Scanning Characteristics of a Self-Adapting Phased-Array Antenna on a Wedge-Shaped Conformal Surface

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***Abstract*—The scanning characteristics of a linear five-element antenna array on a wedge-shaped conformal surface is investigated in this work. In particular, the half-power beamwidth (HPBW) of a self-adapting array is studied for various changing conformal surfaces. A general array factor expression is derived and used to compute the HPBW. From these results, the self-adapting limitations of the array are outlined. Finally, analytical computations are validated with measurements.**

***Index Terms*—Microstrip Array and Phased Array Antennas**

I. INTRODUCTION

Conformal antennas are finding more applications in modern communication systems [1] - [2]. Some of these applications include antennas on vibrating surfaces such as aircrafts [3] and textile antennas [4]. Throughout much of this development, several different phase and amplitude compensation techniques [5] - [8] have been developed to autonomously recover the radiation pattern of a conformal antenna if the surface the antenna is attached to changes shape during operation. Within much of this work on antenna compensation, various antenna parameters such as pattern distortion and gain have been investigated and reported. The objective of this work is to investigate the scanning properties of a phase-compensated antenna array on various wedge-shaped conformal surfaces.

II. PHASED-ARRAY ANTENNAS ON SINGLY CURVED SURFACES

Two properties of conformal antenna arrays are of interest in this work. First, the self-adapting capabilities of preserving the scanning characteristics of the array for various surface deformations are of importance. Second, computing the appropriate phases for various distortions is required. To explore these two properties, the five-element linear array shown in Fig. 1 will be considered. The array is attached to a conformal surface with a bend angle of θ_b measured from the x-axis. The inter-element spacing is denoted as d and each element is assumed to be isotropic with labels a_n where n = 0, ±1 and ±2. To compute the desired phases to preserve the scanning characteristics of the array, a plane wave propagating in the θ_o direction is defined. To support a plane wave in the θ_o direction, the elements on the conformal surface can be projected on the

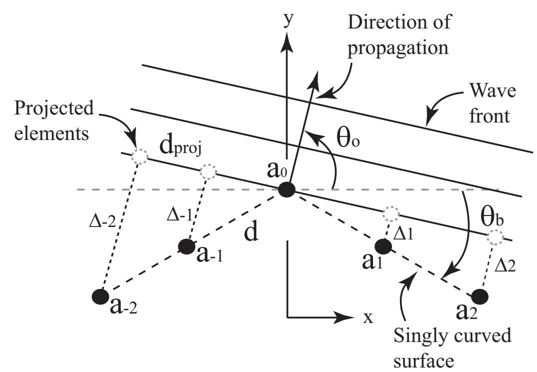

Fig. 1. A drawing of the five-element phased-array antenna on the wedge-shaped conformal surface.

plane wave surface corresponding to element a_0. Then, by adjusting the phases of elements a_n, where $n = \pm1$ and ±2, in the appropriate manner, the fields from these elements will arrive in the plane with the same phase as the field radiated from element a_0. This will then support radiation in the direction of θ_o (i.e., scan angle θ_o).

Next, using the angles θ_b and θ_o defined in Fig 1 , the angles required to drive the n^{th} element can be written as

$$\alpha_{nt} = kd(|n| \sin\theta_b \sin\theta_o - n\cos\theta_b \cos\theta_o) \qquad (1)$$

where k is the wave number. It should be noted, that further reduction of (1) will result in the phase-compensation equations reported in [8]. Then, the field from the array can be computed by using the following compensated array factor for a general linear array on a singly curved surface [8]:

$$AF_c = \sum_{n=1}^{N} V_n e^{j\alpha_{nt}} e^{jk[x_n(u-u_s)+y_n(v-v_s)+z_n\cos\theta]} \qquad (2)$$

where V_n are the complex voltages driving each element and (x_n, z_n) is the location of the n^{th} element in the linear array on the conformal surface in Fig. 1. Also in (2), a spherical coordinate system is assumed with $u = \sin\theta\cos\phi$, $u_s = \sin\theta_s\cos\phi_s$, $v = \sin\theta\sin\phi$, $v_s = \sin\theta_s\sin\phi_s$, θ_s is

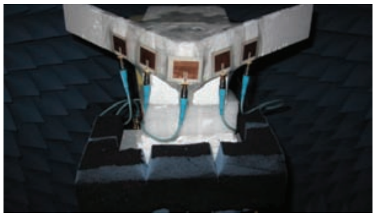

Fig. 2. Picture of the array being measured in the anechoic chamber.

the elevation steering angle and ϕ_s is the azimuth steering angle. In the next section, the half-power beamwidth (HPBW) properties of the five-element array will be investigated for various bend angles.

III. SIMULATION AND MEASUREMENT RESULTS

To validate the computations by (2), the five-element conformal array shown in Fig. 2 was manufactured and attached to a wedge-shaped surface with θ_b = $45°$. Voltage controlled phase shifters manufactured by Hittite Microwave Corporation [9] (PN: HMC928LP5E) were used to implement the phase correction. The phase compensation was then computed using (1) for scan angles θ_o = $50°$, $70°$, $90°$, $110°$ and $130°$. The HPBW measurements are shown to agree with the computations from (2) in Fig. 3, illustrating the accuracy of the phase compensations using (1).

Next, the HPBW properties of the five-element array were computed using (2) for wedge-shaped conformal surfaces with θ_b = $5°$, $15°$, $25°$, $35°$ and $45°$. The results from these computations are shown in Fig. 4. The case for $45°$ is shown again for comparison.

IV. DISCUSSION

Several unique comments can be made about the results in Fig. 4. The objective of this work was to investigate the limitations of phase compensation in conformal antennas. One of the limitations related to the HPBW is shown in Fig. 4. As the conformal surface the antenna is attached to becomes more deformed, the HPBW begins to increase beyond the HPBW of the array on a nearly flat surface (i.e., for the case $\theta_b = 5°$). This is a limitation of the phase-compensated antenna and can be kept in mind during the design process.

V. CONCLUSION

Expressions for exploring the HPBW of a five-element array on a wedge-shaped conformal surface have been presented. A prototype conformal phased-array antenna was constructed to validate the computations made by these expressions. Finally, it was shown that the HPBW of a phase-compensated conformal antenna is increased as the surface is more deformed, showing the limitation of this compensation technique.

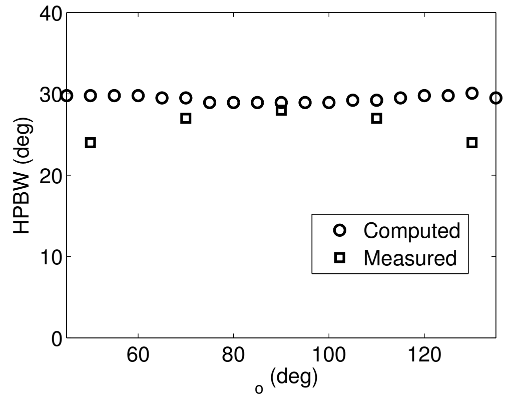

Fig. 3. Computed and measurement validation of the Half-power Beamwidth of the array at various scan angles for θ_b = $45°$.

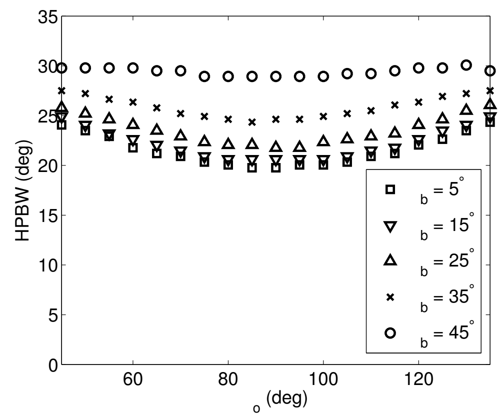

Fig. 4. Computed Half-power Beamwidth at various scan angles of the array for θ_b = $5°$, $15°$, $25°$, $35°$ and $45°$.

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