GENERAL DYNAMICS
Mission Systems

Hawaii Pacific Teleport

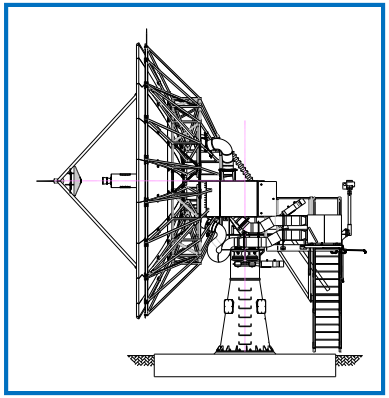
9.2m Ka-Band Gateway Antenna with IOT

Section 3

Microwave Subsystem

Antenna Microwave Subsystem

- 9.2m Antenna Specification Summary
- Antenna Configuration & Geometry
- Calculated Antenna Performance
- Ka-Band Feed Assembly & Components
- Ka-Band LNA Plate Assembly & Components
- Microwave Test Plan



9.2m Antenna Specification Summary

Parameter	Band	Specification	GD Mission Systems Compliance
Frequency Bands	Rx Tx Trk	18.400 – 19.200 GHz 27.500 – 29.200 GHz 19.2002 GHz	18.400 – 19.200 GHz 27.500 – 29.900 GHz 18.400 – 19.200 GHz
Figure-of-Merit (G/T) @ 20° El, Clear Sky	Rx	≥ 38.5 dBi/K	≥ 38.5 dBi/K
Antenna Gain (@ Feed Interface)	Rx Tx		≥ 62.3 dBi @ 18.400 GHz ≥ 62.5 dBi @ 18.800 GHz ≥ 62.7 dBi @ 19.200 GHz ≥ 65.4 dBi @ 27.500 GHz ≥ 65.8 dBi @ 29.200 GHz ≥ 66.0 dBi @ 29.900 GHz
Antenna Sidelobes Co-Pol (EESS Module 502)	Tx & Rx	29-25log(θ) dBi $1.0^\circ \le \theta \le 7.0^\circ$ +8.0 dBi $7.0^\circ \le \theta \le 9.2^\circ$ 32-25log(θ) dBi $9.2^\circ \le \theta \le 48.0^\circ$ -10 dBi $48.0^\circ \le \theta \le 180^\circ$	29-25log(θ) dBi $1.0^\circ \le \theta \le 7.0^\circ$ +8.0 dBi $7.0^\circ \le \theta \le 9.2^\circ$ 32-25log(θ) dBi $9.2^\circ \le \theta \le 48.0^\circ$ -10 dBi $48.0^\circ \le \theta \le 180^\circ$
Cross-Pol (EESS Module 502)	Tx & Rx	19-25log(θ) dBi $1.0^\circ \le \theta \le 7.0^\circ$ -2.0 dBi $7.0^\circ \le \theta \le 9.2^\circ$	19-25log(θ) dBi $1.0^\circ \le \theta \le 7.0^\circ$ -2.0 dBi $7.0^\circ \le \theta \le 9.2^\circ$
Polarization	Tx Rx Trk	Dual Circular (RHCP & LHCP) Dual Circular (RHCP & LHCP) RHCP or LHCP Selectable	Dual Circular (RHCP & LHCP) Dual Circular (RHCP & LHCP) RHCP or LHCP Selectable
Cross-Polarization Isolation	Tx Rx	≥ 30.7 dB [0.50 dB Axial Ratio] ≥ 30.7 dB [0.50 dB Axial Ratio]	≥ 30.7 dB [0.50 dB Axial Ratio] ≥ 30.7 dB [0.50 dB Axial Ratio]

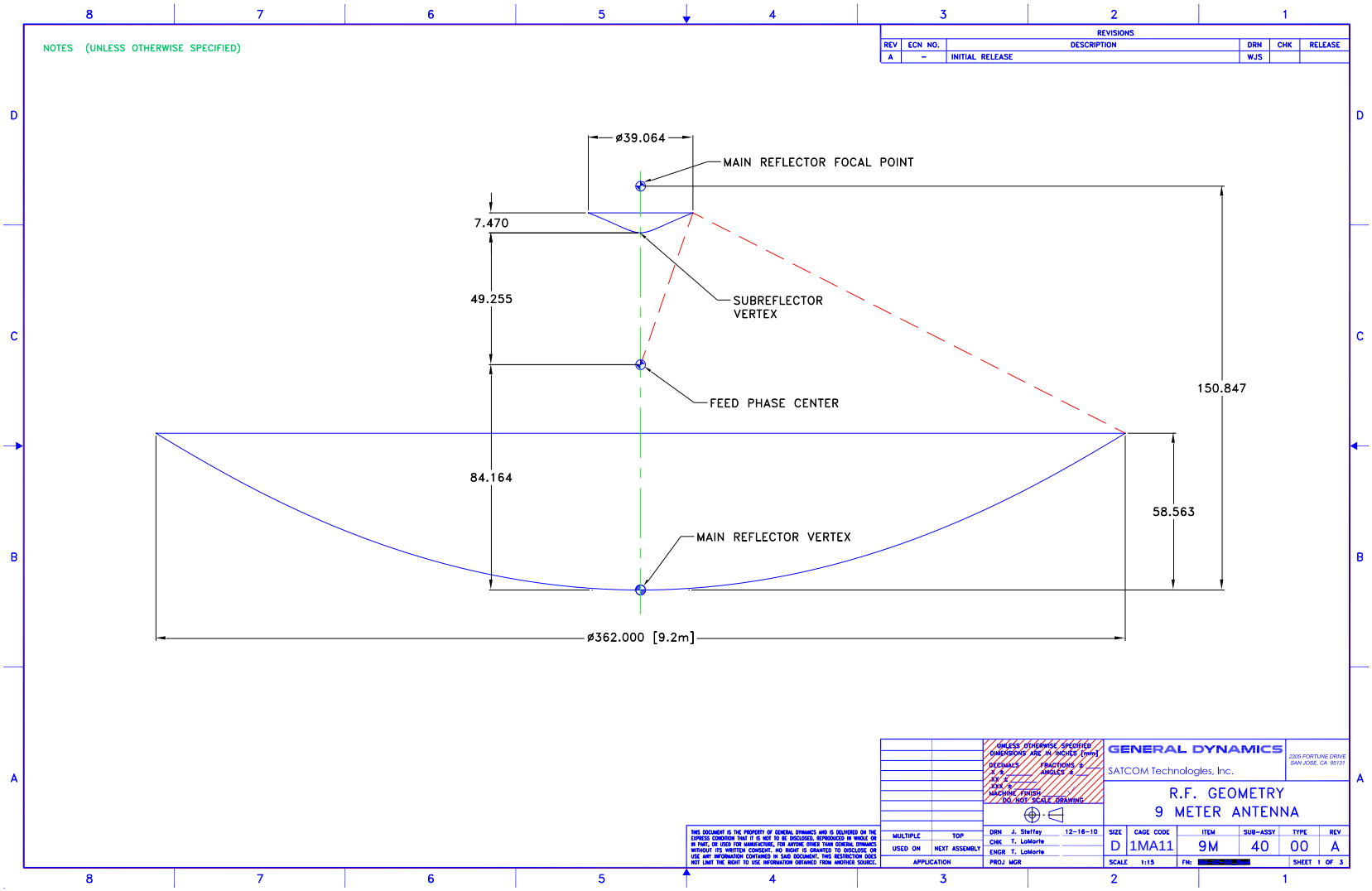
9.2m Antenna Specification Summary

Parameter	Band	Specification	GD Mission Systems Compliance
Port to Port Isolation			
	Tx to Rx	≥ 85 dB	≥ 85 dB
	Rx to Tx	≥ 85 dB	≥ 85 dB
	Rx to Rx	≥ 20 dB	≥ 20 dB
	Tx to Tx	≥ 20 dB	≥ 20 dB
	Tx to Trk		≥ 120 dB (Tx Band)
VSWR (Feed Interface)			
	Tx	1.30:1 maximum	1.30:1 maximum
	Rx	1.30:1 maximum	1.30:1 maximum
Power Rating			
	Tx		1 kW CW per port
Receive Test Inject Couplers			
Coupling	Rx	-50 dB	-50 ± 1.0 dB
Directivity	Rx		≥ 20 dB
Configuration	Rx	Dual Access	Dual Access WR-42 Crossguide
Injection Port	Rx	3.5mm Female (Coax to WG Adapter)	3.5mm Female (Coax to WG Adapter)
Monitor Port	Rx	3.5mm Female (Coax to WG Adapter)	3.5mm Female (Coax to WG Adapter)
Feed Waveguide			
	Tx		WR-34
	Rx		WR-42
Feed Interface Type			
Feed Transmit Port	Tx	WR-34	WR-34 Groove Flange (thru holes)
Feed Receive Port	Rx	WR-42	WR-42 Groove Flange (thru holes)
Feed Tracking Ports	Trk	WR-42	WR-42 Groove Flange (thru holes)
Pressurization			
Operational	Tx & Rx		0.5 psi
Maximum	Tx & Rx		2.0 psi
Leak Rate	Tx & Rx		< 10 SCF/day @ 0.5 psi

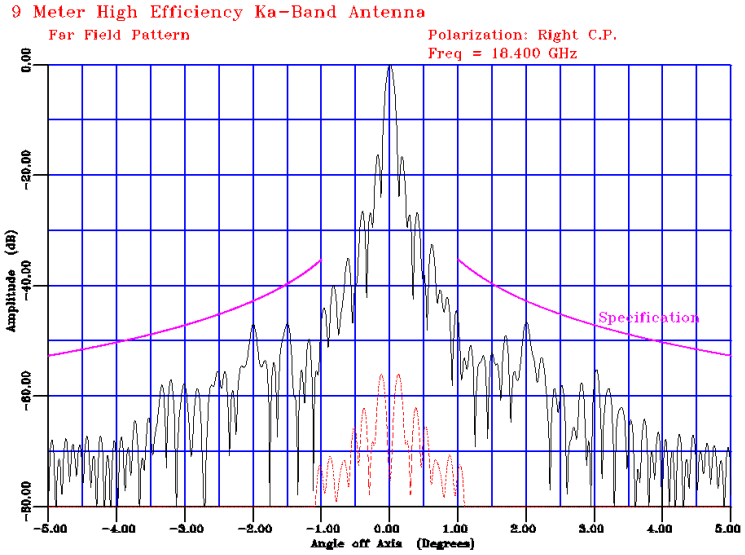
9.2m Reflector Design

- Designed for Low Sidelobes
  - EESS Module 502
    - 29-25 log(θ) dBi $1.0^o < \theta < 7.0^o$
    - +8.0 dBi $7.0^o < \theta < 9.2^o$
    - 32-25 log(θ) dBi $9.2^o < \theta < 48.0^o$
    - -10 dBi $48.0^o < \theta < 180.0^o$
- Designed for Ka-Band Operation
- Designed for Maximum Gain
- Designed for Low Noise Temperature

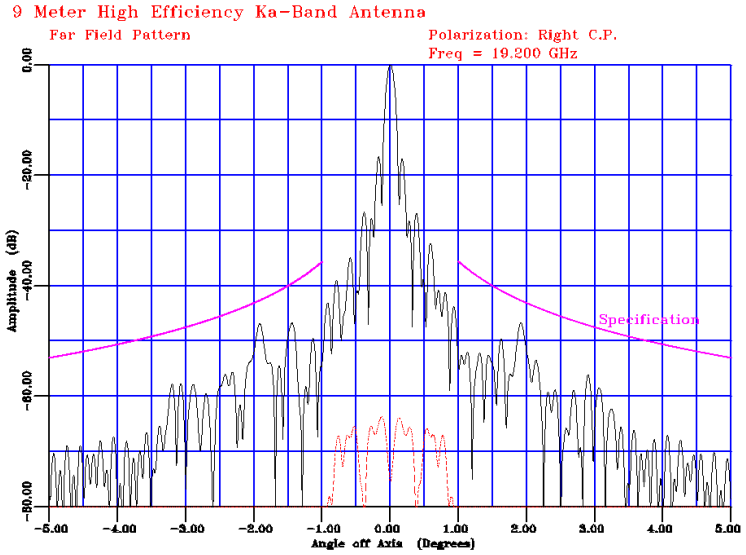
9.2m Antenna Geometry



Ka-Band Receive Main Beam Patterns

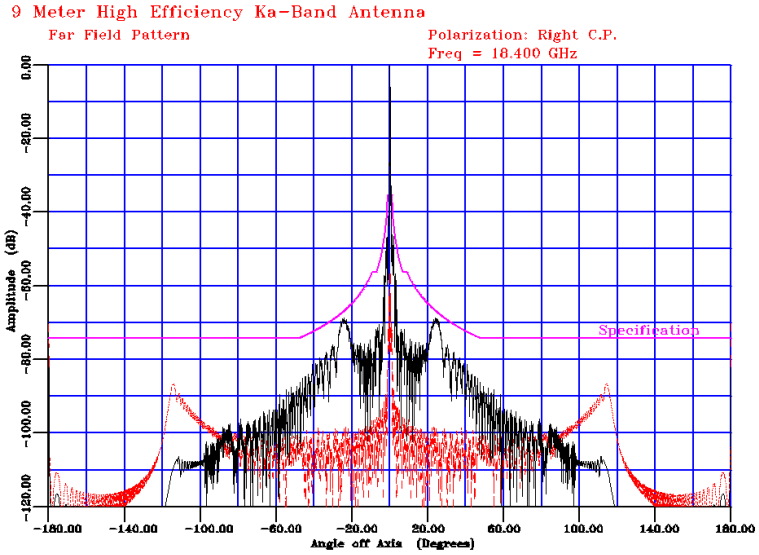


18.400 GHz

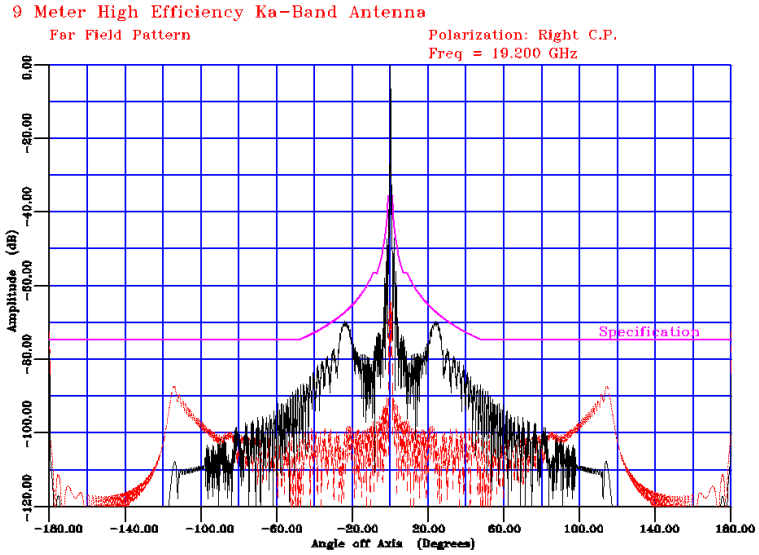


19.200 GHz

Ka-Band Receive Wide Angle Sidelobes

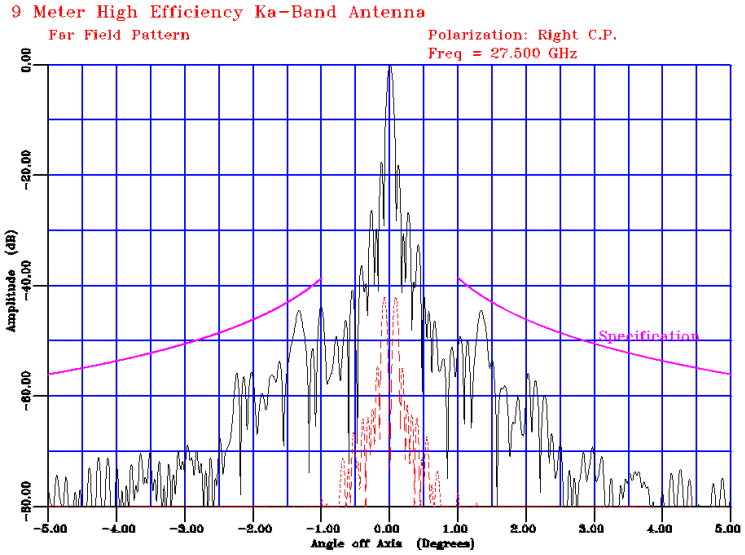


18.400 GHz

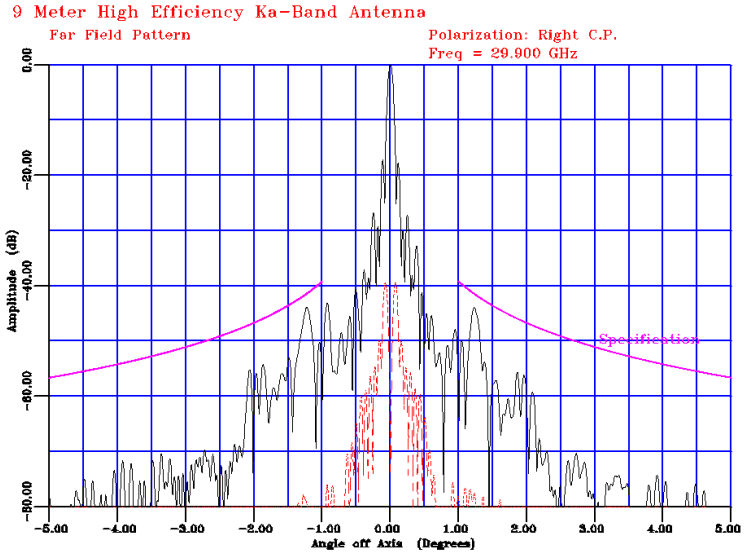


19.200 GHz

Ka-Band Transmit Main Beam Patterns

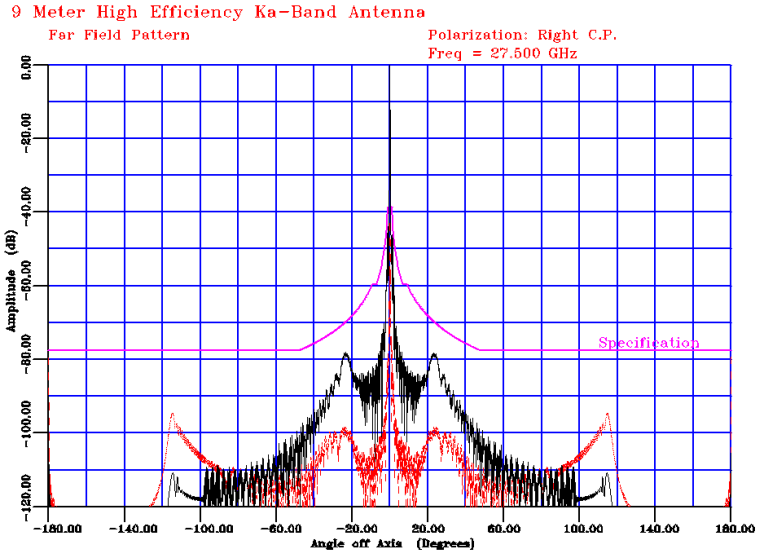


27.500 GHz

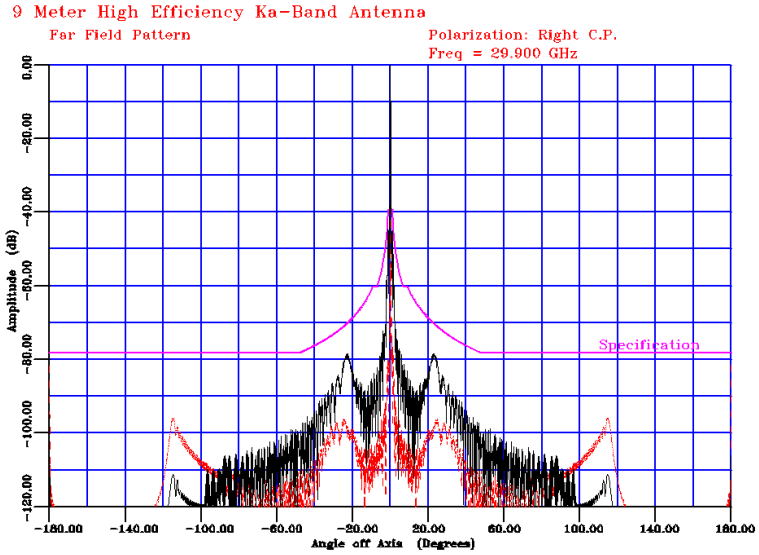


29.900 GHz

Ka-Band Transmit Wide Angle Sidelobes



27.500 GHz



29.900 GHz

Receive Gain & G/T Calculation

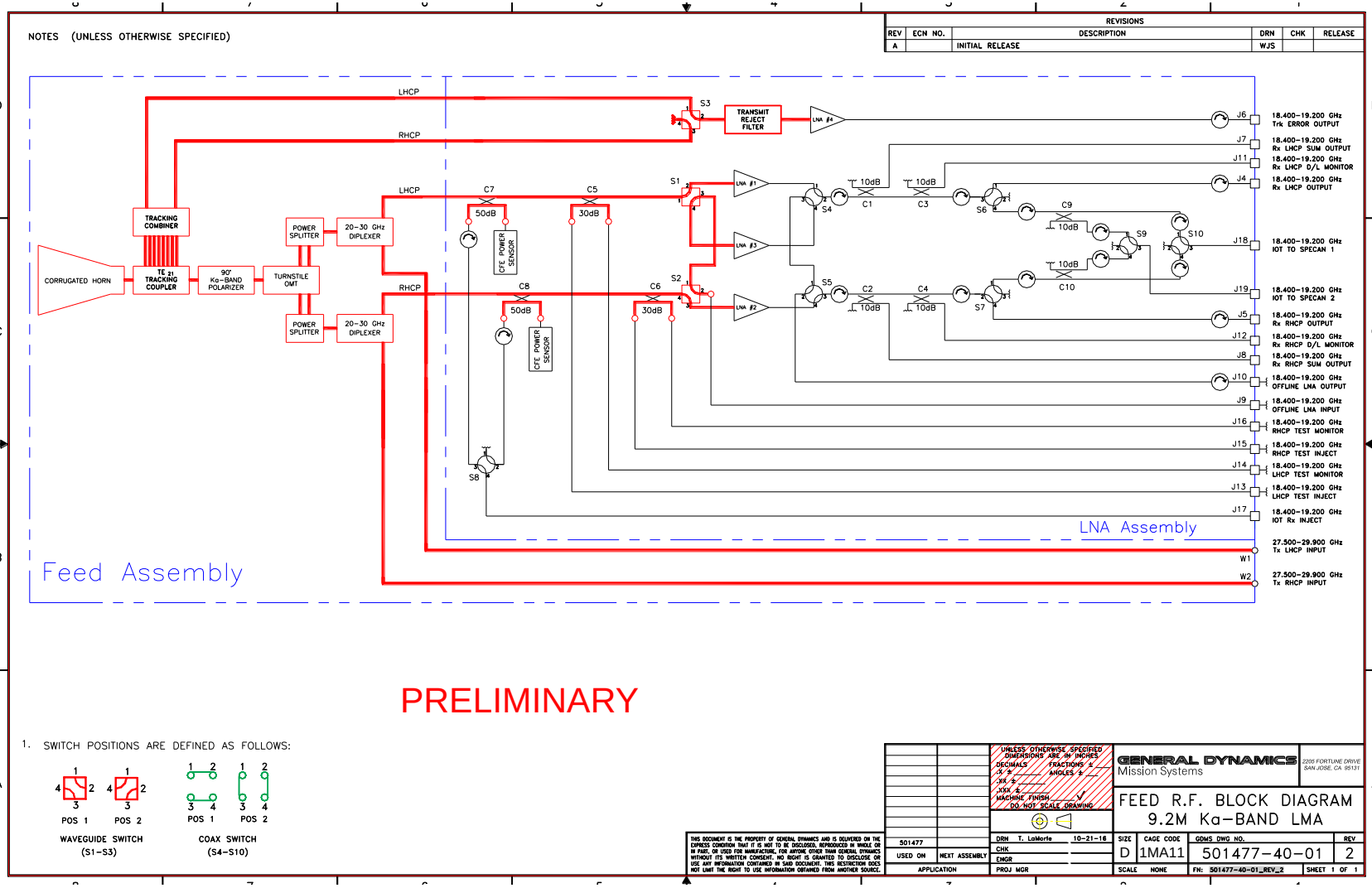
Main Reflector RMS = 0.011 Subreflector RMS = 0.003	Frequency					
	18.400 GHz		**18.800 GHz**		**19.200 GHz**	
Ideal Gain		64.97 dBi		65.16		65.34
	%		%		%	
Cross Polarization	0.998	-0.01 dB	0.998	-0.01 dB	0.998	-0.01 dB
Spillover	0.992	-0.03 dB	0.992	-0.03 dB	0.993	-0.03 dB
Diffraction	0.998	-0.01 dB	0.998	-0.01 dB	0.998	-0.01 dB
Aperture Illumination	0.926	-0.33 dB	0.922	-0.35 dB	0.919	-0.37 dB
Phase Error	0.946	-0.24 dB	0.950	-0.22 dB	0.955	-0.20 dB
Surface Error	0.951	-0.22 dB	0.949	-0.23 dB	0.947	-0.24 dB
Blockage	0.930	-0.32 dB	0.930	-0.32 dB	0.930	-0.32 dB
Overall Efficiency	0.766		0.764		0.765	
Calculated Gain at Feed Aperture		63.81 dBi		63.99 dBi		64.18 dBi
Feed Loss		-0.95 dB		-0.95 dB		-0.95 dB
Feed VSWR Loss 1.30:1		-0.07 dB		-0.07 dB		-0.07 dB
Calculated Antenna Gain (Feed Output)		62.79 dBi		62.97 dBi		63.15 dBi
Guaranteed Antenna Gain (Feed Output)		62.29 dBi		62.47 dBi		62.65 dBi
Margin		0.50 dB		0.50 dB		0.50 dB
Antenna Temperature (20 deg. el.)		29.70 K		33.40 K		37.70 K
Net Antenna Temperature		84.40 K		87.32 K		90.72 K
LNA System Noise Temperature		164.76 K		164.76 K		164.76 K
Calculated Antenna G/T @ 20 deg. El. (LNA Output)		38.83 dBi/K		38.95 dBi/K		39.08 dBi/K
Specified Antenna G/T @ 20 deg. El. (LNA Output)		38.50 dBi/K		38.50 dBi/K		38.50 dBi/K
Margin		0.33 dBi/K		0.45 dBi/K		0.58 dBi/K

Transmit Gain Calculation

Main Reflector RMS = 0.011 Subreflector RMS = 0.003	Frequency					
	27.500 GHz		**29.200 GHz**		**29.900 GHz**	
Ideal Gain		68.46 dBi		68.99		69.19
	%		%		%	
Cross Polarization	0.998	-0.01 dB	0.998	-0.01 dB	0.998	-0.01 dB
Spillover	0.997	-0.01 dB	0.998	-0.01 dB	0.998	-0.01 dB
Diffraction	0.998	-0.01 dB	0.998	-0.01 dB	0.998	-0.01 dB
Aperture Illumination	0.883	-0.54 dB	0.877	-0.57 dB	0.875	-0.58 dB
Phase Error	0.987	-0.06 dB	0.981	-0.08 dB	0.977	-0.10 dB
Surface Error	0.895	-0.48 dB	0.882	-0.55 dB	0.877	-0.57 dB
Blockage	0.930	-0.32 dB	0.930	-0.32 dB	0.930	-0.32 dB
Overall Efficiency	0.720		0.701		0.693	
Gain at Feed Aperture		67.04 dBi		67.45 dBi		67.60 dBi
Feed Loss		-1.05 dB		-1.05 dB		-1.05 dB
Feed VSWR Loss 1.30:1		-0.07 dB		-0.07 dB		-0.07 dB
Calculated Antenna Gain (Feed Output)		65.91 dBi		66.32 dBi		66.47 dBi
Guaranteed Antenna Gain (Feed Output)		65.41 dBi		65.82 dBi		65.97 dBi
Margin		0.50 dB		0.50 dB		0.50 dB

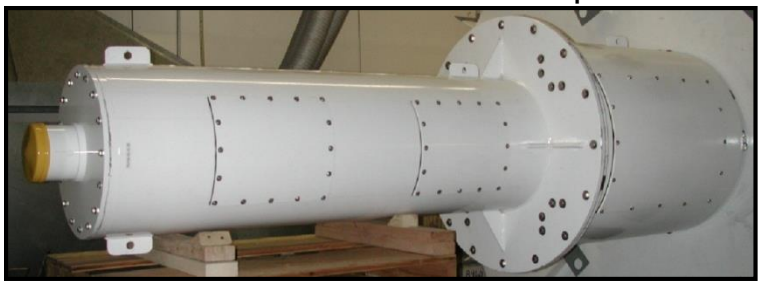
Ka-Band Feed Assembly

Ka-Band Feed R.F. Block Diagram



Ka-Band Feed Performance Summary

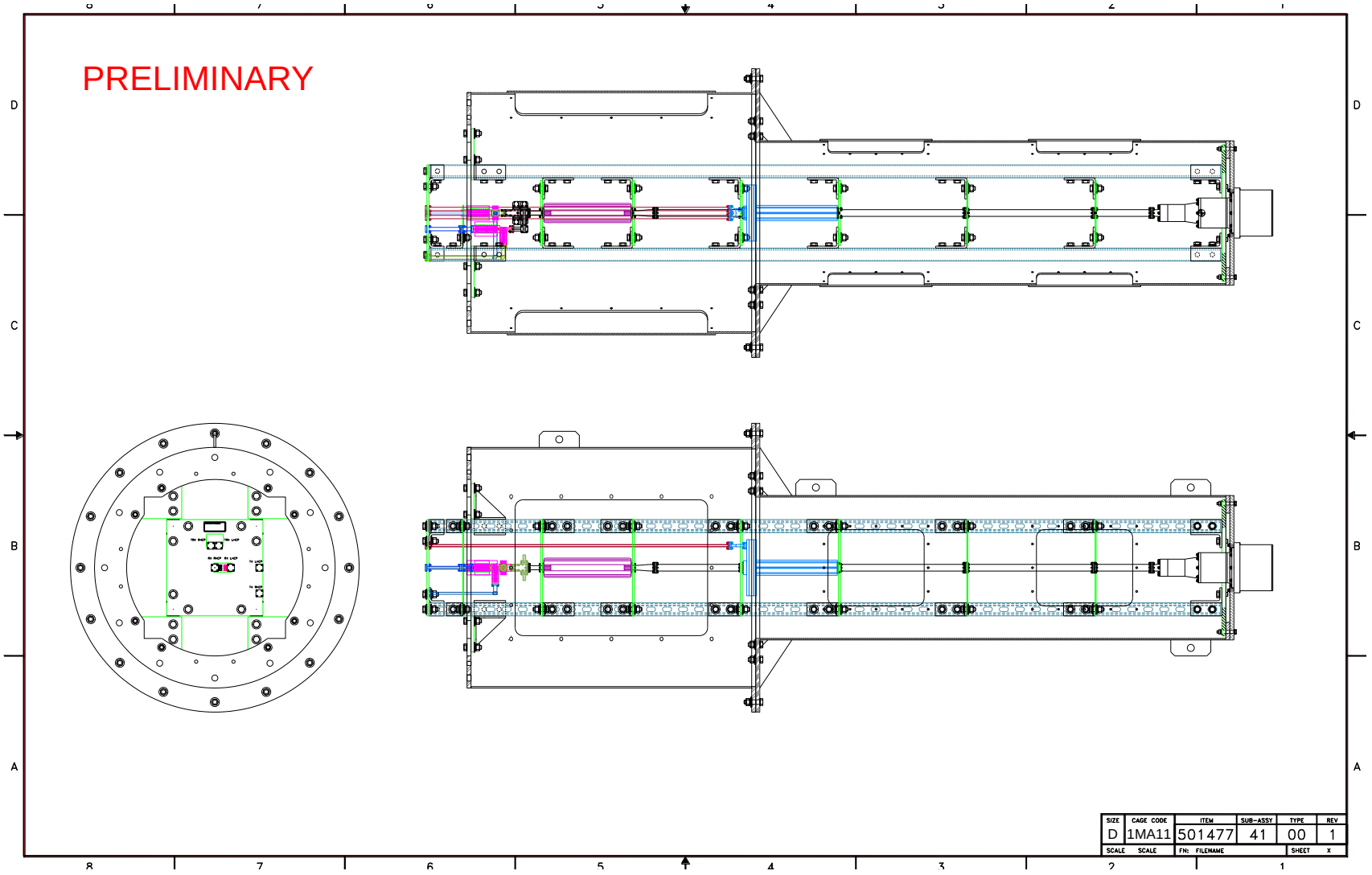
- Frequency Bands
  - Receive — 18.400 – 19.200 GHz
  - Transmit — 27.500 – 29.900 GHz
  - Tracking — 18.400 – 19.200 GHz
- Polarization
  - Transmit — Dual Circular (RHCP & LHCP)
  - Receive — Dual Circular (RHCP & LHCP)
- Cross-Polarization Isolation
  - Transmit — ≥ 30.7 dB [0.50 dB Axial Ratio]
  - Receive — ≥ 30.7 dB [0.50 dB Axial Ratio]
- Port-to-Port Isolation
  - Tx-Rx & Rx-Tx — ≥ 85 dB
  - Tx-Tx & Rx-Rx — ≥ 20 dB
- Tx Power — 1 KW per Port



9.2m Ka-Band Feed Assembly

Ka-Band Feed Assembly Layout

PRELIMINARY



SIZE	CAGE CODE	ITEM	SUB-ASSY	TYPE	REV
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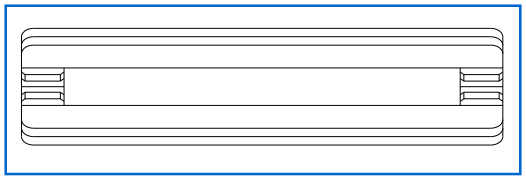
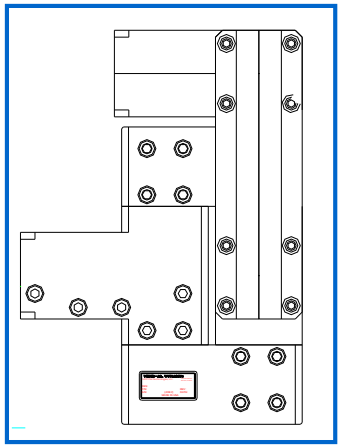
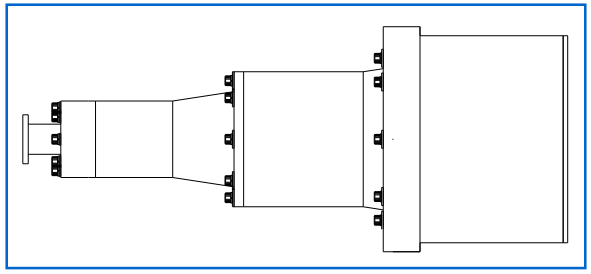
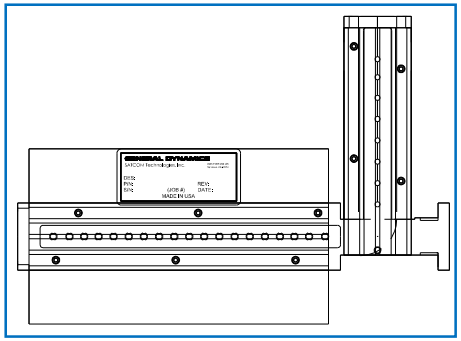
Ka-Band Feed Components

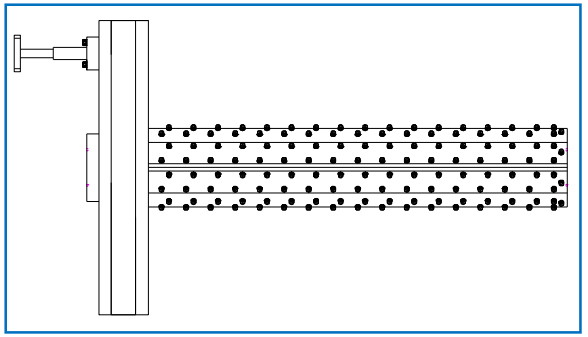
- Feed Horn Assembly
- TE_{21} Monopulse Tracking Coupler
- Phase Delay Circular Polarizer
- OMT Assembly
- Transmit / Receive Diplexer Assembly



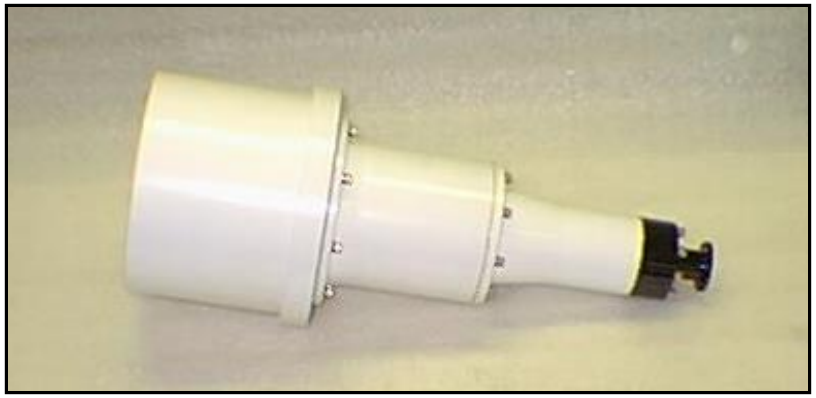


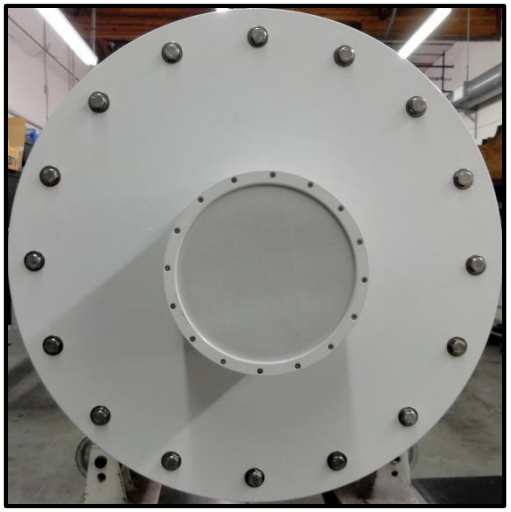






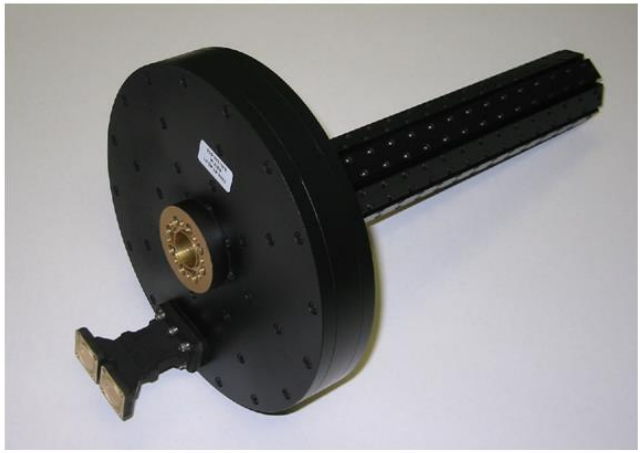
Feed Horn Assembly

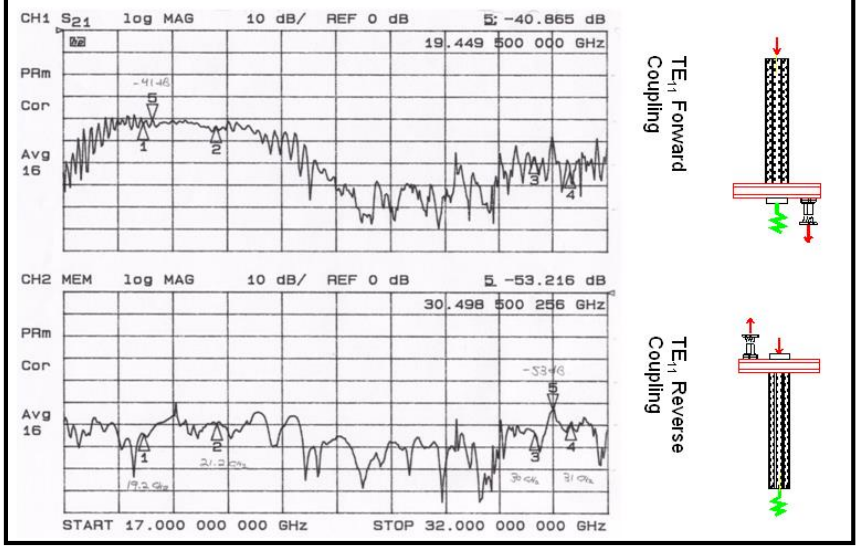




- Wideband Corrugated Feed Horn
- Corrugated Matching Section Integrated into the Horn Assembly
- Wide Operating Band 18.40 to 29.90 GHz
- Low VSWR Typically < 1.06:1 Over the Entire 18.40 to 29.90 GHz Band
- Flat Dielectric Radome Seals the Horn Aperture

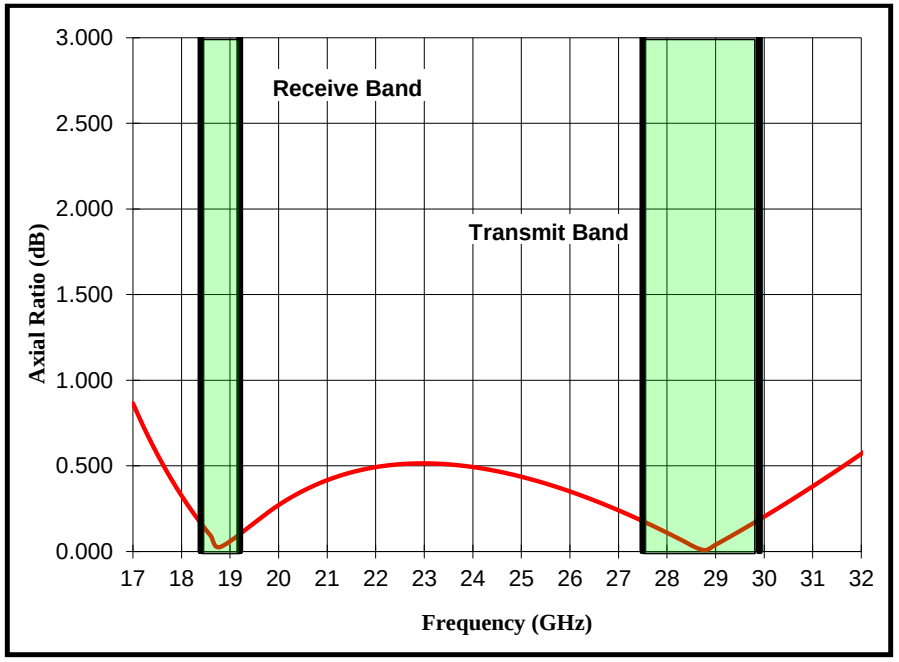
TE_{21} Monopulse Tracking Coupler





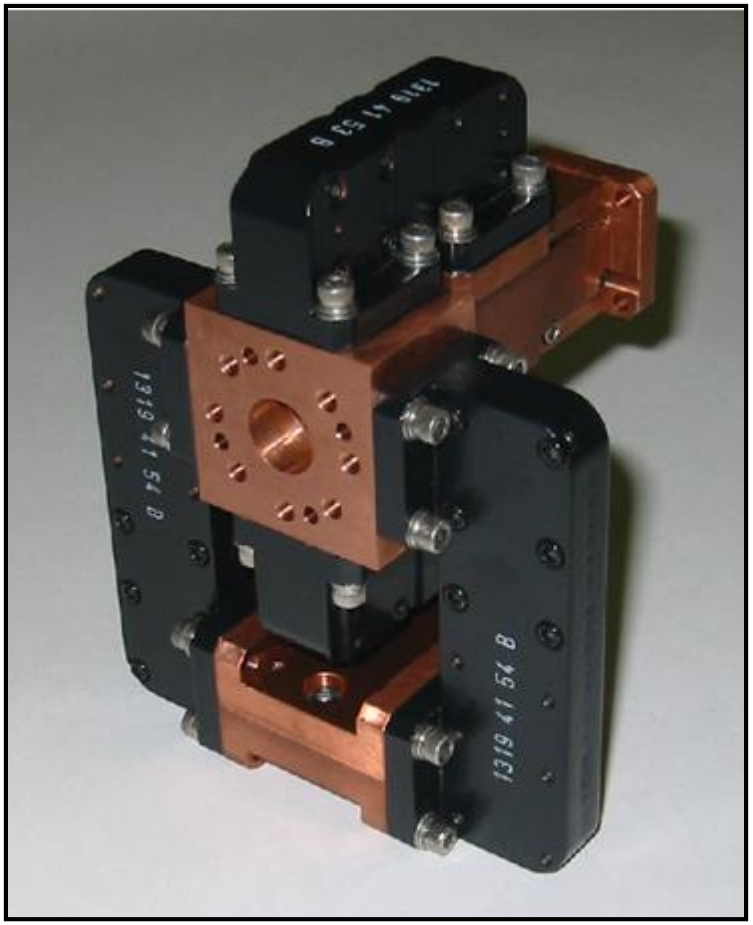
- Provides the Monopulse Error Channel Signal to the Tracking System
- Tracking Band 18.40 to 19.20 GHz
- Communications Channel Operating Band 18.40 to 29.90 GHz
- Tracking Channel VSWR < 2.00:1
- Communications Channel VSWR < 1.02:1
- Communications Channel Coupling
  - -40 dB or Better Rx Band
  - -50 dB or Better Tx Band

Phase Delay Circular Polarizer Assembly



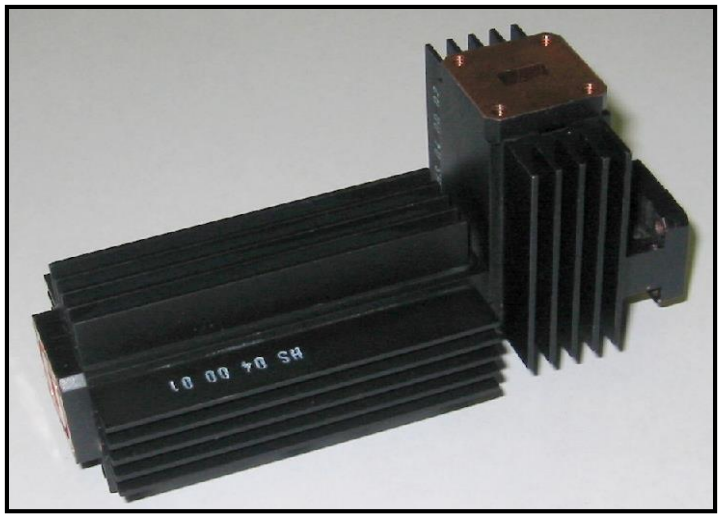
- Wideband Dual Crossover Design
- Generates Circular Polarization
- Reliable Phase Delay Design
- Rx Band 18.40 – 19.20 GHz
- Tx Band 27.50 – 29.90 GHz
- High Power Capability – No Tuning Screws

Ka-Band OMT Assembly



- Operating Band 18.40-29.90 GHz
- Separates Orthogonal Linear Field Components
- Consists of Turnstile, Two Power Dividers and Phase Matched Interconnect Waveguide
- Return Loss (VSWR)
  - Rx: >20 dB (<1.22:1)
  - Tx: >23 dB (<1.15:1)
- Power Handling
  - 1.0 KW per Port
  - 2.0 KW Total

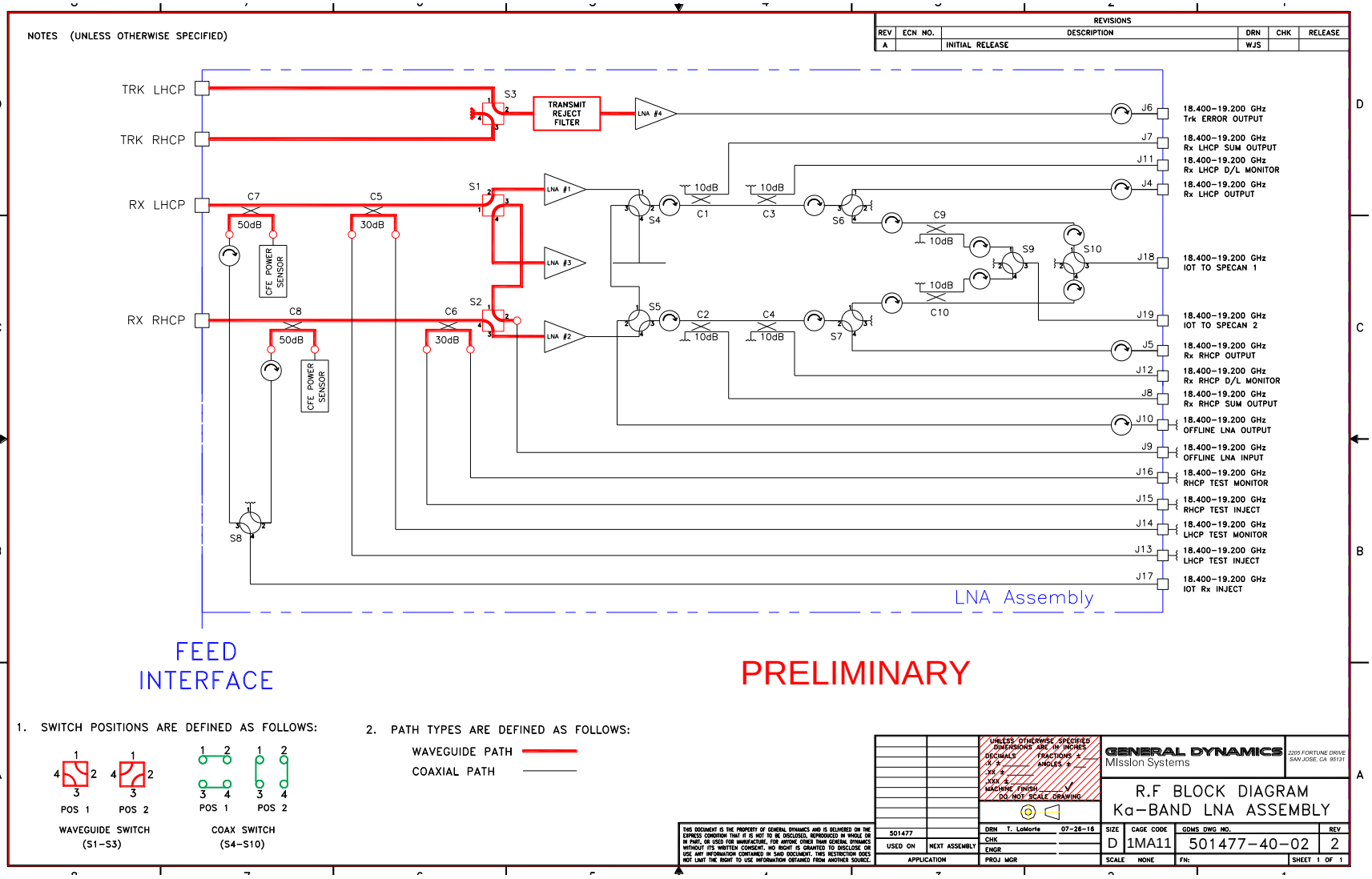
High Power Tx / Rx Diplexer Assembly



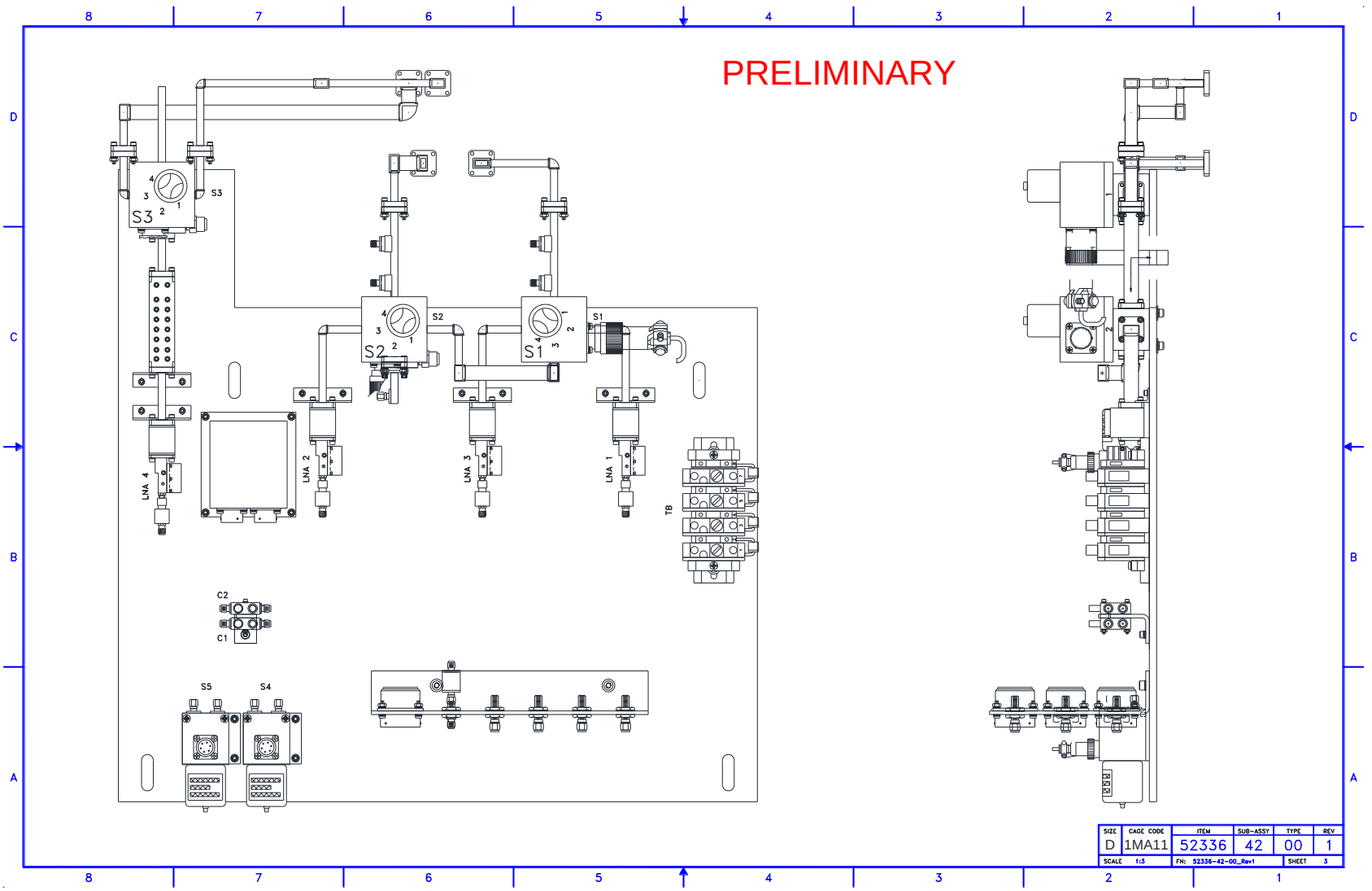
- Multi-Section, Iris-Coupled Waveguide Low-Pass / Band-Pass Tee Junction Diplexer
- Separates the Transmit and Receive Band Frequencies
- One Diplexer Per Polarization
- Return Loss > 26 dB Typical
- 85 dB Isolation Minimum
- Power Handling 1.0 KW
  - Solid Copper
  - Low Insertion Loss
  - Fin Cooling for Efficient Heat Dissipation

Low Noise Amplifier Assembly

LNA Subsystem R.F. Block Diagram



Typical 1 for 2 Ka-Band LNA Plate Layout



1 for 2 Ka-Band LNA Subsystem

LNA System Noise Temperature

LNA Noise Temperature =	120.00	K
LNA Gain =	50.00	dB
Post LNA NF =	0.00	dB
Post LNA Contribution =	0.00	K
L (Input Losses) =	1.109	
Net LNA System Temp =	164.76	K

LNA System Input Losses

Worst Case Shown - Redundant LNA Online

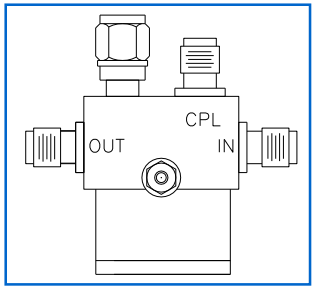
WR-42 Switch	0.10 dB
WR-42 Switch	0.10 dB
30 dB Coupler	0.05 dB
50 dB Coupler	0.05 dB
Waveguide	0.15 dB
Input Losses	0.45 dB

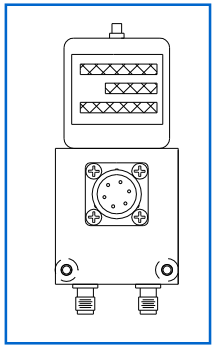
Ka-Band LNA Specifications

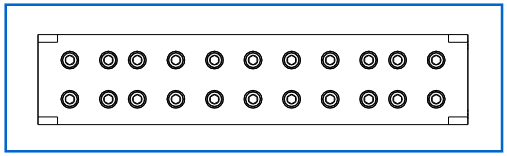
Parameter	Specification	GD Mission Systems Compliance
LNA Frequency Band	18.400 - 19.200 GHz	18.400 - 19.200 GHz
LNA Noise Temperature @ +25° C	120 K Maximum	120 K Maximum
LNA Gain @ +25° C	50 dB Minimum	50 dB Minimum 52 dB Maximum
LNA Gain Flatness Full Band Per 40 MHz		 ±0.50 dB Maximum ±0.20 dB Maximum
LNA Gain Stability (@ Constant Temp.) Per 24 Hours Per 7 Days Gain Change with Temperature	 0.20 dB pk-to-pk Maximum 0.50 dB pk-to-pk Maximum 0.50 dB pk-to-pk / ^{o} C Maximum	 0.20 dB pk-to-pk Maximum 0.50 dB pk-to-pk Maximum 0.50 dB pk-to-pk / ^{o} C Maximum
Group Delay (Per 40 MHz) Linear Parabolic Ripple		 0.010 ns/MHz Maximum 0.002 ns/MHz^{2} Maximum 0.20 ns peak-to-peak Maximum
AM-PM Conversion (@ -10 dBm Output)		0.03 ^{o}/dB Maximum
1dB Compression Point (Output)	+20 dBm Minimum	+20 dBm Minimum
3rd Order Intercept Point (Output)	+25 dBm Minimum	+25 dBm Minimum
Input Overdrive Protection		0 dBm CW input at any frequency with no permanent degradation of amplifier performance.
LNA VSWR Input Output	 1.25:1 Maximum 1.30:1 Maximum	 1.25:1 Maximum 1.30:1 Maximum
LNA Interfaces RF Input RF Output		 WR-42 Cover Flange Precision SMA Female
Power Requirements		+15 Vdc @ 450 mA Maximum
LNA Pressurization		0.5 psig dry air Operational 2.0 psig dry air Maximum

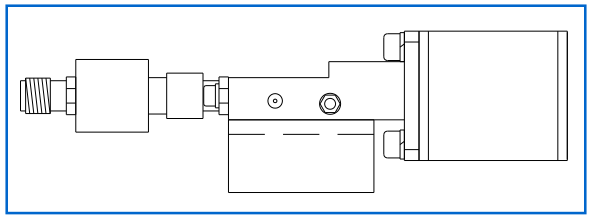
Ka-Band LNA Plate Components

- Low Noise Amplifiers
- Rx Inject/Monitor Waveguide Couplers
- WR-42 Waveguide Transfer Switches
- Coaxial Transfer Switches
- Sum Channel Sample Couplers
- Transmit-Reject Filter



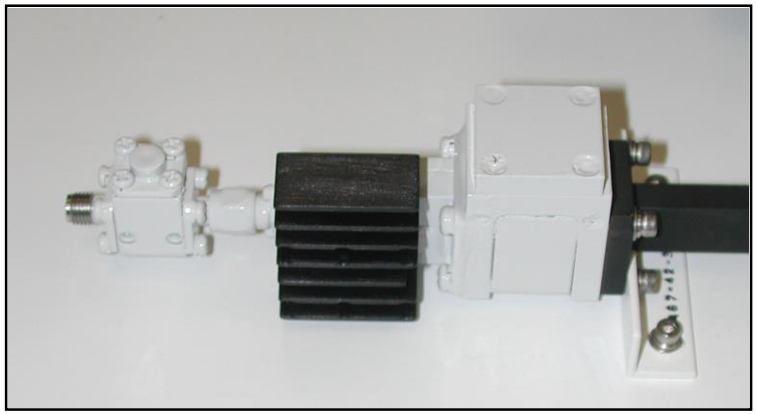






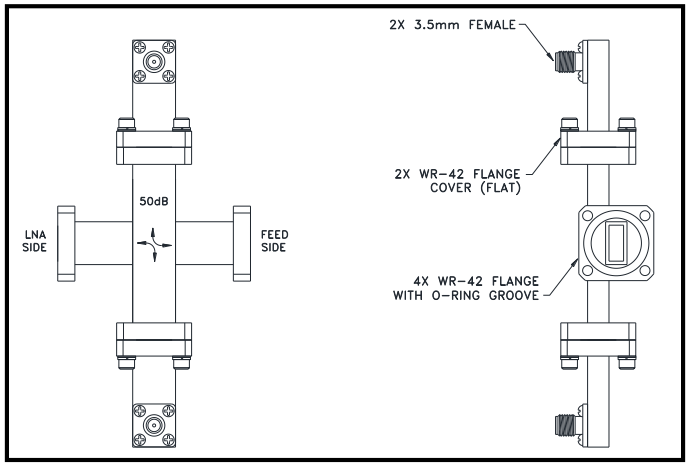
Low Noise Amplifiers (LNA1-LNA4)

- Frequency Band: 18.40 to 19.20 GHz
- Gain (@ +25˚C): 50 to 52 dB
- Noise Temperature (@ +25˚C): ≤ 120K
- Output Power @ 1 dB Comp. Pt. +20 dBm Minimum



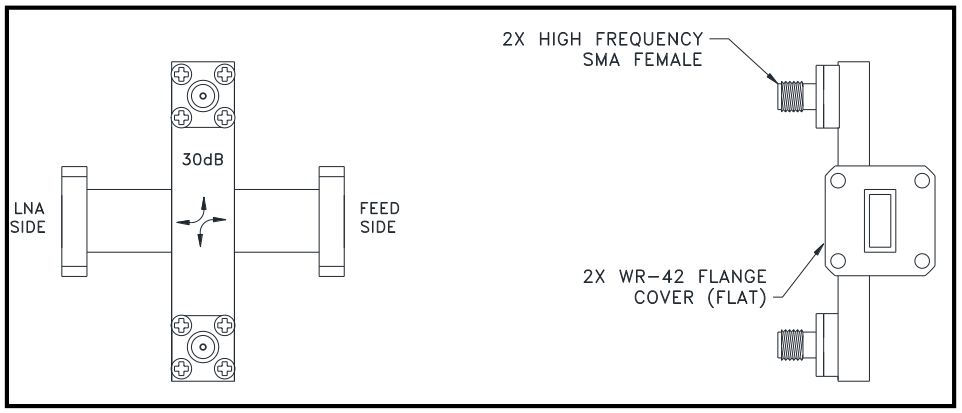
IOT Inject/Monitor Waveguide Couplers (C7,C8)

- Frequency Band: 18.40 - 19.20 GHz
- Coupling: -50 dB ± 1.0 dB
- Coupling Flatness: ≤ ±0.2 dB
- Directivity: ≥ 20 dB
- VSWR (Mainline / Coupled Ports): ≤ 1:07:1 / ≤ 1.25:1
- Calibration: 50 MHz intervals (18.40-19.20 GHz)
- Calibration Accuracy: ± 0.2 dB @ 50 MHz Intervals
- Coupled Port Interfaces: 3.5mm Female via Coax/WG adapters
- Configuration: WR-42 Crossguide (dual access)
- Purpose: Provides pre-LNA injection/monitor of test signals. Coupled ports extended, via semi-rigid and coax switch *(S8)*, to the LNA plate bulkhead.



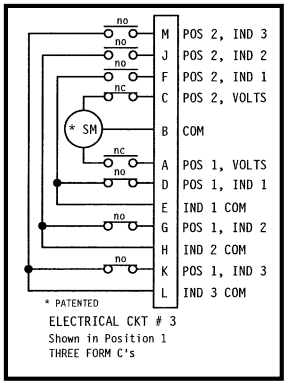
Rx Inject/Monitor Waveguide Couplers (C5,C6)

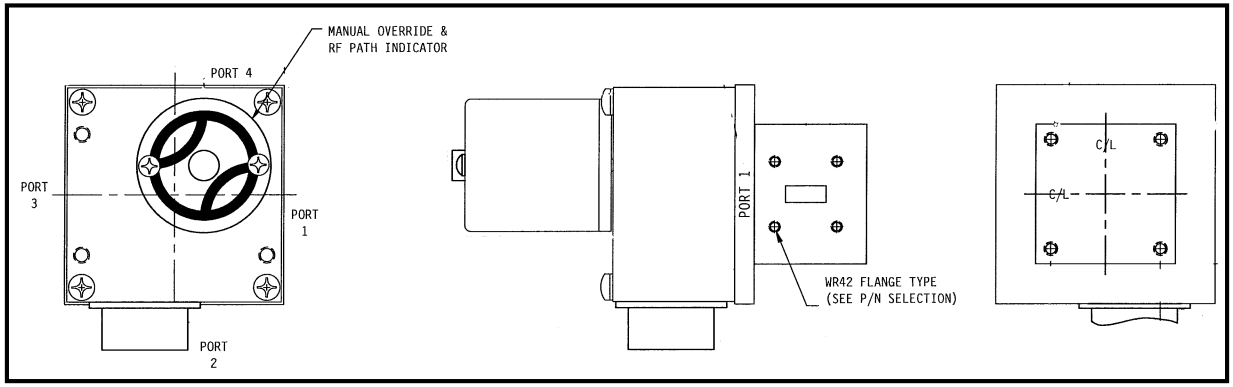
- Frequency Band: 18.40 - 19.20 GHz
- Coupling: -30 dB ± 1.0 dB
- Coupling Flatness: ≤ ±0.2 dB
- Directivity: ≥ 20 dB
- VSWR (Mainline / Coupled Ports): ≤ 1:07:1 / ≤ 1.25:1
- Calibration: 50 MHz intervals (18.40-19.20 GHz)
- Calibration Accuracy: ± 0.2 dB @ 50 MHz Intervals
- Coupled Port Interfaces: High Frequency SMA Female
- Configuration: WR-42 Crossguide (dual access)
- Purpose: Provides pre-LNA injection/monitor of test signals. Coupled ports extended, via semi-rigid, to the LNA plate bulkhead.



WR-42 Waveguide Transfer Switches (S1-S3)

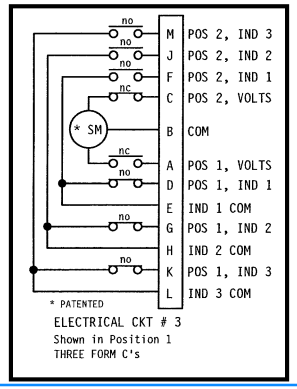
- Frequency Band: 18.40 - 19.20 GHz
- VSWR: ≤ 1.10:1
- Insertion Loss: ≤ 0.10 dB
- Isolation: ≥ 60 dB
- Switching Time: 50 mSec Typical
- Voltage: -28 Vdc Nominal
- Purpose: Provides switching between LNA's *(S1,S2)* for redundancy and between tracking polarizations *(S3).*

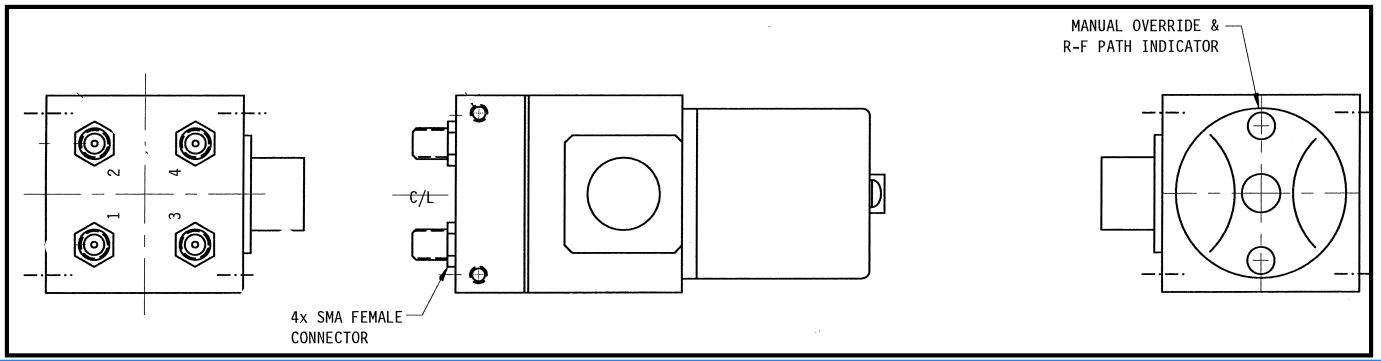




Coaxial Transfer Switches (S4-S10)

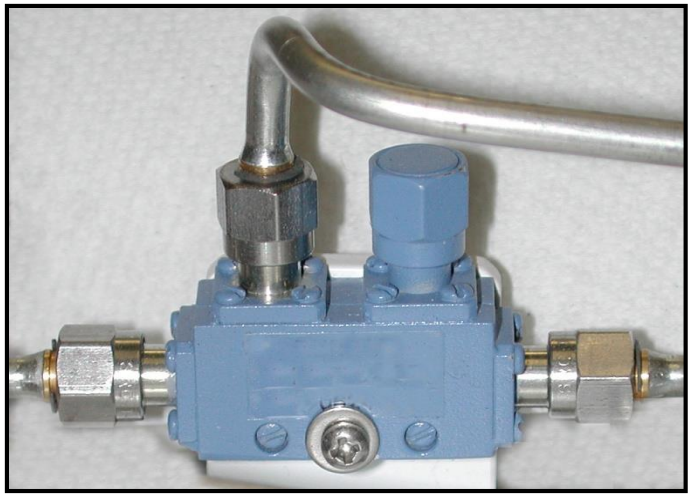
- Frequency Band: 18.40 - 19.20 GHz
- VSWR: ≤ 1.50:1
- Insertion Loss: ≤ 0.50 dB
- Isolation: ≥ 60 dB
- Switching Time: 50 mSec Typical
- Voltage: -28 Vdc Nominal *(S4,S5)*
  +28 Vdc Nominal *(S6-S10)*
- Purpose: Provides switching between LNA's for redundancy *(S4,S5)* and IOT functionality *(S6-S10).*





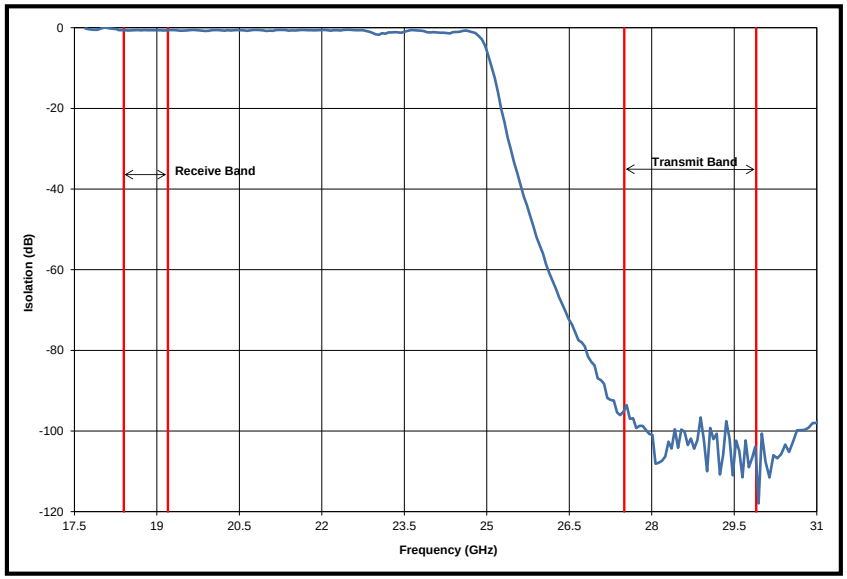
Coaxial Sample Couplers (C1-C4,C9,C10)

- Frequency Band: 18.40 - 19.20 GHz
- Coupling: -10.0 dB ± 1.0 dB
- Coupling Flatness: ≤ ± 0.7 dB
- Directivity: ≥ 15 dB
- Insertion Loss: ≤ 0.8 dB
- VSWR: ≤ 1.40:1
- Interface: High Frequency SMA Female
- Purpose: Provides downlink monitor *(C3,C4)*, IOT functionality *(C9,C10)* and tracking reference signal to the Monopulse tracking system *(C1,C2).*

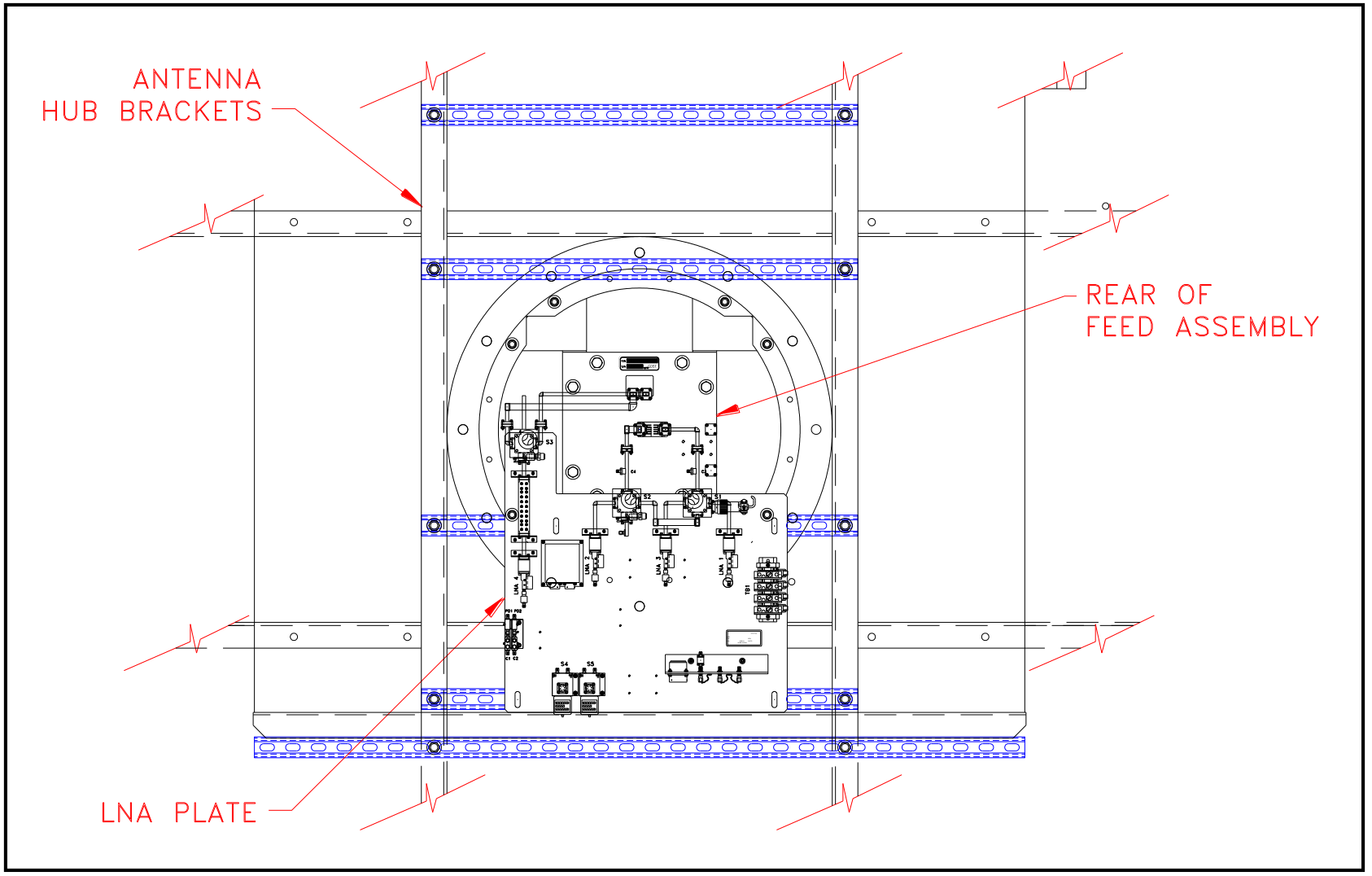


Transmit-Reject Filter

- Passband: 18.40 - 19.20 GHz
- Reject band: 27.50 – 29.90 GHz
- Insertion Loss: < 0.2 dB Typical
- VSWR: ≤ 1.20:1 Typical
- Isolation: ≥ 90 dB Typical
- Configuration: Multi-Section Iris-Coupled Low-Pass Filter.
- Purpose: Rejects TX frequencies in the TRK Channel prior to signal amplification.
- Location: Between the TE_{21} Tracking Coupler and Tracking LNA.



Typical LNA Plate Layout in Hub



Microwave Test Plan

Microwave Test Plan

- **In-Plant Tests (2 Test Procedures)**
  - Feed Assembly R.F. Acceptance Tests
  - LNA Assembly R.F. Acceptance Tests
- **On-Site Tests (1 Test Procedure)**
  - Microwave System Tests

Feed Assembly R.F. Acceptance Tests

- Return Loss (VSWR)
- Axial Ratio
- Insertion Loss
- Port-to-Port Isolation
- Transmit-to-Receive Isolation
- Primary Radiation Patterns
- Air Leak Rate

LNA Assembly R.F. Acceptance Tests

- Return Loss (VSWR)
- Gain
- Noise Temperature

Microwave System Tests

- Antenna System Noise Temperature
- G/T (Figure of Merit)*
- Antenna Transmit & Receive Gain*
- Axial Ratio*
  - *(based on in-plant test data)*
- Secondary Antenna Radiation Patterns*
- Power Handling Capability

** Testing of these parameters requires the availability of a Ka-Band Satellite and Cooperating Station.*