A 470 TO 960 MHz Resonant Antenna: Covering UHF Mobile TV and CDMA/GSM without Tuning Circuits

A novel wideband antenna has been developed for UHF mobile digital TV. The new antenna has a bandwidth of more than 68 percent. It is an unbalanced resonant antenna that does not need any tuning or matching circuits. It resonates from 470 to 960 MHz and can cover all bands of UHF mobile digital TV (470 to 862 MHz or a portion of it), CDMA/TDMA/GSM800 (824 to 894 MHz) and E-GSM900 (880 to 960 MHz). The overall size of the new antenna is very small and its manufacturing costs are very low. It has a very small cross-section and is made of a flexible material. Bending the antenna in more than one direction considerably reduces the effect of the human body and the surrounding environment on the antenna. It also increases its sensitivity to different polarizations. Since the new antenna is multi-polarized, it significantly reduces the need for separate diversity antennas. The new antenna can be used as an internal, external or partially internal and partially external antenna.

Antennas for mobile TV are usually required to have a very wide frequency band. For example, ultra high frequency digital video broadcasting-handheld (UHF DVB-H) is designed to work in the frequency band from 470 to 862 MHz or a portion of it. This is a very wide bandwidth, which is difficult to cover with a single resonant antenna. Therefore, matching circuits are usually used to tune the antenna for this band[1] or even for narrower bands such as 470 to 770 MHz[2] and 470 to 702 MHz.[3] Matching circuits increase the complexity and the costs of the antenna and also reduce its efficiency.

On the other hand, the mobile TV band overlaps with the CDMA/GSM800 band (824 to 894 MHz). It is also too close to the E-GSM900 band (880 to 960 MHz). This overlapping may cause severe coupling and interference between antennas of both applications, especially if they are placed close to each other in the limited space inside handsets, which are getting smaller and smaller. A novel solution to

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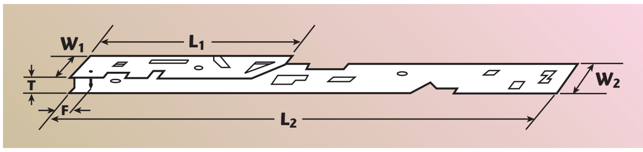
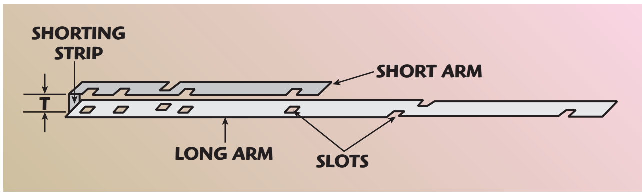
overcome this interference problem is to use only one antenna that can cover all bands of UHF mobile digital TV, CDMA/TDMA/GSM800 and E-GSM900. In this case the antenna is required to cover an overall band from 470 to 960 MHz, which is very challenging.

A wideband antenna for UHF mobile digital TV has been developed. The new antenna can cover a bandwidth of more than 68 percent. It is an unbalanced resonant antenna that does not need any tuning matching circuits. It resonates from 470 to 960 MHz and hence can cover all bands of UHF mobile digital TV, CDMA/TDMA/GSM800 and E-GSM900. Of course, if it is undesirable to merge the frequency bands of mobile TV and CDMA/GSM, the new antenna can be designed with a narrower bandwidth that can only cover the mobile TV band or any other band. Actually, narrowing the bandwidth increases the efficiency of the antenna. The new antenna can be used with cellular phones, palmtop, notebook, laptop computers or any other portable communication equipment.



▲ *Fig. 1 Geometry of the new antenna.*



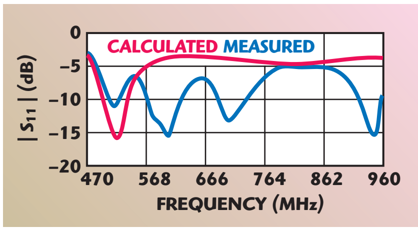
▲ *Fig. 2 The selected sample antenna configuration.*

DESCRIPTION OF THE NEW ANTENNA

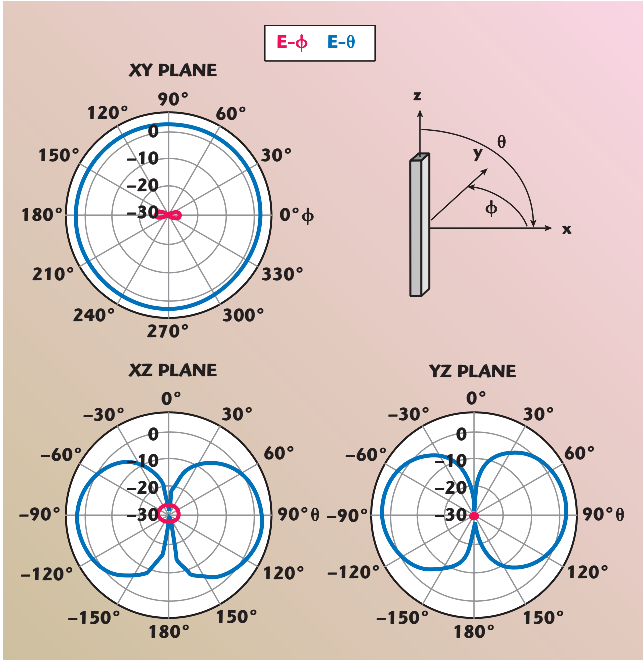
Figure 1 shows the geometry of the newly developed UHF digital mobile TV antenna. It consists of two narrow printed metallic arms connected together by a shorting metallic strip. The two arms may be parallel to each other or may have any angle between them. The length of the short arm is L_1 and its width is W_1 while the length of the long arm is L_2 and its width is W_2, the thickness (the height) is T and the antenna is fed 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.

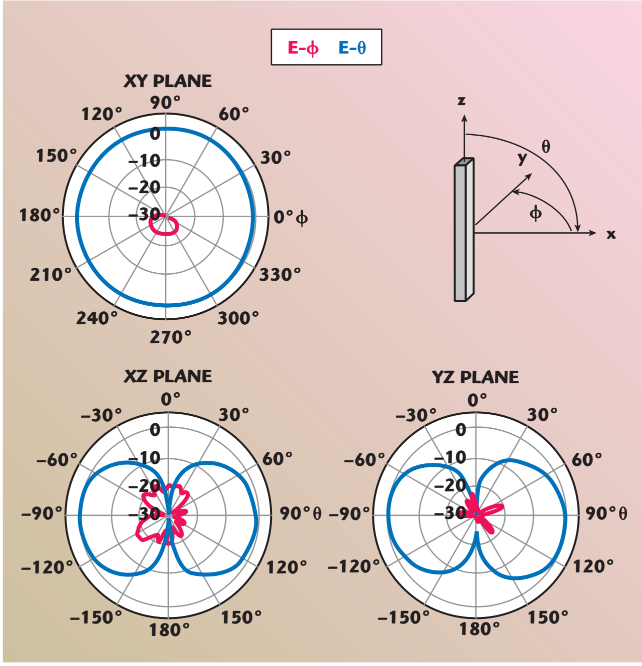
The antennas are completely self-contained and do not need extended ground planes or any additional components. Thus, the new antenna can be mounted anywhere, inside or outside any handset, because the antenna does not use a part of the handset as an extended ground plane, which usually happens with 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.



▲ *Fig. 3 Calculated and measured return loss of the new antenna.*



▲ *Fig. 4 Calculated radiation patterns at 800 MHz.*



▲ *Fig. 5 Measured radiation patterns at 800 MHz.*

RESULTS

Different prototypes of the new mobile TV antenna have been designed, manufactured and tested. The results for a selected sample antenna configuration are presented. The sample is made of a flexible printed material "PET" with a dielectric constant ε_r = 3.5 and a loss tangent δ = 0.015. The geometry of the selected antenna configuration is shown in ***Figure 2***.

The two arms of the selected sample antenna are parallel to each other. The length L_1 of the short arm is 11.5 cm while the length L_2 of the long arm is 25 cm. The width W_1 of the short arm is 2.6 mm while the width W_2 of the long arm is 3.5 mm and the antenna thickness T is 2 mm. The overall size of the antenna is 25 × 0.35 × 0.2 = 1.75 cm^3. It should be noted that this is the overall volume of the antenna because it does not require an additional ground plane, a matching circuit or any other components. All slots in both arms 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 is D_1. The distances between the successive slots are D_2, D_3,…., D_8, respectively.

The locations of the first five slots are similar in both arms. This means that the first five slots in the short arm are located exactly above the first five slots in the long arm. However, since the long arm is wider than the short arm, the first five slots are positioned close to the middle of the long arm, while they are located at the edge of the short arm as shown. The values of D_1, D_2, …., D_8 are as follows: D_1 = 5 mm, D_2 = 10 mm, D_3 = 15 mm, D_4 = 5 mm, D_5 = 45 mm, D_6 = 35 mm, D_7 = 5 mm and D_8 = 75 mm.

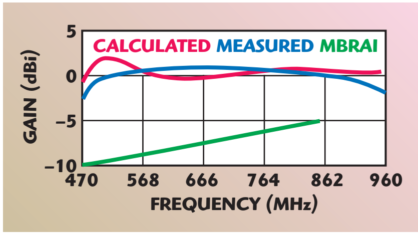
The return loss and the radiation

patterns of the antenna were numerically calculated using a software package that utilizes the moment method. They were also measured at the IMST antenna labs in Germany.[13] ***Figure 3*** shows the calculated and the measured return loss of the antenna. The measured return loss is better than 5 dB from approximately 470 to 960 MHz, which is more than 68 percent bandwidth. The calculated radiation patterns at 800 MHz, as a sample frequency, are shown in ***Figure 4***. The corresponding measured patterns are shown in ***Figure 5***.

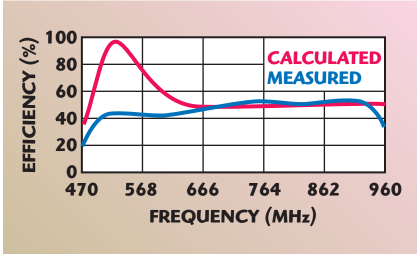
Figure 6 shows the calculated and the measured peak gain of the new antenna from 470 to 960 MHz, which is approximately 0 dBi over most of the band. The measured peak gain is much higher than the MBRAI specifications of UHF DVB-H mobile TV.[14] The calculated and measured efficiencies of the new antenna are shown in ***Figure 7*** from 470 to 960 MHz. The average measured efficiency over the whole frequency band is approximately 45 percent.

REDUCING THE ANTENNA SIZE

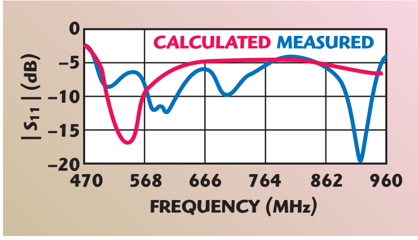
The antenna size can be further reduced by decreasing its width and/or its thickness. For example, if the width W_1 of the short arm of the above configuration is reduced from 2.6 to 2 mm while the width W_2 of the long arm is reduced from 3.5 to 2.8 mm and the antenna thickness T is also reduced from 2 to 1 mm, the overall size of the new antenna configuration is $25 \times 0.28 \times 0.1 = 0.7$ cm^3. Thus, the size of the antenna is reduced from 1.75 to 0.7 cm^3. ***Figure 8*** shows the calculated and the measured return loss of the new antenna after reducing its overall size from 1.75 to 0.7 cm^3. The return loss is still approximately 5 dB over most of the band from 470 to 960 MHz. The calculated and the measured peak gain and efficiency of the antenna after reducing its overall size from 1.75 to 0.7 cm^3 are shown in ***Figures 9*** and ***10***, respectively. It is clear that the peak gain is still much



▲ *Fig. 6 Calculated and measured peak gain of the antenna.*



▲ *Fig. 7 Calculated and measured efficiency of the antenna.*



▲ *Fig. 8 Calculated and measured return loss of the reduced size antenna.*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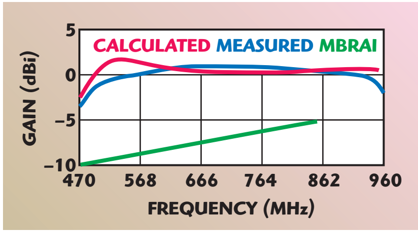
higher than the MBRAI specifications of UHF DVB-H mobile TV.

The width W_2 of the long arm of the new antenna is further reduced from 2.8 to 2 mm in order to make it equal to the width W_1 of the short arm. The overall size of the new antenna configuration is now $25 \times 0.2 \times 0.1 = 0.5$ cm^3. ***Figure 11*** shows the calculated and the measured return loss of the new antenna after the second reduction in its size from 0.7 to 0.5 cm^3. The return loss is better than 6 dB over most of the band from 470 to 960 MHz. The measured peak gain of the 0.5 cm^3 antenna is still much higher than MBRAI specifications of UHF DVB-H mobile TV. It is not shown because of space limitations.

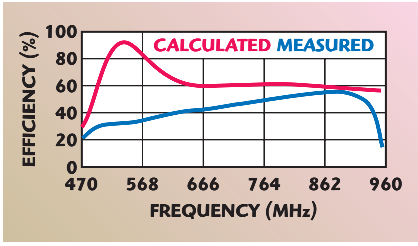
From all the results shown above, it can be seen that there are some considerable differences between the calculated and measured results. This is because the software package used assumes an infinite substrate. This assumption affects the accuracy of calculations when the width of the antenna substrate is very narrow as in the earlier antenna configurations. The difference between calculations and measurements is significant in efficiency curves because the efficiency depends on radiation patterns in all directions and in all planes; hence, there is an accumulated reduction in the accuracy of calculations. This was clearer at the lower part of the frequency range, where the antenna width is very narrow in terms of wavelengths. Furthermore, the difference between calculations and measurements was further increased when the width of the antenna was reduced from 3.5 to 2.8 mm, as can be observed by comparing Figures 7 and 10.

BENDING AND FOLDING THE ANTENNA

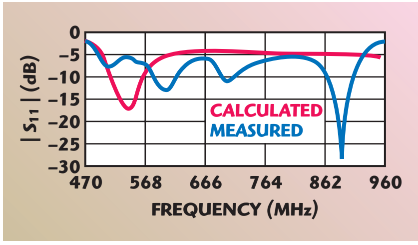
As mentioned before, the new antenna has a very small cross-section area and is made of a flexible printed material that can be easily bent and/or folded in order to fit the available space in any wireless equipment. Therefore, although the length of the



▲ *Fig. 9 Calculated and measured gain of the reduced size antenna.*



▲ *Fig. 10 Calculated and measured efficiency of the reduced size antenna.*



▲ *Fig. 11 Calculated and measured return loss of the 0.5 cm^3 antenna.*

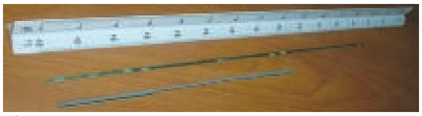


Fig. 12 *Straight and folded antennas.*

Fig. 13 *The antenna folded around a handset.*

antenna is 25 cm, it can be easily reduced in different ways. For example, the two ends of the antenna can be folded, as shown in ***Figure 12***, where the length is reduced from 25 to 16 cm without significant effect on its performance.

On the other hand, the new antenna can be folded to form a rectangular shape around the handset from the inside and/or outside, as shown in ***Figure 13***. The performance of the new antenna while it is folded in the form of a rectangular shape was also measured at IMST labs in Germany. The calculated and measured return loss of the folded antenna in the y-z plane is shown in ***Figure 14***. The calculated radiation patterns at a sample frequency 800 MHz are shown in ***Figure 15***; the correspond-

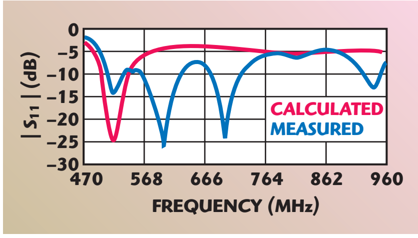


Fig. 14 *Calculated and return loss of a bent antenna.*

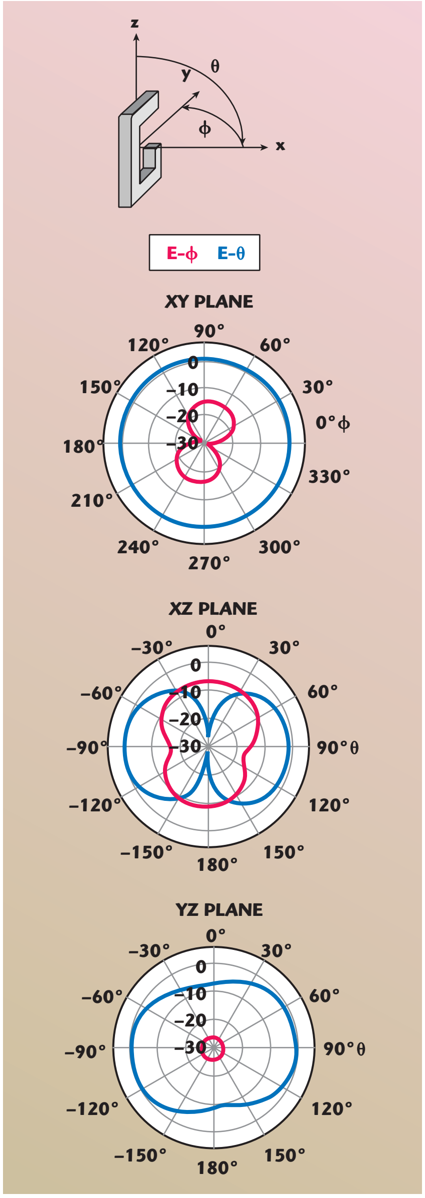
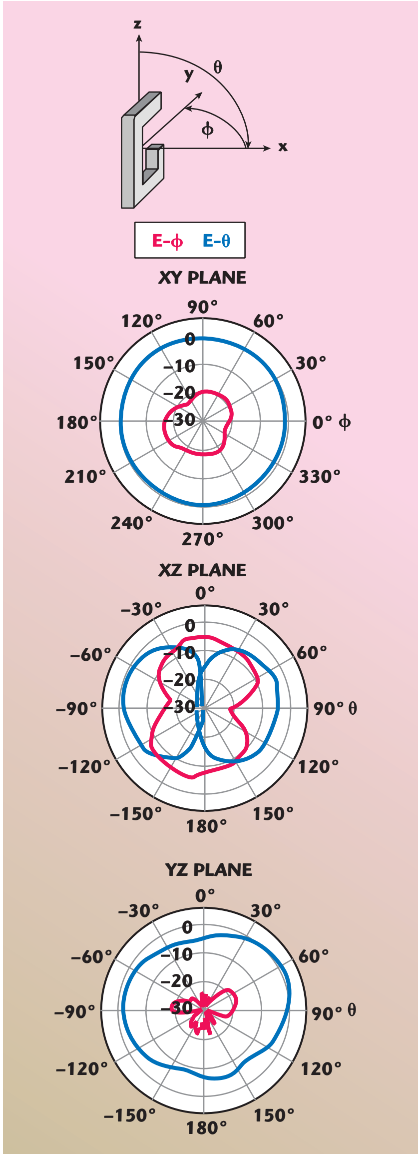


Fig. 15 *Calculated radiation patterns of the bent antenna.*

ing measured patterns are shown in ***Figure 16***. Comparing Figures 5 and 16, it can be seen that the main difference between the performance of the folded antenna and the straight antenna is the sensitivity to more than one polarization. It is clear that the straight antenna is sensitive to only one polarization. Folding the antenna in two perpendicular directions in the y-z plane makes the radiation patterns sensitive to two perpendicular polarizations. This is very important in MIMO and in all indoor applications, where the waves are randomly oriented because of multipath reflections and rotation of polarization.

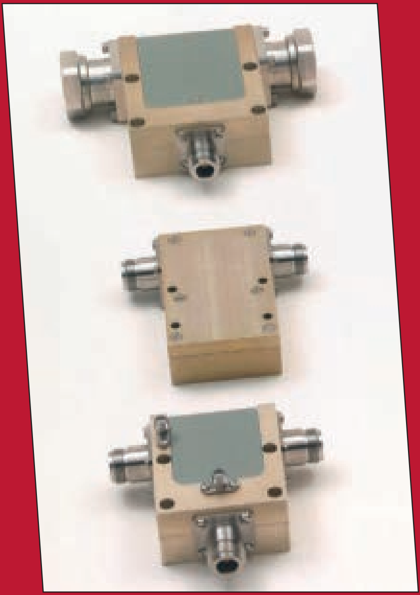
MULTI-POLARIZED CONFIGURATIONS

From the above results, it was shown that bending the new antenna in two perpendicular directions significantly increased its sensitivity to two perpendicular polarizations. Of course, the optimum situation for polarization diversity is to make the antenna sensitive to three perpendicular polarizations. This can be achieved by bending the new antenna in three perpendicular directions. Bending the antenna in three



▲ *Fig. 16 Measured radiation patterns of the bent antenna.*

▲ *Fig. 17 A palm top computer with the antenna bent in three perpendicular directions.*



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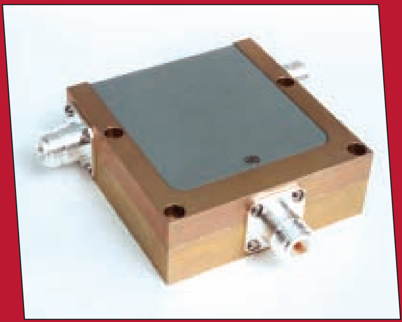

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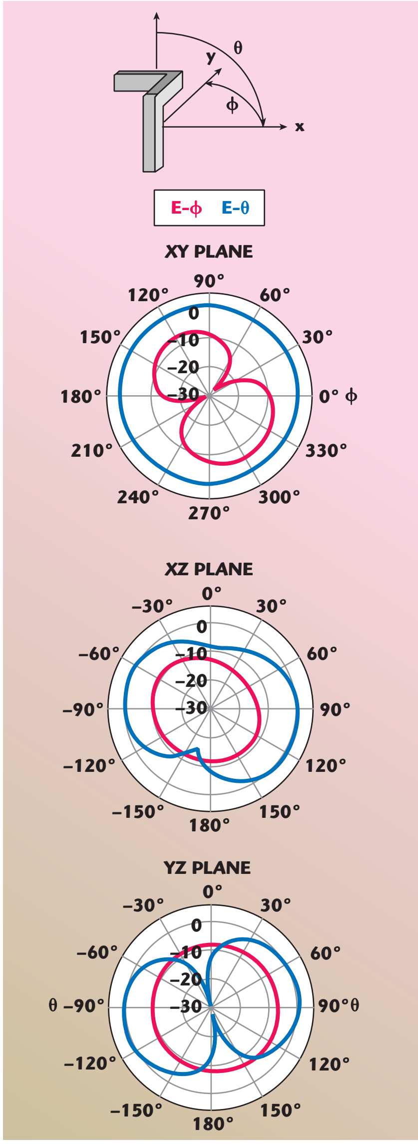
Contact us for more information on our extensive product line and current catalog. We accept Visa, MC, Amex perpendicular directions will also reduce the effect of the human body and the environment on the antenna. Since the new antenna has a very small cross-section area and is made of a flexible material, bending the antenna in three perpendicular directions can be easily accomplished depending on the form factor of the wireless equipment. For example, the new antenna can be folded in three perpendicular directions inside notebook, laptop and palmtop computers, as shown in ***Figure 17***. It is clear that the antenna configuration can be fully embedded inside the portable computer. The calculated radiation patterns of the new antenna while it is folded in three perpendicular directions are shown in ***Figure 18***. The antenna is sensitive to all polarizations in all planes.

On the other hand, the form factor of some wireless equipment does not allow the new antenna to be internally folded in three perpendicular directions, as in cellular phones.



▲ *Fig. 18 Calculated radiation patterns of a bent antenna in three perpendicular directions.*

In such cases, special methods have to be found in order to bend the new antenna in three perpendicular directions. In one of these methods, a part of the antenna is embedded inside the handset while the other part is kept external to the handset. The internal part of the antenna is folded in two perpendicular directions parallel to the handset. The external part of the antenna is retractable and can be used as a mechanical support for the handset while it is used as a mobile TV. In this case, the external part of the antenna is mechanically supported by a thin plastic rod in order to make it mechanically rigid.

CONCLUSION

A novel wideband antenna for mo-

bile digital TV has been developed. The new antenna covers a bandwidth of more than 68 percent. It is an unbalanced resonant antenna that does not need any tuning or matching circuits. It resonates from 470 to 960 MHz and hence can cover all the UHF bands of mobile digital TV (470 to 860 MHz or a portion of it), 700 MHz WiMAX band (698 to 806 MHz), CDMA/TDMA/GSM800 (824 to 894 MHz) and E-GSM900 (880 to 960 MHz). The new antenna can be used with cellular phones, palmtop computers, notebook computers, laptop computers or any other portable communication equipment. The overall size of the new antenna is very small and its manufacturing costs are very low. Different configurations of the new mobile TV antenna have been designed, manufactured and tested. The overall sizes of the sample prototypes were 1.75 cm^3, 0.75 cm^3 and 0.5 cm^3. These were the overall sizes of the antenna because the new antenna does not require extended ground planes or any other additional components.

The antenna is made of a flexible material that can be bent and/or folded and shaped in different forms to fit the available space in any wireless equipment. It can be used as an internal, external or partially internal and partially external antenna. On the other hand, some configurations of the new antenna are aimed to be multi-polarized, which is a very important factor in MIMO and in all indoor applications. Multi-polarization can be easily achieved by bending the new antenna in three perpendicular directions. ■

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