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4-Port Vector Antenna for MIMO Applications

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Abstract

A wideband 4-port vector antenna previously reported for radio-goniometry applications using four ports is investigated here for MIMO applications. Thank to the polarization diversity capabilities inherent to vector antennas, the MIMO performances are very good for wideband frequency operation. The main metrics that are generally used for MIMO antennas are reported. These characteristics enable the 3D-half-space angular coverage.

I. Introduction

Wireless telecommunication systems cover more and more all modern human activity fields. Moreover, the congestion of the radio frequency spectrum implies to optimize the spectral efficiency of these systems. Using Multiple Input Multiple Output (MIMO) antenna systems presents a great interest to increase data rate while guarantying spectral efficiency [1]. MIMO antennas exploit polarization diversity and pattern diversity to decrease the signal correlation due to propagation channel and antennas coupling [2]. Some works have demonstrated the capability of increasing the channel capacity using polarization diversity due to six uncorrelated signals based on three electric dipoles and three magnetic dipoles. This radiating element is known as vector antenna (VA) [3], [4]. Moreover, VAs are very attractive to estimate the direction of arrival (DoA) of incident electromagnetic (EM) fields.

The intrinsic characteristics of the VA previously reported for radio-goniometry in [5] seem relevant for MIMO applications. In this paper, we show that the MIMO performances of this VA are very good for wideband frequency operation. These performances are obtained for 3D-half-space coverage.

II. Antenna presentation

The antenna reported in [5], [6] is shown in Fig. 1. It is composed of two orthogonal and colocated semi-circular arrays of Vivaldi antennas above a metallic ground plane. Each sub-array contains 4 Vivaldi antennas connected by mean of slotlines to a dual-port feeding through a splitter. One 4-Vivaldi sub-array is then connected to ports labeled 1 and 2, while the orthogonal sub-array is connected to ports labeled 3 and 4. These slotlines associated with each Vivaldi antenna are electromagnetically coupled through a microstrip-to-slot transition ended by a circular cavity of 5.5 mm radius and an 80° radial stub of 5.5 mm radius.

According to simulation results, the bandwidth at VSWR $\leqslant$ 2.6 is of 8.72:1 (1.28 GHz to 11.34 GHz). The isolation S_{ij} parameters are plotted in Fig. 2. The values are lower than -20 dB for frequencies above 1.89 GHz.

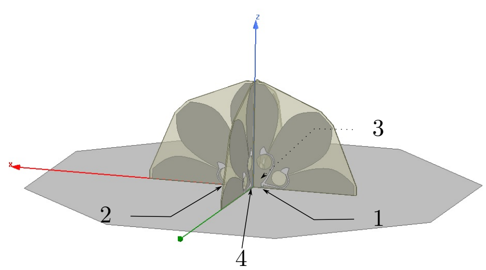

Fig. 1. Proposed MIMO antenna.

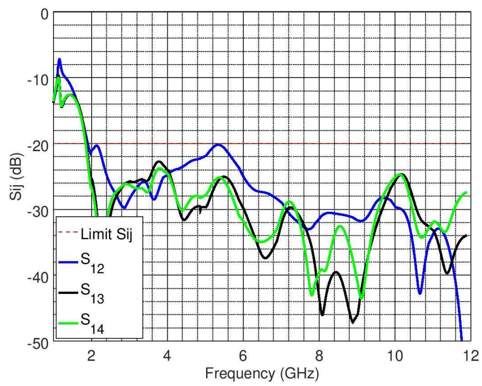

Fig. 2. Simulated isolation parameters of the 4-port MIMO antenna.

III. MIMO PERFORMANCES

The main metrics for MIMO antenna systems are reported in [7]. Here we report the antenna performances through the diversity characteristics, the total active reflection coefficient and the channel capacity losses.

A. The envelop correlation coefficient

The envelop correlation coefficient (ECC_{ij}) [7] relates the ability of the MIMO antenna to discriminate the multipaths through its diversity in terms of radiation pattern, source location and polarization. ECC_{ij} between port i and $j \neq i$ is plotted in Fig. 3 from the far field radiation pattern relation from 1.3 GHz to 9.8 GHz. This relation takes into account the radiated field coupling. Values lower than 0.06 are obtained from 1.6 GHz and up to 10 GHz (according to the 3GPP technical specification, an ECC of 0.3 is usually considered as acceptable for 4G wireless systems).

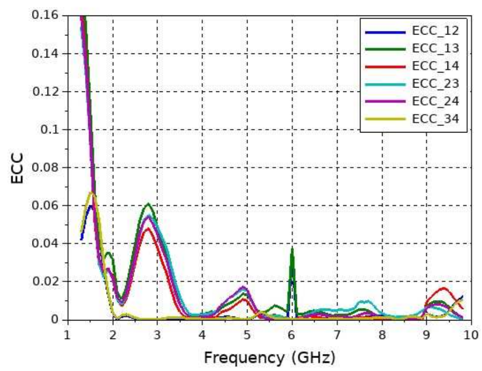

Fig. 3. Envelop correlation coefficient between port i and $j \neq i$ of the 4-port MIMO antenna vs. frequency.

B. Total active reflection coefficient

Because in MIMO systems all antennas operate simultaneously, it is important to consider the impedance matching by taking into account the EM coupling between antennas. the so-called total active reflection coefficient (TARC) is used to characterize bandwidth of the MIMO antenna by including the efficiency. The corresponding voltage standing wave ratio ($VSWR$) is calculated according to [8] from the set of 50 excitations with random phases from 0 to 2π (see Fig. 4). The total bandwidth is found to be 6.17:1 (1.85 GHz to 11.43 GHz) with a $VSWR$ which does not exceed 2.3.

C. The channel capacity losses

The channel capacity losses (CCL) is computed by taking into account the total efficiency through the TARC as follows [8]:

$$CCL = -2log_2(1 - TARC^2) - log_2(Det(\Psi^R)) \quad (1)$$

Where Ψ^R denotes the receiving antenna correlation matrix obtained from the correlation coefficients computed in section III-A and $Det(\Psi^R)$ designates the determinant of this matrix. The Fig. 5 displays the variation of CCL with frequency. It can be observed that CCL is lower than 0.4 bits/s/Hz in the entire bandwidth, i.e., from 1.85 GHz to 11.43 GHz.

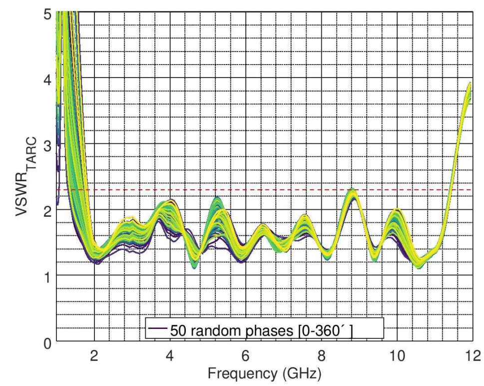

Fig. 4. $VSWR$ of the total active reflection coefficient for 50 random phase excitation states (from 0 to 2π).

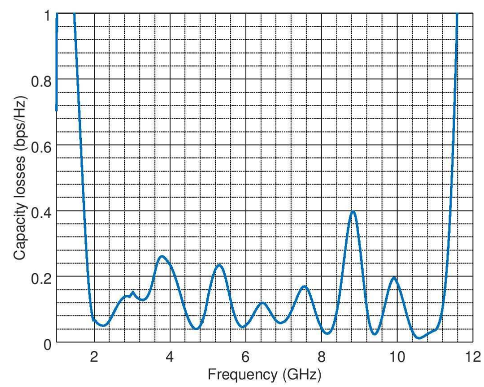

Fig. 5. Channel capacity losses in Bits /s/Hz vs. frequency.

IV. Conclusion

A Vivaldi array antenna originally designed for radio-goniometry applications has been investigated in MIMO context. The main metrics used for characterizing the MIMO antenna performances have been evaluated. The isolation between the antenna ports are lower than -20 dB, the envelop correlation coefficient is lower than 0.06, the TARC bandwidth for VSWR lower than 2.3 is of 6.17:1 (1.85 GHz to 11.43 GHz) and the channel capacity losses are lower than 0.4 bits/s/Hz. As expected, this antenna is a good candidate for wideband MIMO applications with a very good angular coverage (semi-spherical coverage).

References

[1] R. G. Vaughan and J. B. Andersen, "Antenna diversity in mobile communications," *IEEE Transactions on vehicular technology*, vol. 36, no. 4, pp. 149–172, 1987.

[2] L. Dong, H. Choo, R. W. Heath, and H. Ling, "Simulation of mimo channel capacity with antenna polarization diversity," *IEEE Transactions on wireless communications*, vol. 4, no. 4, pp. 1869–1873, 2005.

[3] J. B. Andersen and B. N. Getu, "The mimo cube-a compact mimo antenna," in *The 5th International Symposium on Wireless Personal Multimedia Communications*, vol. 1. IEEE, 2002, pp. 112–114.

[4] T. Svantesson, "On capacity and correlation of multi-antenna systems employing multiple polarizations," in *IEEE Antennas and Propagation Society International Symposium (IEEE Cat. No. 02CH37313)*, vol. 3. IEEE, 2002, p. 202.

[5] J. Duplouy, C. Morlaas, H. Aubert, P. Potier, and P. Pouliguen, "Wideband and reconfigurable vector antenna using radiation pattern diversity for 3-d direction-of-arrival estimation," *IEEE Transactions on Antennas and Propagation*, 2019.

[6] J. Duplouy, C. Morlaas, H. Aubert, P. Potier, P. Pouliguen, and C. Djoma, "Reconfigurable grounded vector antenna for 3-d electromagnetic direction-finding applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 2, pp. 197–200, 2018.

[7] M. S. Sharawi, "Printed multi-band mimo antenna systems and their performance metrics [wireless corner]," *IEEE Antennas and Propagation Magazine*, vol. 55, no. 5, pp. 218–232, 2013.

[8] D. Valderas, P. Crespo, and C. Ling, "Uwb portable printed monopole array design for mimo communications," *Microwave and Optical Technology Letters*, vol. 52, no. 4, pp. 889–895, 2010.