

A 31 Pixel Flared 100-GHz High-Gain Scalar Corrugated Nonbonded Platelet Antenna Array

Miikka M. Kangas, Markus Ansmann, Briony Horgan, Nicole Lemaster, Rodrigo Leonardi, Alan Levy, Philip Lubin, Josh Marvil, Paul McCreary, and Thyrsos Villela

Abstract—A compact 100-GHz corrugated platelet antenna array has been developed based on a corrugated feed design for the background emission anisotropy scanning telescope (BEAST) optics. The antennas in the array result in a gain of 20 dB, and a bandwidth across the full range of W-band 75–110 GHz. The side lobes are down by about -25 dB, a requirement comparable to feed horns used for observation of the cosmic microwave background. The design and fabrication presented in this letter is straightforward and inexpensive. A feature is that because the plates are not permanently bonded, the horn can be disassembled and modified to change its properties such as addition of flare plates or modified rib structures.

Index Terms—Corrugated feed, cosmic microwave background, millimeter-waves, platelet horn.

I. INTRODUCTION

ARRAYS of corrugated millimeter and submillimeter wave feed antennas are important for low background measurements of the cosmic microwave background [1]. Smooth walled horns tend to have significant cross-polar contamination, but are simpler to make than corrugated feeds. The typical manufacturing process for corrugated horns is either direct machining for longer wavelengths or electroforming. Another method is the machining or lithographic patterning of metal plates and bonding them together [3]. Previously, Kangas *et al.* [2] have constructed a mechanically captured single pixel horn. Other work has also been performed recently on platelet array antennas [4] with epoxy bonded plates [5]. Since the process

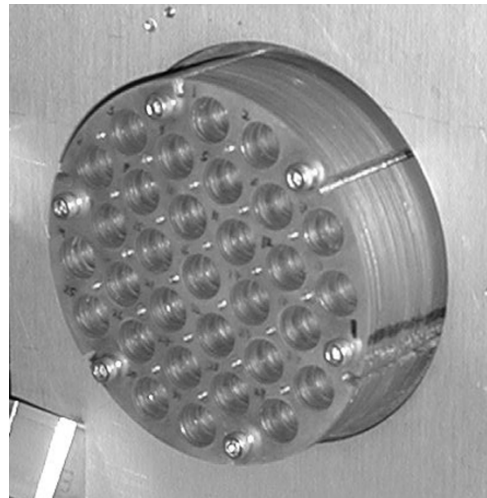


Fig. 1. 31-pixel 100-GHz platelet array.

of diffusion bonding plates is specialized, diffusion bonded platelet horns have not gained use in corrugated feed array based instruments such as background emission anisotropy scanning telescope (BEAST) and other cosmic microwave background (CMB) experiments [6].

This letter presents a inexpensive array of polarization preserving corrugated feeds suitable for millimeter wave astronomy (see Fig. 1). These corrugated horns were all constructed in our lab with a closed loop desktop computer numerically controlled (CNC) mill.

Typically, corrugated horns utilize $\lambda/4$ ribs on the inner walls of the horn and the resulting destructive interference to reduce interaction between the propagating waves and the metallic walls of the horn [7]. The construction requirements are particularly difficult for millimeter wave corrugated horns as they require direct machining or sacrificial electroformed mandrels.

In this novel design, brass plates are CNC machined and then stacked together to form the array which is held together with stainless steel screws and pins. A removable flare plate with elongated quarter elliptical flares was also constructed and mounted for some of the measurements as shown in Fig. 2. The single pixel horn internal structure is described in [2]. The array is designed to fit into the BEAST telescope optics as an optional part of a bolometric receiver described in [8]. Center and edge pixels performed comparably in S parameter measurements described later.

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M. M. Kangas, M. Ansmann, A. Levy, P. M. Lubin, and J. Marvil are with the Physics Department, University of California at Santa Barbara, Santa Barbara, CA 93106 USA (e-mail: Miikka@deepspace.ucsb.edu; markus@mcansi.net; alevy@deepspace.ucsb.edu; lubin@deepspace.ucsb.edu; marvil@deepspace.ucsb.edu).

B. Horgan is with the Physics Department, Oregon State University, Corvallis, OR 97331 USA (e-mail: briony@orst.edu).

M. N. Lemaster was with the Physics Department, University of California at Santa Barbara, Santa Barbara, CA 93106 USA. She is now with Princeton University, Princeton, NJ 08540 USA (e-mail: nicole@deepspace.ucsb.edu).

R. Leonardi and T. Villela are with the Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil (e-mail: Rodrigo@deepspace.ucsb.edu; villela@das.inpe.br).

P. McCreary is with the Engineering Department, University of California at Santa Barbara, Santa Barbara, CA 93106 USA (e-mail: pimccreary@umail.ucsb.edu).

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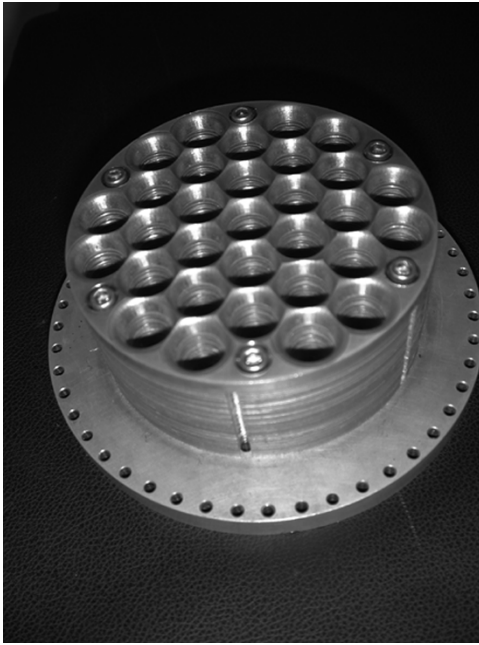


Fig. 2. Removable flare plate.

II. BEAM PATTERNS OF ELEMENT ANTENNAS

A. Antenna Design and Experimental Setup

The 31-pixel array is made from individual pixels similar to the horn described in [2] and [9]. The sheets of brass are captured with machined $1/8''$ steel pins and 8–32 stainless socket cap screws. All elements are nearly identical and perform similarly independent of the distance from the captivating screws and steel alignment pins. Comparisons of varied pixels to the center pixel show no noticeable perturbation of the edge pixels in either beam patterns or s-parameters.

The sidelobe data in this paper was taken with a computerized azimuth elevation. The detector was a monolithic microwave integrated circuit (MMIC) high electron mobility transistor (HEMT) amplifier based radiometer. The source was a fixed frequency 90-GHz Gunn diode with a variable attenuator and a KHz modulated power supply. The detector signal was locked in to the Gunn power modulation. An additional variant was constructed by adding a quarter ellipsoidal flare plate shown in Fig. 2. Bit noise can be seen in some of the data sets such as Fig. 3. The cross-polar signal is high in Fig. 3 possibly because of the flare plate, and when the flare plate is removed the beam size increases and the cross-polar level decreases to a lower level as seen in Fig. 4.

The detector is made up of W-band (75–110 GHz) low noise amplifiers (LNAs) feeding into a hybrid tee, with one input port terminated. This splits the signal into a W-band power amplifier and an isolator. The power amplifier is turned on or off by computer. The isolator prevents a feedback loop from being significant. The two signals are then combined in another hybrid tee, with one of the output ports terminated. This variable gain “bi-arm” radiometer exhibits a 20 dB gain differential based on a signal sent to a power relay to drive the W-band power amplifier.

The distance to the Gunn source, attenuation, and gain of the amplifiers is set so the detector diode is not saturated or under

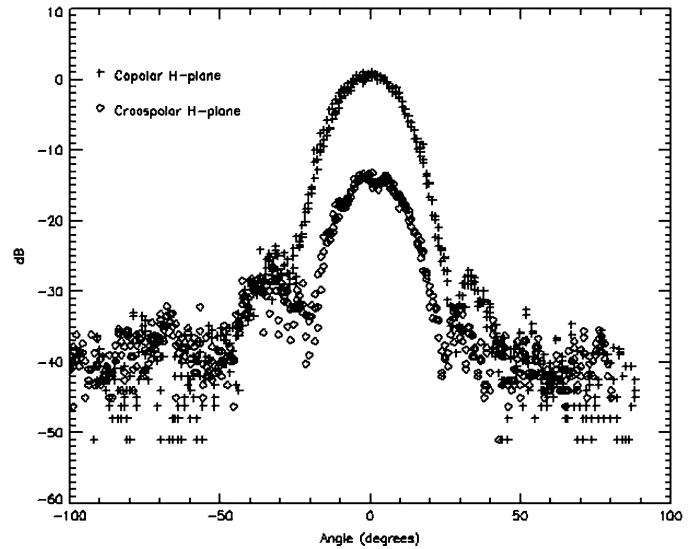


Fig. 3. Flare plate H-plane center pixel.

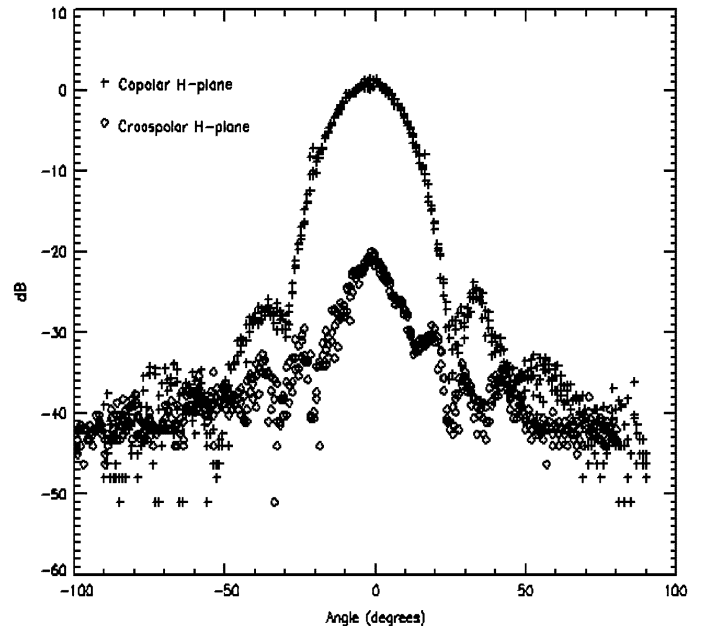


Fig. 4. No flare plate H-plane center pixel.

excited during normal operation. The source is rotated 90° with respect to the receiver for a cross-polar scan.

B. E and H Plane Results

Scans along the E-plane and H-plane resulted in sidelobe measurements at levels comparable to similar design electroformed silver or copper horns and single pixel platelet horns. For CMB anisotropy instrument feeds typical first sidelobe levels are at -25 dB. The measurements indicate the flare plate slightly reduced the beam width but at the cost of greater cross-polar contamination (Figs. 3 and 4).

The E-plane sidelobes were measured directly by scanning in Azimuth, while the H-plane sidelobes were scanned by adding 90° waveguide twists into the source and detector.

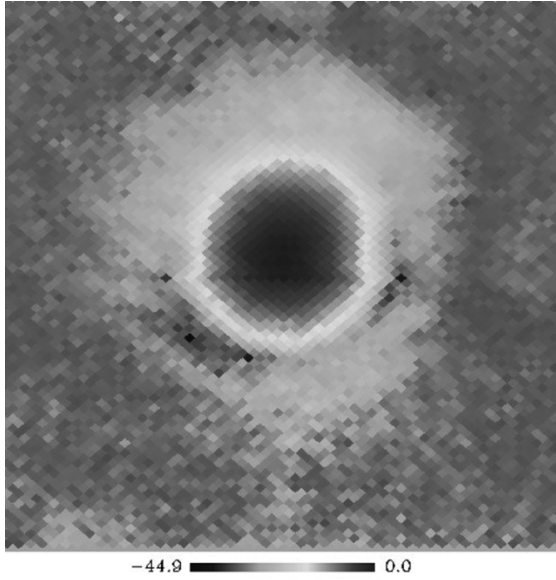


Fig. 5. Typical flared co-polar beam pattern.

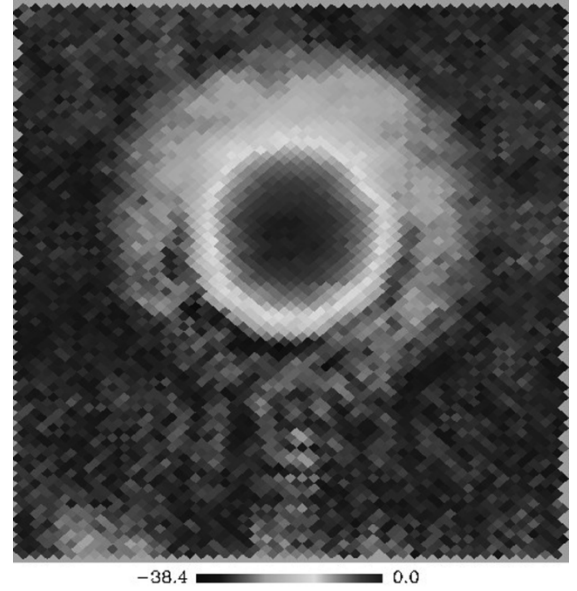


Fig. 7. Typical co-polar beam pattern.

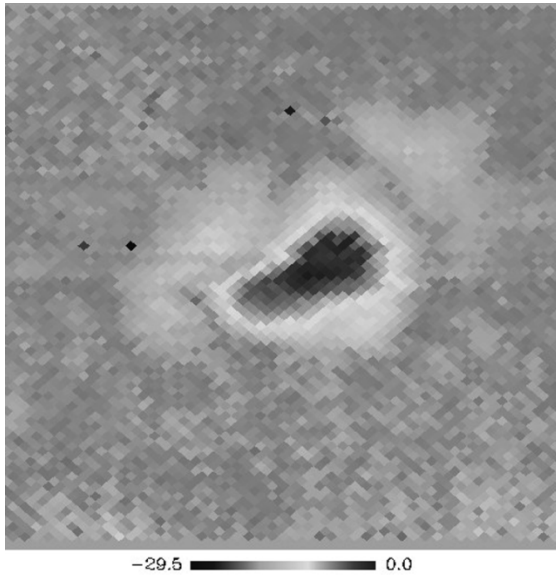


Fig. 6. Typical flared cross-polar beam pattern.

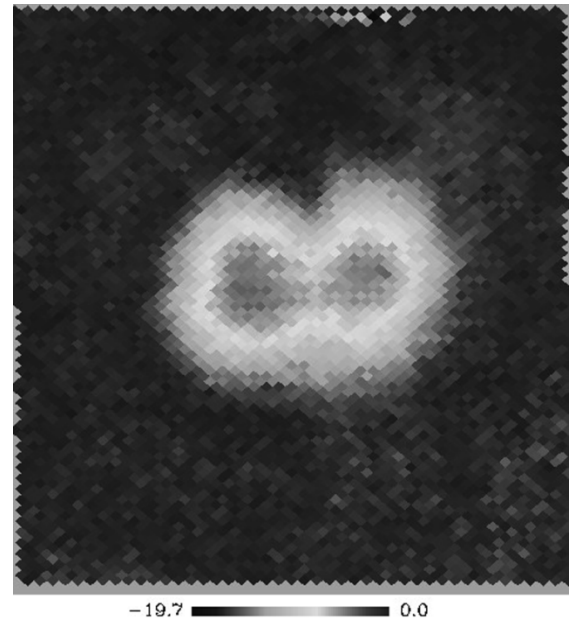


Fig. 8. Typical cross-polar beam pattern.

C. Two Dimensional Sidelobe Pattern

Full two-dimensional scans of the lobe structure of the horns were possible with the computerized azimuth-elevation stages. Several different physical locations including the roof of the physics building and inside a dedicated laboratory room were tried with similar resulting sidelobe measurements.

The data was reconstructed into a map using a data analysis package for interactive data language (IDL) called HealPIX. The copolar beam structure in Fig. 5 and the cross-polar beam structure in Fig. 6 for the flare plate array was distorted by the flare plate such that the copolar beam structure in Fig. 7 was comparable to the unflared result but the cross-polar result in Fig. 8 was not.

D. Reflection and Loss Measurement

Reflection coefficients were measured with a W-band vector network analyzer (VNA). The array is oriented so two horns are in the top and bottom row, and 5 horns make up the center row. The horns are numbered consecutively from left to right row by row, so the center pixel is #16, and two pixels to the left and near the edge and a tightening bolt is pixel #14. The E-plane for the measurements was the vertical plane up from the center pixel in this numbering scheme, and the H-plane was the horizontal plane that cut through pixels 14–18. The S_{11} measurement of the platelet pixels were different but comparable in general magnitude to the S_{11} measurements of a copper electroformed horn and a previous straight platelet horn [2] and shown in Fig. 9. Also, the difference between center (pixel 16) and edge pixels

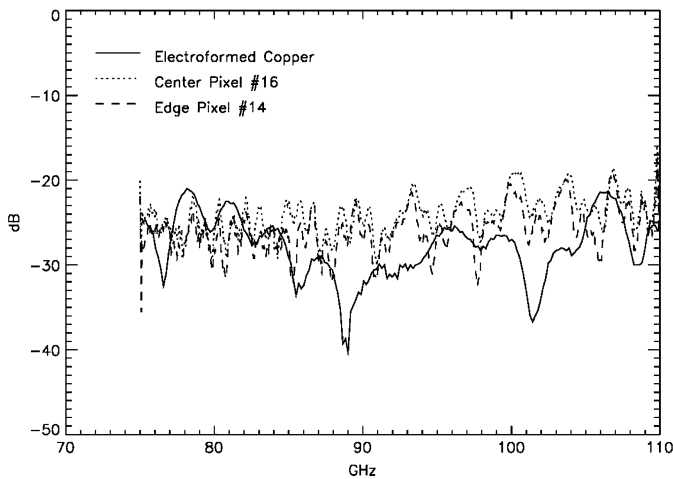


Fig. 9. S11 parameters.

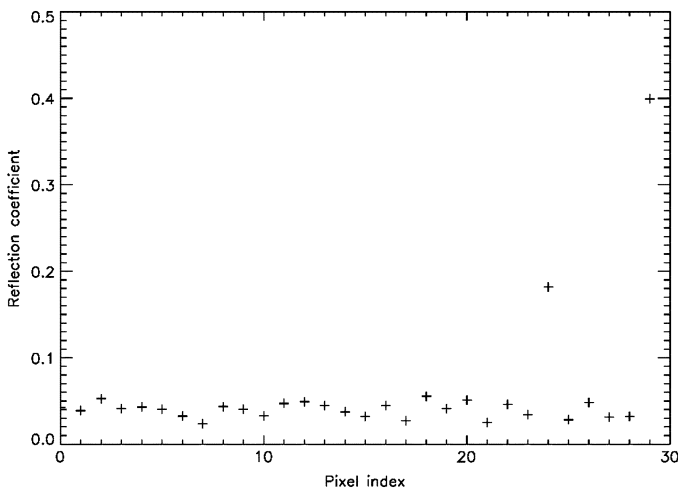


Fig. 10. Pixel number versus reflection coefficient.

(pixel 14 shown) in the measured S parameter were insignificant. This difference from electroformed horns in reflection coefficient may not be important for many applications such as millimeter-wave astronomy [10].

The pixel reflection coefficients for signal fed into the circular waveguide feed and transmitted out of the horn into an eccosorb load is calculated based on a broadband average across 80–100 GHz and is shown in Fig. 10. A few pixels such as 24, 30, and 31 were bad because of a atypical gross machining defect in the base plate. These were caused by a drilling position error

in the test mount leading to a test waveguide position error and high reflection coefficient, and not in the platelet horns themselves and therefore do not reflect on the platelet technology construction reliability. Ignoring these gross machining errors the platelet stack had a fairly uniform performance independent of proximity to the alignment pins and clamping screws as seen in Fig. 9. This indicates large arrays of mechanically clamped corrugated feeds can be constructed cost effectively without significant filling factor from the mechanical clamping screws or pins.

III. CONCLUSION

A new form of platelet horn array has been developed. The low cost and ease of construction allows manufacture of arrays of corrugated feeds in laboratory settings, and the ability to disassemble and reassemble the horn allows for modification of the feed post-installation in a millimeter-wave instrument such as the addition of flared plates to alter beam properties.

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