# ELECTROMAGNETIC COUPLED MICROSTRIP PATCH ANTENNAS

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**Abstract:** In EMC antennas the feed line is in between the two substrates and the patch is etched on the top of upper substrate. In this communication the electromagnetic coupled antennas are studied using cavity model. The capacitance is calculated using variational method of analysis. The numerical results are compared to simulated results which are obtained by IE3D based on Method of Moments.

**Keywords:** Admittance, Capacitance, Cavity Model, Dielectric, Substrate.

**Introduction:** Electromagnetic coupling scheme also known as proximity coupled feed. Two dielectric substrates are used such that the feed line is in between the two substrates and the radiating patch is on the top of upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13 %) due to overall thickness of the microstrip patch antenna. The major disadvantage of this antenna is that it is difficult to fabricate because two dielectric layers need proper alignment. During the past decades a number of different types of microstrip radiators have been described [1-3]. The majority of these employs resonant elements and differs primarily in their particular shapes and manner in which microstrip feed line are attached. The method of moments (MOM) has been applied for the determination of current distribution in the longitudinal dimension; the current dependence in transverse direction has been chosen so as to satisfy the edge condition at the effective width location.

In the present work a numerical model using, the cavity model along with circuit theory has been used to calculate input impedance of a ring resonator loaded by a microstrip line. A ring resonator is fed by a narrow microstrip line underneath the ring. The proposed structure is analyzed and the input impedance is computed. The computed results are then compared with simulation. This model is a simple method to predict the input impedance of a loaded ring resonator by a microstrip line. In this proposed model a ring is used for the purpose of radiation in its fundamental mode.

The ring is fed by a transmission line of length $l$ and width $w$ underneath with an insertion of $s$. The computation method has three steps; first the impedance of a probe-fed ring is computed. It is then transformed by a capacitive tap constituting the overlap area of the ring and the microstrip line. The capacitance is calculated using variational method, where the addition of the two components is obtained. This technique is described in detail in literature [4]. Figure 2 displays the structure under study.

For this structure the admittance has been computed on the charge plane (line) as $Y_+$ and $Y_-$A probe fed ring resonator for dominant $TM_{11}$ mode is analyzed using cavity model. Initially the impedance of a probe fed ring resonator is obtained. The input impedance for a probe location at $r_o$ is given thereby [5]

**Impedance Expression for Annular Ring Antenna Electromagnetically Coupled to a Microstrip Line**: The geometry of electromagnetically coupled ring resonator is shown in figure1. The ring resonator is constructed on a substrate of thickness $h$ and relative dielectric constant $\varepsilon_r$. The inside radius is $a$, the outside radius is $b$.

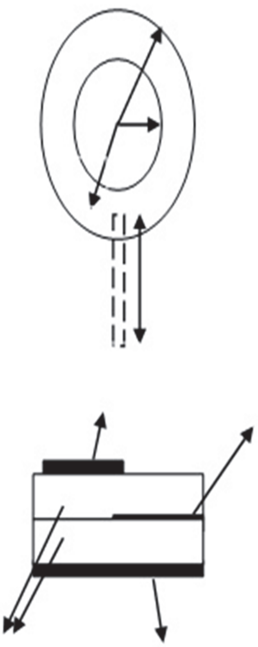

Figure 1 Geometry of the microstrip line fed ring resonator.

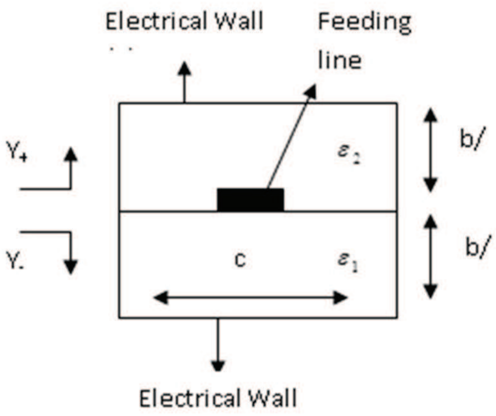

**Figure 2** Structure of multilayered stripline.

$$Z_{in} = \mu^2 h^2 \sum_n \sum_p \frac{(j\omega + A) C_n^{(1)^2} \omega^2 \left[ (J_n(k.r_0) Y_n^{'}(k.b_e) - J_n^{'}(k.b_e) N_n(k.r_0)) J_0 \left( \frac{nd_f}{2r_0} \right) \right]^2}{(j\omega - C)(j\omega + A) + \omega_{np}^2} \qquad (1)$$

The parameters *A* & *C* are given as

$$A = Z_s \int |H_i|^2 \, dS \qquad (2)$$

$$C = -Y_w \int |E_i|^2 \, dS$$

where $\omega_{np}$ corresponds to the resonance of eigen-mode corresponding to $TM_{np}$ mode, $b_e$ and $a_e$ represent the effective radius due to fringing fields. $J_n(k.r)$ is the Bessel function of order *n* and $J_n^{'}(k.r)$ is the derivative of first order Bessel function. For the computation of impedance, the expression for wall admittances and mutual admittances has been obtained using [6-7]. Once the input impedance of ring resonator has been obtained, the same impedance has been transformed to impedance of electromagnetically coupled transmission line of length *l* and width *w*. Substituting the parameters in the following expression gives the capacitance between line and the respective walls.

$$C = \frac{(1 + 0.25A)^2}{\sum_{n\,odd} \left( \frac{T_n P_n}{Y} \right)} \qquad (3)$$

$$Y_+ = \varepsilon_0 \varepsilon_1 \coth \beta b / 2 \qquad (4)$$

$Y_- = \varepsilon_0 \varepsilon_2 \coth \beta b / 2$ (5) where

$$T_n = (L_n + AM_n)^2$$

$L_n = \sin(\frac{\beta_n \omega}{2})$ here

$$\beta_n = \frac{n\pi}{c}$$

$$M_n = (2/\beta_n w)^3 [3\{(\beta_n w/2)^2 - 2\} \cos(\beta_n w/2) + (\beta_n w/2)\{(\beta_n w/2)^2 - 6\} \sin(\beta_n w/2) + 6]$$

$$P_n = (2/n\pi)(2/\beta_n w)^2$$

$$A_n = -\frac{\sum_{nodd} \dfrac{(L_n - 4M_n)L_n P_n}{Y_+}}{\sum_{nodd} \dfrac{(L_n - 4M_n)M_n P_n}{Y_-}} \qquad (6)$$

where *c* represents the transverse wall spacing. For the present case *c* is taken to be a large value. Using the equation (6) capacitance in a multilayer structure can be obtained. It is also seen that the simple equation given by (3) also shows reasonably accurate results. Let the transmission line of characteristic impedance $Z_0$ and length *l* be loaded by $Z_R$ that is impedance of ring and the capacitive tap, the combined load on the transmission line may be denoted as $Z_L$. Therefore the input impedance seen by a source is given as

$$Z = Z\frac{Z_L + jZ_0\tan(\beta l)}{Z_0 + jZ_L\tan(\beta l)} \quad (7)$$

For our analysis we have considered a loss less line. Therefore by using equations (1),
(2) and (7) we have evaluated the input impedance of ring resonator. For accuracy,
an exact estimation of capacitance in multilayer structure is necessary.

**Results and discussion:** the theory formulated in the previous section is validated by comparing the results obtained through computation and simulation on ie3d software which is based on the method of moments. The dimension of the ring is chosen as follows; *a* = 30 mm, *b* = 60 mm, $h_1$ = 0.787 mm, $h_2$ = 0.787 mm and $\varepsilon_r$ = 2.2. A microstrip line of given width *w* and length *l* is drawn on height $h_2$ = 0.787 mm with an insertion of s underneath the ring. The characteristic impedance of the line in the proposed environment is evaluated. If the proposed insertion is, for example, 10 mm underneath the ring (from the edge), then equation (1) is evaluated for the input impedance of the ring considering a probe location $r_0$ = 35 mm. From figures (3), (4) and (5), it is seen that excellent agreement exists in the resonant resistance of $TM_{11}$ mode of the loaded ring resonator between theory and simulation with transmission line loading. The comparison is done for widths, *w* = 0.50 mm and *w* = 0.95 mm. There is an excellent agreement between the measured and numerical results. The higher order mode is more suitable for radiation purposes.

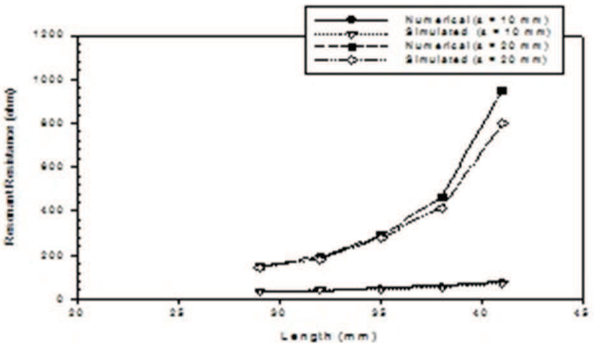

**Figure 3**Comparison of present theory with simulated data Resonant Resistance

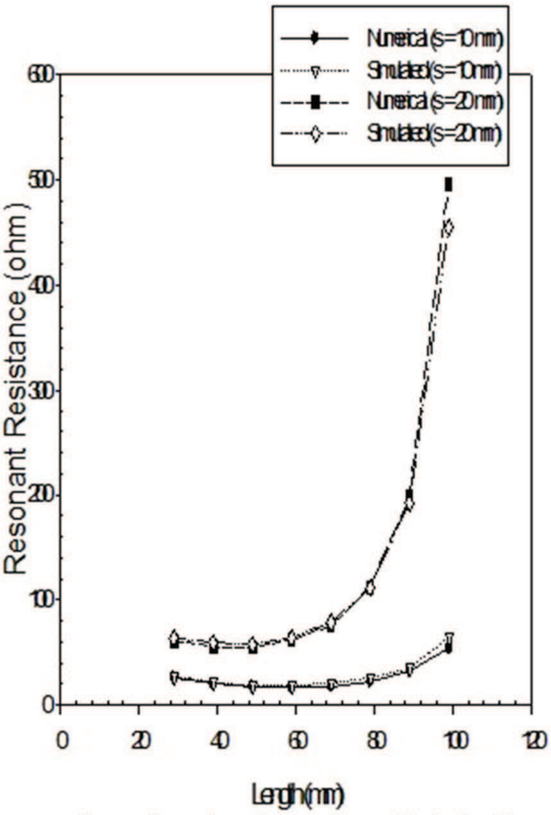

**Figure 4** Comparison of present theory with simulated data and Resonant Resistance with Length for *w* = 0.95 mm for n = 1. with Length for *w* = 0.95 mm for *n* = 1.

The discrepancies observed for the higher width is due to the fact that in the present proposal, we are considering the capacitive coupling between two cylindrical lines. Such assumption, though reasonably accurate for thin lines, starts failing once the width of the line increases. Present theory displays a resonance at 733 MHz whereas the measurement shows 745 MHz for dominant mode. For higher mode ($n$ = 2), the resonance is at 1440 MHz where as the measured values show resonance at 1467 MHz. The corresponding error in frequency estimation is less than 2 % for dominant mode and 1.8 % for higher mode The discrepancies observed for the higher width is due to the fact that in the present proposal, we are considering the capacitive coupling between two cylindrical lines. Such assumption, though reasonably

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