VLBA ELECTRONICS MEMO NO. 120

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

January 11, 1991

MEMORANDUM:

TO: VLBA Electronics Group

FROM: S. Srikanth

SUBJECT: Design and Fabrication of 43 GHz Feed

INTRODUCTION:

The feeds at the cassegrain focus of the VLBA antenna up to 22 GHz, with the exception of the L-band feed, are all scaled from the same design. These feeds are conical corrugated horns, while the L-band feed is a profiled corrugated horn (a compact design). At 43 GHz, when scaled from the above (conical horn) design, the slot and ridge widths of the feed are 0.039" and 0.013", respectively. The dimensions of the feed are too small for machining and hence electroforming is resorted to for fabricating the horn. At millimeter wavelengths electroforming has been successfully used. In this process, an aluminum mandrel is machined with inverse groove pattern, plated with a thin layer of gold and then copper is electroformed on the mandrel. The mandrel is then dissolved with a solvent. The slots on the mandrel which correspond to ridges on the horn, are 0.013" wide with a depth of 0.073". The aspect ratio (depth to width) of these slots is 5.6:1, while the aspect ratio of the slots closer to the throat approaches 10:1. When the aspect ratio is about 4:1 or greater, copper does not grow uniformly inside the slots during electroforming. This results in cavities in the center of the electroformed copper where acid could be entrapped. In order to overcome this, the design of the corrugations on the 43 GHz feed has been changed and an alternate fabrication technique has been adopted.

NEW DESIGN:

The aperture diameter and the length of the feed in the new design are 1.662" and 4.697", respectively (the scaled version would have 1.657" and 4.680" for these dimensions). The slot width and the ridge width are 0.030". The number of corrugations per wavelength reduces from 5.3 in the scaled design to 4.6 in the new design. The depth of the slots has been carefully chosen so that the guide wavelength of the hybrid mode changes gradually along the length of the horn. The depth of the first slot near the throat section of the feed is 0.136" and the slot depth gradually reduces to 0.072" at the sixth slot. The depth of the rest of the slots is 0.072". The deepest slot on the mandrel has an aspect ratio of 4.5:1 and hence is very close to the 4:1 aspect ratio limit. Detailed dimensions of the feed are available in NRAO Drawing No. D53213M023.

FABRICATION TECHNIQUE:

First, the mandrel is machined from aluminum to precise dimensions. Then a thin layer of zinc is formed on the mandrel by the zincate process. The zinc layer is required as copper will not grow on aluminum. Over this a 0.0001" layer of copper is formed. After this a 0.0003" layer of gold is grown on the mandrel. This gold will form the inner surface of the feed when electroformed and finished. The gold deters the formation of copper oxide on the otherwise naked copper which is undesirable at millimeter-wave frequencies. Electroforming of copper is carried out until the copper has grown to about one-quarter of the slot width on either side along the width of the slot. The mandrel is taken out of the bath at this point, rinsed and dried.

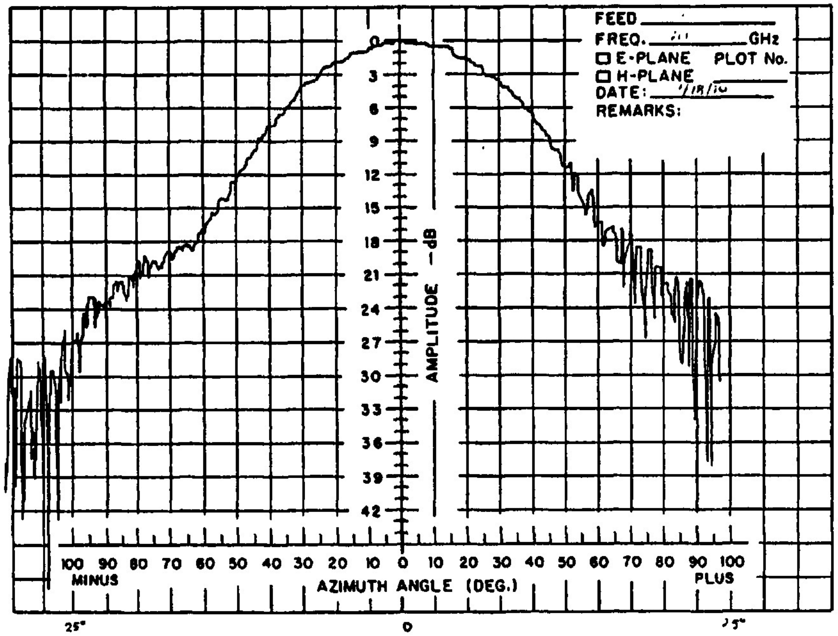
A two-component, silver-filled, conductive adhesive is then applied inside the slots. The adhesive used is Eccobond 83C (of Emerson & Cuming) along with catalyst 9. A technical bulletin of this product is shown in Appendix 1. Conductive adhesive is necessary for reasons of good bonding between the adhesive and copper which is electroformed on top of it. The mandrel is mounted in the collet of a lathe and the adhesive is applied with a soft brush while the mandrel spins, until the adhesive completely and uniformly fills the slots. After curing the mandrel is flashed with 0.000025" thick copper in a cyanide-based copper bath. The mandrel is then rinsed and electroformed with copper. The outside is machined to the required dimensions and gold-plated to a thickness of 0.0002". The mandrel is dissolved in a solution of 50% concentrated hydrochloric acid and 50% water. The rest of the machining including drilling of holes, etc. is done. Finally, a 0.0001" thickness of gold is formed on the feed.

MEASUREMENTS:

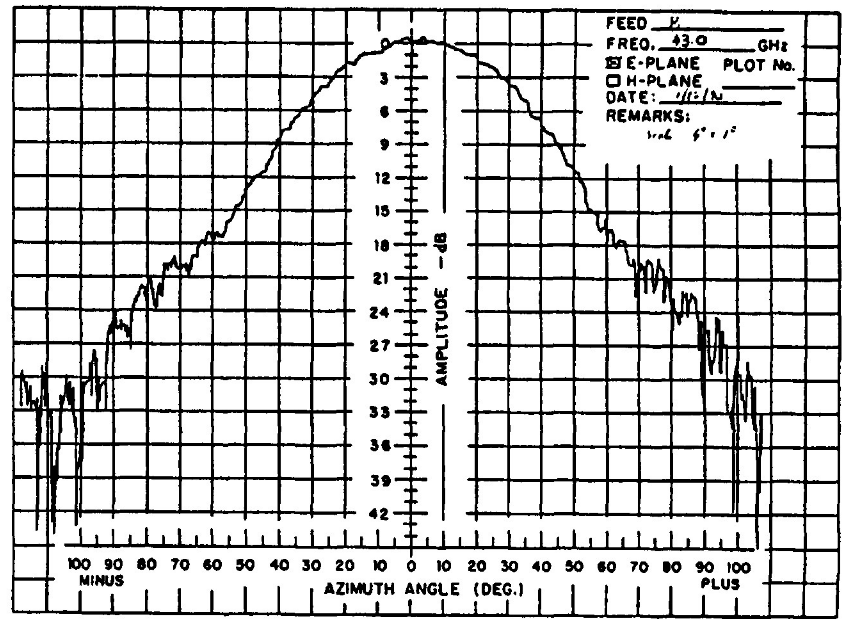
Far-field radiation patterns of the feed were measured in the frequency range of 41 GHz to 45 GHz. The patterns in E- and H-planes are shown in Figures 1 and 2, respectively. The principal plane patterns have good match and the taper is -13.7 dB at the edge of the subreflector at 43 GHz. The cross-polarization is better than -29 dB in the 45° plane. Figure 3 shows the VSWR measurements, with and without the 0.0001" thick mylar window at the aperture of the feed. The return loss is better than 20 dB in the frequency range 40.8 GHz to 47.6 GHz.

CONCLUSION:

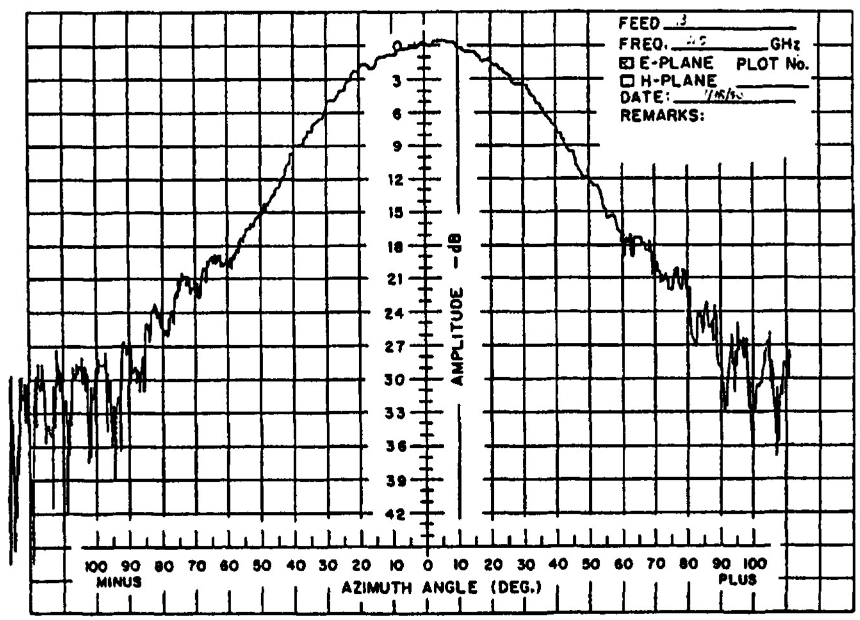
The technique of filling the slots with conductive adhesive seems to be a solution for preventing the formation of cavities within the electroformed copper. The technique was suggested by D. Dillon and refined by A. R. Kerr. The machining and the application of adhesive were done by D. Dillon; the electroforming was done by V. Summers.



(a) 41 GHz.

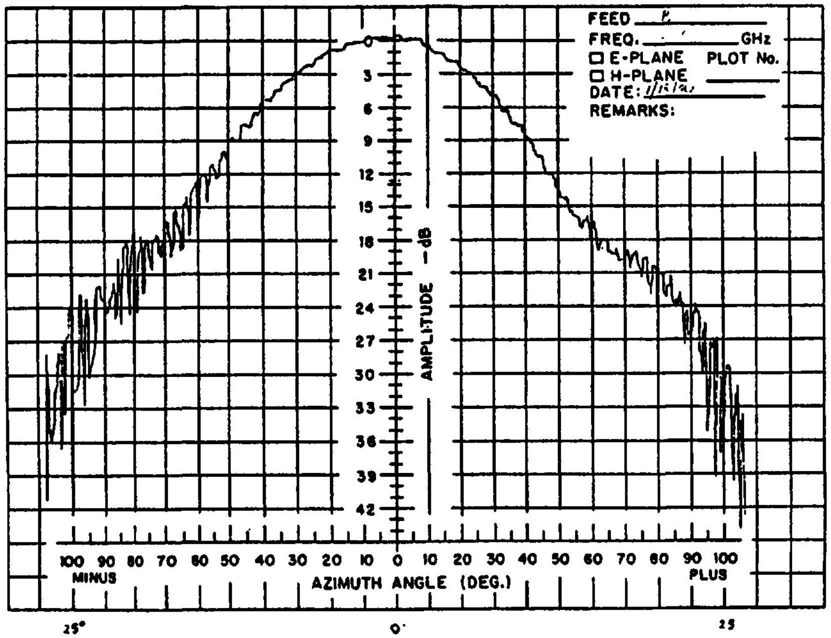


(b) 43 GHz.

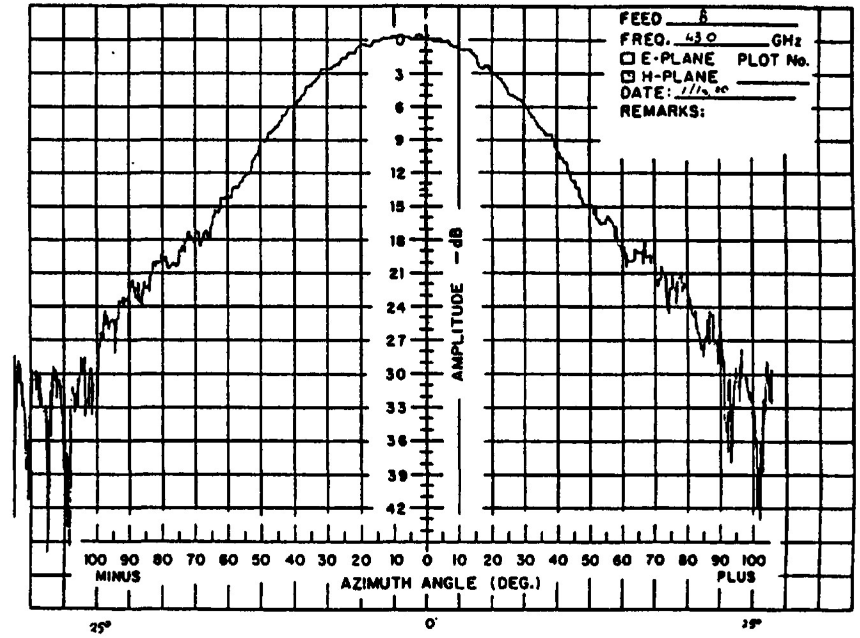


(c) 45 GHz.

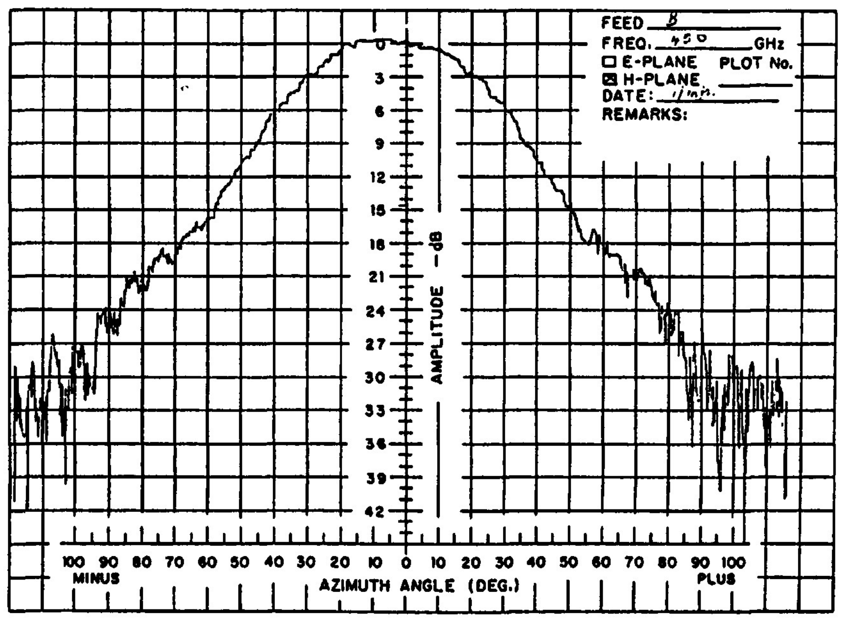
Fig. 1. Far-field radiation patterns E-plane.



(a) 41 GHz.

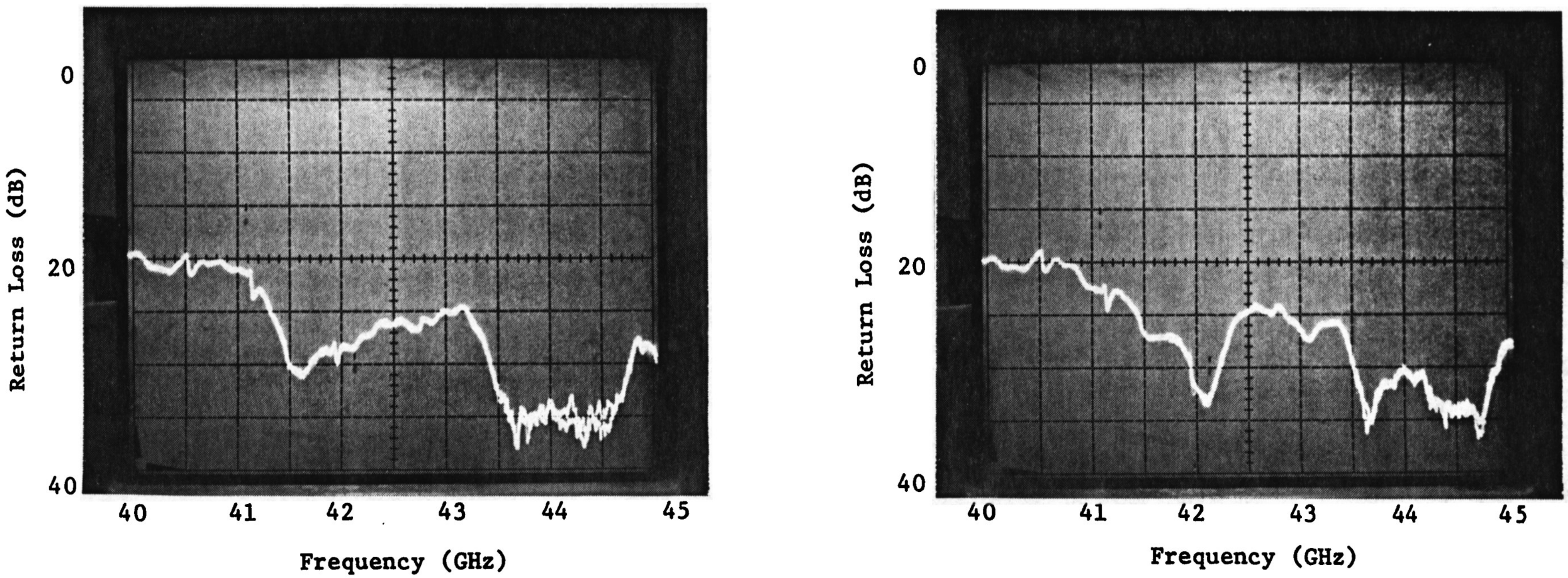


(b) 43 GHz.



(c) 45 GHz.

Fig. 2. Far-field radiation patterns H-plane.



(a) Without mylar window.

(b) With mylar window.

Fig. 3. Measured return loss.

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TECHNICAL BULLETIN

ECCOBOND® 83C

TWO COMPONENT, SILVER FILLED CONDUCTIVE ADHESIVE

BEST FOR ELECTRICAL AND THERMAL CONDUCTIVITY

ECCOBOND 83C is the resinous component of a two part, electrically conductive silver adhesive. When properly mixed and cured it will give volume resistivities of 10^{-4} ohm-cm and thermal conductivities of 18 (BTU)(in)/(hr)(ft^2)(°F). It is an easily applied, smooth, creamy paste designed to replace ECCOBOND 56C, 66C and 57C. Users will find that ECCOBOND 83C cured with Catalyst 9 or Catalyst AC 42 will give equivalent electrical, thermal and physical properties to ECCOBOND 56C but will be significantly easier to mix, handle and apply. It is available from Emerson & Cuming in standard 1/4 pound or 1 pound kits. (TWIN PAKS are available upon request if volume permits.)

TYPICAL PROPERTIES (AS SUPPLIED)

Pigment	silver
Binder	epoxy
Physical Appearance	smooth, creamy, thixotropic paste
Density	3.0
Shelf Life	1 year at 75°F or below
Dispensibility	pass 0.010 inch needle

TYPICAL PROPERTIES (CURED)

	Catalyst 9	Catalyst AC 42
Mix Ratio	100:3.5	100:4
Volume Resistivity, ohm-cm	4×10^{-4}	4×10^{-4}
Thermal Conductivity		
(BTU)(in)/(hr)(ft^2)(°F)	18	18
(Cal)(cm)/(sec)(cm^2)(°C)	0.006	0.006
Lap Shear Strength, psi	1000	1400
(kg/sq. cm)	(70)	(98)
Thermal Expansion Coefficient	25×10^{-6}/°F (45×10^{-6}/°C)	25×10^{-6}/°F (45×10^{-6}/°C)
Service Temperature Range	-65°F to +300°F (-54°C to 149°C)	-65°F to 300°F (-54°C to 149°C)
Recommended Cure Schedule	60 min. @ 150°F (66°C)	30 min. @ 250°F ([illegible]1°C)
Usable Pot Life	30 min. @ 75°F (24°C)	8 hours @ room temp. 3 days @ 40°F (4°C) 1 month @ 0°F (-18°C)

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