Research Article

A Horizontally Polarized Omnidirectional Antenna Using Stacked Curve Dipoles for DTV Reception

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This paper presents an omnidirectional antenna using stacked curve dipoles radiating horizontal polarization for digital television (DTV) reception. The proposed antenna consists of stacked curve dipoles designed on brass sheet. The parametric study is carried out for various dimensions of curve dipoles to improve the impedance bandwidth. The results show good impedance matching for $|S_{11}|$ of less than -10 dB along the frequency range from 404 MHz to 871 MHz. The antenna gain is between -10 dBi and 0.67 dBi along the frequency range from 470 to 862 MHz.

1. Introduction

Nowadays, television broadcasting services have switched from analog system to digital television (DTV) system. The DTV technology enables TV broadcasters to transmit high-definition (HD) image and audio signals [1, 2]. The technology also makes the introduction of multimedia and interactive services possible. A second-generation terrestrial transmission system for digital television broadcasting, the so-called DVB-T2, is the most efficient DTV technology which is widely adopted in the European zone and operates on a frequency band of 470–862 MHz [3–5]. In the DTV system, a receiving antenna is an essential device to receive signals from a transmitting antenna. In literature, a stub-and capacitor-loaded folded dipole antenna has been proposed [1] for digital terrestrial TV reception. The numerical investigation clarified the effects of the stub and capacitor on bandwidth enhancement. In [2], a compact broadband microstrip-line-fed sleeve monopole antenna was presented. The design of meandering the monopole into a compact structure is applied for size reduction. A broadband printed dipole antenna with a step-shaped feed gap [3] has been

proposed for 470–806 MHz band. The wide operating band is formed by two excited resonant modes: one 0.5-wavelength mode controlled by the antenna length L and one 1.0-wavelength mode controlled by the total effective length (about $1.25L$) of two radiating arms. A J-shaped monopole antenna array with matching circuits of a slot transmission line was considered in [4] for the purpose of compact size and thin structure. Reference [5] presented a miniaturized internal spiral multimode antenna for 470–862-MHz band. This antenna uses seven spiral lines on the ground plane of microstrip line for multimode resonance. In combination with the multimode operational band, the entire DTV band of 470–862 MHz is achieved. A dual-band 3D PIFA for DVB-T (470–862 MHz) and WiMAX (3300–3800 MHz) applications was presented [6]. This antenna is suitable to be integrated in a monitor. Additional resonant path was presented in this configuration. The thickness can be reduced by 43% (in terms of electrical length). An internal antenna was also developed for indoor reception of UHF terrestrial digital TV broadcasting system [7]. The new antenna can cover a bandwidth of larger than 60%. It can resonate from 470 MHz to higher than 900 MHz. A wideband microstrip slot antenna

FIGURE 1: Configuration of the proposed antenna: (a) top view and (b) side view.

FIGURE 2: Configuration of the stacked curve dipoles (5 elements): (a) top view and (b) side view.

[8] was proposed for DTV (496 MHz to 862 MHz) band along with fully planar frequency reconfigurable microstrip loop structure with MIMO implementation for wireless LTE compatibility. The PIN diode switches had been used as the switching element between the LTE bands 3 and 7. Additionally, there are some researches about the antennas radiating horizontal polarization with omnidirectional pattern. A broadband vertically/horizontally dual-polarized omnidirectional antenna with high isolation was proposed [9]. The element for vertical polarization is a modified low-profile monopole, whereas the element for horizontal polarization is a planar circular loop antenna that contains four arc dipoles. In [10], a new compact omnidirectional antenna with horizontal polarization was proposed. The antenna etched on two sides of a circular substrate is characterized with low profile and light weight. An ultrahigh frequency (UHF) low-profile antenna was proposed [11] based on the disccone

geometry with addition of a back cavity, a short-circuiting structure, and a two-plate top structure to achieve both low-profile and wideband characteristics. A novel wideband planar omnidirectional horizontally polarized antenna for 4G LTE wireless systems and networks was presented [12]. From the mentioned references, the research about the flat antenna radiating horizontally polarized omnidirectional pattern is necessary for the DTV reception that is suitable for installing on the mobile station or vehicular applications. This paper deals with the optimal design of a receiving antenna suitable for DTV reception. Generally, a receiving antenna for DVB-T2 system requires horizontal polarization with omnidirectional beam and wide impedance bandwidth. The proposed antenna uses stacked curve dipoles designed on brass sheet. The structure of the antenna yields horizontal polarization and omnidirectional pattern. The rest of the paper is organized as follows: Section 2 describes the initial

FIGURE 3: Simulated results for different radii of feeding structure (r_3) of the initial antenna (5 elements): (a) input resistance, (b) input reactance, and (c) $|S_{11}|$.

design of antenna and subsequently the proposed antenna structure. Section 3 discusses simulated and measured results of the antenna. Section 4 is the concluding remarks.

2. Antenna Structure

This paper proposes a horizontally polarized antenna for DTV reception, as shown in Figure 1. The antenna structure is made from a thin brass sheet that consists of a number of curve dipoles. Each curve dipole is made of two overlapped arms located on two horizontal planes separated by an air gap. The structure of stacked curve dipoles is fed by a 75Ω coaxial transmission line. This proposed antenna uses a technique to enlarge dimension of stacked curve dipoles to improve the impedance bandwidth of antenna.

2.1. The Five-Element Stacked Curve Dipoles with Extended Feeding Structure (Initial Antenna). The initial antenna structure consists of the five elements of curve dipoles arranged to form the circular configuration. Two curved dipoles are stacked between each other in opposite directions with an air gap in between them. The feeding structure is located between the top and bottom layers as shown in Figure 2. The antenna is designed to operate in the UHF band at the frequency range from 470 MHz to 862 MHz. The radiation pattern is omnidirectional beam. The polarization is horizontal direction. The antenna structure is made of thin brass with thickness h of 1 mm and the feeding point is at the middle between two layers. The CST Microwave Studio [13] is used as the simulation tool for this antenna investigation.

FIGURE 4: Simulated results for different spacing between stacked curve dipoles (H) of the initial antenna (5 elements): (a) input resistance, (b) input reactance, and (c) $|S_{11}|$.

The initial antenna parameter is the outer radius of curve dipole r_1 with the dimension of the half wavelength of the center frequency (666 MHz) of 22.5 cm. The inner radius of curve dipole r_2 is $\lambda/2.25$ or 20 cm in the initial stage. The width of dipole arm (W) is 2 mm. The thickness of the brass sheet h is 1 mm. The suitable angle of curve dipole α is around 40° . The antenna parameters that will be varied to determine the suitable condition are the radius of feeding structure r_3 and spacing between stacked curve dipoles H . Subsequently, the outer and inner radii of curve dipole, r_1 and r_2 , will be considered to study the effect on the resistance and reactance. The criteria of $|S_{11}| < -10$ dB along the frequency range will be considered to cover the UHF band of the entire DTV system from 470 MHz to 862 MHz. The radiation characteristics of omnidirectional beam will also be inspected.

From Figure 2, the antenna structure of 5 elements will be studied. The feeding structure is the circular geometry of radius of r_3 . The antenna structure becomes completely overlapped between the curve dipoles in the opposite sides with the circular feeding structure.

From Figure 3, the radius of the feeding structure r_3 is varied. It is obvious that the radius of the feeding structure r_3 of 24 mm is the appropriated size. The reason is that the resistance is near 75 Ω and the reactance approaches zero. However, the bandwidth becomes narrower when r_3 is wider because the electrical size of the antenna is reduced. The increase of r_3 has also influenced spacing between stacked curve dipoles H . Thus, the parameter H will be varied again as shown in Figure 4.

When the radius of the feeding structure r_3 is 24 mm, the spacing between stacked curve dipoles H is varied. When

FIGURE 5: Simulated results for different outer and inner radii of curve dipoles (r_1 and r_2) of the initial antenna (5 elements).

the spacing between the circular stacked curve dipoles is changed from 8 mm to 6 mm, the bandwidth of the antenna can be enhanced as illustrated in Figure 4. However, it is found that the bandwidth cannot cover the frequency from 470 MHz to 862 MHz. The area of the feeding structure will be influenced to the length of dipole or the outer radius of the curve dipole, r_1 , and the inner radius of the curve dipole, r_2 . When the length of dipole arm is shortened, the difference between r_1 and r_3 is decreased. These parameters will be adjusted to determine the appropriated parameters.

From Figure 5, the suitable parameters of the outer and inner radii of curve dipoles (r_1 and r_2) are 190 mm and 180 mm, respectively. The reason is that the resistance and reactance are close to 75Ω and 0Ω , respectively, along the frequency range between 470 MHz and 862 MHz. The $|S_{11}|$ is less than -10 dB at this frequency band. However,

the simulated results show that the initial antenna with five elements still has relatively high $|S_{11}|$ along the frequency band.

2.2. The Five-Element Stacked Curve Dipoles with Extended Feeding Structure and Additional Branch Curve (Final Proposed Antenna). From Figure 2, the initial antenna is started with the antenna consisting of 5 elements and area extension of the feeding point to improve the $|S_{11}|$. The additional branch curved to the curve dipole can improve the impedance characteristics. There are two parameters to be varied, that is, the radius of branch curve, r_4 , and the angle of branch curve β . The CST Microwave Studio [13] is used as the simulation tool. Figure 6 shows the input impedance and $|S_{11}|$ of the antenna versus the frequency for different r_4 and β . From the simulated results, the antenna can

FIGURE 6: Simulated results for different radii of the branch curve r_4 and angles of the branch curve β of the proposed antenna.

achieve the impedance close to $75 + j0 \Omega$ corresponding to $|S_{11}| \leq -10$ dB.

From the parametric study of the antenna with five elements and branch curve structure, the $|S_{11}|$ can be improved to cover the UHF range of the entire DTV system. The parameters of the antenna with five elements and branch curve structure are tabulated in Table 1.

3. Simulated and Measured Results

To validate the simulated results, the prototype antenna was fabricated as depicted in Figure 7. The measurement of $|S_{11}|$, radiation pattern, and gain are carried out. It is obvious that the prototype antenna possesses $|S_{11}| \leq -10$ dB covering the frequency range between 404 MHz and 871 MHz (467 MHz bandwidth) as shown in Figure 8. Figure 9 shows

TABLE 1: Designed parameters of the proposed antenna.

Parameter	Description	Size
r_1	Outer radius of curve dipole	190 mm
r_2	Inner radius of curve dipole	180 mm
W	Width of dipole arm	2 mm
H	Spacing between stacked curve dipoles	6 mm
h	Thickness of brass sheet	1 mm
α	Angle of curve dipole	37 deg
r_3	Radius of feeding structure	24 mm
r_4	Radius of branch curve	186 mm
β	Angle of branch curve	24 deg

the simulated and measured gains of the antenna. It is apparent that the measured maximum and minimum gains are -10 dBi and 0.67 dBi, respectively.

FIGURE 7: Photograph of the proposed prototype antenna: (a) top view and (b) bottom view.

FIGURE 8: Simulated and measured $|S_{11}|$ versus frequency of the proposed antenna.

FIGURE 9: Simulated and measured gains of the proposed antenna.

Figure 10 shows the comparison between the simulated and measured results of the radiation patterns at the frequency of 470 MHz, 666 MHz, and 862 MHz. The prototype antenna radiates omnidirectional beam. The results include the radiation pattern in azimuth plane (vary ϕ and fix $\theta = 90^\circ$) and elevation plane (vary θ and fix $\phi = 0^\circ$). It is noted that the cross-polarization levels in azimuth plane along the operating frequency band from simulation and measurement are lower than -20 dB and -15 dB, respectively. In the elevation plane, the simulated and measured cross-polarization levels are lower than -20 dB, and -9 dB, respectively. The simulated half-power beamwidths in the elevation plane, at the frequencies of 470 MHz, 666 MHz, and 862 MHz, are

121.8° , 140° , and 38.9° , whereas those of the measured results are 100° , 70° , and 40° , respectively.

4. Conclusion

An omnidirectional antenna using stacked curve dipoles radiating horizontal polarization has been proposed for digital terrestrial TV reception. The measured results show that good impedance matching for $|S_{11}|$ less than -10 dB covers the frequency range from 404 MHz to 801 MHz. The antenna radiates omnidirectional patterns from 470 MHz to 862 MHz. The measured gain of the proposed antenna

FIGURE 10: Simulated and measured radiation patterns (a) 470 MHz, (b) 666 MHz, and (c) 862 MHz.

along the operating frequency from 470 MHz to 862 MHz is between -10 dBi and 0.67 dBi.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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