Electrically Small Antenna Based on Low Order Mie-Resonances

Ahmed Abdelraheem[(1)], Karim Seddik[(1)], Dimitrios Peroulis [(2)]

(1) Electronics and Communications Engineering Department, American University in Cairo, Cairo 11835, Egypt

(2) Elmore Family School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907, USA

Exciting magnetic/electric multipoles in dielectric radiators remains an insufficiently explored area in the context of super-directive electrically small antennas (ESAs) design. This is a design problem of devising a single-port ESA with one or more dielectric NFRPs to host a mixture of magnetic/electric multipoles. Here, we employ the Mie resonances to engineer a simple Huygen's source in an all-dielectric near-field resonant parasitic (NFRP).

First, we simulate the scattering problem of a dielectric sphere illuminated by a planewave. The radius is comparable to the wavelength $\lambda_0/\sqrt{\epsilon_r}$, where λ_0 is the free-space wavelength and ϵ_r is the relative permittivity (inset of Fig. 1a). The total normalized power scattered off the sphere and its decomposition into the constituting multipolar contents (Fig. 1a) show that the first Mie-resonance is a magnetic dipole (MD) at 30.6 GHz and the second is an electric dipole (ED) at 39.2 GHz. The sphere scatters a train of multipoles of interchanging characters (magnetic and electric). The vectorial characters of the MD and the ED (Fig. 1b) show that the electric and magnetic fields vectorial characters interchange between ED and MD. At 33.2 GHz, contributions from ED and MD are equal leading to Huygen's source. This simple formation of a Huygen's source without the complexity following from the independent excitations of the required ED and MD, is the basic design idea. The directivity of the formed Huygen's source is the typical 4.77 dB (Fig. 1c). The proposed ESA design is shown in Fig. 1d with $ka \approx 0.9$. It features a high-k disk of $KTaO_3$ ($\epsilon_r = 241$) illuminated by the near field of an infinitesimal dipole. The multipolar decomposition of the radiated power (Fig. 1f) exhibits a simple Huygen's source at 30.6 GHz with directivity of 5 dB, see Fig. 1e. The pattern in Fig. 1e shows unidirectional performance. The ESA is matched by stubs as shown in Fig. 1d and verified by S_{11} in Fig. 1g.

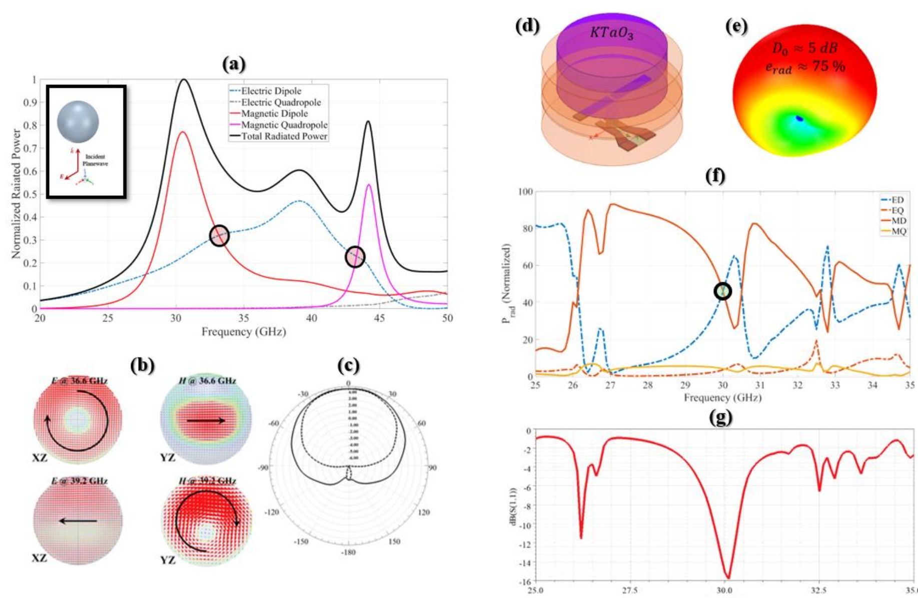

Figure 1: (a) Typical scattering of a dielectric sphere illuminated by an x-polarized plane-wave. (b) The vectorial characters of the first Mie-resonances (ED and MD). (c) The radiation pattern at the formed Huygen's source. (d) the structure of the proposed ESA. (e) The radiation pattern at the formed Huygen's source. (f) The multipolar decomposition of the radiated power from the ESA. (g) The reflection loss of the proposed ESA.