A SUBMILLIMETER WAVE PLATELET HORN ARRAY: FABRICATION AND PERFORMANCE

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Abstract

A technique has been developed for the economical construction of arrays of efficient corrugated conical feedhorns for use in multiple beam antenna systems. These horns, called "platelet horns", are constructed from platelets, thin metallic plates in which holes are photoetched and which are then stacked and diffusion bonded together to form a monolithic structure with internal features. This technique was first demonstrated by the fabrication and test of a nine element array for W-Band [1]. Since that demonstration, this technique has been further advanced with the fabrication and test of a 16-element array of profiled corrugated horns for W-Band as well as an array for 550 - 750 GHz operation.

This paper presents the results of performance measurements of these arrays at W-band and at 527 GHz and 762 GHz.

Introduction

Millimeter wave and submillimeter wave remote sensing systems such as those used for radio astronomy and earth observations from space require highly efficient antenna systems. This high efficiency translates directly into reduced observation time and more accurate calibration. Platelet horn arrays were developed in response for a need for a method to fabricate relatively large arrays of highly efficient feed horns for focal plane array remote sensing systems.

It is well known that the corrugated horn is an excellent feed because of its symmetrical Gaussian beam, low side lobes and low cross polarization. However, with conventional methods, the manufacture of arrays of such horns for millimeter wave frequencies and higher is very expensive since the horns must be individually fabricated using non-reusable mandrels. Also, it is extremely difficult to make them for frequencies above 400 GHz.

Platelet Horn Arrays

As shown in Figure 1, the platelet horn array is fabricated using platelet technology. Platelets are thin sheets of metal containing patterns of holes. These sheets are sandwiched together in a stack of many layers, and then diffusion bonded together to make a single monolithic construction, having within it, holes, channels, cavities, etc., or arbitrary shapes. These hole patterns are defined and etched in the platelets using standard photolithographic or laser machining techniques. Thus, once a design is completed, and the photolithographic masks or machine programs are created, many platelets can be reproduced accurately and economically. It is estimated that arrays for up to 1200 GHz can be fabricated with this technique.

Besides etching out holes in the platelets to form the horns, additional cavities can also be created to lighten the structure. Also channels through which a coolant can be circulated can be incorporated for thermal control of the attached electronics.

In the original work on platelet horn arrays [1], the fabrication and test of an array of nine W-band conical corrugated horns was reported. It was shown, that for this array, which was made out of zirconium copper, the horns performed just as well as an identical electroformed horn, which demonstrated that there was no deterioration in performance due to this new manufacturing technique. However, that array was quite heavy, as it was mostly solid copper. Accordingly, a second array was fabricated with the goal of making a much lighter array, suitable for eventual space applications. This was accomplished by using shorter “profiled” horns, substituting aluminum for copper, and etching out much of the unnecessary material between the horns. The resulting W-band sixteen-horn array is shown in Figure 2. Again, measurements demonstrated that these array horns also performed just as well as an identical electroformed version. Typical patterns are shown in Figure 3. This figure also shows that this particular profiled horn design [2], does not produce the Gaussian patterns expected from a conical horn; note the shoulders at -8 dB. It is possible to get a much better pattern [3], but it takes a computer intensive optimization routine which is usually very slow [4].

Submillimeter Wave Horn Array

Having demonstrated the suitability of platelet technology for producing horn arrays at W-band, it was next attempted to extend this technology to the submillimeter regime. The above sixteen horn design was scaled up to 626 GHz to be compatible with an SIS receiver at this frequency at JPL and is shown in Figure 4. The same horn design was used to save platelet design time. The resulting horns were 0.296 inches long with aperture diameters of 0.1232 inches. The design called for platelets of only 0.002 inches thick and they were made of #347 stainless steel, copper plated, both as a bond aid and to reduce the surface electrical resistance.

In order to make the pattern measurements, a matching detector array was fabricated at the University of Michigan. This array consisted of dipole fed bolometers suspended on membranes in etched silicon pyramidal cavities. The geometries of these integrated horn antennas are shown in Figures 5 and 6. It has previously been demonstrated that such integrated horn antennas can be used to drive metallic horn extensions [5]. In this case, the "extensions" were the platelet horns. The array of integrated horn antennas was mounted behind the SMMW platelet horn array and aligned by looking down the boresight of the platelet horn with a microscope. The aperture of the integrated horn was brought into firm contact with the feed side of the platelet horn array using x-y-z micrometers and kept flush by mechanical pressure. Pattern measurements were made at 527 GHz and 762 GHz and the results are shown in Figure 7. The groove depths are such that the horn should work reasonably well from 550 GHz to 750 GHz.

527 GHz Measurements

These measurements were made at the University of Michigan using a RPG-Radiometer 450-520 GHz sixtupler fed by a Carlstrom tunable Gunn oscillator operating at 87.8 GHz. The specified output power was 460 μW. However, the power was coupled out using a 345 GHz standard gain horn which probably lost a significant fraction of the power to higher order modes. This resulted in a low dynamic range of about 18 dB. The measured patterns show excellent rotational symmetry. No cross-polarization measurements could be made due to the low signal-to-noise ratio, but no cross-polarization could be detected above the noise floor. The directivity of the horn, calculated from the E-plane measured data and assuming perfect rotational symmetry, is 21.75 dB. Since the physical aperture is 7.7 mm^2, this directivity translates into an aperture efficiency of 50% at 527 GHz.

762 GHz Measurements

These measurements were performed at the NASA Goddard Space Flight Center using a CO_2 -laser-pumped FIR gas laser. The 762 GHz radiation was produced from the 393.6 μm line of Formic acid. The output of the laser was estimated to be 500 μW and it was chopped at 100 Hz with a mechanical chopper. The resulting dynamic range was about 20 dB. The pattern showed good rotational symmetry and the shoulders expected from the W-band measurements were clearly observed. In fact, the 3- and 10- dB beamwidths were almost exactly the same as those measured on the W-band array at 106 GHz and the shoulders were at the same power level (762 GHz scales to 110 GHz). The directivity of the horn at this frequency, calculated from the E-plane measured data and again assuming perfect rotational symmetry, is 23.2 dB, which translates into an aperture efficiency of 34%.

Conclusion

A technique has been demonstrated for the production of arrays of submillimeter wave corrugated horns and it is estimated that the technique can be used for horns up to 1200 GHz. Measurements have been made up to 762 GHz and show the radiation patterns to be similar to those measured from a W-band version. While measurements have shown no added losses due to this manufacturing technique at W-band, loss measurements have not yet been performed at submillimeter wave frequencies. but are planned for the near future.

References

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[4] Olver, A.D., Private communication, Aug. 1993

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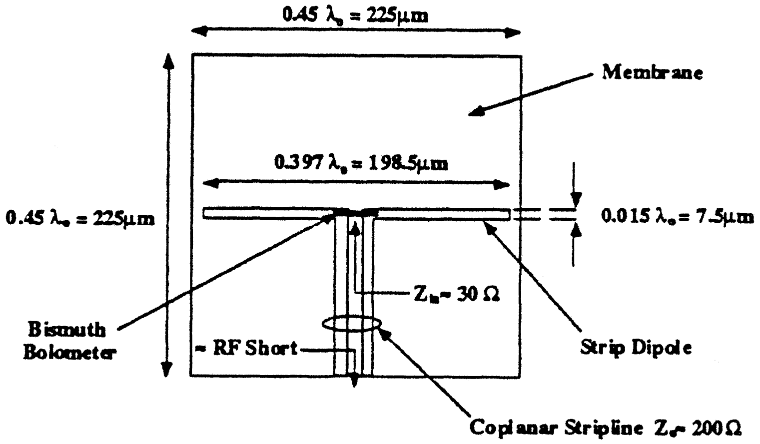
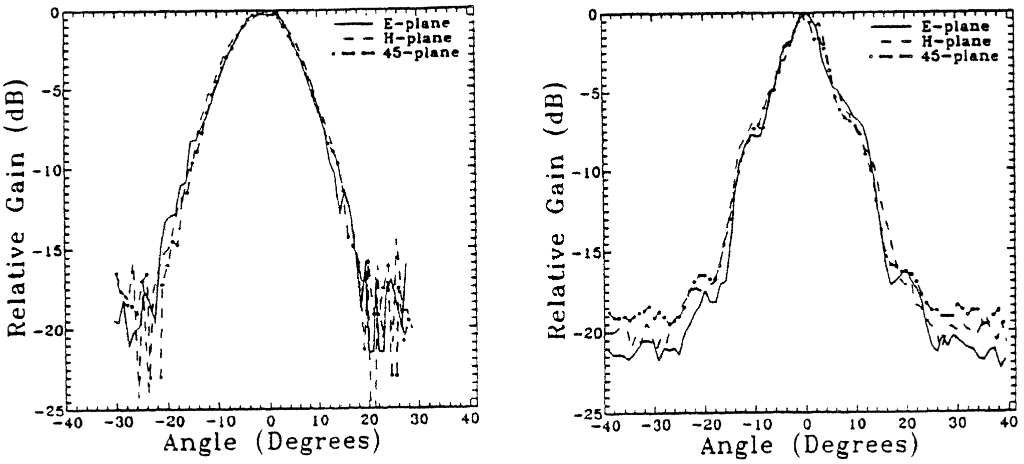


Figure 6. Antenna and Feed Structure



527 GHz

762 GHz

Figure 7. Submillimeter Wave Array Radiation Patterns

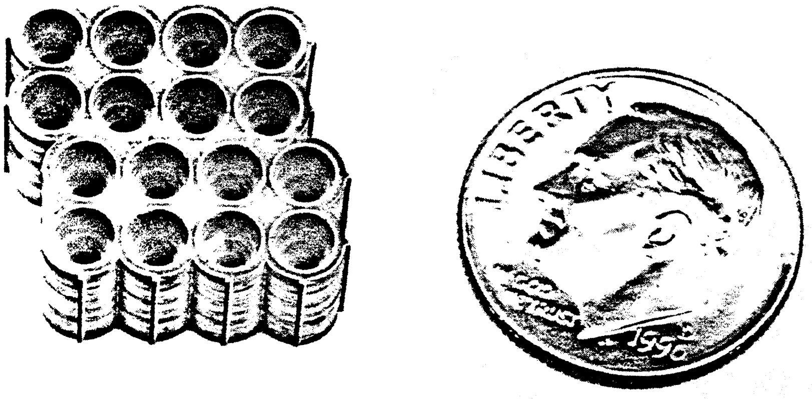


Figure 4. Submillimeter Wave Platelet Horn Array

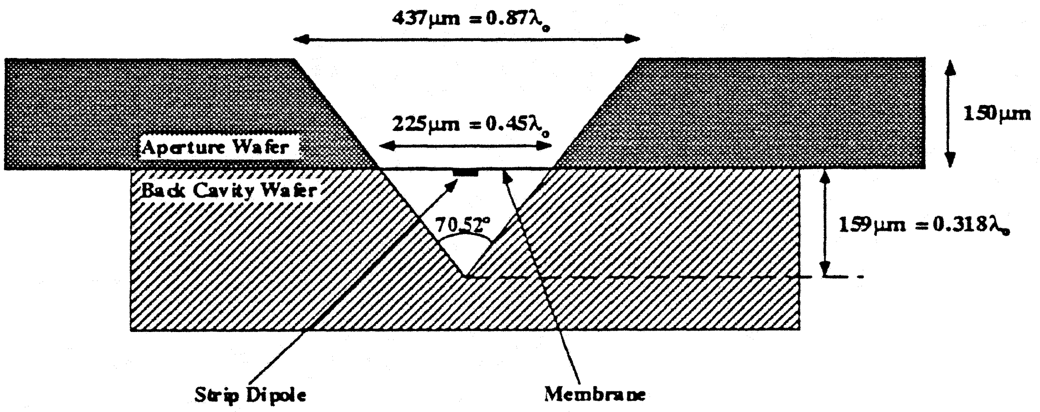


Figure 5. Integrated Pyramidal Horn Structure

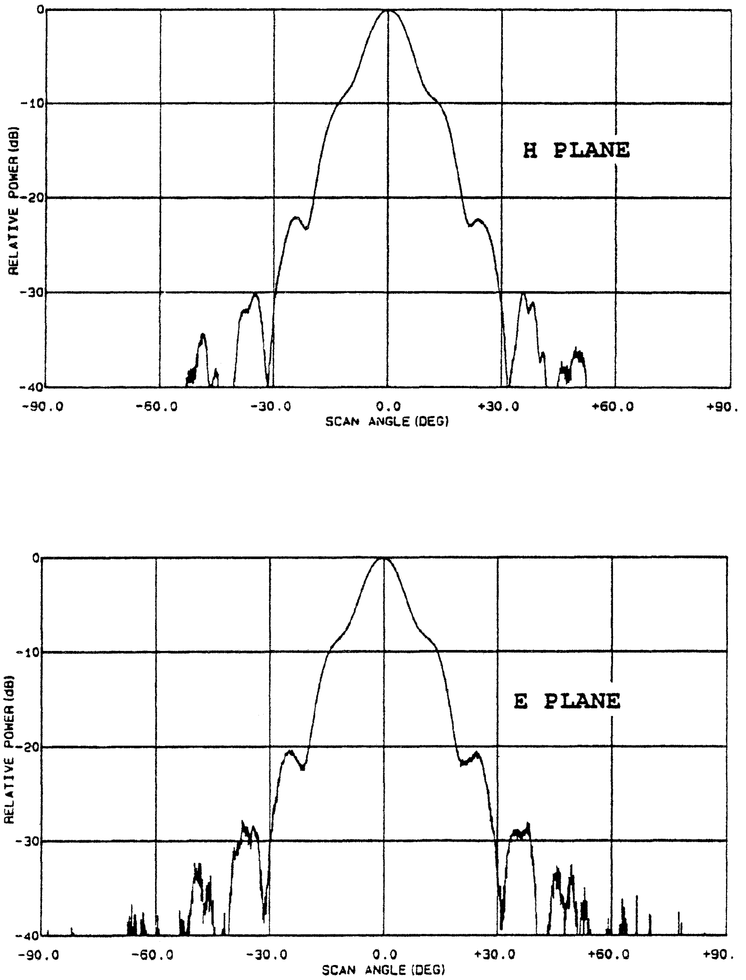


Figure 3. 94 GHz Radiation Patterns of Profiled Platelet Horns

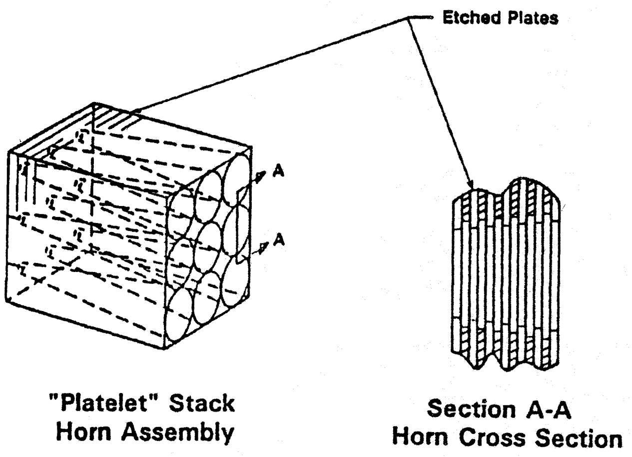


Figure 1. Principle of the Platelet Horn Array

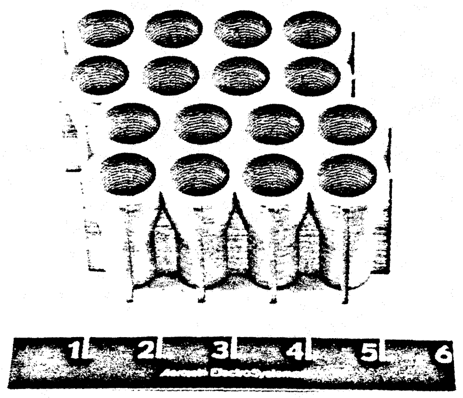


Figure 2. W-Band Array of Profiled Platelet Horns