Radiating and Nonradiating toroidal sources

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Non-radiating sources are promising in the inverse scattering problems, as elements for open resonators based on anapole nanophotonics and cloaking [1,2]. The concept of anapole is determined by the destructive interference between the electric and toroidal dipole moments, which have identical radiation patterns. In this paper, we discuss the electrodynamics of toroidal sources and their radiating and non-nonradiating regimes. Let us consider an advanced toroidal configuration with wounds in the form of asymmetrical ellipses. Geometry of toroidal coil assumed infinitely thin PEC wire and can be described by following formulas:

$$\begin{aligned} x &= (d - a * \cos(N\theta)\cos(\alpha) + b * \sin(N\theta)\sin(\alpha))\cos(\theta) \\ y &= (d - a * \cos(N\theta)\cos(\alpha) + b * \sin(N\theta)\sin(\alpha))\sin(\theta) \\ z &= a * \cos(N\theta)\sin(\alpha) + b * \sin(N\theta)\cos(\alpha) \end{aligned} \quad (1),$$

where d- distance from the center of toroid to the center of ellipse, a and b focuses of ellipse and α is tilt angle. In general case far-fields of toroidal source are defined of toroidal multipoles, while intensity of electric dipole is zero [2]. The radiation patterns of toroidal source and electric dipole are identical, Figure 1a. This statement is applicable only for the case of ideal toroid characterized by T_z and a=b. However in our case of elliptical based toroid, the radiation is formed by T_x and T_y components, as well. Thus, we demonstrate in this paper, that simulated radiation pattern of such toroidal source can be different from electric radiation, as depicted in Figure 1b. Moreover, we show nonradiating anapole configurations due to insertion of electric dipole to the center of the system for compensation of toroidal radiation. We also discuss different applications of our structures in photonics.

(a) (b)

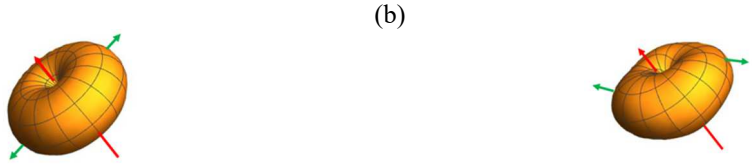

Figure 1. (a)- radiation pattern for a=b, (c)- radiation pattern for a>b.

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References

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