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A Wideband Vivaldi Antenna

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Abstract

Even though several Vivaldi antenna designs have been discussed in the literature with a wide impedance bandwidth, the usable bandwidth is often limited by pattern degradation at the higher frequencies of the operating bands. The widest usable bandwidth achieved is around 30:1. This paper presents a bilateral Vivaldi antenna with a usable bandwidth of 50:1 (1–50 GHz). The bilateral form of the antenna and the optimization of the flares resulted in achieving this improved bandwidth.

1. Introduction

Many wireless systems have ever-increasing bandwidth requirements, hence the need for wider bandwidth antennas for use in these systems. The Vivaldi antenna has received significant attention in the literature due to its wide bandwidth potential along with high gain, directional radiation patterns, and simple planar structure [1]. Possible applications are ElectroMagnetic Compatibility / Interference (EMC/I) testing, wideband communication technology, surveillance, and antenna measurements.

The Vivaldi antenna, due to its flared structure, has extremely wide bandwidth potential [2]. However, as seen in the literature, a common problem is that the bandwidth is limited by the feeding structure. The different types of Vivaldi antennas, e.g. coplanar or antipodal, have specific feeding structures. Many coplanar designs use a microstrip line with a radial stub matching section. This limits the bandwidth since the stub significantly radiates. The antipodal type can typically achieve a wider bandwidth than the coplanar type, however it has higher cross-polarization levels.

There are a few designs in literature that achieved relatively wide bandwidths. In [3] an all-metal Vivaldi achieved a bandwidth of 25:1 (2–50 GHz). At the higher frequencies of the band, however, the side lobe level significantly increased. The *E*-plane patterns were also asymmetric. The antipodal Vivaldi antennas in [4] and [5] achieved usable bandwidths of 28:1 and 30:1, respectively. In [6] a bilateral Vivaldi achieved a usable bandwidth of 28.6:1 (0.7–20 GHz). The patterns were stable, but the gain deteriorated above 16 GHz.

A bilateral Vivaldi antenna is effectively a double-sided coplanar Vivaldi fed with a stripline and a bilateral slotline section. In [7] an improved version of the bilateral Vivaldi was presented. Usable patterns were claimed from 0.57–20 GHz, but the patterns were only shown from 0.7 GHz. The VSWR was also not consistently below 2:1 over the full measured frequency range.

In this paper, a bilateral Vivaldi antenna is presented using a stripline to bilateral slotline feeding structure and a Bezier flare profile with a 50:1 (1–50 GHz) usable bandwidth. The bilateral structure allows for a significantly wider impedance bandwidth, while maintaining stable, symmetrical radiation patterns over the full band. The incorporation of the Bezier curve allows for more control over the flare profile compared to the exponential curve that is typically used for Vivaldi antennas.

2. Bilateral Vivaldi Antenna

The main advantage of the bilateral feed presented in [8] was the stability of the characteristic impedance of the bilateral slotline. It was shown to be almost constant over a 200:1 bandwidth, compared to the impedance of a conventional slotline that varies significantly over frequency.

A stripline to bilateral slotline feed is used in this design. This feed consists of a stripline to bilateral slotline transition. The bilateral slotline with a characteristic impedance of 50 Ω consists of two 100 Ω slotlines on either side of the bilateral Vivaldi. This results in a transition from a 50 Ω stripline to two 100 Ω slotlines in parallel and hence no additional impedance transformer is necessary. Both slotlines are terminated in an open circuit cavity, as shown in Figure 1. Instead of a radial stub matching section, the stripline is short-circuited to both sides of the bilateral Vivaldi using a metal via. The use of a metal via instead of a radial stub also allows for a wider impedance bandwidth.

It was found that the feed is sensitive to the substrate thickness and relative dielectric constant, ε_r. A lower ε_r and a thinner substrate helped to minimize the radiation from the circular cavities at higher frequencies, hence improving the useable bandwidth. Rogers RT5880 with an ε_r of 2.2 and a thickness of 0.508 mm was used. This substrate allows the feed to operate up to 50 GHz with a low insertion loss. It was also found that the distance between the via and the slotline; and the distance between the stripline and the circular cavities had a significant effect on the impedance bandwidth of the feed.

A bilateral flare profile was used for the Vivaldi antenna. In [9] a Double-Ridged Guide Horn (DRGH) antenna, utilizing a Bezier curve ridge profile was presented, achieving a bandwidth of 100:1 (0.5–50 GHz). This Bezier curve profile was adapted for use as the flare for the bilateral Vivaldi antenna. The control points of the Bezier curve allow for more control over the flare profile. A cubic Bezier flare profile with four control points, listed in Table 1, is used.

The substrate between the curved profiles of the two flared sections was cut away. Therefore, the flare structure almost mimicked the all-metal structure in [3]. This improved the patterns at the higher frequencies of the band.

3. Simulation Results

The structure of the proposed bilateral Vivaldi antenna with final dimensions is shown in Figure 1. The substrate has a total thickness of 1.016 mm, L_0 = 189.75 mm, W_0 = 191.80 mm, L_1 = 35 mm, d_0 = 20 mm, W_1 = 0.2 mm, W_2 = 0.84 mm, and the via diameter is 0.5 mm.

The simulated VSWR and realized boresight gain versus frequency results are shown in Figure 2. The simulations were performed with CST Studio Suite 2023 [10]. The time domain solver was used for the full frequency range. The frequency solver was then used to verify the results at the lower frequencies of the range. Adaptive meshing was used with both solvers to ensure sufficient accuracy of the simulations. The VSWR is below 2:1 in the range 1–50 GHz (50:1). The gain varies from 3.9–13.7 dBi with the peak gain at about 43.5 GHz. The drop in the gain near 5 GHz is due to a slight dip in the *E*-plane pattern. This is shown at 5.5 GHz in Figure 3. Although there is slight variation in the gain at the higher frequencies, the patterns do not deteriorate at the higher frequencies of the range. This is evident at 25.5 GHz and 50 GHz as shown in Figure 4 and Figure 5, respectively. The radiation patterns are well-behaved over the full frequency range.

The usable bandwidth of the proposed antenna is significantly wider compared to other wideband Vivaldi antennas in the literature. This is summarized in Table 2, where λ_L is the wavelength at the lowest frequency.

4. Conclusion

The proposed bilateral Vivaldi antenna achieved an extremely wide usable bandwidth of 50:1 (1–50 GHz). The gain is stable and the VSWR is below 2:1 over the full frequency range. The main features that aided in achieving this wide bandwidth were the bilateral structure, the use of an optimal substrate and the removal of the substrate between the flares. Measured results of a prototype bilateral Vivaldi antenna will be presented at the conference.

Table 1. Bezier curve control points

Design control points (in mm)	
Parameter	***Value***
Bezier point 0 (start point)	(Y: ±0.1, Z: 0)
Bezier point 1 (start tangent point)	(Y: ±0.1, Z: 224.75)
Bezier point 2 (end tangent point)	(Y: ±95.89, Z: 189.74)
Bezier point 3 (end point)	(Y: ±95.90, Z: 189.75)

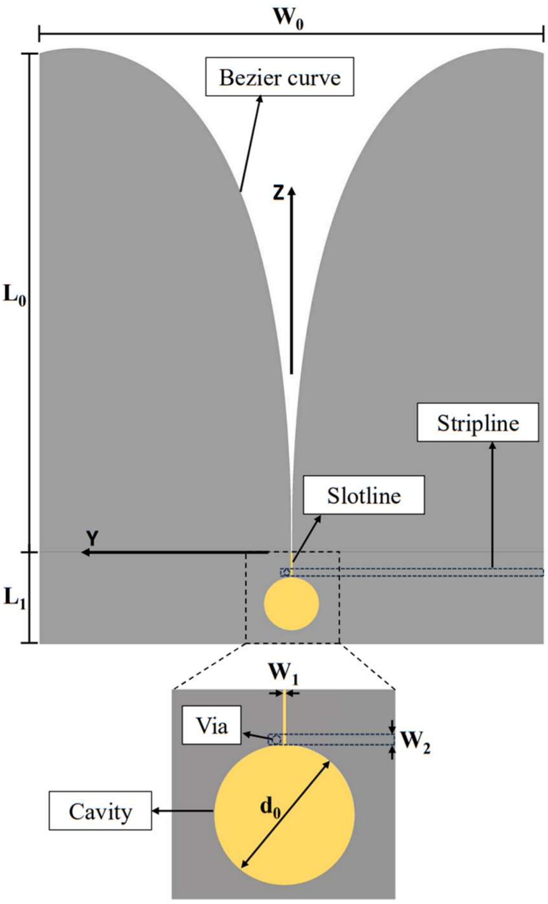

Figure 1. The proposed bilateral Vivaldi antenna (Grey is conductor and yellow is substrate)

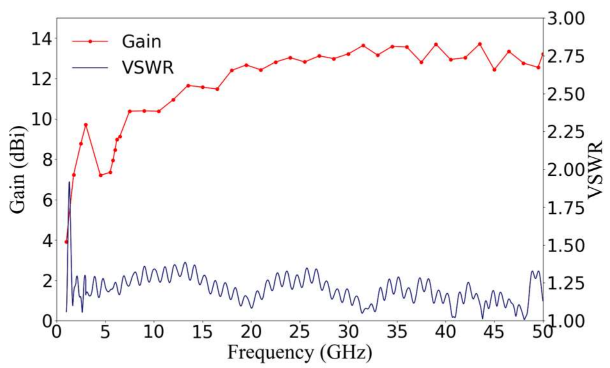

Figure 2. The simulated VSWR and realised boresight gain versus frequency

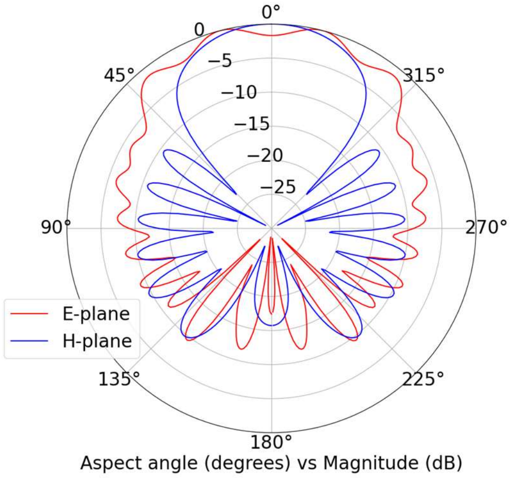

Figure 3. The simulated radiation patterns at 5.5 GHz

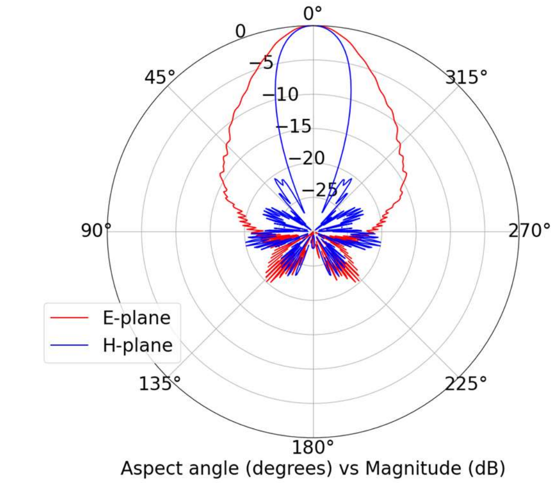

Figure 4. The simulated radiation patterns at 25.5 GHz

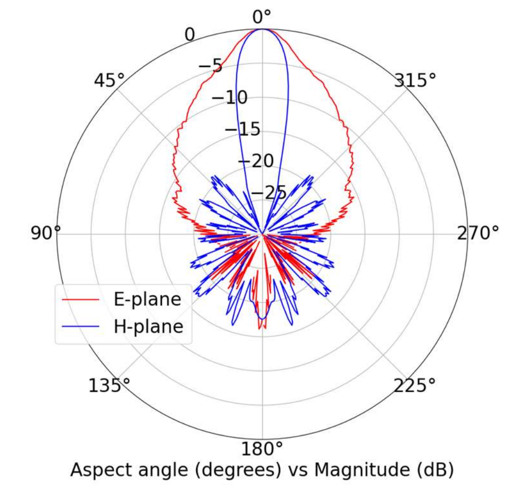

Figure 5. The simulated radiation patterns at 50 GHz

Table 2. Comparison of the performance of other Vivaldi antennas to the proposed antenna

Ref.	**Parameters**		
	Dimensions **(λ_L^2)**	***Bandwidth*** **(GHz)**	***Gain*** **(dBi)**
[3]	0.40 × 0.53	2–50 (25:1)	4.5–12
[4]	0.60 × 1.30	1–28 (28:1)	4.9–14.6
[5]	0.32 × 0.46	1–30 (30:1)	2.2–11
[6]	0.54 × 0.77	0.7–20 (28.6:1)	3–11.3
[7]	0.48 × 0.64	0.57–20 (35:1)	3.5–16.5
Proposed	0.64 × 0.75	1–50 (50:1)	3.9–13.7

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