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HIGH PERFORMANCE PLANAR SLEEVE DIPOLE ARRAY ANTENNA WITH DIRECTIONAL RADIATION

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Abstract—A planar sleeve dipole array antenna is analyzed and successfully implemented. The proposed antenna is designed for operating at 1800/1900 MHz band of basic station applications. To achieve sufficient bandwidth for the requirement of the PCS 1800 MHz band (1710–1880 MHz) and 1900 MHz band (1880–1930 MHz) for DECT (Digital Enhanced Cordless Telecommunications), the proposed antenna comprises of a 1×5 coplanar back-to-back sleeve dipole elements, and the microstrip line to balanced transmission line feeding

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technique was adopted in this design. This structure is easily constructed by being printed on both sides of a dielectric (FR4) substrate. The measured -10 dB S_{11} (VSWR 2 : 1) impedance bandwidth is around 13.2% (1690–1930 MHz). A reflector is put behind the dipole array to obtain directional radiation and high gain, and the measured antenna gain for operating frequencies across the 1800/1900 MHz band is about 7.2–9.1 dBi. The measured results of radiation efficiency, radiation pattern, antenna gain and S_{11} show that the sleeve dipole array antenna has a good performance.

1. INTRODUCTION

Wireless communications are developed widely and rapidly in the modern world. Users are surrounded by different types of communication technology such as mobile phones, wireless local area networks (WLAN), global system for mobile communications (GSM), digital cellular service (DCS), personal communication services (PCS) [1] and other personal communication systems. Nowadays microstrip print circuit board (PCB) antenna is widely used for communication systems. Microstrip antenna array is widely used due to its several advantages, such as low profile, light weight, and low cost, etc. [2, 3]. Those array antennas are the solution of choice for many radar and access point applications in space and on earth [4–7]. However, microstrip antenna suffers from low gain, low efficiency, and low power handling capability [8, 9]. Various broadband techniques have been reported using multilayer or stacking the patches [10]. High-gain antenna is usually realized by using either line-fed antenna arrays or reflectarrays [4–10].

In this case, we proposed a 1×5 coplanar back-to-back sleeve dipole antenna with a microstrip line to balanced transmission line feeding and tuning pad [11]. In addition, a reflector is put behind the dipole array antenna in order to obtain directional radiation and high gain. This case can be easily constructed by being printed on both sides of a dielectric substrate (shown in Fig. 1) [12–14]. The proposed antenna was analyzed, fabricated, and successfully optimized for the improved performance. Details of the printed dipole array antenna design and the simulated and measured results are presented.

2. ANTENNA DESIGN

In this article, we design a novel coaxial collinear printed dipole structure with respect to the antenna elements which are used to compose the array antenna. Fig. 1 shows the structure of the

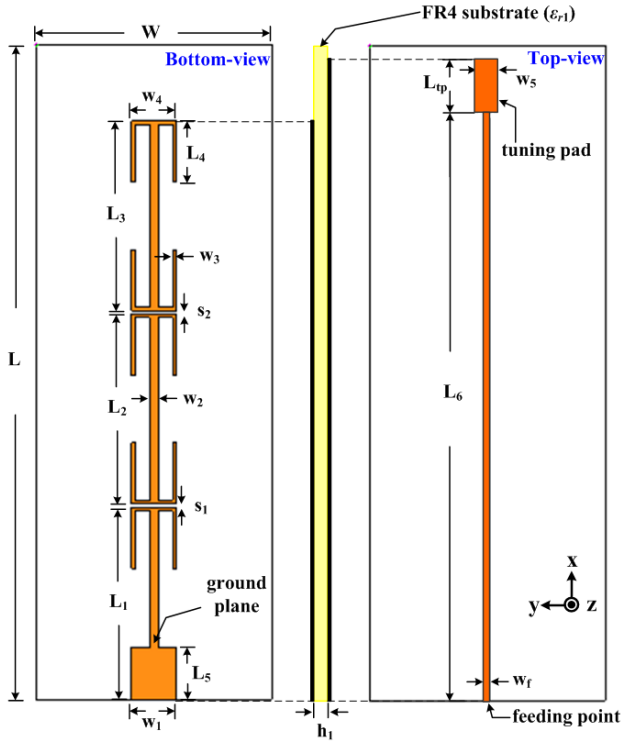

Figure 1. Dimensions of the proposed sleeve dipole array antenna.

antenna array with no reflector, and the radiation elements are planar dipoles. The geometry of the proposed planar dipole array antenna at the PCS 1800 MHz band (1710 MHz–1880 MHz) and 1900 MHz band (1880 MHz–1930 MHz) is for DECT system operation.

The proposed dipole array antenna is printed on the front surface (top-view) and back surface (bottom-view) of a low cost substrate (FR4) with thickness $h_1 = 0.6$ mm and relative permittivity $\varepsilon_{r1} = 4.4$. It mainly consists of a 1×5 half-wave sleeve linear dipole array which is printed on one side of the substrate (bottom-view). The antenna array is fed by a microstrip line to the balanced transmission line, which is printed on the front surface of the FR4 substrate. The coaxial feed cable is connected to a 50 Ω SMA connector directly to feed the microstrip line. A very thin metal slab is put 22 mm (h_2) away from the dipole array as the reflector with an air gap $\varepsilon_{r2} = 1.0$ spacing (shown in Fig. 2) [1, 4, 12, 15]. This behavior agrees with the expectation, and the metal slab in this design thus mainly acts as a

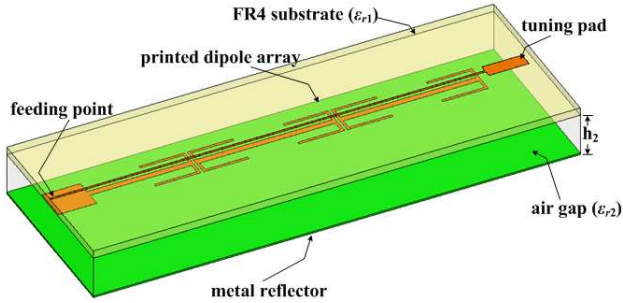

Figure 2. The proposed sleeve dipole array antenna structure.

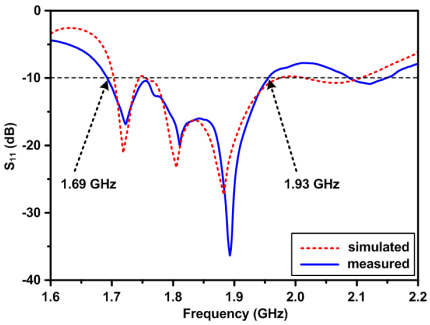

Figure 3. Measured and simulated results of S_{11}.

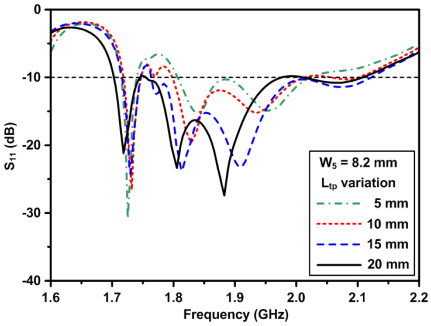

Figure 4. Variations of the simulated S_{11} of different Ltp values.

reflector, which makes directional radiation possible for the proposed dipole array antenna. The parameters of the proposed antenna are shown in Fig. 1. The dimensions of the proposed antenna are $W = 120$, $L = 280$, $w_1 = 19\,\text{mm}$, $w_2 = 3.5\,\text{mm}$, $w_3 = 1.5\,\text{mm}$, $w_4 = 19\,\text{mm}$, $w_5 = 8.2\,\text{mm}$, $w_f = 1.2\,\text{mm}$, $L_1 = L_2 = L_3 = 80.5\,\text{mm}$, $L_4 = 26\,\text{mm}$, $L_5 = 22$, $L_5 = 247.5$, $L_{tp} = 20\,\text{mm}$ and $s_1 = s_2 = 1.5\,\text{mm}$. All the simulations are done by using Ansoft HFSS [16].

3. SIMULATION AND MEASUREMENT RESULTS

3.1. Return Loss

The antenna is measured by using the Anritsu 37369C network analyzer. The simulation and measurement results of return characteristics are shown in Fig. 3. Good agreement between the

measurement and simulation has been obtained. Concerning the -10 dB S_{11} (VSWR 2 : 1), the measurement impedance bandwidth of the antenna ranges from 1690 MHz to 1930 MHz with the fractional bandwidth around 13.2%. Thus, the response can cover the operating bandwidth of the PCS 1800 communications (1710–1880 MHz) and the DECT system (1880–1930 MHz). To study the effect of the tuning pad length (L_{tp}) on the directional radiation of the proposed planar dipole array antenna, prototypes with various values of L_{tp} were constructed and studied. Fig. 4 shows variations of the simulated S_{11} of the cases with $L_{tp} = 5$, 10, 15, and 20 mm. Based on these simulation results of different L_{tp}, in the final design we chose $L_{tp} = 20$ mm for impedance matching better.

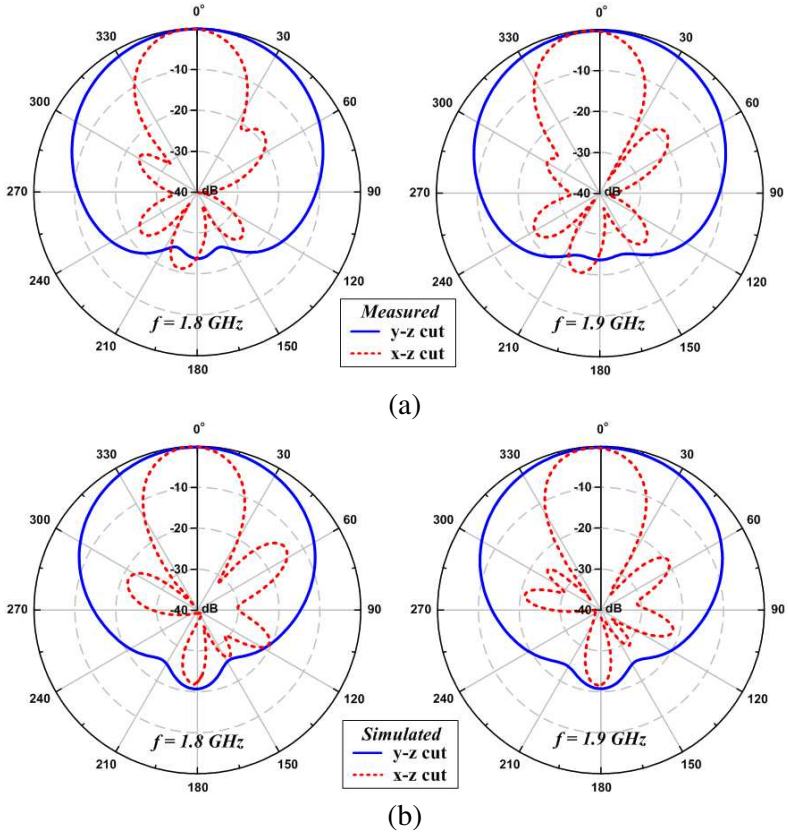

Figure 5. Measured Radiation patterns of the proposed antenna. (a) Measured. (b) Simulated.

3.2. Radiation Patterns

In field analyses, Fig. 5(a) and Fig. 5(b) illustrate the measured and simulated results of two-cut patterns respectively. For field coordinates, the antenna is located on the x-y plane, and the radiation direction is pointed to the z-direction. The measured radiation patterns of the proposed antenna at 1800/1900 MHz are shown in Fig. 5(a), and the x-z cut (E-plane) 3 dB beamwidth is 15°/14°. The first side-lobe on the right side is −18.1/−17.6 dB, and the front to back ratio of the E-plane pattern is 36.5/37.2 dB. For the y-z cut (H-plane) radiation pattern, its 3 dB beamwidth is 45°/46°, and the front to back ratio of the H-plane pattern is 25.2/24.3 dB. The measured radiation pattern results are in good agreement with simulated ones.

3.3. Antenna Gain and Radiation Efficiency

Figure 6 shows the measured antenna gain and measured radiation efficiency for the proposed planar dipole array antenna. The antenna gain is in the range of 7.2–9.1 dBi, and the radiation efficiency varies from 47%–63% for the PCS 1800/DECT (1710–1930 MHz) bands.

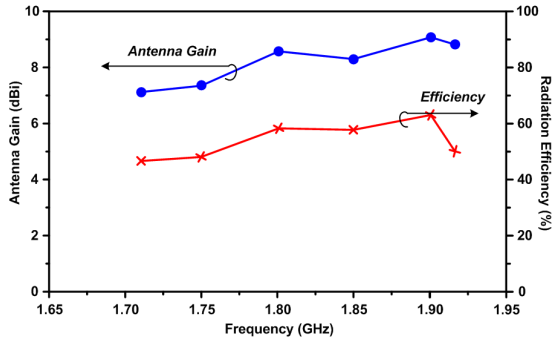

Figure 6. Measured results of antenna gain and radiation efficiency.

3.4. Current Distribution

Figure 7 illustrates the simulated surface current distributions, which clearly provides a physical insight for understanding the behavior of the proposed planar sleeve dipole array antenna. Fig. 7(a) shows that the sleeve dipole array is excited with concentrating current distributions at the 1900 MHz resonance while the maximum amplitude is located at the 1×5 linear element. As shown in Fig. 7(b), owing to the condition

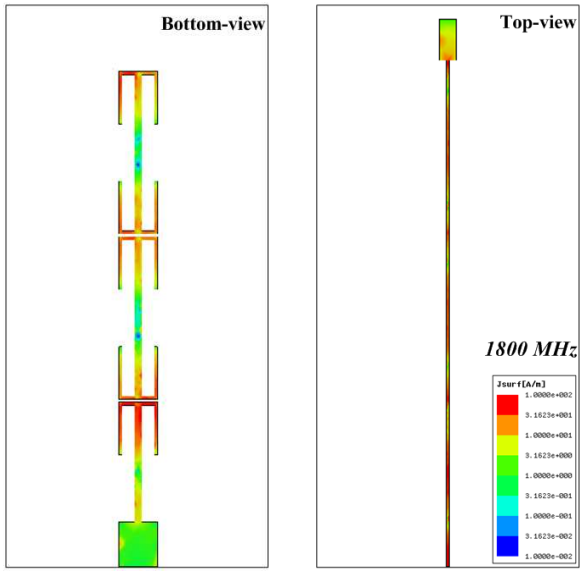

Figure 7. Current distribution.

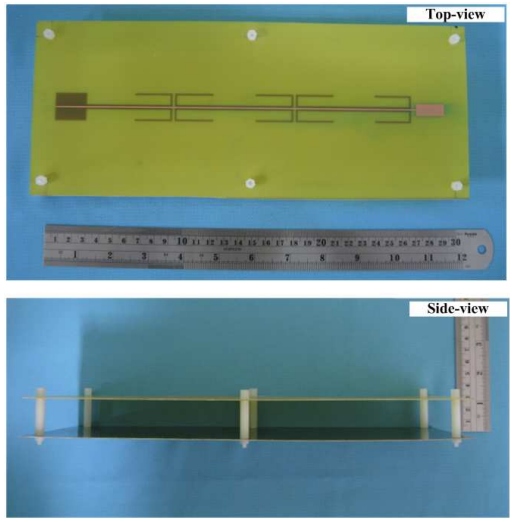

Figure 8. Photography of the planar sleeve dipole array antenna.

of microstrip line to the balanced transmission line, the uniform surface currents with respect to the excitation of the sleeve dipole array are seen in this case, and the photography of the planar sleeve dipole array antenna is shown in Fig. 8.

4. CONCLUSION

A novel planar sleeve dipole array antenna with directional radiation has been proposed, and a prototype has been implemented and measured. The measured -10 dB S_{11} impedance bandwidth is around 13.2% (1690–1930 MHz).

The radiation patterns of the proposed antenna at 1800/1900 MHz are also measured. The x-z cut (E-plane) 3 dB beamwidth is 15°/14°; the first side-lobe on the right hand side is $-18.1/-17.6$ dB; and the front to back ratio is 36.5/37.2 dB. In practice, the antenna gain is in the range of 7.2–9.1 dBi, and the measured radiation efficiency varies from 47%–63%. In applications, it can be applied to the PCS 1800 communications and the DECT system. Both simulated and measured results agree with the verified frequency responses and radiation characteristics.

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