Dielectric Resonator Antennas, Theory and Design

EuCAP, November 8, 2006

Ahmed A. Kishk

Abstract: Recently, interest in dielectric resonator antennas has increased because of their attractive features such as small size, high radiation efficiency (98%), wide bandwidth, and high power capability for radar applications and base stations. The dielectric resonator antenna is made from high dielectric constant materials and mounted on a ground plane or on a grounded dielectric substrate of lower permittivity. The short course will start by an overview for the development of the dielectric resonator antennas. The theory of operation will be discussed step by step to provide basic understanding. The discussion is provided in simple forms to satisfy audience of different background levels. Design curves will be provided for the circular disc and hemisphere dielectric resonators. Use of these models with other geometries is discussed.

Different excitation mechanisms are demonstrates such as the probe, slot, image line and waveguides. Applications in dielectric resonator arrays are provided with discussion on the mutual coupling level and the wide scanning capabilities of the dielectric resonator array. The array bandwidth limit is discussed based on the element size and the spacing between the array elements.

The problems related to the practical implementations are considered. Results of a numerical study pertaining to the effect of an air gap, between the dielectric disc and the ground plane or an air gap surrounding the feed probe, on the input impedance and resonant frequency of a cylindrical DRA operating in the $TM_{01ä}$ mode or $HEM_{11ä}$ mode as a function of dielectric constant will be presented. Some of the numerical results are validated experimentally.

Formulation of the surface integral equations, derived from the equivalence principle, and the method of moments (MoM), are presented. Use of the MoM to compute the natural complex resonant frequency for a specified mode from which the radiation Q factor of the antenna and the (actual) real resonant frequency are obtained. Analytic expressions are obtained for the resonant frequency and the Q-factor for a circular disk resonating at different modes. Then the field distribution inside the dielectric disk is computed and plotted at the resonant frequency in order to determine the proper excitation mechanism that excites such a mode.

A formulation based upon MoM will be presented for the computation of input impedance of the DRA. The class of antennas modeled by this method consists of axially symmetric dielectric resonators fed by thin wire or a narrow slot in the ground plane of a microstrip line. The formulation is general in that the feed structure may be interior or exterior to the dielectric resonator. To demonstrate the utility of this technique, parametric studies are performed on a cylindrical DRA operating at frequencies, which excite the important $HEM_{11ä}$ resonator antenna mode. The integrity of this technique is established both experimentally and numerically.

Finally, suggestions for size reduction of the DRA will be presented to demonstrate the flexibility of the DRA to satisfy the required small size for some applications.