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Accurate Design of A Corner Fed Square Slot Patch Antenna For Circular Polarization

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***Abstract:* -** New fast form analytic expressions to determine the impedance elements of the desegmentation matrix have been obtained. These results, using the Green's function approach, enable an accurate determination of the dimensions of the slot at the centre of a corner fed square patch antenna to produce circular polarisation.

INTRODUCTION

The desegmentation technique [1] applied to the antenna with a slot (Fig. 1) is outlined in [2], Perturbation analysis, together with the determination of the initial estimates of the overall patch dimensions, is given in [3], In this Letter new fast form expressions have been obtained to determine the impedance elements of the desegmentation matrix. These expressions, used in the desegmentation technique together with the procedure reported in [3], enable the geometric design to be fully and accurately determined.

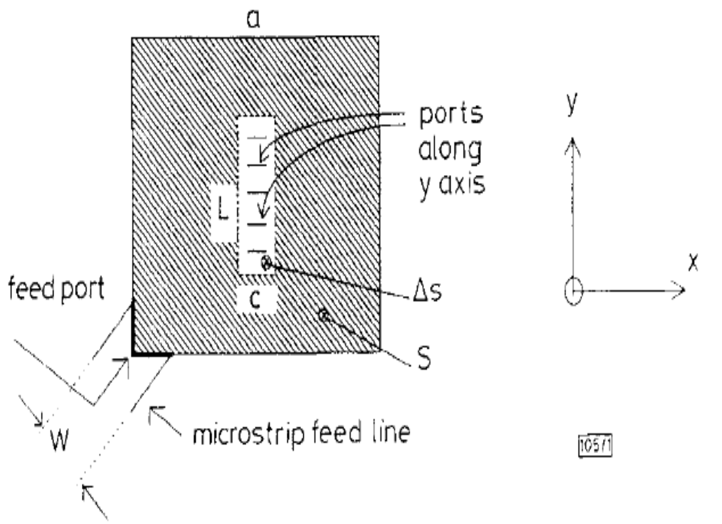

Fig. 1 *Corner microstrip fed square patch antenna with slot at centre*

$W = 1.25\text{mm}, h = 1.575\text{mm}, \delta = 0.0012, \varepsilon_r = 2.33, s = a^2, \Delta_s = L \times C$

I. ANALYSIS

The submatrix elements Z_{pp}, Z_{pq}, Z_{qp} and Z_{qq} of the Zmatrix, for both lower and higher excitations, are determined bythe procedure described in [2], and evaluated with the aid of thenew closed form expressions given below. In these expressions thevalues of z_p, z_q, $z_>$ and $z_<$ are assigned according to the given selec-tion rules, eqn. 1 has been reported in [3].

$$Z_{pp} = -\frac{j\omega\mu_o h}{4\sqrt{2}a}\frac{1}{k\sin(ka)}\left[1+\cos\left(k\frac{W}{2\sqrt{2}}\right)\sin c\left(k\frac{W}{2\sqrt{2}}\right)\right] \times\left[\cos(ka)+\cos\left[k\left(\frac{W}{2\sqrt{2}}-a\right)\right]\sin c\left(k\frac{W}{2\sqrt{2}}\right)\right] \quad (1)$$

$$Z_{pq} = -\frac{j\omega\mu_o h}{2a}\frac{1}{k\sin(ka)}\left[\cos[k(z_q-a)]\sin c\left(k\frac{W_q}{2}\right)\right] \times\left[1+\cos\left(k\frac{W}{2\sqrt{2}}\right)\sin c\left(k\frac{W}{2\sqrt{2}}\right)\right] \quad (2)$$

$$Z_{qp} = -\frac{j\omega\mu_o h}{2\sqrt{2}a}\frac{1}{k\sin(ka)}\left[\cos[k(z_q-a)]\sin c\left(k\frac{W_q}{2}\right)\right] \times\left[1+\cos\left(k\frac{W}{2\sqrt{2}}\right)\sin c\left(k\frac{W}{2\sqrt{2}}\right)\right] \quad (3)$$

$$Z_{qq} = -\frac{j\omega\mu h}{a}\frac{1}{k\sin(ka)}\cos[k(z_>-a)]\cos(kz_<) \times\sin c\left(k\frac{W_p}{2}\right)\sin c\left(k\frac{W_q}{2}\right) \quad (4)$$

where *h* = substrate thickness, *k* = effective wave number, sine(x) = sin(x)/x.

The closed form of the above equations is obtained by removing the summation in the Green's function using the formula in[4].The centre co-ordinates z_p and z_q of the desegmentation ports, widths w_p, w_q, take the values x_p, x_q, y_p or y_q according to the port orientation.

II. THEORETICAL AND PRACTICAL RESULTS

The area of the patch *S* and the area of the slot (perturbation element, *As)* of dimension *L* x *c*, were first estimated by following the procedure described in [3], The submatrixelements $z_p = x_p$, z_a - x_a, and, for the higher modes $z_p = y_p$, $z_a = y_a$. In eqn. 4, z, = max(z_p, z_q) and z< = min(z_p, z_q). The desegmentation technique is then applied to determine the modal impedances.

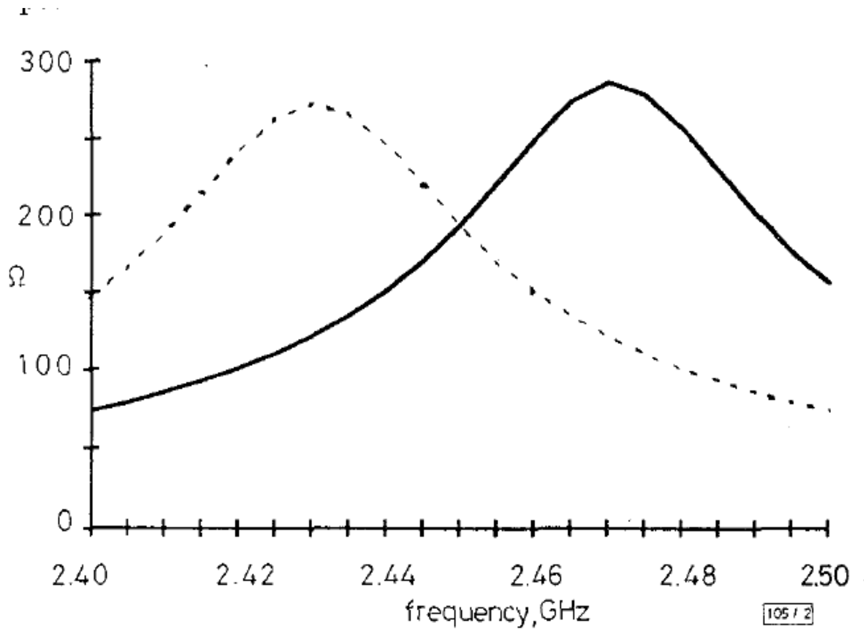

Fig. 2 Theoretical magnitude of modal impedances
mag. of higher mode
mag. of lower mode

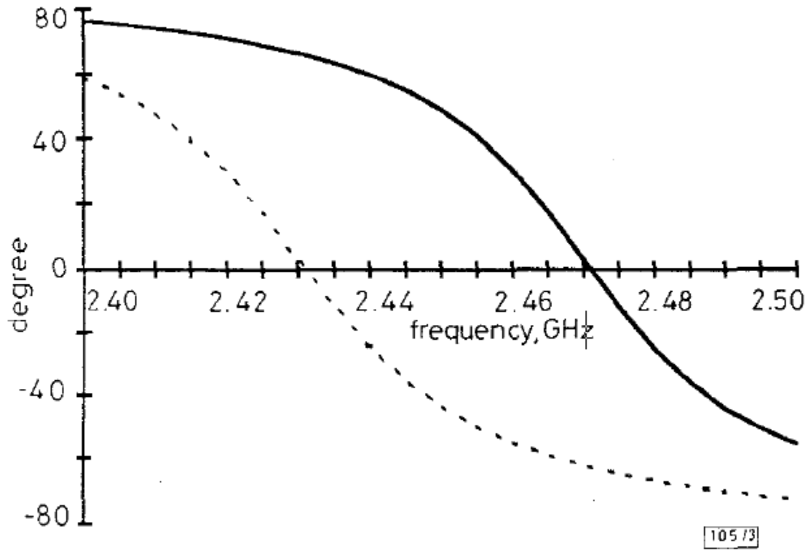

Fig. *3 Theoretical phase of modal impedances*
-------------phase of higher mode
-------------phase of lower mode

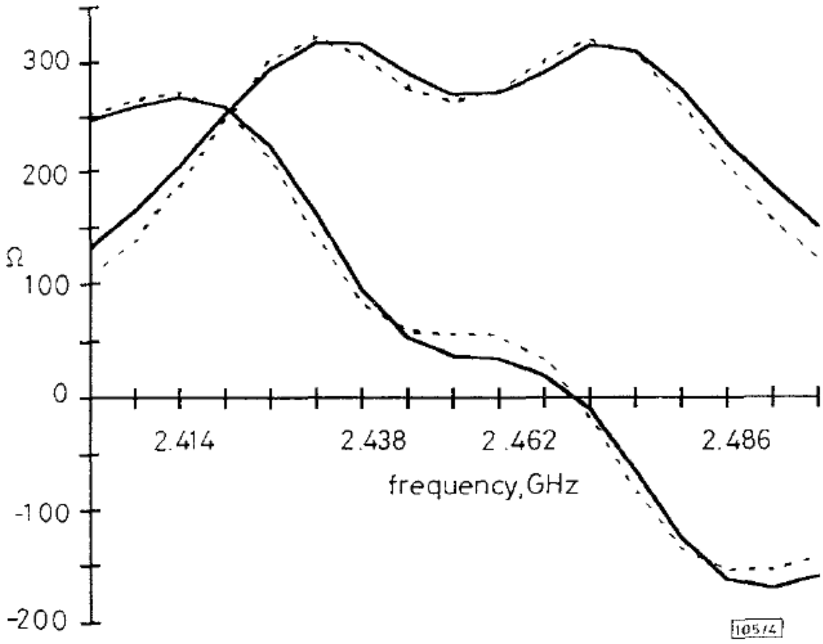

Fig. 4 *Theoretical and practical input impedance*
Re(Zin), practical
Im(Zin), practical
-~~~ Re(Zin), theory
~~~~ Im(Zin), theory

III. THEORETICAL AND PRACTICAL RESULTS

The area of the patch *S* and thearea of the slot (perturbation element, *A$* of dimension *L* x c,were first estimated by following the procedure described in *[3]*.The submatrix elements of the *Z* matrix used in the desegmentation technique were evaluated using eqns. 1 ~ 4 for the lower and higher modes. Graphs of the magnitude and phase of the modalimpedances against the frequency were then plotted. The outward extensions of the patch caused by the flinging fields are includedin the model, but the fringing fields in the slot are not taken into account. By altering the dimensions of the patch and slot the magnitudeand phase modal responses were adjusted to satisfy the necessary conditions for circular polarisation, i.e. the equal magnitude and phase quadrature requirement. At the design frequency of2.45GHz, the optimised dimensions were *a* = 37.9mm, *L* = 8.5mmand *c* = 2.5mm . The theoretical values of the magnitude and the phase of the modal impedances against
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frequency are shown inFigs. 2 and 3, respectively. In the desegmentation procedure,excellent convergence was obtained using 20 interconnection ports.The computed values of the impedances caused by the orthogonal higher and lower modes are obtained and combined. In Fig. **4** the graphs of the real and imaginary parts of the combined impedance values are compared with graphs of measured values, and are in good agreement.

IV. CONCLUSION

New fast form analytic expressions for the detenninationof the submatrices *Zpq,Z <,n*a nd *Zqq*b, ased on the Green'sfunction approach, have been obtained. These sub matrices were then used in the deseg mentation technique to determine the modal impedances of a square patch antenna with a slot. The optim umdimension of the antenna was then found by adjusting these responses in order to satisfy the two conditions for circular polarization .The theoretical and practical results are in very good aggreement.This procedure can be used to optimise the dimensions of any corner fed patch antenna with rectangular perturbation segments designed to produce circular polarisation. This type of antenna can be used as a microwave tag in a moving vehicle for a variety of traffic applications.

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