EVOLUTION OF 3D RADIATION PATTERNS FOR A MULTIMODE DRA

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Introduction

The multimode dielectric resonator antenna with variable permittivity/ permeability, first introduced in [1], presents a unique opportunity to control the radiation pattern by means of variation of its electric dimensions. In comparison with phased arrays this technique of pattern control has some inherent merits of smaller size of antenna, less complicated beamforming network, and no package problem. This suggests that the multi-mode DRA is useful to realize pattern synthesis, beamforming, etc., which can be applied to, for example, the space division multiple access system in mobile and personal communication systems. The results of preliminary analysis of the hemispherical multimode DRA radiation pattern depending on its parameters were presented in [1]. However, in that analysis the antenna feed system was not discussed and only 2D cross-sections of the radiation pattern were presented.

It should be pointed that depending of the feed system the radiation pattern of the multimode hemispherical DRA can have no axial symmetry and forms essentially 3D shape. In the case the only adequate form of the radiation pattern presentation is a 3D surface plot. In the present paper 3D radiation pattern of the multimode DRA is analyzed depending on its parameters and type of the feeding system (magnetic/electric equivalent currents). The results are formatted as video clips to show the evolution of the 3D-radiation pattern with the electrical dimensions of the antenna. This form of presentation gives an opportunity for visual estimation of the antenna efficiency, the resonances experienced by the antenna, bandwidth of a specific mode of operation, and the shape of the radiation pattern.

II. Theory

Method of Dyadic Green function [2] is used in the paper in analysis of the multimode hemispherical DRA placed on the infinite conducting screen (Fig1). Dyadic Green function allows calculating the intensity and polarization properties of the fields radiated by a system of arbitrary oriented magnetic/electric currents. Due to a simple geometry of the hemispherical dielectric resonator antenna its Dyadic Green function can be found in a closed form. The rigorous expressions of magnetic and electric type of the Dyadic Green functions are given in [2] for a spherical dielectric resonator. Using a straightforward technique of the image method [3] the rigorous solution can be obtained for the hemispherical geometry. For the sake of simplicity we will omit here the details of these calculation. The corresponding formulas for the magnetic type of the Green tensor in the region outside the dielectric resonator can be represented as

$$\underline{\Gamma}_{out}(\vec{R},\vec{R}_o)=\frac{i}{4\cdot p\cdot k_2}\cdot\sum_{n=1}^{\infty}\frac{2\cdot n+1}{n\cdot(n+1)}\cdot\left(a_n\cdot\underline{N}(\vec{R},\vec{R}_o)+k_2^2\cdot b_n\cdot\underline{L}(\vec{R},\vec{R}_o)\right), \qquad (1)$$

where

$$\underline{N}(\vec{R},\vec{R}_o) = \left(k_2^2 \cdot \vec{I}_1 + grad_o \frac{\partial}{\partial R_o} \right)\left(k_1^2 \cdot \vec{I}_1 + grad \frac{\partial}{\partial R} \right) \cdot R_o \cdot R \cdot j_n(k_2 \cdot R_o) \cdot h_n(k_1 \cdot R) \cdot P_n(x)$$

$$\underline{L}(\vec{R},\vec{R}_o) = \left(\vec{R}_o \times grad_o\right)\left(\vec{R} \times grad\right) \cdot j_n(k_2 \cdot R_o) \cdot h_n(k_1 \cdot R) \cdot P_n(x) \tag{2}$$

$$x = \sin q \cdot \sin q_o \cdot \cos(f - f_o) + \cos q \cdot \cos q_o \tag{3}$$

$$a_n = \frac{i}{ak_2 \left(j_n(ak_2) h_n^{(2)}(ak_1) \left(\frac{k_1^2}{k_2^2} - \frac{e_1}{e_2} \right) + a \frac{k_1^2}{k_2^2} h_n^{(2)}(ak_1) \frac{\partial}{\partial a} j_n(ak_2) - a \frac{e_1}{e_2} j_n(ak_2) \frac{\partial}{\partial a} h_n^{(2)}(ak_1) \right)} \tag{4}$$

$$b_n = \frac{i}{ak_2 \left(j_n(ak_2) h_n^{(2)}(ak_1) \left(\frac{e_1}{e_2} - 1 \right) + a \frac{e_1}{e_2} h_n^{(2)}(ak_1) \frac{\partial}{\partial a} j_n(ak_2) - a j_n(ak_2) \frac{\partial}{\partial a} h_n^{(2)}(ak_1) \right)}$$

$j_n(x), h_n^{(2)}(x)$ are spherical Bessel functions, $P_n(x)$ is a Legendre polynomial, *a*- radius of the hemisphere, e_1, e_2 - dielectric permittivity outside and inside the resonator; k_1, k_2 – wave numbers outside and inside the resonator.

The excitation magnetic currents here are placed entirely inside the DRA. Due to a resonance nature of the terms (2) only a few of them should be taken in account. Numerical analysis shows that within a reasonable range of the antenna parameters ten terms of the series (1) provide the accuracy of calculations better than 5%. The efficiency of the expansion (1) gives an opportunity for detailed analysis of the 3D-radiation pattern of the multimode DRA and its evolution with the electrical dimension of the DRA and the parameters of the excitation currents.

III. Results

In Fig. 2-5 are presented typical 3D radiation patterns of the multimode DRA. The excitation magnetic currents are oriented transverse to the radius of the hemisphere and are placed in the plane of the screen. This type of a source can be modeled with a slot cut on the ground plane [4]. The appropriate excitation of the slot can be done with known methods, for example [4-5]. The actual video clips with the evolution of the DRA radiation patterns will be presented and discussed during the presentation.

Conclusion

Full wave analysis of the hemispherical DRA radiation pattern depending on radius of the hemisphere, its dielectric constant, position and orientation of the excitation current was presented. The radiation efficiency and the radiation pattern bandwidth are discussed. The results show the possibility of controlling 3D-radiation pattern by means of variation in parameters of the dielectric integrated into a DRA and can be used for design of a DRA with tunable radiation patterns.

References.

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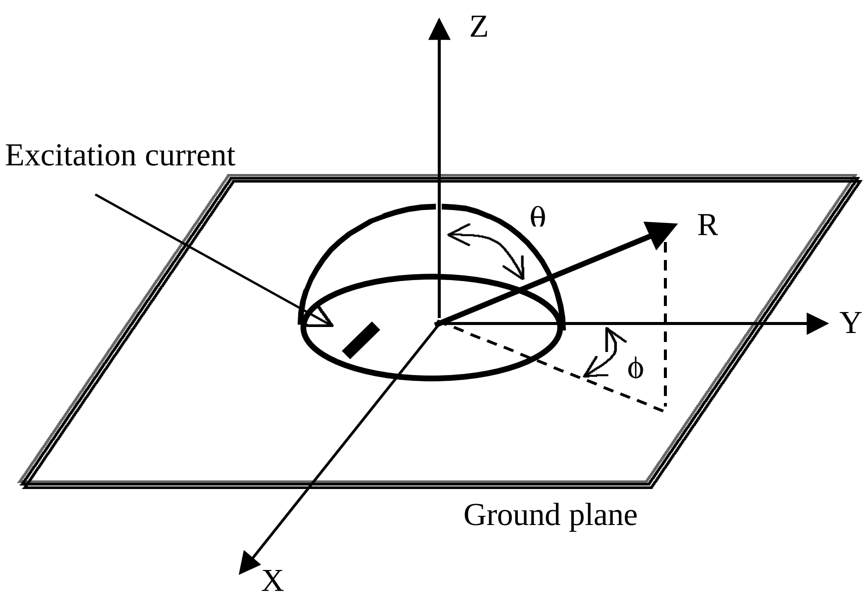

Fig.1 Hemispherical Dielectric Resonator Antenna

3D Plot of the hemispherical DRA radiation pattern

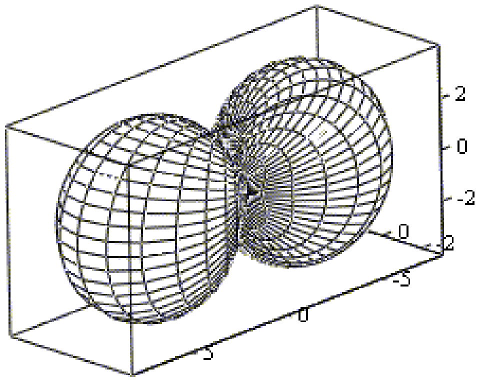

Fig.2 Radius of the hemisphere a=.15λ, relative permeability μ_2=1 dielectric constant ε_2=10, excitation current - transverse magnetic, excitation point R_o=.2a

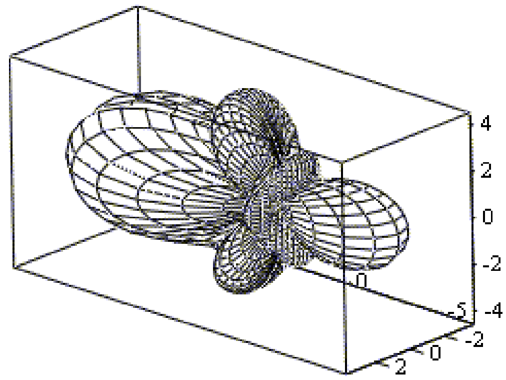

Fig.3 Radius of the hemisphere a=.5λ, relative permeability μ_2=1 dielectric constant ε_2=10, excitation current - transverse magnetic, excitation point R_o=.42a

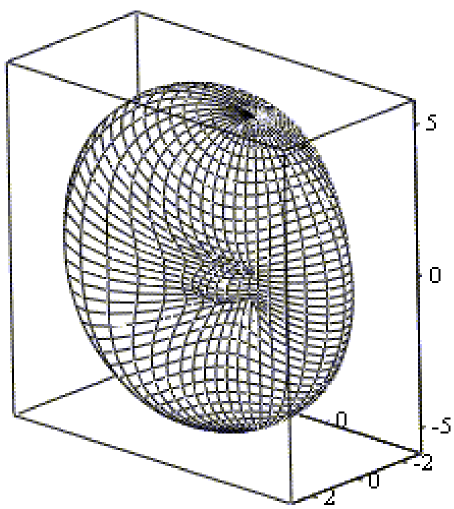

Fig. 4 Radius of the hemisphere a=.22λ, relative permeability μ_2=1 dielectric constant ε_2=10, excitation current - transverse magnetic, excitation point R_o=.2a

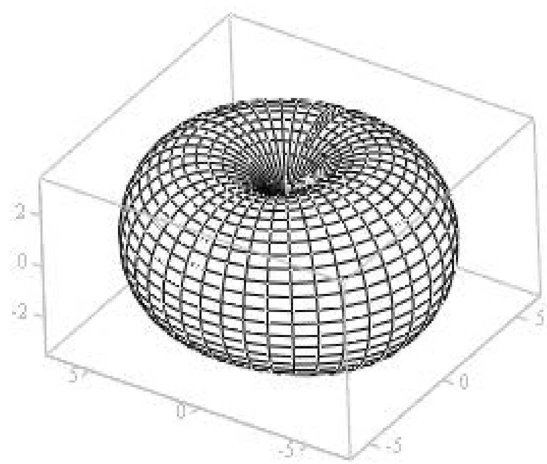

Fig.5 Radius of the hemisphere a=.15λ, relative permeability μ_2=43 dielectric constant ε_2=1, excitation current - transverse magnetic excitation point R_o=.2a