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Application Article

Low-Interference Dual Resonant Antenna Configurations for Multistandard Multifunction Handsets and Portable Computers

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Low-interference dual resonant antenna configurations are developed for multistandard multifunction mobile handsets and portable computers. Only two wideband resonant antennas can cover most of the important wireless applications in portable communication equipment. The frequency bands of the dual antenna configuration can be adjusted according to the wireless applications that are required to be covered. The bandwidth that can be covered by each antenna is about 80% without using matching or tuning circuits. Three sample dual antenna configurations with different frequency bands are presented. The interference between the low-band and high-band antennas of these three configurations is investigated, and the ways of reducing this interference are studied. The most effective factor on the interference between the low-band and high-band antennas is their relative orientations. When the low-band and high-band antennas of each configuration are perpendicular to each other, the isolation between them significantly increases. This eliminates the need for any special tools or techniques to suppress the mutual coupling between them. The new antennas have very small cross-sectional areas, and they are made of a flexible material. They do not require any additional components or ground planes. They can be used as internal, external, or partially internal and partially external antennas.

1. Introduction

The number of mobile wireless applications is continuously increasing. Furthermore, most wireless applications have different standards with different frequency allocations worldwide. Hence, it is desirable to have multistandard multifunction handsets and portable computers. In order to cover the frequency bands of all applications, several antennas have to be used. The problem is that the frequency bands of some applications are very close to each other or even overlapping as in GSM (824–894 MHz) and UHF mobile TV "DVB-H" (470–862 MHz) [1]. As a result, there will be a severe interference between their antennas. In this research, low-interference dual resonant antenna configurations are developed for multistandard multifunction mobile handsets and portable computers. Only two wideband antennas can cover most of the important wireless applications in portable communication equipment. The frequency bands of the dual antenna configuration can be adjusted according to the wireless applications that are required to be covered. The maximum bandwidth that can be covered by each antenna is about 80% without using matching or tuning circuits.

Three sample dual antenna configurations will be presented. The first configuration covers a frequency band from 470 MHz to 2.7 GHz, which is divided into two subbands; 470–960 MHz and 1.2–2.7 GHz. Each subband is covered by a wideband resonant antenna. Since the low-band antenna resonates from 470 to 960 MHz, it can cover the bands of UHF mobile digital TV "DVB-H" (470–862 MHz), 700 MHz WiMax, CDMA/TDMA/GSM800 (824–894 MHz) and E-GSM900 (880–960 MHz) [2]. The high-band antenna resonates from 1.2 to 2.7 GHz, and it can cover the bands of low L band GPS (1.2 GHz), L-band DVB-H (1452–1492 MHz), GPS (1575 MHz), GSM1800 (1710–1880 MHz), PCS1900 (1859–1990 MHz), UMTS (1900–2170 MHz), Bluetooth/WiFi (2.4 GHz), WiMax (2.3–2.5 GHz), and IMT-2000 WiMax (2.5–2.69 GHz). The bandwidths of these two

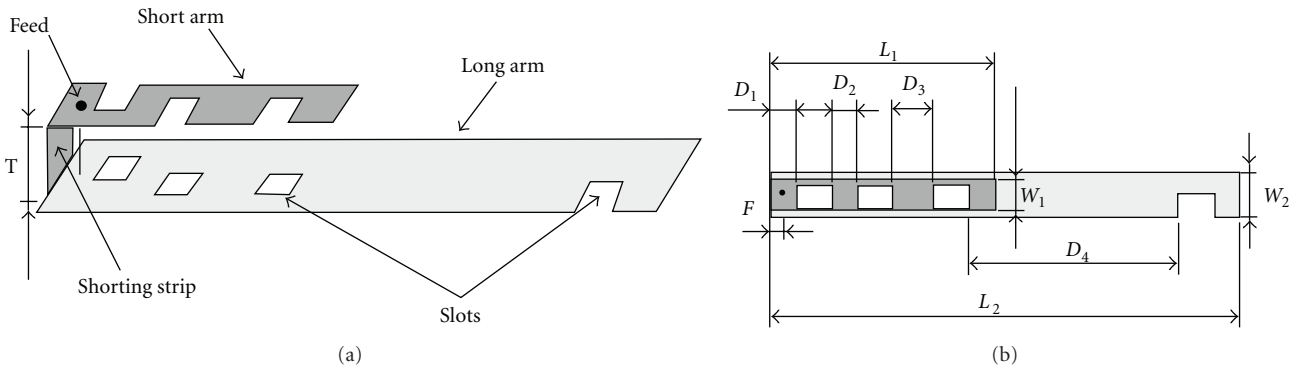

Figure 1: Geometry of the new wideband resonant antenna.

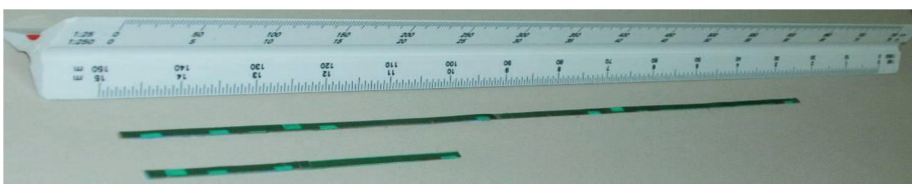

Figure 2: The antennas of the first dual antenna configuration.

antennas are 69% and 77%, respectively. There is a frequency gap between the two subbands which is not utilized by any important application. This frequency gap helps in increasing the isolation between the low-band and high-band antennas, which means reducing the mutual coupling and the interference between them. It should be noted that linearly polarized antennas can be used with all the above applications including GPS, which is circularly polarized. This is because the advantages of using circularly polarized GPS antennas disappear in heavy multipath environments as it was experimentally verified in [3].

In another dual antenna configuration, the high-band antenna is modified to resonate from 1.575 to 3.6 GHz (with 78% bandwidth) instead of resonating from 1.2 to 2.7 GHz in order to cover the 3.5 GHz WiMax band. This also increases the frequency gap between the low and high subbands which further reduces the mutual coupling between their antennas. A third dual antenna configuration covers the frequency bands; 750 MHz–1.65 GHz and 1.71–3.9 GHz. The antennas of this configuration are much shorter than the antennas of the other two configurations. The interference between the low-band and high-band antennas of the above three configurations are investigated, and the ways of reducing this interference will be presented.

2. Results

Figure 1 shows the geometry of the new wideband resonant antennas [2]. They consist of two narrow printed metallic arms connected together by a shorting metallic strip. The two arms may be parallel to each other or may have any angle between them. The length of the short arm is L_1 and its width is W_1, while the length of the long arm is L_2 and its width is W_2 and the antenna is fed with a coaxial feed line at a distance F from the shorted edge. The two arms of the antenna can have equal or unequal widths W_1 and W_2. Furthermore, the two arms can be shaped in different ways in order to optimize the antenna performance. As shown, each arm has a set of slots having different configurations. These slots can be circular, rectangular, square, triangular, or other shapes. The arm lengths of the new antenna, especially the length of the short arm, are the main parameters that determine the operating frequency of the antenna. The feed location is adjusted in each configuration in order to improve the return loss as much as possible. The bandwidth, the peak gain, and the efficiency of the antenna are mainly determined by the widths of the two arms, the angle between them, the thickness of the antenna, and the configurations of the slots, which are all optimized together in order to enhance the antenna performance, especially the bandwidth. The antennas are completely self-contained and do not need extended ground planes or any additional components. Thus, the new antenna can be mounted anywhere, inside or outside any handset, because the antenna does not use a part of the handset as an extended ground plane, which usually happens with most available internal antennas. Furthermore, the antenna is made of a flexible printed material and can be bent and/or folded in different forms in order to fit any available space inside or outside the handset. Actually, it can be used as an internal, external, or partially internal and partially external antenna. Moreover, the overall size of the antenna is small and its manufacturing costs are low.

Different prototypes of the new antennas have been designed, manufactured, and tested. Figure 2 shows the low-band and the high-band antennas of the first configuration that covers a frequency band from 470 MHz to 2.7 GHz,

Table 1: The distance between the successive slots in the arms of the high-band antenna.

D_1	D_2	D_3	D_4
5 mm	5 mm	10 mm	45 mm

which is divided into two subbands; 470–960 MHz and 1.2–2.7 GHz. The antennas are made of a flexible printed material "PET" with a dielectric constant $\varepsilon_r = 3.5$ and a tangent loss $\delta = 0.015$. The dimensions and the results of this low-band antenna were presented in [2]. The dimensions of the high-band antenna are $L_1 = 4$ cm, $L_2 = 9$ cm, $W_1 = 2.6$ mm, $W_2 = 3.5$ mm, and $T = 2$ mm. Hence, the overall size of the high-band antenna is $9 \times 0.35 \times 0.2 = 0.63\ \text{cm}^3$. It should be noted that this is the overall volume of the antenna because it does not require additional ground planes, matching circuits, or any other additional components. All slots in both arms of the antenna are selected to be rectangular in shape. The length of each slot is 5 mm, and its width is 2 mm. The distance between the shorted edge and the first slot and the distances between the successive slots are shown in Table 1. The locations of the slots in the short arm are exactly repeated in the long arm. However, since the long arm is wider than the short arm, the slots are positioned close to the middle of the long arm forming rings while they are located at the edge of the short arm as shown in Figure 1.

The return loss and the radiation patterns of the new antennas are numerically calculated by a software package that uses the moment method. They were also measured at IMST antenna labs in Germany [4]. Figure 3 shows the calculated and the measured return loss of the high-band antenna. The agreement between the numerical and the measured results is within the acceptable limits. The return loss is less than −5 dB over most of the band, which has more than 77% bandwidth. The calculated and the measured radiation patterns of the high-band antenna at a sample frequency of 2.4 GHz are shown in Figures 4(a) and 4(b), respectively. The agreement between them is very good. The coaxial feed connection was included in the simulation model. Figure 5 shows the calculated and the measured efficiency of the high-band antenna from 1200 MHz to 2700 MHz. The average efficiency is about 50%. The antenna efficiency was measured using the radiation pattern method.

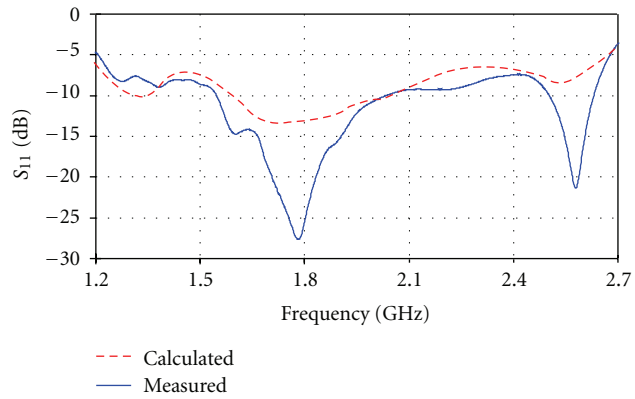

Figure 3: Calculated and measured return loss of the high-band antenna of the first dual antenna configuration.

3. Adjusting the Frequency Bands of Dual Antenna Configurations

The frequency band of the above dual antenna configuration can be adjusted according to the wireless applications that are needed to be covered by a mobile handset or a portable computer. However, the maximum bandwidth that can be covered by each antenna is about 80%. For example, if L2-GPS (1227.6 MHz) and L-band DVB-H (1452–1492 MHz) are not required to be added to a mobile handset or a portable computer while the 3.5 GHz WiMax is needed, the high-band antenna can be modified to resonate from 1575 to 3.6 GHz (with 78% bandwidth) instead of resonating from 1.2 to 2.7 GHz. This also increases the frequency gap between the low-band and the high-band antennas from 240 MHz (960 MHz –1.2 GHz) to 600 MHz (960 MHz–1.56 GHz), which results in increasing the isolation between them. The length of the modified high-band antenna is reduced from 9 cm to 6.5 cm. The modified high-band antenna and the original low-band antenna form a second sample of dual antenna configurations, which ranges from 470 MHz to 3.6 GHz. The measured return loss of the modified high-band antenna is shown in Figure 6. The return loss is better than −7 dB over most of the band.

On the other hand, if the L-band mobile TV "DVB-H" is used instead of the UHF DVB-H, the length of the low-band antenna can be significantly reduced [5]. In a third sample dual antenna configuration, the low-band antenna is designed to resonate from 750 MHz to 1.65 GHz while the high-band antenna resonates from 1.71 to 3.9 GHz. The length of the low-band antenna is reduced from 25 cm in the first configuration to 14 cm in the third configuration, while the length of the high-band antenna is reduced to 6 cm. The calculated and measured return loss of the low-band and high-band antennas of the third configuration are shown in Figures 7 and 8, respectively. The third configuration covers an overall bandwidth ranges from 750 MHz to 3.9 GHz. Thus, although it still covers the 750 MHz WiMax, it can also cover more WiMax standards (3.7–3.9 GHz).

4. The Isolation between the Low-Band and High-Band Antennas

It is important to increase the isolation between the low-band and high-band antennas in dual antenna configurations as much as possible in order to reduce the mutual coupling and the interference between them. Usually, special techniques have to be used in order to suppress or reduce the mutual coupling between adjacent antennas in multiantenna configurations [6–11]. The isolation between the two antennas of the above three dual antenna configurations is investigated. The isolation between the low-band and high-band antennas depends on the distance and the frequency gap between them as well as their relative orientations. The isolation is

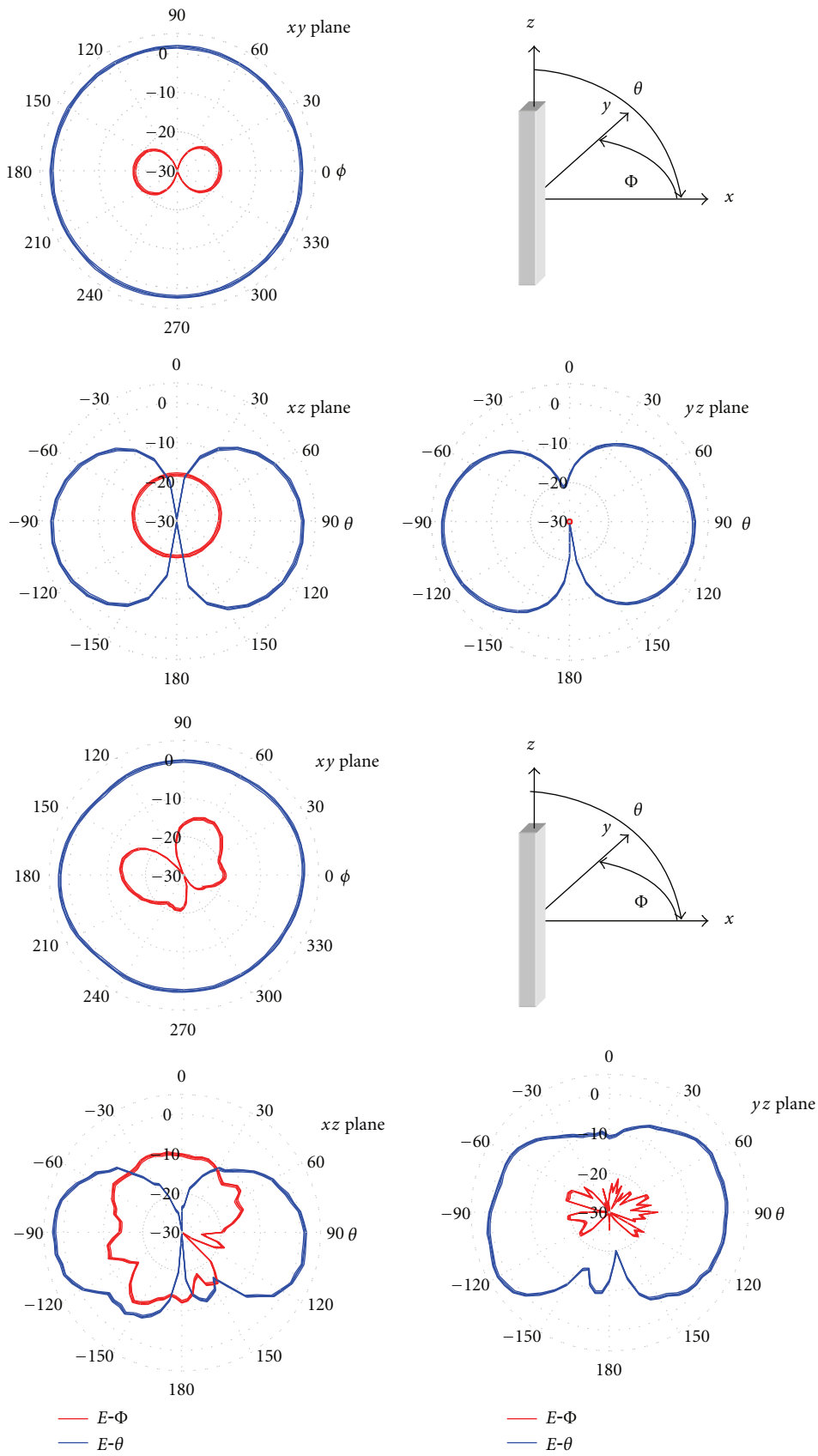

Figure 4: (a) Calculated radiation patterns of the high-band antenna at 2.4 GHz. (b) Measured radiation patterns of the high-band antenna at 2.4 GHz.

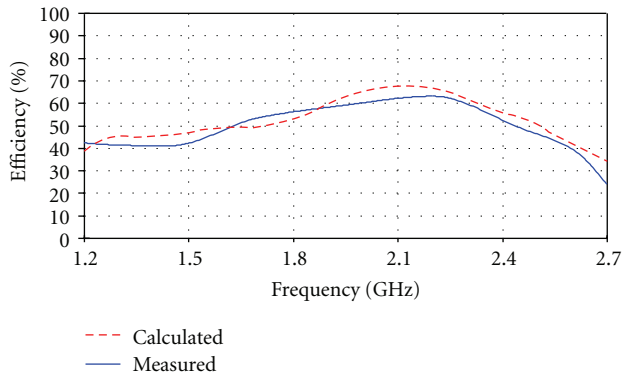

Figure 5: Calculated and measured efficiency of the high-band antenna of the first dual antenna configuration.

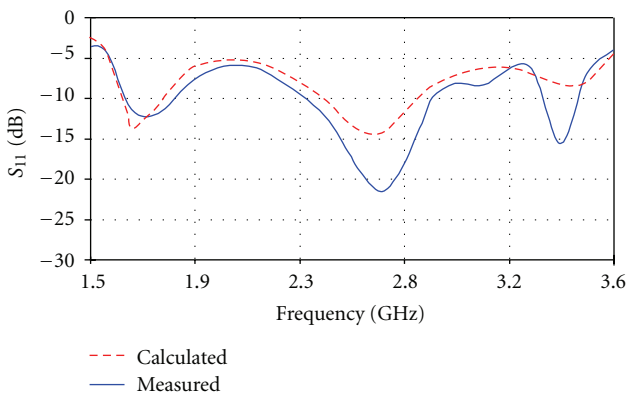

Figure 6: Calculated and measured return loss of the high-band antenna of the second dual configuration.

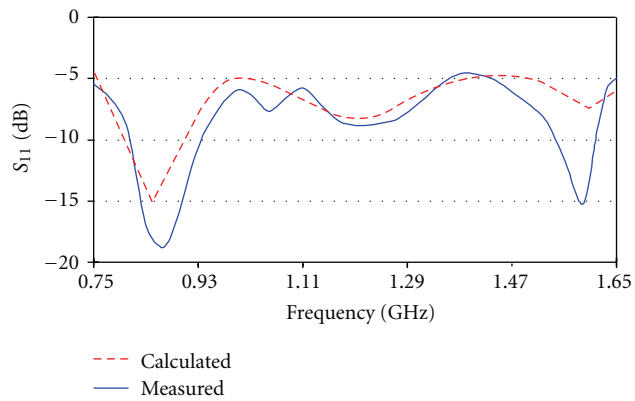

Figure 7: Calculated and measured return loss of the low-band antenna of the third dual antenna configuration.

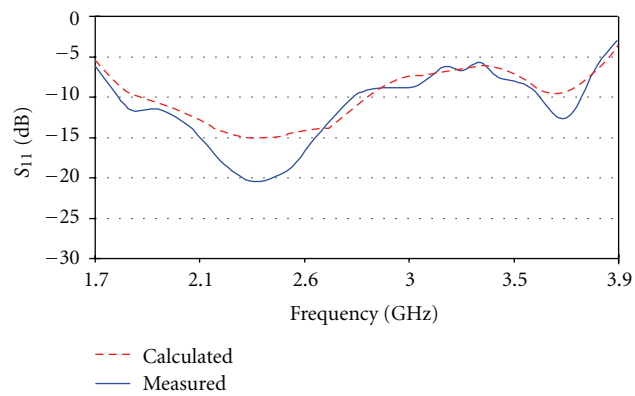

Figure 8: Calculated and measured return loss of the high-band antenna of the third configuration.

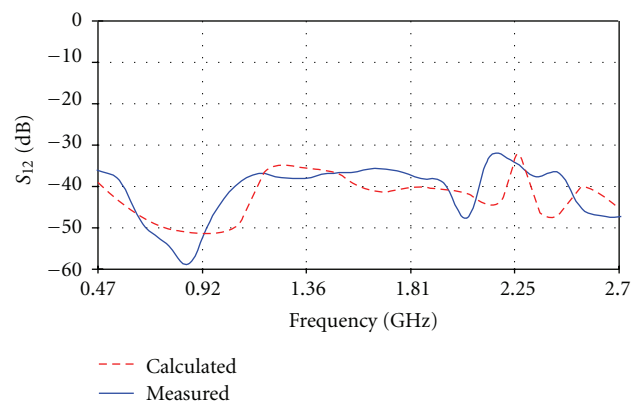

Figure 9: Mutual coupling (S_{12}) between the antennas of the first configuration while the antennas are perpendicular to each other.

also significantly affected by the harmonics of the low-band antenna [12]. For example, the low-band and high-band antennas are oriented parallel to each other and separated by 5 cm. In this case, the measured maximum isolation in the three configurations is −21 dB, −25 dB, and −16 dB, respectively. Thus, for a fixed distance between the low-band and high-band antennas, the second configuration has the highest isolation because it has the widest frequency gap between the low and high bands while the third configuration has the lowest isolation because it has the narrowest frequency gap.

On the other hand, the calculated and the measured mutual coupling S_{12} between the low-band and high-band antennas of the above three configurations while the two antennas are perpendicular to each other is shown in Figures 9, 10, and 11, respectively. In the measurement setup, a piece of foam was used to fix the distance between the antennas under test. In the first configuration, the maximum isolation is increased from −21 dB when the two antennas were parallel to each other to −32 dB when they were perpendicular to each other. In the second configuration, the maximum isolation is increased from −25 dB to −38 dB while for the third configuration it is increased from −16 dB to −36 dB. It should be noted that, although the third dual antenna configuration has the smallest frequency gap between the low-band and the high-band, it has a higher isolation than the first configuration when the low-band and high-band antennas are perpendicular to each other. This is because with such high isolation levels, the effect of the harmonics on the isolation level is more dominant than the effect of the width of the frequency gap.

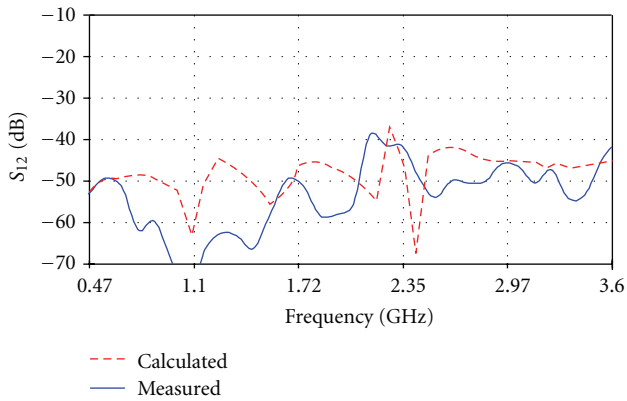

Figure 10: Mutual coupling (S_{12}) between the antennas of the second configuration while the antennas are perpendicular to each other.

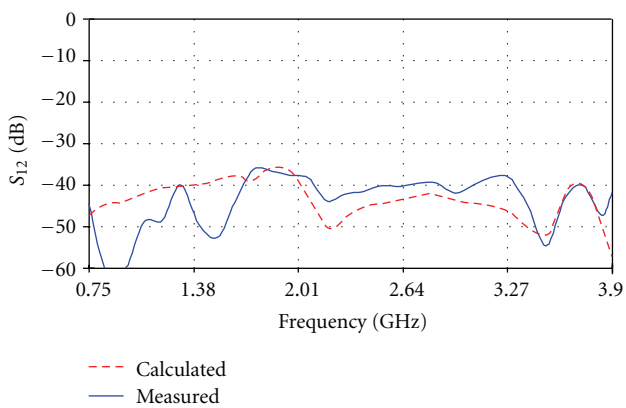

Figure 11: Mutual coupling (S_{12}) between the antennas of the third configuration while the antennas are perpendicular to each other.

The isolation between the low-band and high-band antennas is also affected by the objects and components located between them, which are usually parts of a handset or a portable computer. Locating the two antennas of the dual antenna configuration on handsets is always more challenging than portable computers because of the small size of handset. The positions and orientations of the two antennas on the handset have to be optimized according to the available space in order to increase the isolation between them as much as possible. Figure 12 shows a sample handset with the two antennas of the third configuration positioned perpendicular to each other. The space on the handset does not allow the two antennas to be located away enough from each other. Furthermore, a small part of the low-band antenna is folded in order to reduce the length of the antenna without causing any significant effect on its performance [2]. Figure 13 shows the calculated and measured mutual coupling between the two antennas with a maximum isolation of about –31 dB. Since portable computers do not suffer from such size limitations, the locations of the low-band and high-band antennas can be easily optimized in order to reduce the isolation between them as shown in Figure 14. The calculated and the measured mutual coupling are shown in Figure 15 with about −53 dB isolation. In the numerical EM software, an ABS plastic material was used to simulate the parts of the handset and the portable computer on which the antennas were mounted.

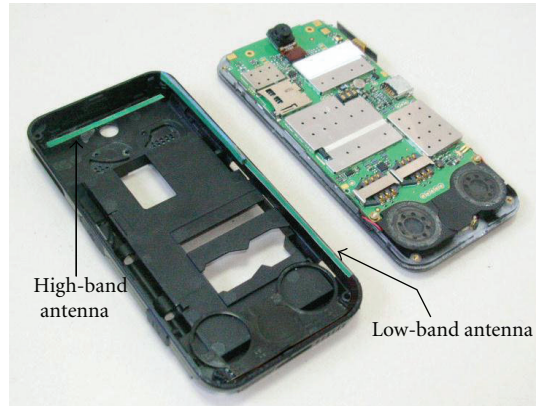

Figure 12: The third dual antenna configuration on a handset.

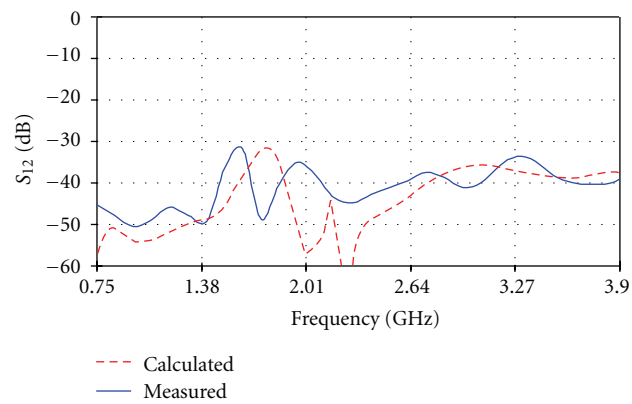

Figure 13: Mutual coupling (S_{12}) between the antennas of the third configuration on a handset.

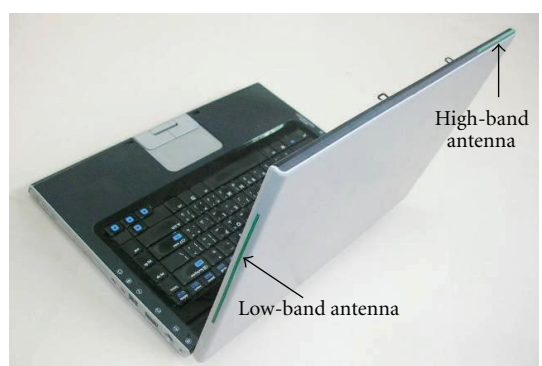

Figure 14: The third dual antenna configuration on a laptop computer.

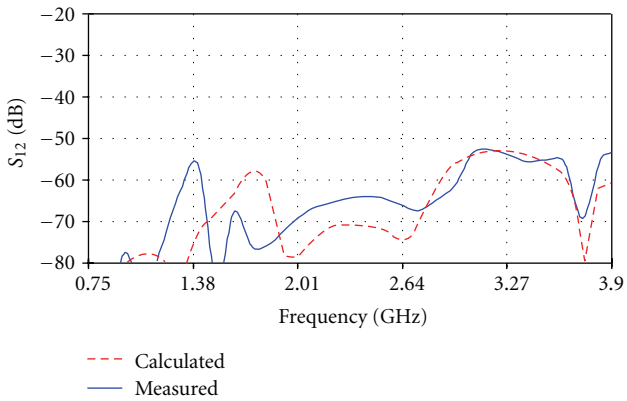

Figure 15: Mutual coupling (S_{12}) between the antennas of the third configuration on a laptop computer.

5. Conclusions

Low-interference dual resonant antenna configurations were developed for multistandard multifunction mobile handsets and portable computers. Only two wideband antennas could cover most of the important wireless applications in portable communication equipment. The frequency bands of the dual antenna configuration could be adjusted according to the wireless applications that were required to be covered. The maximum bandwidth that could be covered by each antenna was about 80% without using matching or tuning circuits. Three sample dual antenna configurations were presented. The first configuration was designed to cover a frequency band from 470 MHz to 2.7 GHz, which was divided into two subbands; 470–960 MHz and 1.2–2.7 GHz. Each subband was covered by a wideband resonant antenna. There was a frequency gap between these two subbands which was not utilized by any important application. This frequency gap helped in reducing the coupling between the low-band and high-band antennas. In another dual antenna configuration, the high-band antenna was modified to resonate from 1.575 to 3.6 GHz instead of resonating from 1.2 to 2.7 GHz in order to cover the 3.5 GHz WiMax band. This also increased the frequency gap between the low and high subbands which further reduced the mutual coupling between their antennas. A third dual antenna configuration was designed to cover the frequency bands; 750 MHz–1.65 GHz and 1.71–3.9 GHz. The antennas of this configuration were much shorter than the antennas of the other two configurations.

The isolation between the two antennas of the above three configurations was investigated. The isolation between the low-band and high-band antennas depended on the distance and the frequency gap between them as well as their relative orientations. The isolation was also significantly affected by the harmonics of the low-band antenna. The mutual coupling S_{12} between the low-band and the high-band antennas of the above three configurations while the two antennas were parallel to each other and separated by 5 cm was measured. The second configuration had the highest isolation because it had the widest frequency gap between the low and high bands. The third configuration had the lowest isolation because it had the narrowest frequency gap. On the other hand, when the low-band and high-band antennas of the above three configurations were perpendicular to each other, the isolation between them significantly increased. This eliminated the need for any special tools or techniques to suppress the mutual coupling between them.

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