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 frequency 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 frequency 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 frequency 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 frequency 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 adopting 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[11], 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 Augmentanon System (SBAS) and Ground Eased Augmentation Systems (GBAS). In the United States the SBAS is the Wide Area Augmentation System (WAAS) and the GBAS is **the** Local Area Augmentation System (LAAS). These augmentation **system** 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 Inc., 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 adequate. 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." 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 to Further Streamline the Equipment Authorization Process for Radio Frequency Equipment, Modify the 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 OPERATTONAL 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 tracking 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 Idormation Administration, IB Docker No. 99-67, at 8 (July 21, 1999).

[16] Comments of the National Telecommunications and Information Administration, IB Docket 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	6dB
Aviation GPS Receiver Susceptibility Threshold (Tracking Mode)	-110.5 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 dBi. 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 -40 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 ($EIRP_{MT}$) is computed using the following equation:

$$EIRP_{MT} = I_T + L_P - G_R \tag{1}$$

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 MT (dBi).

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.

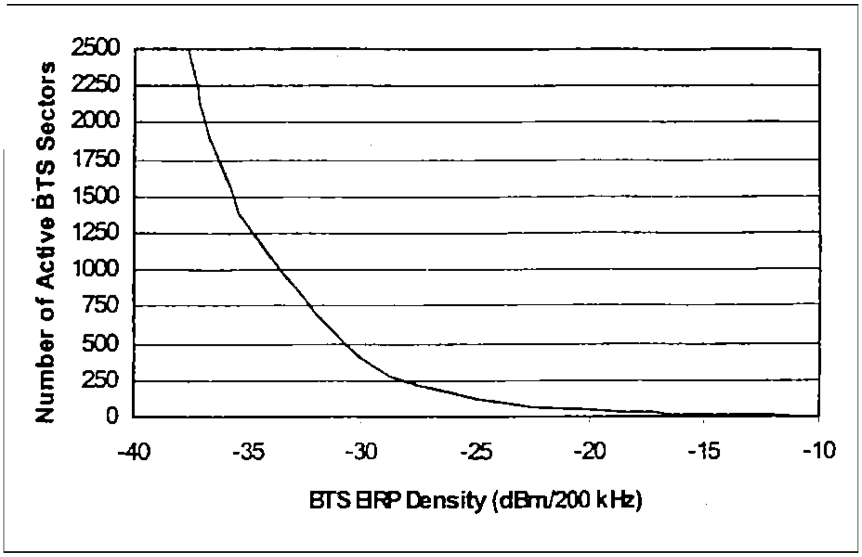

Figure 1

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 (E_{max}) is computed using *the* following equation:

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

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:

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

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 dBW = -90.2 dBm (Mini-M)

I_T = -105 - 25.2 + 21 = -109.2 dBW = -79.2 dBm (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 **LRAC** Representative, **to** E. Davison, Electronics Engmeer. NTIA Office of Spectrum Management **(May 31, 2002)** (hereinafter "Coat **Guard** E-mail").

[14] *Id.*

[15] *Id.*

Off-Axis Angle	OK-Axis Antenna Gain (dBi)
$0° < \phi < 30°$	10
$30° < \phi < 120°$	49 - 27 Log(ϕ)
ϕ > 120"	-9

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

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:

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

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 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 1 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:

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

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:

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

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[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.**

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

Analysis Results

The maximum 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	I
GMDSS Receiver OTR (dB)	17.6	11.2
Maximum Allowable **EIRP** per BTS Carrier (dBm/200 kHz)	-16.1	-22.5

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 portion 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.

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 ormi-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 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).

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:

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

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 computed using Equation 1, represents the available margin (M_{avail}). The number of BTS (N_{BTS}) that would have to be simultaneously transmitting before the interference susceptibility threshold is exceeded is determined by:

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

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, (dBW/Hz)	-101.9
Conversion from Hz to 200 kHz (dB)	10 Log (200x103) = 53
Conversion from dBW to dBm	30
Adjacent Channel EIRP,, Carrier (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

AMS(R)S Receive Antenna Gain (G_R). The AMS(R)S receive antenna is located on top of the aircraft. In a previous analysis of terrestrial interference to Global Positioning System receivers used for aviation applications, an antenna gain below the aircraft of -10 dBi was used.[5] 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

[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.

[4] *Id.* at 28.

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

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:

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

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:

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

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").**

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:

$$OTR = 10 \text{ Log } (600/200\times10^3) = -25.2 \text{ dB}$$

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_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.[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.[9] 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.[10] 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 of a Geostationary Satellite Nerwork 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 Associared Feeder Links Caused by Other Networks of this Service and the Fixed Satellite Service* **(1997).**

[10] *Id.*

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/N of -12.2 dB the receiver interference susceptibility threshold used in this analysis is computed using the following equation:

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

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

Analysis Results

The maximum number of BTS sectors simultaneously transmitting before the AMS(R)S receiver interference susceptibility threshold is exceeded is given in Table 2.

Table 2.

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
Radiowave Propagation Loss (dB)	**-84.9**
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**

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 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 (CM,) 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 *CM,* and the industry is striving to track with a C/N_0 of 10 dB-Hz. Based on a system noise densify 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 *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 + 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). 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:

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

where:

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

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.

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 I5 **of the** Commission's **Rules Regarding** Ultra-Wideband Transmission Systems*, First Report and Order. 17 F.C.C. Rcd. 7435 at ¶107 (2002).

	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
M[illegible] bl EIRP (dB [illegible])	-74.6	-16.1	.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 -1 10.5 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.

used for Category I precision approach landings, an antenna gain below the aircraft of -10 dBi was used." 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; 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.[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 from 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.

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[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-io-Earth) and ARNS Receivers to be Considered in Interference Studies in the Band 1559-1610 MHz* at Annex 5.

Table **4.**

Parameter	Value	
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)	.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

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

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

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 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 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 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.