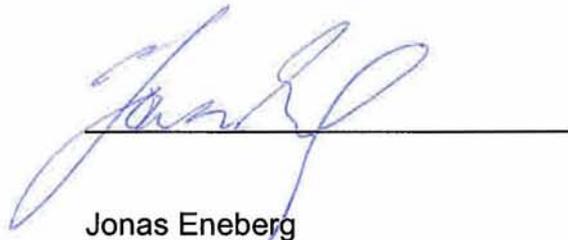
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<sup>1</sup> ATC Order at para 145 ("By limiting the number of base stations carriers permitted to operate on a 200 kHz channel, the noise increase to the MSV satellite is limited to 0.25 dB. We find this restriction is necessary because we are not convinced, based on the record, that MSV can accurately and repeatedly measure this low level of interference at their satellite and we believe that this limitation on MSV's satellite noise increase will provide for MSS ancillary terrestrial service and limit the potential for interference to other co-frequency MSS operators.") and App. C-2 at §1.14.

interference, MSV's representations, and the international considerations inherent in an uplink interference analysis in the L-band. MSV's desire to place a greater percentage of MTs in the U.S. does not warrant a change or waiver of the Commission's existing limits on the number of ATC co-channel base stations in the U.S.

ENGINEERING INFORMATION CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparing or reviewing the engineering information contained in the foregoing submission and that it is complete and accurate to the best of my knowledge and belief.



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Dated: February 3, 2005

**MEMO Number** CSTCOE-EFCL-0220**DATE:** 3-Feb-2005**TO:** Rohan Hiesler**FROM:** E. F. C. LaBerge/Orville K. Nyhus**SUBJECT: Interference Signal Levels for Inmarsat Aero H & S64**

## 1 INTRODUCTION

At the meeting with FCC, NTIA, NII, and MSV representatives on 2-Feb-2005, Mr. David Anderson, representing NTIA, raised a number of questions regarding the -72 dBm interference level established in RTCA DO-210D [1]. We reiterate that this MOPS is the basis for FAA TSO-C132 and, as such, is the only appropriate starting point for any assessment of harmful interference. Mr. Anderson pointed out that the MOPS document permits no degradation beyond the "no interference" specification in the presence of an interfering signal of -72 dBm separated in frequency by at least 1 MHz from the active Aero H<sup>1</sup> channel. Mr. Anderson referenced an early RTCA SC-165 WG1 working paper [2] as the rationale for the -72 dBm value. According to [2], the -72 dBm value would induce a "noise temperature increase of 1 K". This negligible increase in noise temperature is supported by the "no degradation" language in DO-210D. Mr. Anderson clearly expressed his opinion that this level is far below a reasonable criteria for "harmful interference". Therefore, he concluded that the -72 dBm level was unnecessarily pessimistic for use in MSV analysis.

This document confirms both Mr. Anderson's interpretation of [2] and his conclusion regarding the -72 dBm interference level. We then move on to show that, using the same model used for the -72 dBm level, the level of -50 dBm used by MSV in their interference analysis is much too high and clearly results in unacceptably harmful interference to the Aero H channels. We then use the methodology of [2] to arrive at a suggested level of interference for Aero H channels. Existing and future AMSS terminals should be tested to confirm ability to meet this theoretically derived criterion.

We then consider the more critical case of the high data rate channels, known as Swift 64. Under conservative performance assumptions about the effect of compression, and using measured data from representative ground equipment, we show that the 16-QAM signal modulation is substantially more susceptible to signal compression than the Aero H channels. We note that the U.S. Government uses a large number of aeronautical Swift 64 terminals. We further note that future aeronautical BGAN terminals will be at least as sensitive to interference as current Swift 64 terminals. Again applying the methodology of [2], we show that a reasonable threshold for harmful interference is -60 dBm. This is a similar level of susceptibility of other Inmarsat terminals assumed in the ATC Order.

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<sup>1</sup> Throughout this document, the term "Aero H" is imprecisely used to refer to any of the channels, data rates and modulations covered by DO-210D [1].

## 2 SUMMARY OF [2]

In SC165/WG1-WP/140[2], dated 4 August 1994, Dr. Nyhus establishes a third order polynomial model for the saturation characteristics of an amplifier. Using an assumed amplifier voltage gain of  $k_1 = 1000$  volts/volt = 60 dB, and a 1 dB output compression point of +10 dBm, [2] derives a value for the third-order non-linear coefficient as  $k_3 = -1.1517 \times 10^8$  volts/volt<sup>3</sup>.

Referring to SC165/WG1-WP/134 [3], [2] states the simple and fundamental relationship between the large signal voltage compression factor,  $g_c$  and the small signal voltage compression factor  $g_e$  as

$$g_e = 2g_c - 1 \quad (1.1)$$

The value of  $g_e$  reflects the effective compression of a small desired signal when appearing at the input to an amplifier simultaneously with a large signal that drives the amplifier into some degree of compression.

Reference [2] then treats the resulting compression as an effective decrease in a carrier level and, therefore, a decrease in any signal-to-noise ratio factor that is linearly proportional to carrier level. This simplification is a conservative approach that ignores any potential phase error or other distortions that may accompany the voltage compression. Working through the various assumptions, [2] concludes that an input (large) signal level of -72 dBm corresponds to a decrease in (small signal) carrier level equivalent to a 1 K increase in noise temperature of the receiver. Such a small increase should not significantly impact the bit error rate (BER) performance of the receiver.

## 3 CONSIDERATION OF AERO H CHANNELS (<21 KBPS CHANNEL RATE)

We now apply the methods of [2] to an input interference signal of -50 dBm, corresponding to the 1 dB output compression point of the low noise amplifier. By the definition of the 1 dB compression, we have

$$g_c = 10^{(-1/20)} = 0.8913 \quad (1.2)$$

The value is a unitless voltage ratio. Applying (1.1), we have

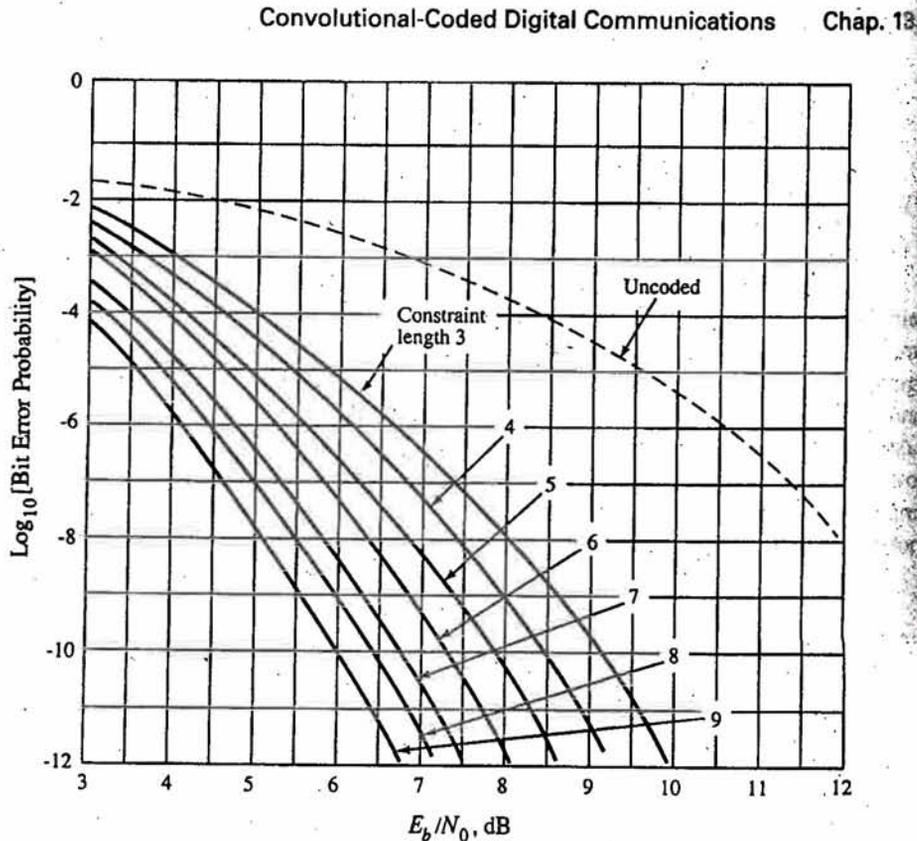
$$g_e = 2(0.8913) - 1 = -2.1 \text{ dB} \quad (1.3)$$

This result indicates that in the presence of a -50 dBm input signal at the LNA, the small desired signal will undergo a compression of about 2.1 dB.

In keeping with the practice established in [2], we treat this compression as a loss in signal to noise ratio. For the purpose of this section, the signal to noise ratio of interest is the usual ratio of the bit energy,  $E_b = CT_b$ , to the noise power spectral density,  $N_0$

The Inmarsat Aero H channels use a rate  $\frac{1}{2}$  convolutional code with constraint length  $K = 7$ . Computing bounds on the bit error rate performance of this code under soft decision Viterbi

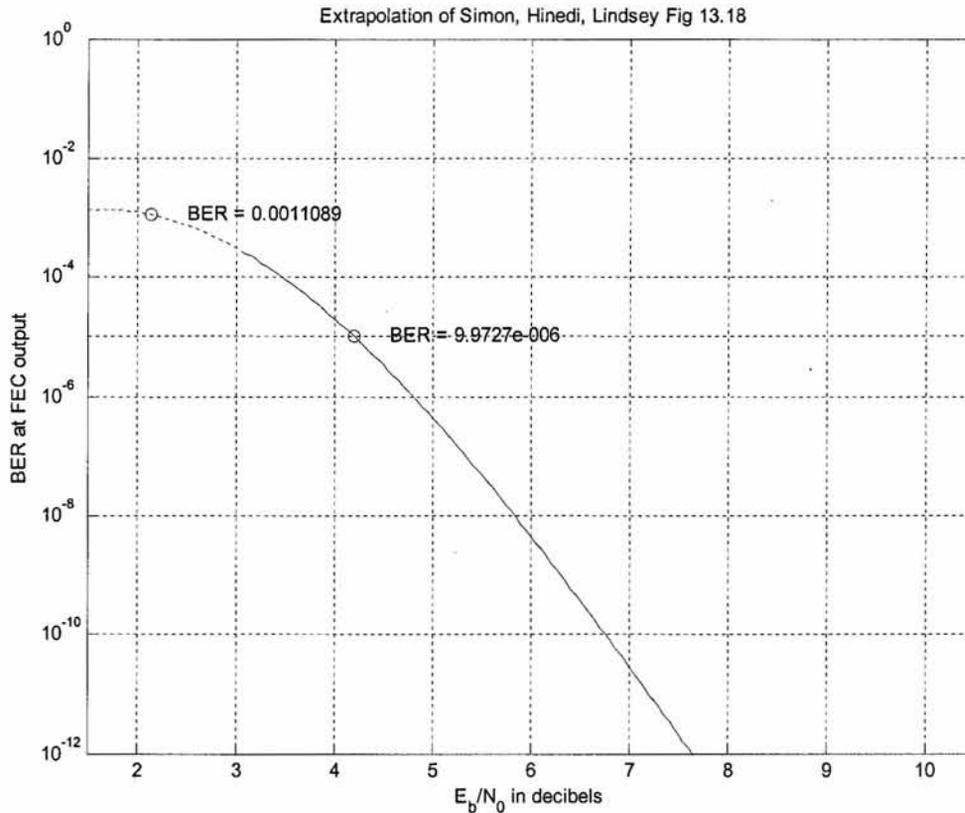
decoding is tedious, so we will use published results from Simon, Hinedi, and Lindsey [4]. The performance curves as a function of  $E_b/N_0$  for a variety of values of  $K$  are shown in [4, Figure 13.18], reproduced here as Figure 1. From Figure 1, we see that the DO-210D [1] BER performance of  $BER = 1 \times 10^{-5}$  is achieved at a value of  $E_b/N_0 = 4.2$  dB.



**Figure 13.18** Bit error probability performance for various rate 1/2 convolutional codes using soft-decision decoding (Reprinted from [18])

**Figure 1: BER Performance for Rate 1/2 Convolutional Codes in AWGN**

Now consider the effect of a -50 dBm interference signal. As just shown, the effect of a signal at the 1 dB compression point of the LNA is a 2.1 dB degradation of the carrier level for the small desired signal. The effect is to reduce the  $E_b/N_0$  at the demodulator from 4.2 dB to 2.1 dB, with a corresponding increase in the BER. By smoothly extending Simon's curves to the left as shown by the dashed region in Figure 2, we estimate that a 2.1 dB



**Figure 2: Extrapolation of Simon, Hinedi, Lindsey Figure 13.18**

decrease in the value of  $E_b/N_0$  results in an increase in the channel BER from  $1 \times 10^{-5}$  to  $1.11 \times 10^{-3}$ . This is a BER expansion ratio of 111:1, which is clearly unacceptable.

Therefore, under the *same* amplifier model used to justify that -72 dBm interference induces only a negligible increase in receiver temperature, we have clearly demonstrated that interference at the -50 dBm level, i.e., the 1 dB compression point of the LNA, causes unacceptably harmful interference by *increasing* the BER by a factor of 111:1.

An interference level of -50 dBm is clearly unacceptably high.

This conclusion begs the question, "what level of interference might be acceptable for the Aero H channels?" Using the techniques of [2], we can estimate the BER expansion ratio as a function of the interfering signal level. The FCC test procedure appears to be predicated on a 10:1 increase in BER. If we adopt this BER expansion ratio the absolute maximum threshold for harmful interference, will be approximately -54 dBm. Such threshold is the *absolute maximum* that can be tolerated for a short duration (180 seconds) for Aero H channels, beyond this short period the link is declared unusable and terminal de-registers from the system. We will now show, even this

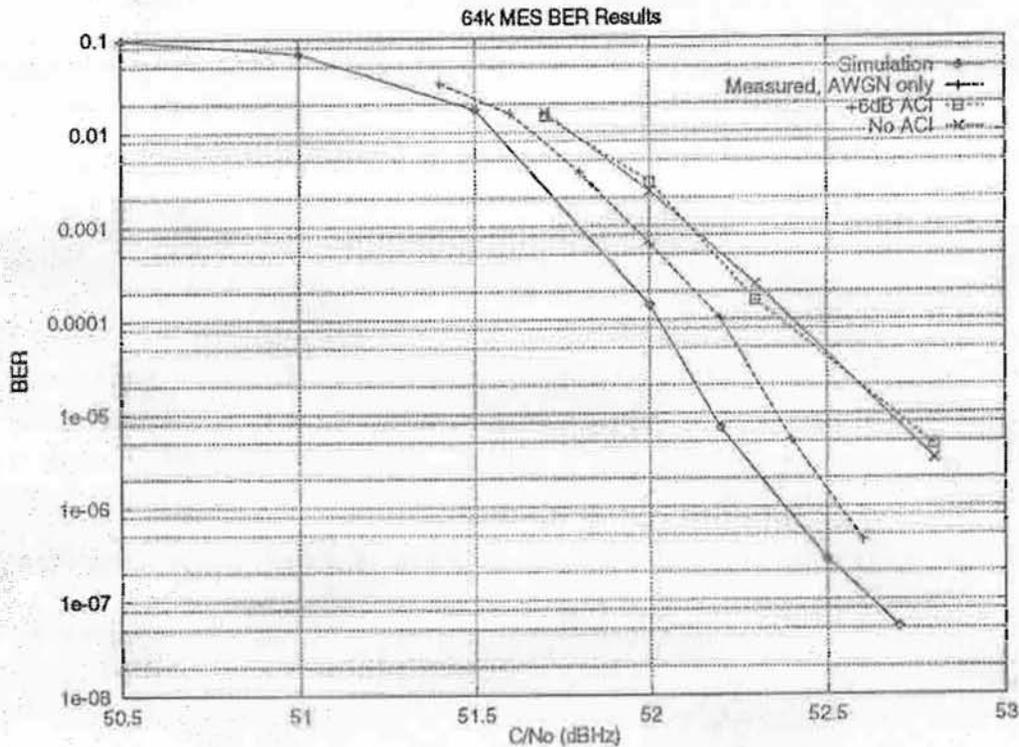
value is far to large to protect the Swift 64 and BGAN channels, which use higher order modulations to promote efficient use of the spectrum by high-data rate services.

#### 4 CONSIDERATION OF SWIFT64 AND BGAN CHANNELS (>64 KBPS USER RATE)

The Swift 64 and BGAN channels use 16 state Quadrature Amplitude Modulation (16-QAM) to obtain higher channel capacity. Several hundred Swift 64 aeronautical terminals are currently in service, primarily in US business corporate and Government aircraft. Both of these high-data rate services are specified by the effective maximum *user* data rate, not the *channel* data rate. Both services use advanced modern turbo coding techniques to operate with relatively low carrier-to-noise density  $C/N_0$  requirements. The penalty for the excellent performance obtained by the higher order constellations and advanced coding techniques is a *much steeper* BER curve. That is, a degradation of a *few tenths of a decibel* in  $C/N_0$  will have major BER impact on the high data rate services. In other words, turbo-codes tend to perform as "on / off" channels, i.e. they provide significant performance gain compared to convolutional codes, but performance will collapse very rapidly beyond the threshold operational point.

##### Consider the measured BER curves shown in

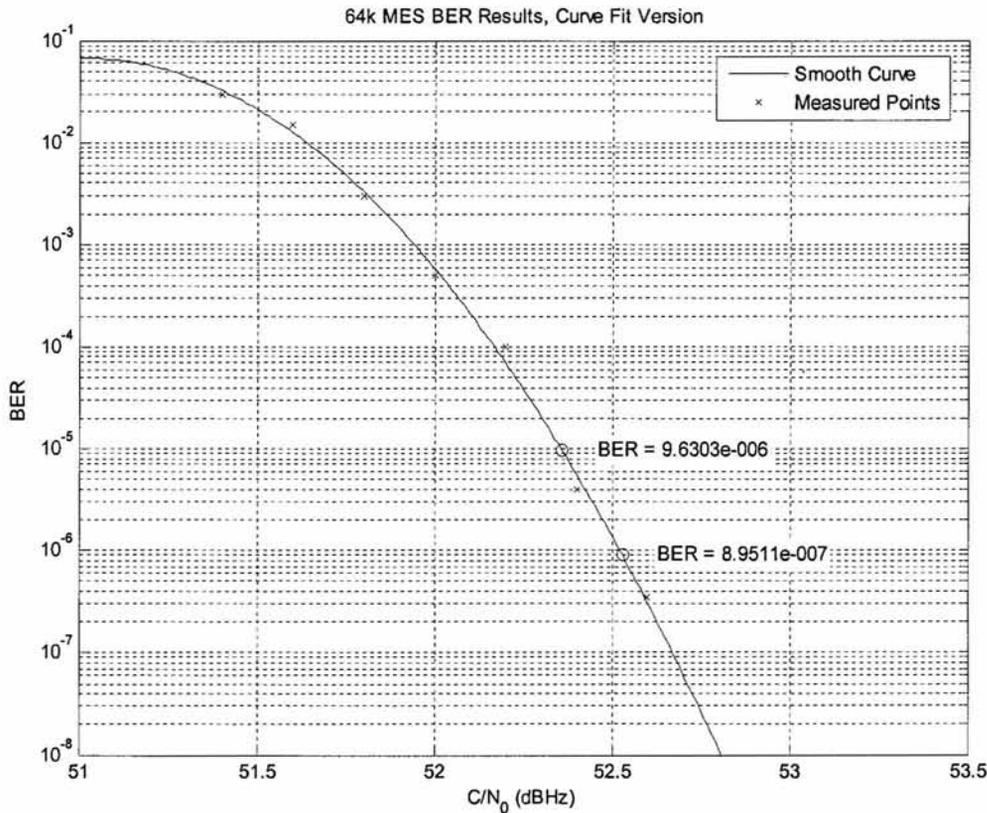
. Because the DO-210D requirements discussed earlier were applied to a channel that was unimpaired by receiver non-linearities other than the LNA saturation, the appropriate curve to consider is the AWGN curve. Note that the slope of the ACI curves is essentially similar, so the results of this analysis using those curves would be similar.



**Figure 3: Measured BER Performance of Swift 64 MES**

Notice that the horizontal axis of Figure 3 is expanded from the axis of Figure 2, covering a range of only 2.5 decibels. It is clear that the effect of interference at the -50 dBm compression point, which induces a 2.1 dB small signal compression as discussed above, can result in a BER expansion ratio of  $10^3$  to  $10^5$ , depending on what initial operating point is chosen. This is clearly unacceptable, so we must once again determine an acceptable value for the small signal compression.

We start by noting that the standard reference operating point for Swift 64 and BGAN is a BER of  $1 \times 10^{-6}$ , as appropriate for the much higher user data rate of these services. For ease of extrapolation, we then used a smoothed curve version of Figure 3, shown in Figure 4.



**Figure 4: AWGN BER Curve for 64k MES**

As in Aero H case discussed earlier, we adopt a BER expansion ratio of 10:1 as the absolute worst case<sup>2</sup> definition of harmful interference. Starting with the reference operating point of  $BER = 1 \times 10^{-6}$  we see from Figure 4 that the allowable degradation is no more than 0.15 dB.

We can now apply the techniques of [2] to determine what level of interfering signal would result in a small signal compression factor of 0.15 dB. Coincidentally, this value is an example specifically given more than 10 years ago in [2]: the answer is -60 dBm.

We note that this approach is rather simplistic in estimating the performance of the 16-QAM channels. It is quite likely that the effects of compression are somewhat more severe than predicted by a simple decrease in signal-to-noise ratio used here. In particular, of major concern is the effect of inter-modulation products between the interfering signal and the Swift-64 (and BGAN) signals, which are based on 16-QAM modulation. These signals are highly spectrally efficient, but on the other hand are significantly more sensitive to inter-modulation interference

<sup>2</sup> By "worst case", we mean that other definitions at lower BER expansion ratios may be more appropriate. Definitions at BER expansion ratios greater than 10:1 are unacceptable to Inmarsat or its terminal manufacturers.

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compared to phase only modulated signals such as QPSK. Hence the results presented in this note should be considered carefully before using them in interference coordination.

## 5 CONCLUSIONS

Based on this analysis, we conclude the following:

1. We extend the methodology of [2] to show that the -50 dBm 1 dB compression point is not a suitable definition of harmful interference for Aero H channels. Interference at this level will increase the BER by a factor of 111, thereby increasing the BER to  $1 \times 10^{-3}$ . Such error rates will cause a failure of Aero H services.
2. We extend the methodology of [2] to show that an interference level of approximately -54 dBm corresponds to an increase in the BER to  $1 \times 10^{-4}$ . This level can only be sustained for a short period of time otherwise there is a severe impact to Aero H operations.
3. We extend the methodology of [2] using measured data from the Swift 64 MES terminals to show that an interference level of -50 dBm could cause a BER expansion of between 1000 and 100,000 for the 16-QAM turbo coded channels.
4. We extend the methodology of [2] to show that an appropriate interference threshold for a BER expansion factor of 10 in the 16-QAM turbo coded channels would be -60 dBm.
5. These theoretical susceptibility threshold levels (based on [2]) must be validated with proper testing of the relevant aeronautical terminals.

/s/

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