

A CLASS OF MULTI-ARM MONOPOLE ANTENNAS FOR MULTI-BAND WIRELESS/MOBILE APPLICATIONS

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ABSTRACT

This paper presents several multi-band, compact, lightweight and low-cost monopole antennas suitable for applications in the wireless local area network (WLAN) and mobile communications. These antennas are two-arm microstrip-fed antenna, two-arm antenna fed by a co-planar waveguide (CPW) line, three-arm microstrip-fed antenna and a diversity antenna pair composed of two two-arm microstrip-fed antennas. Antennas to cover 1.8, 2.4, 4.9, 5.2 and 5.8 GHz bands have been successfully designed. Theoretical and measured results are presented.

INTRODUCTION

In many applications of wireless communications such as Personal Communications Services (PCS), Bluetooth, IEEE 802.11 Wireless Local Area Networks (WLAN, e.g. Wi-Fi i.e. IEEE 802.11a, 802.11b, 802.11g, 802.11j etc.), it is desirable to use multi-band antennas that are small in size [1]. One method to obtain multi-band operation is to use multiple arms or branches in the radiating element. In these antennas, different arms resonate at different frequency bands. Sometimes, one branch can resonate at two or multiple bands. With appropriate tuning techniques, good impedance matching can be obtained at those resonant frequencies. Normally, printed multi-arm monopole antennas have the advantages of compact configuration, low profile and multi-band operation.

In this paper, we describe four multi-band planar monopole antennas designed for WLAN and mobile communication applications. All these antennas are composed of multiple printed metal arms. Theoretical results obtained from HFSS commercial software and measured results are presented.

TWO-ARM MONOPOLE ANTENNA WITH A MICROSTRIP FEED

Fig. 1 shows a two-arm printed monopole antenna suitable for quad-band Wi-Fi applications [1]. The radiating element is fed by a 50- Ω microstrip line and both of them are printed on an FR4 Epoxy substrate, which has a thickness (H) of 0.8 mm and a dielectric constant (ϵ_r) of 4.4. Hence the structure has a very low-profile. The ground is on the other side of the substrate and truncated at or near a point where the feedline is coupled to the first printed metal arm. Since the antenna is printed on a substrate, it is easy to integrate it with associated microstrip circuits, which are printed on the same substrate. The radiating element is composed of two metal arms, which radiate at two different frequency bands. The longer arm is wrapped around the shorter one, leaving a small separation between the two metal arms. There are several advantages of this arrangement: first, it makes the configuration compact. Secondly, by selecting the value of the gap (d) between the two end-stubs of the two metal arms, the first resonant frequency, determined by the length of the longer arms, can be shifted in a small range. Thirdly, the gap d can be adjusted to improve impedance matching at the resonant frequencies. Although the multi-arm antenna can operate at multiple frequency bands, good impedance matching (normally below -10 dB) is not always guaranteed at these resonant frequencies. Fig. 2 shows the theoretical and measured return losses of the antenna. It can be seen from the measured results that two operating bands have been achieved with good impedance matching within them. The lower band (determined by S_{11} of < -10 dB) reaches 218 MHz (9.1%) and covers the IEEE 802.11b or 802.11g band (2.40-2.485 GHz). Comparing the two results in Fig. 2, it is

noted that the measured resonant frequency is about 100 MHz higher than the predicted. On the other hand, the upper band has a bandwidth as large as 1.755 GHz (32%) and covers the bands of IEEE 802.11a and 802.11j in Japan. Table 1 shows the dielectric constant and the thickness of the substrate, the antenna dimensions and the operating bands.

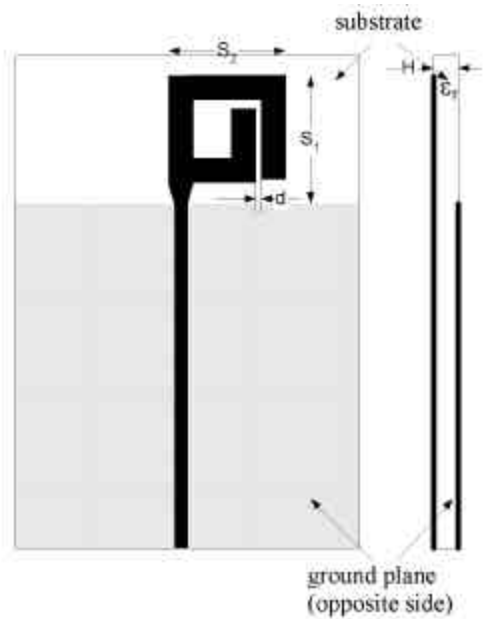


Fig. 1. Geometry of a two-arm monopole antenna fed by a microstrip line

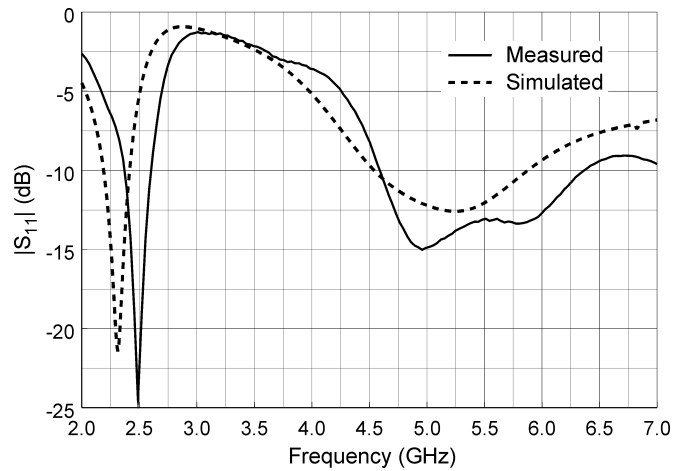


Fig. 2. Measured and theoretical return loss for the antenna shown in Fig. 1

ϵ_r	Substrate Thickness (H) (mm)	Separation (d) (mm)	Antenna Dimension ($S1 \times S2$), (mm ²)	Operating Bands (GHz)
4.4	0.8	0.5	10×10	2.37 – 2.55 4.6 – 6.35

Table 1. Details of the two-arm monopole antenna fed by a microstrip line

TWO-ARM MONOPOLE ANTENNA WITH A CPW FEED

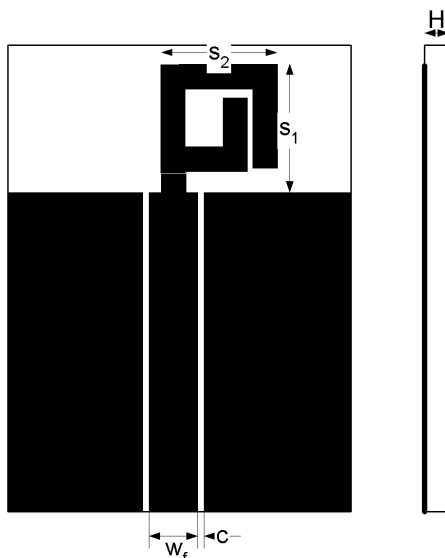


FIG. 3. Geometry of a two-arm monopole antenna fed by a CPW line

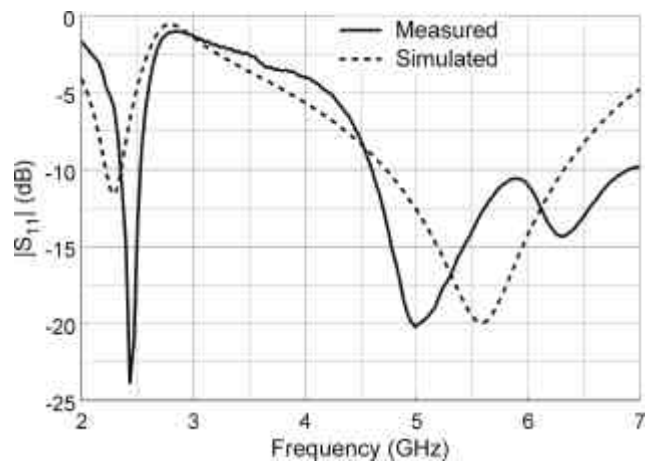


Fig. 4. Measured and theoretical return loss of the antenna shown in Fig. 2

The geometry of a CPW-fed printed monopole antenna [2] is shown in Fig. 3. The radiating element is now fed by a 50- Ω CPW feedline, and both the antenna and the feedline are printed on the same surface of an FR4/Epoxy substrate, which has a thickness of 0.8 mm and a dielectric constant of 4.4. The ground is also on the same side of the substrate and it only surrounds the CPW feedline. Therefore, this antenna can be easily integrated with a CPW-based microwave circuit, which is printed on the same substrate. Fig. 4 shows the theoretical and measured return losses. The lower band, determined by the 10 dB return loss, covers the frequency range from 2.35 GHz to 2.52 GHz, fulfilling the bandwidth requirements of IEEE 802.11b and 802.11g. The upper bandwidth is about 2.28 GHz, from 4.6 GHz to 6.88 GHz, which covers the frequency bands of IEEE 802.11j in Japan, and all three IEEE 802.11a U-NII bands in the USA. The parameters of the antenna and its operating bands are listed in Table 2.

ϵ_r	Substrate Thickness (H) (mm)	Feedline Width (W_f) (mm)	Gap (c) (mm)	Antenna Dimensions ($S_1 \times S_2$), (mm ²)	Operating Bands (GHz)
4.4	0.8	3.0	0.5	10×10	2.35 – 2.52 4.6 – 6.88

Table 2. Details of the two-arm monopole antenna fed by a CPW line

THREE - ARM MONOPOLE ANTENNA WITH A MICROSTRIP FEED

A planar monopole antenna composed of three arms, suitable for DCS1800/PCS1900/WLAN multi-service applications, is described below. The configuration of the proposed antenna is shown in Fig. 5. As can be seen, the three arms are wrapped into a compact rectangular structure and printed on a thin substrate together with its feedline. The ground plane is on the other side of the substrate and only covers the feedline section. In fact, the three-arm antenna is composed of a two-arm antenna element described earlier, and a third arm wrapping around the two-arm element. The two-arm antenna element still operates at 2.4 GHz and 4.9-6.0 GHz bands, covering the bandwidth required for IEEE 802.11a, 802.11b, 802.11g and 802.11j WLAN systems. A third frequency band determined by the third arm can be tuned to appear within the range of 1.7-2.0 GHz, depending on the length of the strip. This band can cover the bandwidth required for the DCS1800 or PCS1900 systems. Fig. 6 gives the theoretical and measured return losses. The parameters of the antenna and operating bands are given in Table 3.

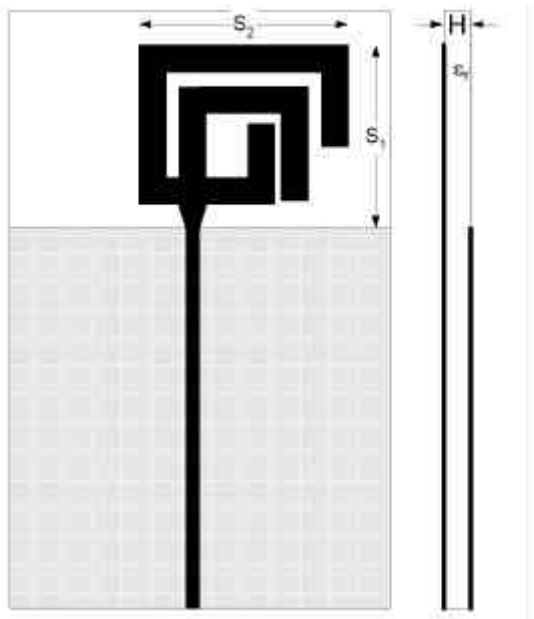


Fig. 5. Geometry of a three-arm monopole antenna

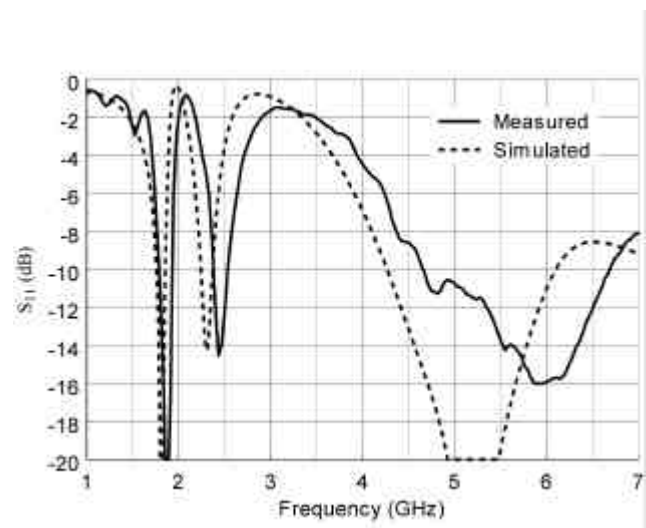


Fig. 6. Simulated and measured return loss of the three-arm antenna

ϵ_r	Substrate Thickness (H) (mm)	Antenna Dimensions ($S_1 \times S_2$), (mm ²)	Operating Bands (GHz)
4.4	0.8	15×17	1.8 – 1.97 2.37 – 2.54 4.64 – 6.7

Table 3 Details of the three-arm monopole antenna

DIVERSITY ANTENNA PAIR BASED ON TWO-ARM MONOPOLE ANTENNAS

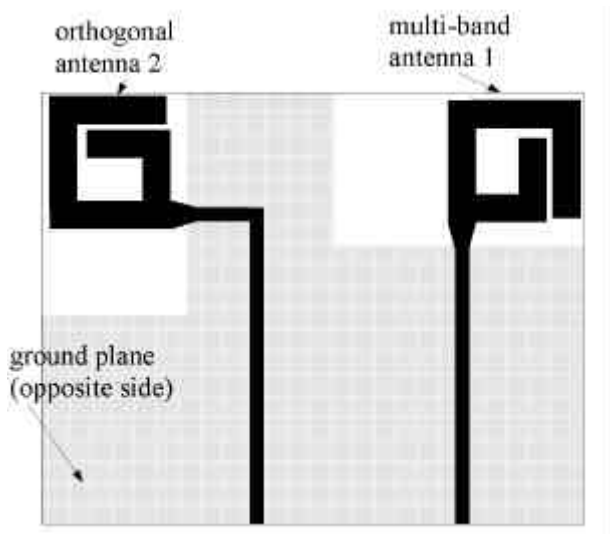


Fig. 7. Geometry of the diversity antenna system

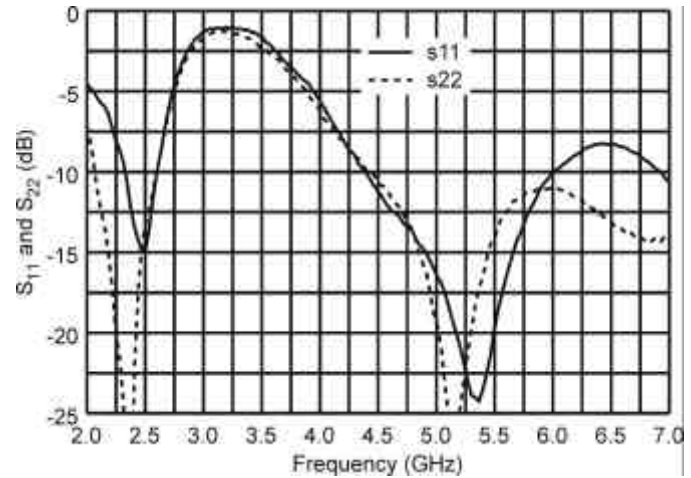


Fig. 8. Measured return loss of the diversity antenna at each input

Diversity antennas are used in indoor WLAN and other communication systems to reduce signal fading from multi-path interference. Diversity antenna systems are composed of two or more single antennas, which may be located at different places and/or make use of at different polarisations so that space diversity, pattern diversity and/or polarisation diversity can be achieved. Here a diversity antenna based on two two-arm microstrip-fed monopole antennas is described. As can be seen in Fig. 7, the two antennas are arranged orthogonal to each other in space. The measured return loss at each antenna input, shown in Fig. 8, indicates that both antennas cover the required bands of IEEE WLAN 802.11a, 802.11b, 802.11g and 802.11j. Therefore, space, pattern and polarisation diversity can be achieved at these bands. Table 4 lists the parameters of the antenna and its operating bands.

ϵ_r	Substrate Thickness (H) (mm)	Substrate Size (mm ²)	Operating Bands (GHz)
4.4	0.8	48×50	1.8 – 1.97 2.37 – 2.54 4.64 – 6.7

Table 4 Details of the diversity antenna system

CONCLUSION

In this paper, several designs of compact multi-band planar monopole antennas have been presented. These antennas are printed on low-cost FR4/Epoxy substrate that has a dielectric of 4.4 and thickness of 0.8 mm. The multi-band operation can be achieved by combining multiple folded metal arms, each of which resonates at different frequency band determined by its effective length. Good agreement between theoretical and experiment results has been obtained. The advantages of low cost, small size, multi-band capability and compatibility with printed (microstrip/CPW) microwave circuits make them attractive for wireless applications.

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