Flat-Panel Wideband Dual-Circularly Polarized 8×8 Phased Array Antenna for SATCOM Applications

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***Abstract*— A wideband, dual-circularly polarized (CP) 8×8 phased array is designed for operation at *K-/Ka*-band, which exhibits wide impedance and axial ratio (AR) bandwidths that encompass both of the desired satellite communication (SATCOM) bands of 22.55–23.55 GHz and 25.5–27.5 GHz. The array has a scan range of ±50° and ±36° at 23.05 GHz and 26.5 GHz, which are the center frequencies of the two aforementioned bands. The array has been integrated with a beamforming network utilizing 5G silicon RFICs, and the measurement results will be presented during the conference.**

Keywords—flat-panel; phased array; SATCOM; stacked patch; sequential rotation; beam scan; beamforming

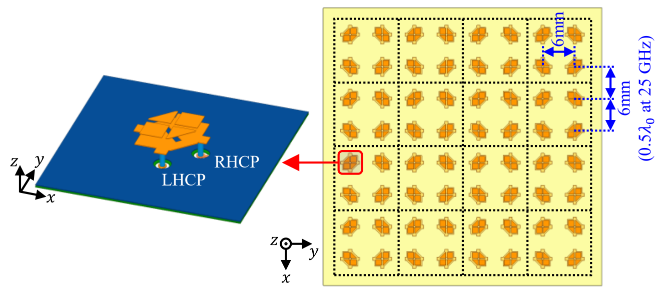


Fig. 1. Proposed 8×8 phased array along with the wideband dual-CP radiating element.

I. Introduction

Flat-panel electronically-scanned phased arrays are quickly becoming a mainstream technology in the areas of SATCOM applications. These antennas are advantageous compared to a mechanically steered reflector solution due to their low-profile, light weight, and fast, accurate beam steering [1]–[2]. The end-goal of this work is to design a flat-panel phased array solution for CubeSats that could be used by the National Aeronautics and Space Administration (NASA) as a relay point between the lunar surface, the lunar gateway, and direct-to-earth. The array should operate in both transmit (Tx) and receive (Rx) modes, while supporting dual-CP radiation in two different operating bands: 22.55–23.55 GHz and 25.5–27.5 GHz (*K-/Ka*-bands).

Typically for flat-panel array applications, microstrip patch antennas are one of the most popular choices, mainly since they are compact, lightweight, inexpensive, easy to fabricate, and do not suffer from back radiation problems. Since the aforementioned bands are fairly close to each other, a wideband antenna was deemed to be a more practical solution. Now, it is relatively straightforward to achieve a wide impedance bandwidth from a patch antenna using a stacked patch configuration [3]. However, it is rather difficult to achieve both wide impedance and axial ratio (AR) bandwidths simultaneously without complicating the structure [4]–[5], which can become a manufacturing issue at higher frequencies, such as *K*- and *Ka*-bands. As a remedy, a sequential rotation technique can be used, which is known for improving the AR bandwidth of an array considerably [6]. In the presented work, a stacked patch configuration has been developed that is easy to fabricate and exhibits a wide impedance bandwidth along with excellent dual-CP characteristics by means of the application of a sequential rotation technique. One issue of using microstrip patch antennas for wideband applications is the appearance of higher order modes within their impedance bandwidth, which typically result in a broadside null, thereby creating a drop in the broadside gain value. In the presented design, a novel modification is introduced to the parasitic patch that resulted in an almost invariant gain profile in the desired frequency band by shifting the gain drop region to higher frequencies.

II. Radiating Element and 8×8 Phased Array

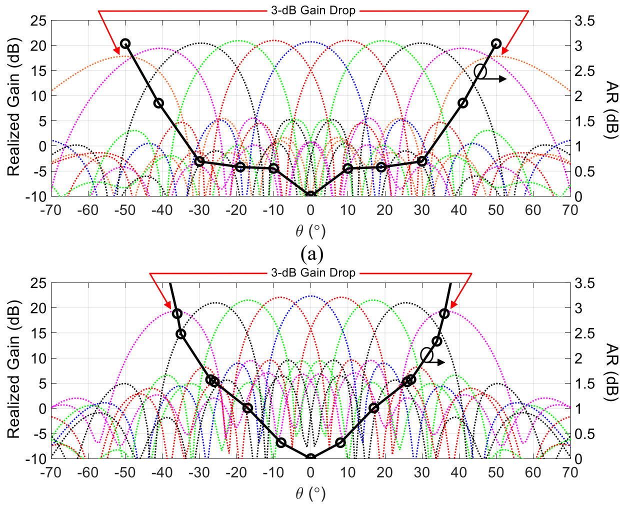
The radiating element selected for this work is a stacked patch antenna that includes two square-shaped corner-truncated patches, where the driven patch additionally comprises a diagonal slot for improving the CP quality and four symmetrical stubs on the four sides of the patch to tune the overall bandwidth. The parasitic patch showcases a novel '+' shaped slot, which helps in realizing an invariant gain vs. frequency profile for the radiating element [3], [7]. Each radiating element features two orthogonally-placed probe feeds, each of them responsible for one particular sense of CP. The simulated impedance bandwidth of the radiating element spans in the range 22.3–43.4 GHz (~64.2%), with a 3-dB gain-bandwidth from <20 GHz to 32.9 GHz (>48.7%). The 3-dB AR bandwidth is expectedly narrow, only 5.14% around 25 GHz.

In order to improve the AR bandwidth, sequential rotation was used during array formation. First, a 2×2 subarray was created using the radiating element following the sequential rotation technique, where each element is rotated physically by 90°, with respect to the neighboring elements, followed by the assignment of another 90° input phase value. The elements are separated by $\lambda_0/2 = 6$ mm (where λ_0 is the free-space wavelength at 25 GHz, i.e., approximately the center frequency of 22.55–27.5 band). This offers a good compromise between

TABLE I
RADIATION PATTERN PARAMETERS FOR THE 8×8 PHASED ARRAY
(IDENTICAL FOR BOTH LHCP AND RHCP EXCITATIONS)

Parameter	23.05 GHz		26.5 GHz	
	$\phi = 0°$	$\phi = 90°$	$\phi = 0°$	$\phi = 90°$
Peak Broadside Gain	21 dBic		22.3 dBic	
HPBW	14°		12°	
AR Beamwidth	28°		26°	
Broadside AR	0.005		0.002	
Sidelobe Level	12.8 dB		13.3 dB	
Peak Co-to-X Pol Sep.*	21.1 dB		29.6 dB	29.7 dB

*Obtained in the range $-90° < \theta < 90°$.



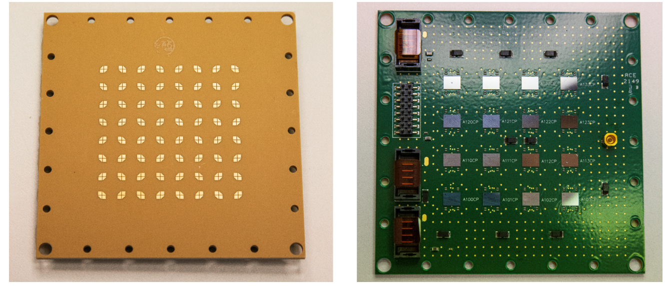
(b)

Fig. 2. Scanned realized gain patterns and AR for the 8×8 phased array at $\phi = 0°$ with LHCP excitation: (a) 23.05 GHz, and (b) 26.5 GHz.

the best available gain values at the higher frequencies and higher scan ranges at the lower frequencies. The full 8×8 phased array was formed by stacking the 2×2 subarrays side-by-side, as shown in Fig. 1.

III. SIMULATED RESULTS FOR THE 8×8 PHASED ARRAY

Uniform amplitude excitation values were applied during this study. The peak broadside realized gain, half-power beamwidth (HPBW), broadside AR, 3-dB AR beamwidth, sidelobe level (SLL), and the maximum co-to-cross-pol separation in the upper hemisphere ($-90°< \theta <90°$) for the two frequencies are presented in Table-I. It can be seen that, due to the symmetry of the structure, the array response is exactly identical on the two principal planes, i.e., $\phi = 0°$ and 90°, and for both LHCP and RHCP polarizations. The scanning performance was also studied by applying progressive phase shifts on the $\phi = 0°$ and 90° planes. The minimum progressive phase step used in this study is 5.625°, which corresponds to the 6-bit phase control ability of the selected beamforming chip. It was observed that at 23.05 GHz the array can successfully scan between ±50° on both $\phi = 0°$ and 90° planes, considering both 3-dB gain drop (from the peak value at $\theta = 0°$) and ≤3 dB AR criteria. At 26.5 GHz, the corresponding scan range is ±36°. The beam scan performance along with the AR at the particular scan angle are shown in Fig. 2. Data are shown only for the $\phi = 0°$ plane and LHCP excitation for brevity. At the highest scan angles, the sidelobe levels remain better than 13 dB and 10 dB for 23.05 GHz and 26.5 GHz, respectively. The 8×8 phased array prototype was fabricated and tested at the measurement facilities at NASA Glenn Research Center (GRC) and San Diego State University. The photographs of the top and bottom sides of the fabricated array are shown in Fig. 3.



(a) (b)

Fig. 3. (a) Top and (b) bottom sides of the fabricated 8×8 dual-CP phased array prototype.

IV. CONCLUSION

A wideband dual-CP 8×8 phased array antenna prototype was designed for *K-/Ka*-band SATCOM applications. The bandwidth of the array encompasses both the specified SATCOM bands while exhibiting a good CP response throughout. The array successfully scans between ±50° at 23.05 GHz and ±36° at 26.5 GHz, considering ≤3 dB gain drop and AR. The corresponding measured scan results, along with the *EIRP* and *G/T*, will be presented during the conference.

ACKNOWLEDGMENT

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