STUDIES OF AN INCLINED-SLOT-COUPLED HEMISPHERICAL DIELECTRIC RESONATOR ANTENNA

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1. Introduction

Dielectric resonator (DR) antennas have recently received much attention as they can offer some advantages of wider bandwidth and higher radiation efficiency over the microstrip patch antennas. With the feeding mechanism of coupling through a slot in the ground plane of a microstrip feed line, the DR antenn can be suitable in MMIC and active DR antenna designs [1]. For this reason the slot-coupled DR antennas have been the interest of many investigations. However, the coupling slot studied is mainly perpendicular to the microstrip line, and there has not yet been any research into the DR antenna with an coupling slot of arbitrary inclination. In this article the problem of a hemispherical DR antenna [2], [3] with an arbitrarily inclined coupling slot (see Figure 1) is studied both theoretically and experimentally. Effects of the inclination of the coupling slot on the antenna's input impedance are analyzed.

2. Theoretical Formulation

As shown in Figure 1, the coupling slot is assumed to be narrow and is inclined with respect to the feeding microstrip line with an angle of $90^\circ - \theta_s$. When $\theta_s = 0^\circ$, the coupling slot is perpendicular to the feed line. In this case the coupling slot with the DR loading can be considered as a series load as seen by the microstrip line [2]-[4]. For an inclined printed slot ($\theta_s \neq 0^\circ$), although some higher-order modes may exist in the microstrip line due to the inclined-slot discontinuity, it can still be treated as a series load with small errors [5]. By adopting this approximation and following the reciprocity analysis and the Green's-function formulation [3], the input impedance of the DR antenna excited in the TE_{111} mode can be derived as, referenced at the slot position,

$$Z_{in} = Z_c \frac{2R}{1-R} - jZ_c \cos\beta L_s, \tag{1}$$

with

$$R = \frac{1}{2}[\Delta v]^t [V] \cos\theta_s, \tag{2}$$

$$[V]=\left\{[Y^f]+[Y^a]+\frac{1}{2}[\Delta v][\Delta v]'\cos^2\theta_s\right\}^{-1}[\Delta v]\cos\theta_s, \tag{3}$$

where Z_c is the characteristic impedance of the microstrip line, β is the propagation constant on the microstrip line, L_s is the length of the open-circuited tuning stub, and R is the reflection coefficient; the elements in $[Y^f]$ and $[Y^a]$ are the admittances at the slot discontinuity due to the contribution of the microstrip line and the DR antenna, respectively; $[V]$ is the unknown expansion coefficient matrix for the slot electric field; the elements in $[\Delta v]$ are derived as

$$\Delta v_n=\frac{1}{2\pi\sqrt{Z_c}}\int_{-\infty}^{\infty}[\tilde{G}_{yx}^{HJ}(-\beta,k_y)F_{ws}(\beta\cos\theta_s+k_y\sin\theta_s)F_{wf}(k_y)$$
$$\times F_b(\beta\sin\theta_s-k_y\cos\theta_s)e^{j(-\beta_f\sin\theta_s+k_y\cos\theta_s)y_n'}]dk_y, \tag{4}$$

where $\tilde{G}_{yx}^{HJ}$ is the spectral-domain Green's function denoting the $\hat{y}$-directed magnetic field at (x, y, 0) due to a unit $\hat{x}$-directed electric field at $(x_0, y_0, -d)$ [6]; F_{ws} [= sinc($Wk_x/2$)] and F_{wf} [= sinc($W_f k_y/2$)] are Fourier transforms of the pulse basis functions [4] used for modeling the x' component of the equivalent magnetic current in the slot and the y component of the electric field on the microstrip line, respectively; F_b is the piecewise sinusoidal (PWS) basis function [6] used for the expansion of the y' component of the equivalent magnetic current in the slot.

It is also noted that there is no difference in orientation for any inclined coupling slot with respect to the hemispherical DR antenna. The expression of the elements Y_{mn}^a in $[Y^a]$ can thus be found in [3]. And the expression of the elements Y_{mn}^f in $[Y^f]$ is written as

$$Y_{mn}^f=\frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}F_{ws}^{\,2}(k_x)\tilde{G}_{y'y'}^{HM(f)}(k_x,k_y)F_b^2(k_y)\cos k_y(y_m'-y_n')dk_xdk_y, \tag{5}$$

where the spectral-domain Green's function $\tilde{G}_{y'y'}^{HM(f)}$ denotes the $\hat{y}'$-directed magnetic field in the slot on the feed side due to a unit $\hat{y}'$-directed equivalent magnetic current in the slot [3].

3. Results and Conclusions

Numerical convergence of the moment-method computation for the unknown equivalent magnetic current in the slot is first tested, and it is found that using four PWS basis functions is enough for obtaining good convergent solutions. Several DR antennas with different inclined coupling slots were also constructed and measured. Typical theoretical and measured results of the input impedance versus frequency are presented in Figure 2. Reasonable agreement between theory and experiment is observed. The calculated input impedance versus frequency for different values of θ_s is shown in Figure 3(a), and Figure 3(b) presents the resonant input resistance as a function of θ_s. It is seen that the resonant input resistance decreases with increasing

θ_s, and the variation in the resonant frequency is slight. This behavior can be useful in achieving impedance matching. More details of the results will be discussed in the presentation.

References

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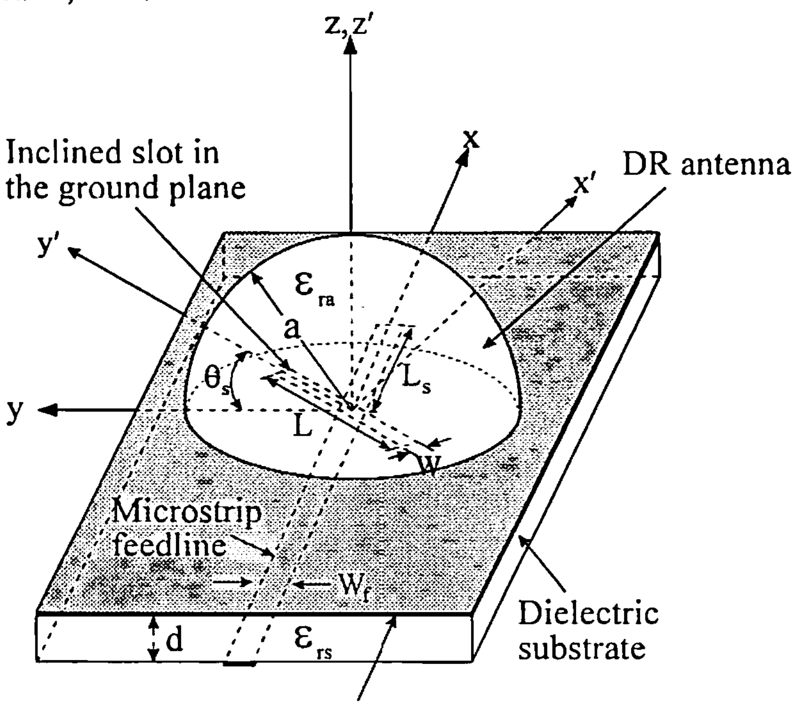

Fig. 1 The geometry of an inclined-slot-coupled dielectric resonator antenna.

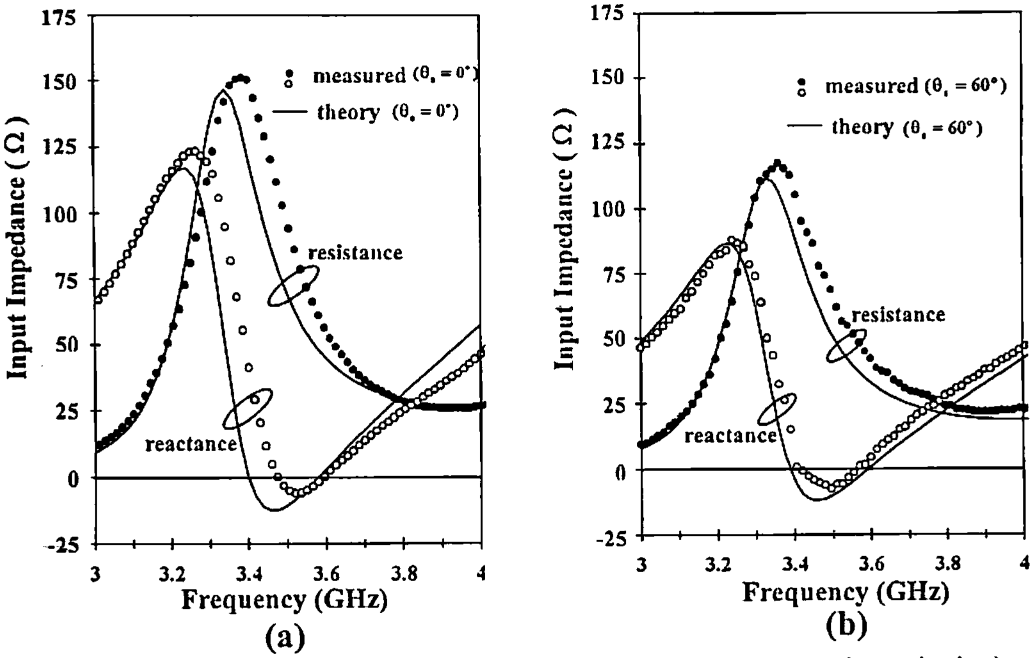

Fig. 2 Input impedance of the hemispherical DR antenna (TE_{111} mode excitation); $\varepsilon_{ra} = 9.5$, $a = 12.5$ mm, $\varepsilon_{rs} = 2.96$, $d = 0.635$ mm. (a) $L = 13.5$ mm, $W = 0.87$ mm, $W_f = 1.45$ mm, $L_s = 13.6$ mm. (b) $L = 13.1$ mm, $W = 1.3$ mm, $W_f = 1.6$ mm, $L_s = 13.6$ mm.

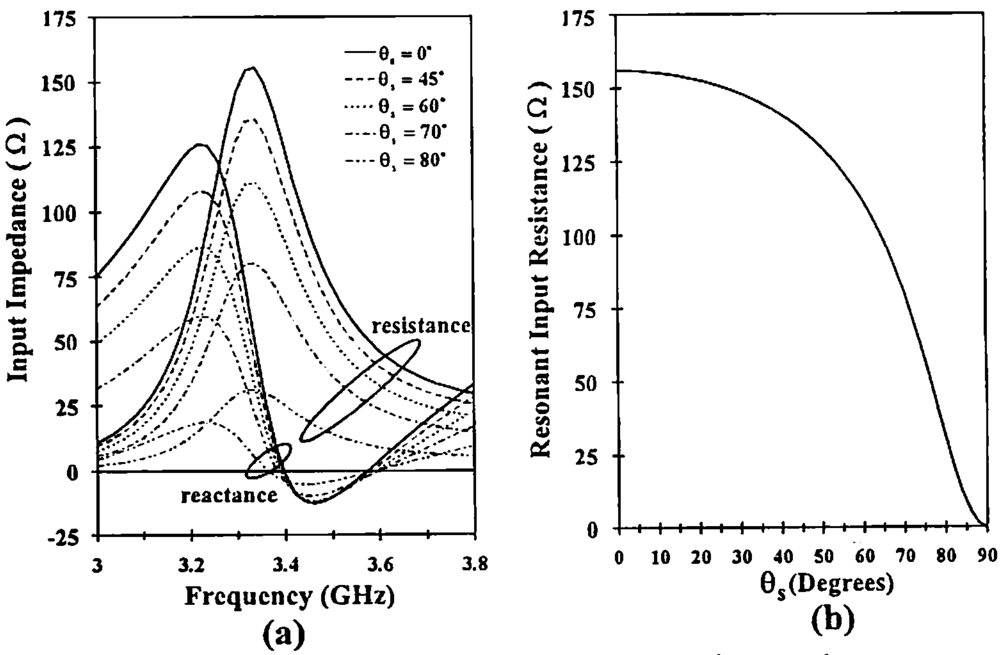

Fig. 3 (a) Input impedance versus frequency. (b) Resonant input resistance versus θ_s. Antenna parameters are the same as given in Fig. 2(b).