Modeling OAM Transmission in Waveguides with COMSOL Multiphysics

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OAM propagation in waveguides:

modes carrying both Orbital Angular Momentum (OAM) and Spin can be obtained by superimposing, pairwise, the waveguide TE (or TM) eigenmodes[1]:

$$\mathrm{TE}_{nj} \pm i\mathrm{TE}_{nj} \quad (\text{or } \mathrm{TM}_{nj} \pm i\mathrm{TM}_{nj})$$

where the index *n* is related to the total angular momentum carried on average by each photon.

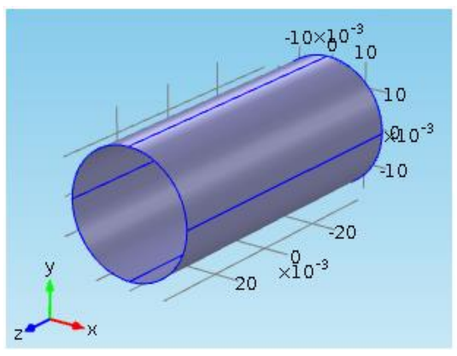

Fig. 1 Circular waveguide

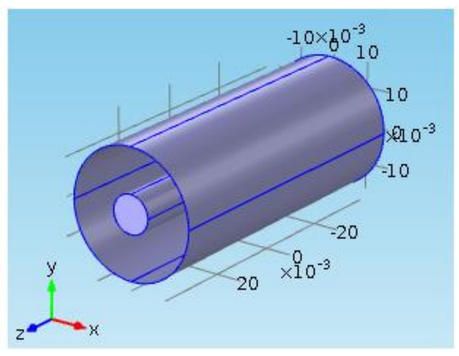

Fig. 2 Coaxial cable

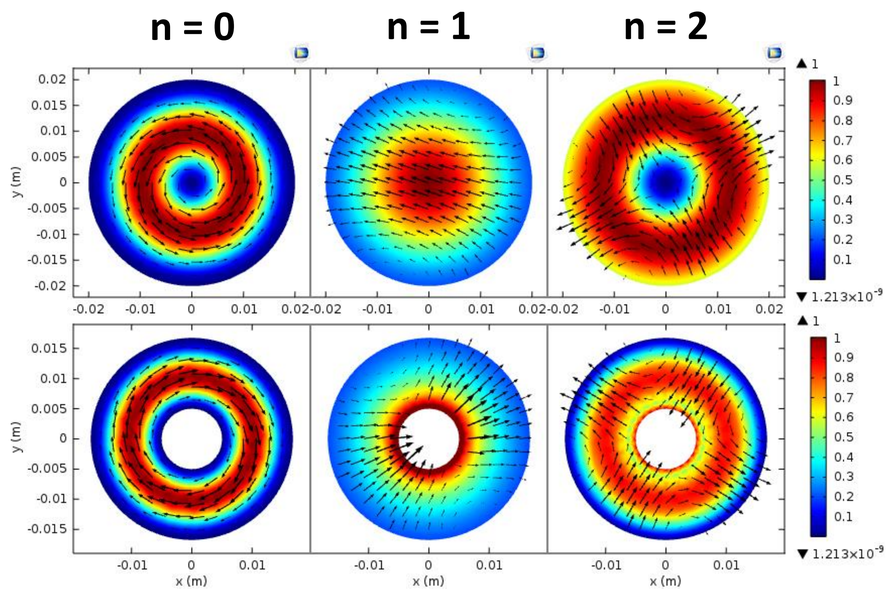

Fig. 3 COMSOL transverse profiles

COMSOL model:

the OAM modes have been implemented by directly inserting the analytic expressions of the electric field in the model ports, placed at the opposite ends of the guiding structures. Then, by means of a parametric sweep in the guide length *z*, we have studied the power attenuation of different OAM modes in a circular waveguide with copper walls.

Fig. 4 S_{21} as a function of the guide length

Results:

The parametric sweep enabled the estimation of the power attenuation law:

$$S_{21} = e^{-2\beta_{nj} z}$$

Table 1. Power attenuation coefficient

β_{n1} (dB/m)	$n=0$	$n=1$	$n=2$
Th. formula (TE)[2]*	0.0313	0.0103	0.0284
COMSOL (TE)	0.0305	0.0101	0.0277
COMSOL (OAM)	0.0305	0.0101	0.0277

$$^{*}\beta_{nj}^{\mathrm{TE}} = \frac{\sqrt{\frac{\omega\mu}{2\sigma}}}{a\eta\sqrt{1-\left(\frac{f_c}{f}\right)^2}}\left[\left(\frac{f_c}{f}\right)^2 + \frac{n^2}{\chi_{nj}^2 - n^2}\right]$$

- ω, f, f_c : operating frequencies and cutoff frequency
- χ_{nj} : waveguide TE mode eigenvalue
- μ : permeability of the interior medium (*air*)
- η : interior medium impedance ($\eta_{air} \approx 377\,\Omega$)
- a : radius of the circular waveguide
- σ : conductivity of the metallic walls (*copper*)

Applications:

The OAM propagation on a Goubau line with coaxial horn launcher/receiver has been verified for the *n* = 1 OAM superposition.

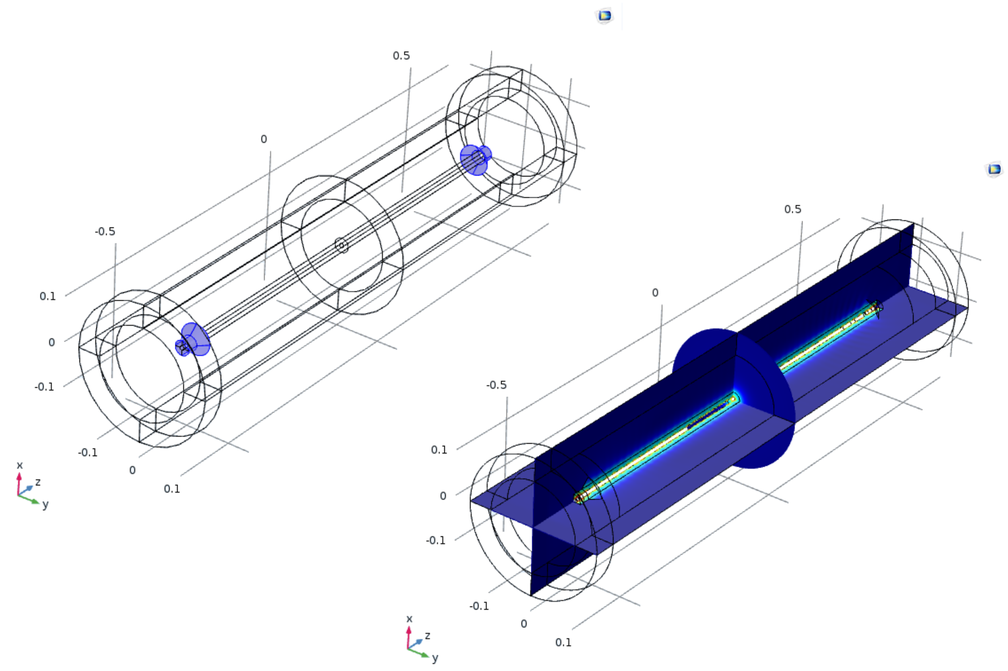

Fig. 5 Goubau line with coaxial horns

References:

1. E. Berglind & G. Björk, "Humblet's Decomposition of the Electromagnetic Angular Moment in Metallic Waveguides", *IEEE Trans. Microw. Theory Tech.* **62**, 779-788 (2014).
2. C. A. Balanis, *Advanced Engineering Electromagnetics*, Wiley, New York (1989)