Orthogonally Polarized MIMO Antennas for all Bands of Portable Computers including Digital TV

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Abstract— **A dual antenna configuration has been developed for multi-standard multifunction portable computers. Two wideband antennas can cover a frequency band from 470 MHz to 3.6 GHz, which is divided into two sub-bands. The low-band antenna resonates from 470 to 960 MHz and the high-band antenna resonates from 1.57 to 3.6 GHz. There is no significant interference between the two antennas because of the frequency gap between them. The new antennas are unbalanced resonant antennas that do not need matching circuits. Two orthogonal low-band antennas and two orthogonal high-band antennas are used for polarization diversity in MIMO applications. The four antennas can be mounted in different configurations according to the size and the geometry of the portable computer.**

I. INTRODUCTION

There has been a fast expansion of wireless applications in portable computers. Cellular network radios are integrated into some modern portable computers in order to offer an access to the Internet in areas not covered by wireless local area networks. Furthermore, computer manufacturers are now offering integrated WiMax as an option on some palmtops, notebooks and laptops. Introduction of other applications such as GPS and digital TV, built into portable computers, is expected in the near future. Moreover, most wireless applications have different standards with different frequency allocations worldwide. For example, WiMax has many frequency allocations such as 700 MHz, 2.5 GHz and 3.5 GHz. On the other hand, MIMO antennas are of a great interest in all indoor applications. Hence, it is desirable to have multi-standard multifunction portable computers with MIMO techniques. In order to cover the frequency bands of all these 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 digital TV (470-862 MHz). As a result, there will be a severe interference between these antennas. In addition, some applications such as UHF digital TV require a very wide frequency bandwidth that is not easy to cover with a single resonant antenna. Matching circuits are usually used to tune antennas for such wide bands [1]-[2]. Matching circuits increase the complexity of the antenna and reduce the efficiency.

In this research, a novel dual antenna configuration has been developed with an overall bandwidth ranges from 470 MHz to 3.6 GHz. The new antennas are resonant antennas that do not need matching circuits. The low-band antenna resonates from 470 to 960 MHz and, hence, it can cover the bands of UHF digital TV (470-862 MHz), 700 MHz WiMax, CDMA / GSM800 (824-894 MHz) and E-GSM900 (880-960 MHz). The high-band antenna resonates from 1.57 to 3.6 GHz and, thus, it can cover the bands of GPS (1575 MHz), GSM1800 (1710-1880 MHz), PCS1900 (1859-1990 MHz), UMTS (1900-2170 MHz), Bluetooth / WiFi (2.4 GHz), 2.4 WiMax (2.3-2.69 GHz) and 3.5 GHz WiMax (3.4-3.6 GHz). The bandwidths of these two antennas are more than 68% and 78%, respectively. There is an isolating frequency gap between the bands of the two antennas which helps in reducing 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].

II. GEOMETRY OF THE NEW ANTENNAS

Fig.1 shows the geometry of the new wideband resonant antenna. It consists of two narrow printed metallic arms connected together by a short metallic strip. 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. The thickness of the antenna is T and the antenna is fed at a distance F from the shorted edge. Each arm has a set of slots having different shapes and locations, which are optimized in order to maximize the bandwidth of the antenna.

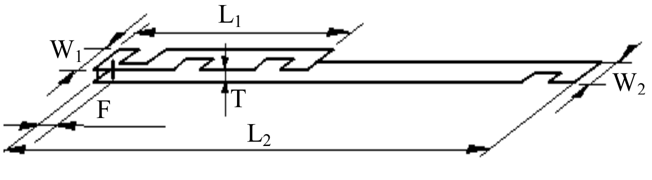


Fig. 1 Geometry of the new wideband resonant antenna

Prototypes of the low-band and high-band antennas have been designed and manufactured as shown in Fig.2. The dimensions of the low-band antenna are: L_1 =11.5 cm, L_2 = 25 cm, W_1 = 2.6 mm, W_2 =3.5 mm and T = 2 mm. The dimensions of the high-band antenna are: L_1 =2.7 cm, L_2 = 6.6 cm, W_1 = 2 mm, W_2 =3.5 mm and T = 2 mm. It should be noted that the length of the low-band antenna can be reduced from 25 cm to 16 cm without any significant effect on the performance by folding the two ends of the antenna [4]. The performance of the new antenna was numerically calculated by a software package that uses the moment method. It was also verified experimentally at IMST antenna labs in Germany [5]. The low-band and high-band antennas are mounted on the display rim of a portable computer. In this configuration, both antennas have minimum blockage by the computer housing.

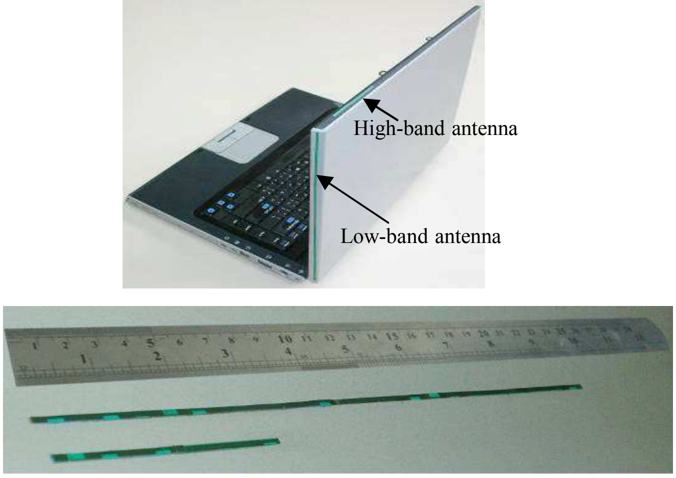


Fig.2 The new low-band and high-band antennas

The return losses of the two antennas with and without a laptop computer are shown in Fig.3. The effect of the computer housing on the return loss is negligible. The return loss of both antennas is less than -5 dB over most of the bands.

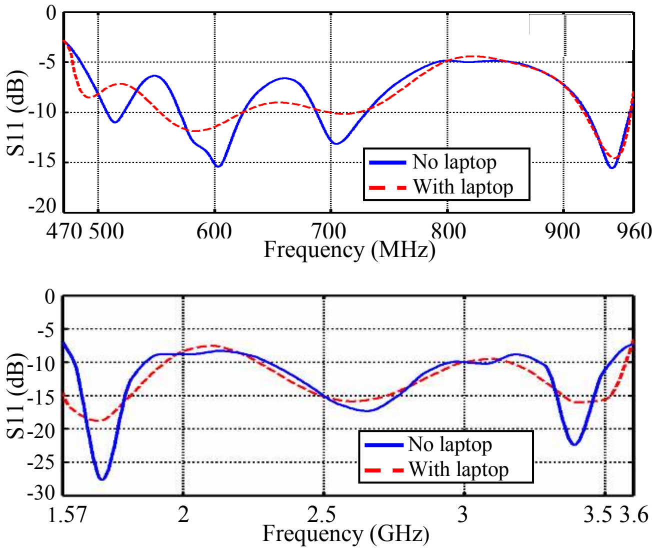


Fig.3 Measured return loss of the two antennas with and without a laptop

Fig.4 shows the peak gain of both antennas which is higher than 0 dBi over most of the two bands. This peak gain is much higher than MBRAI specifications of the UHF DVB-H mobile TV [6]. The efficiency of both antennas is shown in Fig.5. The average efficiency over the two sub-bands is more than 45%.

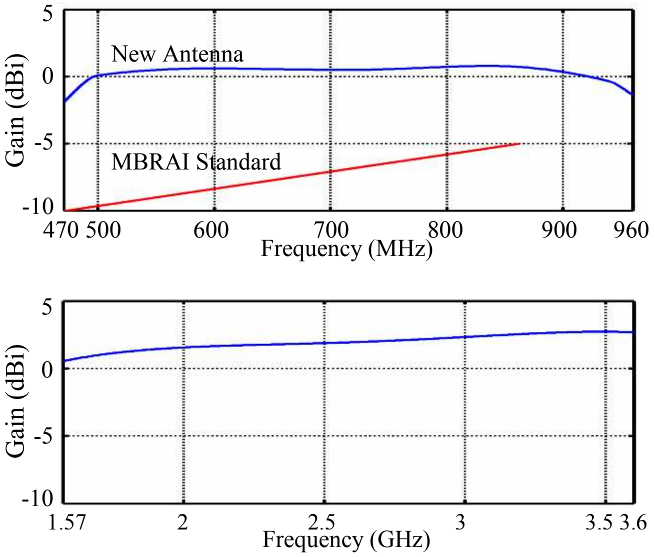


Fig.4 Measured peak gain of low-band and high-band antennas

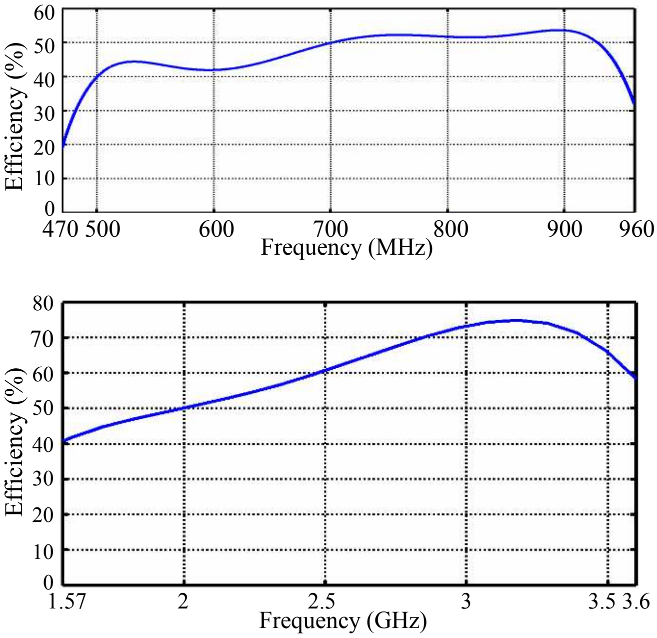


Fig.5 Measured efficiency of low-band and high-band antennas

III. INCREASING THE GAIN AND THE EFFICIENCY

The start of terrestrial digital TV broadcasting considerably reduces the need for on-roof directional receiving antennas and increases the use of internal integrated antennas. Therefore, introduction of digital TV, built into portable computers, is expected in the near future. Most terrestrial digital TV broadcasting channels are in the UHF band. As was shown above, the low-band antenna could cover the whole frequency band of UHF digital TV and its performance was much better than MBRAI specifications of the DVB-H mobile TV. However, for DVB-T (Digital Video Broadcasting - Terrestrial TV) it will be desirable to further increase the gain and the efficiency of the new antenna. This can be easily achieved by increasing the width and the thickness of the antenna as much as possible according to the available space in the portable computer. A prototype of the low-band antenna has been manufactured with an increased width and thickness. The dimensions of the increased-size low-band antenna are: L_1 =11.5 cm, L_2 = 25 cm, W_1 = 8 mm, W_2 =12 mm and T = 4 mm. Fig.6 shows the return loss of the increased-size low-band antenna, which is around -8 dB over the whole band. The overall efficiency of the increased-size low-band antenna is shown in Fig.7. The average efficiency was more than 80% over the whole bandwidth. Fig.8 shows the peak gain of the new low-band antenna which is about 2 dBi over the whole bandwidth. Fig.9 shows the radiation patterns of the new antenna at 600 MHz which are omni-directional with about 2 dBi peak gain.

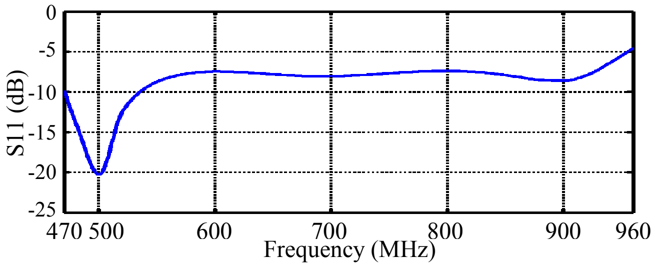


Fig.6 Return loss of the increased-size low-band antenna

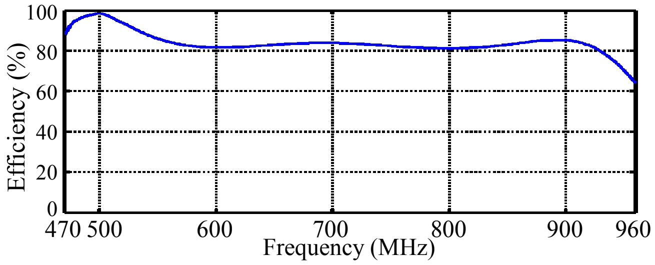


Fig.7 Efficiency of the increased-size low-band antenna

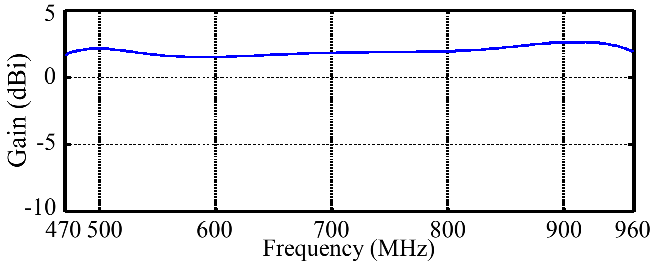


Fig.8 Peak gain of the increased-size low-band antenna

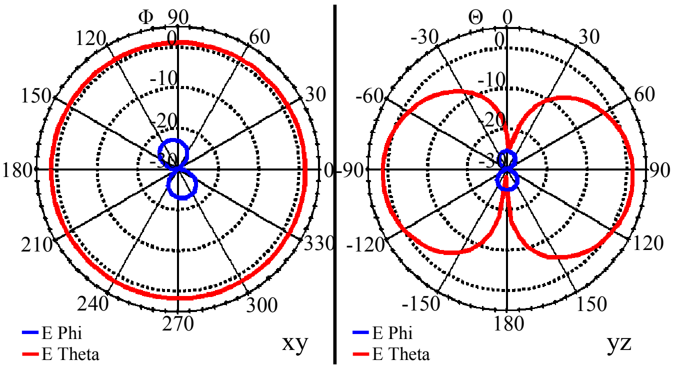


Fig.9 Radiation patterns of the increased-size low-band antenna at 600 MHz

The width and the thickness of the high-band antenna are also increased in order to increase the gain and the efficiency. The dimensions of the increased-size high-band antenna are: L_1 = 2.7 cm, L_2 = 6.6 cm, W_1 = 6 mm, W_2 =8 mm and T = 4 mm. Fig.10 shows the return loss of the increased-size antenna. The return loss is better than -7 dB over the whole band. The efficiency of the antenna is shown in Fig.11. The average efficiency was more than 80% over the whole band. Fig.12 shows the peak gain, which is about 2 dBi over the whole band. Fig.13 shows the radiation patterns at 2.4 GHz which are omni-directional with about 2 dBi peak gain.

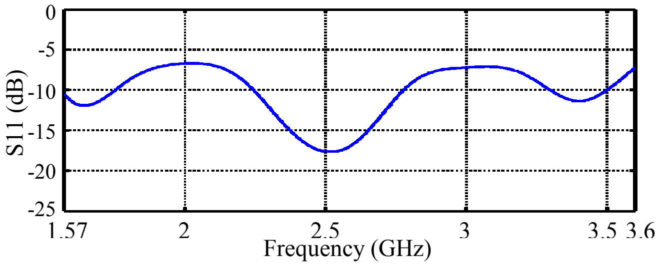


Fig.10 Return loss of the increased-size high-band antenna

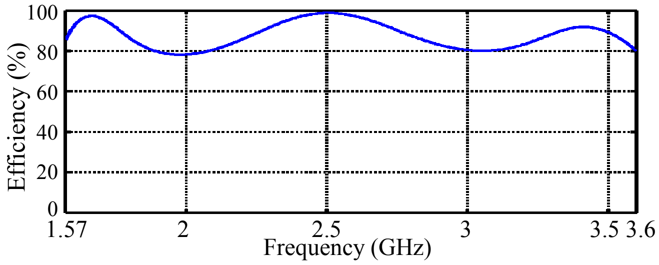


Fig.11Efficiency of the increased-size high-band antenna

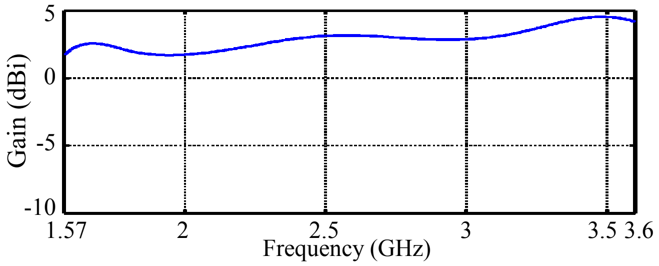


Fig.12 Peak gain of the increased-size high-band antenna

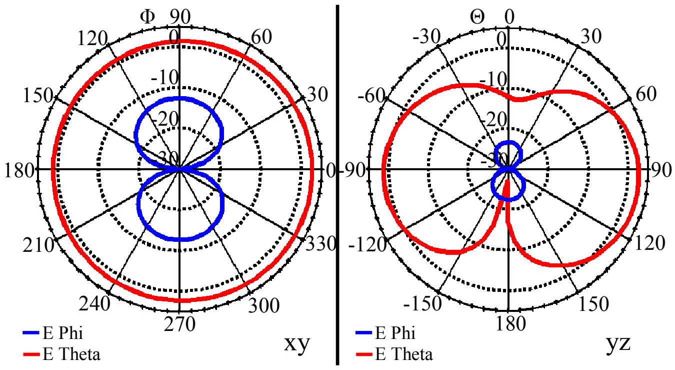


Fig.13 Radiation patterns of the increased-size high-band antenna at 2.4 GHz

IV. ORTHOGONALLY POLARIZED MIMO ANTERNNAS

Orthogonal polarization diversity is usually preferred over space diversity in order to reduce the coupling between MIMO antennas [7]. Different polarization diversity configurations have been tried on portable computers. For example, two orthogonal low-band antennas and two orthogonal high-band antennas can be mounted on the display rim of the computer in order to minimize the blockage by the computer housing. On the other hand, the MIMO antennas can be mounted on both sides of the display of the computer such that a low-band antenna and a high-band antenna are installed on each side of the display as shown in Fig.14. In this case, at least one of the low-band antennas and one of the high-band antennas will not be blocked by the computer housing. This configuration eliminates the limitations on the antenna widths and, hence, the increased-size antennas can be used. The low-band and high-band antennas can be located parallel to each other and very close to each other, as shown in Fig.14, without a significant interference between them. This is due to the frequency gap between their bands.

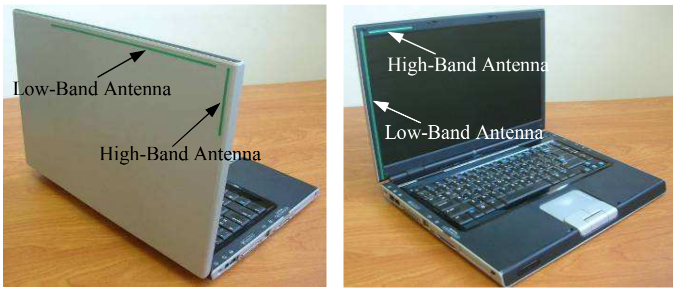
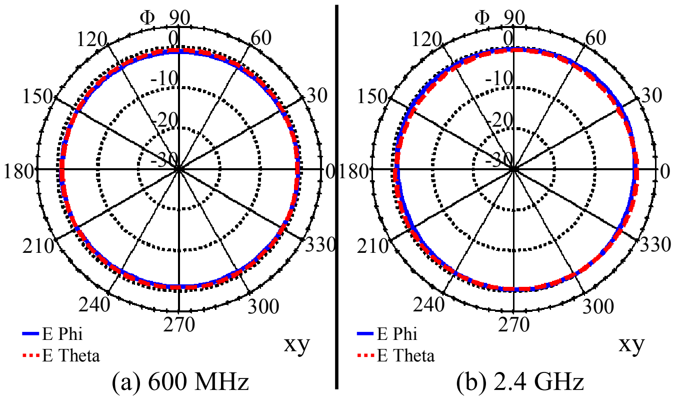


Fig.14 MIMO antennas on both sides of the computer display

Since the interference between the MIMO antennas is negligible, the return loss and the efficiency of the low-band and high-band antennas are not affected by the MIMO configuration and they are almost the same as the above presented results. However, as expected, the radiation patterns are significantly affected by MIMO configurations. The low-band and high-band MIMO radiation patterns are the summations of the radiation patterns of the orthogonal low-band and high band antennas, respectively. Fig.15 (a) shows the co-polar and cross-polar components of the radiation patterns of two orthogonal low-band antennas at 600 MHz in the plane of the antennas. Fig.15 (b) shows the co-polar and cross-polar patterns of two orthogonal high-band antennas at 2.4 GHz. In both cases, the orthogonal antennas are 1 cm apart from each other. As expected, the co-polar and cross-polar components are exactly the same.



(a) 600 MHz

(b) 2.4 GHz

Fig.15 Radiation patterns of two orthogonal low-band antennas at 600 MHz and two high-band antennas at 2.4 GHz

V. CONCLUSIONS

A dual antenna configuration was developed for multifunction multi-standard portable computers. The low-band antenna resonated from 470 to 960 MHz and the high-band antenna resonated from 1.57 to 3.6 GHz. The new antennas were resonant antennas that did not need matching circuits. Two orthogonal low-band antennas and two orthogonal high-band antennas were used together for polarization diversity in MIMO applications. The four antennas could be organized in different configurations according to the size and the geometry of the computer. In all configurations, the interference between the four antennas was negligible regardless of their locations and the distances between them.

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