Abstract

This paper presents the design of small ceramic antenna optimized for mobile handset applications. The monopole-type antenna is directly integrated with a simple matching circuit minimizing the total antenna losses. The proposed antenna demonstrates high total and radiation efficiencies and can be utilized in a variety of single- and multi-element antenna system designs for mobile handsets and wireless terminals.

Keywords: Small Antennas, Ceramic Antennas, Matching Circuit

1. Introduction

Design of small antennas continues to attract a substantial attention and development efforts as the next generations of more compact wireless terminals and mobile handsets are being introduced to the wireless market. Ceramic antennas offer several design benefits for mobile handset system integration, such as small footprint, compact size, mechanical sturdiness, and ability to be used in both single antenna element and multi-antenna configurations [1-4]. At the same time, ceramic chip antennas should satisfy all the necessary requirements for efficiency, impedance bandwidth, and antenna gain for mobile communications applications. Most of the ceramic antennas utilize the meander line design approach which results in monopole-type chip antenna [1,2] or dipole-type ceramic chip design [3]. This paper presents the modified approach to design a ceramic chip antenna being integrated with a simple input matching circuit. The advantages of the proposed antenna include very small size, high efficiency and gain, and the ability to tune the resonant frequency according to the design needs. Two monopole-type antennas will be presented here. The first design is the ceramic antenna optimized for IMT-2000 bandwidth (1920-2170 MHz) applications while the second one is the antenna element operating at GPS band (1575 MHz). The mechanism of impedance matching due to the integrated matching circuit will be introduced and antenna radiation performance will be presented in the detail.

2. Antenna Configuration and Performance

The layout of the proposed antenna is illustrated in Figs. 1 and 2. Small copper monopole with 3D layout is embedded into the rectangular dielectric pad. In this design, Rogers alumina-type ceramic characterized by \( \varepsilon_r = 10.2 \) and \( \tan \delta = 0.0023 \) has been utilized. The initial design has been a 3D meander narrow line and on the next stage the meander turns have been made solid while the central metal pad (in X-Z plane) has been added. It has been assumed that such a layout of metallic element would produce several electric lengths and thus increase the antenna bandwidth. As illustrated in Fig. 2 the monopole is placed inside the ceramic substrate. Antenna is fed by a short microstrip line on the same Rogers substrate of thickness 0.25mm as shown in Fig. 1. There is a serial chip inductance which, together with a microstrip line, forms the impedance matching circuit of the proposed antenna. The antenna design presented in Fig. 1 has been optimized for the IMT-2000 bandwidth so that the geometrical parameters indicated have been selected for 1920-2170 MHz antenna operation. The outer dimensions of ceramic antenna are 6mmX5mmX10mm while the inner monopole dimensions are 4.2mmX2.6mmX9.25mm. Using the ceramic material with
higher dielectric constant would result in even more compact design but the choice of such a ceramic reduces the antenna bandwidth so that alumina-type Rogers material has been utilized here.

Figure 1: Layout of the ceramic antenna utilized with a PCB of mobile handset.

Figure 2: Side view of ceramic antenna shown in Fig. 1.

Figure 3: Schematic of a conventional antenna-LC matching circuit, left, and the proposed design, right.

LC matching circuit is a well-known approach in matching the antenna input impedance to the standard 50-Ohm port. The drawback of this design is that it reduces the bandwidth and thus is not suitable for wideband applications. Fig. 3 illustrates an alternative approach utilized in the proposed ceramic antenna. Serial chip L is used to lower the antenna central frequency while varying width of short microstrip line contributes to minimizing of return loss. Compared to LC circuit, the proposed matching circuit doesn't reduce the antenna bandwidth and allows to change the operational band by optimizing the value of L and microstrip width. The calculated VSWR of UMT-2000 antenna is presented in Fig. 4. Radiation performance is illustrated by 3D antenna gain pattern calculated at 2 GHz and shown in Fig. 5. It is clear that the proposed antenna produces typical monopole-like radiation pattern. Top antenna gain is 4.08 dB, radiation efficiency is 97%.
and total antenna efficiency is 96%. Taking into account the compactness of proposed antenna, it should be noted that high antenna gain and efficiency are obtained and these parameters remain high within the entire 1920-2179 MHz band.

Figure 4: Calculated VSWR of ceramic antenna shown in Fig. 1.

Figure 5: Calculated gain pattern of the proposed antenna at 2 GHz.

3. Design of GPS Antenna

The second prototype is the similar ceramic antenna optimized for the GPS band. Because of the narrow band of GPS operation, it was possible to design more compact ceramic antenna as illustrated in Fig. 6. Outer dimensions are 4mmX3.5mmX4.75mm and 18nH chip L with narrower microstrip have been used to match the antenna at 1.575 GHz.

Figure 6: Layout of the GPS ceramic antenna for mobile handset design.
Fig. 7 presents the calculated 3D gain pattern of GPS-band antenna at 1.575 GHz. Again, typical monopole-type radiation pattern is produced. Top antenna gain is 2.72 dB while the radiation and total antenna efficiencies are 99% and 98%, respectively. Compared to the previous design, smaller antenna gain is due to the reduced antenna dimensions but the efficiencies remain very high as a result of proper impedance match at the central frequency of operation.

Figure 7: Calculated gain pattern of antenna shown in Fig. 6 at 1.575 GHz.

The performance of the proposed antennas has also been tested in a dual-element handset antenna 2-port arrangement where the UMT-2000 ceramic antenna has been used with another 950 MHz meander monopole. Very low level of ports mutual coupling has been observed despite the close spacing between 2 antenna elements placed on common ground plane. Measured performance of ceramic antenna prototype agrees well with the simulation data and will be presented at the Symposium.

4. Conclusions

Small ceramic antenna integrated with a matching circuit has been introduced. The design proposed here is scalable and two design examples of mobile handset antennas, one for UMT-2000 band and another for GPS band applications, have been presented. Considering antenna's small dimensions, it demonstrates high gain and efficiency and covers the impedance bandwidth required for modern mobile handset applications.

References