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Computation of Mutual Coupling for Gap-Coupled Circular Patch Antennas Loaded with Shorting Post

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Abstract: *In this paper, the numerical computation of mutual coupling between gap-coupled circular microstrip antennas loaded with shorting post has been presented. The cavity model and reaction theorem is used. The mutual admittance between two circular patches is computed and computed results are compared with simulated results. The simulation is performed with Method-of-moments based software (IE3D). The accuracy of prediction is reasonable good.*

Keywords: *Microstrip antennas, mutual coupling, mutual admittance.*

1. INTRODUCTION

There are many advantages of the microstrip antennas such as low profile, low manufacture cost, compatible with MMIC design etc. Due to these advantages, they are used in aircraft, satellite, missile, wireless and mobile communications etc. The major disadvantages of the microstrip antennas are narrow bandwidth and low efficiency. The bandwidth of the microstrip antenna can be increased by using various techniques such as by using thicker substrate, by reducing the dielectric constant, by using gap-coupled multiple resonators and by loading a patch [1-3].

The bandwidth of the microstrip antennas can be increased by using gap-coupling. In some applications, multi-frequency operations are required, this can be achieved by gap-coupling [4].The trend for technology in recent times is towards miniaturization and the demand for more compact and robust designs has been growing. The size of the microstrip antenna can be reduced by shorting patch [5]. For analysis of gap coupled microstrip antennas, consideration of mutual coupling is essential.

In [6] the experiment is performed on gap-coupled circular microstrip antennas and the mutual coupling is measured. In [7], the theoretical calculations of mutual coupling for the rectangular microstrip antennas are presented. The cavity model and the equivalence theorem are used to reduce the problem to that of the interaction between two magnetic current loops. Calculations agree with experiments. One of the observations is that the contributions from all four edges are important in mutual coupling. In [8], the coupling characteristics between spherical concentric annular ring and circular microstrip antennas is studied by using full wave analysis. Both the annular ring and the circular patches are fed by a coaxial probe. The circular patch is excited at TM_{11} mode and the annular ring is excited at TM_{12} mode. S_{12} is obtained from the scattering matrix. In [9-10], mutual coupling is calculated between the patches.

In the present communication, we present a method of computation of mutual admittance between gap-coupled circular microstrip antennas loaded with shorting post and results are compared with the simulated results (IE3D).

2. THEORY

The magnetic current model can be used to determine the wall admittances of a patch antenna. In this model, the patch is replaced by the equivalent magnetic current source at its periphery. The wall admittances of the patch are equivalent to the radiation admittances of the corresponding magnetic currents [11]. However, the mutual admittance between two edges at $u = u_1$ and $u = u_2$ can be calculated accurately as:

$$y_{12}^{m} = \frac{\langle u_1, u_2 \rangle}{V_1 V_2} \tag{1}$$

where $\langle u_1, u_2\rangle$ is the mutual reaction between the sources at $u = u_1$ and $u = u_2$. The mutual reaction $\langle u_1, u_2\rangle$ is given by [12]:

$$\langle u_1, u_2 \rangle = \iiint (E^{u_1} \cdot J^{u_2} - H^{u_1} \cdot M^{u_2}) dr \tag{2}$$

where J and M are the surface and magnetic current respectively. We consider that u_1 and u_2 represent the two circular patches hitherto called simply as 'a' and 'b' only. Here J^b is impressed (source) current and E^a is the electric field generated in 'b' due to J^a. For computation of mutual admittance of two circular patches, we consider only the first term of expression (2).

Fig 1 gives the geometry of two gap coupled circular patches. A patch of radius 'r_1' is placed at the center and another patch of radius 'r_2' is placed around the central patch

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as shown in fig.1. Here we have segmented the structure into two regions with origin at the centre of region I. The inner radius of region II is 'b' and outer radius is 'c'. The distance between the centers of the patches is 'ρ_0'. The central patch is shorted by a pin of diameter 'p'.

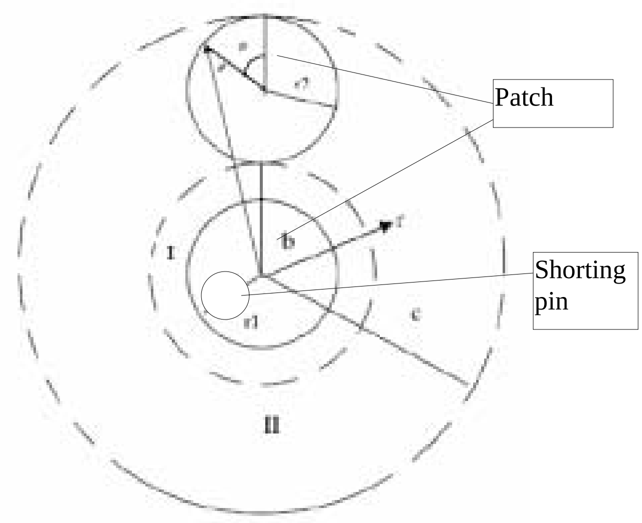

Figure 1: Two Gap Coupled Circular Patch Antennas Loaded with Shorting Post.

The field expressions in region I ($0 \le r \le b$) are:

$$E_z^{(1)} = -j\omega\mu\,[C_1 J_n(kr) + C_2 N_n(kr)]\cos n\phi \tag{3}$$

$$H_\phi^{(1)} = -k\,[C_1 J_{n'}(kr) + C_2 N_{n'}(kr)]\cos n\phi \tag{4}$$

The expression for $H_r^{(1)}$ is omitted for brevity. The terms incorporated in expression (3) and (4) have their usual meanings.

In region II ($b \le r \le c$)

$$E_z^{(2)} = -j\omega\mu\,[C_3 J_n(kr) + C_4 N_n(kr)]\cos n\phi \tag{5}$$

$$H_\phi^{(2)} = -k\,[C_3 J_{n'}(kr) + C_4 N_{n'}(kr)]\cos n\phi \tag{6}$$

Considering the parasitic patch in isolation, the boundary condition of vanishing $H_\phi^{(2)}$ gives:

$$\frac{C_4}{C_3} = -\frac{\int_0^{2\pi} J_{n'}(k\rho(\alpha))d\alpha}{\int_0^{2\pi} N_{n'}(k\rho(\alpha))d\alpha} = \frac{I_2}{I_1} \tag{7}$$

where $\rho(\alpha) = \rho_0 + r_2 \cdot \cos\alpha$

Therefore the field expression in region II can be rewritten as:

$$E_z^{(2)} = -j\omega\mu\, C_n^{(2)} F_n^{(2)}(kr)\cos n\phi \tag{8}$$

$$H_\phi^{(2)} = -kC_n^{(2)} F_{n'}^{(2)}(kr)\cos n\phi \tag{9}$$

where $C_n^{(2)}$ is a constant dependant on given mode 'n' and

$$F_n^{(2)}(kr) = J_n(kr)\,I_1 - I_2\,N_n(kr) \tag{10}$$

Similarly,

$$E_z^{(1)} = 0 \qquad \text{for } r = \frac{p}{2}$$

$$\frac{C_1}{C_2} = -\frac{N_n\left(\frac{kp}{2}\right)}{J_n\left(\frac{kp}{2}\right)} = \frac{I_3}{I_4} \tag{11}$$

Thus the field expression in region I is:

$$E_z^{(1)} = -j\omega\mu C_n^{(1)} F_n^{(1)}(kr)\cos n\phi \tag{12}$$

$$H_\phi^{(1)} = -kC_n^{(1)} F_{n'}^{(1)}(kr)\cos n\phi \tag{13}$$

where $C_n^{(1)}$ is a constant and

$$F_n^{(1)}(kr) = J_n(kr)I_3 - N_n(kr)I_4 \tag{14}$$

Using expression (2), the reaction is given by:

$$\langle a,b\rangle = \int_0^{2\pi}\int_{r_2}^{r_2+h} E_z^{(2)}(\rho(\alpha))H_\phi^{(1)}(r_e)\,r\,dr\,d\alpha \tag{15}$$

where r_e is the effective radius of the patch.

The voltages are evaluated at the edges of respective patches and are given by:

$$V_1 = -\,hE_z^{(1)}(r_1) \tag{16}$$

$$V_2 = -hE_z^{(2)}(r_2) \tag{17}$$

Therefore using (2) the mutual admittance is given by:

$$y_{12}^m = \frac{\int_0^{2\pi}\int_{r_2}^{r_2+h} E_z^{(2)}(\rho(\alpha))H_\phi^{(1)}(r_e)\,r\,dr\,d\alpha}{h^2 E_z^{(1)}(r_1)E_z^{(2)}(r_2)} \tag{18}$$

Now mutual admittance is computed using equation (18). The computed results are compared with simulated results. The mutual coupling parameter $S(1, 2)$ can be calculated by considering that the two edges of gap coupled circular patches form a π type network and shown in fig 2

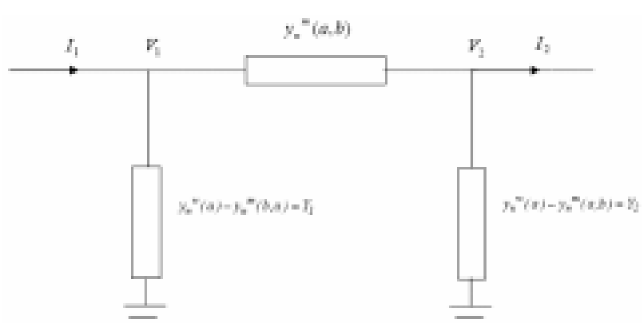

Figure 2: Equivalent Circuit Diagram for Gap

[2], [13]. In this figure $y_n^w(a/b)$ are the wall admittances of individual patches and $y_n^m\,(a, b)$ is the mutual admittance. For such π type network [14]

$$S_{12} = -\,y_{12}^m \tag{19}$$

3. RESULTS

Using (18) the mutual admittance $Y(1,2)$ is calculated and using (19) $|S(1, 2)|^2$ (dB) is calculated. The computed results are compared with the simulated data. For simulation two circular patches are placed as shown in fig-1. One patch is shorted by a pin at its center. Both the patches are fed and the driving point impedance is set to approximately 50Ω by varying the feeding points. For 50Ω driving point impedance the mutual admittance parameter $Y(1,2)$ is taken. The dimensions of the antennas used here are shown in table-I. The comparison of computed and simulated results is shown in fig 3 and fig 4. In fig 3, the variation of mutual coupling parameter $S(1,2)$ with pin radius is shown at various frequencies for fixed gap between adjacent edges, is shown. In fig 4, the variation of mutual coupling parameter $S(1,2)$ with gap between adjacent edges for fixed pin radius is shown. The agreement between simulated results and computed results is reasonable good.

Table 1
Dimensions of Antennas used

Radius of feed patch (r_1) (mm)	*Radius of parasitic patch (r_2) (mm)*	*Thickness of substrate (h) (mm)*	*Dielectric constant (ε_r)*
15	15	1.59	2.2

4. CONCLUSION

In the present proposal, a numerical model for mutual coupling between two circular microstrip gap-coupled microstrip antennas loaded with shorting post has been developed. The mutual impedance is calculated using cavity model and reaction theorem. The comparison between the computed and the simulated results show good agreement. The present model can be extended to the multiple patches.

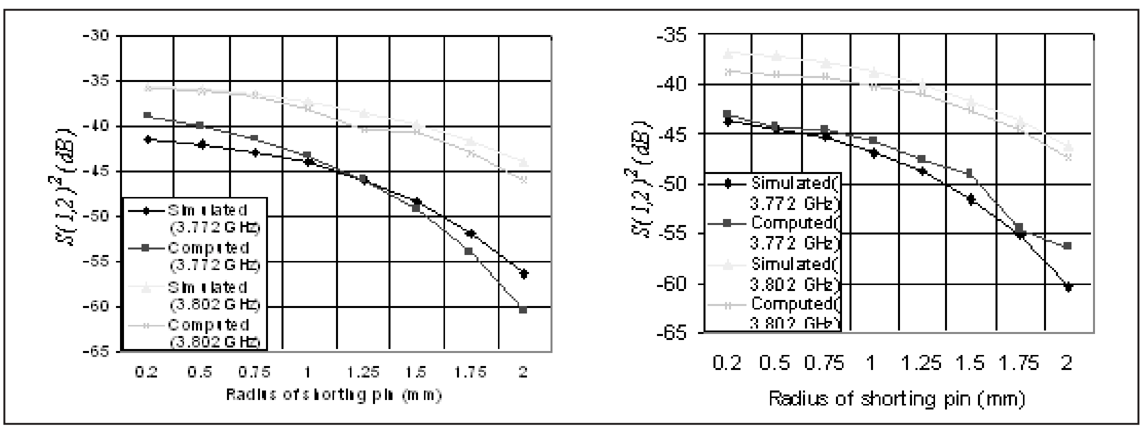

Figure 3: Variation of Mutual Coupling Parameter $S(1, 2)$ with Radius of Shorting Post for (a) Gap between Adjacent Edges = 0.5 mm, and (b) Gap between Adjacent Edges = 1 mm

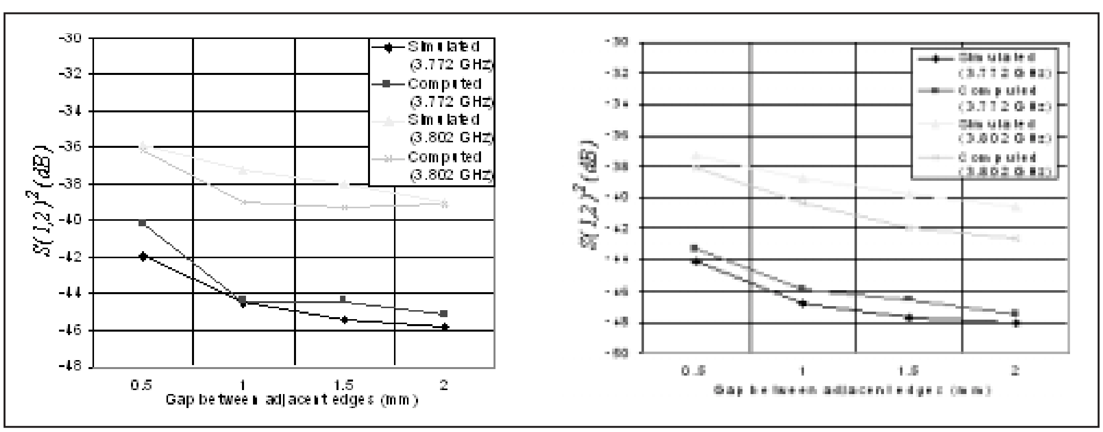

Figure 4: Variation of Mutual Coupling Parameter $S(1, 2)$ with Gap between Adjacent Edges for (a) Pin Radius = 0.5 mm, and (b) Pin Radius = 1 mm

REFERENCES

[1] Constantine A. Balanis, “Antenna Theory: Analysis and Design”, *Wiley*, (2005).

[2] Pradeep Kumar, A. Kr. Singh, G. Singh, T. Chakravarty and S. Bhooshan, “Terahertz Technology-A New Direction”, *IEEE- International Symposium on Microwave*, Bangalore, India, (2006), 195–201.

[3] G. Kumar and K. C. Gupta, “Broadband Microstrip Antennas Using Additional Resonators Gap Coupled To the Radiating Edges”, *IEEE Trans. Antennas and Propagation*, **32**, (12), (Dec., 1984).

[4] Pradeep Kumar, G. Singh, S. Bhooshan and T. Chakravarty, “Gap-coupled Microstrip Antennas”, *International Conference on Computational Intelligence and Multimedia Applications*, Sivakasi, India, (2007), 434–437

[5] Y. J. Wang and C. K. Lee, “Compact and Broadband Microstrip Patch Antenna for the 3g Imt-2000 Handsets Applying Styrofoam and Shorting-Posts”, *Progress In Electromagnetics Research, Pier* **47**, (2004), 75–85

[6] R. P. Jedlicka, M. T. Poe, K. R. Carver, “Measured Mutual Coupling Between Microstrip Antennas”, *IEEE Trans Antennas and Propagation*, **29**, (1981), 147–149.

[7] E. Penard and J. P. Daniel, “Mutual Coupling between Microstrip Antennas”, *Electronics Letters*, **18**, (1980), 605–607.

[8] Hong-Twu Chen, Jeen-Sheen Row, and Yuan-Tung Cheng, “Mutual Coupling between Spherical Annular-Ring And Circular Microstrip Antennas”, *IEEE*, (1997), 1521–1524.

[9] U.K. Revankar and A. Kumar, “Mutual coupling between Stacked Three Layer Circular Microstrip Antenna Elements”, *Electronics Letters*, **30**, (24), (1994).

[10] K. Mahdjoubi, E. Penard, J. P. Daniel and C. Terret, “Mutual Coupling between Circular Disc Microstrip Antennas”, *Electronics letters*, **23**, (1), 27–28, (1987).

[11] R. Garg, P. Bhartia, I. Bahl, A. Ittipiboon, “Microstrip Antenna Design Handbook”, *Artech House Publishers*, Boston, London, (2001).

[12] R.F. Harrington, “Time-Harmonic Electromagnetic Fields”, *John Wiley*, New York, (2000).

[13] Pradeep Kumar, T. Chakravarty, G. Singh, S. Bhooshan, S. K. Khah and A. De, “Numerical Computation of Resonant Frequency of Gap Coupled Circular Microstrip Antennas”, *Journal of Electromagnetic Waves and Applications*, **21**, (10), (2007), 1303–1311.

[14] G. G. Bhise, P. R. Chaddha and D. C. Kulshrestha, “Engineering Network Analysis and Synthesis”, *Umesh Publications*, New Delhi, India, (2006).