Novel Multi-Band Broadband Planar Wire Antennas for Wireless Communication Handheld Terminals

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Abstract—A novel type of multi-band broadband antennas is developed for wireless handheld terminals. The broadband performance is achieved by introducing a small gap in a wire loop whereas the multi-band operation is implemented by simultaneously exciting one or more additional antenna elements. The dual-band operation is obtained by employing a combination of a loop and a monopole while the triple-band antenna consists of a loop, a monopole, and an Inverted-L antenna. It is found that the VSWR≤2 bandwidths are 31% in band 1 and 55% in band 2 for the dual-band antenna, and 31% in band 1, 55% in band 2 and 38% in band 3 for the triple-band antenna. The bandwidths of the dual-band antennas can cover the frequency bands of all existing cellular mobile communication systems around the world, including AMPS/PCS in America, GSM/DCS in Europe, and PDC/PHS in Japan, the emerging 3G systems, and the 2.4-GHz WLAN systems, while the bandwidth of the triple-band antenna additionally covers the 5-GHz ISM bands for WLAN applications.

I. Introduction

The growth in the wireless communication industry has resulted in a number of wireless standards used throughout the world. For example, the existing 1st and 2nd generation cellular mobile communication systems operate at the AMPS (824-894 MHz) and PCS (1850-1990 MHz) bands in America, at the GSM (880-960 MHz) and DCS (1710-1880 MHz) bands in Europe, and at the PDC (810-915 MHz) and PHS (1895-1918 MHz) bands in Japan. For future mobile communication systems, such as the emerging 3rd generation systems or beyond, new spectrum may be allocated around 2 GHz. In addition to different operating frequency bands adopted in cellular mobile communications systems, Wireless Local Area Networks (WLANs) also use different frequency bands. IEEE 802.11b, Bluetooth, and HomeRF operate in the 2.4 GHz ISM band while IEEE 802.11a and HiperLAN (in Europe) will use the 5-GHz ISM bands.

The antenna will be a key component in the realization of the future wireless world where multi-mode terminals operating over several frequency bands will be inevitable. For example, the 3G antennas will need to operate both in the IMT 2000 frequency bands and in the already established frequency bands. Also, the future wireless terminals will need to support high data speeds in combination with high mobility. To enable a wireless handheld terminal to provide multi-functional services (such as voice, video, and data transmissions) with automatic access and seamless roaming across different operating frequency bands over the globe, it is generally expected that a multi-band antenna will be needed. This antenna should be capable of providing coverage of all or a part of the frequency bands mentioned above. Therefore it would be desirable for an antenna to have a broadband (successive bands) as well as a multi-band (far-separated bands) performance.

In recent years, a great number of new antenna structures have been developed for dual-band or triple-band operations in wireless communication handsets [1]-[4]. However, most of multi-band antennas have a narrow bandwidth at each band. In this paper, a new type of multi-band broadband antennas will be proposed. The multi-band operation is realized by directly feeding different antenna elements, each of which has a different resonant frequency. The bandwidth at each separate band is enhanced through the coupling of parasitic elements. The dual-band broadband antenna consists of a loop and a monopole while the triple-band broadband operation is achieved by adding one

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additional inverted-L antenna to the dual-band structure. All of these antennas have a simple planar structure, allowing them to be readily manufactured as printed circuits.

II. Antenna Design

The design for the multi-band broadband antennas starts with a wire loop printed on an electrically thin dielectric substrate (e.g. RT/Duroid 5880) that is mounted at the top of a finite ground plane to model a PCB, as shown in Fig. 1. When interrupting the rectangular loop ABEF with a small gap CD, it is possible to increase the bandwidth of the loop antenna by adjusting the position of the gap [5]. Actually the interrupted loop has derived in two Inverted-L Antennas (ILAs): one (ABC) is directly fed by a coaxial cable and the other (FED) is excited through electromagnetic coupling. The broadband performance is achieved by making the length of the coupled ILA (FED) slightly longer than the directly fed ILA (ABC). To achieve a dual-band operation, we add a monopole (OM) at the middle of the loop antenna. To directly feed both the ILA ABC and the monopole OM, we move the coaxial cable to the middle of the loop and connect the ILA ABC to the monopole OM at O′ by introducing a piece of wire O′A (O′A with its image below the ground plane acts as a transmission line). The monopole OM is designed for resonance at a higher frequency and the height of O′A is optimized for an optimal VSWR. Note that the wire O′A has a negligible contribution to the radiation fields due to its proximity to the ground plane. In order to achieve a triple-band operation, another short piece of wire is added in the dual-band antenna. The added short wire (O′L) with the feed probe OO′ acts as a new inverted-L antenna in the highest band. Note that the radiation contribution from O′A or O′L is no longer negligible in the highest band since the height of O′L above the ground plane becomes comparable to a significant friction of one wavelength.

III. Results

The above antenna structures were simulated using the TLM (Transmission-Line Method) based software-Microstripes 5.6. The calculated VSWR for a dual-band operation in 1 GHz (band 1) and 2 GHz (band 2) bands is shown in Fig. 2. The VSWR≤2 bandwidths are 31% in band 1 and 55% in band 2. It is also observed that the VSWR in band 2 is quite low and has a flat variation (VSWR≤1.5 from 1.6 to 2.4 GHz). Such a dual-band broadband antenna is suitable for use in AMPS/PCS, GSM/DCS, PDC/PHS, IMT2000, and 2.4 GHz ISM band WLAN. Note that the broadband performance in band 2 benefits from a combination of the fundamental mode of the monopole OM and the high-order mode of the coupled loop (ABCDEF).

The simulated VSWR for the triple-band antenna is shown in Fig. 3. An additional broadband (38%) operation is obtained in the 5-GHz band (band 3) (covering the two ISM subbands for 802.11a/HiperLAN2). This broadband performance also benefits from a combination of the fundamental mode of the additional ILA (OO′L) and the high-order modes of the loop (ABCDEF) and monopole (OM). It can be noted that the addition of the new ILA does not affect the broadband performance of the original dual-band loop-monopole antenna in bands 1 and 2.

The simulated radiation patterns for the multi-band antennas are plotted in Fig. 4. The dual-band and triple-band antennas share similar radiation characteristics in bands 1 and 2. It can be observed that the radiation patterns in bands 1 and 2 are polarization mixed and the total-field pattern is nearly omni-directional in the azimuth plane (x-y). The power gain in the x-y plane is around 0 dBi. The vertical component (E_θ) comes from the asymmetrical reflection by the ground plane. There is a reduced gain in the –z plus –x direction due to the shield of the ground plane. In band 3, the feature of the omni-directional pattern is missing due to the contributions from the stronger high-order currents on the loop and the monopole. This radiation pattern may be suitable for multipath propagation environments, where this antenna may serve as a diversity antenna. Experimental results will be presented in the conference for validation purposes.

IV. Conclusion

A novel type of planar wire antenna structures has been proposed to achieve multi-band broadband operations. It has been demonstrated that a combination of a loop with a gap and a monopole can result in a dual-band operation with bandwidths of 31% in the lower band and 55% in the higher band. The triple-band operation can be realized through adding one additional inverted-L antenna to the dual-band structure. The bandwidth in the third band has been found to be 38%. When mounted on a wireless handheld terminal, the multi-band broadband antenna produces an omni-directional and polarization-mixed radiation pattern. This type of antennas could find use in most existing or/and emerging mobile communication systems and WLAN where multi-band operation and/or antenna diversity are needed.

Acknowledgement

The authors wish to acknowledge the support of Yamacraw Design Center of the State of Georgia, the NSF Career Award under contract NSF #9964761, and the NSF Packaging Research Center.

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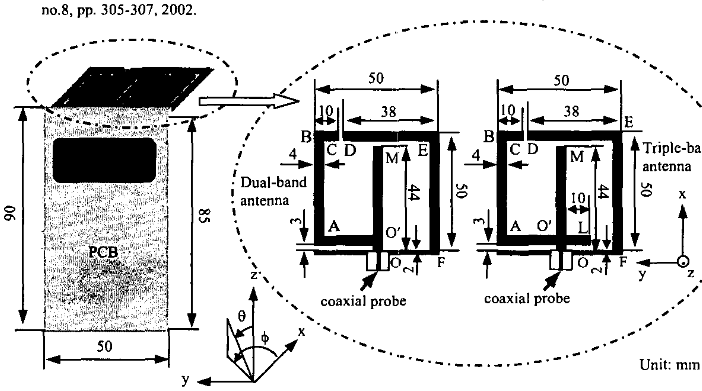


Fig. 1. Multi-band broadband antennas for wireless handheld terminals.

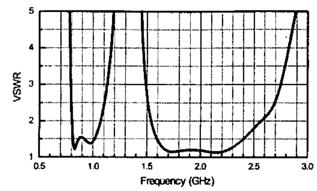


Fig. 2. VSWR of a dual-band antenna.

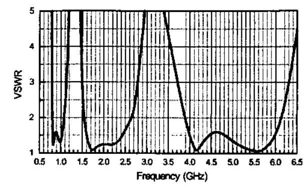
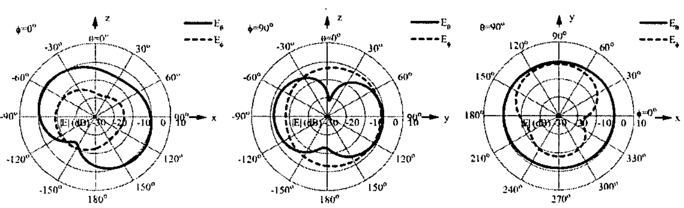
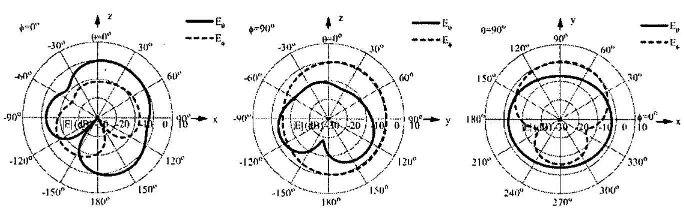


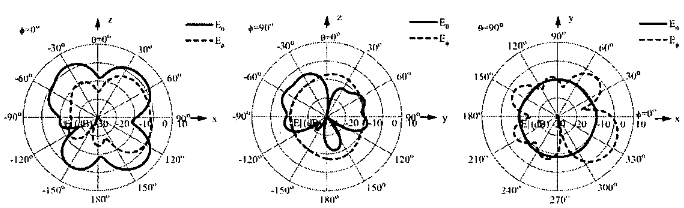
Fig. 3. VSWR of a triple-band antenna.



(a) at 950 MHz



(b) at 2000 MHz



(c) at 5500 MHz

Fig. 4. Radiation patterns of a multi-band broadband antenna.