Dual Polarized Vivaldi Antenna for Digital Television Applications

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Abstract - **In this paper, a dual-orthogonal polarized Vivaldi antenna with high port isolation is presented. The dual-polarized antenna structure is achieved by inserting two orthogonal Vivaldi antennas in a cross-shaped form without a galvanic contact. To satisfy the low-end bandwidth requirements and improve the radiation characteristics in the lower frequencies, a novel exponential tapered slot edge (ETSE) structure is proposed. The measured results show a reasonable agreement with the simulation results. The proposed antenna can be used for the digital television (DTV) applications.**

Index Terms — **Dual-polarized Vivaldi antenna, exponential tapered slot edge (ETSE), DTV applications.**

1. Introduction

DTV broadcasting has drawn worldwide attention in the past few years [1]. However, DTV face the problems of signal fading in a multi-path environment. This adversary can be improved by the application of polarization diversity.

The Vivaldi antenna, which was firstly created by Gibson in 1979 [2], has been widely used. In [3], the Vivaldi antennas were combined as cross-shaped dual polarized antennas, which were used for ultra-wideband applications. A printed Vivaldi antenna with two pairs of eye-shaped slots was presented in [4]. By using the eye-shaped slots, the side lobe levels of the radiation pattern can be reduced. However, the antenna is not dual-polarized.

In this paper, a dual-polarized Vivaldi antenna is designed for the DTV applications. The measured bandwidth of the proposed antenna, defined by $|S_{11}| \le -10dB$, ranges from 470 to 794 MHz, which covers the DTV frequency band. The isolation between the antenna ports is better than 25 dB. And the main beam direction of these two polarized patterns is concurrent.

2. Antenna Design

Fig. 1 demonstrates the evolution of the antenna. A reference classical Vivaldi antenna as shown in Fig. 1(a) is simulated. This antenna is printed on an FR4 substrate with a thickness of 1.6 mm and dielectric constant of 4.4.

The exponential taper profile is defined by

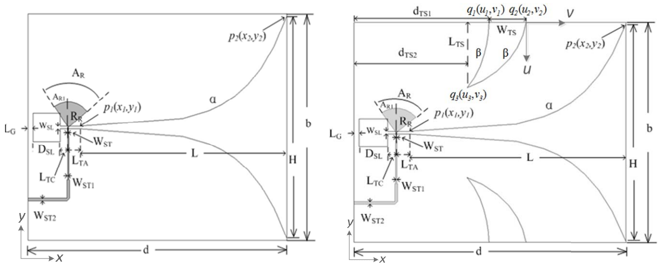
$$y = c_1 e^{\alpha x} + c_2 \quad (1)$$

where c_1 and c_2 are determined by the opening rate α and two points $p_1(x_1, y_1)$ and $p_2(x_2, y_2)$

$$c_1 = \frac{y_2 - y_1}{e^{\alpha x_2} - e^{\alpha x_1}}$$

$$c_2 = \frac{y_1 e^{\alpha x_2} - y_2 e^{\alpha x_1}}{e^{\alpha x_2} - e^{\alpha x_1}}$$

To improve the performance of the antenna, the ETSE modification is therefore proposed. As shown in Fig. 1(b), The exponential tapered slot edge consists of two exponential curves, which is described by the equation (1) in $u - v$ relative coordinate system. The proposed antenna is optimized and finally fabricated with the parameters indicated in Table 1. Some of the parameters are specified as follows: $\alpha = 0.02, \beta = 0.03, A_R = 86°, A_{R1} = 35°$.



(a) (b)

Fig. 1. Evolution of the proposed configuration. (a)Original Vivaldi. (b)Modified Vivaldi antenna

TABLE I
Parameters of the Proposed Antenna

Parameters	***L_G***	***D_{SL}***	***W_{SL}***	***L_{TC}***	***L_{TA}***
Values/mm	6	34	3	10	12.5
Parameters	***W_{ST}***	***W_{ST1}***	***W_{ST2}***	***d***	***L***
Values/mm	0.89	1.62	3.05	322.5	260
Parameters	***R_R***	***H***	***b***	***W_{RS}***	***L_{RS}***
Values/mm	30	266	270	44	80
Parameters	***d_{RS}***	***W_{TS}***	***L_{TS}***	***d_{TS1}***	***d_{TS2}***
Values/mm	160	44	80	160	134

Fig. 2 illustrates the simulations of the $|S_{11}|$ variation of original Vivaldi and the ETSE Vivaldi. As shown in the figure, the lower-end limitation of the original Vivaldi antenna with $|S_{11}| \le -10dB$ is 510 MHz, which does not cover the frequency 470MHz, while the ETSE Vivaldi antenna extends the operating frequency to 470 MHz. Thus, the modified ETSE Vivaldi antenna is well suitable for the DTV applications. To further study the behaviors of the ETSE structure in the lower frequency range, current distribution of both classical and ETSE Vivaldi antenna at 510 MHz is given in Fig. 3. It is easy to find that the proposed modification is able to decrease the unwanted currents on the outer edges, such that the side lobe levels of the radiation pattern are reduced as shown in Fig. 4.

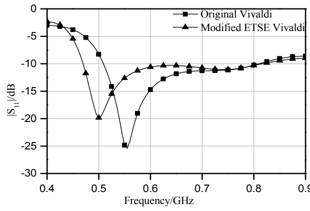


Fig. 2. Simulated $|S_{11}|$ of original and modified Antenna.

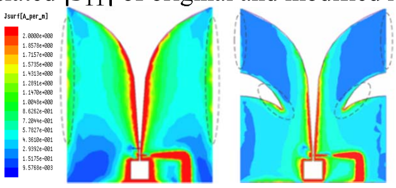


Fig. 3. Surface current distribution at 510MHz of original Vivaldi and ETSE Vivaldi.

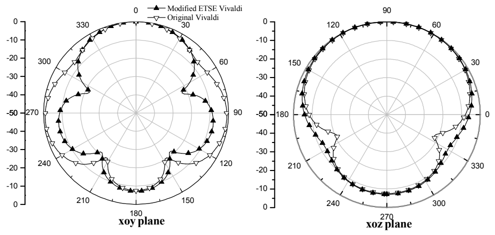


Fig. 4. Simulated radiation patterns of original Vivaldi and modified ETSE Vivaldi at 510 MHz in xoy and yoz plane.

3. Fabrication and Measurement of the Designed Vivaldi Antenna

According to the structure and size of the designed Vivaldi antenna, a dual polarized Vivaldi antenna is fabricated and measured. Fig. 5 shows the photos of the constructed antenna.

The measured and simulated $|S_{11}|$ and $|S_{21}|$ of the dual-polarized Vivaldi antenna are shown in Fig. 6. Good impedance matching with the 50 Ω coaxial line is achieved for both ports, which satisfies the required operating frequency band from 470MHz to 794MHz. The isolation between the two input ports of the dual-polarized antenna is better than 25 dB over the desired bandwidth. However, there is a discrepancy between simulated and measured $|S_{21}|$, which comes from the fabrication error and the influence of the SMA connector. The simulated and measured radiation patterns for the xoy and yoz planes of the antenna excited by port 1 at 530 MHz and 794 MHz are plotted in Fig. 7. The proposed antenna has good unidirectional radiation patterns and the main lobes are fixed in the endfire direction (x-axis direction) within the effective bandwidth. The measured gains curve for different frequencies is shown in Fig. 8.

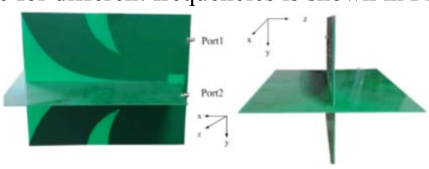


Fig. 5. The photo of the dual polarized Vivaldi antenna.

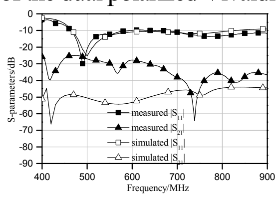
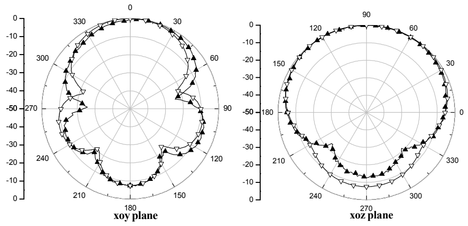
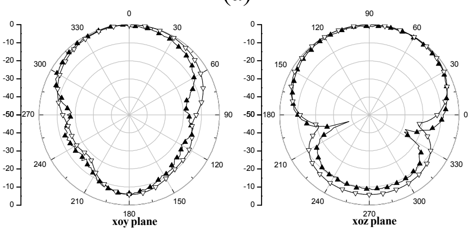


Fig. 6. Measured and simulated S-parameters of antenna.



(a)



(b)

Fig. 7. Measured and simulated xoy plane and yoz plane radiation patterns for port1. (a)530MHz，(b)754MHz. -▲- measured co-polarization -△- simulated co-polarization

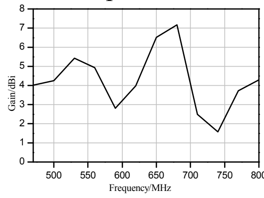


Fig. 8. Measured gain of the proposed antenna.

4. Conclusion

A novel dual-orthogonal polarized Vivaldi antenna has been designed in this paper for DTV applications. The antenna consists of two orthogonally orientated Vivaldi antenna elements in a cross form. By using the ETSE structure, the lower-end 10-dB limitation of the modified antenna is extended to 470 MHz from the original 510 MHz. Besides, the side lobe levels of the radiation pattern are reduced in the lower frequency band.

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