# Half-Power Beamwidth of a Self-Adapting Conformal 1 X 4 Microstrip Array

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***Abstract*—A new four element self-adapting conformal microstrip antenna array with an embedded sensor system and voltage controlled phase shifters is introduced. The sensor systems consists of a flexible resistive sensor used to measure the shape of the conformal surface and circuitry for measuring the resistance of the sensor. The voltage controlled phase shifters are controlled by the sensing circuitry and are used to introduce a specific phase compensation that dynamically preserves the radiation pattern of the array as the shape of the antenna changes. Specifically, in this work, the autonomous recovery of the half-power beamwidth (HPBW) of the four element array is investigated.**

## I. INTRODUCTION

Conformal arrays are very useful for nonplanar applications that require an antenna with the beneficial characteristics of a phased array antenna [1]. One of the draw backs of using conformal arrays is the negative effect that a conformal surface may have on the radiation pattern [1]-[3]. In fact, the results presented in [1] indicate that the directivity of a conformal array can be reduced by 5 - 15 dB by changing the shape of the conformal surface the antenna may be attached to. To compensate for this reduction in directivity, the antenna reported in [3] introduced fixed meander-line phase shifters to improve the radiation pattern of a conformal array. However, this method of phase compensation is restricted to a fixed conformal surface.

The antenna design presented in this paper is a self-adapting semi-flexible conformal antenna that can be applied to conformal surfaces that change shape over time. A schematic of the antenna is shown in Fig. 1. This new type of antenna consists of a 1 x 4 microstrip array, varactor diodes, flexible resistive sensors (strain gauges) and sensor circuitry. The varactor diodes are used as voltage controlled phase shifters to continuously compensate for surface deformation. The flexible strain gauge is attached to the back side of the array to measure the deformation of the array while the sensor circuitry is used to measure the resistance of the strain gauge and use this information to control the voltage controlled phase shifters. The meander lines were used to compensate for the insertion phase introduced by the varactor phase shifters. In summary, the antenna presented in this work compensates for surface deformation autonomously.

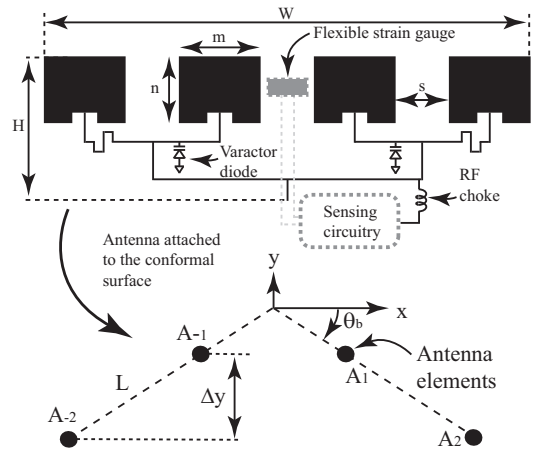


Fig. 1. A schematic of the four-element self-adapting microstrip antenna array.

## II. THE FOUR ELEMENT SELF-ADAPTING MICROSTRIP ARRAY: RESULTS

Consider the case when the array in Fig. 1 is attached to the singly curved surface, also shown in Fig. 1. When the array is in the flat position, each radiating element has a specific x- and y-location; however, when the array is attached to the curved surface, an x- and y-translation from the flat position is associated with each antenna element. To compensate for this translation, the equation [1]: $\delta_n = -k(|x_n|\cos\phi_s + |y_n|\sin\phi_s)$ where $k$ is the free space wave number, $\phi_s$ is the scan angle and $(x_n, y_n)$ is the location of the $n^{th}$ element in the linear array on the curved surface, can be used to compute a specific phase that can be introduced to the inner two radiating elements to recover the radiation pattern after deformation.

The surface mount voltage controlled varactor phase shifters were used to implement $\delta_n$ and were manufactured by Skyworks Solutions, Inc. [4] (part number: SMV1247-079). For the antenna array, a 1 x 4 microstrip array with a corporate feed network was designed with an operating frequency of 2.95 GHz on a flexible 1.27 mm thick Rogers RT/duroid 6010 [5] substrate in Momentum [6]. An image of the manufactured

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a) b)

Fig. 2. a) Picture of the prototype microstrip array and b) picture of the flexible strain gauge [7].

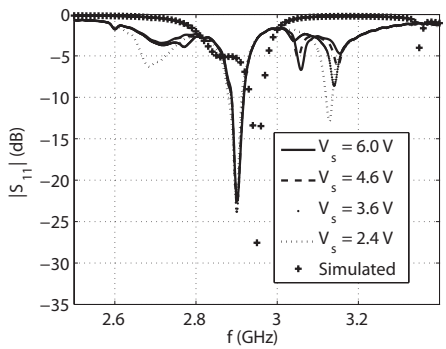


Fig. 3. Measured and simulated S-parameters for the 4-element array.

prototype array is shown in Fig. 2a). The flexible strain gauge was attached to the back side of the antenna design in Fig. 2a) to measure the surface deformation. A picture of the flexible strain gauge is shown in Fig. 2b) and the overall size of the gauge is 5 mm x 12 mm. To amplify the affects of the changing resistance, a Wheatstone bridge and instrumentation amplifier were used to control the phase shifters.

### A. S-Parameter Measurements

The prototype antenna in Fig. 2a) was then bent to specific angles to represent the attachment to the wedge-shaped conformal surface in Fig. 1. Then, the S-parameters were measured with the phase compensation circuitry active for bend angles $\theta_b = 0°, 5°, 10°, 15°$. The results are shown in Fig. 3 and a good impedance match can be observed at 2.9 GHz.

### B. Pattern and HPBW Measurements

For each bend angle, $\theta_b = 0°, 5°, 10°, 15°$, the performance of the phase compensation circuitry was tested by measuring the field of the antenna in the x-z and y-z planes. Specifically, to determine if the antenna is indeed self-adapting to the different conformal surfaces, the HPBW was measured in the x-z plane and compared to the simulated field patterns of the array in the flat postion. The results from these measurements are shown in Figs. 4 and 5. The measured results in Fig. 4 are for the antenna attached to a conformal surface with a bend angle of $\theta_b = 15°$. The self-adapting properties of the array are validated by comparing the compensated (corrected) and uncompensated (uncorrected) fields to the simulated fields.

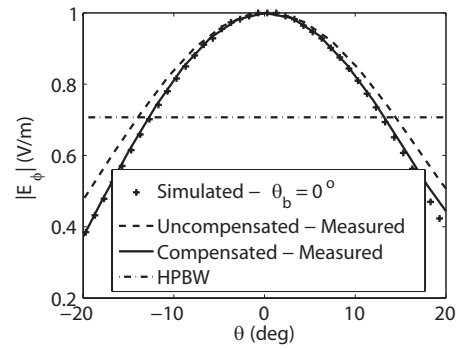


Fig. 4. Fields showing the HPBW in the x-z plane.

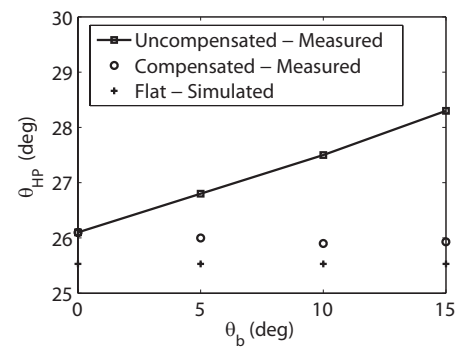


Fig. 5. HPBW in the x-z plane.

Furthermore, the flat compensated results in Fig. 5 show that the HPBW can be recovered for each bend angle.

## III. ACKNOWLEDGEMENTS

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## IV. CONCLUSION

A new self-adapting four element microstrip array has been developed and presented. An embedded sensor system has been used to sense the deformation of the antenna and control the varactor phase shifters used to introduce the appropriate phase compensation for pattern recovery. It is shown that this antenna design can be used on many different conformal surfaces with autonomous self-adapting capabilities.

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