THIN INTERNAL PLANAR ANTENNA FOR GSM/DCS/PCS/UMTS OPERATION IN A PDA PHONE

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ABSTRACT: A novel thin internal planar antenna for GSM/DCS/PCS/UMTS quad-band operation in a PDA (personal digital assistant) phone is presented. The proposed internal antenna has a small thickness of only 3 mm, yet it is capable of providing two wide operating bands at about 0.9 and 2 GHz so as to meet the bandwidth requirements of the GSM/DCS/PCS/UMTS systems. Details of the design considerations of the proposed antenna are described, and the experimental results of the constructed prototype are presented. © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 47: 423–426, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21190

Key words: antennas; mobile antennas; internal mobile-phone antennas; multiband mobile antennas; planar antennas

1. INTRODUCTION

Planar antennas such as PIFAs (planar inverted-F antennas) or shorted patch antennas have been found to be very attractive for applications in mobile devices as internal antennas [1]. Recently, for covering the bandwidth requirements of the GSM (global system for mobile communication, 890–960 MHz), DCS (digital communication system, 1710–1880 MHz), PCS (personal communication system, 1850–1990 MHz), and UMTS (universal mobile telecommunications systems, 1920–2170 MHz) systems, a variety of internal planar antennas have been demonstrated [2–5]. However, for this kind of quad-band operation, these reported internal planar antennas require a thick substrate of about 7–11 mm between the antenna’s top patch and the system ground plane. This thick-substrate requirement greatly limits their potential application in thin mobile devices such as the thin mobile phones or PDA phones, which are becoming very attractive for wireless users and have been considered as one of the major trends for mobile-device development.

In this paper, we present a novel thin internal planar antenna for PDA-phone applications. The proposed antenna requires a thin substrate of only 3 mm, and the total occupied volume is also less than that reported in [2–5]. The proposed antenna is a PIFA with its top patch embedded with two slits (one modified T-shape slit and one linear slit), which effectively separate the top patch into three resonant paths. By further extending a small portion of the top patch over the top edge of the system ground plane and then bending it toward the system ground plane, enhanced coupling between the internal antenna and the system ground plane is obtained, which has been found to be useful for successfully exciting wide resonant modes for the proposed internal antenna. In this case, the longest resonant path in the antenna’s top patch can generate a wide resonant mode at about 0.9 GHz for GSM operation, while the other two resonant paths can generate two close resonant modes at about 2 GHz so as to form a wide bandwidth covering the DCS/PCS/UMTS operation. Prototypes of the proposed antenna have been constructed and experimentally studied. The obtained experimental results are presented and discussed.

2. ANTENNA DESIGN

Figure 1(a) shows the geometry of the proposed thin internal planar antenna for quad-band operation in a PDA phone. Detailed dimensions of the antenna’s top patch are shown in Figure 1(b). The antenna is mounted at the top portion of the system ground plane (size 70 × 120 mm²) of a practical PDA phone. The antenna’s top patch occupies an area of 23 × 70 mm², and is mounted above the system ground plane with a height h of only 3 mm. That is, the antenna shows a thickness of only 3 mm, which is much less than that of the conventional internal planar antennas [1–5].

In the antenna’s top patch, two slits (one modified T-shape slit and one linear slit) are embedded so as to separate the top patch into three resonant paths. The modified T-shape slit or the branch-line slit [6] effectively separate the top patch into two resonant paths: paths 1 and 2, as shown in Fig. 1(b). Path 1 has a length of about 75 mm, which corresponds to about one-quarter wavelength of the frequency at 900 MHz, and can thus generate a resonant...
mode for GSM operation. Path 2 has a length of about 40 mm, corresponding to about one-quarter wavelength of the frequency at 1900 MHz. In this case, path 2 can generate a resonant mode for PCS operation.

In order to cover DCS and UMTS operation, an additional resonant mode for the upper band of the antenna is required. For this purpose, a linear slit of length 17 mm \( (t) \) is embedded in the top patch. This linear slit has been found to be effective in separating a third resonant path in the antenna’s top patch. This additional resonant path (path 3) has a length of about 30 mm, which is about one-quarter wavelength of the frequency at 2300 MHz, and can lead to the successful excitation of an additional resonant mode. This additional resonant mode contributed by path 3 and the resonant mode by path 2 can be formed into a wide operating band, and hence easily cover DCS/PCS/UMTS operation. Effects of the linear slit on generating an additional resonant mode will be discussed in more detail in section 3.

It should also be noted that a small portion of the antenna’s top patch is extended over the top edge of the system ground plane and further bent toward the system ground plane, resulting in a small gap \( g \) of 2 mm between the top edges of the antenna’s top patch and the system ground plane. This small gap in the proposed design can result in some capacitive coupling between the top edge of the system ground plane and the end portions of paths 1, 2, and 3, which is expected to result in more uniform excited current distributions for the three resonant paths. This will be helpful in achieving wider bandwidths for the three resonant modes controlled by paths 1, 2, and 3. Thus, wider bandwidths of the antenna’s lower and upper bands can be obtained, allowing the proposed antenna easily covering the GSM/DCS/PCS/UMTS quad-band operation.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the design dimensions shown in Figure 1, the proposed antenna is constructed and tested. Figure 2 shows the measured and simulated return losses for the constructed prototype. The simulated results are obtained using the Ansoft simulation software HFSS (high-frequency structure simulator) [7]. Good agreement between the measurement and simulation is observed. Based on the bandwidth definition of 2.5:1 VSWR, which is generally acceptable for PDA-phone or mobile-phone applications (some even adopt the definition of 3:1 VSWR only [2–5]), the bandwidths of the antenna’s lower and upper bands cover the bandwidth requirements of GSM/DCS/PCS/UMTS systems. Also note that the antenna’s upper band is formed by two close resonant modes, which are generated by paths 2 and 3. This behavior agrees with the design considerations discussed in section 2.

To analyze the effect of the embedded linear slit, a simulation study for the return loss as a function of the slit length \( t \) is shown in Figure 3. When the linear slit is not present \( (t = 0) \), the excited resonant mode can cover the PCS operation only. With the linear slit embedded in the top patch \( (t = 13 \text{ and } 17 \text{ mm}) \), the bandwidth of the antenna’s upper band is seen to be enhanced, especially for the case of \( t = 17 \text{ mm} \). In this study, there exists an optimal slit length \( (t = 17 \text{ mm}) \) for achieving a maximum bandwidth in the antenna’s upper band.

The radiation characteristics of the proposed antenna were also studied. Figures 4–7 show, respectively, the measured radiation patterns at 925, 1795, 1920, and 2045 MHz (center frequencies of the GSM, DCS, PCS, and UMTS bands). As shown in Figure 4 for 925 MHz, monopolelike radiation patterns are seen. For 1795, 1920, and 2170 MHz, as shown in Figures 5–7, respectively, the radiation patterns are seen to be less smooth. These obtained radiation patterns in general are all similar to those of the conven-
tional internal planar antennas [1–6], with no special distinction observed. The measured antenna gain is shown in Figure 8. For frequencies over the GSM band [see Fig. 8(a)], the measured antenna gain is in a range of about 1.0–1.7 dBi. For frequencies over the DCS/PCS/UMTS bands [see Fig. 8(b)], the measured antenna gain varies from about 2.4 to 3.5 dBi.

4. CONCLUSION
A novel thin (only 3 mm) internal planar antenna suitable for quad-band operation in the GSM/DCS/PCS/UMTS bands in a PDA phone has been proposed and successfully implemented. The experimental results have shown that the proposed antenna has generated two wide operating bands, covering the bandwidth requirements of the GSM/DCS/PCS/UMTS systems, and good radiation characteristics have also been obtained. The proposed
antenna is very suitable for practical applications in thin PDA phones or mobile phones.

REFERENCES
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LOAD MATCHING IN MICROWAVE-HEATING APPLICATORS BY MEANS OF GENETIC-ALGORITHM OPTIMIZATION OF DIELECTRIC MULTILAYER STRUCTURES

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ABSTRACT: In this paper, the design of a dielectric multilayer around a dielectric sample in order to avoid the appearance of undesired reflections and achieve higher matching-efficiency values within multimode microwave-heating ovens is presented. The permittivity and geometric values for the sample surrounding layers are optimized by means of genetic algorithms (GAs) in order to maximize the system matching. Several dielectric-mould configurations are studied and the results show that the use of dielectric layers surrounding the product substantially improves the load matching. © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 47: 426–430, 2005; Published online in Wiley InterScience (www.inter science.wiley.com). DOI 10.1002/mop.21191

Key words: genetic algorithms; load matching; microwave heating; multimode applicator; power efficiency

1. INTRODUCTION
In most microwave-heating processes, load matching is required in order to achieve high energy efficiency and avoid magnetron damages [1]. In fact, electric-field reflections within the microwave-heating applicator are identified as one of the most important problems in microwave-heating applications because they affect energy consumption and electric-field uniformity [2]. Traditionally, the methods used to achieve load matching in multimode applicators involve the use of stubs or irises [1, 2]. An alternative load-matching method was reported recently in [3], in which the applicator is fed by means of a combination of optimally positioned sources, which reduces both the reflection and the mutual coupling among them.

Prior to this work, other studies [4–6] have used dielectric layers surrounding the sample as a way to improve matching efficiency in 2D multimode structures, obtaining matching efficiency values of around 99%. Furthermore, an iterative search has been carried out to compute the optimal permittivity for dielectric layers with a given thickness that surround a dielectric sample [5]. On the contrary, the permittivities of the dielectric surrounding layers are fixed and their thickness iteratively changed in order to achieve load matching in [6]. However, these works were only 2D approaches and even though high computing times were required to calculate the optimum values for the adapting layers, due to the large number of simulations required to solve the problem. Additionally, it is clear from recent studies in the literature that interfacing electromagnetic (EM) simulators with optimization algorithms can lead to good results both in terms of efficient designs and computational resources [2, 7]. However, for complex problems in which the optimum value depends on many input parameters, classic optimization techniques may not lead to good results and usually demand large computing resources.

Neural networks is an optimization technique typically used in EM since the 1990s. Several works confirm its efficiency, for example, [8, 9]. Nevertheless, the use of genetic algorithms (GAs) in EM design has proven its reliability for different areas of electromagnetics as well, mainly in antennas and filters’ design. GA is a general optimization technique, mainly focused on problems that depend on many input parameters or complex combinatorial problems due to its powerful heuristic features [7].

For the design of multimode microwave-heating ovens, there are a few remarkable works, such as the one presented in [10]. In this work, uniform electric-field distributions in microwave multimode applicators are achieved by identifying the optimum waveguide feeding positions by means of a GA.

In the present work, a novel load-matching technique based on the use of dielectric moulds with variable geometric and permit tivity values is presented. Moulds surrounding the product are necessary in some applications in order to avoid the formation of bubbles (rubber vulcanization) or the risk of explosion of the product container (food sterilization). So, this technique provides another function to these layers.

In comparison with [4–6], more realistic 3D scenarios are now being proposed and studied. Additionally, optimization methods based on GAs are presented to correctly design the dielectric and geometric properties of the materials that make up the structure enclosing the sample.

Although the mode-matching technique has been successfully applied in combination with a GA, showing faster computing times than commercial simulators [10], it must be remarked that this technique is restricted to canonical structures. The general methodology presented here may deal with irregular geometry or inhomogeneous samples or elements of the applicator.

2. THEORETICAL STUDY
The problem to be solved consists of a $24 \times 24 \times 24$ cm$^3$ metallic rectangular applicator. The multimode cavity is fed by means of a WR340 waveguide centered at the upper wall of the oven and excited with the $TE_{10}$ mode at 2.45 GHz (electroheat frequency, ISM band).

The product inside the cavity was clay, with a relative permittivity of 24.64 – 5.45. The clay sample has been chosen in order