GBT Surface Accuracy

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1.0 Introduction

The GBT antenna tipping structure design is now essentially complete. Finite-element analysis of the structure has also been completed, and this memorandum presents an estimate of the surface RMS performance based on these results, and presents estimated antenna efficiency versus elevation curves for a few frequencies of operation. The RMS values presented for the antenna structure are based on structural deformations at the panel supports, for uniform illumination.

2.0 Phase 1 Operation

Phase 1 refers to operation of the antenna as a passive structure, that is, the main reflector surface actuators are fixed and the surface deforms under gravity as it moves away from the rigging angle of 44 degrees. Table 1 presents the estimated surface RMS at the zenith/horizon, under two environmental conditions. The TEMP column gives the performance with a 5 degree centigrade 3-D linear temperature gradient across the structure, and a 2 degree centigrade gradient front-back on the surface panels. The WIND column gives the performance for an isothermal structure under wind loads of 6 m/s, gusting to 7 m/s. Figures 1 and 2 are contour plots of the Gravity surface deformations at the zenith and horizon respectively.

It should be noted that the antenna as-delivered Measuring/Setting term will be approximately 40 mils, which represents an estimate of the best achievable using the planned optical measurement technique. Thus, to achieve the performance given in Table 1, NRAO will have to refine the surface setting to 18 mils, probably using holography as the measurement technique. As described in GBT Memo 113, the surface actuators, rather than manual adjustments, will be used to adjust the surface for this refinement.

The structural Temperature term of 4 mils represents a significant improvement over the performance which was originally estimated for an antenna of this size.

3.0 Phase 2 Operation

Table 2 presents estimated performance for a second phase of operation. Two significant improvements over the Phase 1 operation are represented in this table. Firstly, the antenna Measuring/Setting has been further refined to 8 mils. Secondly, the Open-Loop Active Surface has been turned on to compensate the

surface as the antenna travels in elevation, which we assume will reduce the Gravity term to 8 mils. It should also be noted that the environmental conditions in Table 2 are more benign than those assumed in Table 1.

The antenna Gravity term while the Open-Loop Active Surface is operating is a strong function of how well the structural model matches the as-built structural performance, or how well we can measure and model the actual deformations. It is probably impossible to know an accurate value before experience with the structure is obtained.

4.0 Phase 3 Operation

It was recognized early in the project that an accurate measurement system for the main reflector surface would be necessary to determine thermal deformations, and to characterize the actual gravitational deformations. A system using laser ranging techniques is under development to provide this capability. Table 3 gives the estimated RMS budget when this surface measurement system is operational. The 6 mil Gravity, Temperature, & Measure/Setting term in the antenna budget represents the measurement system accuracy, but a thorough analysis has not yet been done to justify this value. The accuracy is further discussed in GBT Memo 37.

5.0 Antenna Efficiency

Figures 3-5 give calculated antenna efficiency as a function of elevation for 8, 20, and 50 GHz. The efficiency plotted is the product of a spillover/illumination efficiency, calculated using diffraction analysis programs and measured or modeled feed patterns, and a surface efficiency, calculated from the estimated Phase 1-3 surface RMS using the Ruze formula. Application of the Ruze formula to surface errors which might be highly correlated over the surface (e.g. Joint Rotation or Gravity) is somewhat suspect, but the formula has been found to provide fairly accurate results on past problems. The spillover/illumination efficiency used for the three frequencies is 71%, 71%, and 76% respectively. Note that even though the Phase 1 surface accuracy is lambda/16 at 16 GHz, according to the structural model results, the efficiency is still quite high at 20 GHz over a fair range of elevations.

6.0 Acknowledgements and Recommendations

L. King provided the structural analysis results and S. Srikanth provided the spillover/illumination efficiencies.

The analysis of the surface laser measurement system accuracy given in GBT Memo 37 should be updated, because the laser locations studied there have changed significantly.

TABLE 1
PHASE 1 OPERATION
PASSIVE STRUCTURE

WIND 6 m/s, GUSTING TO 7 m/s
STRUCTURAL $\triangle T = 5^{\circ} C$

ITEM		GBT SURFACE RMS (mils) TEMP	WIND
Surface Panel :			
Manufacturing		3	3
Gravity		3	3
Temperature	($\triangle T = 2^{\circ} C$)	4	—
Wind		—	2
Measurement		1	1
PANEL RSS SUBTOTAL		6	5
Antenna Structure			
Gravity		41	41
Joint Rotation		2	2
Temperature		4	—
Wind		—	9
Measuring/Setting		18	18
STRUCTURE RSS SUBTOTAL		45	46
Subreflector		4	4
Total Surface Accuracy	**(mils)**	46	46
	(mm)	1.17	1.17
	λ /16 @	16 GHz	16 GHz

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FIGURE 1

GBT SURFACE WITH RESPECT TO
ZENITH BEST-FIT PARABOLOID

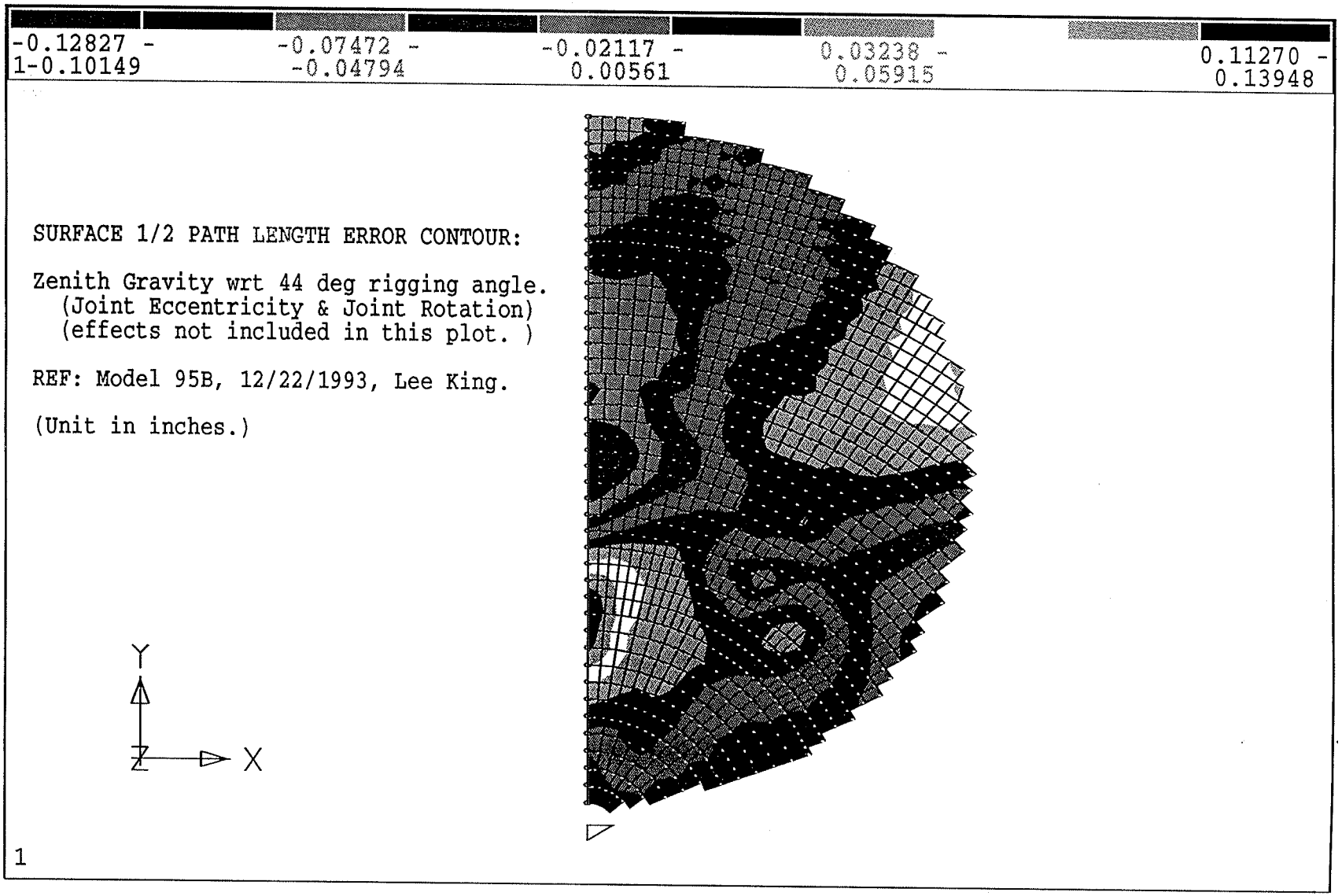

FIGURE 2

GBT SURFACE WITH RESPECT TO
HORIZON BEST-FIT PARABOLOID

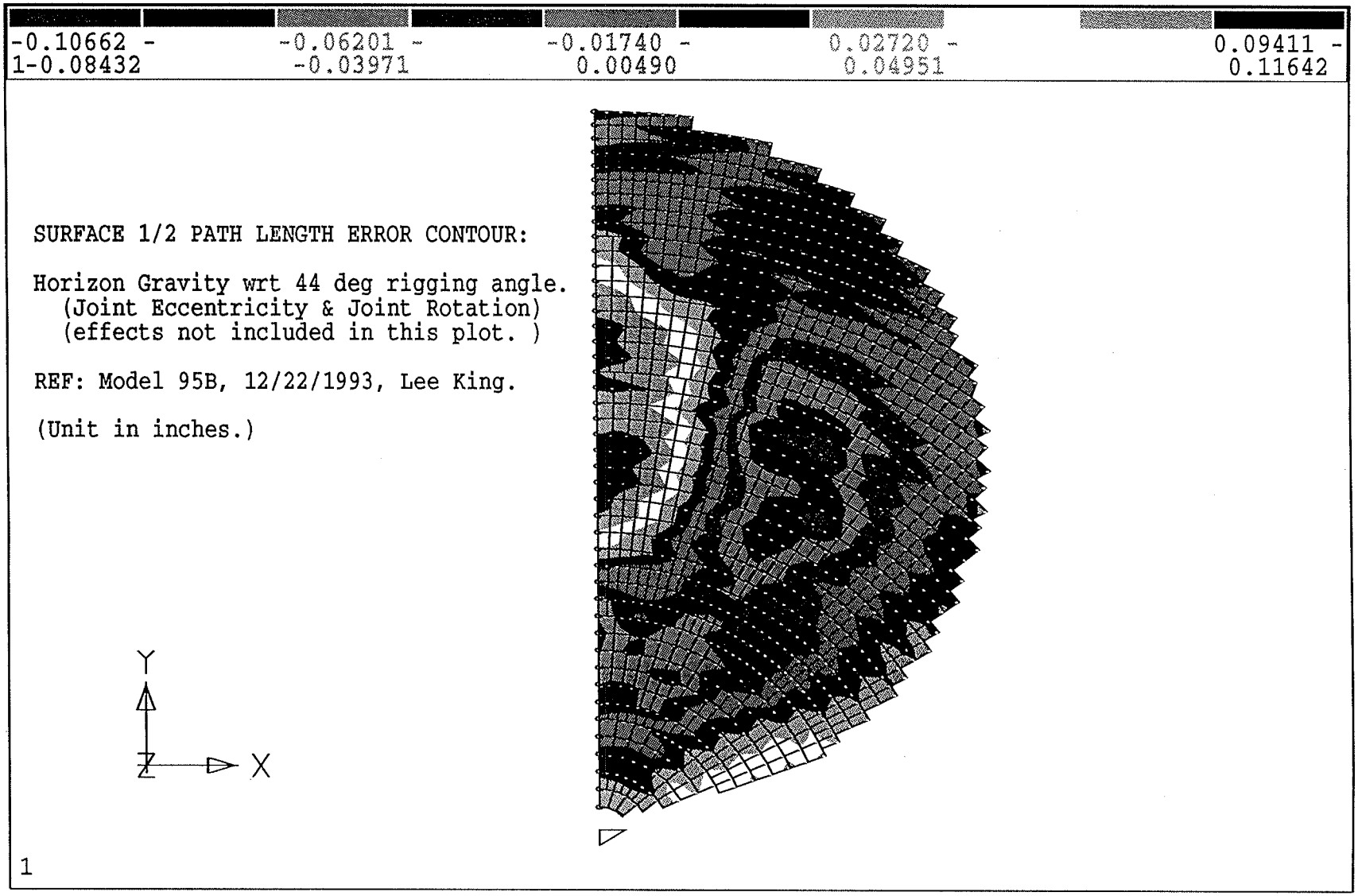

TABLE 2
PHASE 2 OPERATION
ACTIVE SURFACE OPERATIONAL

WIND 3 m/s, GUSTING to 4 m/s
STRUCTURAL $\triangle T = 2^\circ C$

ITEM		GBT SURFACE RMS (mils) TEMP	WIND
Surface Panel :			
Manufacturing		3	3
Gravity		3	3
Temperature	($\triangle T = 2^\circ C$)	4	—
Wind		—	1
Measurement		1	1
PANEL RSS SUBTOTAL		6	5
Antenna Structure			
Gravity		8	8
Joint Rotation		2	2
Temperature		2	—
Wind		—	5
Measuring/Setting		8	8
STRUCTURE RSS SUBTOTAL		12	13
Subreflector		4	4
Total Surface Accuracy	**(mils)**	14	14
	(mm)	0.36	0.36
	λ /16 @	52 GHz	52 GHz

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TABLE 3
PHASE 3 OPERATION
LASER RANGING AND ACTIVE SURFACE OPERATIONAL

ITEM	
Surface Panel :	
Manufacturing	3
Gravity	3
Temperature ($\triangle T = 2^{\circ} C$)	4
Wind	—
Measurement	1
PANEL RSS SUBTOTAL	6
Antenna Structure	
Gravity, Temperature, & Measure/Setting	6
Joint Rotation	2
STRUCTURE RSS SUBTOTAL	6
Subreflector	4
Total Surface Accuracy **(mil)**	9
(mm)	0.24
λ **/16 @**	78 GHz

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Figure 3

GBT at 8 GHz

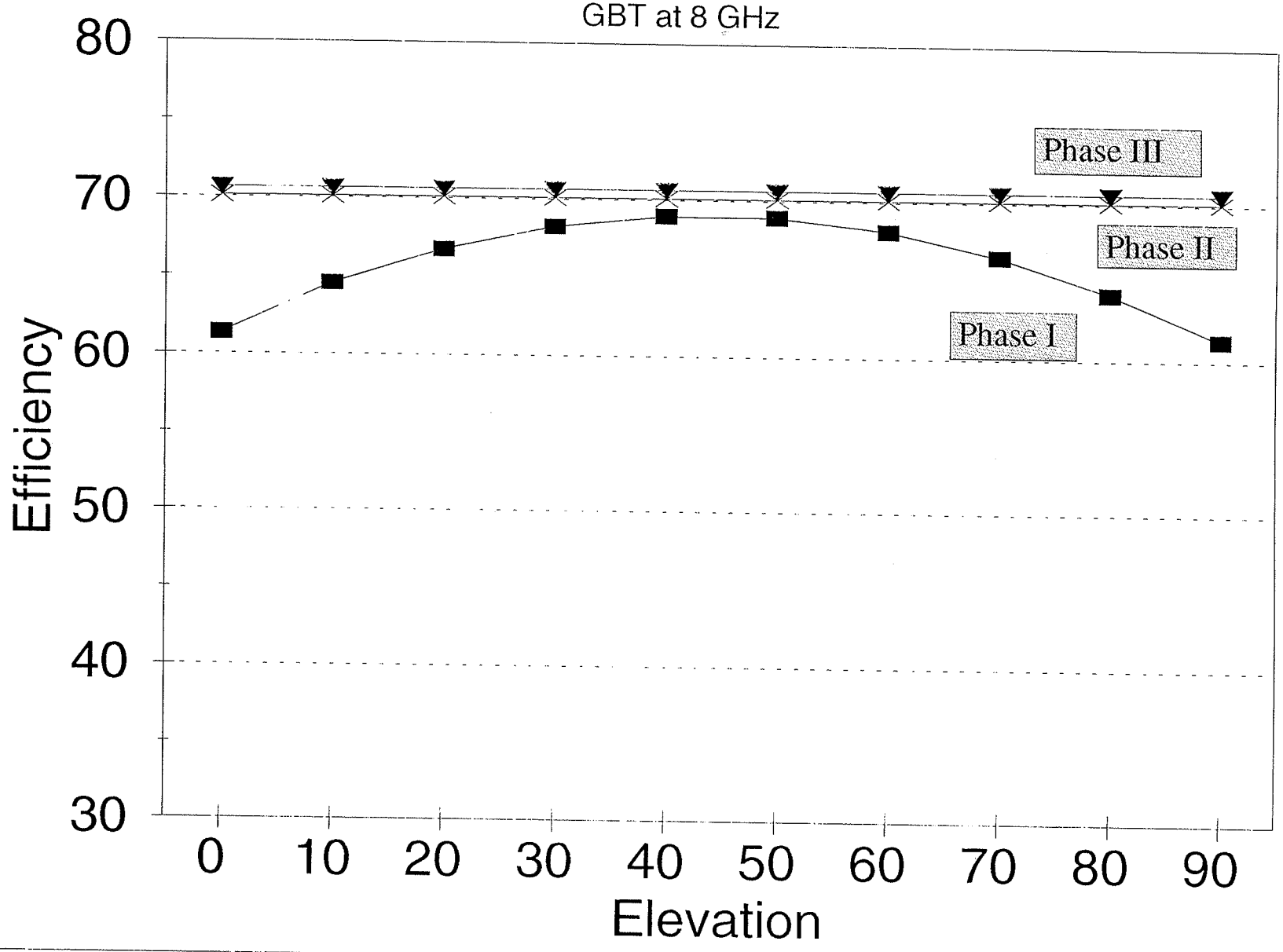

Figure 4

GBT at 20 GHz

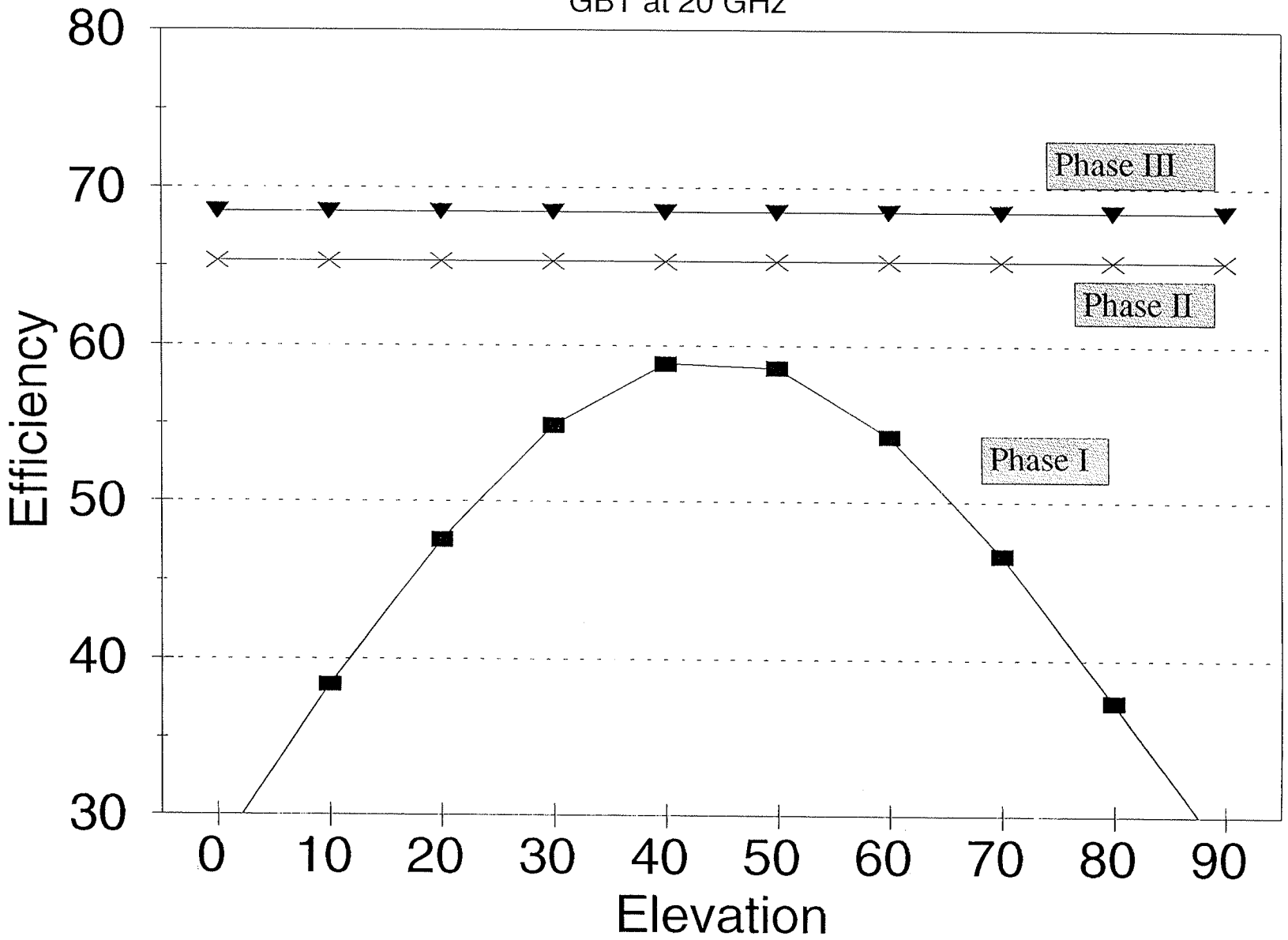

Figure 5

GBT at 50 GHz