Dual-orthogonal polarized Vivaldi Antenna for Ultra Wideband Applications

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Abstract

This paper presents a design of a dual polarized Vivaldi antenna. The problems that were met during the design of such an antenna are depicted and proper solutions are described. The prototype of the proposed antenna is introduced and finally the full characterization of the dual polarized antenna is given. Since UWB is originally a time domain based technique, a time domain characterization of the antenna is also included.

Introduction

Ultra Wideband is one of the emerging technologies that has gained a big attention of scientists and industry in the whole world. Due to its enormous bandwidth UWB has a big potential in almost all microwave systems from telecommunication to radar applications. The advantages occur, dependent on application, in the high data rates, very high resolution or very fine localization possibilities. The efficiency of such systems can be enhanced by the application of polarization diversity. Especially interesting is polarization diversity in the high-end systems such as imaging systems, radars or precise localization techniques. Polarization information delivers additional information about a target, which leads to a significant improvement of the performance.

In radar or through-wall localization systems antennas with high gain are desirable. The common phase center of radiations for both polarizations is of big interest, since it has a direct influence on the performance. One of the best antennas for UWB systems with relatively high gain and convenient time domain behavior is a Vivaldi antenna [1]. The antenna consists mainly of an exponentially tapered slot, which radiates the wave by traveling wave principle. There are numerous versions of this antenna, which differ mainly in the feeding techniques. In this paper an aperture coupled feed is considered, which is well suited for the considered case. The requirements on such antennas are not only good matching and decoupling between ports but also constant and symmetrical radiation pattern over frequency and a good polarization purity in the far field of the antenna in all directions.

Aperture coupled dual polarized Vivaldi antenna

There exist numerous single polarized Vivaldi antennas that have an aperture coupling [1]. The main idea of such a coupling is the transformation of micro-strip line to slot line, which feeds the antenna. The schematics of such an aperture coupled Vivaldi antenna is shown in Fig. 1a. The connector is soldered to the micro-strip line (yellow marked) and the antenna itself. The metallization of the antenna serves as a ground plane for the micro-strip line. The structure was designed for the substrate Duroid 5880 with a relative dielectric permittivity ε_r=2.2 and a thickness of h=0.79 mm. The substrate with low relative permittivity supports the broadband radiation.

The realization of dual orthogonal polarized Vivaldi antenna with common phase center of radiation can be carried out by shifting two single polarized elements orthogonally into each other as shown schematically in Fig. 1b. For this purpose a slot has to be cut out in front and in the back of the elements, respectively. It can be noticed that after shifting of the antennas into each other, the metallization on the backside of one antenna has to be interrupted. The resulting slot has to be galvanically connected and soldered at the end of the realization process. The thickness *h* of the substrate was intentionally chosen to 0.79 mm in order to keep the slot width as small as possible. On the other hand the substrate must not be to thin in order to guarantee a good mechanical stability of the antenna structure.

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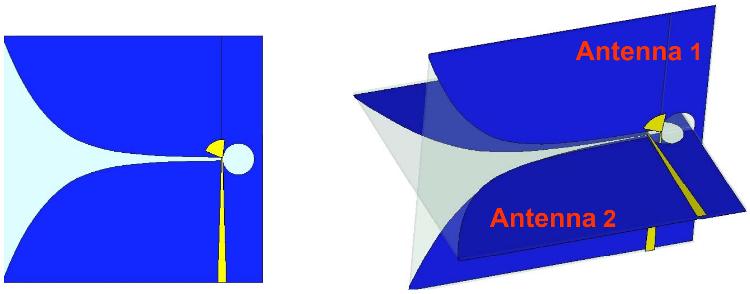
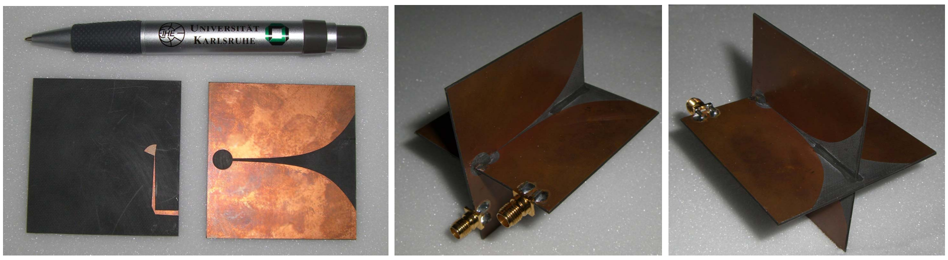


a) b)

Fig. 1 Schematics of an aperture coupled Vivaldi antenna (the metallizations on the opposite sides of the substrate are marked yellow and blue)
a) aperture coupled Vivaldi antenna
b) dual orthogonal polarized Vivaldi antenna

Since the antenna will be used for construction of an antenna array the feeding point of micro-strip line was placed on the back of the structure in order to have a better degree of freedom by setting the distance between elements in the array. In a so realized antenna the minimal distance between the elements in the array equals the width of a single element, which equals 62 mm.

The proposed realization demands a longitudinal shift of both elements, which results in systematic error between both polarizations in the range measurements. Since the UWB systems allow for localization with the accuracy of sub-cm [2], the problem has to be optimized. The shift of 3 mm was compensated by a proper dimensioning of the length of feeding micro-strip line in one of the antenna elements. The realized antenna is shown in Fig. 2.



a) b) c)

Fig. 2 a) mono polarized aperture coupled Vivaldi antennas (left: bottom view; right: top view)
b) dual polarized Vivaldi antenna (rear view)
c) dual polarized Vivaldi antenna (front view)

Results

In this section the measurements results of the aperture coupled dual polarized antenna prototype will be given.

The measurements have shown that for both polarizations a very good matching in the FCC frequency range (3.1 GHz – 10.6 GHz) was achieved and that decoupling between ports is lower than -25 dB.

The gain was measured in an anechoic chamber from 3 GHz to 11 GHz in the E- and H-Plane and is shown in Fig. 3. A symmetry of the beam around 0˚ can be observed, which implies that both polarizations radiate with similar performance in all directions. Such an antenna can be successfully applied to polarimetric systems. The maximal gain was achieved at approx. 8 GHz and equals 8 dBi.

Since UWB is originally a pulse-based i.e. time domain-based technique, a common description of the antenna by the radiation pattern and gain is not sufficient. In the description of the antenna the phase behavior of the device must be included. It can be carried out either by calculation of the phase response of the antenna or by measurement of the impulse response in the time domain. However the impulse response can be also calculated by the Fourier-transformation of the complex transfer function of the antenna into the time domain [3].

From an UWB antenna is expected that it exhibits distortion of the radiated pulse as small as possible. For this reason the impulse response of an UWB antenna should be very short and its form should be constant over spherical angle. Concluding, the following parameters describing an UWB antenna in the time domain can be defined [4].

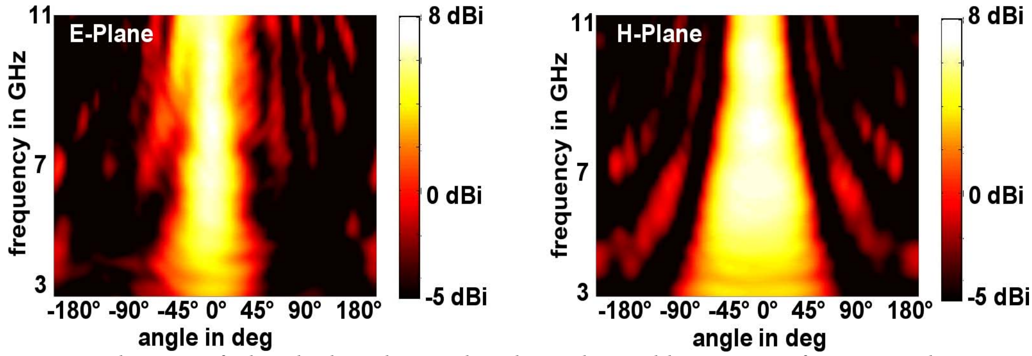


Fig. 3 Measured gain of the dual orthogonal polarized Vivaldi antenna for one polarization in Co-Polarization in the E-plane (left) and H-plane (right)

- Peak value p describes the maximal value of the envelope of antenna impulse response $|h^{+}(t)|$ and is expressed in m/ns. The higher that value is, the more concentrated is the radiated energy in time. Peak value can be mathematically described by the following formula:

$$p = \max_{t} \left| h^{+}(t) \right| \qquad (1)$$

- FWHM (Full Width at Half Maximum) value describes the broadening of the pulse by an antenna and is defined as a length of the envelope of the antenna impulse response $|h^{+}(t)|$ at the half peak value p. The FWHM value is expressed in seconds and is defined as:

$$\tau_{FWHM} = \left| t_1 \big|_{|h^{+}(t_1)| = p/2} - t_2 \big|_{|h^{+}(t_2)| = p/2} \right|_{t_1 \neq t_2} \qquad (2)$$

- Ringing τ_r describes the duration of a decay of the envelope of antenna impulse response $|h^{+}(t)|$ from peak value p to a certain level r. The unit of the ringing time is second and is expressed by the following formula:

$$\tau_r = \left| t_2 \big|_{|h^{+}(t)| = r \bullet p} - t_1 \big|_{|h^{+}(t)| = p} \right|_{t_2 > t_1} \qquad (3)$$

The designed dual polarized antenna is well suited for UWB impulse response, which is presented for E-plane and for H-plane in Fig. 4. The antenna impulse response is very short and has relatively high peak value. In the main beam direction the parameters have the following values: peak value p=0.4 m/ns, FWHM value τ_{FWHM}=85 ps and τ_r=150 ps for r=0.22. These values characterize a very good performance for an UWB antenna. It can be also noticed that the performance of the Vivaldi antenna does not change by making it dual polarized.

Cross polarization properties

For dual polarized antennas the decoupling of polarizations in the far field is very important. However it is very hard to design a non-resonant antenna that has acceptable polarization purity. That is why there exist almost no dual polarized antennas for UWB systems. The here designed antenna shows a good separation of polarizations. In the main beam direction it is larger than 20 dB for most frequencies for the both polarizations (see Fig. 5). Such a performance allows a successful application of the antenna to polarimetric UWB systems.

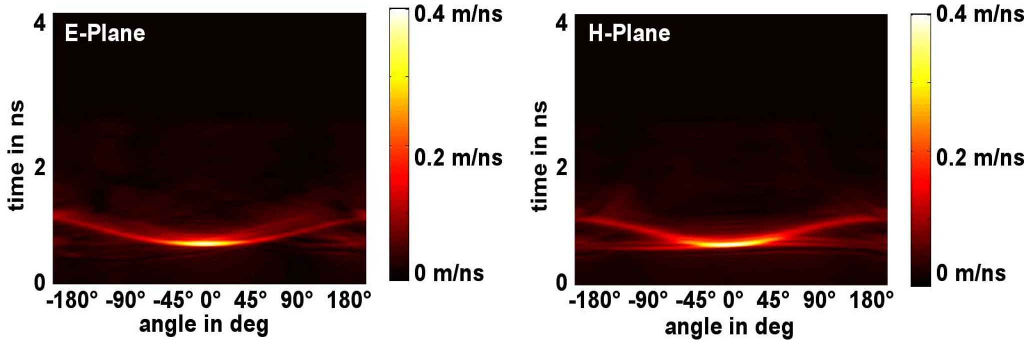


Fig. 4 Measured impulse response of the dual-orthogonal polarized Vivaldi antenna for one polarization in the E-plane (left) and H-plane (right) (both Co-Polarization)

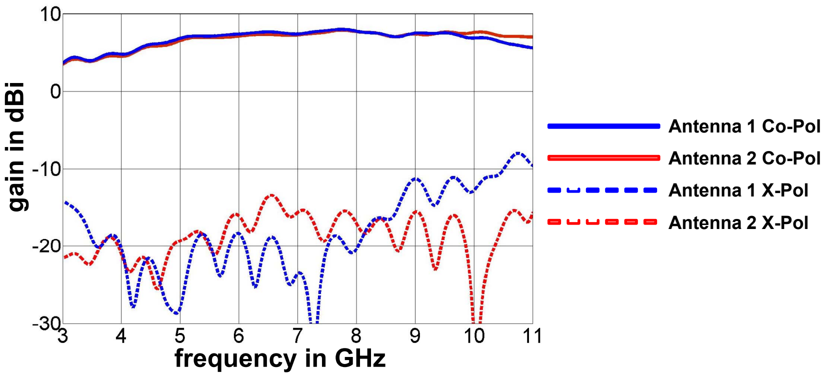


Fig. 5 Measured gain of the dual orthogonal polarized Vivaldi antenna in the main beam direction for both polarizations (Co- and X-Polarization)

Conclusions

The introduced antenna is one of the first compact, dual polarized antennas suitable for Ultra Wideband technique. It shows very similar radiation properties for both polarizations. The phase center is constant over the considered frequency range for both polarizations. This makes the antenna very interesting for UWB imaging, radar and localization systems, especially where a high gain is required.

References:

[1] Sörgel, W., Waldschmidt, C., Wiesbeck, W.; "Transient responses of a Vivaldi antenna and a logarithmic periodic dipole array for ultra wideband communication", Antennas and Propagation Society International Symposium, 2003. IEEE Volume 3, Page(s):592 – 595, 22-27 June 2003

[2] Gezici, S., Zhi Tian, Giannakis, G.B., Kobayashi, H., Molisch, A.F., Poor, H.V., Sahinoglu, Z.; "Localization via ultra-wideband radios: a look at positioning aspects for future sensor networks" ; Signal Processing Magazine, IEEE Volume 22, Issue 4, Page(s):70 – 84, July 2005

[3] W. Sörgel, S. Knörzer, W. Wiesbeck, "Measurement and Evaluation of Ultra Wideband Antennas for Communications", Proceedings International ITG-Conference on Antennas, pp. 377–380, Berlin, September 2003

[4] W. Sörgel and W. Wiesbeck, "Influence of the Antennas on the Ultra Wideband Transmission", EURASIP Journal on Applied Signal Processing, special issue UWB - State of the Art, pp. 296–305, March 2005