UWB Antenna Element on Conformal Substrate for S-K_U Band Applications

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Abstract*—We present an ultra-wideband (UWB) antenna element printed on a Rogers/Duroid flexible substrate for S-K_u band sensing applications. The element is based on a planar rectangular combination monopole antenna (PRCMA), which obtains UWB operation over a frequency range of 2-18 GHz without significantly compromising the gain compared to a standard monopole design. The PRCMA is based on a simple planar rectangular monopole antenna (PRMA) and obtains wideband operation with a parabolically curved feed structure. The elements were designed at a frequency of 9 GHz, yielding a fractional bandwidth of 160 %. The antenna was analyzed as a function of the radius of curvature of the substrate to evaluate the performance when integrated onto various curved surfaces. The antenna was measured at a maximum curvature radius of 25 cm and minimum of 3.5 cm. The antenna was simulated and measured, yielding a maximum gain of 2.53 dBi across the lower band of 2-6 GHz and 6.24 dBi across the upper band of 6-18 GHz.

I. Introduction

Common approaches to UWB conformal antenna designs, specifically those for UAV-based applications, are generally focused on Vivaldi or monopole antennas in conjunction with additive reflectors in order to achieve a design with sufficient bandwidth and gain across the desired band [1]–[3]. However, such designs are often limited by a combination of mechanical and electromagnetic restraints. Such mechanical challenges can include complex mounting mechanisms due to complicated antenna designs or complex surfaces. Electromagnetic challenges are often characterized by gain and radiation pattern instability near the upper limits of the bandwidth, leading to lower average gain across the band as a consequence. To overcome challenges of integration onto complex surfaces, conformal or flexible substrates can be used [4], [5]. Conformal substrates have been explored in many works. In [6] the radius of curvature was shown to cause the radiation characteristics to vary appreciable over the bandwidth of operation. These challenges have been addressed in recent years, with various approaches attempted. Among these are planar elliptical monopole antenna (PEMA) designs and similar structures [7]–[9]. Such antennas have relatively straightforward designs determined by specifying the lower and upper frequency bounds [4], [5], [10]. Here, we implement a planar rectangular monopole antenna with a parabolically curved feedings structure. Planar rectangular combination monopole antenna (PRCMA) are similar, but implement the physical taper of the antenna with discrete steps, whereas here we use a continuous structure.

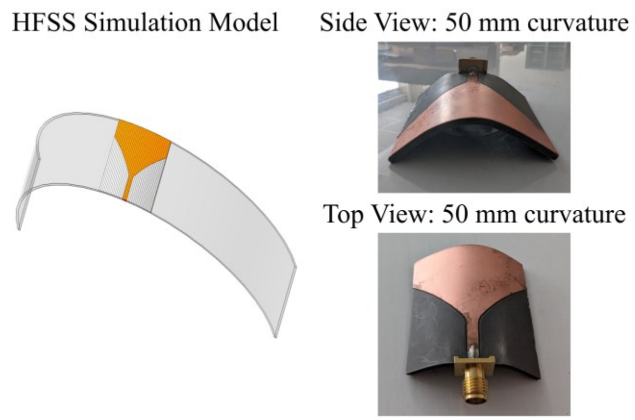

Fig. 1. HFSS Model and image of the printed planar rectangular combination monopole antenna, demonstrating the conformal capabilities of the Duroid 5870 substrate.

II. Antenna Design and Measurement

The UWB antenna element, shown in Fig. 1, was designed to operate over a frequency range of 2 − 18 GHz. The antenna had a length (from the 50 Ω feed line to the top) and width of 4 cm each. The structure was printed onto a curved Rogers 5870 substrate with a thickness of 1.524 mm and that had a dielectric constant of 2.8. The antenna was simulated in Ansys HFSS over a the frequency range for a set of radii of curvature. An example of the manufactured antenna is shown in Fig. 1, which was chemically etched with a tolerance of 250 μm. The antenna was then measured over a range of curvature radii, ranging from the largest radius of 250 mm down to a small radius of 30 mm. The antenna was measured in an anechoic chamber over the 2-18 GHz bandwidth and the radiation pattern in the H-plane in 1-degree increments. The radiation pattern was measured for five different curvature radii. Due to limitations in the measurement equipment, the measured frequency ranges were 2−6 GHz and 6−18, leading to slight discontinuities along the boundary in the measured responses. The results of these measurements can be shown in comparison to simulation in Figs. 2-4.

The measured S11 and the peak realized gain at the smallest radius of curvature of 30 mm is shown in Figs. 2 and 3, which demonstrate good agreement across the 2-18 GHz bandwidth of the antenna. This shows that the design obtains good wideband performance with the most stringent curvature of the substrate. The error between the simulation and measured effects of the realized gain at various frequencies and radii

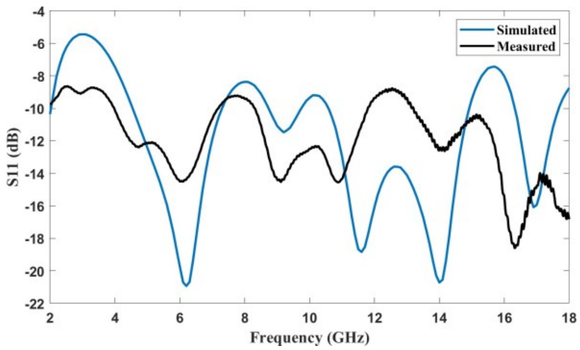

Fig. 2. Comparison of the simulated and measured S11 values of the antenna at a 30 mm radius of curvature.

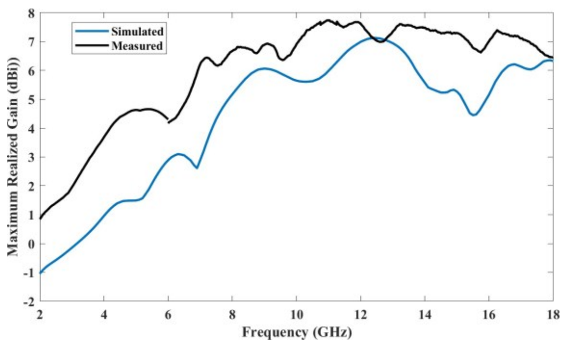

Fig. 3. Comparison of the simulated and measured gain values of the antenna at a 30 mm radius of curvature.

TABLE I
MEASURED GAIN VARIATION

Frequency (GHz)	Maximum (dB)	Average (dB)
3	1.54	1.40
6	0.73	0.44
9	1.85	1.22
12	1.03	0.31
15	3.68	3.01
18	1.21	0.94

of curvature yields and average value of 1.22 dB with the outlier frequency of 15 GHz showing an average error of 3.68 dB, demonstrating the designs robustness to various conformal applications.

The measured radiation patterns of the element is shown for all radii of curvature are shown in Fig. 4 at 6 GHz and at 18 GHz. The change in curvature us most prominent at 6 GHz, but various by only approximately 1 dB. At the high frequency of 18 GHz, the variation due to curvature is less prominent. The antenna pattern at 18 GHz also displays a slight bimodal shape, due to the antenna size becoming electrically large at this frequency. The variance of the gain across all curvature radii is shown in Table I. The variation in gain was most prominent at 15 GHz; at other frequencies the gain varied by less than 2 dB.

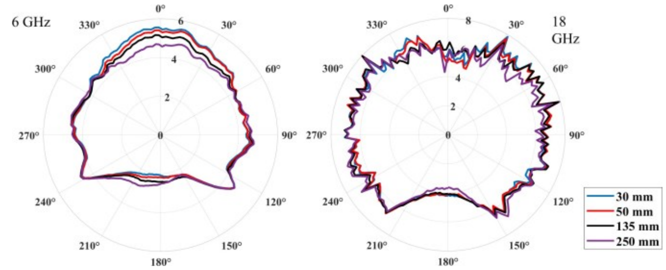

Fig. 4. Measured H-plane radiation patterns of the antenna element across all measured curvature radii at 6 GHz and 18 GHz.

III. CONCLUSIONS

In this work, a wideband, conformal antenna for S-K_u band sensing applications was designed and measured. The antenna was printed on a flexible substrate to ease integration onto complex platform surfaces. The antenna obtained good performance over the 2-18 GHz frequency range, for a fractional bandwidth of 160%, and achieved a maximum gain of 7.22 dB. The performance was evaluated as a function of the radius of curvature of the substrate, demonstrating consistent performance in gain and for a range of curvature radii. Furthermore, the antenna maintains a relatively broad radiation pattern across the operational bandwidth. While the antenna was evaluated individually in this work, the characteristics of the antenna, such as the wide radiation pattern, make it appropriate for implementation in array topologies, and may thus be used in a wide range of applications.

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