A UHF Band Compact Conformal PIFA Array

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***Abstract*-A compact conformal planar inverted-F antenna (PIFA) array, working at UHF band, is presented in this paper. This array consists of four PIFA elements. The parallel feeding network has been designed to drive the elements. The size of the proposed array is 100.5 mm × 48 mm. The proposed antenna is fabricated on a very thin substrate with a thickness of 0.254 mm, which is benefit for conformal structure. For the prototype, this array is assembled around a 16 mm diameter cylinder. The antenna has been successfully simulated, fabricated and measured, and the simulated and measured results show a good agreement with each other. The antenna has an omni-directional radiation pattern and a good gain in a very compact structure. The measured peak gain is -0.2 dBi at 432 MHz, and the bandwidth of the conformal antenna is 6 MHz.**

I. Introduction

Antennas are essential components in communication systems. In recent years, there has been an increased interest in operating at the ultra-high frequency (UHF) band [1]. Conventional antennas can be very large in size when they operate at UHF band. With the development of technology, all the systems demand small footprint and excellent performance, and a minimized antenna which is one of the important parts in the design of such systems. As we know, gain and bandwidth of the antenna are rapidly decreased when the antenna size is reduced to be less than $\lambda_0/8$ (λ_0 is the free-space wavelength), thus it is a challenging task to miniaturize the antenna into a specified form factor while ensuring reasonably good performance [2]. In recent years, there are various types of miniaturized UHF antennas in use, such as miniaturized helix antennas, miniaturized patch antennas, small spirals and so on.

A compact coplanar waveguide (CPW)-fed multi-band monopole antenna loaded with spiral ring resonators is presented in [3]. An ultra-compact antenna using a magneto-dielectric material suited for Digital Video Broadcasting is presented in [4], but its design takes long times and costly. A new miniaturization technique based on an original combination of a modified fractal shape and a sinusoidal profile is proposed in [5]. The bandwidth of a small circularly polarized antenna can be significantly increased by employing four radiating elements and exciting them in equal magnitude and successive phase difference of 90° [6] . When a single or dual radiator is used instead of four, the bandwidth is reduced. The miniaturized version [7] of the classic quadrifilar helix antenna [8] is a familiar example of this approach. In [9] and [10], four straight or meandered inverted-F elements have been employed to realize a circularly polarized antenna.

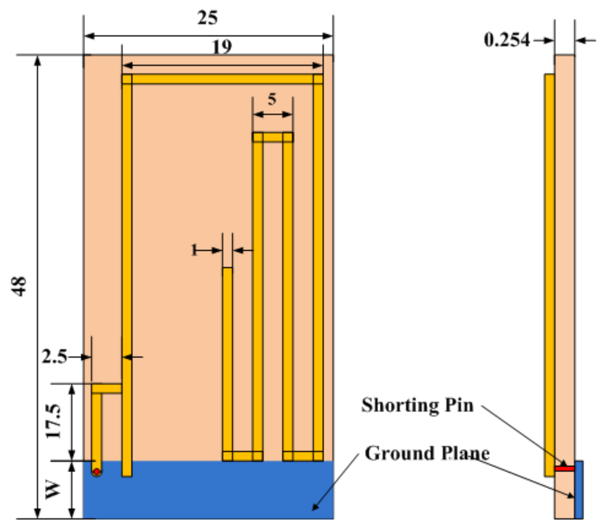

Fig.1 Geometry of antenna element.(unit: mm)

In this paper, we present a compact inverted-F antenna used for radiating elements of a conformal array. A four-port microstrip-line power divider is employed to excite radiating elements. The antenna is constructed in a flexible substrate so that it can stick on a teflon cylinder.

The paper is organized as follows. In section II, a antenna element is studied first, and parameters of the antenna element are discussed; In section III, a planar array structure is simulated and measured; Furthermore, a performance comparison between planar array and conformal array is also given in this section.

II. Antenna Element Design

Fig. 1 shows the proposed PIFA element. The antenna is designed and operated at the 430 MHz frequency band that is used in communication system. A very thin substrate with a thickness of h = 0.254 mm, and dielectric constant of $\varepsilon_r = 2.2$ is used to fabricate the antenna. The PIFA element with dimensions of 25 mm×48 mm, is designed to roughly resonate as a quarter wavelength structure. Moreover, shorting pin with a radius of 0.2 mm and the meander line are used to reduce the size. The ground plane is located at the bottom of the antenna element, which is used to support the feeding microstrip line. More detail parameters have been given in Fig. 1.

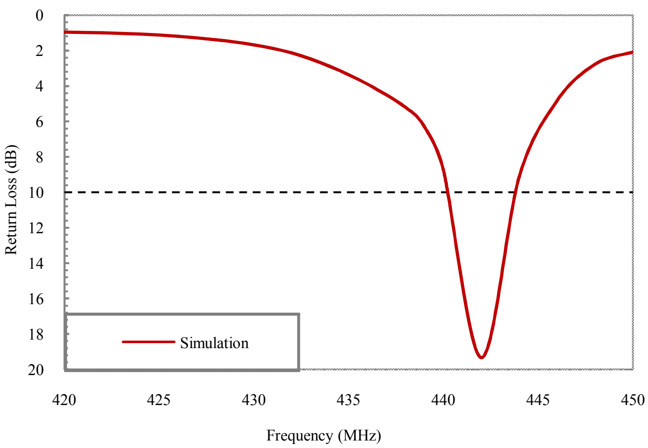

Fig. 2 Simulated return loss of antenna element.

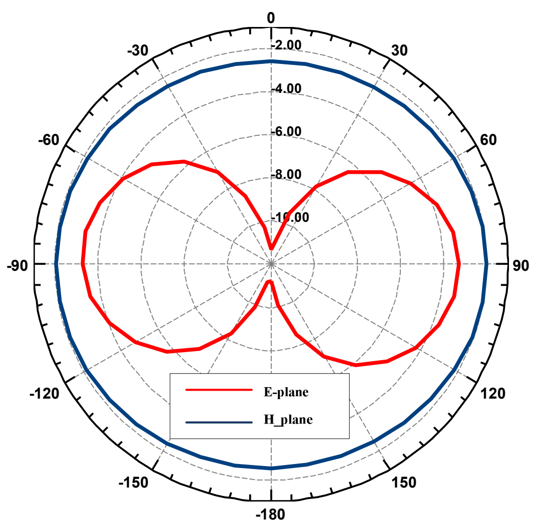

Fig. 3 Radiation patterns for the proposed antenna element at 432MHz.

Fig. 2 presents the simulated return loss of the antenna element. The measured 10dB band of the element is from 440 MHz to 444 MHz. The radiation patterns of the antenna element have been given in Fig. 3. From the figure, the antenna has a good omni-directional along horizontal plane. The maximum element gain is -1.9 dBi, which achieves at 432 MHz. In the investigation of the antenna element, besides the length of antenna element, the size of ground is also a key parameter that should be optimized to achieve the good performance. In Fig. 4, it reveals that the height of the ground plane has a significant impact on shifting the working frequence. The resonate frequency moves towards the low frequency with the increment of W. It is seen that the antenna with a length of W = 8 mm has resonating frequency about 430 MHz, while the antenna with a length of W = 6.5 mm has resonating frequency about 450 MHz. This investigation can be served as a guideline to optimize the antenna element. Through the optimization, the final W is chosen as 7 mm, which is considered the effects of the conformal structure.

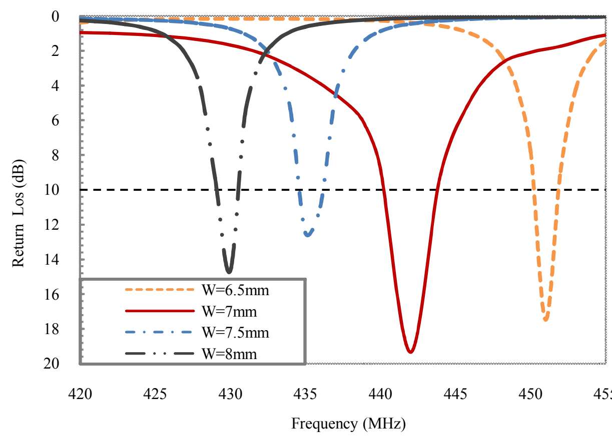

Fig. 4 Return loss of the antenna with four different lengths.

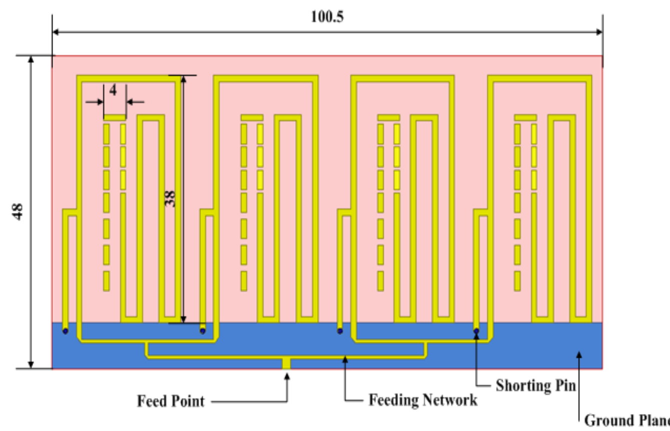

Fig. 5 Structure of the proposed antenna. (unit: mm)

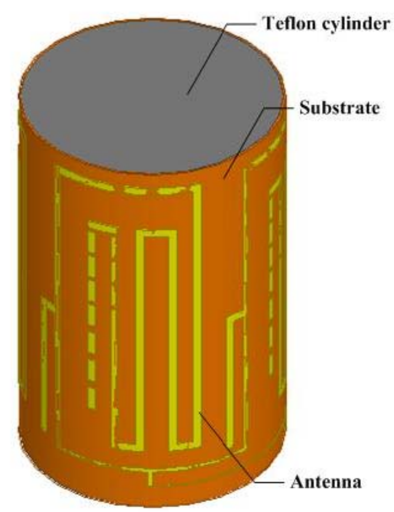

Fig. 6 Geometry of the conformal antenna.

III. Antenna Array Design

Fig. 5 shows the proposed PIFA array, which is parallel fed by a microstrip-line network. It consists of four identical PIFAs and a four-port microstrip-line power divider. The total

(a) Planar case

(b) Conformal case

Fig. 7 Photographs of fabricated antenna.

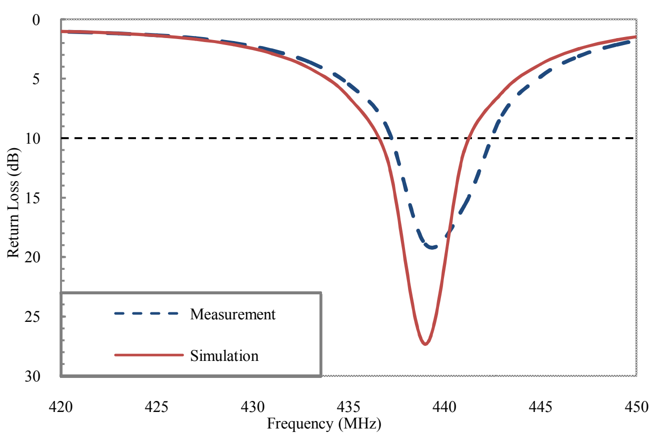

Fig. 8 Simulated and measured return loss of planar array.

size of the PIFA array antenna structure is 100.5 mm×48 mm. This size is fit for the circumference of conformal structure. Geometry of the conformal antenna is shown in Fig. 6. The assembled cylinder with 16 mm diameter is used to support the antenna array. The antenna model was designed and simulated in Ansoft HFSS software.

The proposed antenna array is fabricated. The photos of planar array and conformal array assembled on the teflon cylinder are shown in Fig. 7. The performances of the antenna are measured with a network analyzer. Fig. 8 presents

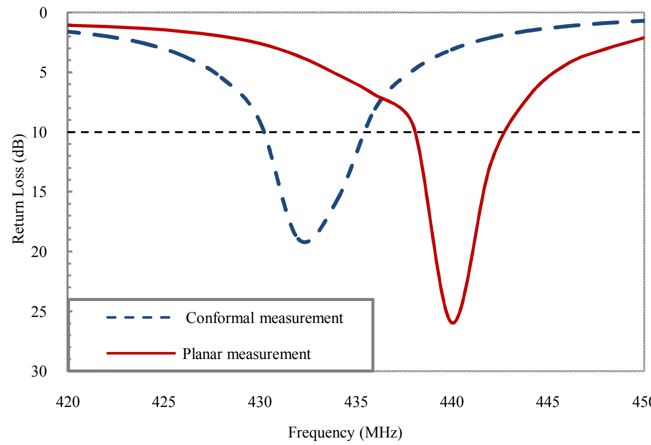

Fig. 9 Measured return loss of planar array and conformal array.

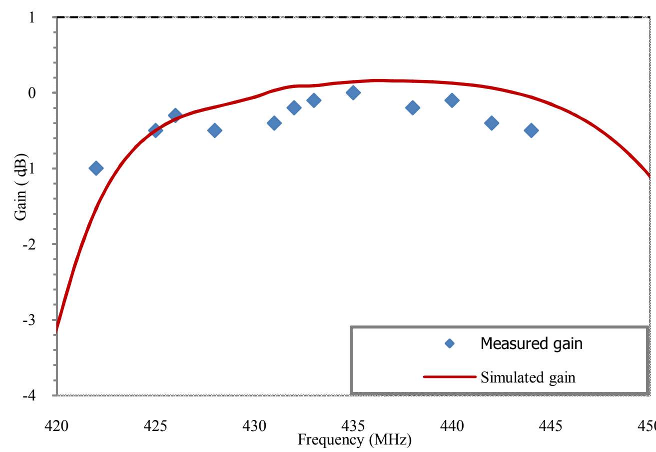

Fig. 10 Simulated and measured gain of conformal array.

simulated and measured return loss of planar array. The agreement is good between the measurement and the simulation, but a 2 MHz shift of the central operating frequency is observed. The 10 dB bandwidth is about 5 MHz (437 – 442 MHz). Fig. 9 shows the measured return loss of planar and conformal case. As shown in Fig. 9, the resonating frequency of the conformal antenna is about 432 MHz with the working band (430 – 436 MHz). The working frequence shifts down by 8 MHz when assembled around the cylinder. It is seen that the resonating frequency is shifted to the lower band with the effect of the conformal structure. The gain of the conformal antenna is given in Fig. 10. The results show that peak simulated gain can reach as high as 0.16 dBi, meanwhile the measured value is about -0.2 dBi. Moreover, the simulated and measured gain curves versus frequency are very stable, and the bandwidths of ±1 dB gain are more than 30 MHz. Fig. 11 shows the simulated radiation patterns for the conformal array. In Fig. 11, we need to note that the radiation pattern of the array antenna at the frequency of 432 MHz is well omni-direction.

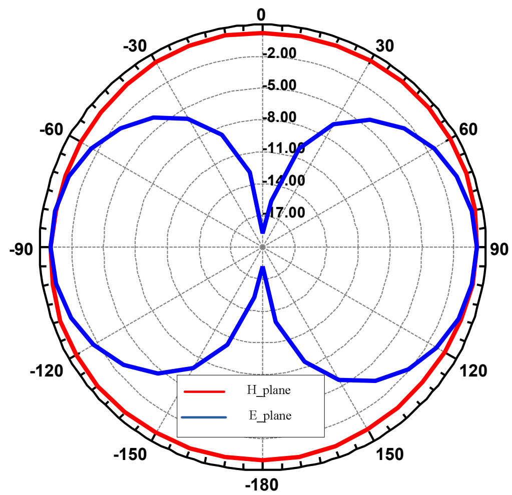

Fig. 11 Radiation patterns of conformal array at 433 MHz.

Ⅳ. CONCLUSION

In this paper, a compact conformal PIFA array antenna for UHF band has been presented. It consists of four identical PIFAs and a four-port microstrip-line power divider. The planar antenna and conformal antenna are fabricated and measured. The antenna has an omni-directional radiation pattern and a good gain in such a small volume. The peak gain is -0.2 dBi at 432 MHz, and the bandwidth is nearly 6 MHz.

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