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# BROADBAND INTEGRATED DTV ANTENNA FOR USB DONGLE APPLICATION

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**ABSTRACT:** *A novel broadband planar antenna integrated in the USB dongle for digital television (DTV) signal reception is presented. The planar antenna is printed on a dielectric substrate and electrically connected to the system ground plane of the USB dongle. When in operation, the planar antenna is swung upward to be perpendicular to the system ground plane and can provide a wide operating bandwidth (2.5:1 VSWR) of larger than 50% centered at about 630 MHz, allowing it to cover the DTV signal reception in the 470–806-MHz band. While not in operation, the planar antenna can be swung downward and attached onto the housing of the USB dongle, keeping the aesthetic appearance of the device. Detailed design considerations of the proposed antenna are described, and obtained experimental and simulation results are presented and discussed.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1018–1021, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22329

**Key words:** *mobile antennas; DTV antennas, broadband antennas, integrated antennas, USB dongle*

## 1. INTRODUCTION

The universal series bus (USB) dongles [1] embedded with antennas for achieving wireless communications are becoming very attractive for application in the laptop computers. For this kind of perspective application, promising internal multiband antenna for mobile communications for the USB dongle has recently been reported [2, 3]. Since other possible functions for the USB dongle, such as the digital television (DTV) [4–6] signal reception, are expected to be very attractive for wireless users, we demonstrate in this paper a novel broadband planar antenna integrated in the USB dongle for DTV signal reception in the 470–806 MHz band [7]. The proposed planar antenna is of a simple, long inverted-U shape with an open gap, and is easy to fabricate by printing on a dielectric substrate. By properly selecting the position of the open gap, the proposed planar antenna incorporating the system ground plane of the USB dongle can generate two adjacent resonant modes to form into a wide operating band of larger than 50% to cover the 470–806 MHz band for DTV signal reception. Moreover, owing to its planar structure [8], the proposed antenna can be attached onto the housing of the USB dongle when not in operation, keeping the aesthetic appearance of the device. Details of the design considerations of the proposed integrated planar DTV antenna are described. A parametric study on analyzing the effects of various antenna parameters on the performances of the antenna is also conducted. The proposed antenna is also constructed and tested, and obtained experimental and simulated results are presented and discussed.

## 2. PROPOSED INTEGRATED DTV ANTENNA

Figure 1(a) shows the geometry of the proposed broadband integrated planar DTV antenna for application in the USB dongle. Note that the geometry shown in Figure 1(a) is for the operation condition in which the proposed antenna is perpendicular to the system ground plane of the USB dongle. When not in operation, the proposed antenna can be bent to be parallel to the system ground plane of the USB dongle [Fig. 1(b)] and attached onto the housing of the USB dongle (see the example of a promising USB dongle embedded with the DTV tuner module and proposed antenna shown in Fig. 2).

The proposed antenna has a long inverted-U strip with an open gap of length $g$ printed on a 0.8-mm thick FR4 substrate of size $120 \times 30$ mm$^2$. Owing to the presence of the open gap, the inverted-U strip is separated into two portions. One is a long straight strip of length $h$ and uniform width $w$ and is denoted as strip 1 in this study. The other is an inverted-L strip of uniform width 10 mm and is denoted as strip 2 here. One end of strip 2 is electrically connected to the system ground plane of size $110 \times 30$ mm$^2$ at point C shown in Figure 1(a). The system ground plane in the study is printed on a 0.8-mm thick FR4 substrate, which can be considered as the system circuit board of the USB dongle. Also, the chosen dimensions of the system ground plane here are reasonable ones for general USB dongles. Across one end of strip 1 and the system ground plane, there is a 1-mm feed gap. For testing the antenna, a 50-$\Omega$ mini coaxial line is used, with its central conductor connected to strip 1 at point A and its outer grounding sheath connected to the system ground plane at point B shown in Figure 1.

By incorporating the system ground plane as part of the resonant path, the proposed antenna can first be operated as a half-wavelength resonant loop structure, which begins from point A, then through the inverted-U strip formed by strips 1 and 2, to point C and further to point B through the short side edge of the system ground plane. This resonant loop structure has a mean length of

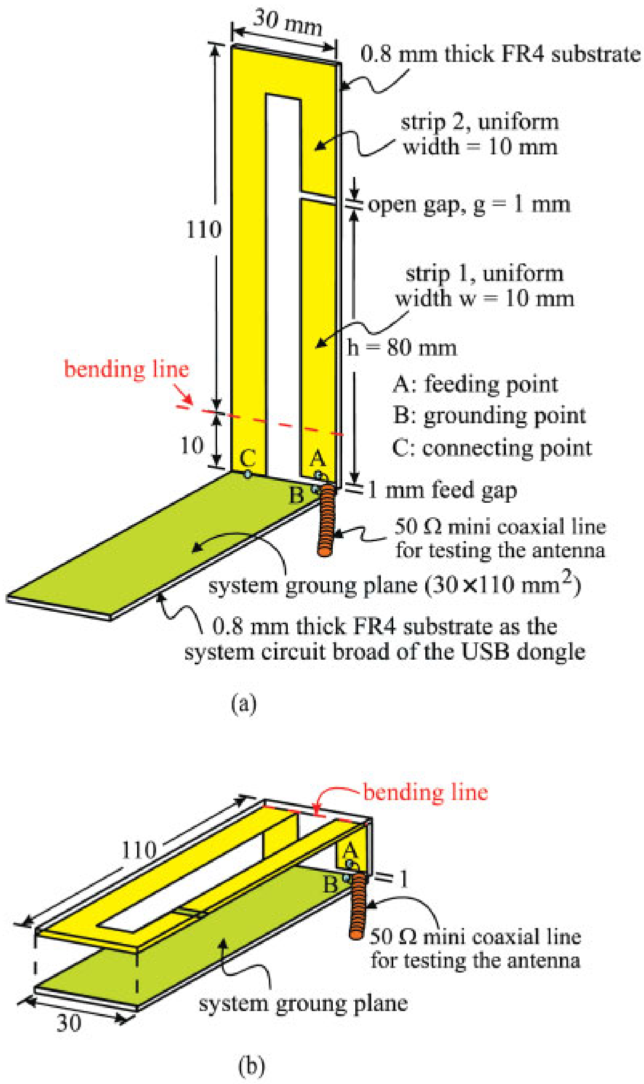


**Figure 1** (a) Geometry of the proposed broadband integrated planar DTV antenna for USB dongle application. (b) Geometry of the proposed DTV antenna when not in operation. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

about 270 mm in this design, which leads to the excitation of a resonant mode at about 500 MHz for the proposed antenna. Then, by properly selecting the position of the open gap, a second resonant mode controlled by strip 1 and the system ground plane can be excited. This second resonant mode is related to a half-wavelength dipole structure formed by two asymmetric dipole arms of strip 1 and the system ground plane. Thus, by adjusting the length $h$ of strip 1, this second resonant mode can be controlled. In this study, this second resonant mode is designed to occur at about 700 MHz. In addition, the length $g$ of the open gap is found to greatly affect the impedance matching of the antenna's two resonant modes. By choosing a proper length of the open gap (1 mm in this study), good impedance matching of the antenna's two resonant modes can be obtained, and a wide operating band formed by the two resonant modes can be achieved for the proposed antenna to cover the DTV signal reception in the 470–806 MHz band. More detailed effects of the length $g$ of the open gap and the length $h$ of strip 1 will be discussed with the aid of Figure 5 in the next section. The width $w$ of strip 1 is also found to have some effects on the impedance matching of the antenna's two resonant

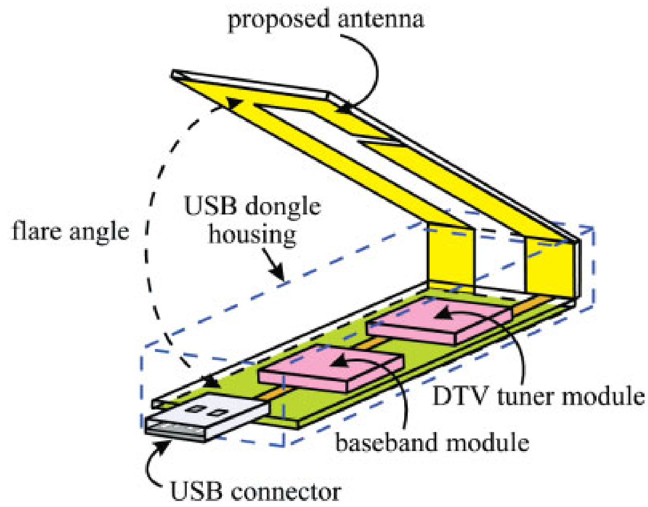


**Figure 2** Example of a promising USB dongle integrated with the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

modes, and the detailed effects will be discussed with the aid of Figure 6.

### 3. RESULTS AND DISCUSSION

A preferred prototype of the proposed planar DTV antenna shown in Figure 1 with $g$ = 1 mm, $h$ = 80 mm, and $w$ = 10 mm was first constructed and studied. Figure 3 shows the measured and simulated return loss for the constructed prototype. The simulated results are obtained using Ansoft simulation software HFSS (High Frequency Structure Simulator) [9], and good agreement between the measurement and simulation is obtained. From the measured results, it is clearly seen that two adjacent resonant modes are generated, which form a wide operating band of about 52% (2.5:1 VSWR bandwidth) centered at about the desired center frequency of 638 MHz to cover the DTV band of 470–806 MHz. Note that the bandwidth definition of 2.5:1 VSWR (about 7.3-dB return loss) is used here, which is generally acceptable for DTV signal reception in practical applications.

To analyze the two excited resonant modes, Figure 4 shows the measured return loss for the constructed prototype studied in

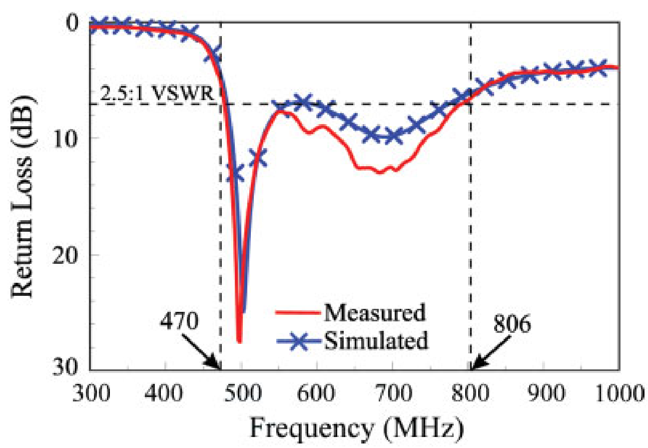


**Figure 3** Measured and simulated return loss for the proposed antenna with $g$ = 1 mm, $h$ = 80 mm, and $w$ = 10 mm. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

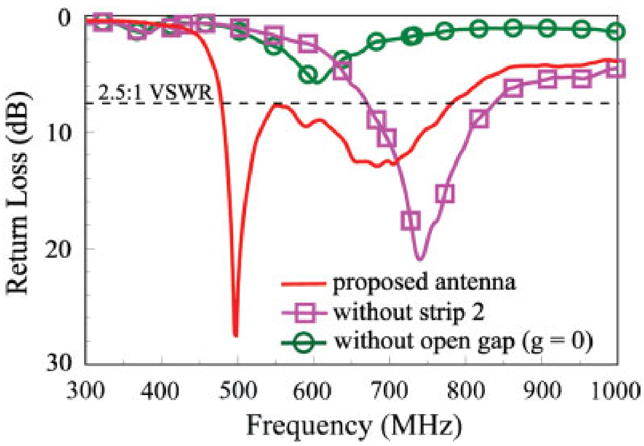


**Figure 4** Measured return loss for the proposed antenna, the antenna without strip 2, and the antenna without the open gap ($g = 0$). The antenna parameters are the same as studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

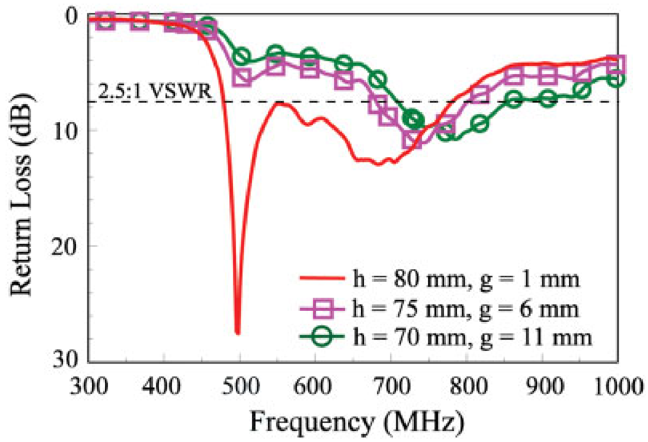


**Figure 5** Measured return loss for the proposed antenna as a function of $h$ (the length of strip 1) with the total length of $h$ and $g$ fixed to be 81 mm; other parameters are the same as studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 3, the antenna without strip 2, and the antenna without the open gap ($g = 0$). It is clearly seen that, when strip 2 is not present, the antenna's first resonant mode disappears, with the second resonant successfully excited only. On the other hand, when the open gap is not present ($g = 0$), the antenna's second resonant mode disappears and only the first resonant mode is excited. The obtained results are expected as described in Section 2. To analyze further, the antenna's radiation efficiency contributed from various portions of the proposed antenna including the system ground plane is studied by using Zeland simulation software IE3D [10]. The simulated results at 500 and 700 MHz are listed in Table 1. From the results at 500 MHz, the antenna's radiation efficiency are mainly contributed from strips 1 and 2, which indicates that the antenna's first resonant mode is mainly related to the half-wavelength loop structure as explained in Section 2. On the other hand, from the results at 700 MHz, the antenna's second resonant mode is mainly contributed from strip 1 and the system ground plane, which serve as the two asymmetric arms of the half-wavelength dipole structure.

An experimental study for analyzing the effects of the parameters $h$ and $g$ on the impedance matching of the two excited resonant modes was also conducted. Figure 5 shows the measured return loss for the antenna with three different values of $h$ and $g$. Note that the total length of $h$ and $g$ is fixed to be 81 mm in this study. From the results, it is seen that the resonant frequency of the antenna's first resonant mode is almost the same for the three different cases; however, the impedance matching is degraded with an increase in the length $g$ of the open gap. This behavior is largely because the larger value of $g$ leads to larger destruction in the antenna's resonant loop structure, hence resulting in the degradation in the impedance matching of the antenna's first resonant mode. On the other hand, it is seen that the resonant frequency of the antenna's second resonant mode is shifted to higher frequencies when the length $h$ is smaller. This agrees with the expectation that the antenna's second resonant mode is related to the half-wavelength dipole structure with strip 1 and the system ground plane as the two asymmetric arms. In this case, the smaller length in $h$ will lead to a smaller total length of the dipole structure, and thus the resonant frequency will be shifted to higher frequencies.

Effects of the width $w$ of strip 1 on the impedance matching of the antenna were also studied. Figure 6 shows the measured return loss for the width $w$ varied from 5 to 15 mm, with other parameters the same as those in Figure 3. Generally, the resonant frequencies of the two excited resonant modes are about the same. However, by selecting a proper width ($w = 10$ mm in this study), improved impedance matching over the desired DTV band can be obtained. The obtained results indicate that the width $w$ is also an important factor for achieving improved impedance matching over the desired DTV band for the proposed antenna.

Radiation characteristics of the proposed antenna were also studied. Since our anechoic chamber cannot operate at low fre-

**TABLE 1 Simulated Radiation Efficiencies (Obtained From Zeland IE3D) for Different Portions of the Proposed Antenna and the System Ground Plane at 500 and 700 MHz**

| | Efficiency at 500 MHz (%) | Efficiency at 700 MHz (%) |
|---|---|---|
| System ground plane | 9 | 56 |
| Strip 1 | 19 | 33 |
| Strip 2 | 72 | 11 |
| Total efficiency | *100* | *100* |

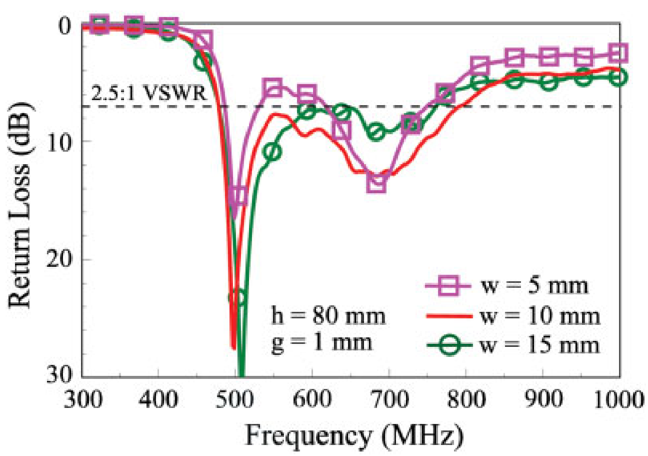


**Figure 6** Measured return loss for the proposed antenna as a function of $w$ (the width of strip 1); other parameters are the same as studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

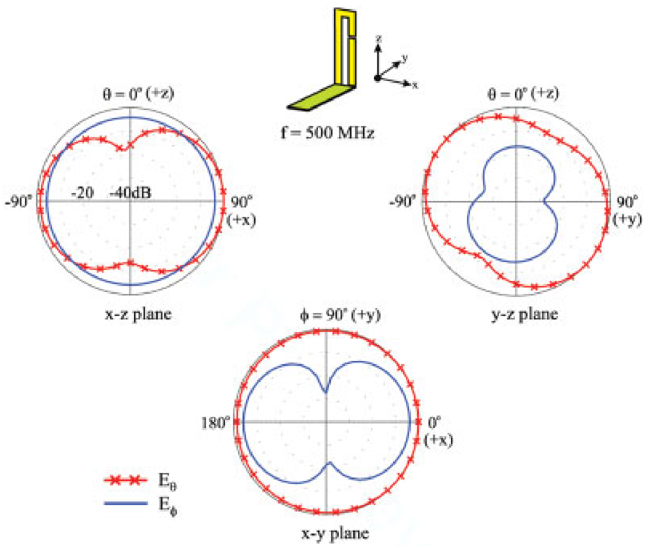


**Figure 7** Simulated radiation patterns at 500 MHz for the proposed antenna studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

quencies such as those in the UHF band, the radiation characteristics of the proposed antenna were studied using Ansoft simulation software HFSS, which is expected to provide reliable results for the proposed antenna. Figure 7 shows the simulated radiation pattern at 500 MHz. In this case, monopole-like radiation pattern patterns with good omnidirectional radiation are observed. The corresponding results at 700 MHz are plotted in Figure 8. From the results, the obtained omnidirectional radiation characteristic is still good. Figure 9 shows the simulated antenna gain and radiation efficiency of the proposed antenna studied in Figure 3. The antenna gain is found to vary from about 0 to 1.9 dBi over the DTV band, while the radiation efficiency for frequencies over the band is all better than 60%.

## 4. CONCLUSION

A novel broadband integrated planar DTV antenna for USB dongle application has been proposed. The antenna is with a simple structure and is easy to fabricate with a low cost. In addition, the antenna can generate two adjacent resonant modes to provide a wide operating bandwidth of larger than 50% to cover the DTV band in the 470–806 MHz. The proposed antenna is designed to be perpendicular to the system ground plane of the USB dongle in the operation condition. However, when not in the operation condition, the planar structure of the proposed antenna makes it very promising to be swung downward and attached onto the surface of the dongle housing to achieve an aesthetic appearance of the device. The proposed antenna has been successfully fabricated and tested. Detailed design considerations for the proposed antenna have been described. Over the 470–806 MHz band for DTV signal reception, good radiation characteristics have also been obtained for the proposed antenna.

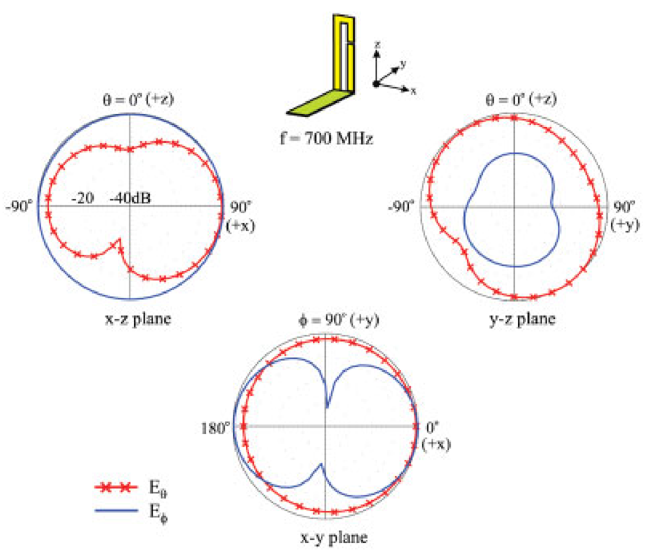


**Figure 8** Simulated radiation patterns at 700 MHz for the proposed antenna studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

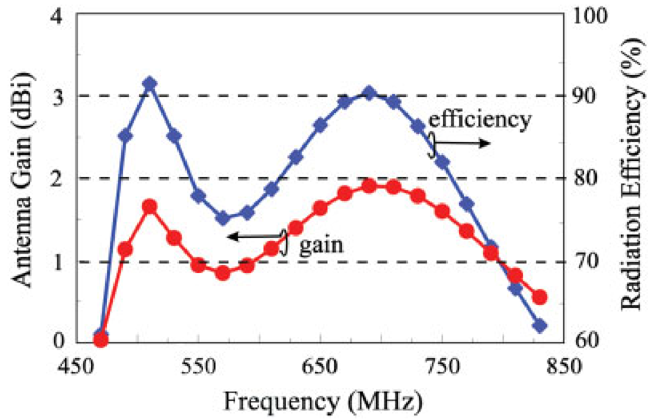


**Figure 9** Simulated antenna gain and radiation efficiency for the proposed antenna studied in Figure 3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]


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