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Helicoidal Plane-Wave Modes in a Rectangular Coaxial Cable Containing DNG Deflectors

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The propagation inside coaxial waveguides of rectangular cross-section has been the subject of extensive studies (see, e.g., [1] and references therein). Some field components present singularities at the edges of the inner conductor, which may lead to dielectric breakdown. In this work, this complication is avoided by the insertion of anti-isorefractive DNG metamaterial prisms at the sharp corners of the inner conductor. The analysis is performed in the phasor domain, with a time-dependence factor exp (+jωt) omitted throughout.

Using Cartesian coordinates (x,y,z), the cross-section of the coaxial waveguide in the (x,y) plane consists of an inner rectangular conductor of dimensions 2a in the x-direction and 2b in the y-direction, and of an outer rectangular conductor of inner dimensions 2(a+d) in the x-direction and 2(b+d) in the y-direction. The two conductors are separated by a lossless dielectric of wavenumber k, intrinsic impedance Z and uniform thickness d. Four lossless anti-isorefractive DNG prisms of wavenumber – k and intrinsic impedance Z are located at the four corners of the cross-sectional area. The cross-section of each prism is a right-angle triangle with equal catets and the hypotenuse in the plane containing a sharp corner of the inner conductor and a concave corner of the outer conductor. Any plane TEM wave propagating inside the dielectric in a direction forming an angle ϑ with respect to the z-axis is deflected by 90^{o} into the next dielectric layer without diffraction at the sharp corner and without change in the angle ϑ.

It is shown that this structure allows for the propagation of plane TEM waves that wrap themselves in a helicoidal fashion around the inner conductor. The number of such waves and the angle ϑ that the direction of propagation of each wave forms with the z-axis depend on the ratio between the perimeter 4(a+b) of the cross-section of the inner conductor and the wavelength, and it is independent of the thickness d of the dielectric.

Reference

[1] H.E. Green, “The characteristic impedance of square coaxial line”, *IEEE Trans. Microwave Theory Tech.*, vol. 11, pp. 554-555, Nov. 1963.