ASSESSMENT OF RF COMPATIBILITY BETWEEN GLOBALSTAR GATEWAY AT CLIFTON AND MLS OPERATIONS AT DYESS AFB

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SCOPE

Globalstar desires to operate its Gateway near Clifton, Texas with a reduced carrier bandwidth for its Gen 2 system (40 kHz instead of 76 kHz) which will result in increased EIRP density of 58 dBW/4kHz. This relates to an uplink (telecommand) carrier with emission designator 40K0G2D on a frequency of 5091.500 MHz (i.e., 5091.38 – 5091.62 MHz). Emissions in the band 5030-5091 MHz will remain at or below -3 dBW/4 kHz on-axis. The Clifton Gateway antenna is approximately 119 nmi from Dyess AFB, which supports a Microwave Landing System (MLS) transmitter operating on a frequency of 5044.200 MHz, sited at 32° 24' 45"N and 99° 51' 27"W. This white paper investigates the projected RF compatibility between a telecommand carrier radiated from this GUSA Gateway antenna, and an MLS station (aircraft) at Dyess AFB.

The analytic technique is similar to that applied for previous coordination studies for Clifton and DFW, as well as Wasilla, Alaska, but details have been adjusted to account for the unique factors at Dyess AFB.

SUMMARY OF FINDINGS

The new emissions regime is compatible with MLS operations at Dyess AFB. It will not cause interference to an MLS station (aircraft) operating with the MLS transmitter.

BACKGROUND

Exhibit A illustrates the runway layout for Dyess AFB. The airport has a 13,500 foot bidirectional runway (officially two runways designated 16 and 34) running substantially north-south, and two shorter bidirectional runways designated Runway 161/341 and Runway 162/342. The FAA lists the runways at the following locations:

Runway	Latitude	Longitude	Field Altitude
16	32-26-20.0900N	099-51-31.8900W	1789.00 ft
34	32-24-09.0400N	099-51-01.3900W	1787.00 ft
161	32-25-15.3587N	099-51-33.8452W	(not provided)
341	32-24-42.3521N	099-51-26.0414W	(not provided)
162	(not provided)	(not provided)	(not provided)
342	(not provided)	(not provided)	(not provided)

The email from Scott Kotler (NTIA; 11/30/2010) indicated an MLS transmit station at 32-25-45N and 99-51-27W with an airborne service volume in the direction of the ES. Exhibit B provides a Goggle Earth view of Dyess AFB with the indicated location highlighted with a yellow push pin. An MLS transmitter at this location (actually, off to the side of the runway) would support Runway 341 which would involve an aircraft approaching from the south. The service volume would indeed extend in the general direction of the GUSA ES at Clifton. This white paper addresses an MLS service volume associated with Runway 341.

The locations of the Gateway antennas at the Globalstar USA Clifton site are:

Call sign	Antenna	Reference File No	Latitude	Longitude
E970199	(CLFN-1)	SES-AFS-20091221-01607	31 ° 48 ' 0.2 " N	97 ° 36 ' 44.3 " W
E000342	(CLFN-2)	SES-MFS-20091221-01608	31 ° 47 ' 57.5 " N	97 ° 36 ' 44.7 " W
E000343	(CLFN-3)	SES-MFS-20091221-01609	31 ° 47 ' 57.4 " N	97 ° 36 ' 47.9 " W
E000344	(CLFN-4)	SES-MFS-20091221-01610	31 ° 48 ' 0.1 " N	97 ° 36 ' 48.9 " W
E000345	(CLFN-5)	SES-MFS-20091221-01611	31 ° 48 ' 3.0 " N	97 ° 36 ' 49.2 " W

Exhibit C is an aerial view of the GUSA Clifton site. CLFN-5 (highlighted with a yellow push pin) is to the northwest, closest to Dyess AFB, and was used as the basis for analysis. The elevation for CLFN-5 is 717 feet.

The Gateway antenna is a 5.5m Alcatel product. Pertinent data are:

- peak on-axis gain = 47.6 dBi;
- 15 dB half-beamwidth = 1.33 degrees;
- The antenna pattern is nominally modeled as $G(\theta) = 32 – 25\log(\theta)$, although this is known to be conservative based on measured performance.

The desired operating regime involves transmission with peak EIRP = 68 dBW and EIRP density of 58 dBW/4kHz on a frequency of 5091.38 – 5091.62 MHz. This is associated with a carrier bandwidth of 40 kHz. Unwanted emissions in the band 5030-5091 MHz are no worse than -3 dBW/4 kHz (on-axis). Minimum antenna elevation angle (boresight) = 5 deg.

Exhibit D indicates the path from CLFN-5 to the MLS transmitter. The path length is 119.93 nmi at an azimuth of 287.24 degrees from true north. The MLS service volume will involve a range of azimuths and shorter distance.

Exhibit E illustrates the terrain mask at the GUSA site. As may be seen, the rough direction of Dyess AFB (azimuth = 287 degrees) is within an area of terrain masking, although there is a notch at an azimuth of 300 deg.

ANALYSIS

The primary analysis in this white paper is for an MLS approach supporting Runway 341. Other runways are addressed qualitatively based on this primary analysis.

The MLS coverage zone for runway 341 is a pie-shaped domain starting at the distant end of the runway (i.e., the threshold for Runway 161) and expanding to the southeast. The relative geometry to the GUSA Gateway, with North oriented up, is illustrated in Exhibit F. The distance from the GUSA Gateway (CLFN-5) to the nearest point of the MLS coverage zone is 99.23 nmi. This point is at a height of 20,000 feet above the local terrain and the MLS transmitter. Considering the relative elevations of the MLS transmitter and the GUSA Gateway, along with the curvature of the Earth, the indicated point is at an optical elevation angle of 1.15 degrees as viewed from the Gateway. Using a 4/3 Earth radius assumption, the elevation angle at this point is 1.4 degrees. Hence, the MLS coverage volume lies well below the main beam of the GUSA Gateway. At closest approach (Gateway antenna oriented at proper azimuth and minimum elevation angle of 5 degrees), the off-pointing angle is 3.6 degrees relative to the antenna boresight (using a 4/3 Earth radius assumption).

Baseline Interference Analysis. Both the in-band (for MLS) and out-of-band (for MLS) RF interference levels, generated by the GUSA Gateway at Clifton, are examined here.

Recommendation ITU-R S.1342 provides a mechanism for calculating “coordination trigger distances” based on in-band and out-of-band emissions levels and separation distances. If the ***actual*** distance between stations is greater than the calculated trigger distances, the MLS service is assumed to be protected. The in-band trigger distance is:

$$R_{in}\ (\text{km}) = (4.775 \times 10^{-6})\ 10^{(P + 160)/20} + 43$$

where P is the EIRP density (dBW/150 kHz) radiated by the emitter in the direction of the MLS coverage volume. The first term on the right-hand side represents a range trigger to the edge of the MLS coverage volume, and the additive term of 43 km represents the additional range to the MLS transmitter itself (assumed to be in the center of a cylindrical volume). The exponent contains the so-called “in-band threshold” of -160 (dBW/150 kHz). This is the relevant threshold for spurious and unwanted emissions from the Gateway antenna which fall in-band to the MLS receiver.

The out-of-band range trigger defined in ITU-R S.1342 is

$$R_{oob}\ (\text{km}) = (4.775 \times 10^{-6})\ 10^{(P + 91)/20} + 43$$

Here, P is the total EIRP (not EIRP density) radiated by the emitter in the direction of the MLS coverage volume. The so-called “out-of-band threshold” is -91 dBW. This is the relevant threshold for the Gateway desired uplink, which is out-of-band to the MLS receiver.

It should be emphasized that one does not simply compare the in-band and out-of-band emissions to the equivalent “thresholds”. Instead, one most calculate the range trigger distances and compare these trigger distances to the actual distance between stations. It should also be noted that the range triggers are based on protecting a cylindrical volume around the MLS station with radius = 43 km. This is appropriate if the line-of-sight from the emitter to the MLS transmitter passes through the MLS service volume (as in the current case). However, if the line-of-sight between transmit stations ***does not*** pass through the MLS service volume, the additive term of 43 km could be adjusted.

<u>In-band analysis (for MLS).</u> The in-band analysis relates to the band 5030-5091 MHz, including the actual MLS frequency of 5044.20 MHz. While the peak EIRP density of the desired uplink is planned to be increased to 58 dBW/4 kHz, associated with a reduction in transmitted carrier bandwidth, ***the GUSA emissions in the band 5030-5091 MHz are unchanged from existing operations, and no worse than -3 dBW/4kHz on-axis.*** This is equivalent to on-axis emissions of 12.74 dBW/150 kHz (the reference bandwidth used for MLS interference calculations).

The main beam of the Gateway antenna provides 47.6 dB peak gain relative to isotropic, with sidelobes conforming to a specification limit of $G(\theta) = 32\text{-}25\log(\theta)$ for values of θ between 1 and 48 degrees. See Exhibit G. At an off-pointing angle of 3.6 degrees, the specified sidelobe gain $G(\theta)$ is given by

$$G(3.6\text{ deg}) = 32\text{-}25\log(3.6) = 18.1\text{ dBi}$$

This represents an off-pointing loss of 47.6 – 18.1 = 29.5 dB.[1]

The worst-case in-band emissions of 12.74 dBW/150 kHz (peak on-axis) are reduced by the off-pointing loss. Hence, the in-band emissions in the direction of the MLS coverage volume are no worse than 12.74 dBW/150 kHz – 29.5 dB = -16.76 dBW/150 kHz.

Applying the in-band trigger distance formula and substituting -16.76 (dBW/150 kHz) for P, we find that R_{in} = 112.3 km = 60.7 nmi. Since the actual distance from CLFN-5 to the MLS transmitter is greater than this trigger distance (i.e., roughly 119 nmi), the MLS service volume is assumed to be protected and no coordination is needed.

It should be noted that the strength of the unwanted emissions (-16.76 dBW/150 kHz in the direction of the MLS coverage volume) is based the emissions specification of -3 dBW/4 kHz (on-axis) which applies across the entire MLS band including 5091 MHz. This corner frequency is only 350 kHz below the transmitted carrier at 5091.350 MHz. The MLS operating frequency at Dyess AFB is 5044.200 MHz, which is over 40 MHz lower in frequency. The normal spectral roll-off of the GUSA transmit carrier will result

[1] Note: the measured antenna pattern for the Globalstar Gateway antenna is actually about 8 dB better than the specification limit at this off-pointing angle (see Exhibit G). However, for this preliminary assessment I have relied on the specification limit instead of the measured data.

in substantially lower levels of unwanted emissions in the 150 kHz band centered on 5044.200 MHz; however, my analysis has relied on the worst-case specification of -3 dBW/4 kHz (on-axis).

Out-of-band analysis (for MLS). The out-of-band range trigger is

$$R_{oob}\ (km) = (4.775 \times 10^{-6})\ 10^{(P + 91)/20} + 43$$

Using an EIRP of 68 dBW for the GUSA carrier and the same value of off-pointing loss as before (29.5 dB), P = 38.5 dBW and the calculated range trigger R_{oob} = 57.3 km = 31 nmi. Again, since the actual distance to the MLS transmitter (119 nmi) is greater than this trigger value, the MLS service volume is assumed to be protected and no coordination is needed.

The primary analytic result is that the intended operating regime of the GUSA Gateway at Clifton will not pose any risk to MLS operations at Dyess AFB. This is primarily due to the significant separation distance between the two sites, which provides significant path loss and off-pointing discrimination relative to the minimum elevation angle of the Gateway antenna beam. The proposed change in EIRP density for the primary carrier does not change the EIRP density for undesired emissions in the 5030-5091 MHz band, and so has no impact on the analysis.

DISCUSSION OF OTHER MITIGATING FACTORS

The basic analysis outlined above indicates that there will be no interference into MLS stations operating at Dyess AFB, due to the operation of the GUSA Gateway at Clifton. This conclusion is based on the coordination guidelines contained in ITU-R S.1342. In addition, there are several factors which indicate that the level of protection is even greater than that implied by the in-band and out-of-band range triggers:

Terrain Masking. A MATLAB script was written to clarify the geometric relationships and provide a basis for consideration of other mitigating factors. Exhibit F, previously referenced, is one output of this script. Another output was the apparent "azimuthal extent" of the MLS coverage volume as viewed from the GUSA antenna. The MLS coverage volume spans azimuths from 277.4 to 288.4 degrees. Exhibit H indicates this volume relative to the terrain masking profile at Clifton. As indicated, the entire MLS coverage volume is well-masked by local and intervening terrain. Terrain masking will further attenuate any Gateway emissions radiated in the direction of the MLS coverage volume.

Transmitter Roll-Off. The above analysis was based on an assumed level of unwanted emissions, in the band 5030-5091 MHz, of -3 dBW/4 kHz (on-axis). This specification applies across the band including the frequency 5091 MHz, which is only 350 kHz below the desired carrier. The actual level of unwanted emissions, in the 150 kHz band centered on the actual MLS frequency of 5044.200 MHz, will be substantially lower.

Antenna Sidelobe Performance. The above analysis was based on the standard sidelobe performance curve $G(\theta) = 32\text{-}25\log(\theta)$ for values of θ between 1 and 48 degrees. The measured pattern is known to be about 8 dB better (lower) in the range of 3 to 5 degrees of off-pointing, providing an equivalent reduction in radiated emissions in the direction of the MLS coverage volume.

Additional Atmospheric Absorption. Due to the long range and low elevation angle, RF signals from the GUSA Gateway at Clifton will be attenuated by excess gaseous atmospheric absorption. The amount of excess absorption is estimated as 0.5 dB based on the methods outlined in ITU-R P.676-6.

MLS Receiver Design And Coordination Criteria. While there does not appear to be any mechanism for reconsidering the MLS receiver design and coordination criteria framed in S.1342, it has been observed in the past that all ICAO-standard MLS receivers contain a 26 kHz video filter which would reduce in-band noise (including unwanted emissions from other services) by approximately 7 dB relative to the value calculated on the basis of a 150 kHz noise bandwidth (as used above).

POTENTIAL RE-SITING OF MLS SYSTEM AT DYESS AFB

The other runways at Dyess AFB have not been analyzed in detail; however, all "south-facing" runways (i.e., Runways 34, 341 and 342) have similar characteristics and would have similar results with regard to separation distance, elevation angle, and coordination trigger distances. Hence, MLS would be fully protected and no coordination is needed.[2]

With respect to the north-facing runways (i.e., Runways 16, 161 and 162), the MLS coverage volumes actually extend ***away from*** the GUSA Gateway at Clifton. As a consequence, the separation distances are somewhat greater and the perceived elevation angles of the MLS coverage volumes, as seen from the GUSA Gateway, are lower. These factors yield an additional 2.5 dB of isolation. Hence, all potential MLS service volumes at Dyess AFB (north-facing as well as south-facing) would be well-protected, as indicated by the baseline analysis provided above.

Note: As indicated in Exhibit I, a north-facing MLS service volume might not enjoy the benefit of full terrain masking. However, terrain masking is ***not required*** for protection of the MLS. It is merely an additional form of isolation that applies to a large part of the potential MLS coverage volume if the MLS is re-sited. Even without any terrain masking, all MLS coverage volumes at Dyess AFB would be well-protected.

[2] The "other mitigating factors" discussed above, with regard to Runway 341, apply equally to the other south-facing runways including the determination of full terrain masking which provides further isolation.

EXHIBIT A

AIRPORT DIAGRAM – DYESS AFB (TEXAS)

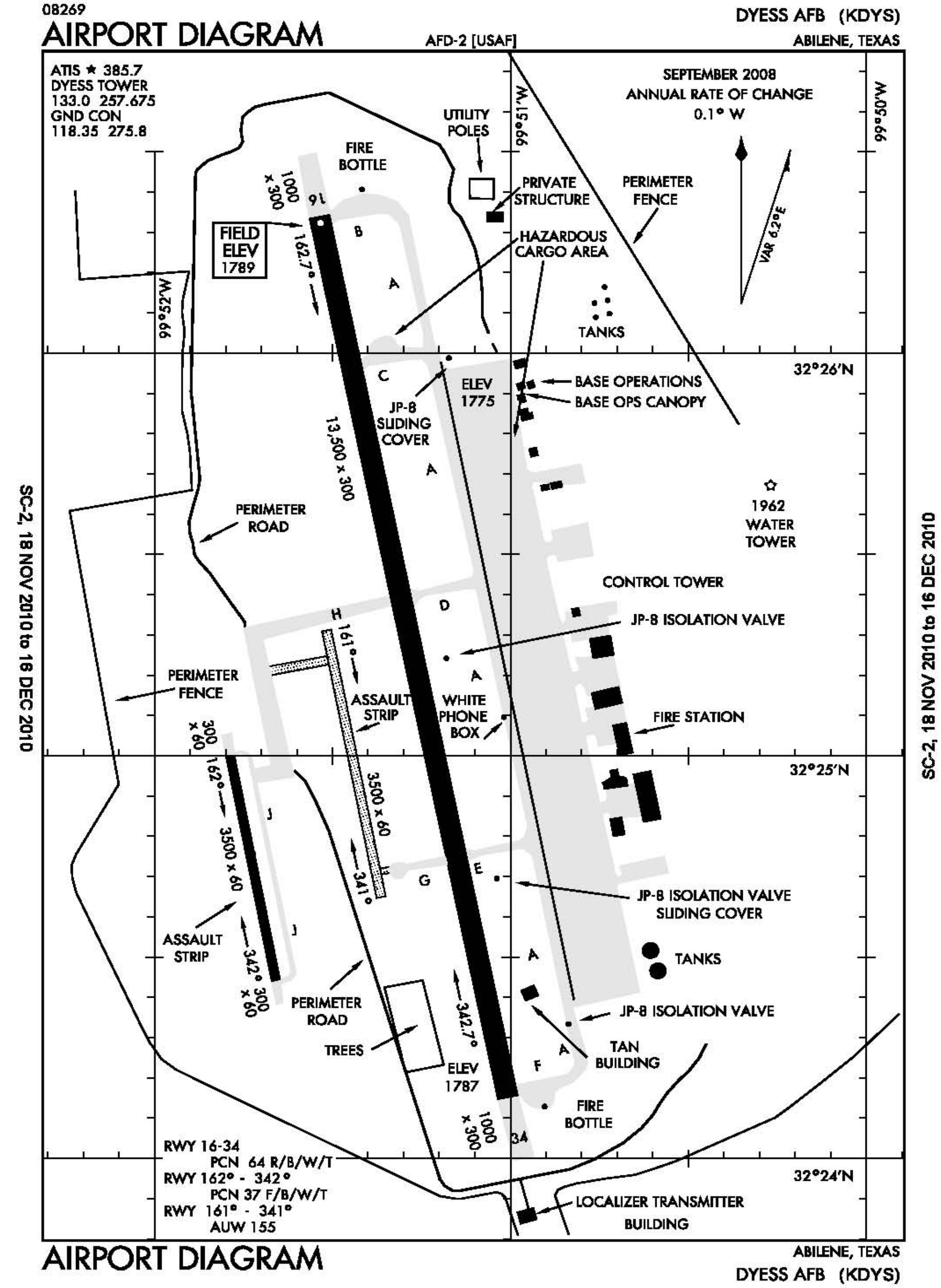


EXHIBIT B

AERIAL VIEW SHOWING LOCATION OF MLS TRANSMITTER

EXHIBIT C

AERIAL VIEW OF GLOBALSTAR GATEWAY SITE (CLIFTON)

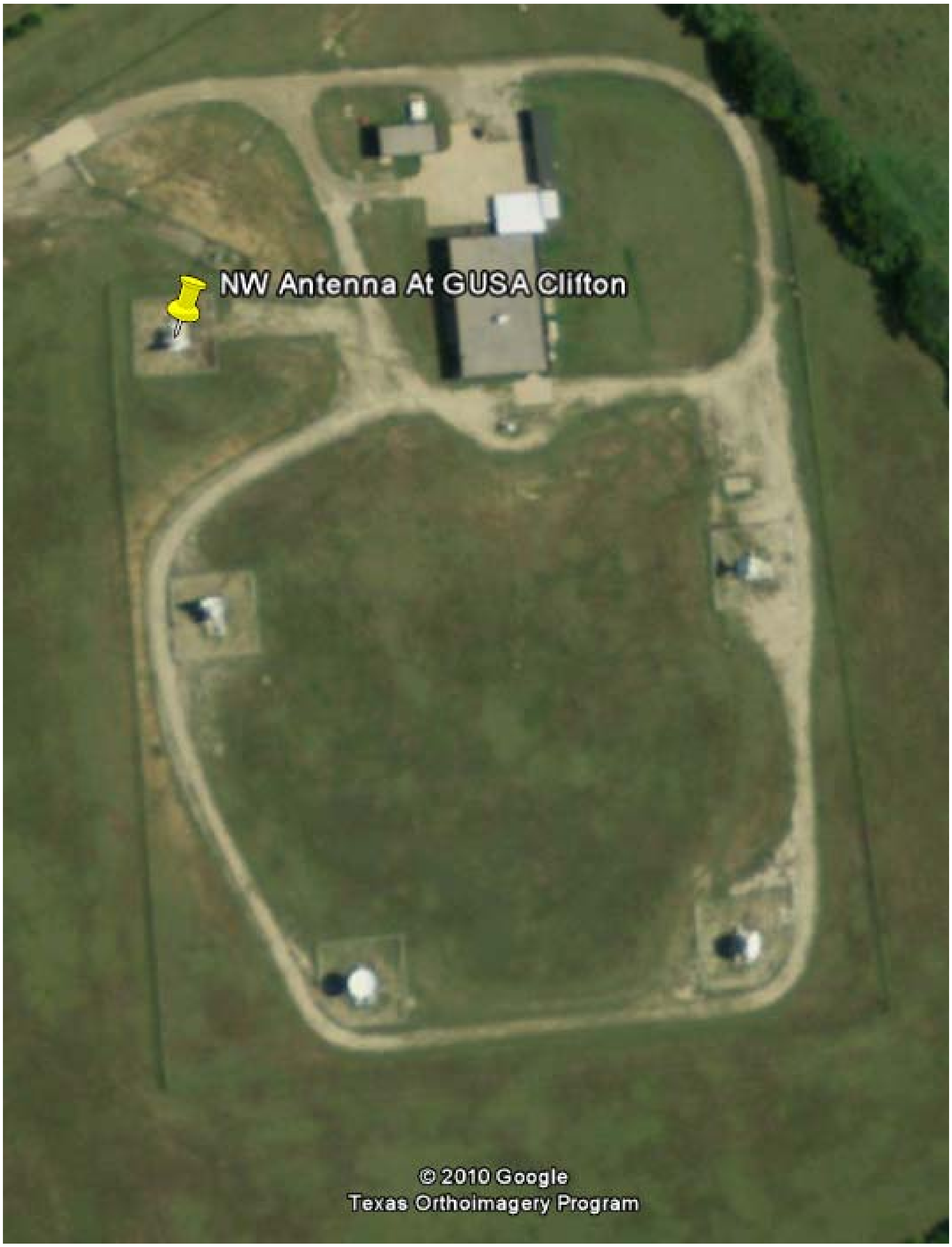


EXHIBIT D

SIGHT LINE FROM GUSA GATEWAY TO MLS TRANSMITTER

As viewed from the GUSA Clifton site, the MLS transmitter at Dyess AFB is at an azimuth of 288.4 degrees (West by Northwest) and at a range of 119.94 nautical miles.

EXHIBIT E

TERRAIN MASKING CHARACTERISTICS AT GUSA GATEWAY

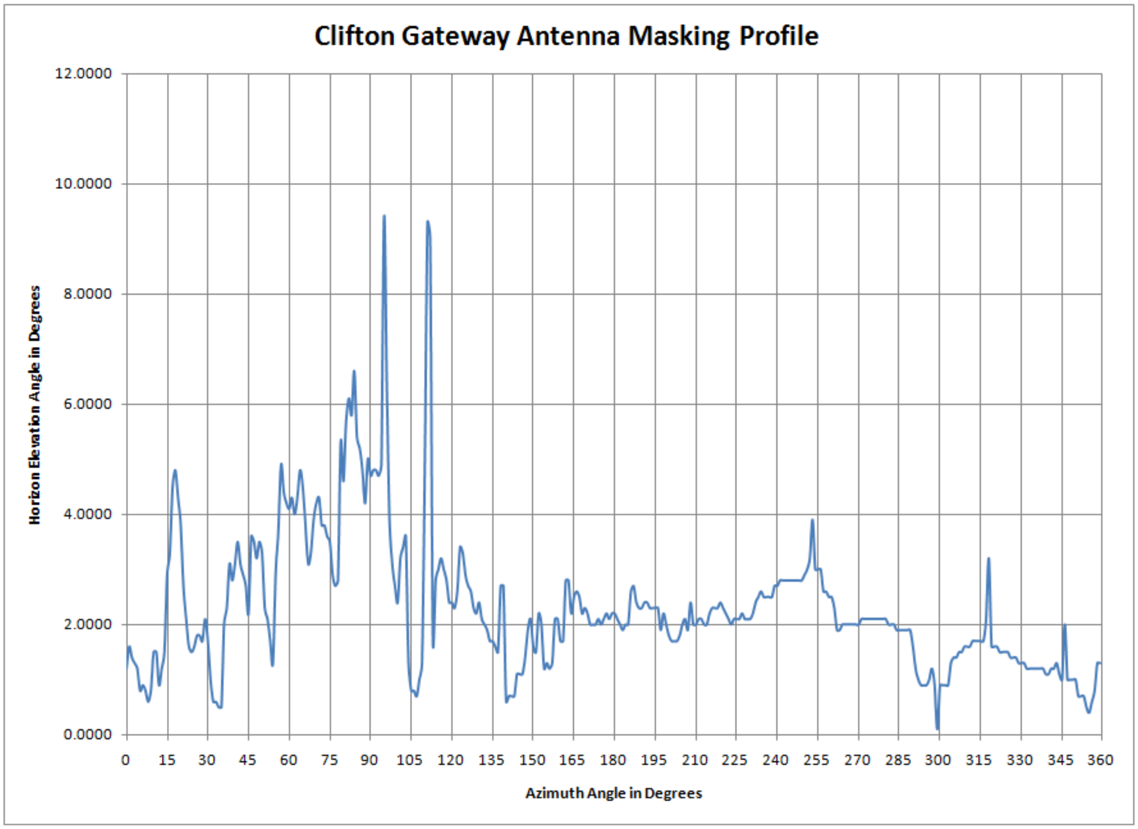
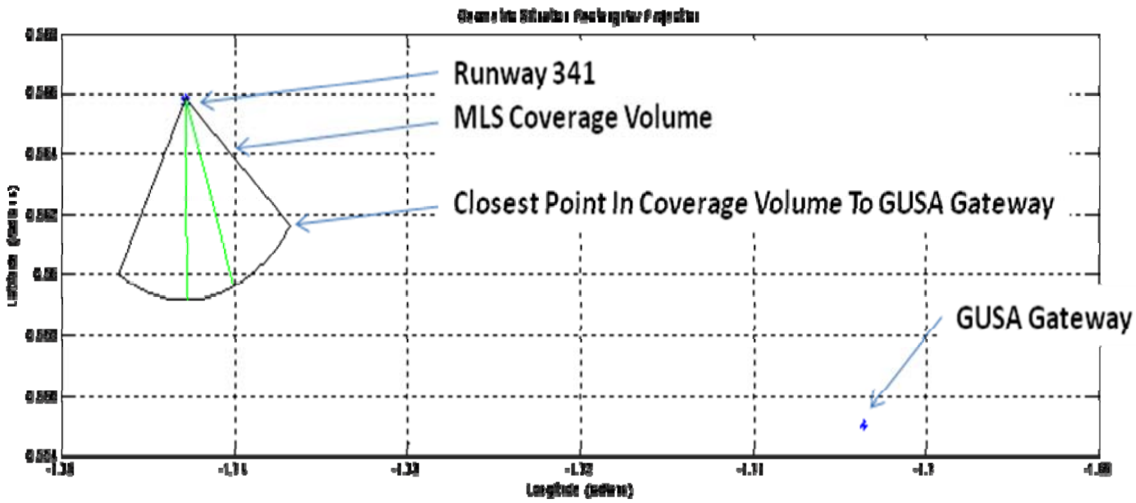


EXHIBIT F

PLAN VIEW SHOWING MLS COVERAGE REGION AND GUSA GATEWAY



Notes:

The MLS coverage domain is generated by an MLS antenna situated alongside runway 341. The coverage zone is ±40 degrees around the runway centerline extending to a range of 23 nmi from the distant runway end. The maximum altitude of the MLS service volume is 20,000 feet above ground level. The indicated point of closest approach is at a range of 99.23 nmi from the GUSA Gateway (CLFN-5).

The green lines indicate the bounds of a “core MLS region” which is likely to contain all aircraft on straight-in approaches. This region has enhanced MLS signal strength and extends ±10 degrees around runway centerline. This is provided for information purposes only; the analysis is performed with respect to the entire MLS coverage volume and the interference thresholds associated with minimum specified MLS signal strength.

EXHIBIT G

ANTENNA GAIN PROFILE FOR GLOBALSTAR GATEWAY ANTENNA

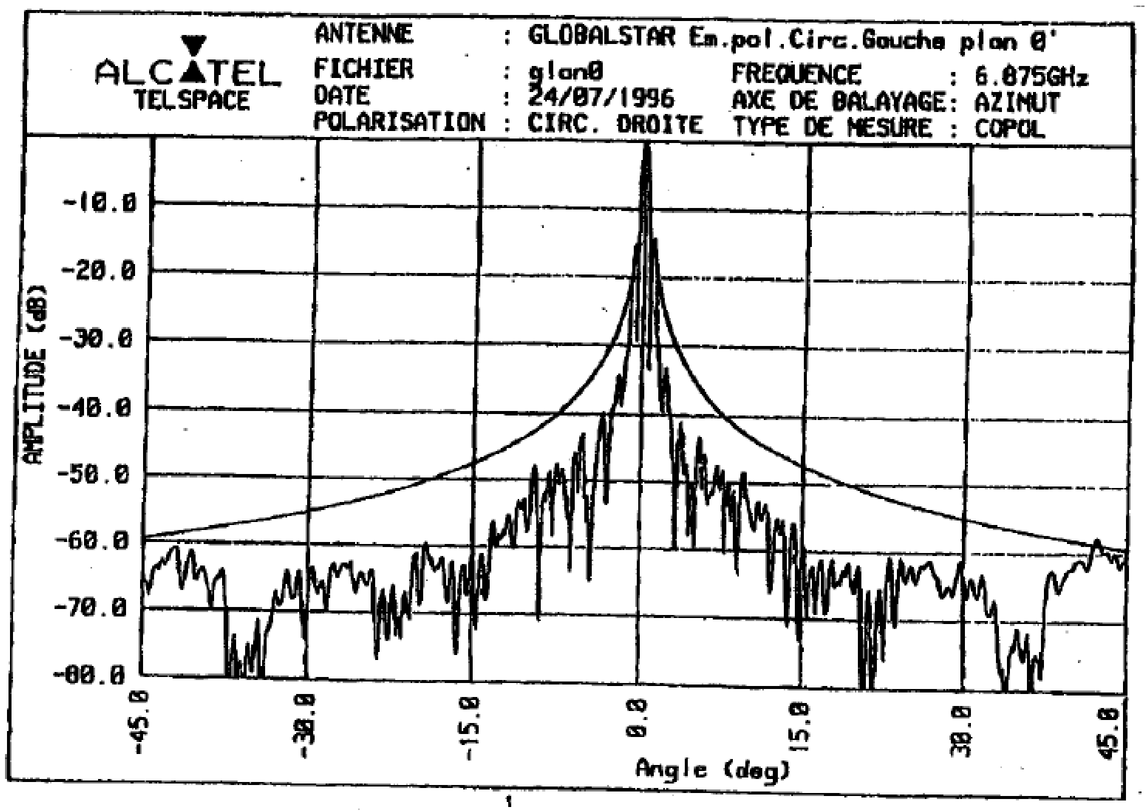
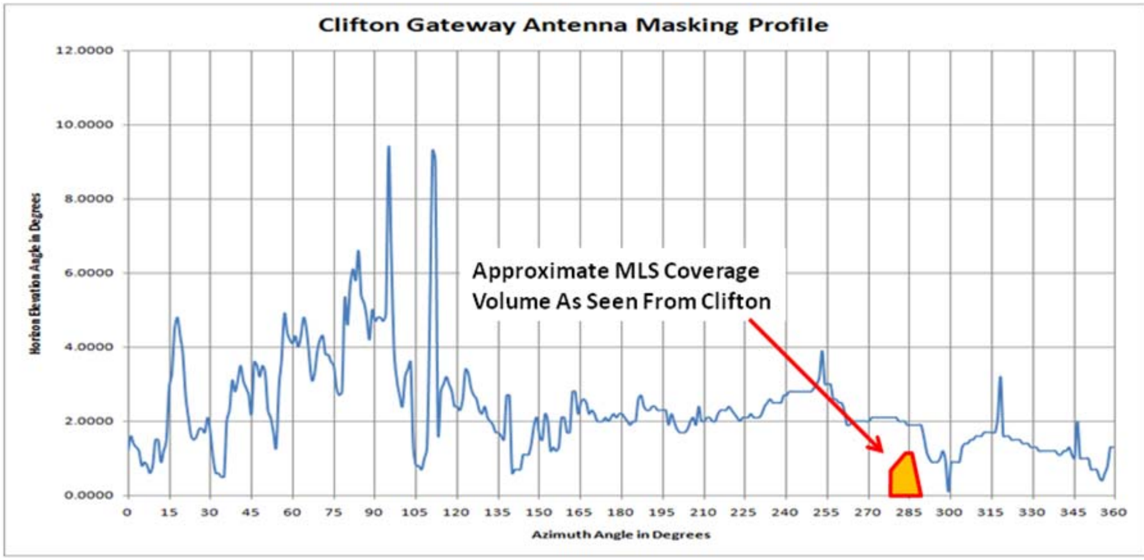


Figure 1-1: Representative Antenna Sidelobe Gain Profile for Globalstar Gateway

EXHIBIT H

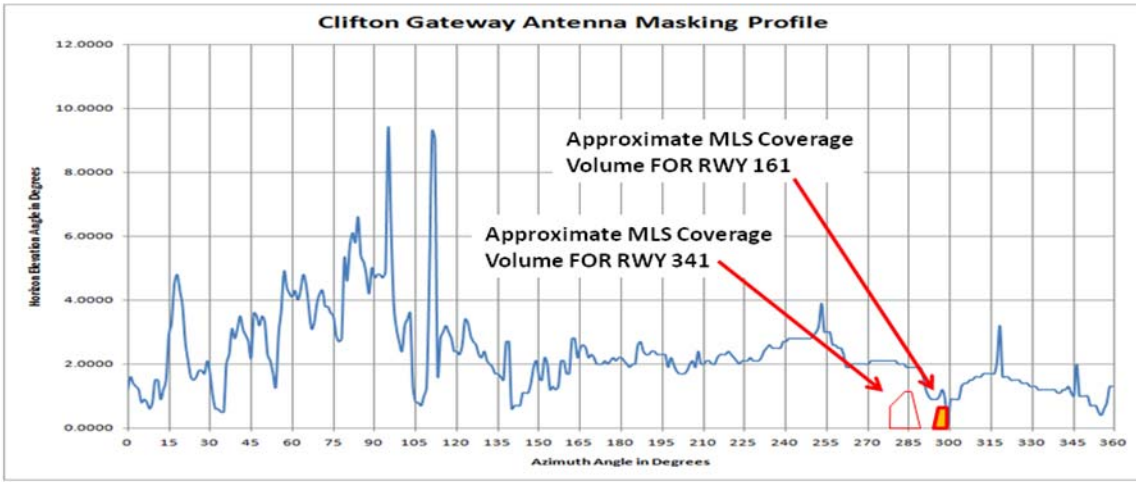
MLS COVERAGE VOLUME (RWY 341) AS SEEN FROM CLIFTON



The MLS coverage volume is masked by local intervening terrain. This provides additional isolation and protection beyond the level afforded by distance and antenna offpointing alone. Note: the MLS coverage volume is well-protected even without the benefit of terrain masking, as demonstrated by the baseline analysis pursuant to Rec. ITU-R S.1342 provided above.

EXHIBIT I

MLS COVERAGE VOLUME (RWY 161) AS SEEN FROM CLIFTON



If the MLS equipment were relocated to support Runway 161, the MLS service volume would appear smaller and at a lower elevation angle as viewed from Clifton. Antenna off-pointing loss would be greater due to the lower peak elevation angle. However, the edge of MLS coverage, subtending about 1 degree of arc as seen from Clifton, might be slightly "unmasked" with respect to terrain. The figure below shows the approximate region that would be unmasked. However, since the terrain mask was measured at intervals of 1degree in azimuth, and since the potential area of unmasking is also on the order of 1 degree, this illustration is approximate.