Technical Brief
For

# Vehicle-Mounted Earth Station Experimental Licensing

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Prepared by

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## Revision History

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# 1. TABLE OF CONTENTS

## 2. INTRODUCTION

TracStar Systems (Call Sign: WC9XGQ) is seeking an experimental FCC license for the operation of its Vehicle-Mounted Earth Station (hereinafter: VMES) IMVS450M Antenna system. Initial verification of the system has been performed since August 2005 under FCC experimental License number 0489-EX-ST-2005.

The FCC has established guidelines for routinely licensing similar Aeronautical and Vessel Earth Station systems of this mobile kind. The FCC requires that the licensee obtain an affidavit from the satellite operator stating that they are aware of and agree to the intended operations of the licensee and that the adjacent operators are also aware of and agree to the intended operations. TracStar Systems has authorization from SES Americom to operate on AMC-6 & 9.

Before the FCC In the Matter of IB Docket No. 07-101, Notice of Proposed Rule Making, Amendment of Parts 2 and 25 of the Commission's rules to Allocate Spectrum and Adopt Service Rules and Procedures to Govern the Use of Vehicle-Mounted Earth Stations in Certain Frequency Bands Allocated to the Fixed-Satellite Service.

TracStar Systems is a manufacturer of Vehicle-Mounted Earth Stations and in anticipation of the Acceptance of the Notice of Proposed Rule Changes to Part 2 and 25 the company is filing for an Experimental License to conduct tests with our VMES systems and various modem types to insure proper operation and compliance to FCC Parts 2 and 25.

This document provides technical information regarding the intended operations of the TracStar VMES system that TracStar Systems is seeking an experimental license for. Operations are such that they comply in particular as it relates to FCC Part 25.222.

The systems under test will utilize advanced antenna pointing technology, various spread spectrum and phase modulations, and centralized distributed controls to ensure that interferences to others meet the requirements of the FCC and the ITU.

**TracStar Systems is seeking an experimental license for:**

- **iDirect**
- **Other Manufacturer's Modems as Necessary**
    - **ViaSat ArcLight, iDirect, ND Satcom, IPstar and Comtech CDM570L**
- **TracStar Systems IMVS450M Antenna Assembly**
    - **Non-Compliant with 47CFR25.209**
- **Ku Band (13.75-14.5 GHz, 10.9-12.7 GHz)**
- **All CONUS operation**
- **Satellites**
    - **AMC-4, AMC-6, AMC-9**
    - **Telstar 14**
- **Mobile Operation**

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# 3. DESCRIPTION

## Network Configuration

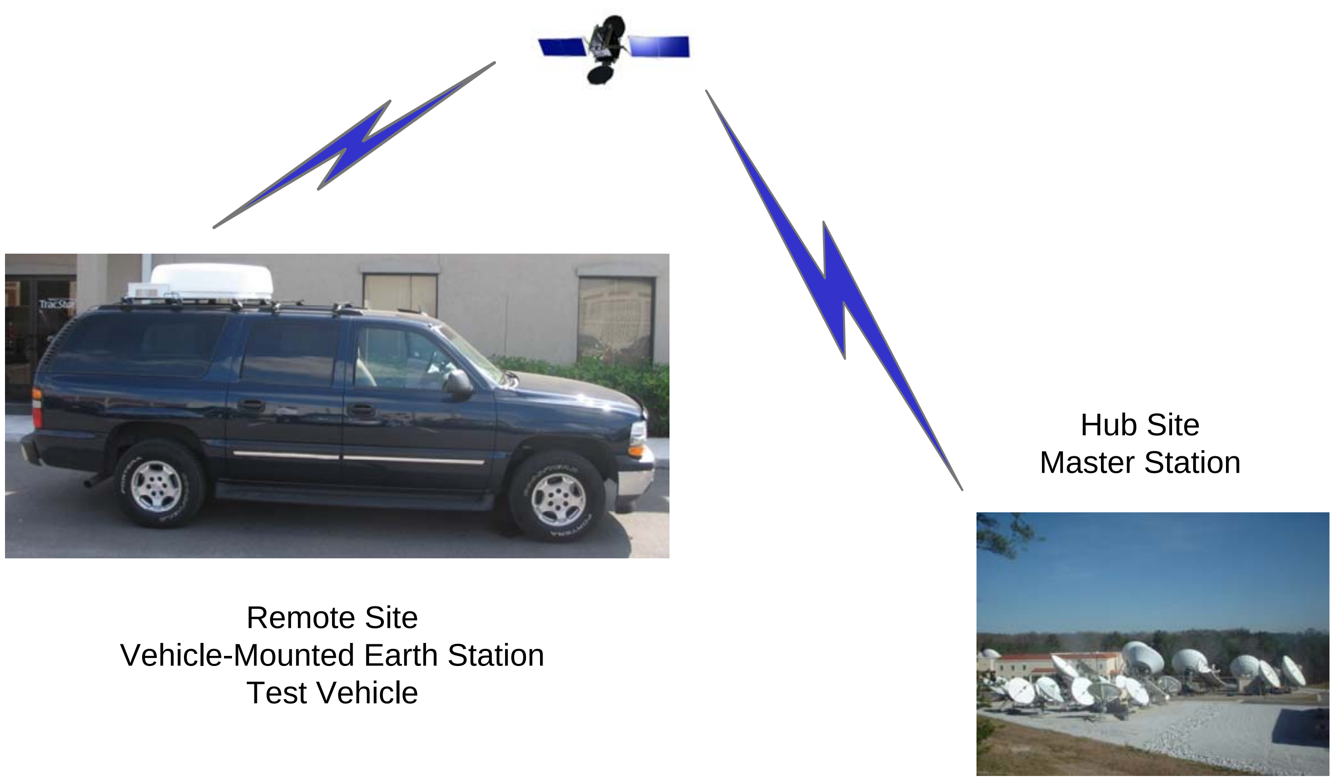
Each testing network will consist of one remote antenna system and one hub antenna system providing a point-to-point 64 kbps to 2 Mbps duplex satellite data link while using a small (<1m) antenna operating in a mobile environment.

The network consists of:

- **Remote Site:** These stations are under continuous (remote) control and monitoring from the NMS. Remote sites can not transmit unless they receive the signaling channel from the Network Controller.
- **Geostationary Satellite:** Space segment resources are leased from the available commercial satellite operators.
- **Hub Site**: The Hub and Network Management System (NMS) provides resource management of the leased space segment and continuously monitors and controls the remote site. The network operator will either provide on-site or remote monitoring 24 x 7 support for the NMS. The satellite space segment operations center will be provided with the network operator's phone number for rapid fault resolution.

### Power, Frequency, Timing Control

Modems and frequency converters are phase locked to an accurate and stable 10 MHz reference. If any converters loose lock, then the transmitter is muted. In addition to managing all remote sites, the NMS monitors and adjusts their power, frequency and timing accuracy.




**Test Network Configuration**

## Remote Site Configuration

The Remote Site consists of the Antenna Assembly and the Modem.

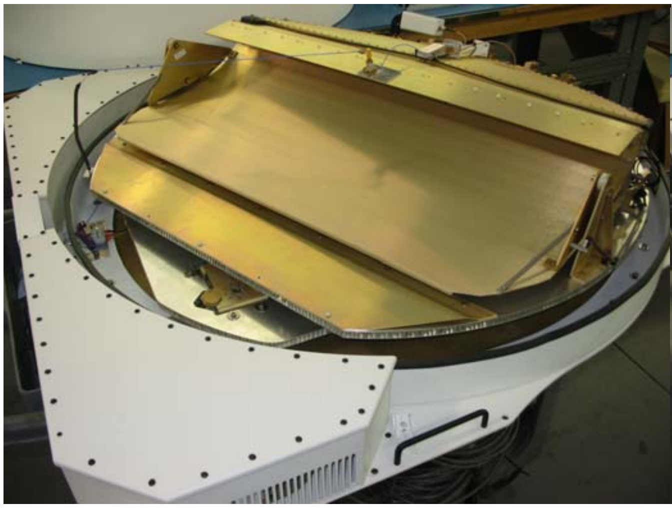
## TracStar Systems IMVS450M Antenna Assembly

The antenna subsystem consists of:

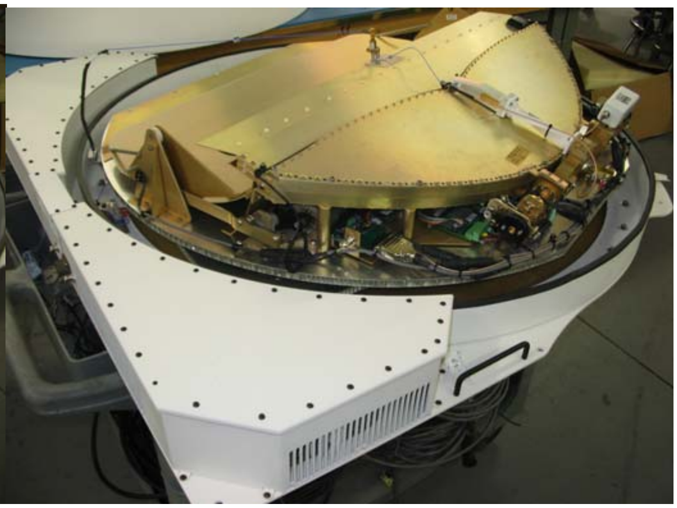
- Antenna Reflector and Aperture (Mirror and Pillbox)
- Positioner
- Radome
- Linear Cross Polarized Feed
- Solid State Power Amplifier (SSPA)
- L-Band to Ku-Band Block Upconverter (BUC)
- Low Noise Block (LNB) Downconverter
- Antenna Control Unit
- Servo Drivers
- Inertial Sensors
- GPS
- Antenna Power Supply Unit and Graphic Display

The antenna controller utilizes GPS, inertial sensor systems, and satellite position to compute the pointing for the antenna. The TracStar Systems IMVS450M Antenna Assembly is a two axis (Elevation over Azimuth) antenna and Polarization adjusting pedestal. The antenna is wider in its azimuth plane than it is in its elevation plane in order to support minimal height requirements. The wide dimension of the antenna remains level with the vehicle that it is mounted to. The Antenna Reflector, shown below, is approximately 40″ x 5.625″ (1.02m x 0.14m). The reflector and aperture (mirror and pillbox) is elliptical in shape with an effective parabolic equivalent diameter of 0.45m.

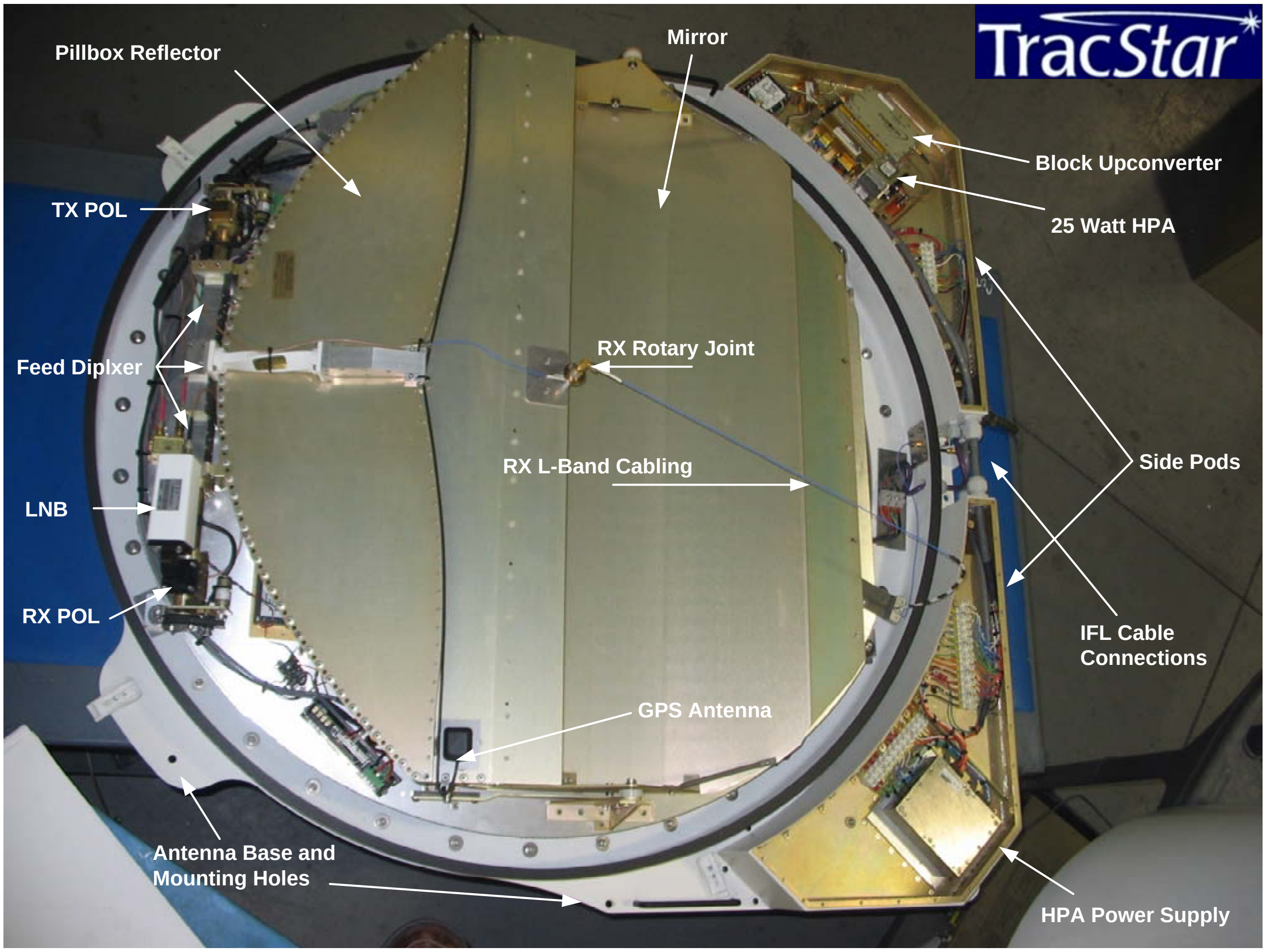
## Antenna Assembly



Front View

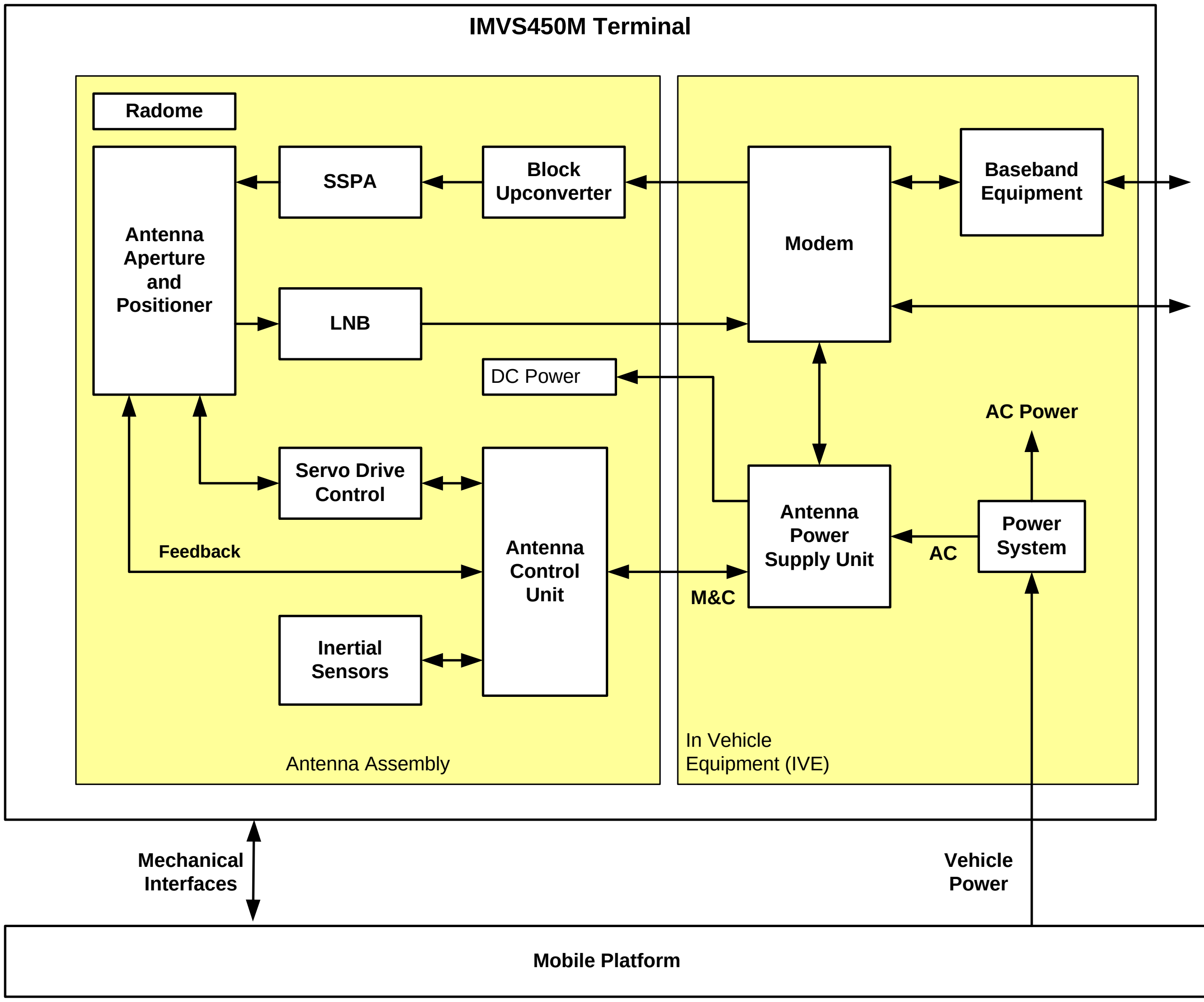


Side/Rear View


Pillbox Reflector
Mirror
TracStar
Block Upconverter
25 Watt HPA
TX POL
Feed Diplxer
RX Rotary Joint
RX L-Band Cabling
Side Pods
LNB
RX POL
IFL Cable
Connections
GPS Antenna
Antenna Base and
Mounting Holes
HPA Power Supply

Top View

## Functional Block Diagram




**Typical IMVS450M System Block Diagram**

## Theory of Operation

- Acquisition and tracking control software currently is capable of acquiring and then maintaining satellite position while mounted on a land vehicle that is stationary or in-motion.
- Designed to have minimal moving parts to compensate for changes in vehicle platform movement.
- Accelerates at greater than 600 degrees per second squared in both the azimuth and elevation planes.
- Continuously peaks at <0.5 degrees per second on a satellite target.
- Antenna and Control Subsystem tested at 4g's, at speeds in excess of 160 kph, traveled 12 hours straight over a distance of more than 1600 km.
- Operates with an electromechanically steered azimuth, elevation & polarization Positioner.

- Uses control/pointing code while mounted on a stationary or moving vehicle traveling over improved or unimproved road conditions.
- After initial acquisition, antenna system remains locked and pointed at the satellite even in the event the satellite line of site has been obstructed (aka: blockage) momentarily or for a periods of time up to 30 minutes.
- For momentary blockages minimal scanning is used, where more elapsed time dependent sequences use gradient scale scanning techniques.
- Designed to compensate for changes in either the pitch, roll or yaw direction.
- Travel 360 degrees continuously in the azimuth direction, changes 20 to 75 degrees in the elevation direction and rotates +/-95 degrees linear polarization.
- Antenna controller user interface is configurable for operation on most satellites.
- Performs precise antenna to satellite alignment with the push of a single button.
- Antenna controller provides for automatic acquisition, tracking and manual jog modes.
- User interface is menu driven by front panel or handheld controller buttons, which provide ease of use for command changes and troubleshooting.
- The satellite acquisition method is less than a 1 minute operation. Upon power up and reception of modem communications, the following deployment and acquisition sequence takes place automatically:
    - Antenna acquires GPS for high precision geographic location information
    - Antenna precisely sets elevation angle and sweeps in azimuth through to the selected satellite while looking for and monitoring signal characteristics of the satellite
    - Antenna communicates with antenna controller to obtain the link signal strength provided from the satellite modem
    - Antenna peaks on the satellite until the center of the antenna beam is located and calibrated
    - Antenna then performs a high precision calibration between the pedestal and controller
    - Antenna controller continues communications with satellite modem to obtain the link signal strength provided from the modem serial port
    - Antenna remains peaked while stationary or in motion
    - Antenna controller constantly maintains communication with modem and transmitter until shut off.
    - Antenna controller constantly monitors antenna pointing and position data to insure proper look angles, if antenna misaligns for more than 100ms, the antenna controller will inhibit the modem and transmitter.

## iDirect iNFINITI 8000 Series Modem Model 8350

Developed to meet the most rigorous user requirements for both mobility and security, the iNFINITI 8000 series satellite routers provide fast, reliable, secure, QoS enabled connections for Communications On-the-Move (COTM).

The Modem consists of:

- Modulator
- Demodulator
- Turbo Codec
- Stable clock, reference, and distribution
- Frequency conversion to/from IF
- Ethernet Interface/Switch
- QOS manager
- Human Machine Interface

Each ground station includes a modem. The modem provides data conversion, error correction encoding/decoding, and modulation/demodulation. The controller provides fault, configuration, account/resource, performance, and security management.

**Modulation**

Station modulates using BPSK Spread Spectrum when using an antenna less than 1m in diameter to keep the EIRP density within FCC limits.

The range of data rates include:

| | | |
|---|---|---|
| Upstream | BPSK (SS): | 64kbps to 3.75 Msps |
| Downstream | QPSK: | 64kbps to 11.5 Msps |

To ensure that the EIRP density meets FCC limits, typical test date rate will be utilized:

| | | |
|---|---|---|
| Upstream | BPSK (SS): | 384 Ksps |
| Downstream | QPSK: | 512 Ksps |

**Access Scheme**

The access scheme uses a Multi-Frequency Time Division Multiple Access (MF-TDMA) Star Topology. The Network Management System (NMS) provides real-time resource management through time slot, frequency, and carrier bandwidth assignments to the remotes via a common signaling channel. In the leased bandwidth, the NMS may assign multiple frequency slots for each burst time. All remote stations can hop frequencies from burst to burst, but there will only be one transmit carrier per frequency slot per burst. While spread spectrum is used as a method to reduce transmitted power spectral density, it is NOT USED as a multiple access scheme. Multiple access is achieved using MF-TDMA and is under control of the NMS.

# 4. REGULATIONS

**FCC, ITU Rulings**

For Ku band operations, while there are no codified rules regarding allowable off-axis EIRP spectral density, the FCC have specified a minimum gain pattern requirement (25.209) and a maximum power spectral density into the antenna (25.212). The FCC will routinely license antennas that do not meet 25.209, as long as the maximum power spectral density into the antenna (per 25.212) is further reduced by the amount of the non-compliance to 25.209. Later in this document, we will refer to this noncompliance as **"excess gain".**

Another accepted interpretation of the FCC rules is that the allowable off-axis EIRP spectral density may be calculated using the two constraints provided by FCC (25.209 and 25.212). The ITU recommendation, ITU-R S.728-1, provides the Maximum permissible level of off-axis EIRP density from very small aperture terminals (VSATs). The ITU recommendation is identical numerically to FCC 25.209 and 25.212, but instead provides an explicit statement of recommended off-axis emissions.

For non-compliant and mobile antenna operation, the FCC requires that the ground station operator obtain and file affidavits obtained from the satellite operator and its adjacent satellite operators stating that all are aware and in agreement with the intended operation.

Following are relevant extracts from 47 CFR 25, FCC Rulings on Satellite Communications.

**47CFR25.209 Antenna Performance Standards**

(a) The gain of any antenna to be employed in transmission from an earth station in the geostationary satellite orbit fixed-satellite service (GSO FSS) shall lie below the envelope defined as follows:

(1) In the plane of the geostationary satellite orbit as it appears at the particular earth station location:
29-25 log (theta) dBi, 1°<=theta<=7°
+8 dBi, 7°<Theta<=9.2°
32-25 log (Theta) dBi, 9.2°<Theta<=48°
-10 dBi, 48°<Theta<=180°

Where:
Theta is the angle in degrees from the axis of the main lobe, and dBi refers to dB relative to an isotropic radiator.

For the purposes of this section, the peak gain of an individual sidelobe may not exceed the envelope defined above for Theta between 1.0° and 7.0° degrees. For Theta greater than 7.0° degrees, the envelope may be exceeded by no more than 10% of the sidelobes, provided no individual sidelobe exceeds the gain envelope given above by more than 3 dB.

### 47CFR25.212 Narrowband transmissions in the 12/14 GHz GSO Fixed-Satellite Service

In the 14 GHz band, an earth station with an equivalent diameter of 1.2 meters or greater may be routinely licensed for transmission of narrowband analog services with bandwidths up to 200 kHz if the maximum input power density into the antenna does not exceed -8 dBW/4 kHz and the maximum transmitted satellite carrier EIRP density does not exceed 13 dBW/4 kHz, and for transmission of narrowband and/or wideband digital services, if the maximum input power density into the antenna does not exceed **-14 dBW/4 kHz** and the maximum transmitted satellite carrier EIRP density does not exceed +6.0 dBW/4 kHz.

### Small Antenna Performance

An antenna smaller than 1m will typically have an antenna gain profile that exceeds the FCC ruling (25.209). FCC will routinely license antennae that do not meet 25.209 if the operator reduces the Power Spectral Density (PSD) into this antenna from **-14 dBW/4 kHz** by the amount that an antenna exceeds 25.209 (described in this document as **excess gain**). The power spectral density may be reduced by dropping the carrier power or by adding or increasing spectral spreading.

Experience shows that the typical EIRP spectral density can be achieved by lowering the Power Spectral Density into the antenna. The combined result of the antenna and the reduced PSD of the transmitted carrier can provide an EIRP spectral density that meets the intent of FCC 25.209 and the ITU recommendation, ITU-R S.728-1.

## 5. ANTENNA POINTING

The TracStar IMVS450M Antenna Assembly controls pointing of the antenna through the use of advanced control systems utilizing GPS, inertial navigation systems, signal tracking assistance, and rate and attitude sensors. This antenna pointing technology has been engineered over several years and has been verified in both lab and operational environments.

For the military and commercial applications foreseen, vehicles may be subjected to a worst case environment described as the Churchville B test course (extreme rugged terrain). The TracStar Systems IMVS450M Antenna Assembly meets or exceeds its pointing objectives while subjected to the shock and vibration of this test course. It should be noted that while the system is designed and tested to this environment, vehicles will typically be subjected to a substantially less severe environment (paved or dirt roads) and as such the antenna pointing system will typically maintain pointing to tighter tolerances.

Antenna pointing errors arise from:

- S = Signal Tracking Assistance Errors – A signal tracking mechanism will measure signal strength and peak the antenna signal strength using receive signal strength measurements resulting from dynamic motion or dithering. Tracking error is +/-0.1° and this eliminates Antenna Static errors (A) and Navigational errors (N).

- A = Antenna static errors due to mechanical alignment of the feed, reflector, and its relation to the inertial navigation system. Typically this error is +/-0.2°, but this is +/-0.0° through the use of signal tracking assistance.

- N = Navigational system dynamic errors due to the motion of the inertial navigation system. Typically this error is +/-0.25°, but this is +/-0.0° through the use of signal tracking assistance.

- D = Dynamic pointing errors between the desired pointing angle and the antenna pointing while in motion. (+/-0.19°, 95%)

Total Error E = expected value of the uncorrelated events (S, A, N, D)
= square root($S_2 + A_2 + N_2 + D_2$)
= square root( $(0.1)_2 + 0_2 + 0_2 + (0.19)_2$)
= **+/-0.2°**

Beyond **+/-0.2°** the transmitter is muted in less than **100 mSec** (47cfr25.222 requirements).

| | |
|---|---|
| Antenna/Vehicle are NOT in motion | E<0.1°, 100% of the time<br>Transmitter is Enabled |
| Antenna/Vehicle are in motion<br>(paved or dirt roads) | E<0.2°<br>Transmitter is Enabled |
| Extreme Terrain<br>Off-road mobile vehicle<br>conditions | E<0.2°, 85% of the time<br>Transmitter is Enabled |
| Antenna/Vehicle are in motion | E>0.2°<br>Transmitter is **MUTED** |

# 6. MAXIMUM POWER SPECTRAL DENSITY – ELEVATION

### Maximum Antenna Gain in Excess of FCC 25.209

Antenna plots of the TracStar Systems IMVS450M Antenna Assembly have been examined for the maximum gain in excess of the FCC 25.209 profile. The maximum allowable transmit carrier energy density will be reduced by the excess gain.

The Antenna Reflector is approximately 40" x 5.625" (1.02m x 0.14m). The reflector and aperture (mirror and pillbox) is elliptical in shape with an effective parabolic equivalent diameter of 0.45m.

The maximum excess gain is 12.0 dB and occurs at 14.5 GHz, vertical polarization, elevation profile (see the attached Antenna Gain Plotted against FCC Antenna Performance Standards 25.209).

Frequency 14.25 GHz Antenna 5.6"x40" (0.45 m)
Polarization VERT Peak Gain 32.5 dB
Plane E Max Difference between antenna and FCC25.209 12.0 dB

Since small antenna pointing errors will occur as a result of the antenna dynamics, we have examined the maximum excess gain resulting from pointing errors (note that the transmitter is MUTED if the antenna exceeds the pointing error threshold).

The maximum excess gain is 13.3 dB and occurs at 14-14.5 GHz, vertical polarization, elevation profile with a 0.2° degree pointing error.

### Maximum Power Spectral Density Allowed To Meet FCC Rulings

For an FCC 25.209 compliant antenna, the maximum input power density into the antenna shall not exceed -14 dBW/4 kHz.

This energy density must be reduced by the maximum excess gain of the "non-compliant" antenna. FCC 25.209 compliant antenna -14 dBW/4 kHz maximum excess gain of the "non-compliant" antenna 13.3 dB

**Maximum Power Spectral Density allowed into the "non-compliant" antenna -27.3 dBW/4 kHz**

## 7. MAXIMUM POWER SPECTRAL DENSITY – AZIMUTH

**Maximum Antenna Gain in Excess of FCC 25.209**

Antenna plots of the TracStar Systems IMVS450M Antenna Assembly have been examined for the maximum gain in excess of the FCC 25.209 profile. The maximum allowable transmit carrier energy density will be reduced by the excess gain.

The Antenna Reflector is approximately 40" x 5.625" (1.02m x 0.14m). The reflector and aperture (mirror and pillbox) is elliptical in shape with an effective parabolic equivalent diameter of 0.45m.

The maximum excess gain is 0.0 dB and occurs at 14-14.5 GHz, horizontal polarization, azimuth profile (see the attached Antenna Gain Plotted against FCC Antenna Performance Standards 25.209).

Frequency 14.25 GHz Antenna 5.6"x40" (0.45 m)
Polarization HORIZ Peak Gain 32.5 dB
Plane E Max Difference between antenna and FCC209 0.0 dB

Since small antenna pointing errors will occur as a result of the antenna dynamics, we have examined the maximum excess gain resulting from pointing errors (note that the transmitter is MUTED if the antenna exceeds the pointing error threshold).

The maximum excess gain is 0.0 dB and occurs at 14-14.5 GHz, vertical polarization, azimuth profile with a 0.2° degree pointing error.

### Maximum Power Spectral Density Allowed To Meet FCC Rulings

For an FCC 25.209 compliant antenna, the maximum input power density into the antenna shall not exceed -14 dBW/4 kHz.

This energy density must be reduced by the maximum excess gain of the "non-compliant" antenna. FCC 25.209 compliant antenna -14 dBW/4 kHz maximum excess gain of the "non-compliant" antenna 0.0 dB

**Maximum Power Spectral Density allowed into the "non-compliant" antenna -14 dBW/4 kHz**

## 8. MAXIMUM POWER SPECTRAL DENSITY

The TracStar Systems IMVS450M Antenna Assembly is a two axis (Azimuth, Elevation) antenna and Polarization feed adjusting pedestal. The antenna is wider in its azimuth plane than it is in its elevation plane in order to support military size requirements. The wide dimension of the antenna remains level with the vehicle. In general the wide dimension of the antenna will not be tangent to the geostationary arc for the desired satellite. To a first order approximation, the actual illumination on the geostationary arc is the vector addition of the azimuth and elevation gain profiles adjusted by the angle between the wide dimension of the antenna and the geostationary arc (relative rotation).

At 0° relative rotation (polarization), the illumination on the geostationary arc is the azimuth gain profile. At 90° relative rotation, the illumination on the geostationary arc is the elevation gain profile. As seen in the previous two sections, the worst case gain difference between azimuth and elevation excess gain is 13.3 dB.

We have examined the relative rotation from locations in CONUS vs. the satellites of interest (listed below) and have found the relative rotation 1.6° (Miami to AMC-9) to 59° (Seattle to T-14).

| Satellite | Longitude | CONUS | Locations |
|---|---|---|---|
| AMC-4 | 101W | Seattle, WA | 48.7N, 122.3W |
| AMC-9 | 83W | Portland, MN | 43.6N, 70.2W |
| AMC-6 | 72W | Miami, FL | 25.7, 80.4W |
| Telstar-14 | 63W | San Diego, CA | 32.7N, 117.2W |

Excess gain increases as a function of relative rotation are shown below. Thus it is conservative to utilize the azimuth antenna pattern, reduced by the increase in excess gain to determining the allowable PSD into the antenna.

**Excess Gain and PSD vs. Relative Rotation (Note 1)**

| Relative Rotation Or Polarization (Degrees) | Increase in Excess Gain (dB) | Maximum Power Spectral Density allowed into the "noncompliant" antenna |
|---|---|---|

| | | (dBW / 4kHz) |
|---|---|---|
| 0 | 0.0 | -14.0 |
| 1 to 10 | 0.0 | -14.0 |
| 11 to 20 | 0.9 | -14.9 |
| 21 to 30 | 1.6 | -15.6 |
| 31 to 40 | 2.2 | -16.2 |
| 41 to 50 | 4.5 | -18.5 |
| 51 to 60 | 6.1 | -20.1 |
| 61 to 70 | 7.4 | -21.4 |
| 71 to 80 | 10.3 | -24.3 |
| 81 to 90 | 13.6 | -27.3 |

**Note 1:** The LP antenna radiation patterns have a different AZ and EL half power beamwidth (HPBW) due to its asymmetric reflector. As the reflector has an approximately elliptical shape, to a first approximation so also does the resulting antenna main beam. The resulting radiation pattern E(Φ) is given by:

$$E(\Phi) = F_{EL} * \sin(\Phi) + F_{AZ} * \cos(\Phi)$$

where $F_{EL}$ is the elevation pattern and $F_{AZ}$ is the azimuth pattern

This is the parametric equation for a perfect ellipse. The resulting pattern amplitude at any arbitrary pattern cut at angle Φi is given by:

$$I\ E(\Phi i)\ I = \sqrt{[F_{EL}{}^2 * \sin^2(\Phi i) + F_{AZ}{}^2 * \cos^2(\Phi i)]}$$

# 9. CONCLUSION

## Managing Transmit Power Spectral Density

TracStar Systems has developed methods to protect adjacent satellite operations. These methods have taken several years to develop and refine and have been verified in laboratory and operational conditions. A conservative analysis has been performed and has and will continue to be used to protect adjacent satellite operations.

Power Spectral Density (PSD) into the antenna shall be managed within the required FCC limits by limiting transmit power and/or utilizing spread spectrum modulation. The actual power required in order to achieve a reliable data link will depend on the site location within CONUS, the associated weather conditions, the satellite performance, and the receiving station performance. If the communications link requires more power, additional spreading will be required. If the communications link requires less power then the spreading factor may be reduced.

The TracStar Systems IMVS450M Antenna Assembly controls pointing of the antenna through the use of advanced control systems utilizing GPS, inertial navigation systems, signal tracking assistance, and rate and attitude sensors. This antenna pointing technology has been engineered over many years and has been verified in both lab and operational environments.

**Interference effects will be less than or equal to those of an FCC 25.209 compliant antenna.**

**The earth station will be operated within CONUS such that the PSD into the antenna will be less than -14.0 dBW / 4 kHz and will be further reduced**

**to account for the relative rotation of the non-circular antenna with the geostationary arc (per paragraph 8).**

**Antenna pointing will be maintained within +/-0.2°. Under extreme mobile environments, the transmitter will be MUTED within 100ms while pointing error exceeds +/-0.2°.**

## 10. APPENDIX - ADJACENT SATELLITES

The following charts show the adjacent satellites to the **desired** operational satellite.

| | | |
|---|---|---|
| Intelsat-9 | 58°W | 5 |
| Amazonas-1 | 61°W | 2 |
| Echostar-3 | 61.5°W | 1.5 |
| Echostar-12 | 61.6°W | 1.4 |
| **Telstar-14** | **63°W** | **0** |
| Nahuel-1A | 71.8°W | 8.8 |

| | | |
|---|---|---|
| Telstar-14 | 63°W | 11 |
| Nahuel-1A | 71.8°W | 0.2 |
| **AMC-6** | **72°W** | **0** |
| DirecTV-1R | 72.5°W | 0.5 |
| SBS-6 | 74°W | 2 |
| Echostar-4 | 77°W | 5 |
| AMC-5 | 79°W | 7 |
| AMC-9 | 83°W | 11 |

| | | |
|---|---|---|
| SBS-6 | 74°W | 9 |
| Echostar-4 | 77°W | 6 |
| AMC-5 | 79°W | 4 |
| **AMC-9** | **83°W** | **0** |
| AMC-2 | 85°W | 2 |
| AMC-16 | 85° | 2 |
| AMC-3 | 87°W | 4 |
| IA-8 | 89°W | 6 |
| Galaxy-11 | 91°W | 8 |

| | | |
|---|---|---|
| IA-6 | 93°W | 8 |
| Galaxy-3C | 95°W | 6 |
| IA-5 | 97°W | 4 |
| Spaceway-F2 | 99°W | 2 |
| DirecTV-8 | 100°W | 1 |
| **AMC-4** | **101°W** | **0** |
| MSAT-2 | 101°W | 0 |
| DirecTV-9S | 101°W | 0 |
| DirecTV-4S | 101°W | 0 |
| Spaceway-F1 | 103°W | 2 |
| DirecTV-10 | 103°W | 2 |
| AMC-1 | 103°W | 2 |
| AMC-18 | 105°W | 4 |

| | | |
|---|---|---|
| AMC-15 | 105°W | 4 |
| MSAT-1 | 106°W | 5 |
| Anik-F1R | 107°W | 6 |
| Echostar-8 | 110°W | 9 |

# 11. APPENDIX - ANTENNA PLOTS

### See separate TracStar Systems document - IMVS450M Patterns

# 12. APPENDIX - EARTH STATION MAXIMUM EIRP

The maximum operational output power of the SSPA will be +44 dBm. The maximum antenna gain (including coupling losses) is 32.8 dBi. The maximum operational EIRP of the station will be 46.5 dBW.