An Internal EBG Antenna for Indoor Reception of UHF Terrestrial Digital TV Broadcasting

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***Abstract*—A novel internal antenna has been developed for indoor reception of UHF terrestrial digital TV broadcasting. The new antenna has a bandwidth of more than 60%. It is an unbalanced resonant antenna that does not need a matching circuit or a balun. The overall size of the new antenna is very small and its manufacturing costs are very low. It is made of a flexible material and it can be bent and/or folded and shaped in any form. It can be used as an internal, external or partially internal and partially external antenna. The new digital TV receiving antenna is linearly polarized. It can also be modified in order to be dual-polarized, which is a very important factor in all indoor applications. This can be easily achieved by bending the antenna 90°. Bending the antenna in more than one direction significantly increases its sensitivity to different polarizations and also reduces the effect of the surrounding environment on the antenna. The overall efficiency of the new indoor digital TV receiving antenna is more than 80% and its peak gain is about 2 dBi over the whole UHF band. The peak gain can be increased to more than 5 dBi over the whole band by adding EBG (electromagnetic band gap) structures to the new digital TV receiving antenna. The EBG structure also improves the return loss of the antenna and increases its efficiency to around 90% over most of the band.**

I. INTRODUCTION

The start of terrestrial digital TV broadcasting may considerably reduce the need for on-roof directional receiving antennas and increase the use of indoor antennas. Most terrestrial digital TV broadcasting channels are in the UHF band. The most common UHF indoor digital TV receiving antennas are loop antennas and triangular dipoles [1]. However, they have large sizes and they are not rigid on top of TV sets. Also, they are balanced antennas and, hence, they need baluns. Furthermore, they are sensitive to only one polarization and, therefore, they have a poor indoor performance. Moreover, they are pure electric field antennas and, hence, their performance is significantly deteriorated in vicinity of conductive objects such as concrete walls. On the other hand, conventional indoor TV receiving antennas cannot be used in multi-input (MI) configurations and techniques for space and/or polarization diversity. In order to overcome some of the above problems, other indoor TV receiving antennas have been developed and published as in references [2]-[4]. However, they are also external antennas that have to be mounted outside TV sets and they are still large in size.

In this research, a novel internal antenna is developed for indoor reception of UHF terrestrial digital TV broadcasting. The new antenna covers a bandwidth of more than 60%. It resonates from 470 MHz to more than 900 MHz. The new antenna is resonant antenna that does not need matching circuits. Furthermore, it does not need an additional extended ground plane or any other components. Thus, it can be mounted anywhere inside or outside any TV set because the antenna does not use a part of the equipment as an extended ground plane as usually happens with internal antennas. Moreover, the new antenna is made of a flexible material and it can be bent and/or folded in different forms. The new antenna can be fully embedded inside TV sets. Actually, it can be used as internal, external or partially internal and partially external antenna. On the other hand, the new digital TV receiving antenna is linearly polarized. It can also be modified in order to be dual-polarized, which is a very important factor in all indoor applications. This can be easily achieved by bending the antenna 90°. Additionally, bending the antenna in more than one direction significantly increases its sensitivity to different polarizations and also reduces the effect of the surrounding environment on the antenna. In order to increase the peak gain of the TV receiving antenna, an EBG (electromagnetic band gap) structure has been used [5].

II. GEOMETRY OF THE NEW ANTENNA

Fig.1 shows the geometry of the new developed UHF digital TV internal antenna. The new antenna consists of two narrow metallic arms connected together by a short 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 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. The arm lengths of the new antenna and their shapes are the main critical parameters, which determine the operating frequency, the bandwidth and the efficiency of the antenna.

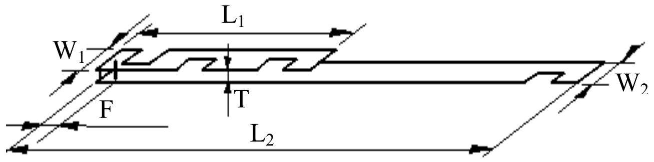

Fig. 1 Geometry of the new UHF digital TV antenna

III. Results

A prototype of the new indoor UHF digital TV receiving internal antenna has been designed, manufactured and tested as shown in Fig.2. The dimensions of the new antenna are: L_1 =11.5 cm, L_2 = 25 cm, W_1 = 8 mm, W_2 =12 mm and T = 4 mm. Thus, the overall size of the new antenna is 25 x 1.2 x 0.4 = 12 cm^3. The return loss and radiation patterns of the new antenna are numerically calculated by a software packages that uses the moment method. They were also verified experimentally at IMST antenna labs in Germany [6]. Fig.3 shows the return loss of the new antenna. The return loss of the antenna is around - 8 dB over the whole band which has more than 60% bandwidth.

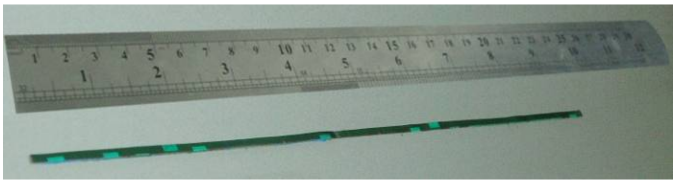

Fig.2 A prototype of the new digital TV antenna

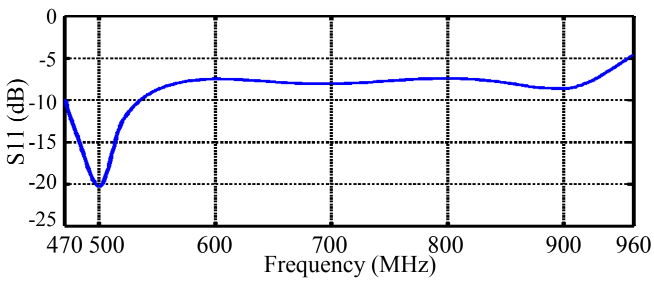

Fig.3 Return loss of the new antenna

The overall efficiency of the new indoor digital TV receiving internal antenna is shown in Fig.4. The average efficiency is more than 80% over the whole bandwidth. Fig.5 shows the peak gain of the new antenna which is about 2 dBi over the whole bandwidth. This gain can be significantly increased by adding EBG structures as will be shown below. Fig.6 shows the radiation patterns of the new antenna at 600 MHz which are omni-directional with about 2 dBi peak gain. The straight antenna is sensitive to only one polarization. Dual polarized antennas can be obtained by bending the antenna as shown in the next section.

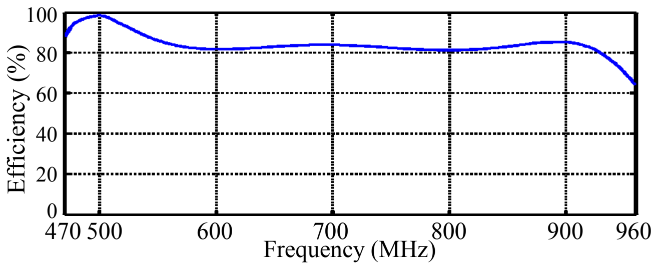

Fig.4 Efficiency of the new digital TV antenna

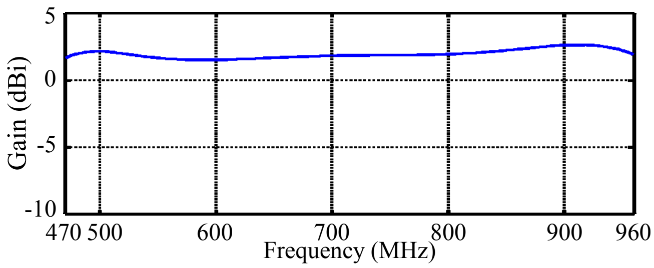

Fig.5 Peak gain of the new digital TV antenna

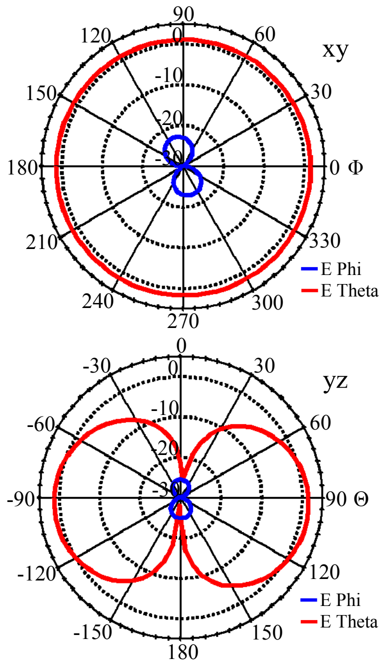

Fig.6. Radiation patterns of the new digital TV antenna at 600 MHz

III. Multi-Polarized Configurations

As mentioned before, the new antenna has a very small cross-section area and it is made of a flexible printed material that can be easily bent in two perpendicular directions to form an L shape as shown in Fig.7. The radiation patterns at a sample frequency 600 MHz are shown in Fig.8. Comparing Fig.8 with Fig.6 it can be seen that the main difference between the performance of the bended antenna and the straight antenna is the sensitivity to more than one polarization. It is clear from Fig.6 that the straight antenna is sensitive to only one polarization. Bending the antenna in two perpendicular directions makes the radiation patterns sensitive to two perpendicular polarizations as shown in Fig.8. This is very important in all indoor applications where the waves are randomly orientated because of multipath reflections and rotation of polarization.

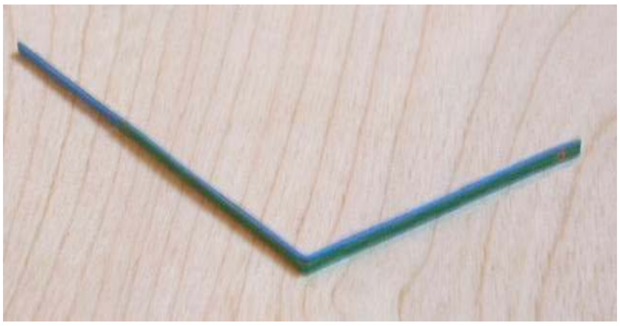

Fig.7 Bent digital TV antenna forming an L shape

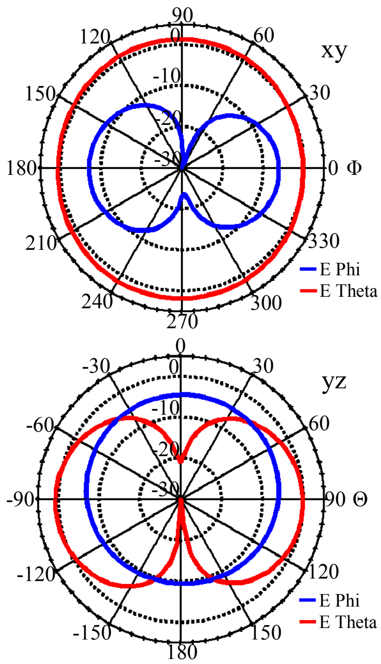

Fig.8 Radiation patterns of the bent digital TV antenna at 600 MHz

IV. DIGITAL TV ANTENNAS WITH EBG STRUCTURES

In order to further increase the peak gain of the new digital TV antenna, a rectangular EBG structure was added to the antenna. The EBG consists of 3 x 11 elements as shown in Fig.9. The dimensions of each element are 24 x 24 mm and the gap between each two elements is 4 mm. The dimensions of the EBG ground plane are 10 x 32 cm. Fig.10 shows the return loss of the new digital TV antenna with the EBG structure. The return loss is better than -10 dB over most of the band. Fig.11 shows the efficiency of the EBG digital TV antenna. The antenna efficiency exceeds 90% over most of the band. The peak gain of the antenna is shown in Fig.12, which is more than 5 dBi over most of the band.

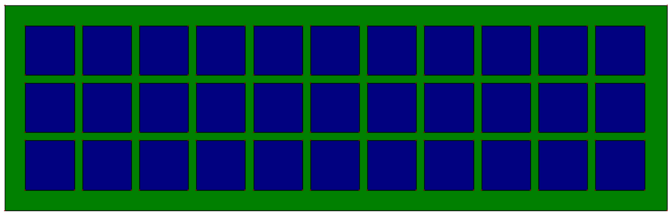

Fig.9 EBG structure

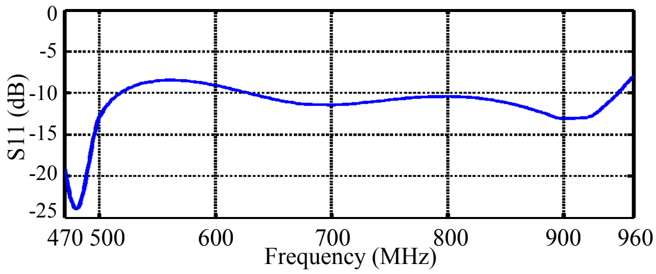

Fig.10 Return loss of the EBG digital TV antenna

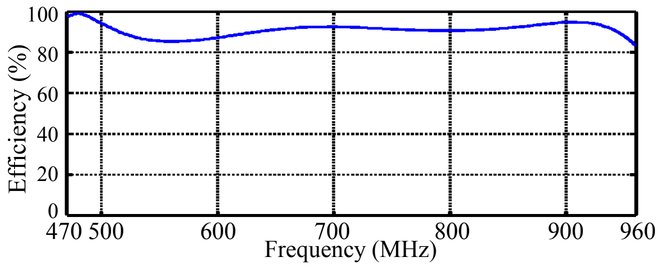

Fig.11 Efficiency of the EBG digital TV antenna

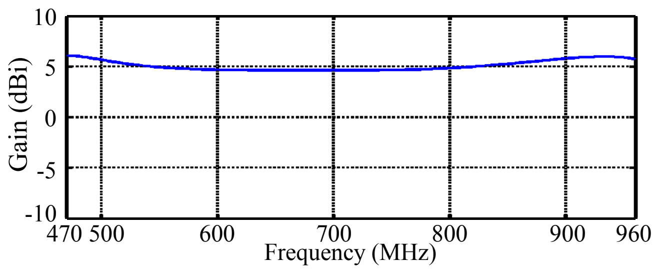

Fig.12 Peak gain of the EBG digital TV antenna

IV. DIGITAL TV ANTENNAS ON TV SETS

The new antenna prototype was mounted at different positions on various TV sets. One of the optimum configurations is shown in Fig.13 where the new antenna is mounted on one of the upper corners of the display rim. In this configuration, the new antenna has a minimum blockage by the TV set housing. This unique configuration is feasible with all TV sets because the widths of the new antenna can always be made narrower than the width of the display rim of any TV set. Furthermore, the new antenna is made of a flexible material. Therefore, it is easy to fold around the 90° corners of the display rim. Moreover, the new antenna can be mounted anywhere because it does not use a part of the TV set as an extended ground plane as usually happens with internal antennas.

Fig.13 Optimum new antenna configuration on the display rim of a TV set

The return loss of the antenna while it is mounted on a TV set is shown in Fig.14. The return loss is better than -10 dB over most of the band. Fig.15 shows the efficiency of the antenna on a TV set. The antenna efficiency still exceeds 90% over most of the band. The peak gain of the antenna is shown in Fig.16, which is around 6 dBi over most of the band.

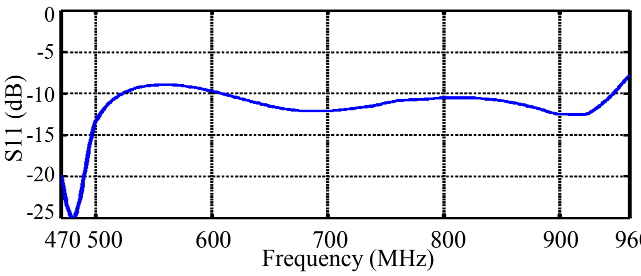

Fig.14 Return loss of the new antenna on a TV set

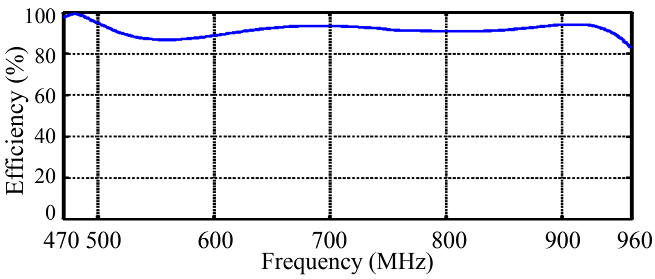

Fig.15 Efficiency of the new antenna on a TV set

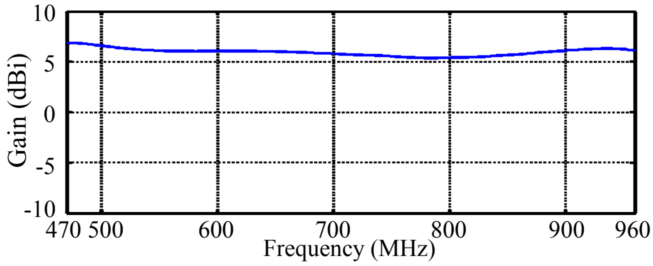

Fig.16 Peak gain of the new antenna on a TV set

V. Conclusions

A novel internal antenna has been developed for indoor reception of UHF terrestrial digital TV broadcasting. The new developed antenna was unbalanced resonant antenna that did not need matching circuits or baluns. Its overall size was very small and its manufacturing costs were very low. The new antenna could be bent or folded and shaped in any form. It could be used as an internal, external or partially internal and partially external antenna. On the other hand, bending the new digital TV receiving antenna in more than one direction significantly increased its sensitivity to different polarizations and also reduced the effect of the surrounding environment on the antenna.

The bandwidth of the new indoor digital TV receiving internal antenna was more than 60%. Its efficiency was more than 80% and its peak gain was about 2 dBi over the whole bandwidth. The peak gain of the new antenna was increased to 5 dBi and the efficiency was increased to 90% by adding an EBG structure to the antenna.

Acknowledgment

The authors would like to thank Mohamed Osama for his great effort in preparing this article.

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