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A COMBINATION OF SYNTHESIS AND ANALYSIS APPROACHES TO THE SPHERICAL ANTENNA WITH ANISOTROPIC SURFACES

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The investigations concerning spherical antennas have almost restricted to the analysis problem. Among them, most were dealing with the antenna of an isotropic conducting sphere[1,2,3]. And only few have paid attention to the antenna of an anisotropic surface[4,5]. In 1964, Mei and Meyer have laid a theoretical foundation for analyzing the spherical spiral antennas[5]. However, there were still many problems unsolved at that time. Some representatives were: (1) the undetermined of the leading coefficients for the asymmetrically excited antenna, (2) the proper formulation for the input admittance of the antenna under asymmetrical excitation, (3) the effect of varying spiral slope and frequency upon the polarization, admittance, and radiation efficiency etc. In this paper, the spherical antenna which consists of a conducting sphere of radius a and a concentric spherical anisotropic surface of radius b ($> a$) is investigated both from the viewpoints of synthesis and analysis. The purposes of this study are three-fold: First, the synthesis work supplies informations concerning polarization and pattern syntheses. It also gives many pictures to the role of the individual modes upon the superposed wave. Second, the proof of the equivalence between the radiation and input admittances suggests a proper definition for the input admittance of the spherical spiral antennas, especially under the asymmetrical excitation exp(jmϕ), $m \neq 0$. Third, the analysis of the symmetrically excited, constant slope, spherical spiral antenna has provided informations regarding the effect of varying spiral slope and frequency upon the antenna radiation characteristics.

In this paper, the principle in handling the polarization for electric fields is applied to the currents and is used as a basis for synthesis of the antenna. The study begins with the process of seeking a linearly polarized current on the outer spherical surface to excite a given field distribution. Then the direction and amplitude distributions of the current will be investigated in detail, with the end of suggesting a possible mechanism for excitation, practical or theoretical. By this study, it is found that the excitation of the individual mode with azimuthal variation of $\{\exp(jm\phi), \sin m\phi, \cos m\phi, m \neq 0\}$ by a current sheet is only possible in theory and not possible in practice. In spite of this, the results for direction distribution are useful in polarization synthesis, since the polarization of the individual mode is determined by the direction of the current. Besides, the amplitude distributions of the symmetrically distributed current flowing along the ϕ-direction can at least be used as a basis in the pattern synthesis.

In analysis work, the antenna having a constant slope type of spiral (the spiral is characterized by the tangent vector of $\vec{T} = \hat{\theta} + u\,\hat{\phi}$) closely wound on the outer spherical surface is investigated. In particular, emphasis is placed on the antenna symmetrically excited across a gap either at the outer spiral (the outer-excited antenna) or at the inner sphere (the inner-excited antenna). Then, the effect of varying the spiral slope u and frequency upon the polarization, input (or radiation) admittance, and conduction losses are studied. As an estimation, the loss-free fields are used in calculating the loss in conductors. For the outer-excited antenna the polarization is mainly determined by the current on the spiral as suggested by the synthesis work, while for the inner-excited antenna the polarization is governed by the aperture or leaky electric field over the spiral surface. A possibility of resonance is also observed to associate with the spiral antennas. Without resonance and for small values of spiral slope u, the radiation from the outer-excited antenna is comparable to that from the conducting sphere of radius b. For large values of u, the radiation from the nonresonant outer-excited antenna is less than that from the conducting sphere, hence, it is not useful for those values of u. The nonresonant inner-excited antenna nearly radiates the same power as the conducting sphere of radius a does for large values of u, hence, it is not efficient. The nonresonant inner-excited antenna is also not effective for small values of u, due to poor radiation. At resonance, the spiral antennas (both the outer- and inner-excited antennas) are characterized by large radiation and losses, and for changing in frequency and spiral slope , they respond sensitively, thus, they must necessarily be a narrow band device. The resonant antenna possesses a property much like that of the conventional L-C resonant circuit, therefore, one may find special applications as the latter does.

References:

1. J. A. Stratton and L. J. Chu, Steady-state solutions of electromagnetic field problems, J. Appl. Phys. Vol. 12, pp. 236-240; March, 1941.
2. L. L. Bailin, and S. Silver, Exterior electromagnetic boundary value problems for spheres and cones, IRE Trans. on Antennas and Propagation, Vol. AP-4, p. 5-16; January, 1956.
3. Y. Mushiake and R. E. Webster, Radiation characteristics with power gain for slots on a sphere, IRE Trans. on Antennas and Propagation, Vol. AP-5, pp. 47-55; January, 1957.
4. H. B. Riblet, A broad-band spherical satellite antenna, Proc. IRE, Vol. 48, pp. 631-635; April, 1960.
5. K. K. Mei and M. Meyer, Solution to spherical anisotropic antennas, IEEE Trans. on Antennas and Propagation, Vol. AP-12, pp. 459-463; July, 1964.