A Ka-BAND CIRCULARLY POLARIZED HIGH-GAIN MICROSTRIP ARRAY*

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Introduction: This article presents a circularly polarized microstrip planar array that resonates at 32 GHz and provides a broadside beam, a minimum gain of 28 dB, and a bandwidth greater than 1 GHz. This low profile, small mass antenna shall be surface mounted on a microspacecraft that is being developed for future, deep space, NASA missions. Challenges arising from the development of this Ka-band antenna include the minimization of the array's feed network loss and the attainment of the required bandwidth.

High-gain microstrip arrays that have previously been developed for Ka-band or higher frequencies have primarily been linearly polarized (l.p.)[1,2] In the case of this array, circular polarization (c.p.) is achieved by employing the sequential rotation technique[3] in which each patch element is excited at a single feed point. This technique is employed to minimize the insertion loss that occurs in the microstrip transmission line feed network and to satisfy the array bandwidth requirement. To further reduce the insertion loss, the feed network uses a combined parallel and series feed technique that was developed recently'< 5]. By designing the microstrip line feed network with matched impedances throughout the entire circuit, the bandwidth performance is further enhanced,

Antenna Design: The antenna array shown in Figure 1 consists of 192 microstrip patches and has an aperture size of 10.8cm x 8.3cm. It is printed on Duroid substrate having a relative dielectric constant of 2.2 and thickness of 0.025cm. The 192 patch elements are separated into 48 identical 4-element subarrays. Such a subarray is illustrated in Figure 2. The four elements in the subarray are identical square patches each of which has two truncated corners, The individual patches differ from one another in orientation and in electrical phase by multiples of 90°[3] The input/output coax connector, located at the center of the array, feeds the microstrip transmission line with a two-way power division which splits the power equally to the left and right identical halves with a parallel divider, Each half array is then fed serially in columns by the microstrip line. The upper and lower halves of the array are fed in parallel at the array's horizontal center line and then serially distributed to the subarrays in each column. This combined parallel/series feed technique[4] is used to minimize insertion loss with its series feeds and to achieve a reasonable bandwidth (without beam squint effect) with its parallel feeds.

The truncated corner patch element design is based on the Cavity Model Theory [e] and the variational method[7]. The microstrip power division circuit was designed using the simple closed-form microstrip line equations, Note that at each power division point in Figure 1, the microstrip line changes width, These changes in width assure uniform power distribution throughout the array. The microstrip lines are impedance matched at every junction point throughout the array so that multiple reflections of the signals are minimized to reduce insertion loss. Furthermore, the bandwidth of this array is greater than the conventional "resonant" array in which impedances are not matched and multiply reflected signals are significant. Although the array in Figure 1 appears to be a resonant array, it is actually classified as a traveling wave array. The horizontal microstrip line length between adjacent columns and the vertical line length between the adjacent subarrays are all integral multiples of the effective wavelength. These line lengths ensure that the far-fields of the patches are all in phase in the broadside direction. Two effective

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wavelengths are used here so that it is long enough to physically accommodate the subarrays and yet short enough to avoid excessive insertion loss, Because of this effective wavelength requirement, the spacing between adjacent patch elements is 0.74 free- space wavelengths.

Experimental Results: The input/output to the array is an OS-50 coax connector. The measured input return loss of the array is given in Figure 3 where a return loss of -23.6dB (1.14: 1 VSWR) is noted at 32 GHz. The 1.5:1 VSWR bandwidth is about 2 GHz. This wide impedance bandwidth is partly the result of well matched lines and relatively large ohmic losses in the lines that attenuate reflections. Two tuning stubs located a quarter wavelength away from the input connector are used to eliminate the input transition mismatch. One of the measured principal plane patterns is shown in Figure 4. The 3dB beamwidths in the two principal planes are 4.5° and 5.7°. These patterns show a peak sidelobe level of -12dB and a peak cross-pot level of -1 8dB (corresponds to 2dB axial ratio). It is believed that the cross-pot radiation is caused primarily by the accumulated phase errors in the series-fed microstrip lines and by the leakage radiation from these lines, The measured 3-dB axial ratio bandwidth of the array is 1.3 GHz. This relatively wide c.p. bandwidth is the result of the sequential arrangement of the subarray elements. The array has a peak gain of 28.4 dB. Based on the radiating aperture size, the calculated directivity of a uniformly distributed array is 31 dB which implies that the array has an overall efficiency of 55°A with a total loss of 2.6 dB. Approximately, half the loss is attributed to the Ohmic loss of the feed network and the remaining loss is due to cross-pol radiation, mismatches, patch loss, etc. The antenna exhibits a 1 dB maximum gain drop across a bandwidth of 0.95 GHz. This drop is surprisingly small because of the combined parallel/series feed. The antenna's total mass, including an aluminum supporting back plate, is 0.05 kg.

References:

1. M.A. Weiss, "Microstrip Antennas for Millimeter Waves,' IEEE Trans. Antennas& Propagation, Vol. AP-29, pp. 171 -174, Jan. 1981.

2. P. Bhartia, et al, "Millimeter-Wave Microstrip and Printed Circuit Antennas, " Artech House, 1991.

3. T. Teshirogi, et al, "Wideband Circularly Polarized Array Antenna with Sequential Rotations and Phase Shifts of Elements," Proc. Int. Symposium on Antennas & Propagation, Japan, pp. 117-120, 1985.

4. J. Huang, 'A Parallel/Series Fed Microstrip Array with High Efficiency and Low Cross-Pol," Microwave & Optical Technology Letters, Vol. 5, No. 5, pp. 230-233, May 1992.

5. D. Pozar and D. Schaubert, "Comparison of Three Series Fed Microstrip Array Geometries," IEEE AP-S/URSI Symposium Digest, pp. 728-731, June 1993.

6. Y. T. Lo, et al, "Theory and Experiment on Microstrip Antennas," IEEE Trans. Antennas & Propagation, Vol. AP-27, pp. 137-145, March 1979.

7. M. Haneishi, et al, "A Design Method of Circularly Polarized Rectangular Microstrip Antennas by One-Point Feed,' Electronics and Communications in Japan, Vol. 64-B, No. 4, pp. 46-54, 1981,

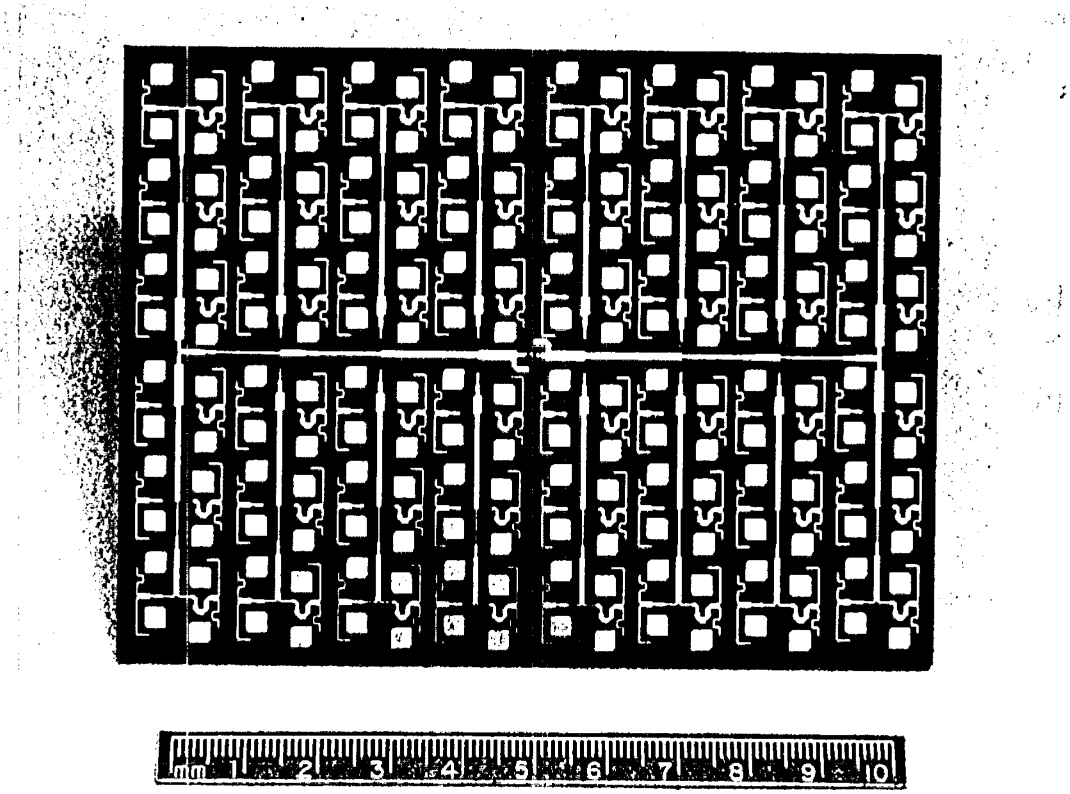

Figure 1. Photo of the circularly polarized Ka-band microstrip array antenna

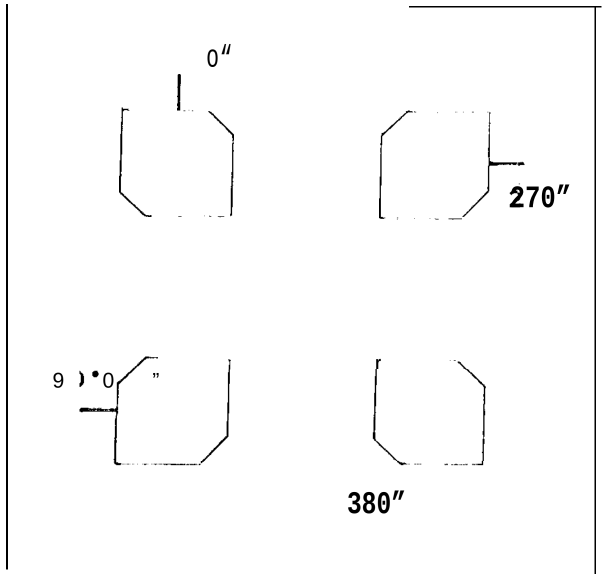

Figure 2. Sequential arrangement of four truncated-corner square patch elements.

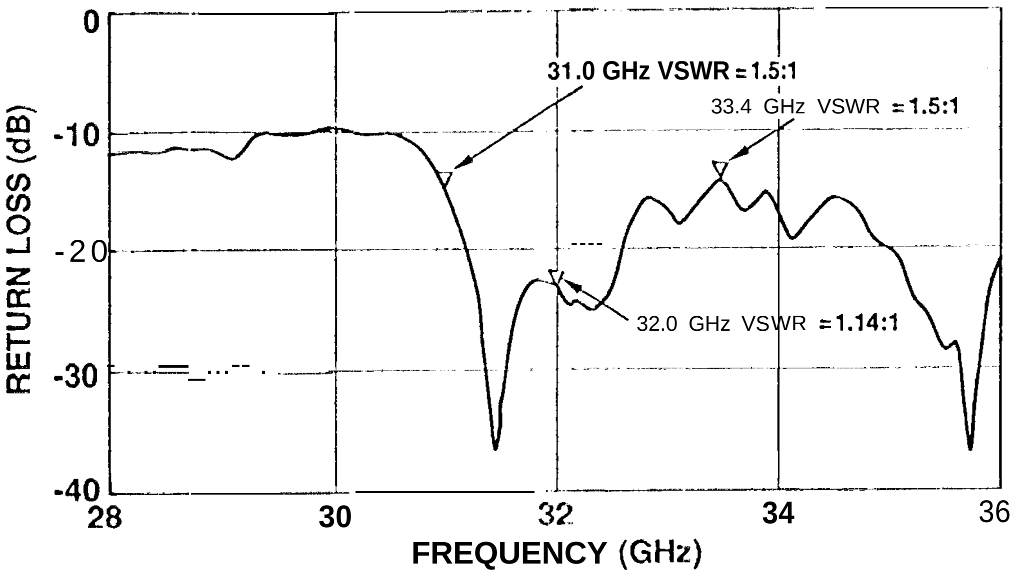

Figure 3. Measured input return loss of the microstrip array shown in Figure 1

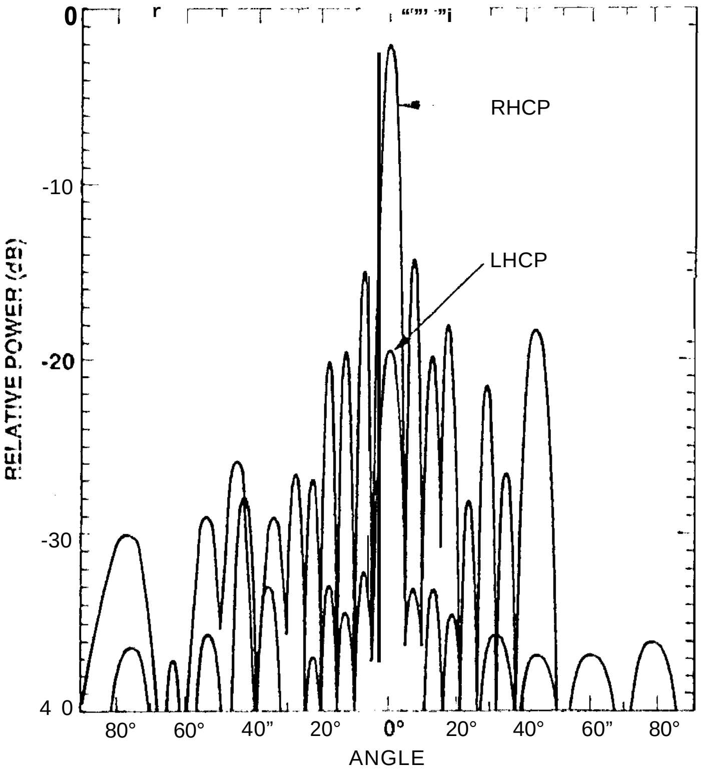

Figure 4. Measured radiation pattern in the narrow-beam plane (horizontal plane of Figure 1)