Characterization of Antennas for Personal Wireless Communications Applications

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The advancement of antenna technology in personal wireless communication systems has been encouraged by the increasingly stringent demands placed upon these systems to provide low-power and highly reliable information transfer. The antenna designer must not only consider the cost, manufacturability, compactness, and system integrability of the radiator but also generate a product which satisfies rigid specifications concerning return loss, bandwidth, and gain while operating in a complex radiating environment. Successful, cost-effective approaches to the design of antennas for communication devices rely upon the implementation of sophisticated analysis tools, such as the finite-difference time-domain (FDTD) method, capable of predicting the electromagnetic behavior of complicated topologies. In this work, the behavior of planar inverted F, monopole, and loop antennas is investigated using tools based upon the FDTD approach. Such factors as the effects of the conducting chassis, plastic casing, and biological tissue on the antenna performance are investigated. Experimental measurements are used to validate the results obtained from computations and to provide further insight into the behavior of the different geometries. The use of antenna diversity to reduce the effects of multipath fading is discussed, and several examples of antenna diversity configurations are provided.

KEY WORDS: Wireless; FDTD; PIFA; monopole; loop antenna; diversity.

1. INTRODUCTION

Personal wireless communication systems have been evolving steadily due to the increasingly stringent demands placed upon them to provide low-power, highly reliable information transfer with ergonomical designs. The antenna, being such a fundamental part of the overall unit, has certainly not been immune from this technological growth. New applications demand that the antenna designer not only consider the cost, manufacturability, compactness, and system integrability of the radiator but also generate a product which satisfies rigid specifications while operating in a complex radiating environment. Specifically, the antenna elements must ideally offer the features:

- Omnidirectionality to ensure reliable communication regardless of antenna orientation
- Wide bandwidth to accommodate spread-spectrum communication schemes
- Minimal coupling to the operator’s biological tissue to avoid performance degradation and health risks
- Low-profile physical geometry to facilitate antenna packaging and provide convenience to the operator

This work presents the results of recent efforts aimed toward the analysis, design, and performance evaluation of antenna structures suitable for implementation in hand-held transceiver units for personal communications applications.

The intricate material and geometrical features as-
sociated with antenna configurations often cannot be practically modeled using conventional approximate analytical techniques. For this reason, cost-effective antenna design approaches must rely upon the implementation of sophisticated analysis tools capable of predicting the electromagnetic behavior of the antenna geometry while incorporating the effects of neighboring bodies such as a transceiver chassis or biological tissue. The finite-difference time-domain (FDTD) algorithm [1-2] provides a means of performing the detailed simulations required, and results of several efforts to model simple antenna systems have appeared in the literature [3-7]. In this work, the performance of several antenna designs suitable for hand-held transceiver units is investigated using computational tools based upon the FDTD approach [8]. The antenna elements considered include the monopole, the planar inverted F antenna, and the loop antenna. Such issues as the effect of the handset conducting chassis and plastic casing and the influence of operator proximity on the antenna behavior are addressed. Experimental verification of the simulated results for these antenna configurations is included to provide further evaluation of the performance of antennas designed for this application.

The concept of antenna diversity [8-12] in which multiple antennas are placed upon a single transceiver unit to increase the received signal-to-noise ratio is also discussed, and the feasibility of incorporating such designs into small portable transceivers and telephones is addressed. Several computational results are presented which evaluate the theoretically achievable improvements obtainable from antenna diversity configurations. Conclusions are drawn based upon the theoretical and experimental results.

2. PHYSICAL MODELING OF ANTENNA CONFIGURATIONS

2.1. Hand-Held Transceiver Geometry

Numerous different geometries and configurations of small antennas suitable for implementation in portable handsets are conceivable. For example, Fig. 1a depicts a typical handset with the monopole or whip antenna mounted on the top panel. This particular configuration has been used extensively in wireless communications applications—mainly due to its simplicity—and as such has been the focus of many theoretical and computational studies [3, 4]. Figure 1b illustrates the handset with a portion of the outer plastic casing removed to show the mounting of the dual planar inverted F antennas (PIFA) [13-15] placed on the handset sides. Figure 1c is a similar example for a loop antenna mounted on the back of the handset. These configurations have received relatively little attention in the

Fig. 1. Typical antenna configurations for hand-held communications devices: (a) monopole; (b) PIFA diversity antennas; (c) loop. The plastic casing has been partially removed from the front of (b) and the back of (c) to reveal the position of the antennas.