UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and
Information Administration
Washington, D.C 20230

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Mr. Donald Abelson
Chief, International Bureau
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

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Federal Communications Commission
Office of the Secretary

01-185

Dear Mr. Abelson:

The National Telecommunications and Information Administration (NTIA) appreciates this opportunity to review and comment on the Federal Communications Commission's (Commission) Notice of Proposed Rulemaking (NPRM) in the *Matter of Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz, the L-Band, and 1.6/2.4 GHz Band.*[1] NTIA is only addressing the interference issues and associated recommendations. We are not taking a position on any other policy issues associated with the NPRM.

In the NPRM, the Commission requests comment on proposals received from New ICO Global Communications (Holding) Ltd. (ICO), Motient Services Inc., and Mobile Satellite Ventures subsidiary (MSV) to operate ancillary terrestrial component (ATC) base station transmitters (BTS) with their networks using assigned mobile satellite service (MSS) frequencies. The BTS would operate in the 1525-1559 MHz band (MSV Proposal), or the 1990-2025 and 2165-2200 MHz bands (ICO Proposal). The BTS is to be integrated with the satellite network and will employ directional antennas that are expected to provide coverage to areas where the satellite signal is attenuated by foliage or terrain or to provide in-building coverage. In addition to the BTS, MSV will employ pico base stations that may be located on ceilings of buildings or on building walls and will use omni-directional antennas. There are also mobile terminals (MTs) that will be used in conjunction with the BTS and pico base stations.

In the NPRM, the Commission recognized that the unwanted emissions from terrestrial stations in the MSS will have to be carefully controlled in order to avoid interfering with GPS receivers.[2] The Commission specifically requested comments on whether limits for base stations similar to those specified in Section 25.213(b) for satellite mobile earth stations (MES) used in

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[1] *In the Matter of Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz, the L-Band, and 1.6/2.4 GHz Band*, IB Docket No. 01-185 (rel. Aug. 17, 2001).

[2] *Id.* at ¶68.

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conjunction with the satellite are adequate to protect GPS receivers.'[3] The frequency range over which the emission limits specified in Section 25.213(b) apply is 1574.397-1576.443 MHz. There are two issues that must be considered in the Commission's request for comment on the protection of GPS: 1) the frequency range over which the emission level would be applicable; and 2) whether the emission level established for a MES should be applied to a base station. Furthermore, the NPRM did not address the emission limits of the MTs used in conjunction with the BTS and pico base stations.

The frequency band 1545-1555 MHz is allocated to the aeronautical mobile satellite route service (AMS(R)S) in the space-to-Earth direction. AMS(R)S is reserved for communications relating to safety of flight (see provisions No. 1.36, 1.59, 5.357A, and Article 44 of the Radio Regulations). The frequency band 1530-1544 MHz is allocated to the Global Maritime Distress and Safety System (GMDSS) in the space-to-Earth direction. This international application is required by international treaty resulting from the Safety of Life at Sea (SOLAS) Convention. Since the BTS will have emissions that fall within the AMS(R)S and GMDSS receiver channels there is a potential for interference. However, the NPRM did not request comment on potential interference to AMS(R)S and GMDSS receivers.

To address the potential interference to GPS, AMS(R)S, and GMDSS receivers, NTIA performed three technical analyses that are provided as enclosures to this letter. Based on the results of the analysis in Enclosure 1, NTIA cannot support the Commission's proposed BTS emission levels in the GPS L1 (1559-1610 MHz), L2 (1215-1240 MHz), and L5 (1164-1188 MHz) frequency bands. Instead, NTIA recommends: 1) a maximum allowable equivalent isotropically radiated power (EIRP) of -71 dBm/MHz (wideband emissions) and -81 dBm (narrowband emissions) in the L1 frequency band; and 2) a maximum allowable EIRP of -73 dBm/MHz (wideband emissions) and -83 dBm (narrowband emissions) in the L2 and L5 frequency bands.

The Commission did not propose an emission level for the MTs used in conjunction with the BTS and pico base stations. Based on the results of the analysis in Enclosure 2, NTIA recommends: 1) a maximum allowable EIRP of -75 dBm/MHz (wideband emissions) and -85 dBm (narrowband emissions) in the L1 frequency band; and 2) a maximum allowable EIRP of -77 dBm/MHz (wideband emissions) and -87 dBm (narrowband emissions) in the L2 and L5 frequency bands.

Also, the Commission did not make a proposal for BTS adjacent channel emissions in the channels used by AMS(R)S and GMDSS receivers. Based on the results of the analysis in Enclosure 3, NTIA recommends: 1) a maximum allowable EIRP of -32.8 dBm/200 kHz per BTS carrier in the 1545-1555 portion (AMS(R)S channels) of the 1525-1559 MHz band; and 2) a maximum allowable EIRP of -22.5 dBm/200 kHz per BTS carrier in the 1530-1544 MHz portion (GMDSS channels) of the 1525-1559 MHz band.

[3] *Id*

The United States Coast Guard and the Navy expressed concern regarding aggregate interference from MTs used in conjunction with BTS to Inmarsat satellite receivers that *are* used to support GMDSS operations (1626.5-1645.5 MHz) and AMS(R)S operations (1646.5-1656.5 MHz). While these federal agencies do not operate the satellite transmitter, the operation of these satellite receivers is required under treaty obligations. The interference to a satellite receiver from a large number of MTs **is** cumulative, and will affect the uplinks from all mobile terminals located in the satellite beam, such as those used for GMDSS and AMS(R)S. Based on the analysis in Enclosure 4, operation of MTs at the **EIRP** level proposed by MSV co-channel with GMDSS and AMS(R)S operations should he avoided. The analysis in Enclosure 4 also shows that operation of MTs at the EIRP levels proposed by MSV on channels adjacent to GMDSS and **AMS(R)S** operations is feasible.

The National Oceanic and Atmospheric Administration (NOAA) operates Search and Rescue Satellite (SARSAT) Local User Terminals (LUTs) in the 1544-1545 MHz portion of the 1525-1559 MHz band. SARSAT provides distress alert and location information to appropriate public safety rescue authorities for maritime, aviation, and land users in distress. The LUTs are used to receive the information from the SARSAT satellites. NOAA currently has 14 LUTs at 7 known locations, therefore coordination with BTS operators is possible. Based on the analysis in Enclosure 5, a 30 km distance separation between a BTS and a SARSAT LUT is necessary for compatible operation. Possible techniques to reduce the distance separation include but are not limited to: 1) reduce the BTS antenna gain in the direction of the SARSAT LUT location; **2)** lower the BTS emission level in the 1544-1545 MHz portion of the 1525-1559 MHz band; and **3)** *take* into account specific terrain features and other obstacles located between the BTS and SARSAT LUT location on a site-by-site basis.

The NTIA proposed emission levels in the GPS bands for the BTS and pico base stations are believed to be achievable with current technology since these stations can implement larger filters that will provide additional attenuation of the out-of-band emissions. The NTIA proposed reduction of the adjacent channel emissions to protect AMS(R)S and GMDSS receivers are also believed to be achievable. **NTIA** recognizes that the emission levels in the GPS bands for the MTs used in conjunction with the BTS and pico base stations may be difficult to achieve using current handset technology. However, the trends in handset development indicate a reduction in adjacent band and out-of-band emissions may be possible.

The calculations of maximum allowable EIRP of the BTS and pico base stations *are* based on a variety of assumptions, not all of which may apply in every installation. Since there are no limitations on the antenna heights for the base stations used in the system architecture proposed by MSV, the analysis results of the pico base station, which represents the limiting interference case, are used to establish the maximum allowable EIRP levels necessary for compatible operation with GPS receivers. Because installations of BTS and pico base stations must be licensed, it may be possible to include installation restrictions in the license. For example, to restrict the maximum density of BTS installations there should be a minimum separation distance between BTSs of 1 km. The license should include limitations on the minimum antenna height of the BTS and pico base stations that will assure sufficient separation from GPS receivers. Provisions should also be included in the license to restrict base station operations within 500 feet of a runway.

NTIA has obtained the views of both industry and the Federal agencies. To this end, NTIA had a number of discussions with MSV. MSV provided NTIA their analysis which was based on a 8 slot Time Division Multiple Access (TDMA) access technique that is consistent with the Global System for Mobile (GSM) communications system architecture. Their analysis also included a specific vo-coder frame occupancy rate that reduces the effective average power of the MT by the duty cycle attributed to the frame occupancy. For example, using an 8 slot TDMA system architecture, employing a quarter rate vo-coder, would reduce the effective average power (averaged over a 20 millisecond period) of an MT by 15 dB (10 Log 32). If these or similar techniques are employed, the EIRP levels specified for the MTs can be achieved.

In *summary,* NTIA has only focused on the interference issues and resolution thereof and not taken a position on any other policy issues. NTIA would appreciate an opportunity to consider our technical analysis with the Commission's staff and stands ready to support the Implementation of this developing technology while ensuring the protection of GPS and other safety related systems.

Sincerelv.

Fredrick R. Wentland
Acting Associate Administrator
Office of Spectrum Management

5 Enclosures

ENCLOSURE 1

ASSESSMENT OF INTERFERENCE TO GLOBAL POSITIONING SYSTEM RECEIVERS FROM ANCILLARY TERRESTRIAL. COMPONENT BASE STATIONS OPERATING IN THE 1525-1559 MHz MOBILE SATELLITE SERVICE BAND

BACKGROUND

The Federal Communications Commission (Commission) received proposals from New ICO Global Communications (Holding) Ltd. (ICO), Motient Services Inc., and Mobile Satellite Ventures Subsidiary (MSV)[1] to operate ancillary terrestrial component *(RTC)* base station transmitters (BTS) with their networks using assigned mobile satellite service (MSS) frequencies. The BTS would operate in the 1525-1559 MHz band (MSV Proposal)[2], or the 1990-2025 and 2165-2200 MHz bands (ICO Proposal). The BTS is to be integrated with the satellite network and will employ directional antennas that are expected to provide coverage to areas where the satellite signal is attenuated by foliage or terrain or to provide in-building coverage. In addition to the BTS, MSV will employ pico base stations that may be located on ceilings of buildings or *on* building walls and will use omni-directional antennas.

In response to the proposals, the Commission initiated a Notice of Proposed Rule Making (NPRM) to obtain comments on the proposals.' The 1525-1559 MHz band of operation proposed by **MSV** is adjacent to the 1559-1610 MHz band that is allocated to the radionavigation satellite service (RNSS). The RNSS systems operating in the 1559-1610 MHz band include: the Global Positioning System (GPS) L1 signal operating in the 1563.42-1587.42 MHz segment of the band and the Russian Federation Global Navigation Satellite System **(GLONASS)** operating in the 1598-1605 MHz segment of the band. GPS and GLONASS are components of the Global Navigation Satellite System (GNSS). The European Union is also planning to operate an RNSS system, Galileo in the 1559-1610 MHz band. It is envisioned that Galileo will also become a component of the GNSS.

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[1] MSV will provide MSS **throughout** North America **using** the satellites launched by Motient Services Inc and TMI Communications and Company Limited Partnership.

[2] *Ex parte* letter from Lawrence H. Williams and Suzanne Hutchings, New ICO Global Communications **(Holdings)** Ltd., to Chairman Michael K. Powell, Federal Communications Commission, IB Docket No. 99-81 (March 8, 2001); Application filed by Motient Services lnc. and Mobile Satellite Ventures Subsidiary LLC for Assignment of Licenses **and** *for* Authority to Launch and Operate a Next-Generation Mobile Satellite Service System (March I, 2001).

[3] *In the Matter of Flexibility for Delivery of Communications by* **Mobile** *Satellite* **Service** *Providers in the 2 GHz, the L-Band, and 1.6/2.4 GHz Band*, IB Docket No. 01-185 (rel. Aug. **17,** 2001) (hereinafter "NPRM").

At the 2000 World Radiocommunication Conference, a new allocation was adopted for the RNSS in the 1164-1215 MHz frequency band. **As** part of the **GPS** modernization program a new GPS signal for aviation and non-aviation applications designated as L5 will be provided in the 1164-1 188 MHz portion of the newly allocated RNSS band. In addition to this new allocation, as part of the **GPS** modernization program a second signal similar to the **L1** coarse/acquisition (C/A) code signal will be provided in the GPS **L2** fiequency band of 1215-**1240 MHz.**[4]

In order to completely assess compatibility of the BTS and pico base stations **with** the GPS service, receivers in the **L1, L2,** and **L5** fiequency bands must be analyzed.

OBJECTIVE

The objective of this analysis is to assess the potential of interference to GPS receivers operating in the L1, **L2,** and L5 fiequency bands from the emissions of BTS and pico base stations operating in **the 1525-1559** MHz band.

APPROACH

To assess the interference potential of BTS and pico base station emissions *to* **GPS** receivers, an analysis will be performed to compute the maximum allowable equivalent isotropically radiated power (EIRP) levels of the emissions in the fiequency bands used by the GPS service that are necessary for compatible operation.

WIDEBAND EMISSION ANALYSIS

In the NPRM, the Commission recognized that the unwanted emissions from terrestrial stations in the MSS will **have** *to* be carefully controlled in order to avoid interfering with GPS receivers.' The Commission specifically requested comments on whether limits for base stations similar to those specified in Section 25.213(b) for mobile earth stations *are* adequate to protect **GPS** receivers.' There are two issues that must be considered in *the* Commission's request for comment on the protection of GPS: I) the frequency range over which the emission level would be applicable; and **2)** whether the emission level established for a mobile earth stations should be applied to a base station.

[4] **The GPS Precision** code (P-code) is currently transmitted in the 1215-1240 MHz band

[5] NPRM **at** ¶68.

[6] ***Id.***

The frequency range over which the emission limits specified in Section 25.213(b) apply is 1574.397-1576.443 MHz. In the current version of the SPS Signal Specification, the GPS L-band SPS ranging signal is defined as a 2.046 MHz null-to-null bandwidth signal centered on L1. The transmitted ranging signal that comprises the GPS-SPS is not limited to the null-to-null signal but extends **through** the band 1563.42 to 1587.42 MHz. Moreover, the Commission's request for comments only addresses the GPS system and not the other present and future components of the GNSS. **As** discussed in RTCA DO-235, the interference protection requirements for GPS and GLONASS are essentially the same.[7] **A** new RNSS system such as Galileo **is** expected to have similar operating characteristics as GPS, and thus will require the same protection from interference. Based on the continuing evolution of the GNSS, the maximum allowable emission level established in this analysis for BTS emissions would apply across the entire 1559-1610 MHz RNSS band. Furthermore, the Commission's request for comment on GPS protection did not include the 1164-1188 MHz and 1215-1240 MHz frequency bands.

The emission levels proposed by the Commission are an EIRP density of -70 dBW/MHz for wideband (noise-like) emissions and an EIRP of -80 dBW for narrowband (continuous wave) emissions. The emission levels are specified for mobile earth stations operating in the MSS. Since base stations and mobile stations can have different operational characteristics, the emission levels established for the MSS mobile earth stations may or may not be adequate to protect GPS receivers. The Commission's request for comment does not address the emission **limits** that are necessary for the mobile earth stations used in conjunction with the BTS and pico base stations.

This analysis considers representative base station operational scenarios in determining the maximum allowable BTS and pico base station wideband emission level that is necessary for compatible operation with GPS receivers. The operational scenarios considered in **this** analysis include: 1) a terrestrial GPS receiver operating in the vicinity of a BTS and pico base station; **2)** a GPS receiver used for en-route navigation flying over multiple BTS; and 3) a GPS receiver used for a precision approach landing operating in the vicinity of a BTS.

Terrestrial GPS Receiver Analysis

The maximum allowable EIRP of the BTS or pico base station ($EIRP_{max}$) is computed using the following equation:

$$EIRP_{max} = I_T + L_P - G_R + L_{allot} - L_{mult} + G(\theta) \quad (1)$$

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[7] Document No. RTCA DO-235, *Assessment of Radio **Frequency Interference** Relevant to the GNSS* **(Jan.** 27, 1997) at **F-12** (hereinafter "DO-235").

where:

I_n is the interference susceptibility threshold of the GPS receiver (dBm/MHz);
L_p is the radiowave propagation **loss (dB)**;
G_R is the GPS receive antenna gain in the direction of the BTS/pico base station (dBi);
L_{allot} is the factor for BTS/pico base **station** interference allotment (dB);
L_{mult} is the factor for multiple BTS carriers (dB);
$G(\theta)$ is the reduction in BTS antenna gain in the direction of the GPS receiver (dB).

The following paragraphs explain each of the technical factors used in the analysis.

GPS Receiver Interference Susceptibility Threshold (I_n). In all GPS bands (L1, **L2,** and L5) the typical GPS receiver system noise density is -171 dBm/Hz for a receiver with a 3 dB noise ***figure.*** The receiver system noise density determines the minimum level of GPS signal that can be used for any application. For example, survey GPS receivers require a fairly high carrier-to-noise density ratio (C/N_0) of about 35 dB-Hz in order to provide the required level of accuracy, while wireless assisted E-911 receivers can provide adequate measurements with a very low C/N_0, such **as 20** dB-Hz. Therefore, with a system noise density of –171 **dBm/Hz,** the survey receiver requires a minimum signal level of –136 dBm, whereas the wireless assisted E-911 receiver can function with a signal as low as –151 dBm. In either case, the receiver system noise density determines the minimum level of **GPS** signal that can be used for a specific application. ***An*** 'x' dB increase in the receiver noise density raises the GPS signal power requirement by the same 'x' dB. Because most terrestrial GPS receivers operate under handicaps such as signal attenuation due to destructive multipath, foliage, or walls, these receivers frequently must operate at their **minimum** signal levels.

Since terrestrial GPS receivers typically operate at their minimum signal levels, any interfering signal which adds to system noise density erodes performance **by** requiring stronger GPS signals to perform the required function. Conventional C/A code GPS receivers require a relatively **high** carrier-to-noise density ratio (C/N_0) because of the wide loop bandwidths that are employed. In contrast, assisted GPS receivers used in E-911 applications can take full advantage of communications network support to obtain and remove the GPS navigation data and to stabilize the receiver clock. In addition, it is assumed that the dynamics *are* very low (e.g., the user is walking). **As** a result, the tracking loop bandwidth can be narrowed very substantially, thus maintaining a positive signal-to-noise ratio in the tracking loop at much lower *CM*, values. Receivers are being designed today that can track with a 20 dB-Hz C/N_0 and the industry is striving to track with a C/N_0 of 10 dB-Hz. Based on a system noise density of -171 dBm/Hz, a 20 dB-Hz C/N_0 represents a receiver signal level of -151 dBm (21 dB below the GPS minimum signal level in the *SPS* ***Signal*** Specification), and a 10 dB-Hz C/N_0 represents a received signal level of -161 dBm (31 dB below the GPS minimum signal level in the SPS Signal Specification). Regardless of the application or the minimum signal level required for that application, it is important to limit any increase in system noise. In this analysis, the increase in system noise caused by the BTS and pico base station emissions is limited to 25%, which equates to an interference-to-noise ratio (I/N) of -6 dB. Based on the I/N of -6 dB, the interference susceptibility threshold used in this analysis is -171 dBm/Hz + 60 - 6 = -117 dBm/MHz.

There are no practical differences in interference susceptibility for GPS receivers operating in any of the three bands, i.e., L1, L2, and L5. Noise interference susceptibility relates only to tolerable increase in noise floor, which for terrestrial applications is identical for all three bands. For example, noise interference susceptibility is not a function of the GPS code structure, e.g., C/A, L2C, or P(Y). It also is not a function of the code tracking technique, e.g., wide correlator, narrow correlator, double delta, multipath mitigation correlator, etc. Therefore, the interference threshold used in this analysis for all GPS bands is -117 dBm/MHz.

Radiowave Propagation **Loss (L_P)**. Initially, the BTS will be used in urban areas where satellite signal levels are low or coverage does not exist. Urban environments can be characterized by non-line-of-sight propagation paths resulting mainly from building blockage. However, even in urban environments there are distances extending several hundred feet where line-of-sight conditions can exist. The propagation model to be used when line-of-sight conditions exist is the free-space model described by the following equation:

$$L_P = 20 \text{ Log } F + 20 \text{ Log } D - 27.55 \quad (2)$$

where:

F is the frequency (MHz);
D is the distance separation between the BTS/pico base stations and the GPS receiver (m).

For the terrestrial GPS receiver analysis the distance separation between the BTS/pico base stations and GPS receiver is the slant range computed using the following equation:

$$D_{sep} = ((h_{GPS} - h_{BTS})^2 + D^2)^{0.5} \quad (3)$$

where:

h_{GPS} is the height of the GPS receiver antenna (m);
h_{BTS} is the height of the BTS/pico base station antenna (m);
D is the horizontal separation between the GPS receiver and BTS/pico base station antennas (m).

The worst-case horizontal distance separation between the BTS/pico base station and GPS receiver exists at the point where the coupling loss is a minimum. The coupling loss is the combination of the propagation loss, the BTS/pico base station antenna gain in the direction of the GPS receive antenna, and GPS receive antenna gain in the direction of the BTS/pico base station. Based on the BTS antenna pattern provided by MSV[8], the GPS antenna model provided in Table 2, and using 6ee space propagation loss, it was determined that the worst-case horizontal distance separation was 150 meters for a BTS antenna height of 30 meters, and 100 meters for a BTS antenna height of 15 meters. The antenna height of the GPS receiver was 1.5 meters. Using Equation 2 the radiowave propagation loss values used in this analysis are provided in Table 1.

Table 1.

Horizontal Distance Separation (m)	Height of BTS (m)	Height of GPS Receiver (m)	Slant Range (m)	Frequency (MHz)	Radiowave Propagation Loss (dB)
150	30	1.5	152.7	1575	80.1
150	30	1.5	152.7	1227	77.9
150	30	1.5	152.7	1176	77.5
100	15	1.5	100.9	1575	76.5
100	15	1.5	100.9	1227	74.3
100	15	1.5	100.9	1176	73.9

In the analysis of pico base stations the antenna heights of the pico base station and GPS receiver are 5 meters and 1.5 meters respectively. The horizontal distance separation-between the GPS receiver and the pico base station is 5 meters. Using Equation 3, the minimum distance separation is:

$$D_{sep} = ((5 - 1.5)^2 + 5^2)^{0.5} = 6.1 \text{ m}$$

Using Equation 2, the radiowave propagation loss values for the L1, L2, and L5 bands are: 52.1 dB (L1), 50 dB (L2), and 49.6 dB (L5).

GPS Receive Antenna Gain (G_R). The GPS receive antenna gain model used in this analysis is provided in Table 2. The antenna gain used in this analysis is based on the position of the BTS/pico base station with respect to the GPS receive antenna, which is determined from the antenna heights of the BTS/pico base station and GPS receiver and the horizontal separation distance.

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[8] Mobile Satellite Ventures LP. *Out-of-Band Emissions of MSV's Ancillary Terrestrial Base Stations Relative to the GPS Bond* (Feb. 25, 2002) at 5 (hereinafter "MSV Analysis").

Off-Axis Angle (Measured with Respect to the Horizon)	GPS Antenna Gain (dBi)
-90 degrees to -10 degrees	**-4.5**
-10 degrees to 10 degrees	**0**
10 degrees to 90 degrees	**3**

The off-axis angle measured with respect to the horizon for antennas heights of 1.5 meters and 30 meters for the GPS receiver and BTS and the **minimum** separation distance of 150 meters is 10.8 degrees. From Table 2 the corresponding GPS receive antenna gain in the direction of the BTS used in *this* analysis is **3** dBi. The off-axis angle measured with respect to the horizon for antennas heights of 1.5 meters and 15 meters for the GPS receiver and BTS and the minimum separation distance of 100 meters is 7.7 degrees. From Table 2 the corresponding GPS receive antenna gain in the direction of the BTS used in this analysis is 0 dBi.

The off-axis angle for the antenna heights of 1.5 meters and **5** meters for the GPS receiver and the pico base station and the horizontal separation distance of *5* meters is 35 degrees. From Table 2, the corresponding GPS receive antenna gain in the direction of the pico base station used in ***this*** analysis is 3 dBi.

BTS Interference Allotment (L_{allot}). The Commission's rules permit adjacent band MSS earth terminals, 700 MHz public safety mobile and portable transmitters, and 700 MHz commercial mobile transmitters to operate with allowable emission levels of -70 dBW/MHz (EIRP) in the 1559.1610 MHz frequency band. There is also another proposal for operating ancillary **base** stations by ICO in the 2 GHz frequency range. To take into account that at least one of these other potential interfering sources could be operating in the vicinity of the GPS terrestrial receiver, 50% of the total interference budget is allotted to the emissions from a BTS or pico base station. **A** 50% interference allotment equates to a **3** dB reduction in the maximum allowable emissions from the BTS and pico base stations (e.g., 10 Log 0.5).[9]

Multiple BTS Carriers (L_{mult}). The antenna for the BTS is divided into three sectors. Within each sector there are three separate carrier signals. **A** terrestrial GPS receiver will only be in view of one of the three sectors. To take into account the multiple carrier signals in each sector a factor of 10 Log(3) or **4.8** dB is included in the analysis. Since the pico base stations are not transmitting multiple carriers, this factor is not applicable.

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[9] The coverage **area** of a BTS is expecred to be on the order of 1 kilometer. Therefore interference from multiple **BTS** of the same **network** to a terrestrial GPS receiver was not considered.

BTS Antenna Gain Reduction (G(θ)). The antenna pattern provided by MSV **was** used to determine the reduction in the BTS antenna gain in the direction of the GPS receiver. The BTS antenna **has** a 5 degree tilt down angle.[10] Table **3** provides the elevation angle to the BTS from the GPS receive antenna, off-axis angle adjusted for the tilt down angle, and the reduction of the BTS antenna gain that are used in this analysis.

Table 3.

Distance Separation (m)	Height of BTS (m)	Height of GPS Receiver (m)	Elevation Angle (Deg)	Off-Axis Angle (Deg)	Reduction of BTS Antenna Gain in the Direction of GPS Receiver (dB)
150	30	1.5	10.8	5.8	3
100	15	**1.5**	7.7	2.7	**0.5**

The pico base stations employ omni-directional antennas, therefore no reduction in antenna gain is necessary.

Analysis Results. The maximum allowable EIRP of the BTS emissions in the L1, **L2,** and L5 frequency bands that are necessary for compatible operation with terrestrial GPS receivers are given in Table **4** for the **30** meter BTS antenna height and in Table **5** for the 15 meter BTS antenna height.

Parameter	**Value**		
	L1	**L2**	**L5**
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-117	-117	-117
Radiowave Propagation Loss (dB)	**00.1**	77.9	77.5
GPS Receive Antenna Gain (dBi)	-3	-3	-3
BTS Interference Allotment (dB)	-3	-3	-3
Multiple BTS Carriers (dB)	4.0	-4.8	4.0
BTS Antenna Gain Reduction (dB)	3	3	3
Maximum Allowable EIRP (dBm/MHz)	-44.7	**-46.9**	47.3

[10] **MSV** Analysis at 3.

Parameter	Value		
	L1	L2	L5
GPS Receiver Interference Susceptib:lity Level (dBm/MHz)	-117	-117	-117
Radiowave Propagation Loss (dB)	76.5	74.3	73.9
CPS Receive Antenna Gain (dBi)	0	0	0
BTS Interference Allotment (dB)	-3	-3	-3
Multiple BTS Carriers (dB)	-4.8	-4.8	-4.8
BTS Antenna Gain Reduction (dB)	0.5	0.5	0.5
Maximum Allowable **EIRP (dBm/MHz)**	47.8	-50	-50.4

The maximum allowable EIRP of the pico base station emissions in the L1, **L2,** and L5 frequency bands that are necessary for compatible operation with terrestrial **GPS** receivers are given in Table *6*.

Table 6.

Parameter	**Value**		
	L1	**L2**	**L5**
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-117	-117	-117
Xadiowave Propagation Loss (dB)	52.1	50	49.6
GPS Receive Antenna Gain (dBi)	-3	-3	-3
BTS Interference Allotment (dB)	-3	-3	-3
Maximum Allowable EIRP **(dBm/MHz)**	-70.9	-73	-73.4

The preceding calculations of maximum allowable EIRP of the BTS and pico base stations are based on a variety of assumptions, not all of which may apply in every installation. For example, a BTS could be installed on a tall building at a height of 30 meters, and GPS users could be in that building or on an observation deck in direct line of sight of the BTS antenna. **A** pico base station could be installed at the ceiling of a large hotel ballroom, and GPS users could be on *the* floor *just* above that installation. In addition, although it is unlikely, it would be undesirable to have a **high** BTS installation density within a metropolitan area or near aviation corridors. Because installations of BTS and pico base stations must be licensed, it may be possible *to* include installation restrictions in the license. For example, to restrict the maximum density of BTS installations there could be a minimum separation distance between BTS of 1 km The license could also include limitations on the minimum antenna height of the BTS and pico base stations that will assure sufficient separation from GPS receivers.

Aviation GPS Receiver Analysis

Two operational scenarios are considered for the examining compatibility between BTS and aviation GPS receivers: 1) the total number of active BTS that are necessary to exceed the aviation receiver interference susceptibility threshold; and 2) a single BTS located in the vicinity of a runway. Since the pico base stations will be employed indoors and in areas where building blockage is high they are not expected to be the limiting interference case and therefore, are not considered in this analysis.

Operational Scenario 1

In this analysis a GPS receiver used onboard an en-route aircraft at an altitude of 1000 feet (300 meters) is considered.[11] The received interference power level is computed using the EIRP level proposed by MSV for the BTS and the antenna gain characteristics of the BTS provided by MSV. The computed received interference power level is then compared to the GPS receiver interference susceptibility threshold to determine the amount of available margin. Based on the available margin, the number of BTS that can be operating simultaneously before the interference susceptibility threshold is exceeded is determined.

The received interference power level is computed using Equation 4.

$$I = EIRP + G_R - L_P + L_{safety} - G(\theta) - L_{allot} - L_B \qquad (4)$$

where:

I is the interference power level at the input of the GPS receiver (dBm/MHz);
$EIRP$ is the EIRP density of the BTS (dBm/MHz);
G_R is the GPS receive antenna gain in the direction of the BTS (dBi);
L_p is the radiowave propagation loss between the BTS and the GPS receiver (dB);
L_{safety} is the aviation safety margin (dB);
$G(\theta)$ is the reduction in BTS antenna gain in the direction of the GPS receiver (dB);
L_{allot} is the factor for BTS interference allotment (dB);
L_B is the loss due to building blockage (dB).

The difference between the interference susceptibility threshold (I_T) and the received interference power level computed using Equation 4, represents the available margin (M_{avail}).

[11] Document No. RTCA DO-235, Assessment of Radio Frequency Interference Relevant to the GNSS (Jan. 27, 1997) at A-2.

The number of BTS (N_{BTS}) that would have to be simultaneously transmitting before the interference susceptibility threshold is exceeded is determined by:

$$N_{BTS} = 10^{Mavail/10}$$

It is expected that based on the central limit theorem, if there are a large number of BTS signals the GPS receiver would actually see an aggregate signal producing a noise-like interference effect in the receiver.

The following paragraphs explain each of factors used in the analysis.

BTS EIRP. The EIRP density for the BTS emissions used in this analysis is -40 dBm/MHz as proposed in the NPRM.[12]

GPS Receive Antenna Gain (G_R). During en-route navigation, the **GPS** receiver is located on top of the aircraft. In a previous analysis of terrestrial interference to GPS receivers used for aviation applications, an antenna gain below the aircraft of -10 dBi was **used.**[13] Since there are no specifications on antenna gain below the aircraft and sufficient installed antenna pattern data is lacking on civil aircraft the value of antenna gain of -10 dBi is used in *this* analysis. The antenna gain used in this analysis assumes a constant antenna gain in the region below the aircraft, the actual antenna pattern contains many peaks and nulls (maximum and minimum values of antenna gain).[14] Therefore this antema gain represents a conservative estimate of the received interference power level.

Radiowave Propagation Loss (L_P). Line-of-sight conditions will exist between the airborne GPS receive antenna and the BTS. **The** freespace propagation model described in Equation **2 is** used to compute the radiowave propagation loss. In this analysis an antenna height of 30 meters is used for the BTS. **The** minimum distance separation between the BTS and aircraft is 270 meters (300 meters - 30 meters). Using Equation 2, the radiowave propagation loss for the two frequency bands to be used by GPS aviation receivers is:

$$L_P = 20 \text{ Log } (1575) + 20 \text{ Log } (270) - 27.55 = 63.9 + 48.6 - 27.55 = 84.9 \text{ dB} \quad \text{(L1)}$$

$$L_P = 20 \text{ Log } (1176) + 20 \text{ Log } (270) - 27.55 = 61.4 + 48.6 - 27.55 = 82.5 \text{ dB} \quad \text{(L5)}$$

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[12] ***NPRM*** at ¶68.

[13] **RTCA** DO-235 **at** F-13

[14] *Id.* at **Appendix E Annex 2.**

Aviation Safety Margin **(L_{safety}).** When using a GPS receiver for en-route navigation, it is appropriate to include a safety **margin.** The aviation safety **margin** is used to account for uncertainties on the aviation side of the link budget that *are* real but not quantifiable. These include but are not limited to: multipath of the GPS signal; receiver implementation losses; antenna gain variations; and approach path deviation. Since the GPS signal level cannot be increased, the aviation safety margin is implemented by lowering the allowable interference. **A** safety margin of *6* dB is included in the analysis for GPS receivers used in aviation applications. The aviation safety **margin** of *6* dB included in this analysis is consistent with the value specified in ITU-R Recommendation M.1477.[15]

BTS Antenna Gain Reduction **($G(\theta)$).** The antenna pattern provided by MSV was used to determine the off-axis reduction in the BTS antenna gain in the direction of the GPS receiver. The aircraft is assumed to be overhead of the ground-based BTS with an off-axis angle of ***90*** degrees. The minimum antenna gain reduction relative to the peak for off-axis angles above 30 degrees is approximately 30 **dB.**[16]

BTS Interference Allotment **(L_{allot}).** In addition to the potential interference &om BTS emissions, several other potential sources of interference to GPS aviation receivers have been identified. These potential sources of interference include but are not limited to: 1) adjacent band interference from MSS handsets; 2) harmonics from television transmitters; **3)** adjacent band interference from super geostationary earth-orbiting (super GEO) satellite transmitters"; **4)** **spurious** emissions **from** 700 MHz public safety base, mobile, and portable transmitters; and ***5)*** **spurious** emissions including harmonics from 700 MHz commercial base, mobile, and portable transmitters. Multiple sources of interference, which might individually be tolerated by a GPS receiver, may combine to create an aggregate interference level (e.g., noise and emissions) that could prevent the reliable reception of the GPS signal. In this analysis, a percentage of the total allotment is attributed to **BTS** emissions. For the en-route operational scenario, larger geographic areas are visible to a GPS receiver onboard an aircraft at altitude. This larger field of view will increase the number of interfering sources that can contribute to the total interference level at the receiver. In this analysis, **25%** of the total interference budget is allotted to BTS emissions. The factor for BTS interference allotment is computed from 10 Log (BTS interference allotment ratio). For the BTS interference allotment of *25%* (a ratio of 0.25), a 6 dB factor is included in the analysis.

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[15] ITU-R **M.1477 at Annex** *5*.

[16] **MSV Analysis** at 3

[17] Super GEOs are geostationary earth orbiting satellites **that** *are* designed to employ **a** high transmit **power** to communicate with mobile handsets.

Building Blockage Loss (L_B). In a large geographic area there will be a percentage of the BTS that have an obstructed view of the airborne GPS receiver resulting from building blockage. The following equation is used to compute the reduction in the aggregate interfering signal level at the airborne receiver taking building blockage into account:

$$L_B = 10 \text{ Log } (P_O/(10^{Lba/10}) + P_U) \quad (5)$$

where:

L_B is the building blockage loss (dB);
P_O is the percentage of BTS that are obstructed;
P_U is the percentage of the BTS that are unobstructed;
Lba is average building attenuation loss (dB).

In this assessment 50% of the BTS *are* assumed to have **an** obstructed **view** of the airborne GPS receiver. ***An*** average value of 9 dB is used for the building attenuation loss for the obstructed BTS.[18] Using Equation 5, this results in a 2.5 dB reduction of the aggregate interfering signal level at the input of the airborne receiver.

GPS Receiver Interference Susceptibility Threshold (I_T). For in-band broadband noise interference, both the **RTCA** and ITU-R limits are -116.5 dBm/MHz for GPS L1 aviation receivers when operating in the acquisition mode.[19]

The interference susceptibility threshold for GPS receivers using the **L5** signal has not been finalized. In ***this*** analysis the interference susceptibility threshold for GPS receivers using the L1 signal of -116.5 dBm/MHz is used.

Analysis Results. Based on the BTS EIRP level proposed by MSV, the maximum number of BTS simultaneously transmitting before the GPS aviation receiver interference susceptibility threshold is exceeded is given in Table 7. Using the maximum allowable EIRP computed for compatible operation in the previous section (Table **4),** the maximum number of BTS simultaneously operating before the GPS aviation receiver interference susceptibility threshold is exceeded is given in Table 8.

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[18] NTIA Report 95-325, Building Penetration Measurements From Low-height Base Stations at 912, ***1920,*** **and** 5990 MHz, National Telecommunications and Information Administration, Institute for Telecommunication Sciences (Sept. 1995).

[19] RTCA DO-229B at 38; ITU-R M.1477 at Table 1

Table 7.

Parameter	Value	
	L1	L5
BTS EIRP (dBm/MHz)	40	40
GPS Receive Antenna Gain (dBi)	-10	-10
Radiowave Propagation Loss (dB)	-84.9	-82.5
Aviation Safety Margin (dB)	6	6
BTS Antenna Gain Reduction (dB)	-30	-30
BTS Interference Allotment (dB)	6	6
Building Blockage Loss (dB)	-2.5	-2.5
Interference Power Level (dBm/MHz)	-155.4	-153
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-116.5	-116.5
Available Margin (dB)	38.9	36.5
Number of Active BTS	7763/9 = 863	4467/9 = 496

Parameter	Value	
	L1	L5
BTS EIRP (dBm/MHz)	44.7	47.3
GPS Receive Antenna Gain (dBi)	-10	-10
Radiowave Propagation Loss (dB)	-84.9	-82.5
Aviation Safety Margin (dB)	6	6
BTS Antenna Gain Reduction (dB)	-30	-30
BTS Interference Allotment (dB)	6	6
Building Blockage Loss (dB)	-2.5	-2.5
Interference Power Level (dBm/MHz)	-160.1	-160.3
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-116.5	-116.5
Available Margin (dB)	43.6	43.8
Number of Active BTS	23909/9 = 2545	23988/9 = 2665

The number of active BTS shown in Table 7 and 8 are divided by 9 to take into account the 3 sector antenna for each BTS with 3 carrier signals in each sector resulting in a total of 9 carrier frequencies for each BTS.

At this time it is extremely difficult to estimate the density of BTS operating in a geographic area However, the small BTS range of 1 km indicates that, in order to provide adequate coverage in **an** urban area, the BTS may be densely spaced. The line-of-sight distance from ***an*** aircraft at an altitude of 1000 feet is approximately *73* km. Therefore, if the density of BTS is **high,** the number that are in view of an aircraft can be quite large.

The calculations shown in Table **7**, that are based on the EIRP level proposed in the NPRM, indicate that it only requires a moderate number of BTS to exceed the GPS receiver interference susceptibility threshold. However, when the EIRP values computed for compatible operation with non-aviation GPS receivers are considered, the maximum allowable number of BTS approaches a number more representative of BTS density in **an** urban area.

Operational Scenario **2**

In this analysis the BTS is located 500 feet from the runway where a GPS equipped aircraft is making a precision approach landing.

The maximum allowable EIRP of the BTS ($EIRP_{max}$) is computed using the following equation:

$$EIRP_{max} = I_T + L_P - G_R + L_{allot} - L_{mult} + G(\theta) - L_{safety} \quad (5)$$

where:

I_T is the interference susceptibility threshold of the GPS receiver (dBm/MHz);
L_P is the radiowave propagation **loss** (dB);
G_R is the GPS receive antenna gain in the direction of the BTS (dBi);
L_{allot} is the factor for BTS interference allotment (dB);
L_{mult} is the factor for multiple BTS carriers (dB);
$G(\theta)$ is the reduction in BTS antenna gain in the direction of the GPS receiver (dB);
L_{safety} is the aviation safety margin (dB).

The following paragraphs explain each of the technical factors used in the analysis

GPS Receiver Interference Susceptibility Threshold (I_T). For in-band broadband noise interference, both the RTCA and ITU-R limits are -110.5 dBm/MHz for GPS L1 aviation receivers when operating in the tracking mode.[20]

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[20] RTCA **DO-229B at 38.**

The interference susceptibility threshold for GPS receivers using the L5 signal has not been finalized. In this analysis the interference susceptibility threshold for GPS receivers using the L1 signal of -110.5 dBm/MHz is used.

Radiowave Propagation **Loss (L_P).** Line-of-sight conditions will exist between the airborne GPS receive antenna and the BTS. The freespace propagation model described in Equation 2 is used to compute the radiowave propagation loss. The **separation** distance between the BTS and aircraft is 150 meters. Using Equation 2, the radiowave propagation loss for the two frequency bands to be used by GPS aviation receivers is:

$$L_P = 20 \text{ Log } (1575) + 20 \text{ Log } (150) - 27.55 = 63.9 + 43.5 - 27.55 = 79.9 \text{ dB} \quad \text{(L1)}$$

$$L_P = 20 \text{ Log } (1176) + 20 \text{ Log } (150) - 27.55 = 61.4 + 43.5 - 27.55 = 77.4 \text{ dB} \quad \text{(L5)}$$

GPS Receive Antenna Gain **(G_R).** For GPS aviation receive antennas, the minimum antenna gain at 5 degrees elevation is -4.5 dBi.[21]

BTS Interference Allotment **(L_{allot}).** **As** discussed in the Operational Scenario 1 analysis, a 25% interference allotment which equates to a ***6*** dB reduction in the maximum allowable emissions from the BTS is used in this analysis.

Multiple **BTS** Carriers **(L_{mult}).** The antenna for the BTS is divided into three sectors. Within each sector there are three separate carrier signals. ***An*** aviation GPS receiver will only be in view of one of the three sectors. To take into account the multiple carrier signals in each sector a factor of 10 Log(3) or 4.8 dB is included in the analysis.

BTS Antenna **Gain Reduction** **(G(θ)).** The antenna pattern provided by MSV **was** used to determine the reduction in the BTS antenna gain in the direction of the GPS receiver. The BTS antenna **has** a 5 degree tilt down angle.[22] The BTS antenna height is the same **as** the aircraft height at the Category II/III decision height of 100 feet (30 meters). The angle used to determine the reduction of the BTS antenna gain is tilt down angle of ***5*** degrees. For a 5 degree angle the reduction of the BTS antenna gain **in** the direction of the GPS aviation receiver is 2 dB.

Aviation Safety Margin **(L_{safety}).** When using a GPS receiver for precision approach landings it is appropriate to include a safety margin. **As** discussed in the Operational Scenario 1 analysis, the aviation safety margin is 6 dB.

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[21] Document No. **RTCA DO-228,** ***Minimum Operational Performance Standards for Global Navigation Satellite System*** *(GNSS)* ***Airborne Antenna Equipment*** (Oct. ***20,*** *1995)* **at *6*.**

[22] MSV **Analysis at** 3.

Analysis Results. The maximum allowable EIRP of the BTS emissions in the L1 and L5 frequency bands that are necessary for compatible operation with aviation **GPS** receivers are given in Table 9.

Table 9.

Parameter	Value	
	L1	**L5**
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-110.5	-1105
Radiowave Prooaeation **Loss (dB)**	**79.9**	**77.4**
GPS Receive Antenna Gain **(dBi)**	*4.5*	**4.5**
BTS Interference Allotment (**dB**)	-6	-6
Multiple BTS Carriers **(dB)**	**4.8**	**4.8**
BTS Antenna Gain Reduction **(dB)**	2	2
Aviation Safetv Margin **(dB)**	-6	-6
Maximum Allowable EIRP **(dBm/MHz)**	40.9	**-43.4**

NARROWBAND EMISSIONS

The NPRM acknowledges that a narrowband emission limit is necessary to protect GPS receivers.[23] The exact impact of interference to a GPS receiver is primarily dependent on the type of interference. **GPS** receivers using the CIA code are known to be susceptible to narrowband interference primarily because of the relatively short period of the C/A code.[24] With **a** period of 1 millisecond, the C/A code spectrum is not continuous, but rather it is a line spectrum with discrete lines at 1 kHz intervals. In addition, there are some "strong lines" in each C/A code that can deviate significantly from a $[\sin(x)/x]^2$ envelope. This makes a C/A code receiver vulnerable to continuous wave (CW) or very narrowband interfering signals since they can mix with a strong C/A code line and affect the code and carrier tracking loops.

The narrow band out-of-band emissions from BTS and pico base stations may be CW if they are synthesizer spurs or they may be modulation artifacts having somewhat wider bandwidths. Since some spectral lines can be as much as 10 dB higher than the $[\sin(x)/x]^2$ envelope, the susceptibility of the C/A code structure to extremely narrowband interference can

[23] ***NPRM*** at ¶68.

[24] RTCA **DO-235 at** C-4

increase by approximately 10dB.[25] This means that the power of a narrowband interfering signal must be 10 dB lower than that of a wide band interfering signal to protect GPS receivers.

OTHER INTERFERENCE ISSUES

Intermodulation Interference. Intermodulation occurs due to interaction (mixing) between two or more different carrier frequencies. This mixing can take place in a transmitter or receiver or external to both devices. **As** the number of transmitters at a base station site is increased, the probability of generating an intermodulation product that can fall in the receiver passband increases accordingly. Each BTS will have 9 carrier frequencies, which could result in intermodulation products being generated that fall in the passband of GPS receivers. The maximum allowable emission limits will apply to all unwanted emissions including intermodulation products.

INTERFERENCE MITIGATION TECHNIQUES

The analysis provided by MSV included several factors that would mitigate interference to GPS receivers. If it **is** possible to include a requirement for these interference mitigation techniques in the service rules adopted for BTS and pico base stations, the maximum allowable EIRP levels could be increased accordingly.

MEASUREMENT TECHNIQUES

The wideband emission level is to be measured using an root-mean-square (RMS) detection scheme. The measurements are to be made with a minimum resolution bandwidth of I MHz and the video bandwidth is not be less than the resolution bandwidth. The measurements are to be made over a 20 millisecond averaging period. The BTS must be transmitting data throughout the averaging period.

The narrowband emission level is to be measured using a RMS detection scheme. The measurements are to be made with a resolution bandwidth of no less than 1 kHz. The measurements are to be made over a 20 millisecond averaging period. The BTS must be transmitting data throughout the averaging penod.

CONCLUSIONS

The calculations of maximum allowable EIRP of the BTS and pico base stations are based on a variety of assumptions, not all of which may apply in every installation. Since there

[25] Christopher J. Hegarty, ***Analytical** Derivation of Maximum Tolerable **In-Band** Interference **Levels** for Aviation Applications of GNSS*, Journal of the Institute of Navigation, Vol. **44,** No. 1 **(March** *1997).*

are no limitations on the antenna heights for the base stations used in the system architecture proposed by MSV, the analysis results of the pico base station, which represents the limiting interference case, are used to establish the maximum allowable EIRP levels necessary for compatible operation with GPS receivers. Because installations of BTS and pico base stations must be licensed, it may be possible to include installation restrictions in the license. For example, to restrict the **maximum** density of BTS installations there should be a minimum separation distance between BTS of 1 km. The license should include limitations on the minimum antenna height of the BTS and pico base stations that will assure sufficient separation from GPS receivers. Provisions should also be included in the license to restrict base station operations within 500 feet of an airport runway.

In the 1559-1610 MHz band for wideband base station emissions the maximum allowable EIRP for compatible operation **is** -71 dBm/MHz (Table 6). For narrowband emissions, the EIRP is 10 dB lower than the level for wideband emissions, resulting in a maximum allowable EIRP of -81 dBm for narrowband base station emissions. These emission limits apply to all unwanted emissions including intermodulation products.

In the 1215-1240 MHz band for wideband base station emissions the maximum allowable EIRP for compatible operation is -73 dBm/MHz (Table 6). For narrowband emissions, the EIRP is 10 dB lower than the level for wideband emissions, resulting in a maximum allowable EIRP of -83 dBm for narrowband base station emissions. These emission limits apply to all unwanted emissions including intermodulation products.

In the 1164-1188 MHz band for wideband base station emissions the maximum allowable EIRP for compatible operation is **-73** dBm/MHz (Table 6). For narrowband emissions, the EIRP is 10 dB lower than the level for wideband emissions, resulting in a maximum allowable EIRP of -83 dBm for narrowband base station emissions. These emission limits apply to all unwanted emissions including intermodulation products.

ENCLOSURE **2**

ASSESSMENT OF INTERFERENCE TO GLOBAL POSITIONING SYSTEM RECEIVERS FROM ANCILLARY TERRESTRIAL COMPONENT MOBILE TERMINALS OPERATING IN MOBILE SATELLITE SERVICE BANDS

BACKGROUND

The Federal Communications Commission (Commission) received proposals from New ICO Global Communications (Holding) Ltd. (ICO), Motient Services Inc., and Mobile Satellite Ventures Subsidiary (MSV)[1] to operate ancillary terrestrial component **(ATC)** base station transmitters (BTS) with their networks using assigned mobile satellite service (MSS) frequencies. The BTS would operate in the 1525-1559 MHz band (MSV **Proposal**)[2], or the 1990-2025 and 2165-2200 MHz bands (ICO Proposal). The BTS is to be integrated with the satellite network and will employ directional antennas. In addition to the BTS, MSV will employ pico base stations operating in the 1525-1559 MHz band that may be located on ceilings of buildings or on building walls and will use omni-directional antennas. The mobile terminals (MTs) that are used in conjunction with the BTS and pico base stations operate in the 1626-1660.5 MHz band.

In response to the proposals, the Commission initiated a Notice of Proposed Rule Making (NPRM) to obtain comments on the proposals.' In the *NPRM*, the Commission recognized that the unwanted emissions from terrestrial stations in the MSS will have to be carefully controlled in order to avoid interfering with GPS receivers.[4] The Commission specifically requested comments on whether limits for base stations similar to those specified in Section 25.213(b) for mobile earth stations are adequate to protect GPS receivers.' However, the NPRM does not address the emission *limits* of the ATC MTs that are operating in conjunction with the BTS. It

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[1] **MSV** will provide MSS throughout North America using the satellites launched by Motient Services Inc. and TMI Communications and Company Limited Partnership.

[2] *Ex parte* letter from Lawrence H. **William** and Suzanne Hutchings, New ICO Global Communications (Holdings) Ltd., to Chairman Michael K. Powell, Federal Communications Commission, IB Docket No. 99-81 (March 8, 2001); Application filed by Motient Services Inc. and Mobile Satellite Ventures Subsidiary LLC for Assignment of Licenses and for Authority to Launch and Operate a Next-Generation Mobile Satellite Service System (March 1, 2001).

[3] *In the Matter of Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz, the L-Band, and 1.6/2.4 GHz Band*, IB Docket No. 01-185 (rel. Aug. 17, 2001) (hereinafter "NPRM").

[4] NPRM at ¶68.

[5] *Id.*

can only be assumed that the emission levels in the 1559-1605 MHz radionavigation satellite service (RNSS) band of an equivalent isotropically radiated power (EIRP) of -70 dBW/MHz (wideband emissions) and -80 dBW (narrowband emissions) established for satellite mobile earth stations (MES) to protect the aviation use of GPS are to be applied to the MTs used in conjunction with BTS and pico base stations.

Over the last several years the RNSS has continued to evolve, adding an additional fiequency allocation in the 1164-1215 MHz frequency band. As part of the GPS modernization program a new GPS signal for aviation and non-aviation applications designated as L5 will be provided in the 1164-1188 MHz portion of the newly allocated RNSS band. In addition to this new allocation, as part of the GPS modernization program a second signal similar to the L1 coarse/acquisition (C/A) code signal will be provided in the GPS L2 fiequency band of 1215-1240 MHz.[6] In addition to the new GPS signals, the applications used by GPS receivers have continued to evolve to include many terrestrial mobile applications and indoor operation. One such application provides Enhanced 911 (E-911) position-determination capability, which the Commission has mandated for terrestrial wireless carriers.[7]

In order to completely assess compatibility of the ATC MTs, used in conjunction with the BTS and pico base stations, with the GPS service, terrestrial receivers in the L1, L2, and L5 frequency bands and aviation receivers in the L1 and L5 fiequency bands must be analyzed.

OBJECTIVE

The objective of this analysis is to assess the potential of interference to terrestrial GPS receivers operating in the L1, L2, and L5 frequency bands and aviation receivers operating in the L1 and L5 frequency bands from the emissions of MTs operating in conjunction with the BTS and pico base stations.

APPROACH

To assess the interference potential of MT emissions to GPS terrestrial and aviation receivers, an analysis will be performed to compute the maximum allowable EIRP levels of the MT emissions in the fiequency bands used by the GPS service that are necessary for compatible operation.

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[6] The GPS Precision code (P-code) is currently transmitted in the 1215-1240 MHz band.

[7] *Revision of the Commission's Rules To Ensure Compatibility with Enhanced 911 Emergency Calling Systems* (Report and Order), 11 FCC Rcd 18,676 (1996), *on recon,* 12 FCC Rcd 22,665 (1997), Second Report and Order, 14 FCC Rcd 10,954 (1999), Third Report and Order, 14 FCC Rcd *17,388* (1999), Fourth Report and Order, 15 FCC Rcd 25,216 (2000), *on recon,* FCC 01-386 (rel. Dec. 28, 2001).

DISCUSSION OF CURRENT EMISSION LIMITS FOR MSS MES

In October 1994, the Commission issued a Report and Order establishing rules for the "Big LEO" service, i.e., voice-and-data MSS provided by non-geostationary satellites accessed by MESs transmitting in segments of the 1610-1626.5 MHz band.[8] The rules included out-of-band emission limits to protect reception of the GPS C/A code signals.[9] Although U.S. consultations with Russian officials indicated a likelihood that the Global Navigation Satellite System (GLONASS) would shift to frequencies below 1605 MHz by the year 2005, the Commission acknowledged that emissions from Big LEO terminals could potentially interfere with GLONASS reception below 1610 MHz in the interim. The Commission refrained from adophng specific out-of-band limits to protect GLONASS, however, leaving the issue to **be** resolved after further study.

In November 1994, representatives of the Commission, the Federal Aviation Administration **(FAA)**, and the NTIA signed a Memorandum of Understanding ("1994 MOU") concerning domestic implementation of a GPS/GLONASS Global Navigation Satellite System (GNSS).[10] The 1994 MOU declared that the Commission would consider adopting any pertinent out-of-band emissions limits for MSS terminals recommended by the RTCA", and that licenses for MSS terminals operating in the bands near the GPS and GLONASS bands issued prior to a U.S. decision to implement GLONASS domestically would indicate that the licensees would be bound by any such limits subsequently incorporated in the Commission's rules. The MOU pertained to all MSS terminals transmitting on assigned frequencies between 1610 and 1660.5 **MHZ.**

In January 1997, Special Committee 159, the RTCA committee that had been commissioned pursuant to the 1994 MOU to study the potential for harmful interference with GNSS operation, issued its final report.[12] The aviation and MSS participants agreed that a wideband EIRP limit of -70 dBW/MHz and a narrowband EIRP limit of -80 dBW would protect

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[8] ***Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile Satellite* Service *in the 1610-1626.5/2483.5-2500 MHz Frequency Bands,*** Report and Order, **CC** Dkt. No. **92-166, 9 F.C.C.** Rcd. **5936** (1994).

[9] **47** C.F.R. §25.213(b)

[10] The GNSS also includes the Space Based Augmentation System (SBAS) and Ground Based Augmentation System (GBAS). In the United Stales the SBAS is the Wide Area Augmentation System **(WAAS)** and the GBAS is the Local Area Augmentanon System (LAAS). These augmentation systems are capable of supporting both GPS and GLONASS signal formats.

[11] RTCA, Inc., formerly known as the Radio Technical Commission for Aeronautics, is a voluntary government/industry group that performs studies and makes recommendations pertaining to radio use for aviation,

[12] RTCA Ins.. Special Committee No. 159, ***Assessment of Radio Frequency Interference Relevant to the*** *GNSS*, Document No. **RTCA/DO-235** (Jan. 27, 1997)(hereinafter "RTCA **DO-235").**

aircraft reception of GPS signals, and the MSS participants agreed that it was feasible for them to meet those limits in the GPS C/A signal band. However, no consensus was reached regarding limits for the protection of GLONASS operations. The aviation representatives maintained that a -70 dBW/MHz wideband limit and a -80 dBW narrowband limit were necessary. The MSS representatives maintained that it was economically infeasible for them to suppress emissions in the GLONASS band to that extent and argued that limits of **-54** dBW/MHz for wideband emission and -64 dBW for narrowband emissions would be ndequate. As a result of this lack of consensus, RTCA SC-159 did not issue a recommendation for the out-of-band emissions to protect. GLONASS.

After the release of the RTCA report, interested private sector parties and officials at the Commission, the NTIA, and the FAA conducted informal discussions concerning emission limits for the protection of GNSS in the United States. The discussions culminated in **NTIA** filing the September 1997 rulemaking proposal ("NTIA Petition"), which **was** placed on public notice with an invitation for comments.[13] The proposal reflects a compromise worked out by the **NTIA,** the FAA, and the representatives of the Globalstar and Iridium Big LEO MSS systems. The out-of-band emission standard that the aviation members of RTCA SC-159 had recommended would be adopted for the protection of aircraft reception of GLONASS signals between 1597 and 1605 MHz, but there would be an initial grace period during which less restrictive limits would apply for emissions in that portion of the band, and no specific limits were proposed for protection **of** GLONASS reception on frequencies above 1605 MHz.

For protection of GPS reception, the NTIA Petition recommended requiring that all MSS MESs transmitting on frequencies between 1610 MHz and 1660.5 MHz conform to two restrictions: a wideband limit of -70 dBW/MHz, averaged over 20 milliseconds, on the EIRP density of the out-of-band emissions in the 1559-1580.42 MHz frequency range and a narrowband limit of -80 dBW/700 Hz, also averaged over 20 milliseconds, on emissions in the 1559-1585.42 MHz frequency range.

Since **NTIA** filed its petition for rulemaking, the Commission in an NPRM, adopted in May 1998, proposed voluntary interim equipment certification procedures to be used prior to adopting final rules to implement the Global Mobile Personal Communications by Satellite (GMPCS) MOU which was signed by the United States and over 120 additional parties in February 1997.[14] In this NPRM, the Commission proposed to certify all GMPCS-related terminal

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[13] NTIA **Petition** for Rulemaking, Amendment to the Commissions **Rules** to Incorporate Mobile Earth **Stations** Out-of-Band **Emissions,** RM No. 9165 (Sept. *19, 1997)* (placed on Public Notice, Report No.2227 (Sept. 23. *1997)).*

[14] *1998* ***Biennial Regulatory Review** – Amendment of Parts 2. 25, and 68 of the* ***Commission 's Rules** ro Further Streamline the Equipment* ***Aurhorizarion** Process for* ***Radio Frequency Eauipmeni.** Modify rhe Equipment Authorization Process for* ***Telephone Terminal Equipment. Implement** Mutual Recognition* ***Agreements and** Begin* ***Implementation** of the* ***Global Mobile Communications** by Satellite* ***(GMPCS)** Arrangements*, Notice of Proposed Rulemaking, GEN Dkt. No. *98-68,* 13 FCC Rcd. *10683 (1998).*

equipment that complies with the Commission's technical and other requirements for that service, including requirements governing emission limits. In addition, the Commission proposed that MSS terminals operating in the 1610-1626.5 MHz band would also have to meet the out-of-band emission limits recommended for implementation by the year 2005 by **NTIA** in its petition for rulemaking. In response to this NPRM, NTIA filed comments supporting the -70 dBW/MHz **and** -80 dBW emission limits in the 1559-1605 MHz band for MES operating in the 1610-1660.5 MHz band.[15]

In a separate rulemaking proceeding for establishing rules for MSS in the **2** GHz bands, NTIA also filed comments supporting the -70 dBW/MHz and -80 dBW emission **limits** in the 1559-1610 MHz band for MES operating in the 1990-2025 MHz band.[16]

The emission limits in the 1559-1610 MHz band for MESs operating in the 1610-1660.5 MHz frequency range, developed within RTCA and supported by **NTIA** were based **on** protection of a GPS receiver used in a precision approach landing operational scenario. At the time the MES emission limits were developed, there were no critical terrestrial operational scenarios identified. However the use of assisted GPS for E911 position location has emerged **as** a critical terrestrial application requiring protection.[17] Other terrestrial applications operating in urban environments will also benefit from assisted GPS technology.

TECHNICAL DIFFERENCES BETWEEN AVIATION AND TERRESTRIAL GPS OPERATIONAL SCENARIOS

The critical operational scenario used to develop the MES emission limits that were necessary for compatible operation with aviation GPS receivers **was** a GPS equipped aircraft *in* the final approach phase of flight. In the final approach phase of flight the GPS receiver will **no** longer be acquiring satellites and will be in the tacking mode of operation. The interfering signal is assumed to be transmitted by a **MES** located beneath the aircraft at a critical decision location during final approach. The technical factors associated with this operational scenario are provided in Table 1. **A** more detailed explanation of this operational scenario and **the** technical factors associated with it are provided in RTCA Document No. DO-235.[18]

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[15] Comments of the National Telecommunications and Information Administration, IB Docket No. 99-61, at 8 (**July** 21, 1999).

[16] Comments of the National Telecommunications and Information Administration, IB Docker No. 99-81, at 9 (June **24,** 1999).

[17] Assisted GPS describes a system where outside sources, such as an assistance server and reference network, help a **GPS** receiver perform **tasks** required to make range measurements **and** position solutions. **In** a 1999 rule modification, the Commission also included handset-based E911 **techniques, among** them assisted GPS.

[18] RTCA DO-235 at Appendix F

Technical Factor	Value
Minimum Signal Level	-134.5 dBm
Minimum Distance Separation	30 m
Aviation GPS Receive Antenna Gain in the Direction of the **MES**	-10 dBi
Aviation Safety Margin	6 dB
Aviation GPS Receiver Susceptibility Threshold (Tracking Mode)	-1 10.5 dBm/MHz

When considering interference to terrestrial GPS receivers several of the technical factors in Table 1 are different. For example, GPS terrestrial receivers do not have the protection provided to the GPS aviation receive antenna that is mounted on top ***of*** the aircraft, and thus is shielded to some extent **from** the MES below the aircraft. The terrestrial GPS receive antenna the gain in the direction of the MES would be 0 dBi instead of the -10 a i . Terrestrial GPS receivers operate under handicaps such **as** signal attenuation due to destructive multipath, foliage, or building shadowing, and frequently operate using a minimum signal level. The receiver susceptibility threshold referenced to the input of the GPS receiver is based on the minimum available C/A code signal level of a low elevation satellite (-130 dBm minimum guaranteed signal level into a **-4.5** dBic antenna). For this discussion the minimum guaranteed signal into a 0 dBic antenna **is** considered. This would have the effect of increasing the receiver susceptibility threshold by 4.5 dB. If the emission level of the MES is at the **EIRP** limit of 4 0 **dBm/MHz** (-70 dBW/MHz), the minimum required distance separation for compatible operation with terrestrial GPS receivers is 30.3 m. It is anticipated that the distance separation between the MES and the terrestrial GPS receiver can be much less than 30.3 m (100 ft). Therefore, it **is** necessary to perform an analysis to determine the maximum allowable EIRP for the protection of terrestrial GPS receivers using a representative operational scenario

TERRESTRIAL GPS RECEIVER ANALYSIS

The maximum allowable EIRP of the MT **(EIRP,)** is computed using the following equation:

$$EIRP_{MT} = I_T + L_P - G_R \quad (1)$$

where:

I, is the interference susceptibility threshold of the GPS receiver (dBm/MHz);
L_P is the radiowave propagation loss (dB);
G_R is the GPS receive antenna gain in the direction of the MT (dBi).

The following paragraphs explain each of the technical factors used in the analysis.

GPS Receiver Interference Susceptibility Threshold **(I_T).** In all GPS bands (L1, L2, and L5) the typical GPS receiver system noise density is -171 dBm/Hz for a receiver with a 3 dB noise figure. The receiver system noise density determines the minimum level of GPS signal that can be used for any application. For example, survey GPS receivers require a fairly **high** carrier-to-noise density ratio (C/N_0) of about 35 dB-Hz in order to provide the required level of accuracy, while wireless assisted E-911 receivers can provide adequate measurements with a very low C/N_0, such as 20 dB-Hz. Therefore, with a system noise densify of –171 dBm/Hz, the survey receiver requires a minimum signal level of –136 dBm, whereas the wireless assisted E-911 receiver can function with a signal as low as –151 dBm. In either case, the receiver system noise density determines the minimum level of GPS signal that can be used for a specific application. ***An*** 'x' dB increase in the receiver noise densify raises the GPS signal power requirement by the same 'x' dB. Because most terrestrial GPS receivers operate under handicaps such as signal attenuation due to destructive multipath, foliage, or walls, these receivers frequently must operate at their minimum signal levels.

Since terrestrial GPS receivers typically operate at their minimum signal levels, any interfering signal which adds to system noise density erodes performance by requiring stronger GPS signals to perform the required function. Conventional C/A code GPS receivers require a relatively high carrier-to-noise density ratio (C/N_0) because of the wide loop bandwidths that are employed. In contrast, assisted GPS receivers used in E-911 applications can take full advantage of communications network support to obtain and remove the GPS navigation data and to stabilize the receiver clock. In addition, it **is** assumed that the dynamics are very low (**e.g.,** the user is walking). **As** a result, the tracking loop bandwidth can be narrowed very substantially, **thus** maintaining a positive signal-to-noise ratio in the tracking loop at much lower C/N_0 values. Receivers *are* being designed today that can track with a 20 dB-Hz C/N_0, and the industry is striving to track with a C/N_0 of 10 dB-Hz. Based on a system noise density of -171 **dBm/Hz,** a ***20*** dB-Hz C/N_0 represents a receiver signal level of ***-15***I dBm (21 dB below the GPS minimum signal level in the SPS Signal Specification), and a 10 dB-Hz *CM,* represents a received signal level of -161 dBm (31 dB below the GPS minimum signal level in the SPS Signal Specification). Regardless of the application or the minimum signal level required for that application, it is important to limit any increase in system noise. In this analysis, the increase in system noise caused by the MES emissions is limited to 25%, which equates to an interference-to-noise ratio (I/N) of ***-6*** dB. Based on the I/N of -6 dB, the interference susceptibility threshold used in this analysis is -171 **dBm/Hz I 6 0 -** 6 = -117 dBm/MHz.

There are no practical differences in interference susceptibility for GPS receivers *operating in any* of the *three bands, i.e., L1, L2, and L5. Noise interference susceptibility relates* only to tolerable increase in noise floor, which for terrestrial applications is identical for all three bands. For example, noise interference susceptibility is not a function of the GPS code structure, e.g., C/A, L2C, or P(Y). It also is not a function of the code tracking technique, e.g., wide

$$EIRP_{BTS} = I_T - G_R + L_P - L_{mult} + G(\theta) - OTR \quad (6)$$

where:

I_T is *the* interference susceptibility threshold of the GMDSS receiver (dBm/MHz);
G_R is the GMDSS receive antenna gain in the direction of the BTS (dBi);
L_P is the radiowave propagation loss between the BTS and GMDSS receiver (dB);
L_{mult} is the factor for multiple BTS carriers (dB);
$G(\theta)$ is the reduction in BTS antenna gain in the direction of the GMDSS receiver (dB);
OTR is the GMDSS receiver on-tune rejection (dB).

The following paragraphs explain each of the technical factors used in the analysis.

GMDSS Receiver Interference Susceptibility Threshold (I_T). The GMDSS receiver interference susceptibility threshold is computed from the maximum aggregate non-co-channel power flux density (PFD). The maximum aggregate non-co-channel PFD for the Inmarsat Mini-M and Inmarsat-B terminals is -105 dB(W/m²).[13] The GMDSS receiver interference susceptibility threshold is computed from the following equation:

$$I_T = PFD + 10 \operatorname{Log}(\lambda^2/4\pi) + G_R \quad (7)$$

where:

λ is the wavelength (m);
G_R is the gain of the GMDSS receive antenna

The wavelength for a frequency of 1537 MHz is 0.195 m. The antenna gains of the Mini-M and Inmarsat-B terminals are 10 dBi and 21 dBi respectively.[14] The GMDSS receiver interference susceptibility thresholds used in this analysis are:

$$I_T = -105 - 25.2 + 10 = -120.2 \text{ dBW} = -90.2 \text{ dBm} \quad \text{(Mini-M)}$$

$$I_T = -105 - 25.2 + 21 = -109.2 \text{ dBW} = -79.2 \text{ dBm} \quad \text{(Inmarsat-B)}$$

GMDSS Receive Antenna Gain (G_R). The GMDSS antenna gain models used in this analysis are provided in Table 3 (Mini-M) and Table 4 (Inmarsat-B).[15]

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[13] E-mail Attachment from J. Hersey, Electronics Engineer, United States Coast Guard/Department of Transportation IRAC Representative, to E. Davison, Electronics Engineer, NTIA Office of Spectrum Management (May 31,2002) (hereinafter "Coast Guard E-mail").

[14] *Id.*

[15] *Id.*

	L1	L2	L5
GPS Receiver Interference Susceptibility Level **(dBm/MHz)**	-117	-117	-117
Radiowave Propagation **Loss** (dB)	42.4	40.3	39.8
GPS Receive Antenna Gain (dBi)	0	0	0
Maximum Allowable EIRP (dBm/MHz)	-74.6	-76.7	-77.2

AVIATION GPS RECEIVER ANALYSIS

When the emission limits for MT operating in the 1610-1660.5 MHz frequency range were originally developed, the new RNSS allocation in the 1164-1215 MHz band that is used by the GPS L5 signal did not exist. To examine the compatibility of MT and a GPS aviation receiver using the L1 and L5 signals, the operational scenario considered in this analysis is the Category I precision approach landing.

The maximum allowable EIRP of the MT ($EIRP_{MT}$) is computed using the following equation:

$$EIRP_{MT} = I_T + L_P - G_R - L_{safety} + L_{allot} \qquad (3)$$

where:

I_T is the interference susceptibility level at the input of the aviation GPS receiver (dBm/MHz);
G_R is the GPS receive antenna gain in the direction of the MT (dBi);
L_p is the radiowave propagation loss between the MT and the *GPS* receiver (dB);
L_{safety} is the aviation safety margin (dB);
L_{allot} is the factor for MT interference allotment (dB).

The following paragraphs explain each of factors used in the analysis.

GPS Receiver Interference Susceptibility **Threshold** (**I_T**). **As** discussed in the terrestrial GPS receiver analysis, for in-band broadband noise interference, both the RTCA and ITU-R limits are -110.5 dBm/MHz for GPS L1 aviation receivers when operating in the tracking mode.[20] The interference susceptibility threshold for GPS receivers using the L5 signal has rot been finalized. In this analysis, the interference susceptibility threshold for GPS receivers using the L1 and L5 signals of -110.5 dBm/MHz is used.

GPS Receive **Antenna** Gain (G_R). During a precision approach landing, the GPS receiver is located on top of the aircraft. In a previous analysis of terrestrial interference to GPS receivers

[20] RTCA DO-229B *at* 38; ITU-R M. 1477 at Table 1.

provided by MSV[16], the GMDSS antenna model provided in Table 3 and Table 4, and using free space propagation loss, it was determined that the worst-case horizontal distance separation was 150 meters for a BTS antenna height of 30 meters, and 50 meters for a BTS antenna height of 15 meters. The antenna height of the GMDSS receiver was 7.5 meters. Using Equation 2 the radiowave propagation loss values used in this analysis are 79.8 dB for the 30 meter BTS antenna height and 70.3 dB for the 15 meter antenna height.

Multiple BTS Carriers (L_{mult}). The antenna for the BTS is divided into three sectors. Within each sector there are three separate carrier signals. In this analysis, it is assumed that a GMDSS receiver will only be in view of one of the three sectors of the BTS. To take into account the multiple carrier signals in each sector a factor of 10 Log(3) or 4.8 dB is included in the analysis.

BTS Antenna Gain Reduction ($G(\theta)$). The antenna pattern provided by MSV was used to determine the reduction in the BTS antenna gain in the direction of the GMDSS receiver. The BTS antenna has a 5 degree tilt down angle.[17] Based on the elevation angle to the BTS from the GMDSS receive antenna, the off-axis angle adjusted for the tilt down angle, the reduction of the BTS antenna gain that is used in this analysis is I dB.

On-Tune Rejection (OTR). The OTR is the rejection provided by the GMDSS receiver selectivity characteristics to a co-tuned BTS as a result of the emission spectrum exceeding the receiver bandwidth. The OTR is computed using the following equation:

$$OTR = 10 \text{ Log } (BW_{GMDSS}/BW_{BTS}) \quad (9)$$

where:

BW_{GMDSS} is the bandwidth of the GMDSS receiver (Hz)[18];
BW_{BTS} is the emission bandwidth of the BTS (Hz).

The receiver bandwidths for the Mini-M and Inmarsat-B terminals used in this analysis are 3.5 kHz and 15 kHz respectively.[19] The bandwidth of the BTS is 200 kHz. The OTR computed using Equation 9 is:

$$OTR = 10 \text{ Log } (3.5x10^3 / 200x10^3) = -17.6 \text{ dB} \quad \text{(Mini-M)}$$

[16] MSV Analysis at 5.

[17] *Id.* at 3.

[18] In this analysis it is assumed that the receiver bandwidth is equal to the carrier occupied bandwidth

[19] *Coast* Guard E-mail.

Table 4.

Parameter	Value	
	L1	**L5**
GPS Receiver Interference Susceptibility Level (dBm/MHz)	-110.5	-110.5
Radiowave Propagation Loss (dB)	65.9	**63.4**
GPS Receive Antenna Gain (dBi)	10	10
Aviation Safety Margin (dB)	***-6***	***-6***
MT Interference Allotment (dB)	**-3**	**-3**
Maximum Allowable EIRP (dBm/MHz)	**-43.6**	-46.1

NARROWBAND EMISSIONS

The exact impact of interference to a GPS receiver is primarily dependent on the type of interference. GPS receivers using the C/A code are known to be susceptible *to* narrow band interference primarily because of the relatively short period of the C/A code.[24] With a period of 1 millisecond, the C/A code spectrum is not continuous, but rather it is a line spectrum with discrete lines at 1 kHz intervals. In addition, there are some "strong lines" in each C/A code that can deviate significantly from a $[\sin(x)/x]^2$ envelope. This makes a C/A code receiver vulnerable to continuous wave (CW) or very narrowband interfering signals since they can mix with a strong C/A code line and affect the code and carrier tracking loops.

The narrowband out-of-band emissions from MTs operating in conjunction with the **BTS** and pico base stations may be CW if they are synthesizer spurs or they may be modulation artifacts having somewhat wider bandwidths. Since some spectral lines can be as much as 10 dB higher than the $[\sin(x)/x]^2$ envelope, the susceptibility of the C/A code structure to extremely narrowband interference can increase by approximately 10 dB.[25] This means that the power of a narrowband interfering signal must be 10 dB lower than that of a wideband interfering signal to protect GPS receivers.

INTERFERENCE MITIGATION TECHNIQUES

The analysis provided by MSV included several factors that would mitigate interference to GPS receivers. If it is possible to include a requirement for these interference mitigation

[24] RTCA DO-235 at C-4.

[25] Christopher J. Hegarty, *Analytical Derivation of Maximum* ***Tolerable In-Band Interference Levels for Aviation Applications of*** *GNSS*, Journal of the Institute of Navigation, Vol. *44*, No. 1 (March *1997).*

operation with GMDSS receivers is -22.5 dBm/200 kHz.

INTERFERENCE MITIGATION TECHNIQUES

The **analysis** provided **by MSV** included several factors that would mitigate interference to AMS(R)S and GMDSS receivers. If it is possible to include a requirement for interference mitigation techniques in the service rules adopted for BTS **and** pico **base** stations, the maximum allowable EIRP levels could be increased accordingly.

CONCLUSIONS

In the AMS(R)S channels in the 1545-1555 pomoo of the 1525-1559 MHz band the maximum allowable EIRP of the BTS that is necessary for compatible operation is **-32.8** dBm/200 kHz per carrier (Figure **1). This** is 13.9 dB lower than the current proposed for BTS adjacent channel emissions **by MSV.**

In the GMDSS channels in the 1530-1544 MHz portion of the **1525-1559** MHz band the maximum allowable EIRP of the BTS that is necessary for compatible operation is **-22.5** dBm/200 kHz per carrier (Table **6). This** is **3.6** dB lower than the current proposal for BTS adjacent channel emissions **by MSV.**

the frame occupancy. For example, using an 8 slot TDMA system architecture, employing a quarter rate vocoder, would reduce the effective average power (averaged over a 20 milisecond period) of an MT by 15 dB (10 Log 32). If these or similar techniques are employed the EIRP levels specified for the MTs can be achieved.

OBJECTIVE

The objective of this analysis is to assess the potential of interference to AMS(R)S and GMDSS receivers from the emissions of BTS operating in the 1525-1559 MHz band.

APPROACH

To assess the interference potential of BTS emissions to AMS(R)S and GMDSS receivers, an analysis will be performed to compute the maximum allowable equivalent isotropically radiated power (EIRP) levels of the BTS emissions that are necessary for compatible operation. Since the pico base stations will be employed indoors and in areas where building blockage is **high** they are not expected to be the limiting interference condition and therefore, are not considered in this analysis.

AMS(R)S RECEIVER ANALYSIS

Analysis Overview

In this analysis, an AMS(R)S receiver used onboard an en-route aircraft at an altitude of 1000 feet (300 meters) is considered. The received interference power level is computed using the EIRP level proposed by MSV for the BTS and the antenna gain characteristics of the BTS provided by MSV. The computed received interference power level is then compared to the AMS(R)S receiver interference susceptibility threshold to determine the amount of available margin. Based on the available margin, the number of BTS that can be operating simultaneously before the interference susceptibility threshold is exceeded is determined.

The received interference power level is computed using the following equation:

$$I = EIRP_{BTS} + G_R - L_p - G(\theta) + OTR \quad (1)$$

where:

- I is the interference power level at the input of the AMS(R)S receiver (dBm/600 Hz);
- $EIRP_{BTS}$ is the EIRP density of the BTS (dBm/200 kHz);
- G_R is the AMS(R)S receive antenna gain in the direction of the BTS (dBi);
- L_p **is** the radiowave propagation loss between the BTS and the AMS(R)S receiver (dB);
- $G(\theta)$ is the reduction in BTS antenna gain in the direction of the AMS(R)S receiver (dB);
- OTR is the AMS(R)S receiver on-tune rejection (dB).

The difference between the interference susceptibility threshold (I_T) and the received interference power level coinputed using Equation 1, represents the available margin (M_{avail}). The number of ETS (N_{BTS}) that would have to be simultaneously transmitting before the interference susceptibility threshold is exceeded is determined by:

ENCLOSURE 3

ASSESSMENT OF INTERFERENCE TO AERONAUTICAL. MOBILE SATELLITE ROUTE SERVICE AND GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM RECEIVERS FROM ANCILLARY TERRESTRIAL COMPONENT BASE STATIONS OPERATING IN THE 1525-1559 MHz MOBILE SATELLITE SERVICE BAND

BACKGROUND

The Federal Communications Commission (Commission) received proposals from New ICO Global Communications (Holding) Ltd. (ICO), Motient Services Inc., and Mobile Satellite Ventures Subsidiary (MSV)[1] to operate ancillary terrestrial component (ATC) base station transmitters (BTS) with their networks using assigned mobile satellite service (MSS) frequencies. The BTS would operate in the 1525-1559 MHz band (MSV **Proposal)**[2], or the 1990-2025 and 2165-2200 MHz bands (ICO Proposal). The BTS is to be integrated with the satellite network and will employ directional antennas that are expected to provide coverage to areas where the satellite signal is attenuated by foliage or terrain or to provide in-building coverage. In addition to the BTS, MSV will employ pico base stations operating in the 1525-1559 MHz band that may be located on ceilings of buildings or on building walls and will use omni-directional antennas.

The frequency band 1545-1555 MHz is allocated to the aeronautical mobile satellite route service (AMS(R)S) in the space-to-Earth direction. AMS(R)S is reserved **for** communications relating to safety and regulatory of flights (see provisions No. 1.36, 1.59, 5.357A, and Article 44 of the Radio Regulations). The frequency band 1530-1544 MHz is allocated to the Global Maritime Distress and Safety System (GMDSS) in the space-to-Earth direction. This international application is connected to and required by international treaty resulting from the Safety of Life at Sea (SOLAS) Convention. Since the BTS will have adjacent channel emissions that fall within the AMS(R)S and GMDSS receiver channels there is a potential for interference.

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[1] MSV will provide MSS throughout North America using the satellites launched by Motient Services Inc. and TMI Communications and Company Limited Partnership.

[2] *Ex parte* letter from Lawrence H. Williams and Suzanne Hutchings, New ICO Global Communications (Holdings) Ltd., to Chairman Michael K. Powell, Federal Communications Commission, IB Docket No. 99-81 (March 8,2001); Application filed by Motienr Services Inc. and Mobile Satellite Ventures Subsidiary LLC for Assignment of Licenses and for Authority to Launch and Operate a Next-Generation Mobile Satellite Service System (March I, 2001).

below the aircraft, the actual antenna pattern contains many peaks and nulls (maximum and minimum values of antenna gain).[6] Therefore this antenna gain represents a conservative estimate of the received interference power level.

Radiowave **Propagation Loss (L_P).** Line-of-sight conditions will exist between the airborne AMS(R)S receive antenna and the BTS. The freespace propagation model described in the following equation is used to compute the radiowave propagation loss:

$$L_P = 20 \text{ Log } F + 20 \text{ Log } D - 27.55 \quad (2)$$

where:

F is the frequency (MHz);

D is the distance separation between the BTS and the AMS(R)S receiver (m).

In this analysis an antenna height of 30 meters is used for the BTS. The aircraft altitude is 1000 feet (300 meters). The minimum distance separation between the BTS and aircraft is **270** meters (300 meters - 30 meters). Using Equation **2,** the radiowave propagation loss used in this analysis is:

$$L_P = 20 \text{ Log } (1550) + 20 \text{ Log } (270) - 27.55 = 63.8 + 48.6 - 27.55 = 84.9 \text{ dB}$$

BTS Antenna **Gain** Reduction ($G(\theta)$). The antenna pattern provided by MSV **was** used to determine the off-axis reduction in the BTS antenna gain in the direction of the AMS(R)S receiver. The aircraft **is** assumed to be overhead of the ground-based **BTS** with an off-axis angle of 90 degrees. The minimum antenna gain reduction relative to the peak for off-axis **angles** above 30 degrees is approximately 30 dB.[7]

On-Tune Rejection (OTR). The OTR is the rejection provided by the AMS(R)S receiver selectivity characteristics to a co-tuned BTS **as** a result of the emission spectrum exceeding the receiver bandwidth. The **OTR** is computed using the following equation:

$$OTR = 10 \text{ Log } (BW_{AMS(R)S}/BW_{BTS}) \quad (3)$$

where:

$BW_{AMS(R)S}$ is the bandwidth of the AMS(R)S receiver (Hz); BW_{BTS} is the emission bandwidth of the BTS (Hz).

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[6] *Id.* **at** Appendix E, Annex **2**

[7] Mobile Satellite Ventures LP, *Out-of-Band Emissions of MSV's Ancillary Terrestrial Base Stations Relative to the GPS Band* at 3 (Feb. **25,** 2002) (hereinafter "MSV Analysis").

$$N_{BTS} = 10^{Mavail/10}$$

It is expected that based on the central limit theorem, if there are a large number of BTS signals the AMS(R)S receiver would actually see an aggregate signal producing a noise-like interference effect in the receiver.

The following paragraphs explain each of factors used in the analysis.

BTS EIRP ($EIRP_{BTS}$). The co-channel per carrier EIRP density for the BTS is 19.1 dBW/200 kHz or -33.9 dBW/Hz.[3] The adjacent channel EIRP density per carrier for the BTS emissions in the AMS(R)S channels was specified as -101.9 dBW/Hz.[4] There are three BTS carriers per sector. The adjacent channel BTS EIRP density per sector in the AMS(R)S channels that is used in this analysis is computed as shown in Table 1.

$EIRP_{Carrier}$ (dBW/Hz)	**-101.9**
Conversion from dBW to dBm	30
Adjacent Channel EIRP (dBm/200 kHz)	**-18.9**
Factor for Multiple **Carriers per** Sector **(dB)**	10 Log (**3** carriers **per** sector) = **4.8**
Adjacent Channel $EIRP_{Sector}$ (dBm/200 kHz)	**-14.1**

[3] Presentation by Mobile Satellite Ventures LP to the National Telecommunications and Information Administration: ***MSV's Next Generation Satellite** System **Coordination and Inreference Considerations*** (Feb. 5, ***2002)*** at ***27.***

[4] *Id.* at ***28.***

[5] Document No. **RTCA** DO-235, *Assessment of Radio* ***Frequency*** *Interference Relevant to* ***the*** *GNSS* (Jan. **27,** 1997) at F-13 (hereinafter "DO-235").

The receiver bandwidths of the AMS(R)S receivers vary between 600 Hz and 21 kHz depending on the receiver channel type.[11] The lowest receiver noise density is specified as -172.1 dBm/Hz.[12] The receiver power for the narrowest bandwidth would represent the lowest receiver noise power. The receiver noise power for a 600 Hz AMS(R)S receiver bandwidth is:

$$N = -172.1 \text{ dBm/Hz} + 10 \text{ Log}(600) = -144.3 \text{ dBm/600 Hz}$$

Using this receiver noise power and the I,'' of -12.2 dB the receiver interference susceptibility threshold used in this analysis is computed using the following equation:

$$I_T = N + I/N \quad (5)$$

$$I_T = -144.3 - 12.2 = -156.5 \text{ dBm/600 Hz}$$

Parameter	Value
Adjacent Channel BTS EIRP per Sector (dBm/200 kHz)	-14.1
AMS(R)S Receive Antenna Gain in the Direction of the BTS (dBi)	-10
BTS Antenna Gain Reduction (dB)	-30
AMS(R)S Receiver OTR (dB)	-25.2
Building Blockage Loss (dB)	-2.5
Interference Power Level (dBm/600 Hz)	-166.7
AMS(R)S Receiver Interference Susceptibility Threshold (dBm/600 Hz)	-156.5
Available Margin (dB)	10.2
Number of Active BTS Sectors	10

[11] Document No. RTCA DO-2 10C, *Minimum Operational Performance Standards for Aeronautical Mobile Satellite Services (AMSS)*, at 25 (Jan. 16, 1996).

[12] *Id.* at 26.

The AMS(R)S receiver bandwidth used in this analysis is 600 Hz. The bandwidth of the BTS is **200 kHz.** The OTR computed using Equation 3 is:

$$OTR = 10 \text{ Log } (600/200x10^3) = -25.2 \text{ dB}$$

Building Blockage **Loss (L_B)**. In a large geographic area there will be a percentage of the BTS that have an obstructed view of the airborne GPS receiver resulting from building blockage. The following equation is used to compute the reduction in the aggregate interfering signal level at the airborne receiver taking building blockage into account:

$$L_B = 10 \text{ Log } (P_O/(10^{Lba/10}) + P_U) \quad (4)$$

where:

L_B is the building blockage loss (dB);
P_O is the percentage of BTS that are obstructed;
P, is the percentage of the BTS that are unobstructed;
Lba is average building attenuation loss (dB).

In this assessment 50% of the BTS are assumed to have an obstructed view of the airborne GPS receiver. ***An*** average value of 9 dB is used for the building attenuation loss for the obstructed BTS.[8] Using Equation **4,** this results in a 2.5 dB reduction of the aggregate interfering signal level at the input of the airborne receiver.

AMS(R)S Receiver **Interference** Susceptibility Threshold **(I_T).** ITU-R Recommendation **M.1234** recognizes that interference from a MSS network contributes to the noise in the AMS(R)S channel and should be taken into account.' ITU-R **M.1234** specifies that the maximum permissible level of interference power in a **digital** channel in the AMS(R)S caused by transmitters of another MSS network or fixed satellite network, should not exceed ***6%*** of the total noise power at the input **to** the demodulator.'' **This** single-entry interference level of 6%of the total noise corresponds to an interference-to-noise ratio (I/N) of **-12.2 dB** (10 Log (0.06)). **This** interference criteria is used to determine the interference susceptibility threshold.

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[8] **NTIA** Report **95-325, Building** Penetration Measurements From Low-height Base **Stations at 912, 1920,** and **5990** MHz, National Telecommunications **and** Information Administration, Institute **for** Telecommunication **Sciences (Sept. 1995).**

[9] Recommendation ITU-R M.1234, *Permissible **Level** of Interference in **a Digital Channel o/a Geostationary Satellite** Network **in the Aeronautical** Mobile-Satellite (R) Service (AMS(R)S) **in the** Bands **1545** to 1555 MHz **and** 1646.5 to 1656.5 MHz **and** its **Associated Feeder Link Caused** by **Other** Networks of this **Service and the Fixed Satellite Service*** **(1997).**

[10] *Id*

correlator, narrow correlator, double delta, multipath mitigation correlator, etc. Therefore, the interference threshold used in this analysis for all GPS bands is -117 dBm/MHz.

Radiowave Propagation Loss (L_P). For this analysis, a minimum distance separation of 2 meters between the MT and terrestrial GPS receiver is considered.[19] The propagation model *to* be used when line-of-sight conditions exist is the free-space model described by the following equation:

$$L_P = 20 \text{ Log } F + 20 \text{ Log } D - 27.55 \quad (2)$$

where:

F is the frequency (MHz);
D is the distance separation between the MT and the GPS receiver (rn).

GPS Receive Antenna Gain (G_R). The GPS receive antenna gain model used in this analysis is provided in Table **2.** The antenna gain used in this analysis is based on the position of the MT with respect to the GPS receive antenna.

Table 2.

Off-Axis Angle (Measured with Respect to the Horizon)	**GPS Receive Antenna Gain (dBi)**
-90 degrees to -10 degrees	**-4.5**
-10 degrees to 10 degrees	0
10 degrees to 90 degrees	**3**

Parameter	**Value**

[19] ***Revision** of Part 15 **of the** Commission's **Rules** Regarding Ultra-Wideband **Transmission** Systems*, Fust Report and Order. 17 F C.C. Rcd. **7435** at ¶1*07* (2002)

The number of BTS sectors shown in Table 2 that can be active before the AMS(R)S interference susceptibility threshold is exceeded is relatively small. Under typical operational conditions, it is likely that there will many more active BTS in the field of view of an aircraft at an altitude of 1000 feet. Figure 1 **shows** the number of active BTS that are required to exceed the AMS(R)S receiver interference susceptibility threshold as a function of BTS EIRP density in the AMS(R)S channel.

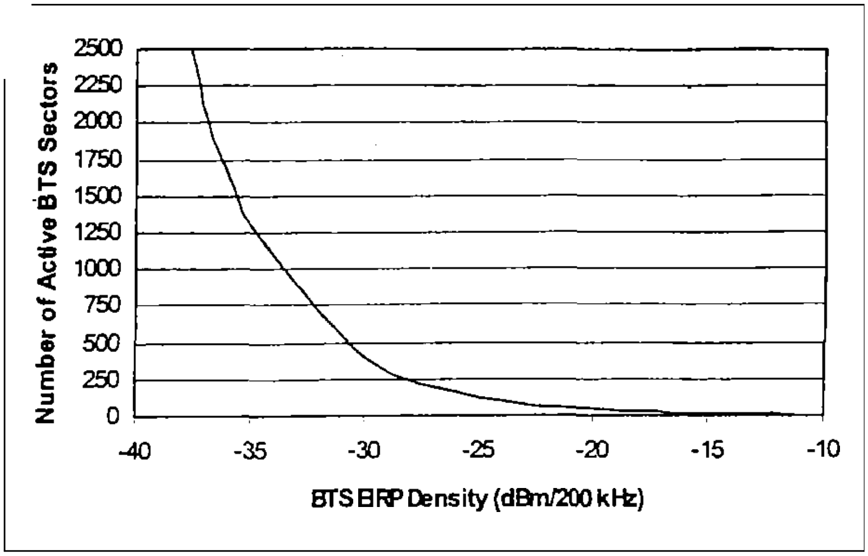

Figure 1

As shown in Figure 1, an EIRP density of -28 dBm/200 kHz per sector or -32.8 dBm/200 kHz per carrier would permit approximately 250 BTS sectors or **750** active BTS carriers (3 carriers per sector) before the AMS(R)S interference susceptibility threshold is exceeded. This would appear to be a reasonable number for a **high** density urban area.

GMDSS RECEIVER ANALYSIS

Analysis Overview

This analysis considers representative base station operational scenarios in determining the maximum allowable BTS emission level that is necessary for compatible operation with GMDSS receivers. In this analysis, a GMDSS receiver is used onboard a vessel operating in constricted waterways.

The maximum allowable EIRP of the BTS ($EIRP_{BTS}$) is computed using the following equation:

used for Category I precision approach landings, an antenna gain below the aircraft of -10 dBi was used.[21] This antenna gain assumes a constant antenna gain in the region below the aircraft, the actual antenna pattern contains many peaks and nulls (maximum and minimum values of antenna gain).[22]

Radiowave Propagation Loss (L_p). Line-of-sight conditions will exist between the airborne GPS receive antenna and the MT. The freespace propagation model described in Equation 2 is used to compute the radiowave propagation loss. The minimum distance separation between the MT and aircraft used in this analysis is 30 meters (100 feet).

Aviation Safety **Margin (L_{safety}).** When using a GPS receiver for precision approach landings, it is appropriate to include a safety margin. The aviation safety margin is used to account for uncertainties on the aviation side of the link budget that are real but not quantifiable. These include but are not limited to: multipath of the GPS signal; receiver implementation losses; antennagain variations; and approach path deviation. Since the GPS signal level cannot be increased, the aviation safety margin is implemented by lowering the allowable interference. **A** safety margin of *6* dB is included in the analysis for GPS receivers used in aviation applications. The aviation safety margin of *6* dB included in this analysis is consistent with the value specified in ITU-R Recommendation M.1477.[23]

MS Interference Allotment (L_{allot}). The Commission's rules permit adjacent band MSS MESs, 700 MHz public safety mobile and portable transmitters, and 700 MHz commercial mobile transmitters to operate with allowable emission levels of -70 dBW/MHz (EIRP) in the 1559-1610 MHz frequency band. There is also another proposal for operating ancillary base stations and MESs by ICO in the 2 GHz frequency range. To take into account that at least one of these other potential interfering sources could be operating in the vicinity of the GPS terrestrial receiver, 50% of the total interference budget is allotted to the emissions born MTs. **A** 50% interference allotment equates to a **3** dB reduction in the maximum allowable emissions from the MTs (e.g., 10 Log 0.5).

Analysis Results. The maximum allowable EIRP of the MT emissions in the L1 and L5 frequency bands that are necessary for compatible operation with aviation GPS receivers is given in Table **4.**

[21] RTCA **DO-235** at F-13

[22] RTCA **DO-235** at Appendix E **Annex** 2

[23] Recommendation ITU-R M.1477, *Technical and Performance Characteristics of Current and Planned RNSS (Space-to-Earth) and ARNS Receivers to be Considered in Interference Studies in the Band 1559-1610 MHz* at **Annex** 5.

Off-Axis Angle	Off-Axis Antenna Gain (dBi)
$0° < \phi < 30°$	
$30° < \phi < 120°$	49 - 27 Log(ϕ)
$\phi > 120°$	-9

Off-Axis Angle	Off-Axis Antenna Gain (dBi)
$0° < \phi < 10°$	21
$10° < \phi < 16°$	18
$16° < \phi < 21°$	8
$21° < \phi < 57°$	41 - 25 Log(@)
$\phi > 57°$	-3

The Mini-M and Inmarsat-B terminals are communicating with a geostationary satellite. Typical elevation angles in the U.S. are between 20 and 30 degrees. With a beamwidth of 60 and 20 degrees for the antenna mainbeam in the direction of the BTS, mainbeam antenna coupling is possible and is used in this analysis.

Radiowave Propagation **Loss (L_p).** Initially, the BTS will be used in urban areas where satellite signal levels are low or coverage does not exist. Urban environments can be characterized by non-line-of-sight propagation paths resulting mainly from building blockage. However, even in urban environments line-of-sight conditions can exist to vessels operating in constricted waterways (e.g., along the Mississippi river). The propagation model to be used when line-of-sight conditions exist is the free-space model described by Equation 2.

The distance separation between the BTS and GMDSS receiver is the slant range computed using the following equation:

$$D_{min} = ((h_{GMDSS} - h_{BTS})^2 + D^2)^{0.5} \quad (8)$$

The worst-case horizontal distance separation between the BTS and GMDSS receiver exists at the point where the coupling loss is a minimum. The coupling loss is the combination of the propagation loss, the BTS antenna gain in the direction of the GMDSS receive antenna, and GMDSS receive antenna gain in the direction of the BTS. Based on the antenna pattern techniques in the service rules adopted for MTs, the maximum allowable EIRP levels could be increased accordingly.

MEASUREMENT TECHNIQUES

The wideband emission level is to be measured using an root-mean-square (RMS) detection scheme. The measurements are to be made with a minimum resolution bandwidth of 1 MHz and the video bandwidth is not be less than the resolution bandwidth. The measurements are to be made over a 20 millisecond averaging period. The MT must be transmitting data throughout the averaging period.

The narrowband emission level is to be measured using a RMS detection scheme. The measurements are to be made with a resolution bandwidth of no less than 1 kHz. The measurements are to be made over a 20 millisecond averaging period. The MT must be transmitting data throughout the averaging period.

CONCLUSIONS

Terrestrial GPS receivers operate under handicaps such as signal attenuation due to destructive multipath, foliage, or building shadowing, and frequently operate using a minimum signal level. Based on the results of the analysis, the GPS receivers used in terrestrial applications, particularly E911 position location, represent the limiting case for establishing emission limits for the MTs used in conjunction with BTS and pico base stations.

Based on the terrestrial use of GPS, the emission levels required for compatible operation in the 1559-1610 MHz band for wideband MT emissions is -75 dBm/MHz (Table 3). The narrowband emission level is 10 dB lower than the wideband level, resulting in a narrowband MT emission level of -85 dBm.

Based on the terrestrial use of GPS, the emission levels required for compatible operation in the 1215-1240 MHz band for wideband MT emissions is -77 dBm/MHz (Table 3). The narrowband emission level is 10 dB lower than the wideband level, resulting in a narrowband MT emission level of -87 dBm.

Based on the terrestrial use of GPS, the emission levels required for compatible operation in the 1164-1188 MHz brnd for wideband MT emissions is -77 dBm/MHz (Table 3). The narrowband emission level is 10 dB lower than the wideband level, resulting in a narrowband MT emissions level of -87 dBm.

The analysis performed by MSV was based on a 8 slot Time Division Multiple Access (TDMA) access technique that is consistent with the Global System for Mobile (GSM) communications system architecture. Their analysis also included a specific vocoder frame occupancy rate that reduces the effective average power of the MT by the duty cycle attributed to

$$OTR = 10 \text{ Log } (15x10^3 / 200x10^3) = -11.2 \text{ dB} \quad \text{(Inmarsat-B)}$$

Analysis Results

The maximu allowable EIRP of *the* BTS emissions in the GMDSS channels that are necessary for compatible operation are **given** in Table 5 for the 30 meter BTS antenna height and in Table ***6*** for *the* 15 meter BTS antenna height.

Parameter	Value	
	Mini-M	Inmarsat-B
GMDSS Receiver Interference Susceptibility Level (dBm)	-90.2	-79.2
Radiowave Propagation Loss (dB)	79.8	79.8
GMDSS Receive Antenna Gain (dBi)	-10	-21
Multiple BTS Carriers (dB)	4.8	4.8
BTS Antenna Gain Reduction (dB)	1	1
GMDSS Receiver OTR (dB)	17.6	11.2
Maximum Allowable **EIRP** per BTS Carrier (dBm/200 kHz)	-6.6	-13

Parameter	Value	
	Mini-M	Inmarsat-B
GMDSS Receiver Interference Susceptibility Level (dBm)	-90.2	-79.2
Radiowave Propagation Loss (dB)	70.3	70.3
GMDSS Receive Antenna Gain (dBi)	-10	-21
Multiple BTS Carriers (dB)	4.8	-4.8
BTS Antenna Gain Reduction (dB)	1	1
GMDSS Receiver OTR (dB)	17.6	11.2
Maximum Allowable **EJRP** per BTS Carrier (dBm/200 kHz)	-16.1	-22.5

The analysis results shown in Tables 5 and 6 represent the maximum allowable EIRP on a per carrier basis. The maximum allowable EIRP per BTS carrier that is necessary for compatible

ENCLOSURE 4

ASSESSMENT OF INTERFERENCE TO INMARSAT SATELLITE RECEIVERS USED TO SUPPORT GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM AND AERONAUTICAL MOBILE SATELLITE ROUTE SERVICE OPERATIONS FROM ANCILLARY TERRESTRIAL COMPONENT MOBILE TERMINALS

BACKGROUND

The Federal Communications Commission (FCC) is currently considering a proposal horn Motient Satellite Ventures (MSV) to operate an Ancillary Terrestrial Component (ATC) in the Mobile Satellite Service (MSS)[1]. The ATC is expected to augment the MSV satellite network by providing coverage in areas where satellite service is not available or significantly attenuated by natural blockage. The proposed ATC would entail a number of terrestrial Base Transceiver Systems (BTS) communicating with handheld mobile terminals (MTs) on MSS frequencies. The MSV MTs would operate in the 1626.5-1660.5MHz band and the BTS in the 1525-1559 MHz band. In addition to the BTS, MSV will employ pico base stations operating in the 1525-1559 MHz band that may be located on ceilings of buildings or on building walls and will use omni-directional antennas.

Since the government and non-govemment share the frequencies of operations for the proposed ATC, MSV engaged the National Telecommunications and Information Administration (NTIA) in February 2002 with a presentation describing the MSV proposal.' At that time, MSV provided coordination and interference analyses that must be considered if and when the Commission allows such an ATC to operate in the MSS frequency bands. The coordination and interference issues presented by MSV addressed the concerns of Inmarsat Ventures PLC, **who** operates satellite networks in the MSS. Based on their interference analyses, MSV concluded that the proposed ATC operations would not cause interference to the Inmarsat satellite system. Inmarsat also briefed **NTIA** in February of 2000, but presented interference calculations that differ with the MSV conclusions.[3] Inmarsat, using similar methodology for calculating interference concluded that if the ATC were permitted, it would cause interference to the Inmarsat system.

The 1626.5-1645.5 MHz portion ***of*** the 1626.5-1660.5MHz band is used by the United States Coast Guard (USCG) and the United States Navy (US Navy) for the Global Maritime Distress and Safety System (GMDSS) in the Earth-to-space direction. The Federal Aviation Administration **(FAA)** uses the 1646.5-1656.5MHz portion ***of*** the 1626.5-1660.5MHz band for

[1] *In the Matter of Flexibility for Delivery of Communications by* ***Mobile Satellite Service Providers*** *in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band. Notice of Proposed* **Rule Making,** IB Docket No. 01-185 **and** ET No. ***95-18*** *(rel.* August 17,2001) **(the** "Flexibility NPRM") .

[2] Mobile Satellite Ventures LP, Presentation to NTIA, IB Docket No. 01-185 (Feb. 5, **2002)** (hereinafter "MSV Presentation").

[3] Inmarsat Ventures PLC, Presentation to NTIA, IB Docket No. 01-185 (Feb. **21,** 2002) (hereinafter "Inmarsat Presentation").

aeronautical mobile satellite route service (AMS(R)S) in *the* Earth-to-space direction. The US Navy and USCG requested that NTIA review Inmarsat's concerns of interference particularly with respect to aggregate interference to the Inmarsat satellite receiver from terrestrial MTs operating in the **1626.5 – 1660.5** MHz band.[4] The US Navy and USCG believe that if interference concerns raised by Inmarsat are justified GMDSS and AMS(R)S operations could be affected.

OBJECTIVE

The objective of this analysis is to perform **an** assessment of the potential for aggregate interference from MSV ATC MTs to an Inmarsat satellite receiver used to support GMDSS and AMS(R)S operations.

AGGREGATE INTERFERENCE TO *Ah'* INMARSAT SATELLITE RECEIVER

Comparison of MSV and Inmarsat Analyses

The MSV terminals will transmit in **1626.5-**1660.5 MHz to communicate with either *the* MSV satellite using mobile earth stations or the BTS using MTs. Since Inmarsat terminals used for GMDSS and AMS(R)S operations will also transmit in this frequency band, Inmarsat is concerned that co-channel transmissions of many MSV terrestrial MTs will cause interference above the normal interference expected with MSV satellite operations without the ATC.[5]

Inmarsat and MSV used similar methodologies when computing the level of interference from the MSV MTs into an Inmarsat satellite receiver, however each analysis reached different conclusions. The different conclusions can be attributed to disagreement on the values of some technical parameters used in the interference calculations. A comparison of the values used for the technical parameters in the MSV and Inmarsat analyses are shown in Table 1.[6]

Table 1. Comparison of Technical Parameters used in Inmarsat and MSV Analyses

Technical Parameter	MSV	INMARSAT	Difference
Shielding Factor	10 dB	3 dB	7 dB
Satellite Receive Antenna Discrimination[7]	20 dB	20dB	0 dB
Vo-Coder Power Reduction Factor	7.4 dB	0 dB	7.4 dB
Power Control Factor	6 dB	2 dB	4 dB
Polarization Isolation	3	1.4	1.6 dB
Voice Activity Factor	1 dB	0 dB	1 dB
MT OOB Emissions	-103.0 dBW/Hz	-96 dBW/Hz	7 dBW/Hz

[4] Memorandum to Executive Secretary, IRAC from J. Hersey Jr., United States Coast Guard/Department Of Transportation IRAC Representative, Subject: Terrestrial Operations in the MSS Upper and Lower "L" bands; FCC IB Docket 01-185/ET Docket 95-18 (Feb. 8, 2002); Memorandum to Executive Secretary, IRAC from Bruce Swearingen, Navy IRAC Representative. Subject: Terrestrial Operaticns in the MSS Upper and Lower "L" bands; FCC IB Docket 01-185/ET Docket 95-18 (May 13, 2002).

[5] Inmarsat Presentation at 19.

[6] The values shown in Table 1 for the **key** parameters are from the MSV and Inmarsat presentations to NTIA.

[7] The MSV interference calculations also used 25 and 30 dB for this parameter.

The MSV and Inmarsat presentations to NTIA included calculations of co-channel and adjacent channel interference to Inmarsat satellite receivers. The parameters of disagreement account for a total of 21dB difference in the analyses presented by MSV and Inmarsat. There is also a difference in the levels for the MT out-of-band emissions used in each analysis. The MSV calculations take a more liberal approach with the various technical parameters, which serve to enhance the power reduction factors. Inmarsat, on the other hand, used more conservative values for the technical parameters.

To address the concerns raised by the USCG and the US Navy regarding GMDSS and AMS(R)S operations, **NTIA** performed an assessment of the potential interference from MSV MTs to an Inmarsat satellite receiver.

NTIA Analysis Overview

In this analysis the interference pswer density is computed using the MSV proposed co-channel and adjacent channel EIRP levels for the MTs. The computed interference power density is then compared to the interference power density threshold for the Inmarsat satellite receiver to determine the amount of available margin. Based on the available margin, the number of MTs that can be operating before the interference threshold is exceeded is determined:

The interference power density is computed using Equation 1.

$$I_0 = EIRP_{MT} + G_R - G(\theta) - L_P + L_{AF} - L_{POL} - L_S - L_{TPC} \qquad (1)$$

where:

I_0 is the interference power density (dBW/Hz);
$EIRP_{MT}$ is the co-channel and adjacent channel EIRP density of the MTs (dBW/Hz);
G_R is the Inmarsat satellite receive antenna gain (dBi);
$G(\theta)$ is the Inmarsat satellite receive antenna discrimination (dB);
L_p is the propagation loss between the Inmarsat satellite and the MTs (dB);
L_{AF} is the MT activity factor (dB);
L_{POL} is the polarization loss factor (dB);
L_S is the shielding loss (dB);
L_{TPC} is the MT transmitter power control factor (dB).

The difference between the interference power density threshold and the interference power density computed using Equation 1, represents the available margin (M_{avail}). The number of MTs (N_{MT}) that would have to be in the Inmarsat satellite beam footprint before the interference power density threshold is exceeded is determined by[8]:

$$N_{MT} = 10^{M_{avail}/10}$$

[8] This **assumes** that the average power from multiple sources will add linearly and that for a **very** large number (central limit theorem) of **signals** a satellite receiver would see an aggregate signal that would produce a noise-like interference effect.

The following paragraphs discuss each of the parameters used in the analysis.

MT Equivalent Isotropic Radiated **Power** ($EIRP_{MT}$). The EIRP levels for the MTs provided by MSV *are* used in ***this*** analysis. The EIRP levels for co-channel and adjacent channel operation are **–53** dBW/Hz[9] and –103 **dBW/Hz**[10] respectively.

Inmarsat Satellite Receive Antenna Gain **(Gr).** The mainbeam gain ***of*** the Inmarsat satellite receive antenna used in this analysis is 41 dBi.[11]

Inmarsat Satellite Receive Antenna Gain Discrimination **(G(θ)).** For co-channel operartion the antenna discrimination of the Inmarsat satellite receive antenna is 22 dB.[12] For adjacent channel operation the antenna discrimination of the Inmarsat satellite receive antenna is 0 dB.

Propagation **Loss (Lp).** The free-space propagation model is used to compute the propagation **loss** between the Inmarsat satellite and the MTs. The propagation model described by *the* free-space loss equation is shown in Equation **2.**

$$L_p = 20 \text{ Log } F + 20 \text{ Log } D + 32.45 \qquad (2)$$

where:

F is the frequency (MHz);
D is the distance separation between the Inmarsat satellite and the MTs (km).

The Inmarsat satellite is in geostationary orbit at a minimum distance of 35,786 km. The free-space propagation loss for a center frequency of 1643.6 MHz is 187.8 &.

MT Activity Factor **(L_{AF}).** To calculate the average transmit power for a large number ***of*** MTs an activity factor should be taken into consideration. The activity factor represents the percentage of time that the MT is actually transmitting. For example, a MT that is transmitting continuously will have an activity factor of 100%. The activity factor **is** on average slightly less than 50% (e.g., each user in a conversation is actually speaking roughly half of the time, and there is some "idle time" for pauses).'' The MT activity factor is computed as follows:

$$L_{AF} = 10 \text{ Log (Percentage of Time MT is Transmitting/100)} \qquad (3)$$

In this analysis it is assumed that each MT is transmitting half of the time and an activity factor of 50% is used. ***An*** activity factor of 50% equates to a **–3** dB reduction in the average power of the MT (e.g., a ratio of 0.5).

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[9] MSV Presentation at 21.
[10] *Id.* at **22.**
[11] Inmarsat Presentation at **22.**
[12] *Id* at 17.
[13] Written **Ex** Parte Communication, **Sprint** Corporation and Cingular Wireless LLC, Mobile Satellite Systems – *Terrestrial Services IB* **Docker No.** *01-185; ET Docket No. 95-18* (May 13,2002) Anachment A at 21 (hereinafter **"2** GHz Study").

Polarization **Loss (L_{POL}).** Polarization loss, also referred to as polarization discrimination or polarization isolation, is the ratio at a receiving point between received power in the expected polarization and the received power in a polarization orthogonal to it from a wave transmitted with a different polarization. The polarization of an antenna remains relatively constant throughout the main lobe of the antenna pattern, but varies considerably in the minor lobes.[14] Since for the antenna directions and polarization are not known for a large number of MTs a value of 0 dB is used in this analysis for the polarization loss.

Shielding **Loss (L_S).** The stated purpose of the ATC is to provide coverage in areas where satellite service is not available or significantly attenuated by natural blockage such as in buildings and in urban canyons where MTs that are associated with the ATC are expected to be operating. The shielding factor is difficult to determine for a large number of MTs that can be widely distributed. The value of average shielding loss that is used in this analysis is 10 dB.[15]

Transmitter Power **Control (L_{TPC}).** Transmitter Power Control (TPC) will reduce the transmitter power of the MT and should be taken into consideration when calculating the average power of multiple MTs. When employed, TPC will reduce the transmit power of the MT depending upon the distance between the BTS and MT (e.g., as the MT gets closer to the BTS the transmit power will be reduced). TPC can also reduce the transmit power of the MT when there is no data to transmit (e.g., when not transmitting speech, the MT transmits a low data rate signal to maintain the link with the BTS). Both Inmarsat and MSV agree that a factor for TPC should be included in the analysis, The value of 2 dB used by Inmarsat would be applicable for a MT that is not located close to the BTS or to a MT that is transmitting data.[16] The value of 6 dB used by MSV would be more applicable to an MT operating close to a BTS or to an MT that is not transmitting data." In this analysis a value of 3 dB is used as a compromise for the TPC of the MTs.

Inmarsat Satellite **Receiver** Interference Threshold

The interference power density threshold used in this analysis is based on an increase in the receiver noise level of the Inmarsat satellite receiver. The interference power density threshold (I_T) is computed using the following equation:

$$I_T = N_0 + I/N \quad (4)$$

where:

N_0 is the noise density of the Imarsat satellite receiver (dBW/Hz);
I/N is the interference-to-noise ratio (dB).

The noise density of the Inmarsat satellite receiver is computed using the following equation:

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[14] *Antenna Engineering Handbook,* R.C. Johnson, H. Jasik (Second Edition) at 1-7.

[15] **NTIA** Special Publication 01-46. ***The Potential for Accommodating Third Generation** Mobile **System in the 1710-1850 MHz Band*** **(March** 2001) Appendix D at B-38.

[16] Inmarsat Presentation at 19.

[17] MSV Presentation at 25.

$$N_0 = 10 \text{ Log } [(1.38 \times 10^{-23}) T] \quad (5)$$

where T is the Inmarsat satellite receiver noise temperature (K). In this analysis, a receiver noise temperature of 650 K is used.[18] The noise density of the Inmarsat satellite receiver is:

$$N_0 = -200.5 \text{ dBW/Hz}$$

The I/N used in this analysis is based on an allowable increase in the receiver noise level and is determined using the following equation:

$$I/N = 10 \text{ Log}(10^{\Delta N/10} - 1) \quad (6)$$

where ΔN represents the allowable increase in the receiver noise. In this analysis a 0.5 dB increase in the receiver noise is used. For a 0.5 dB increase in the receiver noise, the I/N is –9.1 dB. Using Equation 4, the interference power density threshold used in this analysis is:

$$I_T = -200.5 \text{ dBW/Hz} - 9.1 = -209.6 \text{ dBW/Hz}$$

Analysis Results

The results of the analysis for co-channel and adjacent channel operation of MTs are provided in Table 2.

Table 2. Analysis Results

Parameter	Value	
	Co-Channel	Adjacent Channel
MT EIRP Density (dBW/Hz)	-53	-103
Inmarsat Receive Antenna Gain (dBi)	41	41
Inmarsat Receive Antenna Discrimination (dB)	-22	0
Propagation Loss (dB)	-187.8	-187.8
MT Activity Factor (dB)	-3	-3
Polarization Loss Factor (dB)	0	0
Shielding Loss (dB)	-10	-10
MT Transmitter Power Control (dB)	-3	-3
Interference Power Density (dBW/Hz)	-237.8	-265.8
Interference Power Density Threshold (dBW/Hz)	-209.6	-209.6
Available Margin (dB)	28.2	56.2
Number of MTs	661	416,869

In the United States the typical elevation angles to geostationary satellites are between 20 and 30 degrees. For a geostationary satellite the area visible on the Earth for elevation angles greater than 20 degrees is approximately 71.5×10^6 km^2. It is anticipated that over such a large visible area that the number of MTs that are operating can be significant. For co-channel

[18] **Inmarsat** Presentanon at 19

operation of MTs at the emission level proposed by MSV, the results of the analysis show that only 660 MSs can be operating before the interference threshold is exceeded. This appears to be a **small** number of MTs given the large area visible to the satellite. However, at the level proposed by MSV for adjacent channel emissions, the analysis shows that approximately **41**7,000 MSs can be operating before the interference threshold is exceeded. This indicates that adjacent channel operation at the emission level proposed by MSV is feasible.

An analysis of spectrum sharing between MSS and terrestrial wireless services in the 2 GHz frequency range concluded that co-channel sharing is not feasible under any practical conditions.[19] The study also concluded that operating on separate frequencies, with appropriate guard bands to control adjacent channel interference was possible.” These conclusions are consistent with the results of this analysis.

CONCLUSIONS

The main problem with co-channel operation is that all MTs within the Inmarsat beam footprint contribute to the interference seen by the satellite receiver. The conhibution of each MT depends on such factors as its transmit power (which may be subject to power control), and the excess attenuation in the propagation path from the MT to the spacecraft. The interference to the satellite receiver is cumulative, and will affect the uplinks from all MTs located in the satellite beam. Based on the results of the analysis shown in Table **2,** co-channel operation of the MTs at the EIRP level proposed by MSV with GMDSS and AMS(R)S operations should be avoided.

Since the isolation between neighboring channels is not perfect, MTs that operate on adjacent channels will still have emissions that could impact the Inmarsat satellite receiver. Based on the results of the analysis shown in Table 2, adjacent channel operation of the MTs at the EIRP level proposed by MSV with GMDSS and AMS(R)S operations is feasible and can be effectively implemented through the coordination process that exists between MSS operators.

[19] *2* GHz Study **at** 77.
[20] *Id.*

ENCLOSURE 5

ASSESSMENT OF INTERFERENCE TO SEARCH AND RESCUE SATELLITE LAM) USER TERMINAL RECEIVERS FROM ANCILLARY TERRESTRIAL BASE STATIONS OPERATING IN THE 1525-1559 MHz MOBILE SATELLITE SERVICE BAND

BACKGROUND

The Federal Communications Commission (Commission) received proposals from New ICO Global Communications (Holding) Ltd. (ICO), Motient Services Inc., and Mobile Satellite Ventures Subsidiary (MSV)[1] to operate ancillary terrestrial base station transmitters (BTS) with their networks using assigned mobile satellite service (MSS) frequencies. The BTS would operate in the 1525-1559 MHz band (MSV Proposal)', or the 1990-2025 and 2165-2200 MHz bands (ICO Proposal). The BTS is to be integrated with the satellite network and will employ directional antennas that are expected to provide coverage to areas where the satellite signal is attenuated by foliage or terrain or to provide in-building coverage. In addition to the BTS, MSV will employ pico base stations operating in the 1525-1559 MHz band that may be located on ceilings of buildings or on building walls and will use omni-directional antennas.

The National Oceanic and Atmospheric Administration (NOAA) operates polar orbiting and geostationary satellites that carry Search and Rescue Satellite (SARSAT) payloads that provide distress alert and location information to appropriate public safety rescue authorities for maritime, aviation, and land users in distress. SARSAT consists of a network of satellites, ground stations, mission control centers, and rescue coordination centers. When an emergency beacon is activated, the signal is received by satellite and relayed to the nearest available ground station. The SARSAT ground station is referred to as a Local User Terminal (LUT). The LUTs receive information from satellites in the 1544-1545 MHz portion of the 1525-1559 MHz band. NOAA has 14 LUTs at 7 locations, providing total system redundancy and allows maximization of satellite tracking.

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[1] MSV will provide MSS throughout North America using the satellires launched by Motient Services Inc. and TMI Communications and Company Limited Partnership.

[2] *Ex parte* letter from Lawrence H. William and Suzanne Hutchings, New ICO Global Communications (Holdings) Ltd., to Chairman Michael K. Powell, Federal Communications Commission, IB Docket No. 99-81 (March 8, 2001); Application filed by Motienr Services Inc. and Mobile Satellite Ventures Subsidiary LLC for Assignment of Licenses and for Authority to Launch and Operate a Next-Generation Mobile Satellite Service System (March 1, 2001).

OBJECTIVE

The objective of this analysis is to assess the potential of interference to SARSAT LUT receivers from the emissions of BTS operating in the 1525-1559 MHz band.

APPROACH

This analysis will determine the distance separation between the SARSAT LUT and a BTS that is necessary for compatible operation. Since the pico base stations will be employed indoors and in **areas** where building blockage is **high** they are not expected to be the limiting interference condition and therefore, are not considered in this analysis.

Analysis Overview

The received interference power level from the BTS at the input of the SARSAT LUT receiver is calculated using the following equation:

$$I = EIRP - G(\theta) + G_R - L_P - L_S \qquad \textbf{(1)}$$

where:

$EIRP_{BTS}$ is the MSV proposed adjacent channel EIRP for a BTS carrier (dBm/800 kHz);
$G(\theta)$ is BTS antenna **gain** reduction in the direction of the SARSAT LUT receiver **(dB)**;
G_R is the mainbeam gain of the SARSAT LUT receive antenna (dBi);
L_P is the radiowave propagation **loss** (dB);
L_S is the system/insertion loss (dB).

In this assessment compatible operation is defined when the received interference power level from the BTS **is** below the interference susceptibility threshold of the SARSAT LUT receiver (I_T). The difference between the received interference power level computed using Equation 1 and the interference susceptibility threshold of the SARSAT LUT receiver represents the available margin. When the available margin is positive compatible operation is possible. The distance at which the available margin is zero represents the minimum distance necessary for compatible operation. The following paragraphs explain each of the factors used in this analysis.

BTS EIRP ($EIRP_{BTS}$). The co-channel per carrier EIRF' density for a BTS is 19.1 dBW/200 kHz or -33.9 dBW/Hz.[3] The adjacent channel EIRF' density per carrier for BTS emissions in the was

[3] Presentation by Mobile Satellite Ventures LP to the National Telecommunications **and** Information Administration: *MSV's Next **Generation** Satellite System Coordination and Interference Considerations* (Feb. 5, *2002)* at 27.

Parameter	Value
$EIRP_{BTS}$ (dBW/Hz)	-101.9
Conversion from Hz to 800 kHz (dB)	10 Lon $(200x10^3) = 59$
Conversion 60m dBW to dBm	**30**
Adjacent Channel $EIRP_{BTS}$ (dBm/800 kHz)	-12.9

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[4] *Id.* at 28.

[5] **NTIA** Special Publicahon 01-43 at A-23

[6] MSV Analysis at 3

[7] National Telecommunications and Information Administration, NTIA Special Publicahon 01-43, *Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems* (Jan 2001) at A-24 (hereinafter " **NTIA** Special Publication 01-43").

[8] National Telecommunications and Information Administration, NTIA Report 82-100, *A Guide to rhe Use of the ITS Irregular Terrain Model in the Aren Prediction Mode* (April 1982).

features and radio measurements used to predict the median attenuation as a function of distance and the variability of the signal in time and space. The parameters used in the ITM model are shown in Table 2.

ITM Model Parameter	Value
Refractivity	301 N-units
Conductivity	0.0278 S/m
Permittivity	15
DeltaH	30 m
Percent Time	10%
Percent Location	50%
Percent Confidence	50%

System/Insertion Loss (L_t). The system/insertion loss represents the loss between the receiver antenna and receiver input. **A** insertion/system loss of 2 dB is used in the analysis for the **SARSAT LUT** receiver.

SARSAT LUT Receiver Interference Susceptibility **Threshold (I_T).** Annex **A** of the **COSPAS-SARSAT** document C/S T.002 specifies that a bit error rate (BER) of 1×10^{-6} is required to provide reliable performance on the Cospas-Sarsat processed data stream (PDS) channel. Based on the **SARSAT** link parameters, the required BER of 1×10^{-6} is achieved with only a 2.4 dB margin for tracking SARSAT satellites.[9]

The link must maintain a positive margin in order to achieve the required BER of 1×10^{-6}. Therefore, the total of all interference cannot be allowed to degrade the link by more than 2.4 dB. In this case the additional interference noise at the SARSAT LUT receiver is given by the following equation (numeric quantities).

$$N + I \leq 10^{(2.4/10)} * N \qquad (4)$$

where:

I is the additional noise;

[9] Memorandum from Ban Sessions, Subject: Derivation of I/N ratio for UWB interference to L-Band downlink (Dec. 13,2001).

N is the SARSAT LUT receiver system noise.

Equation **4** can be rewritten as follows:

$$I/N \leq (10^{(2.4/10)} - 1) = 0.738$$

If **15%** of the margin were allocated to BTS interference, then $(I/N)_{BTS} = 0.1107$ (numeric) = -9.6 dB dB. This supports the I/N of -9 dB used in a previous analysis examining interference to SARSAT LUT receivers.[10] To compute the SARSAT LUT receiver interference susceptibility threshold the following equation **is** used:

$$I_T = I/N + N \quad (7)$$

The SARSAT LUT receiver system noise in dBm, is computed using the following equation:

$$N = -198.6 \text{ dBm/°K/Hz} + 10 \text{ Log} T_s + 10 \text{ Log } B \quad (8)$$

where

T_s is the SARSAT LUT system noise temperature (K);
B is the SARSAT LUT receiver bandwidth (Hz).

The SARSAT LUT system noise temperature is 176 K[11] and the receiver bandwidth is 800 kHz. Using Equation 8 the receiver system noise is:

$$N = -117 \text{ dBm.}$$

Using Equation 7, the SARSAT LUT receiver interference susceptibility threshold **is:**

$$I_T = -117 - 9 = -126 \text{ dBm}$$

Analysis Results

The results of the analysis are provided in Figure 1. **As** shown in Figure 1, based on the adjacent channel BTS EIRP proposed by MSV, the distance separation that is required for compatible operation with SARSAT LUTs is **30.4** km. **A** spread sheet containing the detailed

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[10] NTIA Special Publication 01-43 at **A-23.**

[11] NTIA Special Publication 01-43 at **A-23.**

calculations **is** provided in Appendix **A.**

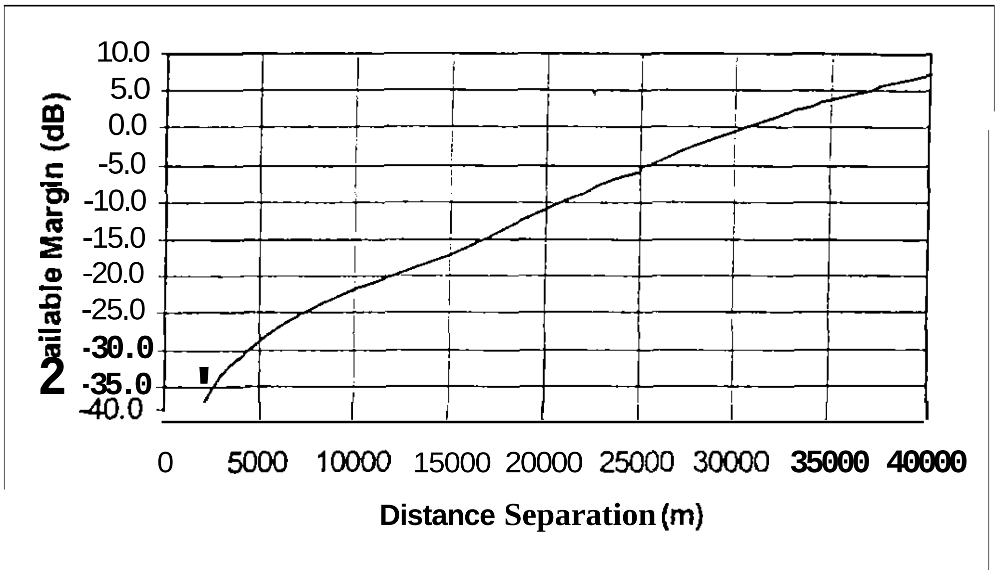

Figure 1

Since the SARSAT LUT locations are known, provisions can be included in the MSV BTS licenses to ensure that this distance separation **is** maintained. Table **3** provides the locations for the **SARSAT** LUTs.

Table 3.

SARSAT LUT Location	Coordinates
Anderson AFB, Guam	13.5784°N 144.9390°E
Vandenberg AFB, CA	34.6624°N 120.5514°W
Sabana Seca USN, PR	18.4317°N 066.1922°W
USCG Station, Wahiawa, HI	21.5260°N 157.9964°W
NASA JSC, Houston, TX	29.5605°N 095.0925°W
Fairbanks, AK	64.9933°N 147.5237°W
Suitland, MD	38.8510°N 076.9310°W

CONCLUSIONS

A distance separation of 30 km is necessary between a BTS and a SARSAT LUT receiver to ensure compatible operation. Since the locations of the SARSAT LUTs are known the required distance separation can incorporated in the MSV BTS license requirements.

Possible techniques to reduce the required separation distance include but are not limited to:

- reduce BTS antenna gain in the direction of the ***SARSAT*** LUT;

- lower the BTS emission level in the 1544-1545 MHz portion of the band;

- take into account specific terrain features or other obstacles located between the **BTS** and SARSAT LUT location.

APPENDIX A

EIRP (dBm/800 kHz)	*Gr* (dBi)	Ls (dB)	DSEP (m)	HBTS (m)	HLUT (m)	SL (km)	F (MHz)	Lp(FS) (dB)	Angle (Rad)	Theta (Deg)	Tilt Angle (Deg)	Theta-Tilt (Deg)	G(Theta-Tilt) (dB)	I (dBm)	It (dBm)	Margin (dB)
-12.9	27	2	1000	30	5	1.0	1544	93.0	0.0250	1.4	-5	-3.6	1.0	-81.8	-126.0	-44.2
-12.9	27	2	2000	30	5	2.0	1544	99.1	0.0125	0.7	-5	-4.3	1.6	-88.6	-128.0	-37.4
-12.9	27	2	[illegible]000	30	5	3.0	1544	102.7	3.0083	0.5	-5	-4.5	1.8	-92.4	-126.0	-33.6
-12.9	27	2	4000	30	5	4.0	1544	105.3	0.0063	0.4	-5	-4.6	1.9	-95.1	-126.0	-30.9
-12.9	27	2	5000	30	5	5.0	1544	107.4	0.0050	0.3	-5	-4.7	1.9	-97.2	-126.0	-28.8
-12.9	27	2	6000	30	5	6.0	1544	109.1	0.0042	0.2	-5	-4.8	2.0	-99.0	-126.0	-27.0
-12.9	27	2	7000	30	5	7.0	1544	110.6	0.0036	0.2	-5	-4.8	2.0	-100.5	-126.0	-25.5
-12.9	27	2	7150	30	5	7.2	1544	110.8	0.0035	0.2	-5	-4.8	2.0	-100.7	-126.0	-25.3
-12.9	27	2	8000	30	5	8.0	1544	111.9	0.0031	0.2	-5	-4.8	2.0	-101.8	-126.0	-24.2
-12.9	27	2	9000	30	5	9.0	1544	113.0	0.0028	0.2	-5	-4.8	2.0	-103.0	-126.0	-23.0
-12.9	27	2	10000	30	5	10.0	1544	114.1	0.0025	0.1	-5	-4.9	2.0	-104.1	-126.0	-21.9
-12.9	27	2	11000	30	5	11.0	1544	115.1	0.0023	0.1	-5	-4.9	2.1	-105.1	-126.0	-20.9
-12.9	27	2	12000	30	5	12.0	1544	116.1	0.0021	0.1	-5	-4.9	2.1	-106.1	-126.0	-19.9
-12.9	27	2	13000	30	5	13.0	1544	117.0	0.0019	0.1	-5	-4.9	2.1	-107.0	-126.0	-19.0
-12.9	27	2	14000	30	5	14.0	1544	118.0	0.0018	0.1	-5	-4.9	2.1	-108.0	-126.0	-18.0
-12.9	27	2	15000	30	5	15.0	1544	119.0	0.0017	0.1	-5	-4.9	2.1	-108.9	-126.0	-17.1
-12.9	27	2	16000	30	5	16.0	1544	120.1	0.0016	0.1	-5	-4.9	2.1	-110.0	-126.0	-16.0
-12.9	27	2	17000	30	5	17.0	1544	121.3	0.0015	0.1	-5	-4.9	2.1	-111.3	-126.0	-14.7
-12.9	27	2	18000	30	5	18.0	1544	122.6	0.0014	0.1	-5	-4.9	2.1	-112.6	-126.0	-13.4
-12.9	27	2	19000	30	5	19.0	1544	123.8	0.0013	0.1	-5	-4.9	2.1	-113.8	-126.0	-12.2
-12.9	27	2	20000	30	5	20.0	1544	124.9	0.0013	0.1	-5	-4.9	2.1	-115.0	-126.0	-11.0
-12.9	27	2	21000	30	5	21.0	1544	126.1	0.0012	0.1	-5	-4.9	2.1	-116.1	-126.0	-9.9
-12.9	27	2	22000	30	5	22.0	1544	127.2	0.0011	0.1	-5	-4.9	2.1	-117.2	-126.0	-8.8
-12.9	27	2	23000	30	5	23.0	1544	128.3	0.0011	0.1	-5	-4.9	2.1	-118.4	-126.0	-7.6
-12.9	27	2	24000	30	5	24.0	1544	129.4	0.0010	0.1	-5	-4.9	2.1	-119.5	-126.0	-6.5
-12.9	27	2	25000	30	5	24.5	1544	130.0	0.0010	0.1	-5	-4.9	2.1	-120.0	-126.0	-6.0
-12.9	27	2	25000	30	5	25.0	1544	130.5	0.0010	0.1	-5	-4.9	2.1	-120.5	-126.0	-5.5
-12.9	27	2	26000	30	5	26.0	1544	131.6	0.0010	0.1	-5	-4.9	2.1	-121.6	-126.0	-4.4
-12.9	27	2	27000	30	5	27.0	1544	132.6	0.0009	0.1	-5	-4.9	2.1	-122.6	-126.0	-3.4
-12.9	27	2	28000	30	5	28.0	1544	133.6	0.0009	0.1	-5	-4.9	2.1	-123.6	-126.0	-2.4
-12.9	27	2	29000	30	5	29.0	1544	134.6	0.0009	0.0	-5	-5.0	2.1	-124.6	-126.0	-1.4

-12.9	27	2	30000	30	5	30.0	1544	135.6	0.0008	0.0	-5	-5.0	2.1	-125.6	-126.0	-0.4
-12.9	27	2	31000	30	5	31.0	1544	136.5	0.0008	0.0	-5	-5.0	2.1	-126.6	-126.0	0.6
-12.9	27	2	32000	30	5	32.0	1544	137.5	0.0008	0.0	-5	-5.0	2.1	-127.5	-126.0	1.5
-12.9	27	2	33000	30	5	33.0	1544	138.2	0.0008	0.0	-5	-5.0	2.1	-128.2	-126.0	2.2
-12.9	27	2	34000	30	5	34.0	1544	139.0	0.0007	0.0	-5	-5.0	2.1	-129.0	-126.0	3.0
-12.9	27	2	35000	30	5	35.0	1544	139.7	0.0007	0.0	-5	-5.0	2.1	-129.7	-126.0	3.7
-12.9	27	2	36000	30	5	36.0	1544	140.4	0.0007	0.0	-5	-5.0	2.1	-130.4	-126.0	4.4
-12.9	27	2	37000	30	5	37.0	1544	141.1	0.0007	0.0	-5	-5.0	2.1	-131.2	-126.0	5.2
-12.9	27	2	38000	30	5	38.0	1544	141.8	0.0007	0.0	-5	-5.0	2.1	-131.9	-126.0	5.9
-12.9	27	2	39000	30	5	39.0	1544	142.5	0.0006	0.0	-5	-5.0	2.1	-132.6	-126.0	6.6
-12.6	27	2	40000	30	5	40.0	1544	143.2	0.0006	0.0	-5	-5.0	2.1	-133.2	-126.0	7.2