Vivaldi Antenna with balun feed for SKA feeding system in UWB

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Abstract

This paper represents a low cost printed Vivaldi antenna at 3-10 GHz bandwidth for Radio telescope Feed system. The idea of this design is to minimize the number of telescope receivers for Square Kilometre Array (SKA) [1]. A minimized tapered slot antenna with a balun feed for receiver systems is proposed. The Vivaldi antenna is design on a relatively low dielectric constant substrate which operates at Ultra-Wideband (UWB). A typical tapered slot antenna is a combination of a wideband balun and a radiator with different tapering shapes such as linear, constant width, exponential and dual exponential. Two feeding configurations are used such as coplanar waveguide (CPW) to slot line transition and microstrip line to slotline transition [2-5]. The antenna modeling is analyzed using two different electromagnetic simulators such as HFSS and CST Microwave Studio. The results are shown that the antenna operates over a wide bandwidth extending from 3.1 to 10.6 GHz with a maximum gain of 7.3 dBi. Stable radiation patterns are observed across the operational bandwidth, with cross-polarization levels below -20 dB. The realized antenna structure occupies a volume of $45 \times 45 \times 0.5$ mm^3, and possesses the essential time domain fidelity needed for UWB Radio telescope Feed system applications. A prototype Vivaldi antenna is constructed and measured for validation. The Voltage Standing Wave Ratio (VSWR) of the proposed antenna is verified against the simulated data results, the measured and simulated results are found to be in good agreement. In particular, a good impedance bandwidth matching and stable directional radiation patterns were achieved across the operating frequency range. The combination of design aims and outcomes described in the paper indicates that the proposed antenna can be a suitable candidate for portable RF systems, or possible sensor element in an UWB antenna array application.

1. Introduction

In communication systems, the antennas are required to have the characteristics such as wide band, low volume, light weight and easy maintenance. The Vivaldi antenna that feed by the microstrip line has all the above advantages. The Vivaldi antennas are widely used in several fields including satellite communication, remote sensing and radio telescope. The Vivaldi antenna is usually developed from the linear tapered slot antenna (LTSA) with the curve slope rate of the LTSA slot is constant; the transition between the slot line and conic slot is not smooth [3, 4]. The Vivaldi antenna arrays also have been investigated in Radio telescope application, for example Vivaldi antenna arrays as a Phased Array Feed in Netherlands FARADY project Low Frequency Band [8]. Meanwhile Vivaldi antenna with a wideband balun feed design could be used in Radio telescope system by Wide Band Single Pixel Feed（WBSPF）method due to its UWB property. It will be a new design technology in Pre-research of SKA Radio telescope.

Therefore, in this paper, a minimized tapered slot antenna with a balun feed design operating at UWB frequency (3-10 GHz) was presented. A typical tapered slot antenna with the combinations of a wideband balun and a radiator with tapering exponential shapes was designed. Meanwhile, for the feeding configurations, coplanar waveguide (CPW) to slot line transition and microstrip line to slotline transition are been used in order to improve the frequency band. The Vivaldi antenna performance characteristics are reported in terms of the voltage standing wave ratio (VSWR) and radiation pattern. From the results, it been found that the proposed Vivaldi antenna have better performances in VSWR and linear polarization characteristics and the performance index met the requirements from the series literatures [3-7]. Therefore, the proposed Vivaldi antenna can be widely used in practical application.

2. Antenna design

The geometrical configuration of the proposed compact Vivaldi Antenna is shown in Fig. 1, which shows the antenna structure and specific dimensions. The proposed design is composed of two exponential shapes, two circle slots, coplanar waveguide to slot line transition and microstrip line to slotline transition. As can be seen in Fig. 1, the two exponential shapes which were analyzed with perfectly electrically conducting. The minimized tapered slot Vivaldi antenna with a balun feed design is fabricated on F4B dielectric substrate with relative permittivity of $\varepsilon_r = 3.3$ (with the antenna volume of $45 \times 45 \times 0.5$ mm^3), to provide some design flexibility. The key designing for the feeding part is required to be characterized to achieve optimum conjugate impedance with respect to the antenna input impedance.

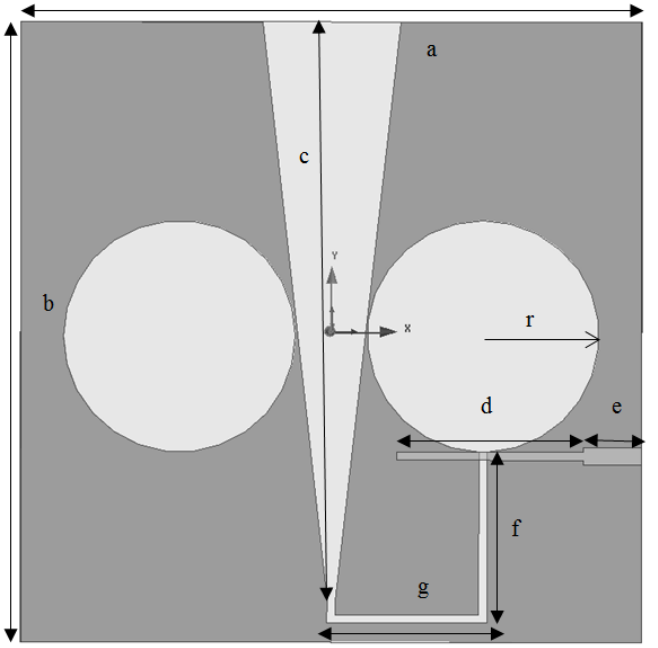


Figure 1: The geometry of the Vivaldi antenna design.

It can be found in design process that the antenna input impedance or matching impedance can be optimized by changing the antenna radius (*r*) and the length of *g, f, d, e*. For the proposed Vivaldi antenna design, the balun feed designing plays a vital role in controlling the operating frequency.

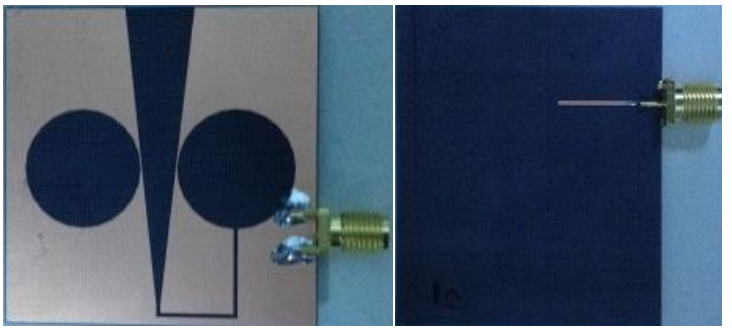
3. Results and discussions

A Vivaldi antenna configuration (see Fig. 1) was proposed in order to achieve a perfect design with compact size at UWB operation. Moreover, a balun feed design was used to enhance the operating bandwidth for the presented design. The antenna modelling is analyzed using two different electromagnetic simulators such as HFSS and CST Microwave Studio with the optimum parameters of the geometry configuration are listed in Table 1.

Table 1: Geometrical specification of the Vivaldi antenna design.

a	45 mm	r	8.4 mm
b	45 mm	e	4.2 mm
c	42 mm	f	11.8 mm
d	13.5 mm	g	11.6 mm

To validate the modelling results, a prototype based on the configuration in Figure 1 was fabricated and tested. The prototype is shown in Figure 2. The VSWR result was measured by Network Analyzer (see Figure 3) and the radiation patterns is measured in an anechoic chamber. Figure 4 shows the comparative VSWR locus between the simulated and measured results. The agreement are generally good, with VSWR achieved less than 2 across the working frequency.



(a) Top view (b) Bottom view

Figure 2: The photo of the fabricated prototype.

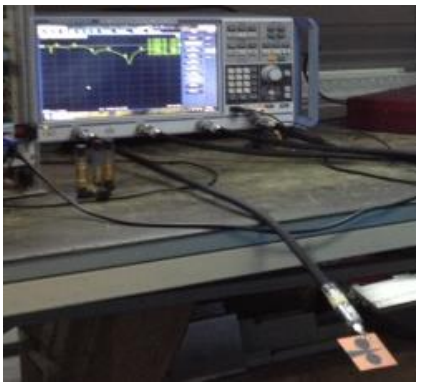


Figure 3: The Vivaldi antenna with Network Analyzer measurement system

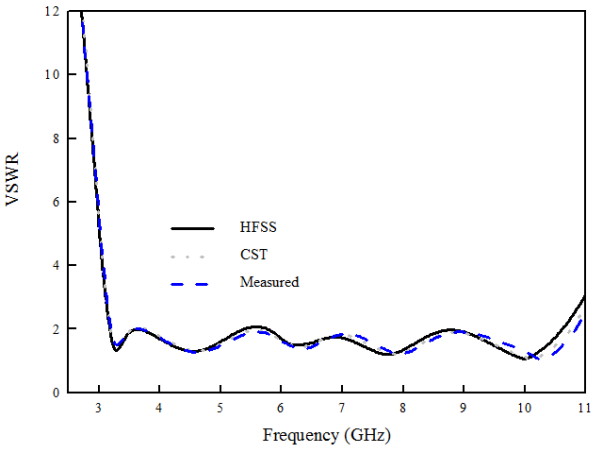
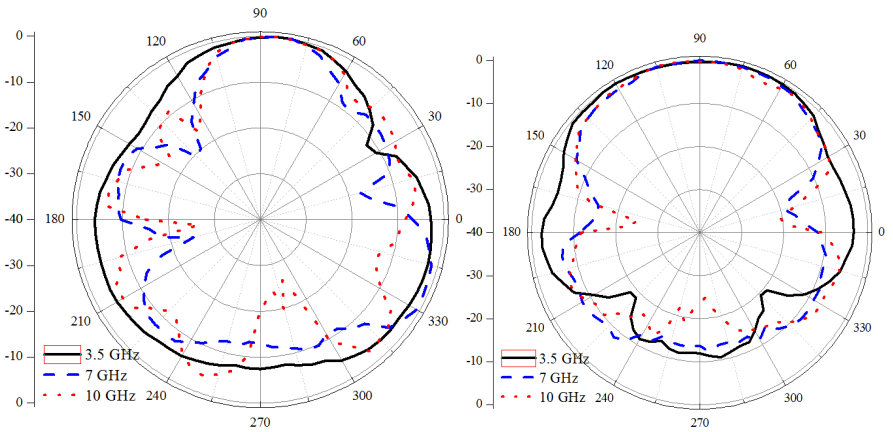


Figure 4: The Vivaldi antenna VSWR results

Meanwhile, the radiation patterns in the E-plane (z-x plane) and H-plane (z-y plane) at UWB corresponding to the normalized results are presented in Figure 5. The maximum antenna gain was found to be about 7.3 dBi and 7.1 dBi for z-x and z-y planes, respectively with the maximum cross-polarization levels below -20 dB.



(a) E-plane (xy-plane) (b) H-plane (yz-plane)

Figure 4: Measured radiation patterns in two main planes at different frequencies.

4. Conclusions

A minimized tapered slot Vivaldi antenna with a balun feed design has been presented. The antenna was studied for Radio telescope Feeding system. The UWB VSWR less than 2 from 3.1 to 10.6 GHz with a maximum gain of 7.3 dBi. Stable radiation patterns are observed across the operational bandwidth, with cross-polarization levels below -20 dB been achieved. The simulated performance for the proposed design was compared with two different electromagnetics software simulators. The measured and simulated results are found to be in good agreement. The obtained results are acceptable for practical implementation in Pre-research SKA Radio telescope feeding system for UWB requirement.

5. Acknowledgments

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