Printed Monopole Antennas with Increased Bandwidth and Gain for Wi-Fi Applications

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Introduction

The increasing demand for low cost, low profile wireless devices has resulted in a need for highly efficient, compact antennas that can integrate well into future portable wireless communication devices. Owing to their advantages in terms of weight, cost, manufacturability and compatibility with microwave circuits, electrically small planar antennas are seen as the favorable candidates to be used in such systems. In particular, printed monopole antennas are gaining in popularity due to their nearly omnidirectional far-field radiation pattern. However, electrically small antennas are mostly high-quality resonators with very narrow bandwidth. This is due to the large amount of stored near-field energy resulting in a very low radiation resistance associated with a very high reactive component [1, 2]. This creates a challenge for the designer due to the demand for electrically small but broadband antennas for use with multiple integrated radios. In addition, the possible frequency shifts due to fabrication tolerances and environmental effects during antenna operation must be accounted for. Furthermore, antenna efficiency is limited by the electrical volume of the antenna [2]. This directly affects the antenna gain which has to be maximized to lower the power consumption of the wireless terminal. A conflicting requirement is the need to meet low weight and low profile in portable devices. Clearly, the designer faces severe constraints in the design of the antenna.

Integration of electromagnetic band gap (EBG) structures with microstrip patch antennas and suspended antennas to achieve high performance has been extensively researched [3-6]. However, the methods employed for these antennas usually results in an increase in the overall size of the antenna [4, 6]. Moreover, these methods have been applied to antennas with a ground plane for improving the bandwidth and gain. These techniques cannot be directly applied to a printed monopole antenna due to the absence of a ground plane. In this paper, a method to enhance the performance of printed monopole antennas is presented. The proposed approach consists of placing a metal patch next to the antenna in order to direct the fields in one direction by using the reflection from the metal patch. This topology provides compact antenna solutions with broader bandwidth and higher peak gain suitable for use in portable electronics. The effects of the periodic pattern and the reflection from the metal patches have also been investigated in this paper.

Antenna Structure and Analysis

A monopole meander antenna has been used in the design. This is the due to its ability to achieve the required length of current path for a specific resonant frequency within a compact size [7]. The fabricated antenna is printed on a 1.6 mm thick FR-4 PCB substrate with dimensions of 23mm X 22mm. The antenna is excited by a 50 ohm microstrip line with a truncated ground covering only the microstrip line. A commercial 3-D electromagnetic simulator, HFSS [8] was used to optimize the dimensions of the antenna to obtain a resonant frequency of 5.4 GHz. The dimensions of the antenna and two different metal patches placed next to the antenna are shown in Figure 1.
During the design process, it was found that the size and shape of the metal patch as well as the distance between the antenna and the metal patch are critical design parameters to optimize the bandwidth and the gain. The effect of the configuration of the metal patches on antenna bandwidth and gain was studied using several test cases. First, patterned top metal patches were used on top of solid bottom patches as shown in Figure 1. Next, identical solid metal patches were added on both top and bottom surfaces. Finally, the bottom patch is removed and only a solid patch was added on top surface. In all cases, the improvement in gain and efficiency was similar, supporting the fact that the increase in the gain and bandwidth are essentially due to the reflection from the metal patches but not due to the periodicity of the pattern. The reflection from the metal patch can be observed from the E-field distribution plots of the substrate field, shown in Figure 2. The return loss and peak gain variations for Design 2, as the antenna-patch separation is swept from 3 mm to 10 mm, are shown in Figure 3. Similar results have been obtained for Design 1. For both cases, the optimum distance has been found to be 10 mm to maximize the bandwidth and the gain. For this optimum distance, the lengths of top and bottom patches in Design 2 (labeled as $a$ in Figure 1) was changed. For this parametric sweep, it is to be noted that the solid top patch is just a replica of bottom patch. Simulated S11 and radiation pattern plots for different values of $a$ are shown in Figure 4. For $a=7mm$, the simulated bandwidth increases from 12% to 18%, and the peak gain increases from 2.06 dBi to 4.5 dBi.

Figure 2: E-field distribution for antenna without patch and antenna with metal patch type 2

Simulation and Measurement Results

The measurements were carried out by using the Agilent E8363B vector network analyzer. Comparisons of the return loss (S11) measurements and simulations of the antenna with and without the metal patches for both Design 1 and Design 2 are presented in Figure 5. As can be seen from the measurement results in the figure, the addition of metal patches improved the 10 dB impedance bandwidth from 30% to 54% for Design 1, and from 30% to 35% for Design 2. The improvement in the peak gain and the change in the far field pattern can be seen in the simulated radiation pattern plots in Figures 6 and 7.
The total peak gain at 5.3 GHz increased from 2.06 dBi to 4.35 dBi for Design 1 and from 2.06 dBi to 3.67 dBi for Design 2. Due to the reflection from the metal patches, the far field patterns become more directional for the cases where metal patches are added.

**Conclusion**

A methodology to enhance the performance of printed monopole antennas without increasing the overall antenna size has been introduced. It has been shown by simulation and measurement results that the increased bandwidth and gain can be achieved by optimizing the shape, size and distance of a metal patch placed next to the antenna. It is also found that the reflection from the metal patch is the main reason for the improved results. The proposed design approach is generic and can be applied to any printed monopole antenna.

**Figure 3:** (a) Return Loss and (b) Peak Gain simulation results of Design 2 for different values of separation between the antenna and the patch.

**Figure 4:** Simulated return loss and radiation pattern (Phi=90 degrees) plots for different values of arm length labeled as distance \( a \) in Figure 1.

**Figure 5:** Measured and simulated S11 results of (a) Antenna and Design 1, (b) Antenna and Design 2.
Figure 6: Radiation pattern of Antenna and Design1, (a) Phi=0, (b) Phi=90, (c) Theta=90.

Figure 7: Radiation pattern of Antenna and Design2, (a) Phi=0, (b) Phi=90, (c) Theta=90.

References


