2012-07-08

Vivaldi Array for Generation of UWB Circular Polarization

Adam Narbudowicz
Technological University Dublin

Matthias John
Technological University Dublin, matthias.john@tudublin.ie

Xiulong Bao
Technological University Dublin, xiulong.bao@tudublin.ie

See next page for additional authors

Recommended Citation

Narbudowicz, A. et al. (2012)Vivaldi Array for Generation of UWB Circular Polarization, *IEEE International Symposium on Antennas and Propagation, Chicago, IL, USA,* IEEE Antennas & Propagation Society, Paper 360.2, 08/07/2012, doi:10.1109/APS.2012.6348767

Funder: SFI

Authors

Adam Narbudowicz, Matthias John, Xiulong Bao, and Max Ammann

Vivaldi Array for Generation of UWB Circular Polarization

Adam Narbudowicz, Matthias John, Xiulong Bao and Max J. Ammann
Antenna & High Frequency Research Centre
Dublin Institute of Technology
Kevin St., Dublin, Ireland
adam.narbudowicz@mydit.ie

***Abstract*—A two antenna array is proposed for generating circular polarization for an ultra-wideband system. It consists of two orthogonal antipodal vivaldi antennas and a feed network which provides the appropriate phase and amplitude over the band of interest. The proposed structure is low cost and easy to manufacture, offering an axial-ratio bandwidth of 74%.**

I. Introduction

It is only recently that circularly-polarized (CP) antennas can provide good axial ratios (AR) across very wide bandwidths [1] (with the exception of spiral antenna). Furthermore, recent regulations by the FCC and European Commission triggered a proliferation of activity in ultra-wideband (UWB) technology. Such systems enable low-power high-speed data transmission. It is therefore advantageous to combine the power efficiency/capacity of UWB with the advantages of circular polarization.

For classical narrowband systems CP can be achieved by employing two orthogonal linearly polarized antennas, fed with 90˚ phase shift. In theory the same method can be applied to UWB, however practical constraints are more demanding. For narrowband systems the 90˚ phase shift is usually generated by a delay line - a solution which is simple, but band limited. Recently UWB phase delay circuits have been developed, which employ aperture coupling mechanism [2]. These offer good phase stability across very wide bandwidths, but with disadvantages of substrate thickness being a design parameter and limited achievable phase shift.

The problem of dual orthogonal linearly polarized UWB antennas has been widely studied [3], [4]. Usually two orthogonal and intersecting antennas are introduced. Although suitable for many dual-polarized applications, this technique exhibits certain manufacturing disadvantages when a constant and stable phase shift is required across UWB. Although in [5] a four rigid horn antenna was successfully employed for UWB CP, the structure is expensive to manufacture. Hence, in this paper a design involving two linearly polarized Vivaldi antennas is investigated. The structure consists of low-cost PCBs which are easy to fabricate.

II. Design

The proposed structure comprises a feed network and two viavaldi antennas, positioned orthogonally to each other and spaced by distance *D*. The general scheme is shown in Fig. 1.

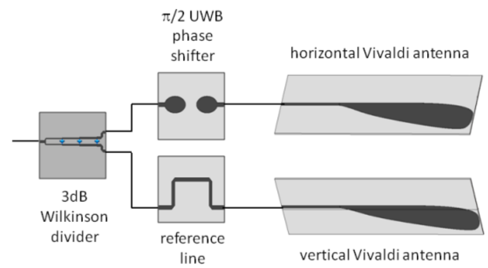

Figure 1. General scheme of the proposed antenna.

A. Feed network

The feed network consists of a 3dB power divider, UWB 90˚ phase shifter and a reference line, printed on Taconic RF-35, ($\varepsilon_r = 3.5$ and $h = 0.5$ mm) and connected as seen in Fig. 1. Three different power dividers were tested for the configuration: a classical T-junction with tapered impedance transformers, a T-junction with slot-line transition [6] and a 3-stage Wilkinson divider. Both T-junction dividers appeared to have poor isolation between the output ports. As the next stage is different for each output, this caused for some frequencies more than 3 dB variation between feeds of the two orthogonal antennas and degraded the AR at those frequencies (see Fig. 3). The use of a Wilkinson divider (with isolation below 20 dB across the band of interest) overcame this problem, providing smooth transmission coefficient with little variation between antenna feeds. UWB operation was achieved by employing three stages of the divider [7].

The UWB phase shifter is a 3 layered structure, which employs an aperture coupling technique [2]. A 45˚ phase shift across UWB is achieved by coupling the signal through the elliptical hole in the ground plane to a microstrip line located on the other side of the substrate. Then another 45˚ shift is applied in the same manner. The circuit with all relevant dimensions is shown on Fig. 2. Parameter values are: $W_{slot} = 7.5$ mm, $L_{slot} = 7.2$ mm, $W_{el} = 4.9$ mm, $L_{ref} = 7.2$ mm, $\Delta_W = 2.4$ mm, $L_{W1} = 8.4$ mm, $L_{W2} = 9$ mm and $D = 21$ mm.

978-1-4673-0462-7/12/$31.00 ©2012 IEEE

Three stages of the divider have characteristic impedances of 89Ω (terminated by $R_1 = 107\Omega$), 71 Ω (terminated by $R_2 = 211\Omega$) and 58Ω (terminated by $R_3 = 400\Omega$).

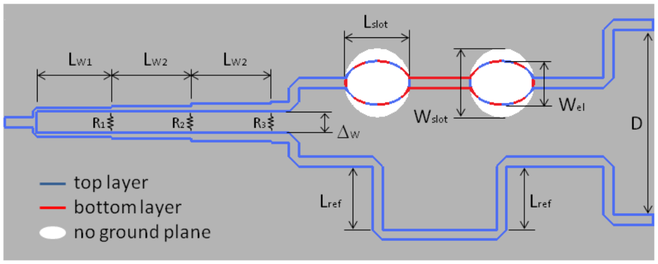

Figure 3. Detailed structure of the feed network.

B. *Antenna configuration*

Two end-fire antipodal vivaldi antennas were designed, using spline curve shapes and an efficient global optimization algorithm [8]. Although for linear polarization the antipodal antennas are known for poor cross-polarization, for CP it is only necessary that both linearly cross-polarized components are the same.

Ideally the antennas should be spaced as close as possible, in order to keep both phase centers close. This is limited by the width of antenna plus spacing needed to prevent coupling. In the optimization process this was solved by fixing the most outer point of the spline curve as (14, 100), resulting in long but relatively narrow vivaldi antenna (40 mm, compared to i.e. 62 mm on $\varepsilon_r = 2.2$ in [4]). The optimized radiator can be described by a spline curve with control points: (0.8, 30), (0.8, 32), (8.7, 49.8), (18, 93.3), (14, 100), (-1, 99), (-0.8, 32) and (-0.8, 30), which is mirrored on the other side of the substrate to form antipodal vivaldi. A third curve with control points: (5.2, 5), (3.2, 28.7) and (0.8, 30) defines a balun from asymmetric 50Ω microstripline to symmetric slot.

III. RESULTS

Simulated results for proposed antenna exhibit $S_{11} < -10$ dB from 2.6 GHz to 8.3 GHz (plot not shown for brevity). Fig. 3 shows the simulated boresight AR for various antenna configurations. It is seen, that for the feed with two independent inputs, a good AR < 3dB is achieved in the band from 3 to 7.5 GHz. This performance degrades when simple T-junction is applied due to poor isolation between two channels. A 3-stage Wilkinson divider solves the problem.

Fig. 4 shows a two-dimensional plot of the AR as a function of angle θ and frequency (for convenience all values above 6 dB are grey) for the antenna with 3-stage Wilkinson divider. The main lobe with LHCP occurs for θ = 90˚ and a back lobe with RHCP can be seen for θ = 270˚. It can be seen, that due to antenna proximity, a small tilt in the main beam is present. Also the CP beam gets narrower with increased frequency, as the electrical distance increases. A comparable problem occurs for classical linearly polarized UWB antenna arrays [3].

ACKNOWLEDGEMENT

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant Number 09/SIRG/I1644.

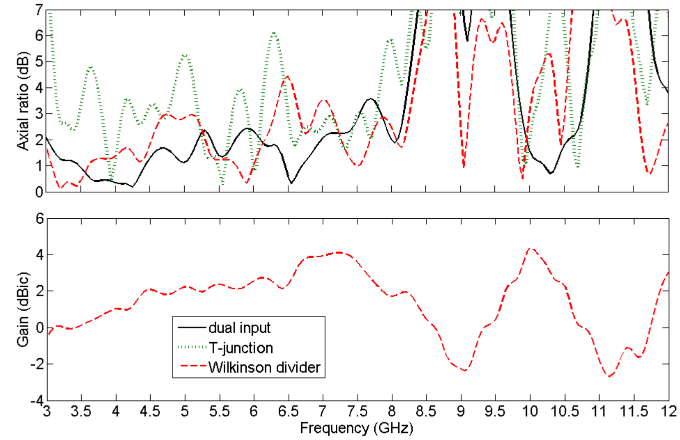

Figure 3. LHCP gain and axial ratio for boresight ($\theta = 90^{O}$).

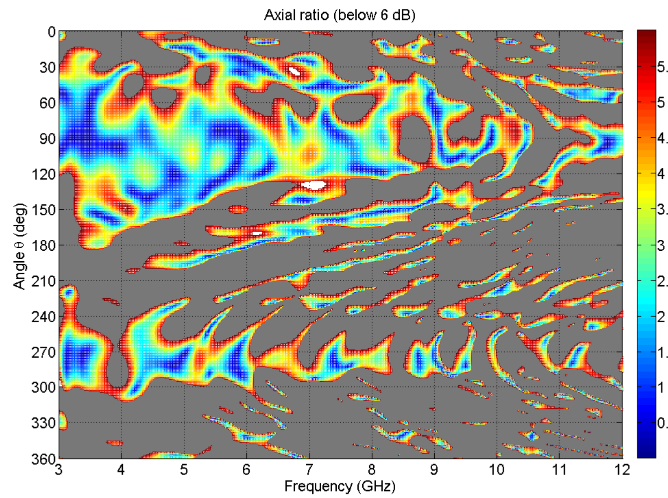

Figure 4. Axial ratio as a function of angle and frequency.

REFERENCES

[1] X.L. Bao, and M.J. Ammann, “Printed circularly polarised antenna with ultra-wide axial-ratio bandwidth,” *IET Microwaves, Antennas & Propagation*, vol. 5, pp. 1089–1096, June 2011.

[2] A.M. Abbosh, "Ultra-Wideband Phase Shifters", *IEEE Trans. Microwave Theory Tech.*, 55, (9), pp. 1935-1941, 2007.

[3] A. Narbudowicz, G. Adamiuk, and W. Zieniutycz "Clover Array — Polarisation Diversity Solution for Ultra Wideband Systems", *Progress In Electromagnetic Research Letters*, vol. 10, pp. 163-170, August 2009.

[4] G. Adamiuk, T. Zwick, and W. Wiesbeck "Dual-orthogonal polarized Vivaldi antenna for ultra wideband applications", *MIKON - Int. Conf. on Microwave, Radar and Wireless Comm.*, Wroclaw 2008, pp. 1-4.

[5] Z. Hradecky, and P. Hamouz "Research of Circular Polarisation Quality by Using Quad Ridged Horn Antenna", *EuCAP - European Conf. on Antennas and Propagation*, Barcelona 2010, pp. 1-5.

[6] M.E. Bialkowski, and A.M. Abbosh, "Design of a Compact UWB Out-of-Phase Power Divider", *IEEE Microwave and Wireless Compontnts Letters*, vol. 17, pp. 289-291, April 2007.

[7] S.B. Cohn, "A Class of Broadband Three-Port TEM-Mode Hybrids", *IEEE Trans. Microwave Theory Tech*, vol 19, (2), 110-116, 1968.

[8] M. John, and M.J. Ammann, "Antenna Optimisation with a Computationally Efficient Multiobjective Evolutionary Algorithm" *IEEE Trans. Antennas & Propagat*, vol. 57, (1), pp. 260-263, 2009.