RF Optics Design

Bill Imbriale, ***Jet Propulsion Laboratory, California Institute of Technology***
Roney Abraham, ***Jet Propulsion Laboratory, California Institute of Technology***

DSN LARGE ARRAY - Microwave Subsystem

RF Optics Design

- **Original Design by Vahraz Jamnejad was for maximum G, not G/T**
  - ~ 2.5 db/°K below optimum at 8.4 GHz
- **Reflector Profile from this design given to Anderson for manufacture**
- **Subreflector and Feed location was redesigned to produce a maximum G/T design**

Dual Reflector Shaping

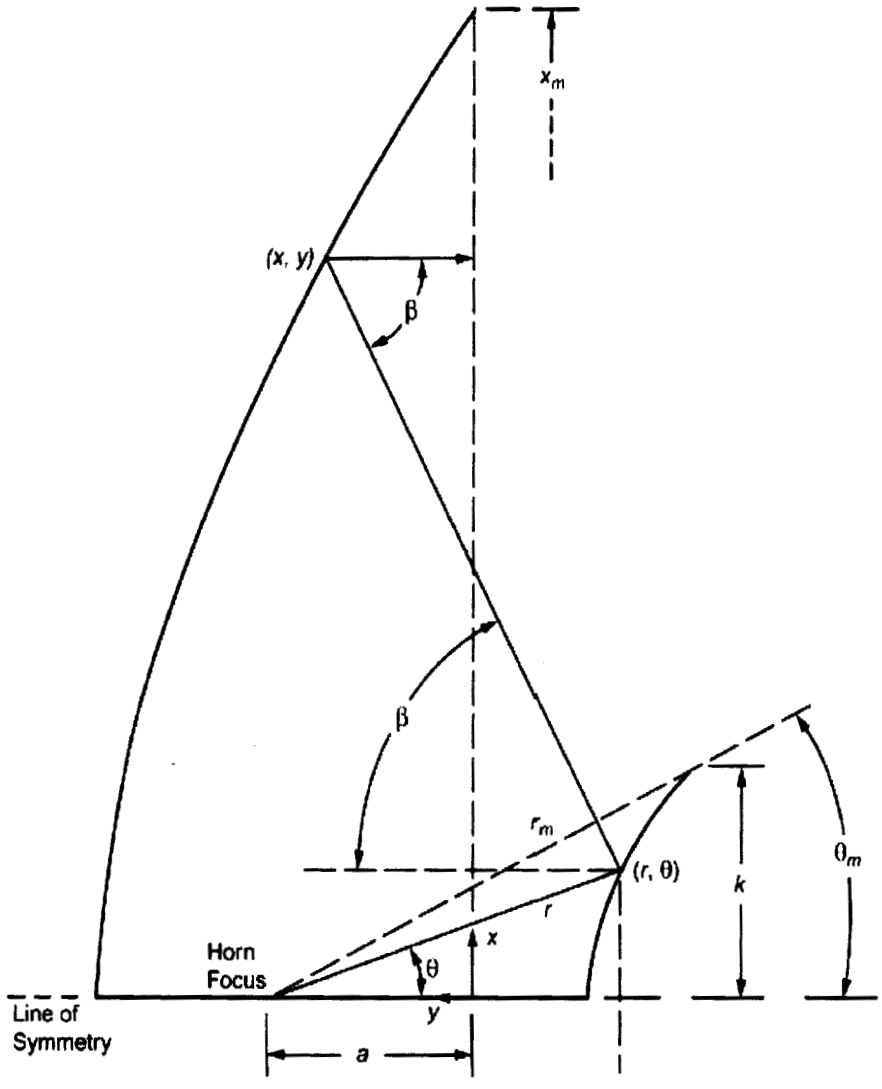
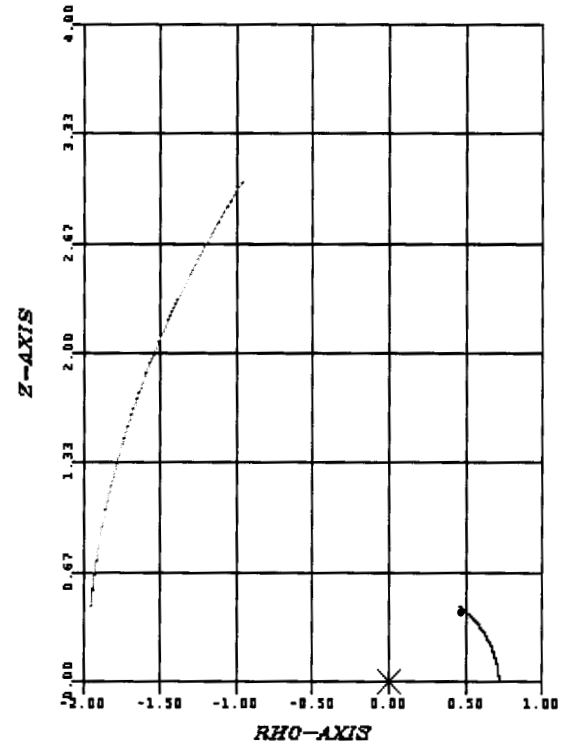
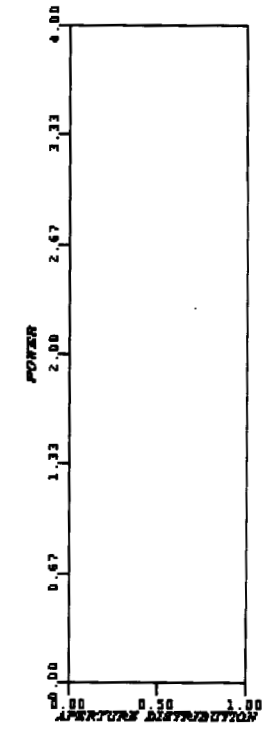


Fig. 1-11. Coordinate system for shaping.





DSN LARGE ARRAY - Microwave Subsystem

Optimum G/T design tradeoff

40 Degrees

Radius (m)	Gain (dB)	T (K)	G/T (@15)
3.048	53.589	16.032	38.671
2.975	53.606	11.544	39.366
2.9	53.568	8.088	39.934
2.8	53.419	5.016	40.405
2.7	53.176	3.168	40.583
2.6	52.851	2.112	40.518

45 Degrees

Radius (m)	Gain (dB)	T (K)	G/T (@15)
3.048	53.818	19.128	38.487
3	53.852	15.192	39.053
2.9	53.817	9	40.015
2.8	53.646	5.16	40.601
2.7	53.365	2.976	40.818
2.6	52.998	1.776	40.751
2.5	52.583	1.176	40.494

[redacted]

50 Degrees

Radius (m)	Gain (dB)	T (K)	G/T (@15)
3.048	53.94	22.896	38.154
2.975	54.002	15.816	39.114
2.9	53.963	10.248	39.941
2.8	53.755	5.448	40.648
2.7	53.419	2.808	40.913
2.6	53.025	1.512	40.847

55 Degrees

Radius (m)	Gain (dB)	T (K)	G/T (@15)
3.048	53.994	26.712	37.791
2.975	54.079	18.6	38.816
2.9	54.031	11.88	39.737
2.8	53.772	5.88	40.575
2.7	53.382	2.736	40.893
2.6	52.96	1.272	40.846

[redacted]

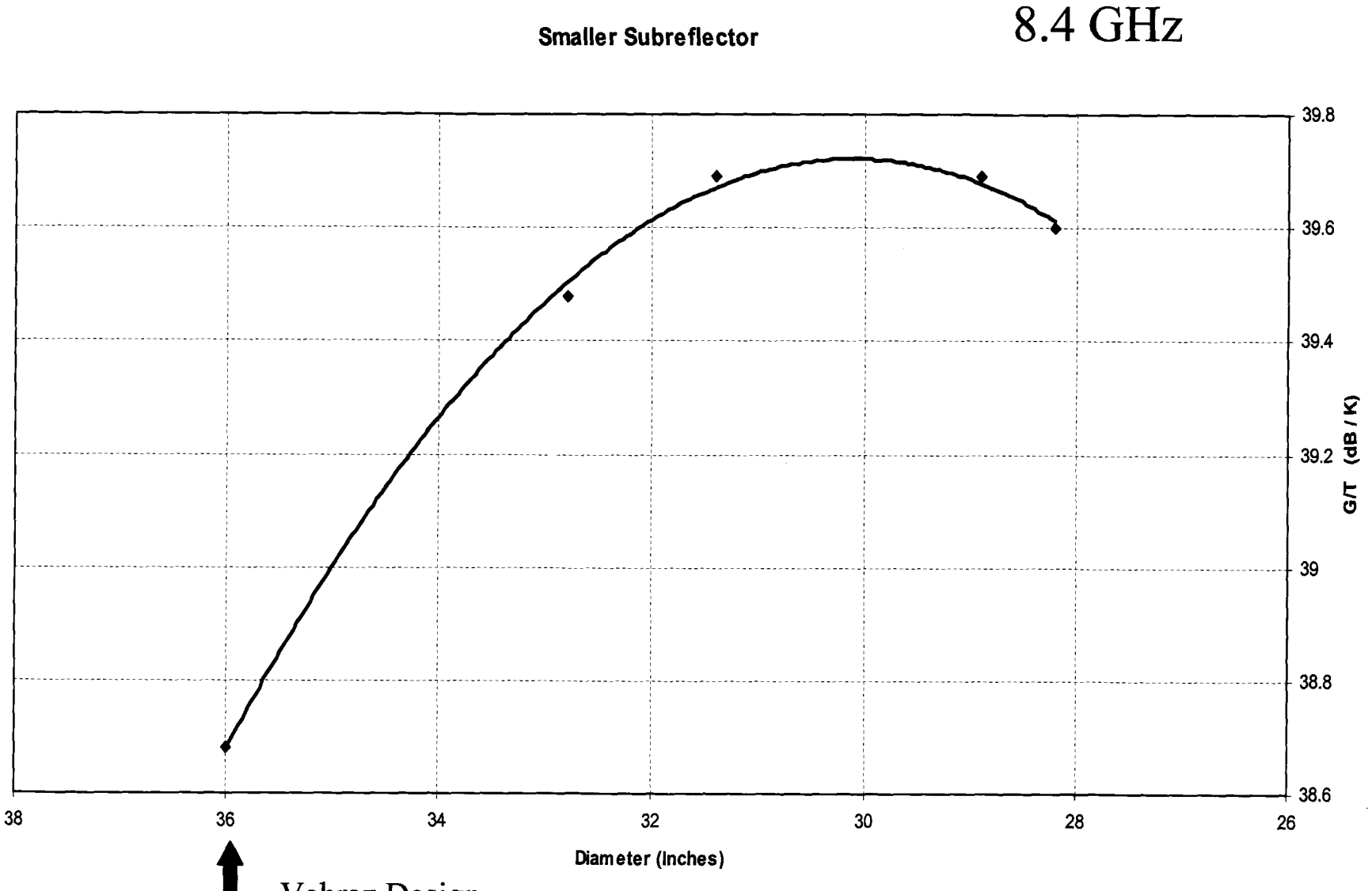
60 Degrees

Radius (m)	Gain (dB)	T (K)	G/T (@15)
3.048	54.01	29.88	37.489
2.975	54.111	21.336	38.508
2.9	54.045	13.704	39.466
2.8	53.722	6.504	40.397
2.7	53.28	2.712	40.797
2.6	52.852	1.128	40.776

8.4 GHz

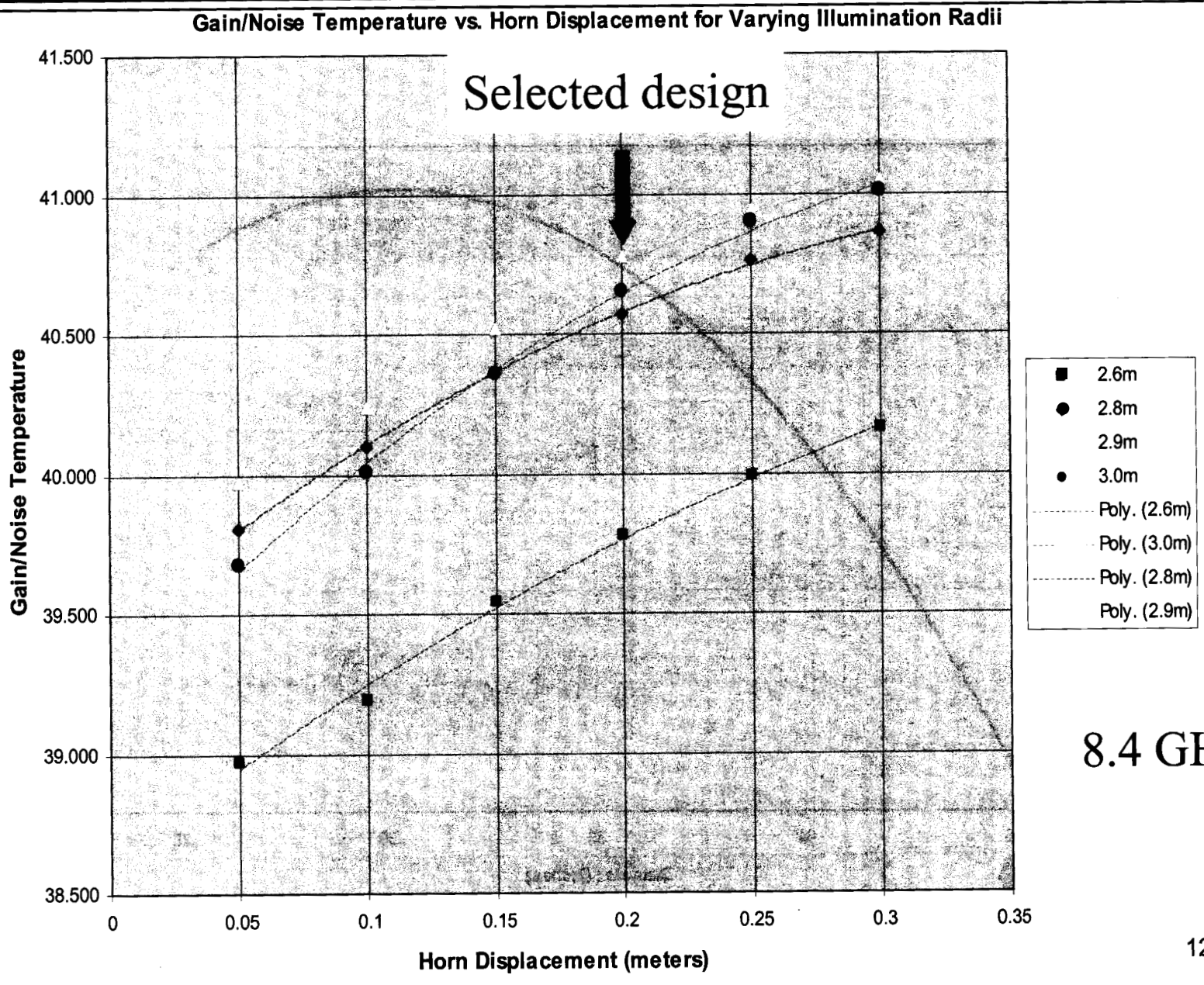
DSN LARGE ARRAY - Microwave Subsystem

Smaller Subreflector



DSN LARGE ARRAY - Microwave Subsystem

Variable Illumination and Feed Movement



8.4 GHz

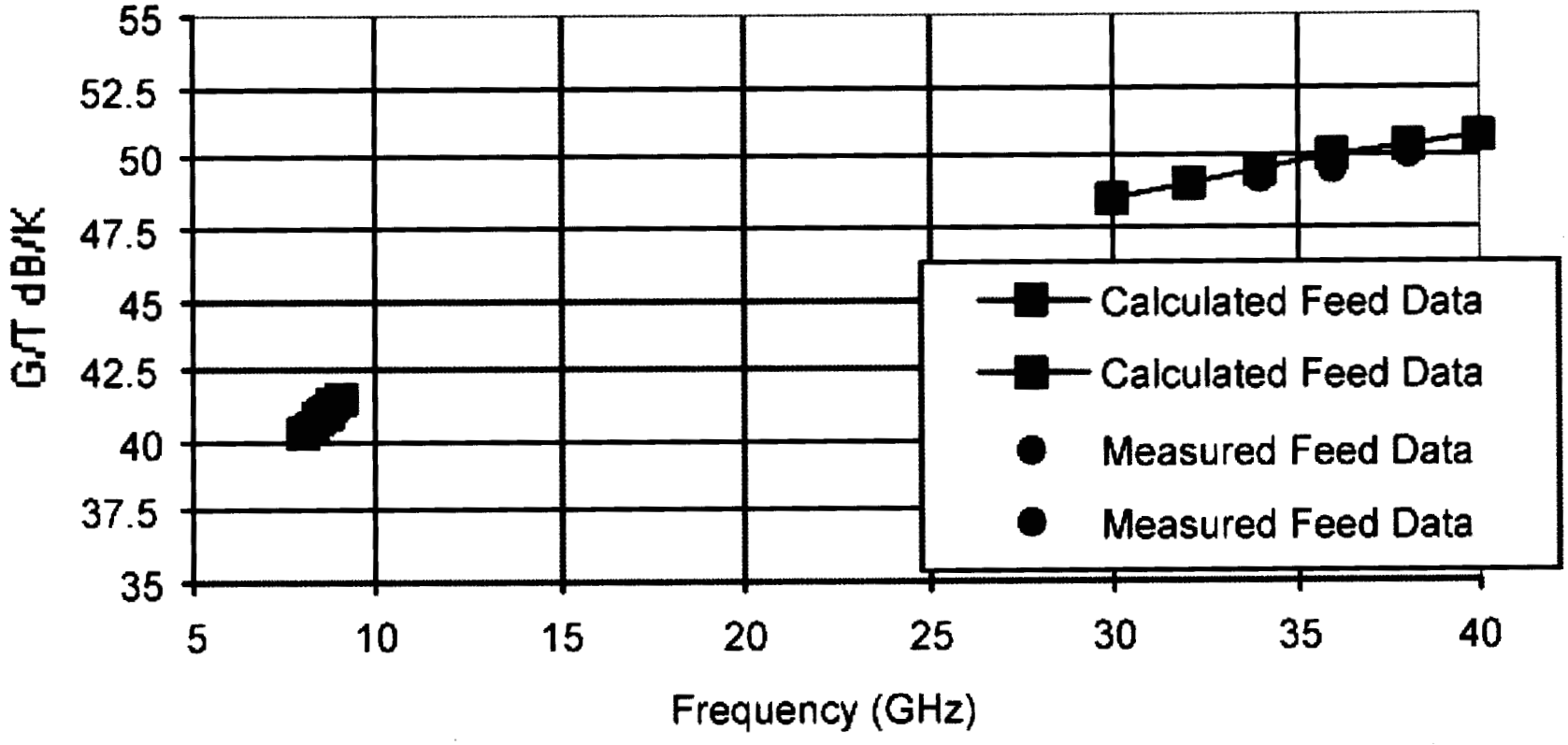
DSN LARGE ARRAY - Microwave Subsystem

Typical efficiency budget

Element	Efficiency		Note
	X-band, 8.4 GHz	K-band, 32 GHz	
P.O. computed	0.777	0.780	100% = 54.59 -X 100% = 66.21 -Ka
Main Reflector I^2R RMS	 0.999 0.988	 0.999 0.846	 12 mils RMS
Subreflector I^2R RMS	 0.999 0.999	 0.999 0.8982	 4 mils RMS
Feed support blockage	0.85/0.9	0.85/0.9	Estimated
Feed VSWR	0.999	0.999	
Efficiency Gain (dB)	0.650/0.688 52.72/52.97	0.549/0.581 63.61/63.85	

DSN LARGE ARRAY - Microwave Subsystem

G/T performance across bandwidth.



At 8.4 Ghz redesign is 40.816 vs 40.913 optimum design

DSN LARGE ARRAY - Microwave Subsystem

Typical noise temperature budget

Element	Noise, K		Note
	X-band, 8.4 GHz	K-band, 32 GHz	
Cosmic background	2.5	2.0	Effective blackbody
Atmosphere	2.2	7.0	Goldstone (ave clear)
Forward spill	0.3	0	6% at X-band
Main reflector rear spill	3.6	1.0	
Main reflector I^2R	0.1	0.2	Aluminum
Subreflector I^2R	0.1	0.2	Aluminum
Quadripod scatter	2/4	2/4	Estimated
Feed/amplifier cont	6.1/12.4	18.6/30.2	Tables 1 and 2
Total Noise, K	16.9/25.2	31.0/44.6	

INTERPLANETARY NETWORK DIRECTORATE

DSN LARGE ARRAY - Microwave Subsystem

X-band noise budget (S. Petty/M. Britcliffe)

Item	Loss L (dB)		Phy Temp T, K		Gain G, dB		Tin, K		Noise, K	
	Goal	Max	Goal	Max	Goal	Max	Goal	Max	Goal	Max
Mismatch loss, vacuum window (included in vacuum window resistive loss term below)									0.00	0.00
X-band combiners isolation noise term. Isolation = 26 dB goal, 23 dB max									0.03	0.06
X-band polarizer isolation noise term. Isolation = 23 dB goal, 20 dB max									0.06	0.12
Vacuum window	0.004	0.015	293	293					0.29	1.00
Goal: 11 mil Teflon, 3 mil Kapton, 1" Propozote Max: 11 mil Teflon, 0.25" Rexolite, 1" Propozote										
Feedhorn	0.008	0.014	50	60					0.10	0.19
Teflon torpedo/foam support	0.015	0.020	20	30					0.07	0.14
Waveguide Cu 1.5 inches	0.002	0.003	15.0	16.0					0.08	0.19
Slot combiner	0.025	0.050	13.0	15.0					0.08	0.18
WR112 7.5 inches straight, 2 miter bends	0.027	0.050	13.0	15.0					0.08	0.18
Slot combiner	0.025	0.050	13.0	15.0					0.08	0.18
Hybrid polarizer	0.030	0.050	13.0	15.0					0.09	0.18
WR bend	0.006	0.008	13.0	14.0					0.02	0.03
WR cal coupler (loss)	0.025	0.035	13.0	14.0					0.08	0.12
WR cal coupler (inj noise)	30.0	29.0	293	293					0.30	0.39
Goal: Coupler integrated in MMIC module										
Max: Coupler separate (same performance)										
WR/SMA male adapter	0.090	0.120	13.0	6.9					0.28	0.21
MMIC HEMT module					35.0	31.0	4.00	7.00	4.24	7.70
0.141 output coax, 12–70K	0.56	0.67	50	50					0.00	0.01
0.141 output coax, 70–293K	0.56	0.67	210	210					0.01	0.04
Loss between vacuum feed through, receiver assembly	0.40	0.50	293	293					0.01	0.04
Receiver assembly							150	250	0.15	0.90
								Input Noise Temp Te(K)	6.14	12.35

WAI-10
12/18/03

INTERPLANETARY NETWORK DIRECTORATE

DSN LARGE ARRAY - Microwave Subsystem

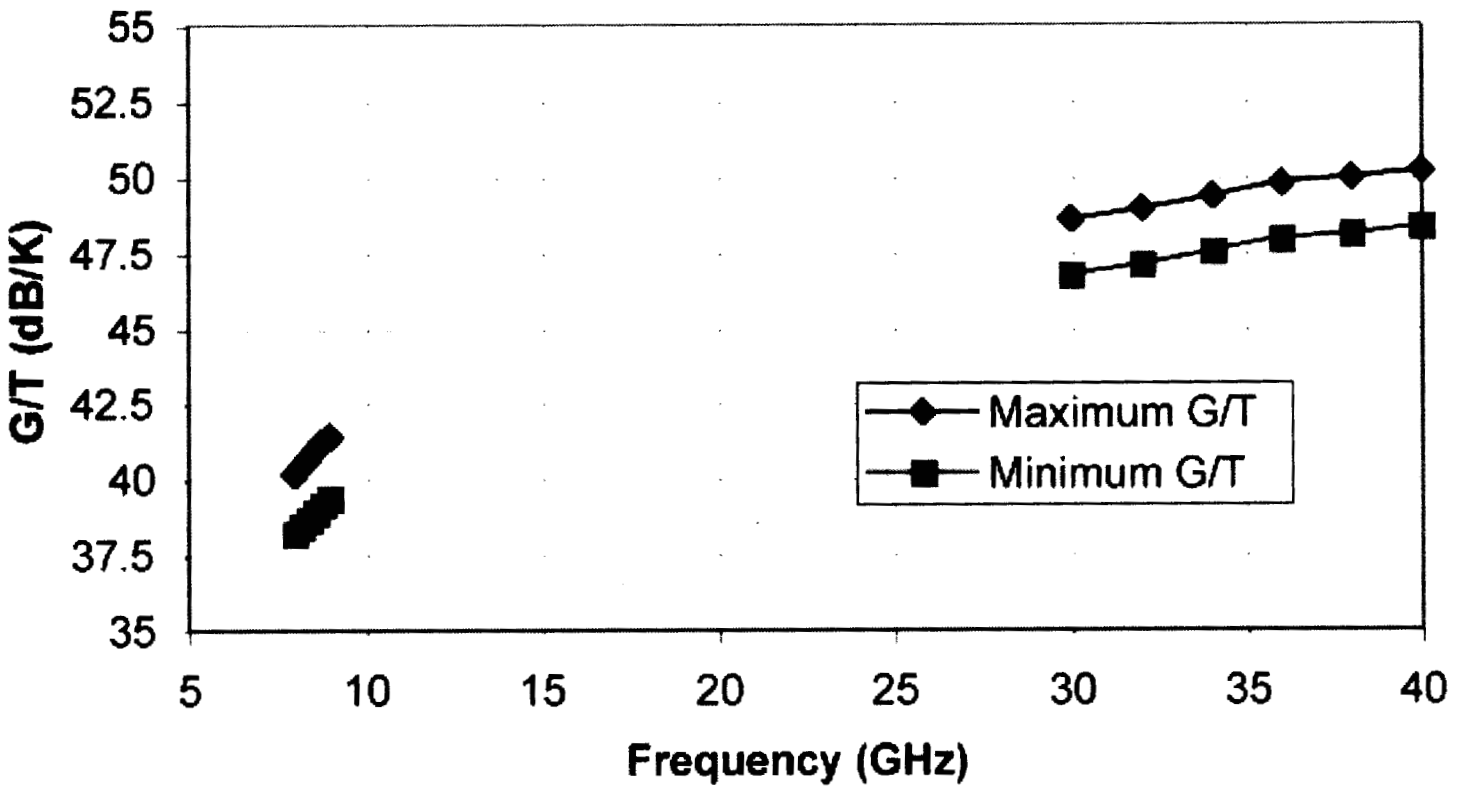
Ka-band noise budget (S. Petty/M. Britcliffe)

Item	Loss L (dB)		Phy Temp T, K		Gain G, dB		Tin, K		Noise, K	
	Goal	Max	Goal	Max	Goal	Max	Goal	Max	Goal	Max
Mismatch loss, vacuum window (included in vacuum window resistive loss term below)									0.00	0.00
Ka-band polarizer isolation noise term. Isolation = 20 dB goal, 17 dB max									0.25	0.35
Vacuum window	0.015	0.038	293	293					1.01	2.57
Goal: 11 mil Teflon, 3 mil Kapton, 1" Propozote										
Max: 11 mil Teflon, 0.25" Rexolite, 1" Polystyrene										
Feedhorn	0.020	0.032	50	60					0.23	0.45
Teflon torpedo/foam support	0.045	0.060	20	30					0.21	0.42
Round WG Cu 4.0 inches	0.004	0.006	15.0	18.0					0.01	0.03
Hybrid polarizer	0.050	0.075	13.0	15.0					0.15	0.27
WR28 waveguide bend	0.005	0.005	13.0	15.0					0.02	0.02
WR28 30 dB cal coupler (loss)	0.060	0.060	13.0	15.0					0.19	0.22
WR28 30 dB cal coupler (inj noise)	30.0	29.0	293	293					0.31	0.39
Goal: Coupler integrated in MMIC module										
Max: Coupler separate										
MMIC HEMT module					40.0	38.0	15	22	15.70	23.44
Output coax, 12–70K, 8 in. long	2.00	2.50	50	50					0.00	0.01
Output coax, 70–293K, 8 in. long	2.00	2.50	210	210					0.02	0.05
Loss between vacuum feed through, receiver assembly	1.00	1.40	293	293					0.02	0.06
Receiver assembly							600	800	0.42	1.59
								Input Noise Temp Te(K)	18.6	30.2

WAI-11
12/18/03

DSN LARGE ARRAY - Microwave Subsystem

Maximum and minimum G/T



Mechanical displacements that give a 0.1 dB G/T loss assuming no repointing of the antenna.

	8.4 GHz	30 GHz
Subreflector Axial	+5.33 / –2.54	+1.91 / –0.51
Subreflector Radial	±3.0	±0.90
Feed Axial	+13.21 / –8.13	+1.78 / –5.96
Feed Radial	±3.0	±0.85

(all dimensions in mm)

Mechanical displacements that give an 18 degree phase error

	32 GHz
Subreflector Axial	+0.3 / –0.3
Subreflector Radial	Large
Feed Axial	+0.5 / –0.5
Feed Radial	Large