Challenges in the Design and Deployment of Ka-Band Ground Systems

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OUTLINE

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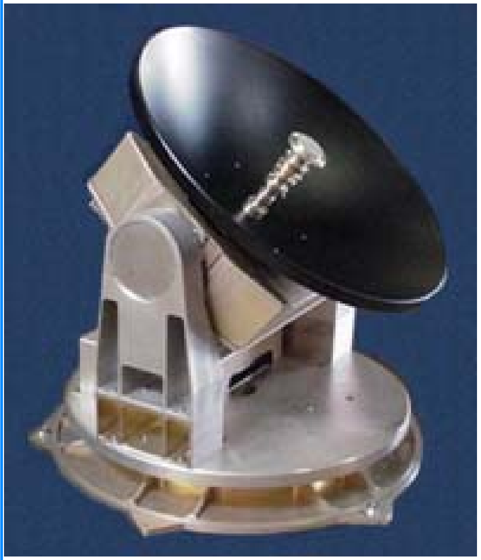
- Pointing and Tracking
- Temperature Effects
- Examples of Deployed Systems

Overview: Ka Band Antennas



- Antennas available from 0.67m to 18.4m
- Technical challenges increase with diameter
- VSAT, Limited Motion (LM), Full Motion (FM), and Satcom on the Move (SOTM) product lines
- Applications: TT&C, Gateways, Direct-to Home (DTH) uplinks, VSAT Terminals (Broadband), DTH receivers, On-the-Move

VSAT Ka-Band Product Sales

Antenna Size	Quantity Sold	Customer Base
.67M	< 100	Broadband – US
.74M	560,000	Broadband – US & Europe
.89M	< 100	Enterprise – US
.98M	14,000	Broadband & Enterprise - US & Europe
1.2M	3,000	Enterprise – Global
1.8M	100	Enterprise – Global
2.4M	< 100	Enterprise – Global

8-9m/13m/18m Ka/DBS Deliveries

GD-SJ Antennas Deployed since 2005

Description	Antenna Size	Frequency Band	Quantity
Breakdown by Aperture	9.2M	DBS/Ku-Band/Ka Band	**77**
	13.2M	DBS/Ku-Band/Ka Band	**39**
	18M	DBS/Ku-Band/Ka Band	**12**
Breakdown by Band	All	Ku-band/DBS/Reverse Band	**40**
	All	Ka-band	**88**
Ka-Band Breakdown by Aperture	9.2M	Ka-band	**61**
	13.2M	Ka-band	**15**
	18M	Ka-band	**12**
Summary	9.2m/13.2/18m	DBS/Ku-Band/Ka Band	**128**

Technical Challenges at Ka-Band

Problem	Description	Problem Mitigation
Diurnal Thermal Effects	Temperature and solar radiation variations produce antenna structure thermal gradients →gain reduction and pointing errors.	Fabrication materials and structural design. Material: Uniformity and lowest coefficient of thermal expansion. Steel better than aluminum Design: FEA (Finite Element Analysis) of a thermal model. Backup Structure (BUS) with a high stiffness/weight ratio. BUS to minimizes the thermal effects.. Use of **counterweights** offers/allows: • Balanced structural loads • Increased lifespan of the elevation actuator • Smoother Elevation motion • Easier and safer actuator replacement • Steel reflector
Reflector Surface Accuracy Requirement	Surface accuracy within 3% of wave length. At 30 GHz surface accuracy required is 0.012 inches rms (0.3mm) deviation from an ideal surface, including alignment, thermals, wind deformation, and gravity.	Quality panel and subrelfector fabrication as well as the robustness. Reflector panel surface accuracies are specified at 0.003 of an inch rms (76 microns). For large aperture antennas, photogrammetry techniques are used to properly align and verify panel installation Panels are typically aligned at the operational elevation angle within 0.003 of an inch rms.

Challenges at Ka-Band

Problem	Description	Problem Mitigation
Anti-Icing	Hot-air systems may produce high antenna gain losses (up to 6 dB if not well designed). Need to control the heat applied to the reflector backup structure, which may cause defocusing (sub-reflector movement) and reflector rms degradation. Closing off of the backup structure introduces thermal gradients even when the anti-icing system is not active.	Precise control of the anti-icing plenum temperature to ensure that sufficient heat is applied to the reflector surface while minimizing the thermal effects on antenna gain. Design based on minimal thermal expansion of structure. Temperature gradients controlled with the use of fans and heat distribution systems within the plenum. Results show gain degradations at Ka-Band controlled to: 9.2m: 0.60 dB 13.2m 0.75 dB 18.2m 1.00 dB
Mechanical Accuracy	Bearing wobble, mechanical backlash, antenna stability	Use of quality mechanical components from reputable suppliers with proper attention to stiffness of reducers, encoder windup, individual component testing and tight quality control.

Operating at Ka-Band

Problem	Description	Problem Mitigation
Antenna Pointing	The narrow antenna beam at Ka-Band imposes stringent tracking accuracy in absolute angular degrees especially in windy environments. Variations of the refractive index profile will depart from its normal exponential decay. This results in bending, scattering and reflections of the antenna beam. At low and high elevations the gravity structure distortion affects the antenna pointing.	Precision structure that provides structural stiffness in wind, quality mechanical components and low thermal effects. Use of antenna servo system with high accuracy and high resolution positioning systems. Proper mechanical alignments are critical for reducing pointing errors which require care and skill during field installation. Antenna Control systems can compensate with different models used to evaluate the refraction correction. Accurate and fresh TLE's (NORAD track) are required for satellite acquisition. The gravity distortion effect is mitigated by adequate calibration and compensation tables in the tracking system.
Antenna Tracking	The narrow antenna beam at Ka-Band imposes stringent tracking accuracy in absolute angular degrees especially in windy environments.	Use the proper tracking system General rule of thumb at Ka-Band: -Diam < 2.4m: No tracking typically needed - Diam < 8m: Steptrack/Optrack - Diam > 8m: Monopulse tracking Rigid structure with precision antenna control

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Operating at Ka-Band

Problem	Description	Problem Mitigation
Low Angle diffraction and scintillation	Degradation effects on signal stability and antenna pointing at low elevation angles At high latitudes, (elevation angles of < 5°) major fading is caused by scintillation. Can be as high as 10 dB	Improved diffraction correction models and antenna program tracking Diversity Site located at least 10 km from primary site
HPA Limitations in Power	HPA technology limits HPA power at Ka-Band.	Phase combine HPAs: Satcom has successfully phase-combined Ka-Band HPAs for many years and delivered reliable high power uplink systems.
High Cost and Reliability of HPAs	HPA cost is high and HPA may have reliability issues, e.g. travelling wave tubes (TWT) limited-life expectancy. Question: Antenna gain vs. HPA size?	Use larger aperture antennas provide additional gain (EIRP and G/T) and lower the number of HPAs. E.g. moving from a 9.2m to a 13.2m Ka-Band has the following advantages: 1) Going from 4 to 2 HPAs the price delta is about the same as the price increase from a 9.2m to a 13.2m antenna 2) Receive gain and G/T is 3 dB higher 3) Mechanical gain is more reliable than electronic TWTA power 4) 3 dB TX Gain (antenna) vs. 2.5 dB TX gain (phase comb) 5) Simpler, more reliable system architecture 6) Lower hub cooling system requirement

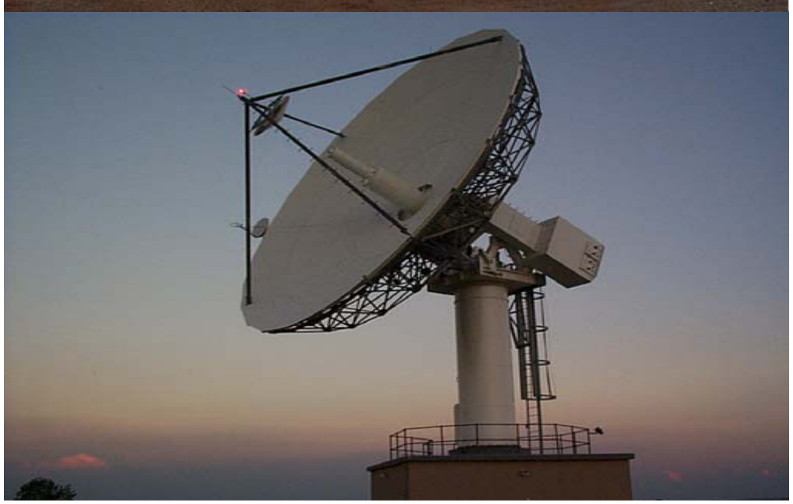
Operating at Ka-Band

Problem	Description	Problem Mitigation
TX Waveguide Losses at Ka-Band	Waveguide loss between the HPA output flange and the antenna feed flange are very high in WR34 and WR28 waveguide. Typical WG losses are about 0.5 dB per meter at Ka band.	Utilize L-band for Inter-facility Links (IFLs) and block conversion to Ka-Band in the Hub Mounting BUCs and HPAs in the antenna hub as close to antenna feed as possible Large, environmentally controlled Hub to provide reliable HPAs operation.
Rain Fades and Uplink Power Control (UPC)	Since rain fades can be very large (>30 dB), at Ka-Band uplink power control and stability become more challenging	Use of large UPC range by providing maximum EIRP during faded conditions and high C/No during clear-sky conditions (20+ dB UPC range). Implement an M&C UPC algorithm that measures the downlink signal level from the tracking receiver to command a block upconverter (BUC) attenuation adjustment. A Diversity site (with typically >10 km separation) is implemented for systems with high availability requirements. Availability can be largely improved due to the statistical independence of turbulent air masses on the signal path.

Deployment at Ka-Band

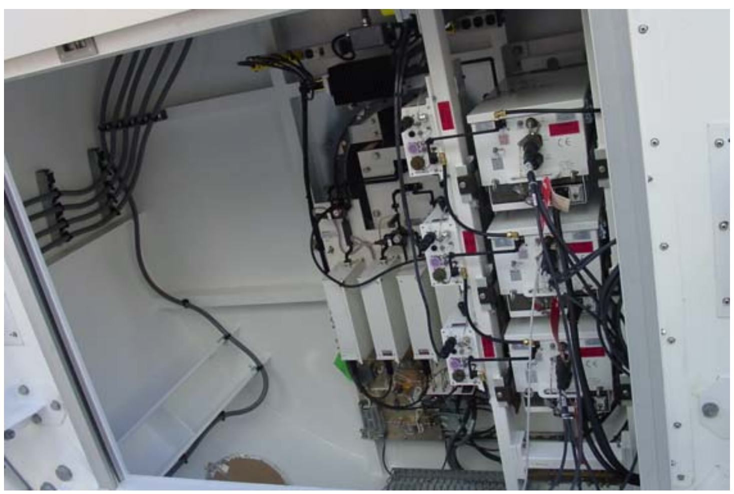
Problem	Description	Problem Mitigation
Radome effects	Signal losses and G/T degradation are significant at Ka band (as high as 3 dB)	Where possible, avoid the use of Radomes with a quality outdoor rated antenna Analysis and optimization studies for the use of Radomes at Ka band.
Antenna range testing	Ka-Band far-field antenna gain testing is difficult for large aperture antennas (up to 40 Km is required)	For large antennas, range testing is impractical. We mitigate this issue by providing accurate, repeatable reflector panel fabrication, precise surface accuracy measurements at the factory and photogrammetry for panel alignment at site. This process is well proven and has a long successful history.
HPA design stability	Ka band amplifiers still require long design and debug cycles.	Close engineering cooperation with the manufacturers . Vendor specific detailed knowledge for high reliability Ka band HPA system implementation.
Antenna focusing	Antenna focus alignment is very sensitive, especially for large antennas	Photogrammetry and computer aided algorithms help in the antenna alignment process along with skilled and experienced site technicians.
Antenna RF testing	G/T, Antenna gain and patterns are difficult to test due to signal stability specifically at low elevations	Special software corrections allows for stable gain and pattern recording in the presence of unstable reference signals

Ka-Band Antenna Systems



- Antenna Designs
  - 18M FMA (MUOS)
  - 13M FMA & LMA
  - 9M LMA
  - 8M LMA
  - 5.5M LMA
- Frequency Ranges:
  - 17.7-21.2 GHz RX
  - 27.5-31.0 GHz TX
  - Custom Bands
- Example of Customers
  - DIRECTV
  - Echostar
  - MUOS (Team Member with GDC4S)
  - ICO
  - Spaceways
  - Telesat
  - KoreaSat
  - Avanti (UK)
  - Intelsat (US, Australia, India)
  - Astrium (YahSat TT&C Stations)
  - US Army (RHN)
  - SES Astra
  - SED
  - INMARSAT
  - Loral

Ka-Band Direct to Home (DTH)



- 13M and 9M Limited Motion Antennas
- FCC & ITU Compliant
- Installed at various sites across the US
- Integrated DTH Uplink Stations
  - All Uplink Electronics Integrated into the Hub
  - Easy Access Platform

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Antenna Systems: 8/9M Antenna Class

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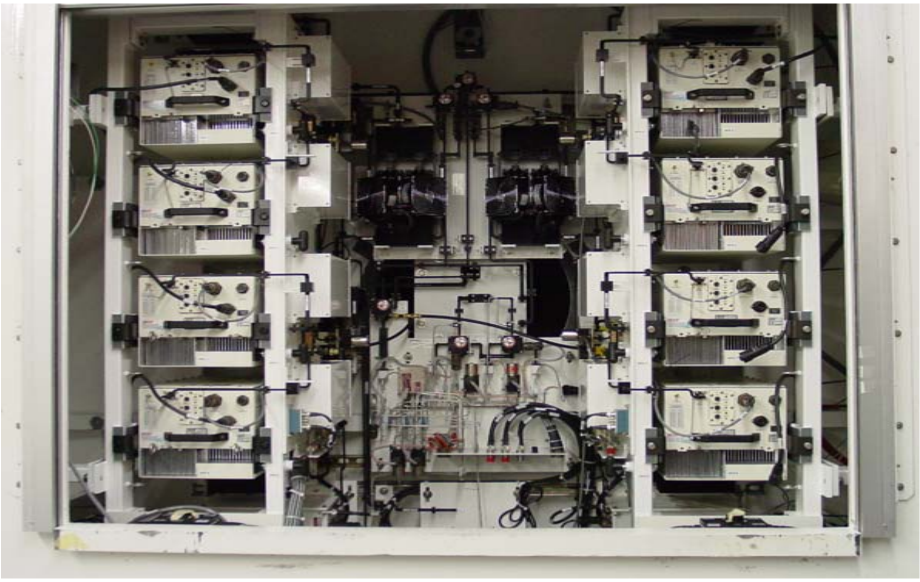
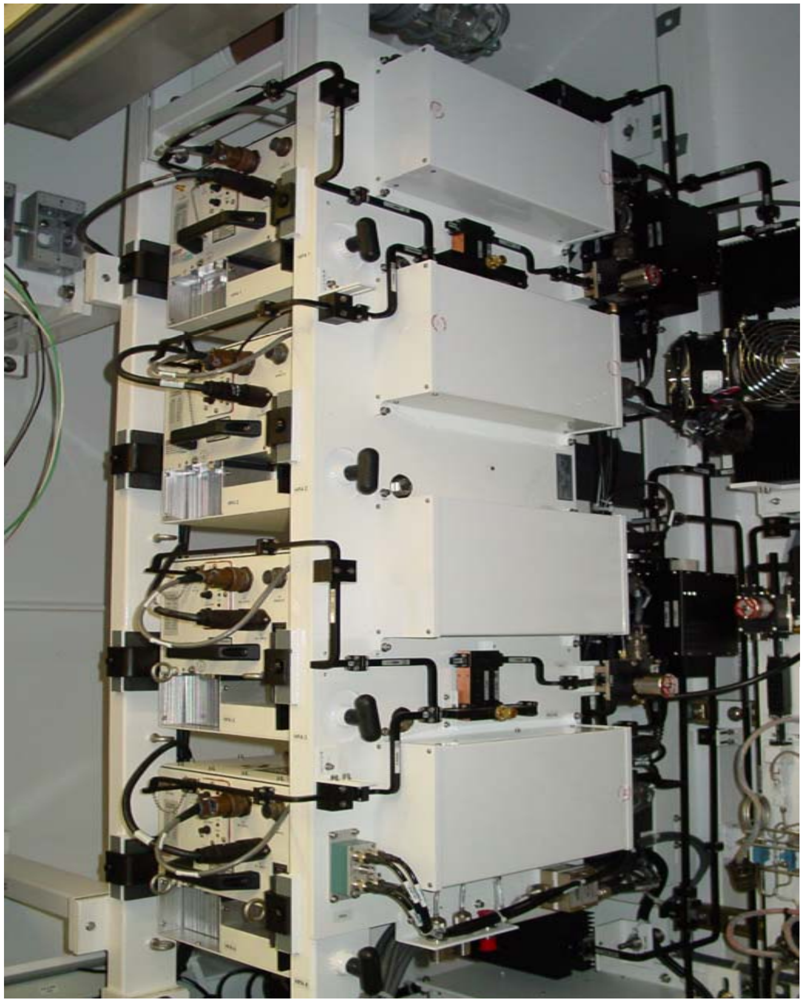
Antenna Hub Systems
9/13M Antenna Class – Hub Integration





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Typical System EIRP Performance

Typical System EIRP @ 30 GHz (500W Peak/350W CW HPA)

Antenna Type	# of HPAs per POL	HPA to Feed Loss (db) See Note 1	EIRP per POL (Saturated, 350W) dBW	EIRP per POL (Linear, 4dB OBO) dBW
6.3m	1	-0.75	86.7	84.3
8.1m	1	-0.75	88.8	86.4
9.2m	1	-0.75	90.0	87.6
9.2m (2-way Phase combined)	2	-1.40	92.4	90.0
9.2m (4-way Phase combined)	4	-2.00	94.7	92.3
13.2m	1	-0.75	93.0	90.6
13.2m (2-way Phase combined)	2	-1.40	95.4	93.0
13.2m (4-way Phase combined)	4	-2.00	97.7	95.3

Note 1: Loss Includes the total losses from the HPA to Feed Flange including the W/G run plus one RF switch and one coupler (and phase combining losses for the applicable cases above)

Typical Transmit Pattern: Elevation

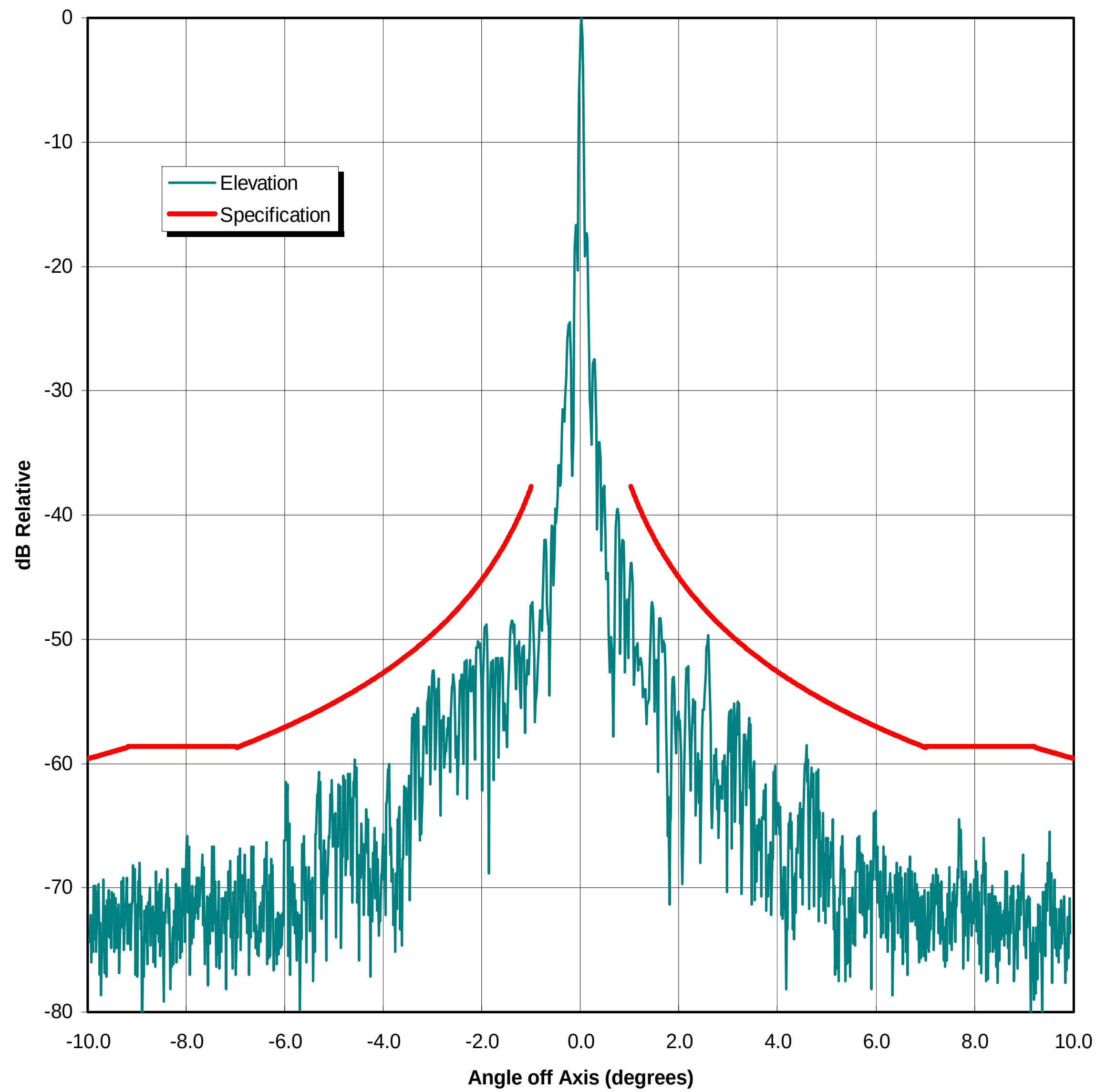
Customer Site	
Satellite	
	Transmit
Axis	**ELEVATION**
Polarization	**LHCP**
Pattern Cut	**20.0** °
Specification	**29-25logθ** (1°< θ < 7°)
	+8 dBi (7°< θ < 9.2°)
	32-25logθ (9.2°< θ < 48°)

Elevation=	45.9 °
Freq=	**29743.750 MHz**
λ=	0.010 metres
Diameter	9.20 metres
Gain=	66.6 dB

Spectrum Analyzer Settings	
RBW	30 Hz
VBW	1 Hz
Sweep	250.0 seconds
Attenuation	0 dB
Ref Level	-50.6 dBm

Test Date: 21/Jul/07

Tested By:



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TT&C Earth Stations (MUOS Program)

18.4m Full Motion Antennas
Networked M&C
TT&C and WCDMA
Geosynch Orbits
IOT functionality

Hub Integration Experience

- Antenna Hub is completely environmentally controlled and monitored.
- Hub space is fully insulated to efficiently keep the enclosed temperature as stable as possible as well as to not heat or cool the antenna structure
- Hub integration includes full factory integration of the all electronic equipment.
- Hub mounts typically utilize equipment slides as well as a de-weighting mechanism for easy and safe removal of an HPA.

Repeatable Results

- History to show that the antenna performance is repeatable by adapting the following processes:
  - All systems go through strict factory testing, specialized field installation, alignments and testing.
  - All tests performed in accordance with engineering released procedures under strict document control.
  - Customers encouraged to witness all acceptance testing.
  - Formally submit to customers released written test reports/data package for all acceptance tests.

Repeatable Results

- 100% successful history with Ka-Band antennas individually tested in the field; antenna-range testing is typically not required.
- Successful process: complete Feed factry test, precision panel/subreflector manufacturing, site photogrammetry for reflector alignment

Hub Air-Conditioning System

- Two (2) identical air conditioning units sized to cool independently the respective volumes at full performance and designed to operate simultaneously to offer full redundancy “1 + 1”.
- Interface to monitor the status of the units.
- The A/C in the center hub uses two split units – evaporator unit mounted on the side of the counterweight arms with air ducted to the center hub and the condenser unit mounted on a platform extension structure.
- Thermally insulated rigid round sheet metal duct used for air circulation; allows for full coverage of the antenna. The inside of the center uses1 inch thick insulation.

Anti-Icing (De-icing)

- Proven de-ice design limits the TX and RX signal degradation to less than 0.75 dB

- De-icing provided for:

  – Antenna Reflector Surface
    - Hot air system utilizing natural gas heater/blower assemblies and hot air circulated in a plenum
  – The Subreflector Surface
    - Electric resistance heaters embedded in the subreflector structure
  – The Feed Aperture Window
    - Hot air system utilizing some of the hot air generated within the reflector plenum

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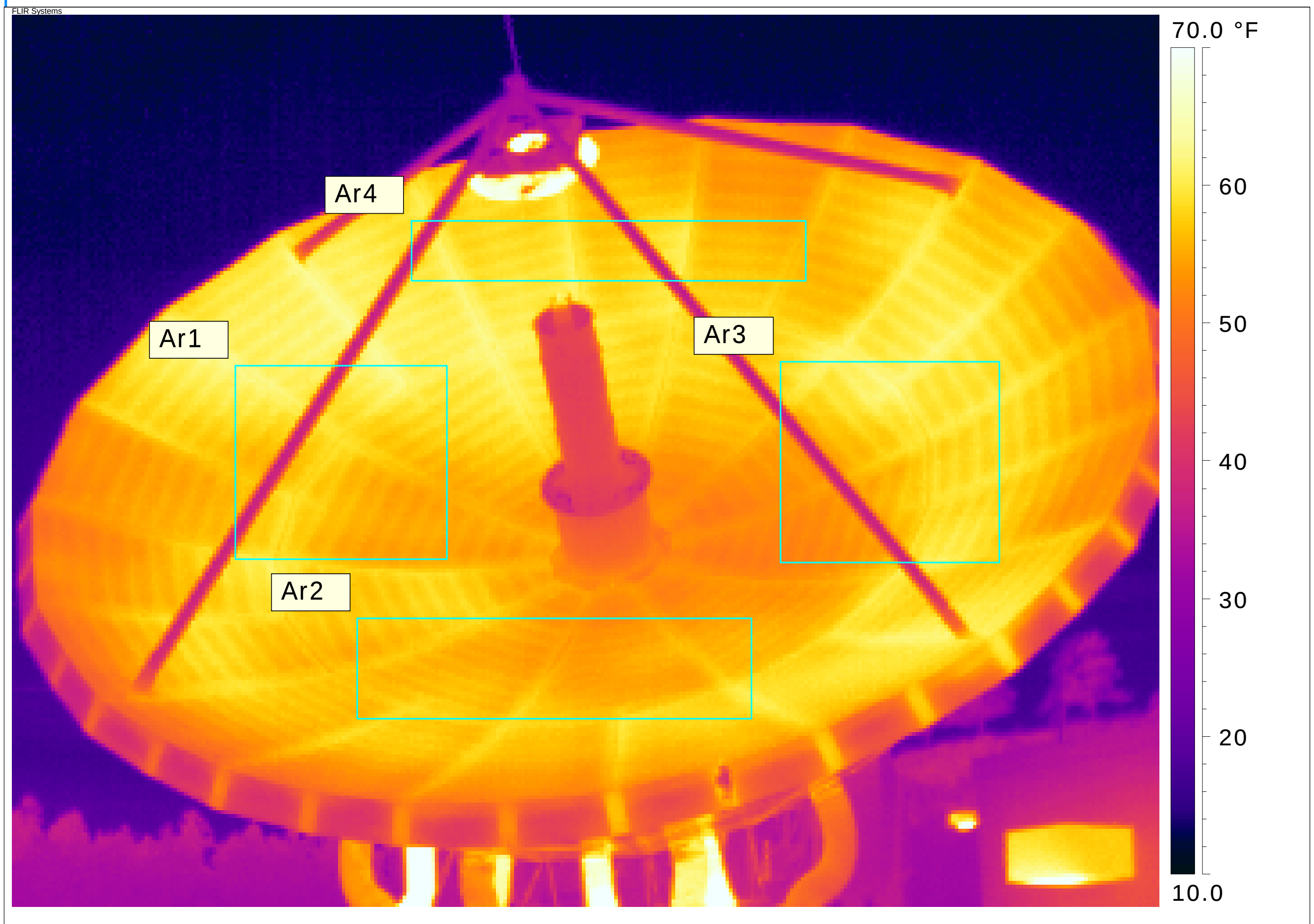
Infra Red Photo Measurements



After 2 Hours:

Object Parameter	**Value**
Emissivity	0.90
Atmospheric Temperature	34.0 °F
Label	**Value**
Ar1: Average	56.3 °F
Ar2: Average	55.8 °F
Ar3: Average	56.3 °F
Ar4: Average	56.7 °F

THANK YOU !

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