Full Simulative Approach to Orbital Angular Momentum (OAM) Transmissions Between Antenna Arrays

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Abstract

In the recent years, electromagnetic waves carrying Orbital Angular Momentum (OAM) have attracted a widespread interest in the scientific community, with several applications ranging from information transfer to astronomical measures [1-3]. OAM beams are characterized by an on-axis intensity null and twisted wave fronts, whose azimuthal phase structure depends on the mode index ℓ related to the orbital angular momentum content [4]. In particular, the intrinsic orthogonality of such waves has suggested the implementation of an OAM-based multiplexing technique in the context of telecommunications [5, 6]. At the radio frequencies, OAM beams can be generated via array synthesis, usually involving properly phased Uniform Circular Arrays (UCAs). Within this framework, the software COMSOL Multiphysics® allowed us to model an OAM communication link and proved to be an essential tool for the experimental implementation of a multimode transmission scheme between UCAs.

We simulated the transmission and reception of OAM waves by means of two facing UCAs of four Yagi-Uda antennas, each composed by five parallel thin metal strips and fed with a lumped port on the driven element (Figure 1). All the numerical analyses were carried out via the RF Module, with resort to the Optimization Module for the antenna geometry design. Two different techniques were realized: first, the simulation of a whole 40 m-length transmission volume wrapped in a cylindrical PML was considered, then a more efficient strategy with separation of the transmitting and receiving parts allowed for the meshing of significantly smaller volumes (Figure 2). Parametric sweeps in both the receiving array rotation angle and the link distance were implemented, enabling a complete estimation of the link budget from the computed model port voltages.

As a first step of the experiment, two UCAs of Yagi-Uda antennas and the relative beamforming electronics were placed at a line-of-sight (LOS) link distance of 40 m in a real-world scenario. Then, in order to test the robustness of the communication link, we determined the link budgets corresponding to the transmission and the proper re-phased reception of OAM modes with indices $\ell = 1$ and $\ell = 0$ (untwisted case), in correspondence of an optimal antenna pointing. As shown in Figure 3, the COMSOL® model predictions fit very well the experimental results, with a percentage error lower than 0.7 % for the $\ell = 1$ transmission. Moreover, the angular sweep performed with COMSOL provides the polar plot of the link budget for the $\ell = 1$ mode as a function of the RX array rotation angle

(Figure 4), showing the expected on-axis power maximum when the proper mode-matching between the facing UCAs is considered [7].

Thanks to its versatility, COMSOL Multiphysics® provided a means for analyzing the whole RF link, paving the way to the realization of a multiple DVB-T signals transmission.

Reference

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Figures used in the abstract

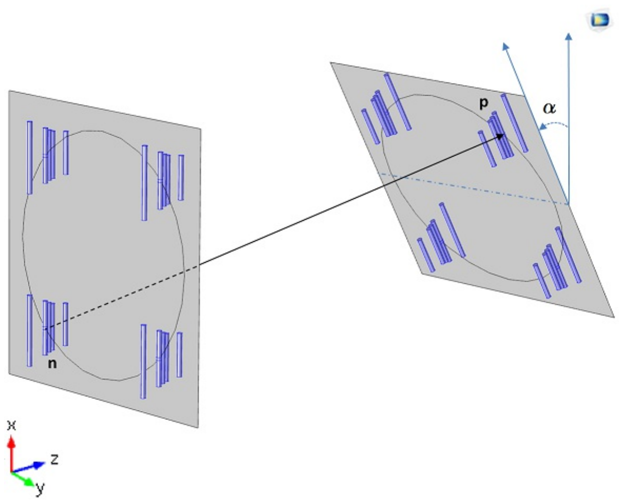

Figure 1: COMSOL model of the communication link.

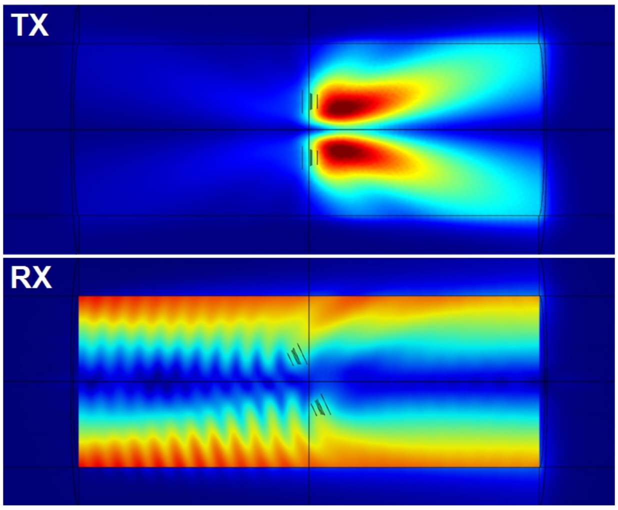

Figure 2: Electric field norm in the two separate models.

Link budget (dB)	$\ell = 0$	$\ell = 1$
Friis equation	-24.40	-
COMSOL simulation	-24.69	-42.96
Experiment	-25.50	-42.99

Figure 3: Link budget comparison in correspondence of an optimal antenna pointing.

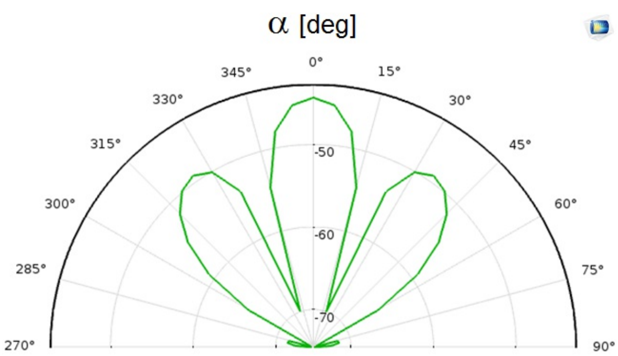

Figure 4: Link budget for the $\ell = 1$ mode as a function of the RX array rotation angle α.