A dual-band reflectarray for X- and Ka-bands

PIERS 2003
Honolulu, Hawaii

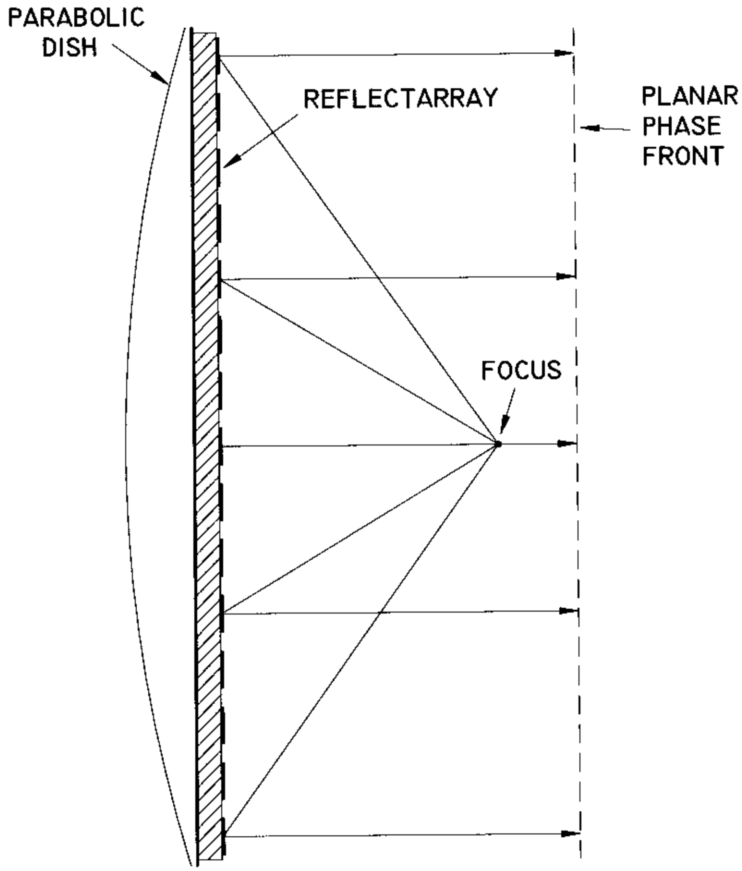
Mark Zawadzki and John Huang

October 15, 2003

A dual-band reflectarray for X- and Ka-bands

Outline

- introduction
  - background, motivation, advantages/disadvantages
  - goal of effort
- design process and results
- fabrication of antenna
- description of testing procedure
- measurement results
- summary and conclusions

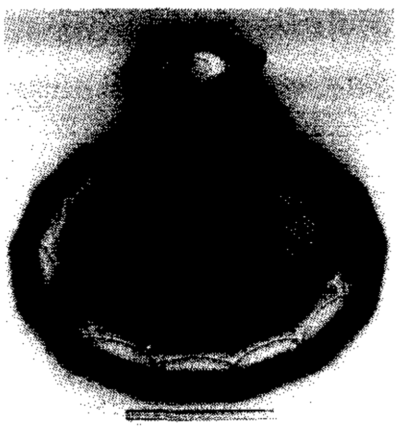


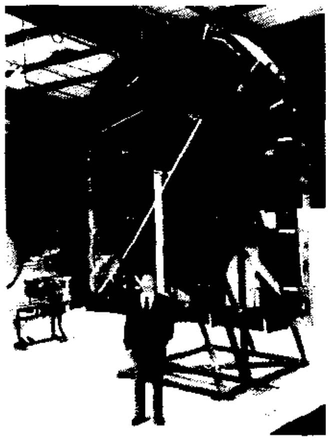
A dual-band reflectarray for X- and Ka-bands

Introduction

- NASA/JPL interest in developing Ka-band for future telecom systems
- flat surface integrates nicely with inflatable structures
- JPL's previous work on inflatable X- and Ka-band antennas
- sharing of aperture makes sense to reduce mass and stowage volume
- natural extension of previous work was to try to merge the two bands

1m X-band inflatable





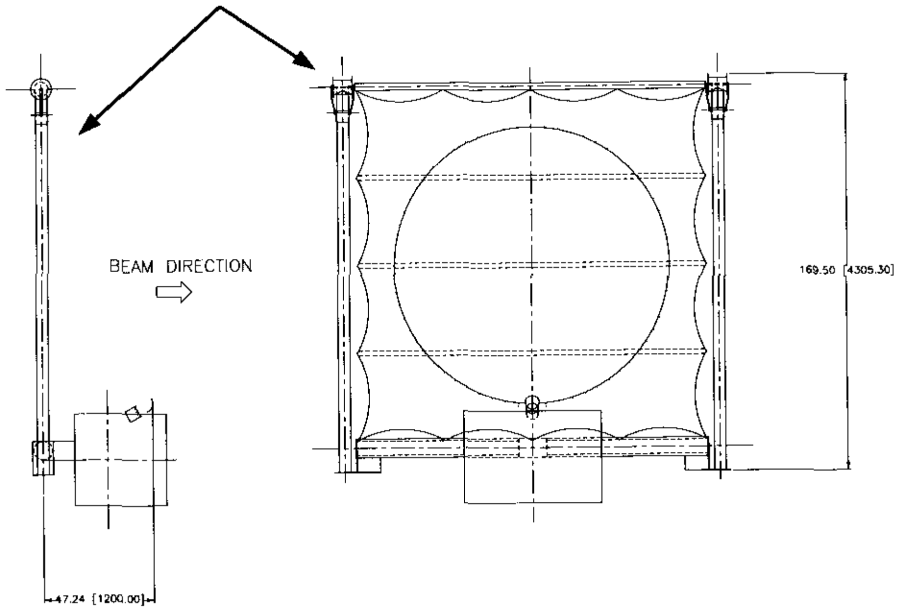
3m Ka-band inflatable

A dual-band reflectarray for X- and Ka-bands

Introduction (cont'd)

Advantages	Disadvantages
relatively low cost	lower bandwidth
high gain	higher losses
flat surface	lower efficiency
space feeding	

"Movie screen" deployment



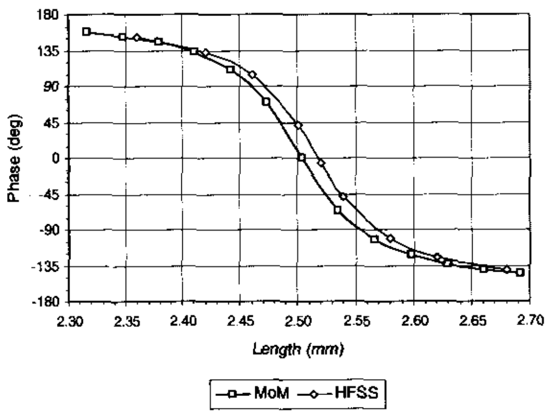
A dual-band reflectarray for X- and Ka-bands

JPL

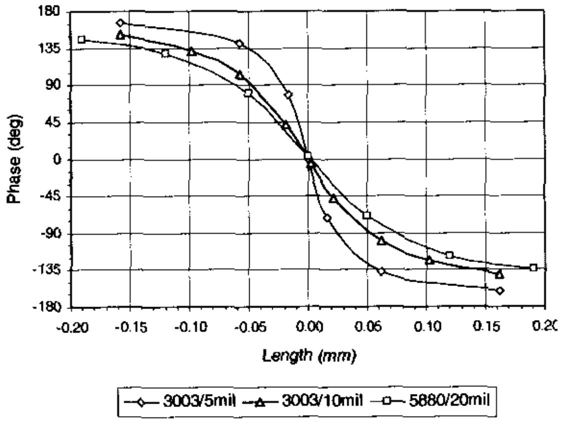
Ka-band reflectarray design

- uses variable size patches to generate proper reflection phase
- patch size determined from S-curve calculated using Method of Moments
  - software developed by D. Pozar at Umass Amherst
- also used HFSS to generate an S-curve for comparison
  - *slight shift in resonant frequency from MoM result*
  - approximately 62° per 0.001" at resonance using Rogers 10mil RO3003
- loss as a function of patch size was calculated

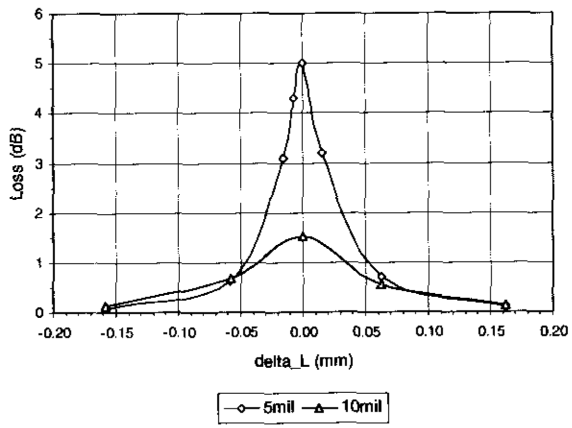
Reflection phase/10mil RO3003
Lo=2.518mm (approx.), f=32GHz



S-curves for RO3003 and 5880 substrates
Normalized to Lo at f=32GHz



Reflection loss for 5 and 10 mil RO3003
Normalized to Lo at f=32GHz

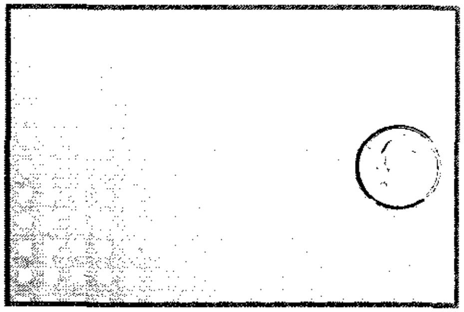


(Note: blue is for CP loop)

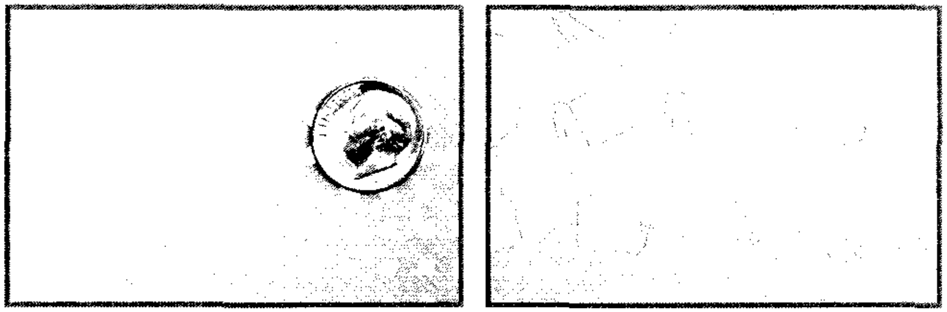
A dual-band reflectarray for X- and Ka-bands

Ka-band reflectarray design (cont'd)

- also designed, built and tested a reflectarray using rotational technique
  - with stub-tuned CP elements
- material used was 5mil Rogers RO3003 substrate
  - sensitive to tolerances and more lossy than 10mil
- elements were off-tune resulting in degraded performance
- results presented here are only for the variable size patch reflectarray



Variable size patches

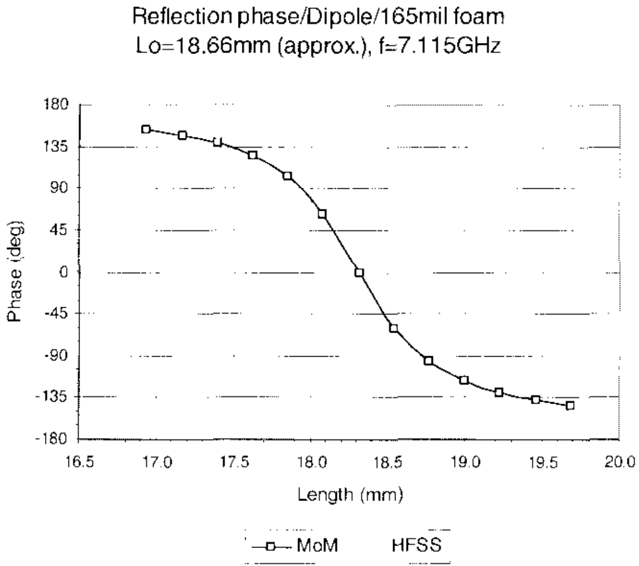


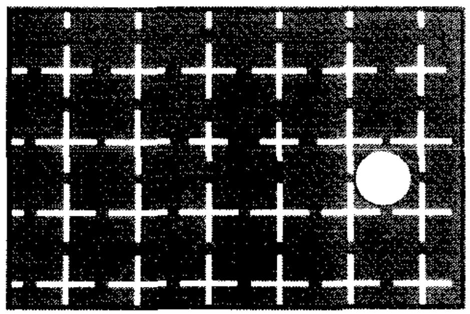
Stub-tuned CP patches using rotational technique

A dual-band reflectarray for X- and Ka-bands

X-band reflectarray design

- uses variable size crossed-dipoles to generate reflection phase
- patch size calculated from S-curve using Method of Moments
  - same software as for Ka-band
- also used HFSS to generate an S-curve for comparison
  - notable shift in resonant frequency from MoM result... which is right?

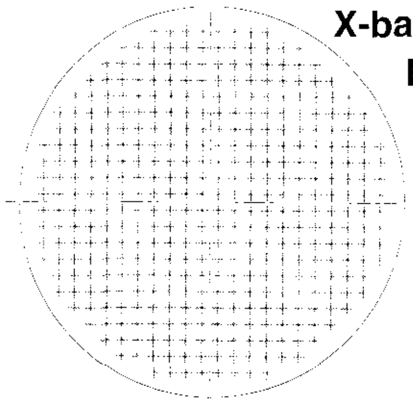




Crossed-dipoles on 2mil Kapton

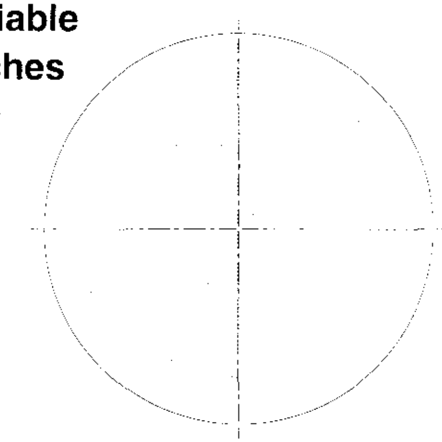
A dual-band reflectarray for X- and Ka-bands

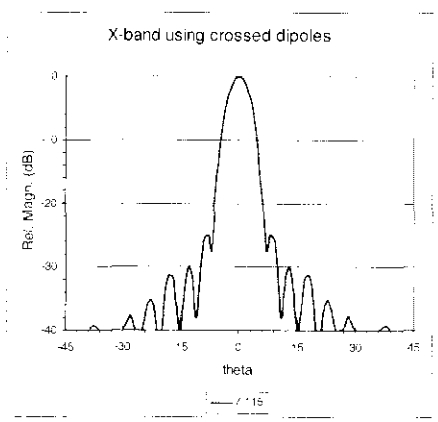
Summary of calculations for individual bands



X-band variable dipoles
D=56cm

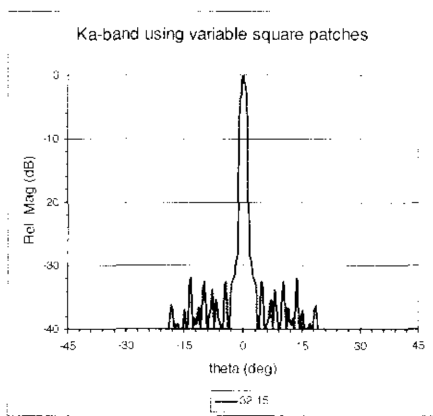
Ka-band variable
square patches
D=56cm





	X-band	Ka-band
f_o	7.115GHz	32GHz
Polarization	circular	circular
No. elem.	392	6,692
Gain	29.5dB	41.9dB
Cross-pol	<-20dB	<-20dB
eff.	59%	48%
Bandwidth[1]	4.6%	3.9%

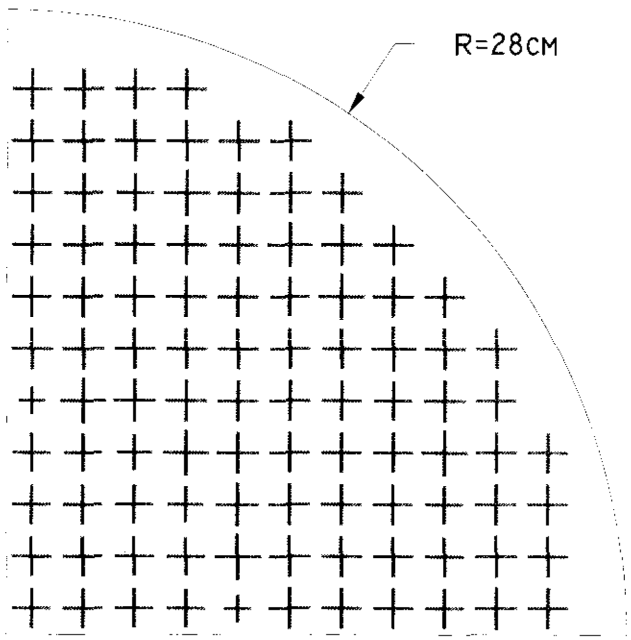
(Note 1: 3dB gain bandwidth)

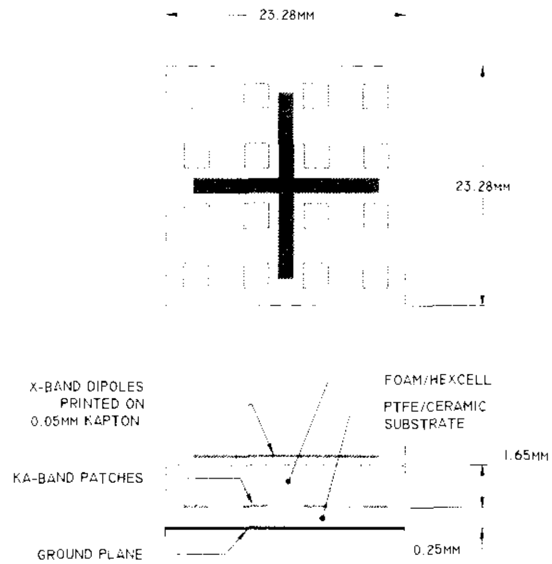


A dual-band reflectarray for X- and Ka-bands

Extension to dual band

- put Ka-band layer on bottom and X-band crossed-dipoles above them
- couldn't easily predict the interactions between the layers
- determine effect of interactions on performance empirically

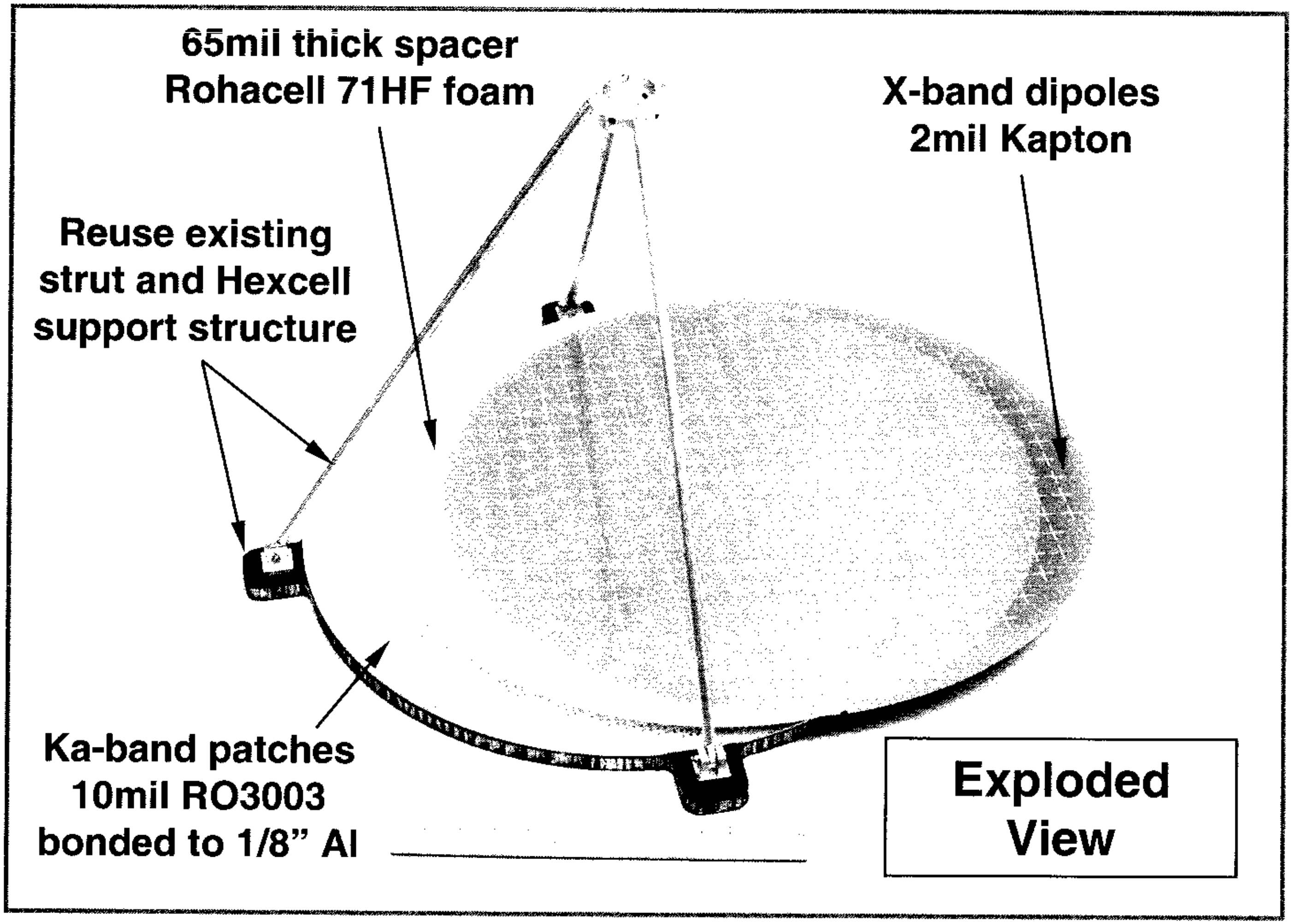




Unit cell

A dual-band reflectarray for X- and Ka-bands

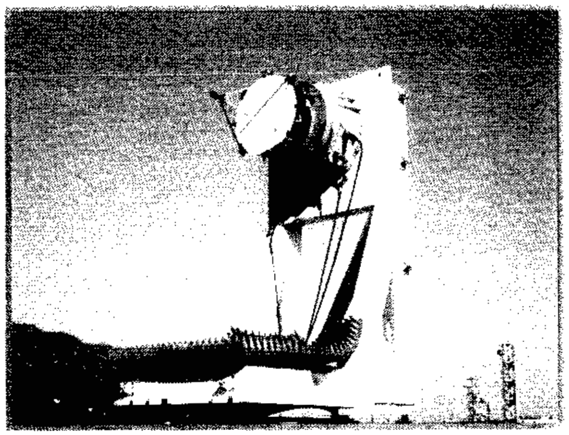
Fabrication

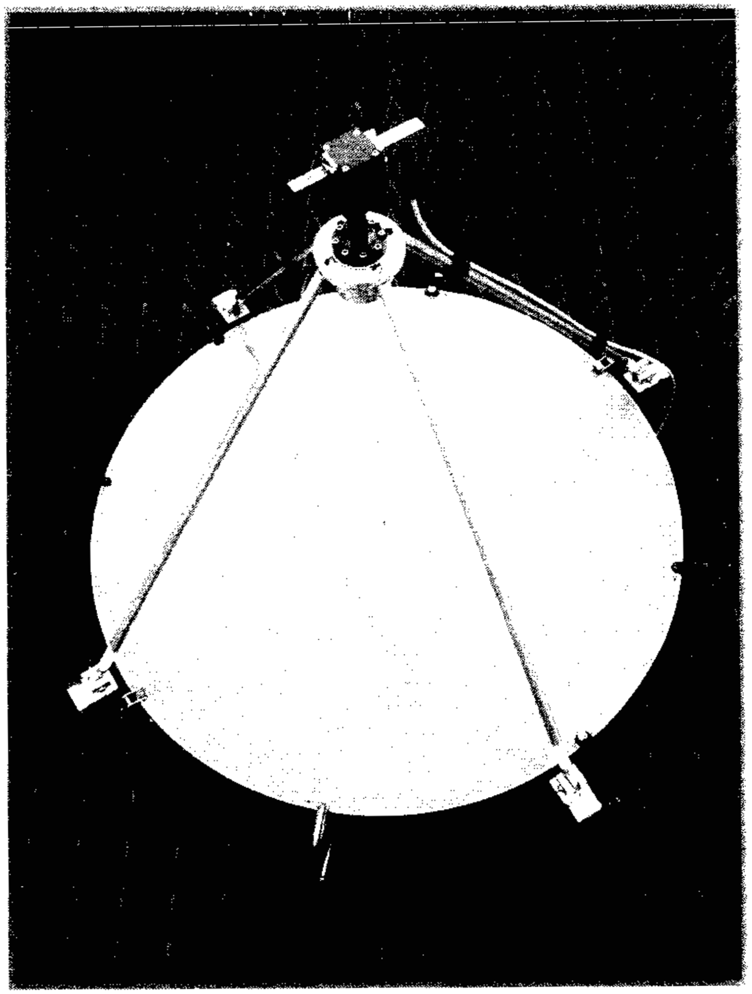


A dual-band reflectarray for X- and Ka-bands

Testing highlights

- calibrate range using known standards
- began testing with X-band alone
- then tested both individual Ka-band reflectarrays (no X-band dipoles)
- bond X-band to Ka-band layers
- retest combined arrays at Ka-band
- retest combined arrays at X-band
- problems: wind, amplifier drift, polarizer

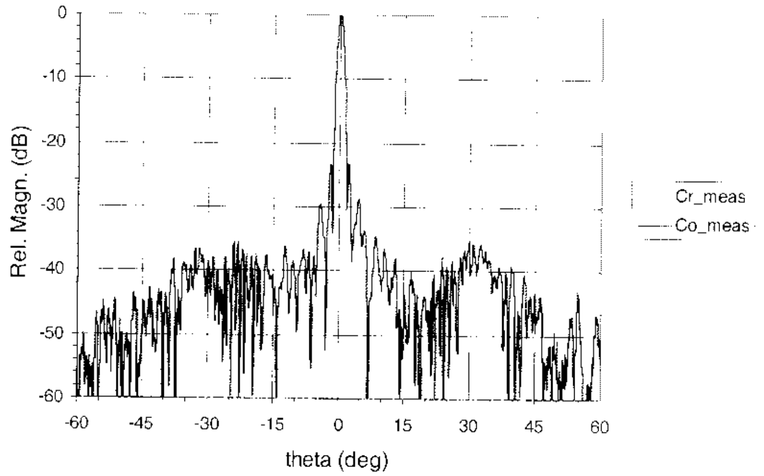




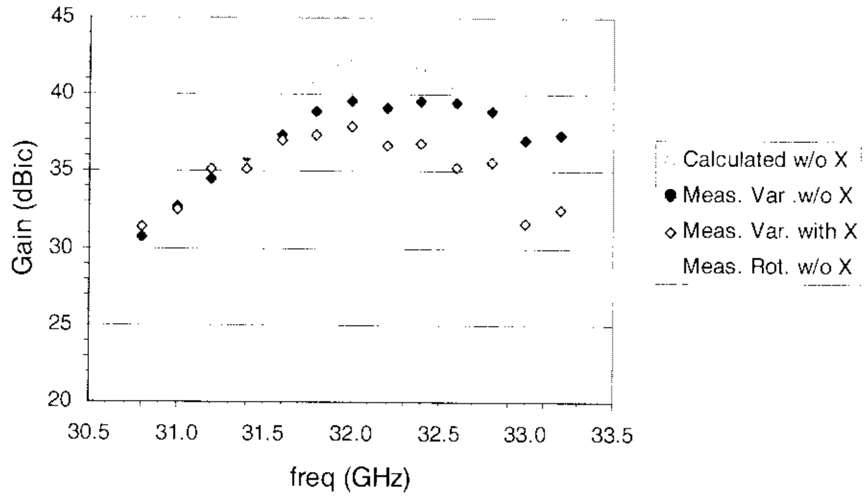
A dual-band reflectarray for X- and Ka-bands

Results for Ka-band without X-band present

Measured CP patterns at 32.0GHz w/o X dipoles



Gain vs. frequency for Ka band reflectarrays
Variable-size vs. Rotated patches

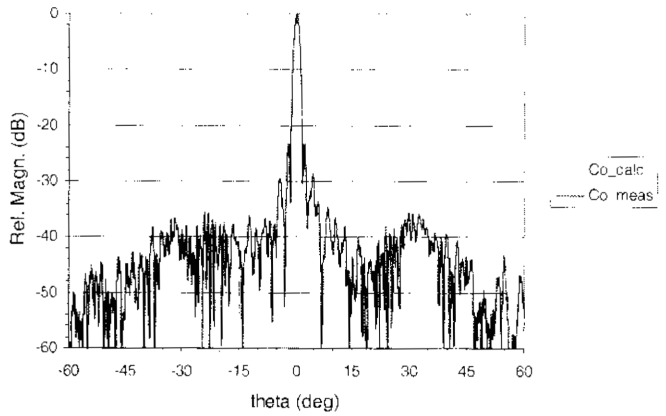


	Targets	Predictions	w/o X-band
frequency	32GHz	32.15GHz	32.3GHz
gain	40.4dBic	42.1dB	39.7dBic
bandwidth	1%	3.9%	~5%
peak sidelobe	-20dB	-25dB	-24dB
cross-pol	-20dB	-24dB	-22dB
efficiency	35%	49.4%	30%

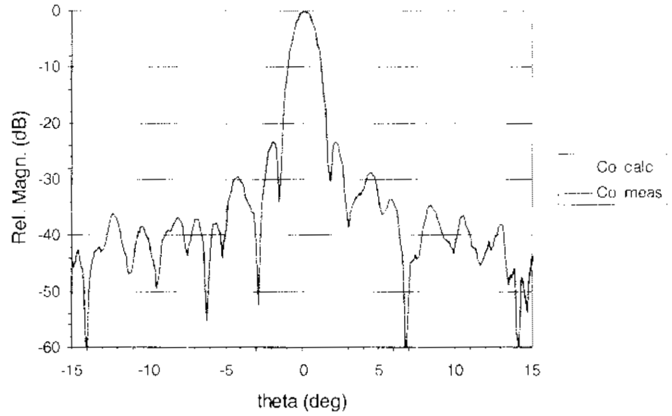
A dual-band reflectarray for X- and Ka-bands

Results for Ka-band without X-band present

Co-pol patterns at 32.0GHz w/o X dipoles

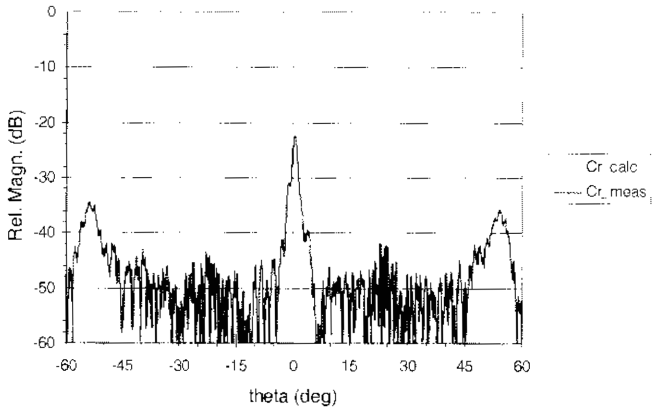


Co-pol patterns at 32.0GHz w/o X dipoles

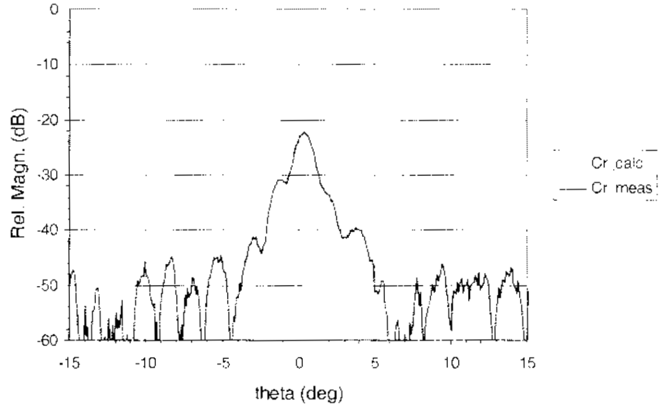


Co-pol pattern compared with prediction

Cross-pol patterns at 32.0GHz w/o X dipoles



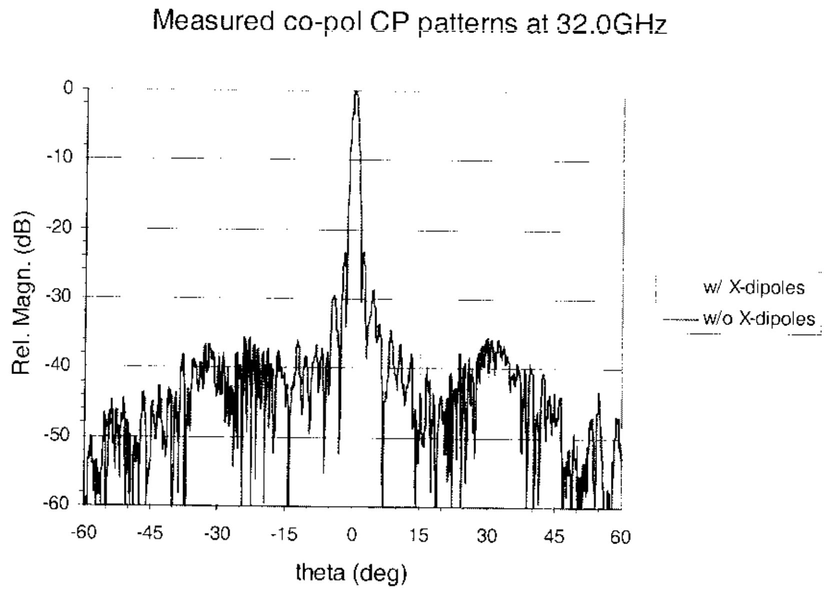
Cross-pol patterns at 32.0GHz w/o X dipoles

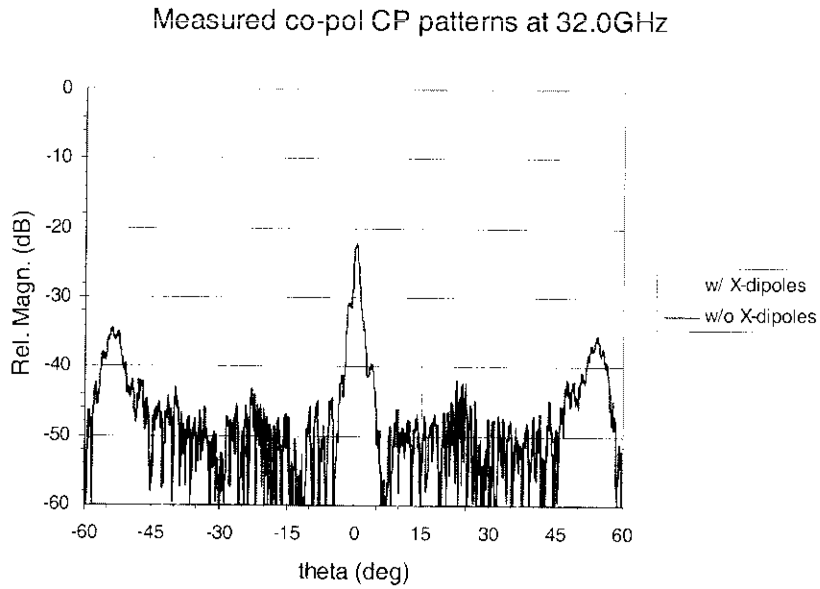


Cross-pol pattern compared with prediction

A dual-band reflectarray for X- and Ka-bands

Results for Ka-band with X-band present

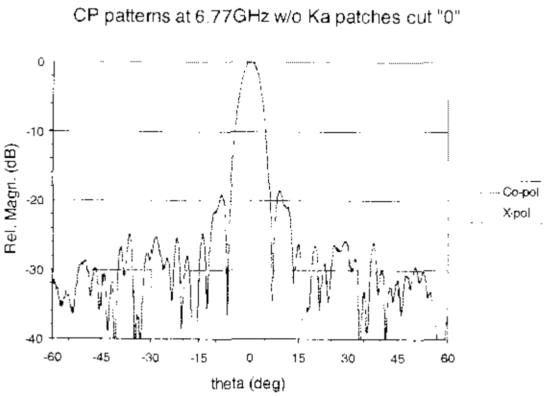




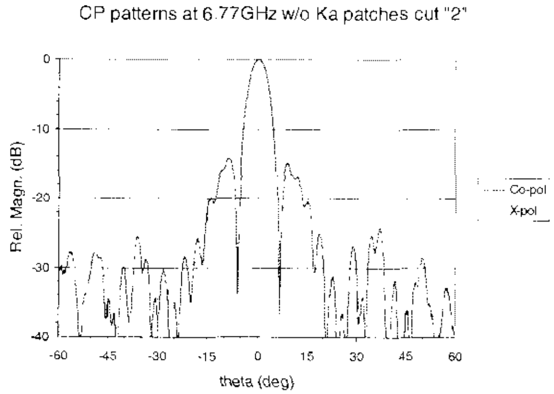
	Targets	w/o X-band	w/ X-band
frequency	32GHz	32.3GHz	32.0GHz
gain	40.4dBic	39.7dBic	37.9dBic
bandwidth	1%	~5%	~4.9%
peak sidelobe	-20dB	-24dB	-24dB
cross-pol	-20dB	-22dB	-22dB
efficiency	35%	30%	20%

A dual-band reflectarray for X- and Ka-bands

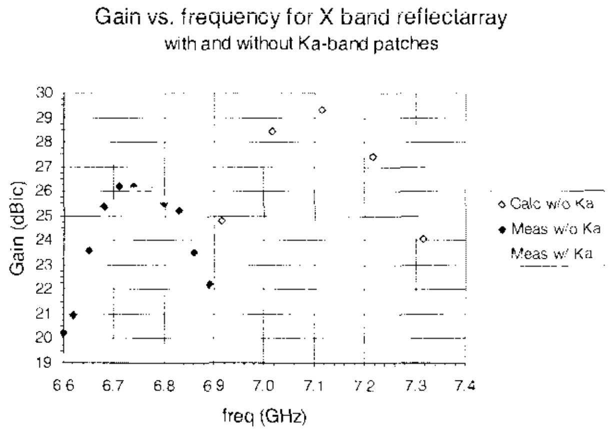
Results for X-band without Ka-band present



Avoiding strut plane



Through strut plane

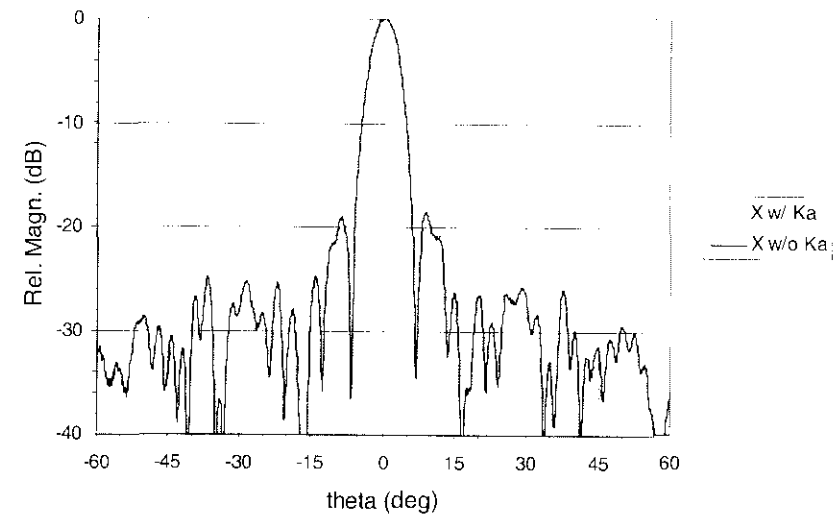


	Targets	Predictions	w/o Ka-band
frequency	7.115GHz	~7.1GHz	6.77GHz
gain	27.8dBic	29.5dBic	26.2dBic
bandwidth	1.4%	~4.6%	~3.4%
peak sidelobe	-20dB	-27dB	-15dB
cross-pol	-20dB	-38dB	-13dB
efficiency	40%	58%	28%

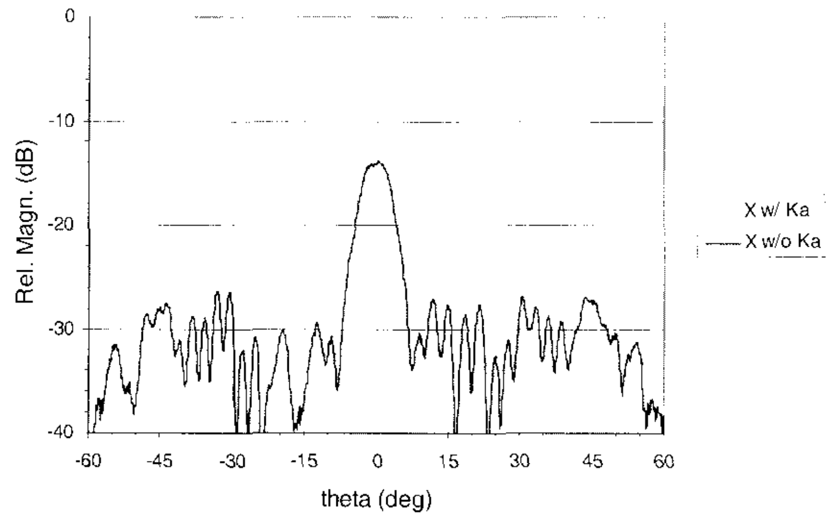
A dual-band reflectarray for X- and Ka-bands

Results for X-band with Ka-band present

Comparison of patterns with and without Ka patches



Comparison of patterns with and without Ka patches



	Targets	w/o Ka-band	w/ Ka-band
frequency	7.115GHz	6.77GHz	6.77GHz
gain	27.8dBic	26.2dBic	26.2dBic
bandwidth	1.4%	~3.4%	~3.4%
peak sidelobe	-20dB	-15dB	-15dB
cross-pol	-20dB	-13dB	-13dB
efficiency	40%	28%	28%

A dual-band reflectarray for X- and Ka-bands

Summary

- introduced JPL's effort to develop a dual-band X/Ka reflectarray
  - background, motivation, advantages/disadvantages, goal of effort
- covered design results, fabrication details, and testing procedure
- highlights of measurement results

Conclusions

- individual reflectarray designs need improvement
  - discrepancy in X-band S-curves still unresolved, check basis function used
  - resolve poor X-band polarizer performance in future testing
  - iterate Ka-band to tune performance
- Ka-band patches had negligible impact on X-band performance
- X-band caused a 1.8dB reduction in Ka-band gain

A dual-band reflectarray for X- and Ka-bands

Acknowledgements

- The presenter would like to thank John Huang and Sembiam Rengarajan for their helpful discussions, and Jeff Harrell for his assistance in the measurements on the antenna range.

- The research in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration