Double-slot Vivaldi antenna with improved gain

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A double-slot structure is proposed to design a new Vivaldi antenna with improved gain. The two slots are excited in uniform amplitude and phase by using a T-junction power divider. The double-slot structure can generate plane-like waves across the slot aperture of the antenna. As a result, the gain of the double-slot Vivaldi antenna is significantly improved compared with that of a typical Vivaldi antenna of the same size. The measured results show that the impedance bandwidth of the double-slot Vivaldi antenna is from 2.5 to 15 GHz. The gain of the proposed antenna is considerably higher than the typical antenna at frequencies above 6 GHz. What is more, the structure proposed is far simpler than those designed before.

Introduction: The Vivaldi antenna, which was first described by Gibson in 1979 [1], has been widely studied and applied due to its simple structure, light weight, wideband, high efficiency and high gain. To improve the gain of the Vivaldi antenna, some approaches have been proposed. Using an array of Vivaldi antennas [2] is the conventional way to obtain high gain and directivity, but it is complicated, costly and bulky for some applications. Other methods such as using a photonic band gap structure that can be formed by micromachining the substrate with holes [3] or placing conductor strip gratings on both sides of the substrate [4], are also complicated because of the need to optimise the parameters of the holes and metal strips. Another method is to employ a 'director' in the aperture of the tapered slot, which can focus the energy in the endfire direction and improve the gain. The 'director' can be formed using a dielectric that has a higher permittivity than the antenna substrate [5, 6] or anisotropic zero-index metamaterials on both sides of the antenna substrate [7]; however, the dielectric 'director' is costly, and the anisotropic zero-index metamaterials are complicated to construct, what is more, the anisotropic zero-index metamaterials can only improve the gain and directivity of the Vivaldi antenna in a narrow band (9.5–10.5 GHz).

In this Letter, a double-slot structure is proposed to develop a novel Vivaldi antenna with improved gain in an ultra-wideband. The double-slot structure makes the aperture field distribution at the end of the antenna more uniform, thus the gain of the proposed antenna is higher than that of a conventional Vivaldi antenna with the same size. It is more important that the proposed structure is far simpler than those mentioned in [2–7].

Antenna configuration: The configuration of the proposed double-slot Vivaldi antenna (DSVA) is shown in Fig. 1*a*. The structural parameters are listed in Table 1, and have already been optimised. The dimensions of the antennas are 80 × 150 mm^2. As shown in Fig. 1, the tapered slot of the DSVA consists of four exponential curves: E_{s1}, E_{s2}, E_{t1} and E_{t2}. Using the structural parameters in Table 1, the four exponential curves can be described by the equations:

$$E_{s1}: \quad y = \frac{1}{2}\left(W_s - g\exp\left(\ln\left(\frac{W_s}{g}\right)\frac{x}{L_s}\right)\right) \quad (0 \le x \le L_s) \qquad (1)$$

$$E_{s2}: \quad y = \frac{1}{2}\left(g\exp\left(\ln\left(\frac{W_s}{g}\right)\frac{x}{L_s}\right) - W_s\right) \quad (0 \le x \le L_s) \qquad (2)$$

$$E_{t1}: \quad y = \frac{1}{2}\left(W_s + g\exp\left(\ln\left(\frac{(W - W_s)}{g}\right)\frac{x}{L}\right)\right) \quad (0 \le x \le L) \qquad (3)$$

$$E_{t2}: \quad y = \frac{1}{2}\left(-W_s - g\exp\left(\ln\left(\frac{(W - W_s)}{g}\right)\frac{x}{L}\right)\right) \quad (0 \le x \le L) \qquad (4)$$

Microstrip/slotline transitions are used to feed the slots of the two antennas. A T-junction power divider excites the two slots of the DSVA in uniform amplitude and phase. An exponential taper is used for the conventional Vivaldi antenna to transform from 100 to 50 Ω. The dielectric substrate used here is chosen as F4B with a permittivity of 2.65 and tangent loss of 0.001. The thickness of the dielectric substrate is 1 mm. The fabricated sample of the DSVA is shown in Fig. 1*b*.

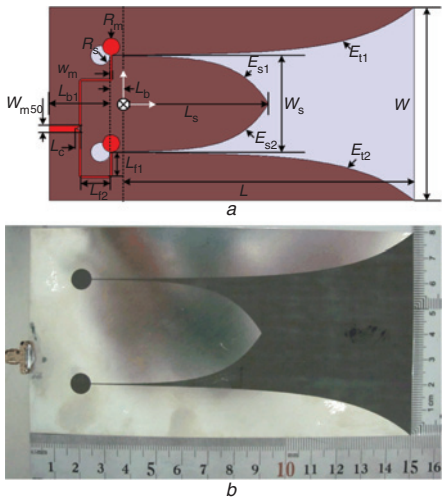

Fig. 1 *Double-slot Vivaldi antenna*
a Antenna configuration
b Fabricated sample

Table 1: Structural parameters of DSVA

Parameters	Value (mm)	Parameters	Value (mm)
W	80	L_b	5
L	120	L_{b1}	25
W_s	40	L_{f1}	10
L_s	60	L_{f2}	12
g	0.3	W_{m50}	2.78
R_m	3.5	W_{m100}	0.77
R_s	4	L_c	1.7

Results: To illustrate how the double-slot structure improves gain, a typical Vivaldi antenna with the same slot length L, slot width W and the same size of the DSVA was simulated for comparison. Fig. 2 shows the reflection coefficients. The impedance band of the DSVA is from 2.5 to 15 GHz, which is almost the same as that of the typical Vivaldi antenna.

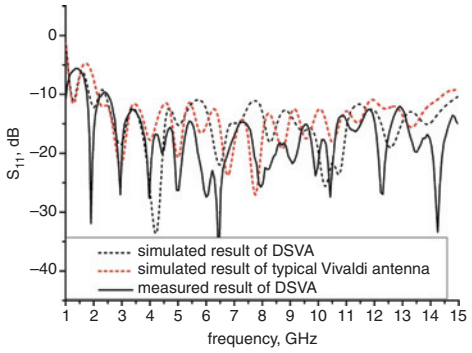

Fig. 2 *Reflection coefficients*

Fig. 3 shows the measured radiation patterns of 10 GHz in the *E*- and *H*-planes of the DSVA together with the simulated ones of the typical Vivaldi antenna. Since the *H*-plane beamwidth of the tapered slot antennas is always determined by the effective radiation region length combined with substrate slowing [8], the *H*-plane patterns of the antennas with the same slot length and the same substrate are almost the same. Moreover, because of the diffractions from the edges which can broaden the pattern and the substrate slowing which can bunch the radiated power, the *E*-plane pattern of the typical Vivaldi antenna is wider than its *H*-plane pattern. In addition, a significant improvement of gain is obviously obtained by the DSVA, as shown in Fig. 3*a*. The mechanism by which the double-slot structure obtains a high gain is shown in Fig. 4. The simulated *E*-field distributions across the slot apertures of the DSVA and the typical Vivaldi antenna show that the typical Vivaldi antenna generates spherical-like waves which result in low gain, whereas the DSVA generates plane-like waves which produce high gain. Fig. 4 gives the root cause for the high gain performance of the proposed

DSVA, especially at frequencies above 6 GHz, as shown in Fig. 5. The operating band of the DSVA with higher gain than the typical Vivaldi antenna is much wider than that of the antenna proposed in [7]. Besides, the structure of the DSVA is much more simple than those of the antennas in [2–7].

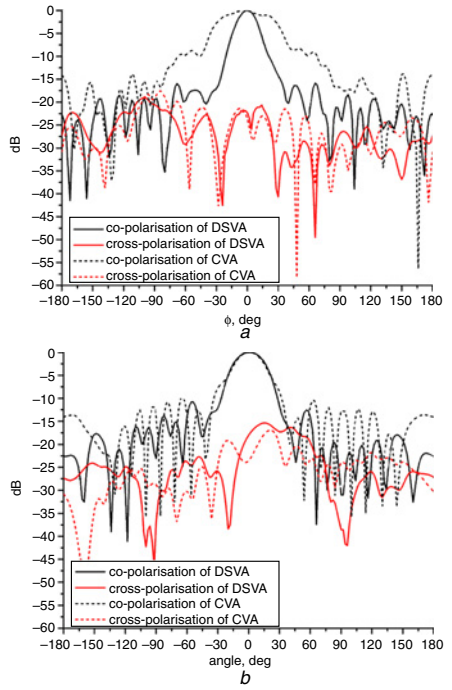

Fig. 3 *Measured radiation patterns of 10 GHz*

a *E*-plane radiation
b *H*-plane radiation

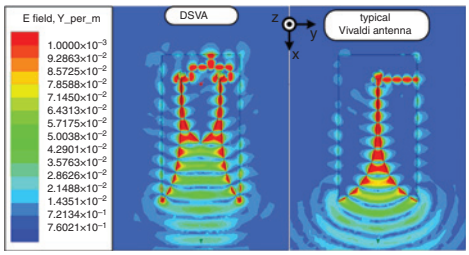

Fig. 4 *Simulated E-field distributions across slot apertures of antennas at 10 GHz*

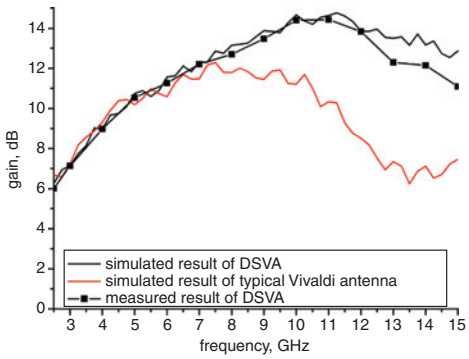

Fig. 5 *E-plane broadside gain*

Conclusion: A novel Vivaldi antenna with improved gain based on the double-slot structure is proposed in this Letter. When the two slots are excited in uniform amplitude and phase by using a T-junction power divider, the double-slot Vivaldi antenna can generate plane-like waves across its slot aperture rather than the spherical-like waves normally generated by a typical Vivaldi antenna. Hence, the double-slot Vivaldi antenna can obtain an improved gain over that of the typical one. The results show that the double-slot Vivaldi antenna works well in the frequency range of 2.5–15 GHz, and its *E*-field peak gain is much higher than that of the typical Vivaldi antenna from 6 to 15 GHz.

Acknowledgments: This work was supported by the National Natural Science Foundation of China (grant 60971118).

26 April 2013
doi: 10.1049/el.2013.2180
One or more of the Figures in this Letter are available in colour online.

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