A Low-Cost Microstrip Antenna for 3G/WLAN/WiMAX and UWB Applications

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Abstract: This paper presents the design of a low-cost ultra-wideband microstrip antenna for wireless communications. The antenna, which is microstrip-line fed, has a partial ground plane flushed with the feed line. The substrate is based on the inexpensive FR4 material, and the patch is circular in shape with a U-shaped slot incorporated. The antenna was simulated in ADS Momentum, which is based on the Method of Moments, and in HFSS, which is based on the Finite-Element Method. The antenna's resulting return loss, input impedance, radiation patterns, gain and efficiency figures are presented. It is shown that the antenna can operate in the bands used for UMTS, Wi-Fi, WiMAX, and UWB applications. Good gain and efficiency values and omnidirectional radiation patterns are recorded over these bands.

Key words: Microstrip antennas, UMTS, UWB, WiMAX

INTRODUCTION

Printed microstrip antennas are characterized by their low profile, small size, light weight, low cost and ease of fabrication [BAL 05], which make them very suitable for satellite and communications applications. They are also compatible with wireless communication integrated circuitry due to their simple feed methods, especially microstrip-line and coplanar waveguide feeds. However, they suffer from inherently narrow bandwidths.

Techniques to increase the bandwidth of microstrip antennas were discussed in [KUM 03]. Another technique consists of the use of partial ground planes [LOW 05] [YAN 05] [ZHA 08] [ZAK 08] [AHM 08]. Notably, the PCB antenna presented in [LOW 05] operates over the 3.4-11 GHz band. In addition to flushing its ground plane with the feed line, the authors introduced slots into the rectangular patch and tapered the connection between the patch and the feed line for better impedance matching. In [YAN 05], a partial ground plane was also used in addition to top-loading the antenna. The reported impedance bandwidth is 8.2 GHz in the 2.4-10.6 GHz range, but for VSWR < 2.5. The bandwidth is much smaller for VSWR < 2, especially for the design with the small ground plane.

In this paper, we present the design of a microstrip-line-fed PCB antenna based on a slotted circular patch, and a partial ground plane. The slot is U-shaped. The antenna is simulated and analyzed using ADS Momentum [ADS 06], which is based on the method of moments, and Ansoft HFSS [HFS 07], which is based on the finite element method. It is shown that the operational band of the antenna spans the bands for 3G, WLAN, Bluetooth, wireless CCTV and video links, WiMAX, and UWB applications.

1. Antenna configuration

The antenna geometry is shown in Fig. 1. The FR4-based board is 1.6 mm in thickness. The feed line is 19.5-mm long and 3-mm wide. The radius of the circular patch is 21.1 mm. The ground plane is flushed with the feed line. The location and dimensions of the U-slot are shown on Fig. 1. For simulation in HFSS, a substrate size of 7×7 cm² was considered.

2. Results and discussion

A comparison between the return loss computed in ADS Momentum and that computed in HFSS in the 1-13 GHz frequency range is shown in Fig. 2. A good agreement is generally observed, however they differ at low frequencies. The HFSS-computed return loss...
crosses the -10 dB line at 1.7 GHz, whereas the Momentum-simulated one does that at 1.9 GHz. This difference is mainly due to the fact that ADS Momentum assumes and infinite substrate, whereas in HFSS we considered a 7×7-cm² substrate. The input impedance of the antenna, simulated in ADS Momentum for frequencies in the 1.5-13 GHz range, is shown in Fig. 3. Consistency with the return loss plot is witnessed. Smaller dB values of the return loss occur when the real part and the imaginary part of the impedance are close to 50 Ω and 0 Ω, respectively.

Figure 1. Antenna structure

Figure 2. Comparison of S11 simulated in ADS Momentum and HFSS

Fig. 4 shows the computed radiation patterns in the X-Z and Y-Z planes, for 1.9, 2.4, 3.5, 5.1, 7, 9 and 11.5 GHz. The nulls present in the X-Z radiation patterns for the ±90° elevation angles are due to ADS Momentum's infinite substrate assumption. For a finite-size substrate, the patterns in the X-Z plane are omnidirectional, as was verified in HFSS. For instance, the HFSS-simulated 3D gain patterns at 1.9, 3.5, and 7 GHz are shown in Fig. 5. These patterns are omnidirectional, having almost equal radiation in the X-Z plane. For low frequencies, the radiation in the Y-Z plane has the shape of an ‘8’. However, this shape is distorted at higher frequencies where sidelobes begin to appear.

Figure 3. Computed input impedance of the antenna for frequencies between 1.5 and 13 GHz (solid line for real part, dashed line for imaginary part)

(1.9 GHz)

(2.4 GHz)
Figure 4. Normalized radiation patterns of the antenna in X-Z plane (red line) and Y-Z plane (blue line).
The peak gain of the antenna, computed in HFSS at the frequencies of interest, is given in Table 1. A lowest gain value of 2.56 dB is recorded at 1.9 GHz. The gain is about 6 dB at 6 GHz, beyond which the gain starts to decrease. At 10 GHz, the gain is about 4.3 dB.

The antenna’s radiation efficiency, computed in HFSS at the frequencies of interest, is given in Table 2. At 1.9 GHz, the efficiency is 97%, and is 97.7% at 2.1 GHz. As the frequency increases, the efficiency decreases due to more losses in the substrate. At 10 GHz, the efficiency is 76.6%.

3. Conclusion

In this paper, we presented the design of a low-cost microstrip-line-fed PCB antenna based on a 1.6-mm-thick FR4 substrate and a partial ground plane flushed with the feed line. The patch is circular with a U-shaped slot. The presented design is suitable for applications such as 3G, Wi-Fi, WiMAX, as well as UWB applications. The antenna’s return loss, radiation patterns, gain and efficiency values were simulated in ADS Momentum and Ansoft HFSS. The computed radiation patterns are omnidirectional and vary little over the antenna’s band, but as expected, sidelobes appear at high frequencies. The gain is about 2.56 dB at 1.9 GHz, and reaches a maximum of about 6 dB at 6 GHz. The gain decreases to 4.3 dB at 10 GHz. The radiation efficiency is about 97% at 1.9 GHz. The efficiency decreases with increasing frequency. At 10 GHz, the antenna has an efficiency of 76.6%.

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