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An Omnidirectional Printed Collinear Microstrip Antenna Array

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Abstract—An omnidirectional antenna array is proposed in this paper. The antenna unit of the array is composed of ten radiation patches and the associated microstrip feeding network. Some gaps between top and back patches are introduced in the antenna to improve matching, ease of feeding and enhance the bandwidth. Microwave experiments and numerical simulations are performed to demonstrate antenna functionalities. The fabricated antenna exhibits a bandwidth of 14% (1–1.15 GHz) for VSWR $\leq$ 1.5, with a gain around 6 dBi. The results are valuable for the design and evaluation of omnidirectional planar antenna arrays with good impedance matching, which are important for airborne and navigation applications.

1. INTRODUCTION

Antennas with light weight, compact size and low profile are required in modern wireless communication systems. In recent years, the need for omnidirectional antennas with narrow beams in the elevation plane is increased considerably. Omnidirectional antennas are used in many frequency bands from 0.8 to 6 GHz in different applications such as local area network (WLAN) access points, positioning and satellite communication. The omnidirectionality is often obtained using omnidirectional elements, such as dipoles, monopoles, and magnetic loops.

As shown in Fig. 1, different collinear-array configurations are designed using radiating elements with an intrinsic omnidirectional pattern. These arrays are based on in-phase feeding of radiating elements that lie in a straight line, and the radiation pattern is typically broadside. The coaxial collinear antenna, introduced by Judasz and Balsley firstly [1], and it has been widely used due to its compact, simple and cheap structure. Several researches further implemented this principle in either coaxial or microstrip antenna technology [2–11]. In applications where the sidelobe level and bandwidth of omnidirectional pattern are critical, some collinear arrays have been presented [12]. All mentioned collinear antenna arrays have nearly omnidirectional radiation pattern due to the more or less longitudinal axis symmetry.

In this paper, we present a simple and low-cost printed collinear antenna with omnidirectional radiation. Design considerations of collinear array of patches fed by microstrip feed networks are described for operating in the 1 GHz band. An array of 10 radiating elements is designed, simulated and fabricated. The main advantage compared to other similar arrays is that this antenna can keep a simple structure with a simple feeding network, good impedance matching and broadband performance compared to coaxial collinear dipole arrays. Furthermore, the proposed antenna has a narrow width comparable to that of coaxial antennas and shows good omnidirectional radiation across the operating band.

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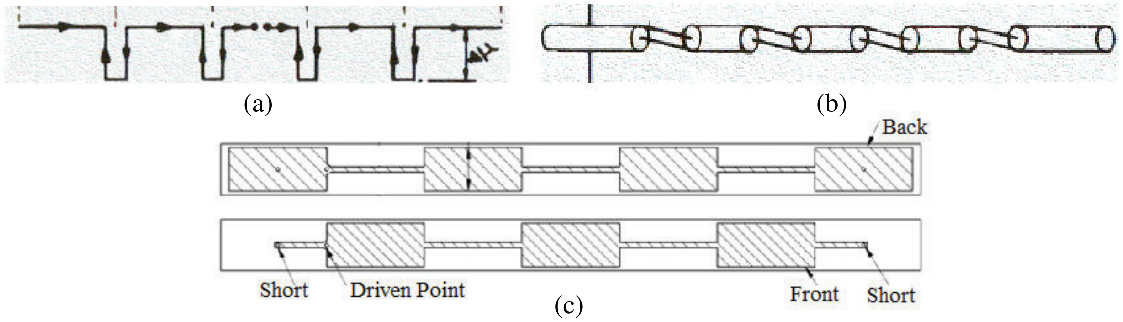


Figure 1. Common approaches to the design an omnidirectional collinear array: (a) Franklin array [1], (b) coaxial collinear array [2], and (c) microstrip collinear array [4].

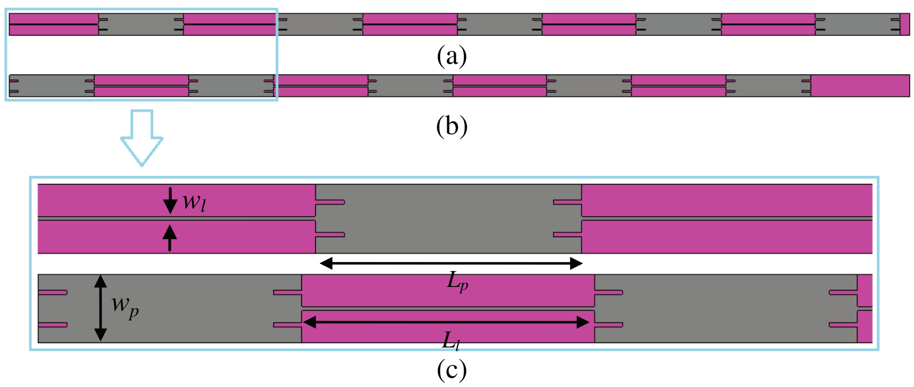


Figure 2. Configuration of proposed omnidirectional microstrip antenna: (a) front view, (b) back view and (c) zoom view.

2. ANTENNA CONFIGURATION

The configuration of antenna is presented in Fig. 2. The top radiation layer of the antenna is composed of five radiation elements by cascading 50-Ω transmission lines. The bottom radiation layer of the antenna consists of five radiation patches by a cascading impedance converter. The terminal of the antenna substrate is designed as a feed point to facilitate its connection with the conventional connectors. The antenna is designed to operate around 1 GHz on a 1.6 mm FR4 substrate with a dielectric permittivity of 4.35 and loss tangent of 0.025.

In the structures of the presented antennas in [4], the impedance matching is achieved by adding an additional microstrip line on the feeding point and end of the array. In these structures, the current on the main radiators may be disturbed and influences the radiation pattern. The proposed structure can overcome this problem, and good impedance matching is achieved by introducing a gap between every top and back patches ($L_l = L_p + 2g$) and setting the feeding point at end of the antenna. The length of any patch (L_p) is about half effective wavelength. In addition, four slots are inserted in any patch in order to achieve a more compact structure. Briefly, by introducing the gaps and slots, we get not only a good matching result and compact structure but also easy feeding.

Electromagnetic simulations and optimizations of the structure are performed using CST Microwave Studio. Optimized values of the structure are tabulated in Table 1. The 3-D radiation pattern of the antenna at frequency 1.1 GHz is shown in Fig. 3. Observe that the antenna possesses a good omnidirectional radiation feature in the azimuthal plane. The current distribution of the antenna at frequency 1.1 GHz is depicted in Fig. 4. Observe that the currents on radiation elements of the antenna are all nearly in phase which results in an omnidirectional pattern.

Table 1. Design parameters of proposed collinear antenna.

Component	**Parameter**	**Value** (mm)
Substrate	length	77.5
	width	19
	thickness	1.6
Radiation Patch	L_p	73
	w_p	19
Microstrip Line	L_l	81.12
	w_l	1.12
Slot	*length*	7.83
	width	1.15

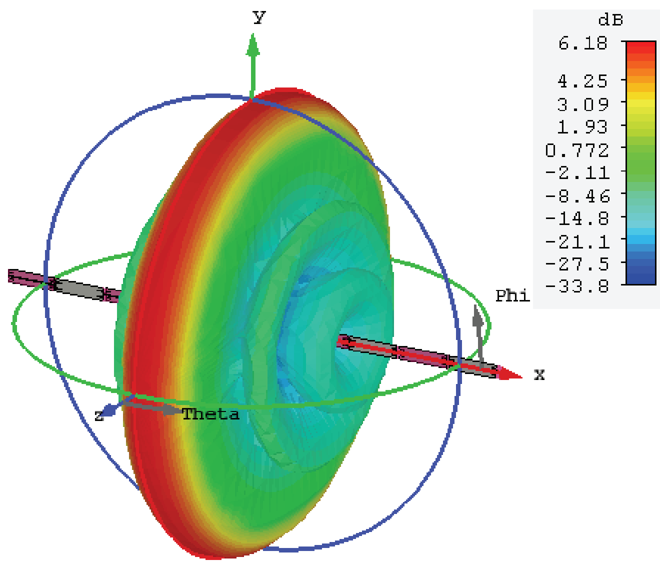


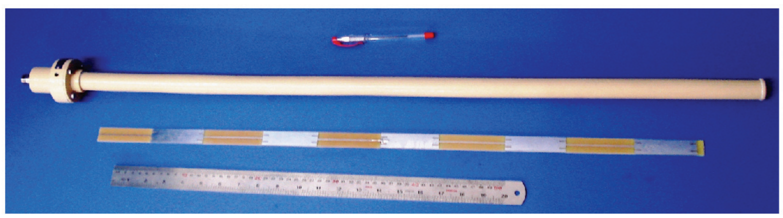
Figure 3. 3-D radiation pattern of proposed collinear antenna.

3. FABRICATION AND MEASUREMENT RESULTS

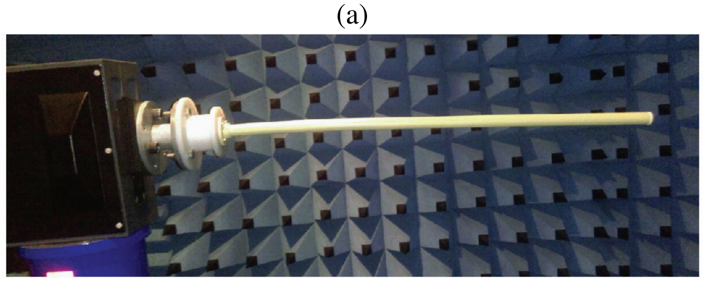
Photograph of the fabricated antenna with its radome is shown in Fig. 5. An innegra tube with an inner radius of 10 mm and thickness of 1 mm is used as a radome to cover the antenna. In the experiment, the feed and ground patch are connected to a 50 Ω coaxial cable with an N-Type connector. VSWR of the antenna has been measured by an Agilent network analyzer 8722ES. A response comparison between the simulation and measurement results is given in Fig. 6. The measured bandwidth for VSWR ≤ 1.5 is 14% from 1 to 1.15 GHz. Good agreement has been achieved between simulation and measurement.

Figure 7 shows the measured gain over the frequency band of 1–1.12 GHz. The antenna can reach a gain around 6 dBi over the desired frequency band. The greatest peak gain is just towards the horizontal direction, which ensures the antenna to work omnidirectionally when being settled vertically. The maximum measured gain is 6 dBi at frequency 1.12 GHz. The measured antenna sidelobes are approximately -13 dB below the main lobe. Fig. 8 shows that the efficiency of antenna is more than 60% over the desired frequency band. The simulated and measured radiation patterns of the proposed antenna at frequency 1.1 GHz are displayed in Fig. 9, which shows a good omnidirectional characteristic. The corresponding half-power beamwidth is 20° in the E-plane.

Figure 4. Simulated current distribution of the proposed antenna at frequency 1.1 GHz.



(a)



(b)

Figure 5. (a) Photograph of the fabricated antenna with radomes. (b) Photograph of packed antenna under test.

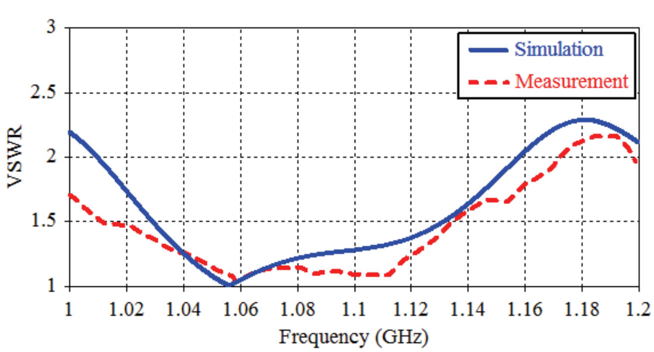


Figure 6. Simulated and measured VSWR of the proposed antenna.

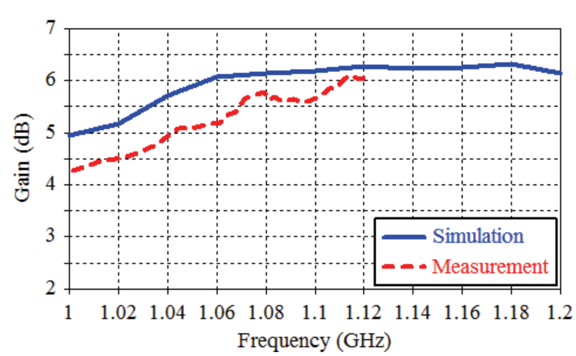


Figure 7. Simulated and measured gain of the proposed antenna versus frequency.

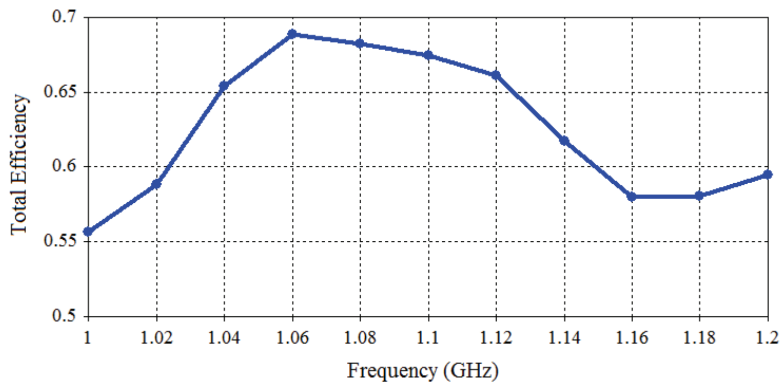


Figure 8. Simulated efficiency of the proposed antenna versus frequency.

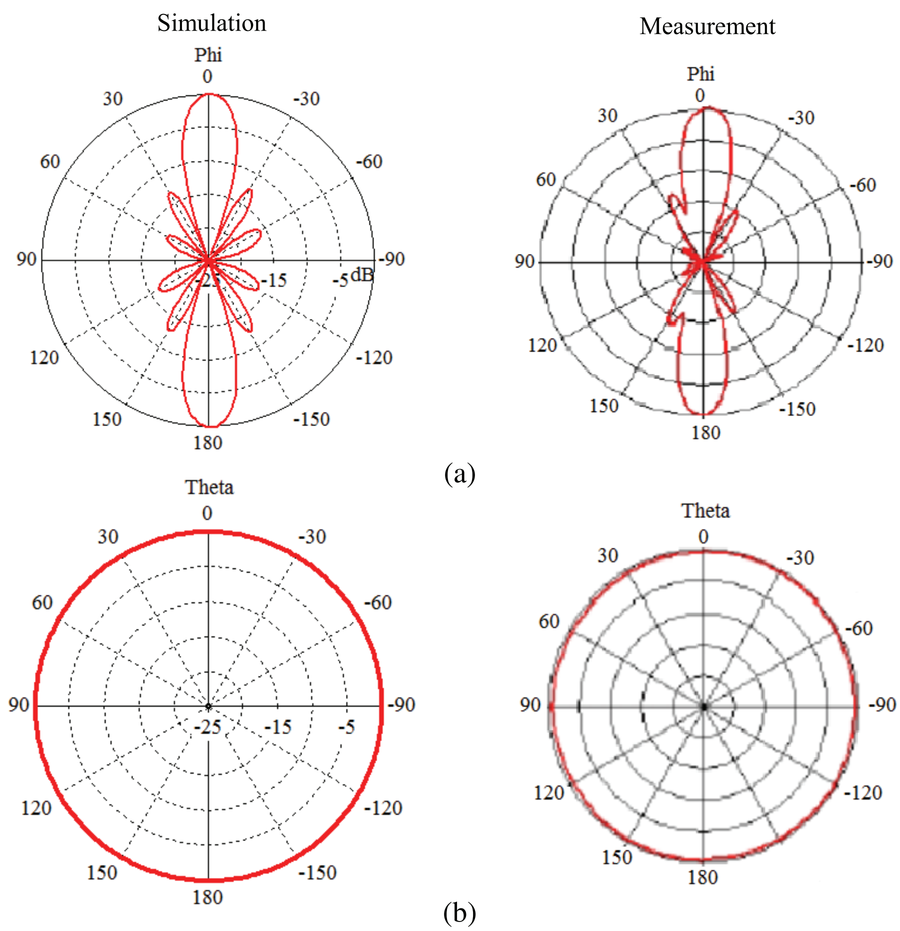


Figure 9. Simulated and measured radiation pattern of proposed antenna. (a) E-plane and (b) H-plane.

4. CONCLUSION

A collinear patch antenna has been designed and measured in microstrip technology. The manifest characteristics of the antenna are with a good omnidirectional radiation pattern in azimuth and a narrow beamwidth in elevation. Simulated and measured results are found in good agreement with each other. The measured gain of the final array is 6 dBi; sidelobe level is less than -13 dB; the half-power beam width is 20 degrees and 14% bandwidth around 1.1 GHz.

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