Satcom-On-the-Move™

Market Brief 2012
WHY GDST SOTM Antenna?

- The GDST SOTM Antenna is the only antenna choice for your On-The-Move communication needs when it is critical to have successful data transmission and reception.

SOTM History

- In early 2003, GDST invested in the development of a “SATCOM-on-the-Move” (SOTM) Terminal product line under its VertexRSI brand name. This investment produced many milestones, including:
  - First on-the-move pedestal to pass U.S. Army tests of pointing accuracy compliance in "Churchville B" off-road conditions.
  - First Ka-band on-the-move Terminal to successfully hold high bandwidth (20 Mbps) downlink from U.S. DOD Global Broadcast Service (GBS) satellite.
  - First ruggedized land-mobile Ku-band SOTM Terminal licensed by FCC.
  - First Ku-band on-the-move system to receive licensing by FCC on multiple domestic U.S. satellites.
  - First Ku-band OTM system to receive license, be granted space-segment, and subsequently operate on any Intelsat satellite.
  - First VMES Alsat License.
The fundamental SOTM issue

Satcom-On-the-Move systems must be designed to provide sufficient on-satellite performance while also generating acceptable levels of Adjacent Satellite Interference.
The fundamental SOTM issue
The challenge facing all satellite communications systems

A satellite system MUST:
- Maximize desired RF radiation
- Minimize undesired RF radiation
- Do both at the same time

Additionally, SOTM systems MUST:
- Tolerate shock and vibration
- Do all this On-the-Move!

This is the issue driving all satellite communications systems!
SOTM regulatory requirements

Satcom-On-the-Move systems must satisfy regulatory requirements for the frequency band and Administration (country) in which they operate.
SOTM links must be designed differently

Satcom system engineers perform a link analysis

- For most satcom systems, the main objective is suitable on-satellite performance
  - The design objective is suitable link data rate /BER at minimum space segment cost
    - This usually means “balanced” use of satellite power and bandwidth
  - After link performance is designed, suitable Adjacent Satellite Interference levels are confirmed
- This same approach is used in satcom and terrestrial links

Satcom-On-The-Move systems are driven by ASI

- Use of smaller antennas results in significant off-axis energy
- Because of this, SOTM link design is a more iterative process
  - Adjacent Satellite Interference is usually the top concern
  - On-satellite link performance can be determined after ASI is satisfied
    - Meaning it usually requires a series of approximations and trade-offs

Satcom-On-The-Move requires different terminal / space segment cost trades

- More satellite bandwidth is required to reduce EIRP PSD to acceptable levels
  - Most SOTM links use more satellite bandwidth than power (satellite use is not “balanced”)
- Space segment is always ultimately more costly than terminal hardware
  - Both can be very significant
  - Terminal trade-offs can have a very large impact on space segment cost
SOTM must meet ASI limits

Uplink interference generated on adjacent satellites is limited by international agreement (ITU Recommendations) and is different for different countries

- Some of the most significant regulatory limits include:
  - ITU-R S.524-9 - Maximum permissible levels of off-axis e.i.r.p. density from earth stations in geostationary-satellite orbit networks operating in the fixed satellite service transmitting in the 6 GHz, 13 GHz, 14 GHz and 30 GHz frequency bands
  - ITU-R S.728-1 - Maximum permissible level of off-axis e.i.r.p. density from very small aperture terminals (VSATs)

- In the United States for civil satcom:
  - FCC Regulation 25.226 - Blanket Licensing provisions for domestic, U.S. Vehicle-Mounted Earth Stations (VMESs) receiving in the 10.95-11.2 GHz (space-to-Earth), 11.45-11.7 GHz (space-to-Earth), and 11.7-12.2 GHz (space-to-Earth) frequency bands and transmitting in the 14.0-14.5 GHz (Earth-to-space) frequency band, operating with Geostationary Satellites in the Fixed-Satellite Service.
  - FCC Regulation 25.222 - Blanket Licensing provisions for Earth Stations on Vessels (ESVs) receiving in the 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) frequency bands and transmitting in the 14.0–14.5 GHz (Earth-to-space) frequency band, operating with Geostationary Orbit (GSO) Satellites in the Fixed-Satellite Service.

- For DoD satcom:
  - Mil-Std-188-164B - Interoperability of SHF Satellite Communications Terminals

SOTM links must be designed to operate within the appropriate ASI limits for the band and country in which operations are conducted
SOTM must meet ASI limits

Comparison of the various ASI regulations is appropriate

- Adjacent Satellite Interference (ASI) levels are based on EIRP power spectral density, not total power
- For FSS Ku-Band, the levels permitted in the United States are lower than in other world regions
  - Mostly because satellites are spaced every 2 degrees over CONUS

On other bands, EIRP Density levels are generally higher and driven by international treaty
SOTM Operational Trade-Offs

Satcom-On-the-Move systems must simultaneously satisfy several different constraints, leading to a number of operational trade-offs
SOTM is affected by downlink aperture size

On the downlink, smaller antennas require more satellite transponder power and bandwidth for all services

- Different satellites have different downlink EIRP capabilities
- Satellite downlink EIRP is always limited to some level to avoid interference with other systems
- Using different waveforms or modulation characteristics, we can design links to operate with different size antennas
  - The smallest size which can be used can be determined with a link analysis
    - It will be driven by the possible S/N to support the selected modem
    - Ultimately, it is limited by satellite EIRP and modem required Eb/No
- Larger antennas will be more efficient in the use of satellite power and bandwidth, but smaller antennas can still be utilized for some links
- The impact of this can be observed on the required downlink EIRP graph

![Graph showing Satellite Downlink Power in dBW for 1 MBPS BPSK](image)
SOTM is dramatically affected by the receive terminal

Satellites have improved
- Now have more EIRP, better G/T in all bands
- This supports smaller antennas
- Smaller antennas still take more power

Affects network architecture
- SOTM peer-to-peer is difficult
- Best efficiency achieved operating like VSATs

In most bands ~3.8 M is good for hub terminals
- Downlink power needed by larger antennas does not go down because Noise is then dominated by satellite, not earth station G/T
- C-Band still typically needs larger antennas
  - Mostly limited by terrestrial interference
SOTM uplink aperture size and pointing drive efficiency

Relatively larger antennas operate like VSATs

- In FSS Ku-Band this happens with effective apertures about 60 cm
- The reason is that suitable on-satellite gain is available to utilize normal waveforms and still satisfy ASI constraints

Smaller antennas require modulation changes

- ASI limits become the dominant factor
- In Ku and Ka-band, improved modem modulation and FEC can satisfy link and ASI requirements for mid-sized SOTM terminals
  - A 50 cm or larger terminal with optimal pointing can satisfy link requirements on most CONUS satellites using BPSK R-1/2 LDPC modulation
  - EIRP PSD limits are higher outside the United States
- For the smallest SOTM terminals, there is no other option than to implement some form of spectrum spreading
  - Can be achieved via FEC, spread spectrum, or a combination of both

Reduced pointing accuracy has the same link impact as reduced antenna size

- Reduces on-satellite gain
- Increases ASI levels
Ku-band close-in EIRP density example
SOTM uplink aperture size and pointing drive efficiency

Consider a relatively large SOTM terminal with degraded pointing

- Larger antenna provides more gain on satellite
- Reduced pointing accuracy imposes significant ASI constraints
SOTM uplink aperture size and pointing drive efficiency

Consider the off-boresight gain effects using a flat array

- When satellite is 90 Degrees relative to array face, gain is maximized
- As angle from array approaches zero, gain approaches zero

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**Gain Decrease**

![Graph showing gain reduction in dB as a function of radiation angle.](image)

- Maximum gain on boresight, perpendicular to array
- dB Reduction
- Radiation Angle in Degrees
- Towards Satellite
- Radiation Angle
- Array Surface

Angle is actually a three-dimensional angle so problem includes azimuth and elevation
Cost also drives SOTM terminal trades

Costs include both terminal procurement and space segment costs

Larger antennas have advantages and disadvantages

- **Advantages include**
  - Lower satellite transponder costs
  - Improved overall efficiency
  - Supports higher data rates

- **Disadvantages include**
  - More expensive to produce due to size and tracking system
  - Must be tracked accurately
  - “Looks big!”
  - Can be too large to mount effectively

Smaller antennas have advantages and disadvantages

- **Advantages include**
  - Lower procurement costs
  - Easier to track
  - Improved vehicle profile

- **Disadvantages include**
  - Lower efficiency, always resulting in higher satellite costs
  - Can be too small to support desired data rate
Size, weight, and power drive SOTM terminal trades

SWAP comes into play because it is not possible to supply arbitrarily high data rate services with an exceptionally small terminal

SWAP is driven by vehicle constraints and service requirements

- Some vehicles simply cannot tolerate higher size, weight, or power
  - Airborne vehicles especially
  - Many land vehicles as well
  - Always important for “target profile”
- High data rate services cannot be provided by exceptionally small terminals
  - Ultimately limited by combined satellite power and bandwidth
    - Per the Shannon-Hartley Theorem– finite limits in channel capacity for power and bandwidth
  - As aperture size decreases, more bandwidth is required to provide sufficient satellite power

The “optimal trade” depends upon several factors

- The usual considerations of “cost” and “data rate” are only part of the equation
  - Vehicle constraints can often be the most significant drivers
- This range of factors directly results in the need for multiple terminal types
  - There will always be a need for “the smallest possible”
  - However, there is a demonstrated need for “the highest data rate”
    - Which leads to the need for several intermediate options
SOTM™ Modular Product Approach

Modular approach

- Integral air-to-air heat exchanger (land/maritime)
- Three pedestals, six antenna sizes
  - 43x33cm (17 X 13in)
  - 43cm (17in)
  - 46cm (18in)
  - 50cm (20in)
  - 60cm (24in)
  - 75cm (30in)
- Interchangeable Ku, Ka, and X-band

Provides custom solutions at standard production prices
GD SATCOM SOTM™ Differentiators

Gyro stabilized / closed-loop control
- Provides high tracking accuracy

Track mode and Point mode tracking modes
- Better tracking options maximize on-satellite EIRP

Transceiver mounted on the RF payload
- Produces higher RF efficiency and higher EIRP

Interchangeable RF payloads*
- Support changing user requirements
- Dynamic space segment utilization

Direct-drive antenna motors
- Provide higher accelerations
- Improved mechanical survivability

Modem Agnostic

*Except for M13A Airborne Series
General Dynamics has now provided over 200 Vehicle Mounted Earth Station (VMES) terminals

- For commercial and military use
- Multiband (X-, Ku-Ka-) Support
- In service in more than 7 countries

We have tested operation on most FSS (Fixed Service Satellites) Ku-Band satellites

- Intelsat and SES in the United States
- Eutelsat, Intelsat, SES, and others in Europe and Asia
- To our knowledge no known interference generated under normal operation
- Demonstrated true broadband operation
Satcom–on-the-Move™ In the Field

- USS Kearsarge Sea Trials
- Bradley Vehicle Yuma Proving Grounds
- Rigid Inflatable Boat NAVAIR Pacific Operations
- Hummer in Desert
- MRAP EDGE Demo GDUK
- Stryker Vehicle Ft. Huachuca
Airborne Satcom-on-the-Move™

Airborne M17-17A SOTM Antenna

- Interchangeable Payload (Ku, Ka and X-bands)
- Can support > 3 MBPS
- < 80 lbs
- Modem Agnostic
- Design based upon proven M17-17 platform
- Production units now flying
Satcom-on-the-Move™ Airborne Strategy

- M17A Series is available in Ku, X and Ka-Mil. Formal Airborne Qualification is pending and expected to be completed in Q3 2012.
- Specific aircraft certification is the responsibility of the Aircraft Integrators.
- Aircraft Integrators are responsible for mounting provisions and the antenna radome.
- IRU/GPS can be provided by GDST but this is usually provided by the Aircraft Integrators.
- Ka-Com is currently being tested and will be available in near future.
- M13A Series is scheduled for production release in July 2012. The M13-17LPA will be available first.
Satcom-on-the-Move™ New Development

M13A Series Airborne SOTM Antenna

- Available in X, Ka and Ku-Band
- Available apertures: 13” and 13”X17”
- Can be optimized to fit various aircraft
- Lightweight: under 45lbs
- Further weight reductions can be realized with off gimbal SSPB and ACU
Improved Road On-the-Move - New Development

SOTM-IR Key Features

- Available in 20”, 24” and 30” size reflectors
- Non-ITAR
- FCC and ITU Compliant
- Modem Agnostic
- Interchangeable RF Payloads available in X, Ku and Ka-Band
- RF to IF Interface
- Flush Mount Above-the-Deck™ modular design for ease of installation
- Terminal includes radome, antenna, positioner, servo amplifier, tracking receiver, block-up and down-converters, antenna control unit, high efficiency solid state power amplifier and integrated AHRS

- Production release scheduled for July 2012
Conclusion

Satcom-On-the-Move has already resulted in the need for a number of different terminal types and options.

Even as further advancements are achieved, no single option promises to meet the complete range of evolving requirements.