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Analysis of Dual Frequency Equilateral Triangular Microstrip Patch Antenna with Shorting Pin

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***Abstract*: The effects of position of shorting pin and feed-probe in an equilateral triangular microstrip patch antenna are theoretically taken into account using transmission line model. At d_s/d_h =0.33, frequency ratio (FR) of upper resonant frequency to lower resonant frequency is minimum. It is observed that the minimum FR decreases if substrate permittivity increases and it varies from 2.81–1.68 for ε_r 1.0 to 9.8. While the FR increases if the distance of the shorting pin from that point (d_s/d_h =0.33) increases. Maximum FR is observed at the triangle tip. The maximum FR varies from 5.43–5.07, and it decreases if substrate permittivity increases. It is also observed that the resonance frequencies are almost constant with probe position.**

***Index Terms*: Shorting pin, Dual-band, ETMSA.**

I. INTRODUCTION

The first study on Triangular Microstrip Antenna (TMSA) dates back to 1978 when Helszajn and James [1] reported theoretical and experimental investigation on Equilateral Triangular Microstrip Antenna (ETMSA) as disk resonator, filter and circulator. TMSA have received much attention due to increased demand of small antennas for personal communication equipment. The triangular MSA is known to require small patch size that of a square or circular MSAs [2]. In many applications, compact MSA capable of operating in multibands are highly desirable.

The conventional ETMSA antennas were studied in [3]-[17]. The basic formulas to design ETMSA antennas are presented in [18]-[19]. The ETMSA has been analyzed and modeled using different techniques, namely, cavity resonator model [3],[5]-[14],[17], geometrical theory [4], Method of Moment (MoM) [10] and genetic algorithm (GA) [14]. It is apparent that most of the analyses are based on the cavity resonator model resulting in simple computer aided design formulas for determining the operating frequencies.

To obtain dual band, a few attempt have been made [20-27]. Dual frequency operation of an ETMSA is demonstrated by using stacked patches [20], using a pair of spur lines [22], using a slit [23], using a V shaped slot [24], by loading two pair of narrow slots in the triangular patch [25] and [26], and also by using shorting pins [27].

Pan and Wong [27] first time presented a working model of a dual band ETMSA with tunable frequency ratio. This patch generates two different operating bands mainly due to the shifting of the null-voltage point, and divide the flow of current in two different streams, having different path lengths.

Recently, Hong and Li [28] investigated the dual-mode operation of microstrip triangular patch resonators in realizing dual-mode microwave planar filters.

In this endeavor the effect of position of shorting pin and feed-probe are theoretically taken into account using transmission line model. Considering the triangular patch as a number of cascaded transmission lines of varying width derives the input impedance.

II.THEORY

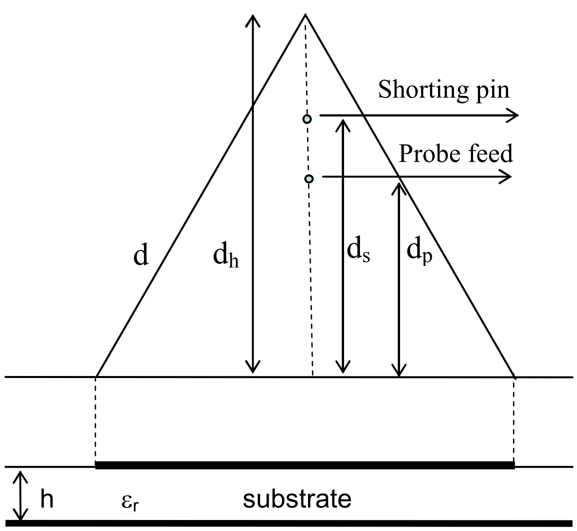

Fig 1: Top and side views

The geometry and transmission line equivalent of the proposed dual-frequency design is shown in Figs. 1-2. Considering the effect of fringing field, dimensions of the triangular MSA has been modified (Fig. 3). In this paper the effect of position of shorting pin and feed-probe are taken into account. It has two different cases: (I) shorting pin is closer to vertex compared to feeding probe and (II) feeding probe is closer to vertex compared to shorting pin. Case-I (Fig. 4), the total input impedance at the feed point may be obtained using transmission line theory as

$$Z_{in} = j\omega L_p + \frac{Z_{in1} Z_{in2}}{Z_{in1} + Z_{in2}} \quad (1)$$

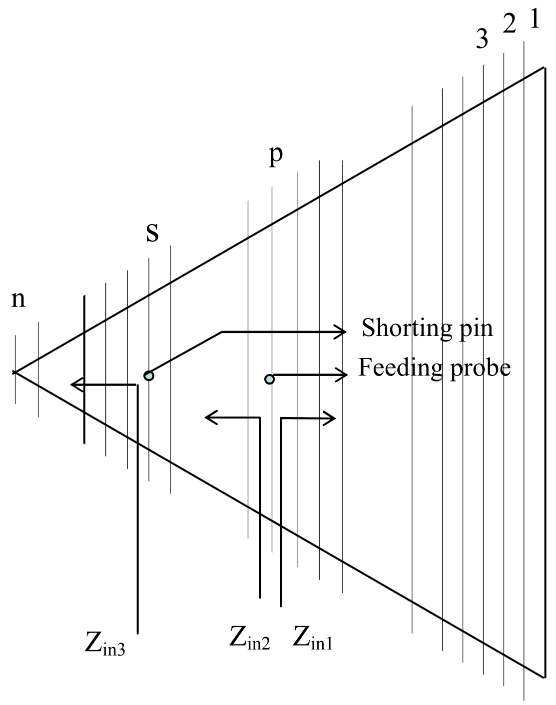

Fig 2: Cascaded T. L. sections

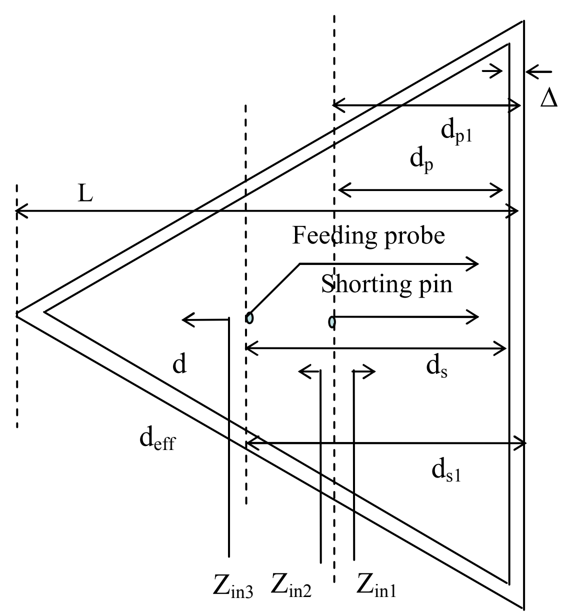

Fig 3: Contribution of fringing field on ETMSA

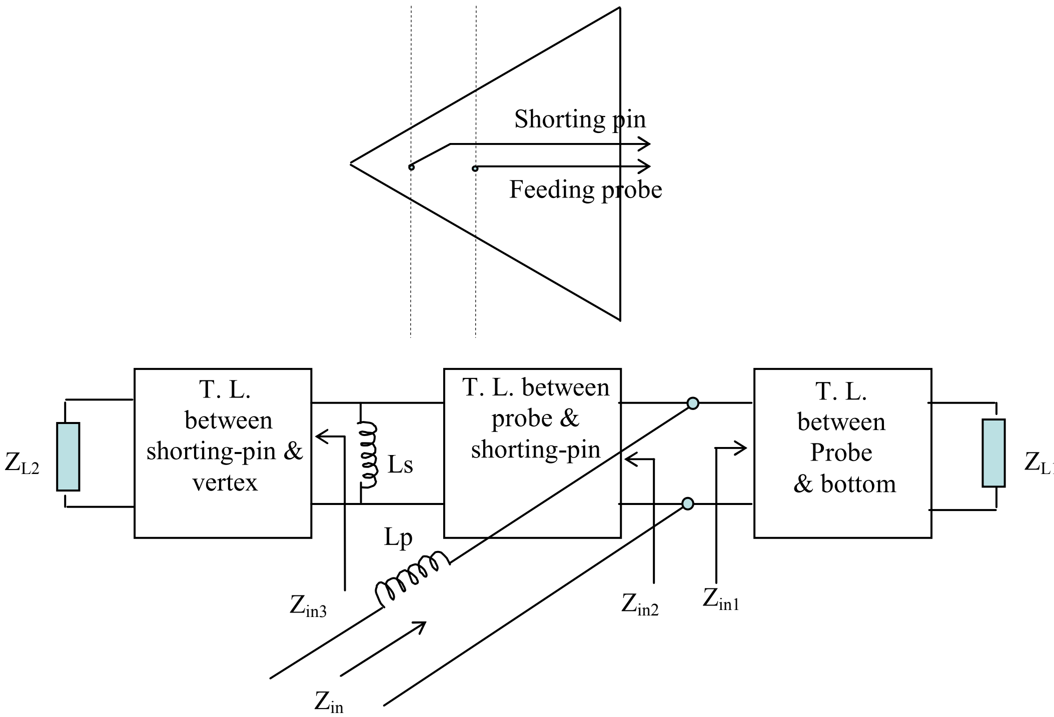

Fig. 4: T.L. equivalent of ETMSA if shorting-pin is towards vertex

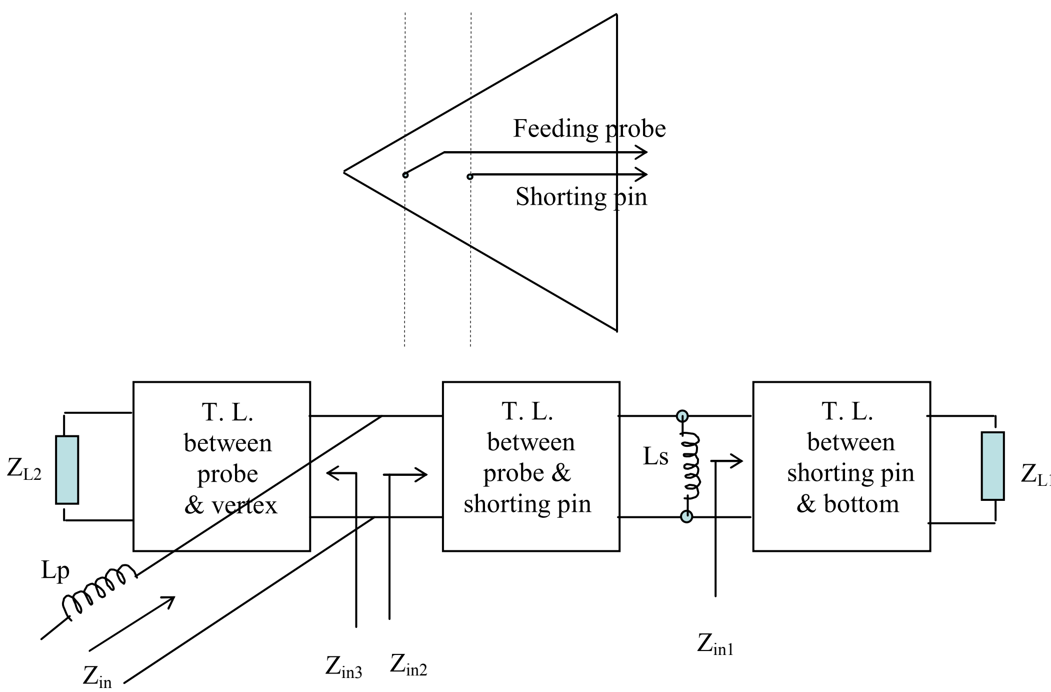

Fig. 5: T.L. equivalent of ETMSA if probe is towards vertex

where L_p is an inductance offered by the current flowing through the center conductor of the feeding probe [19], ω is the operating frequency, and Z_{in1} is the impedance at probe looking towards bottom and may be written as

$$Z_{in1} = Z_{in1k} \big| k = p \tag{2}$$

where Z_{in1k} is the input impedance of k^{th} section looking towards bottom end ($k \le p$), and is defined by

$$Z_{in1k} = Z_{ok} \frac{Z_{Lk1} + jZ_{ok}\tan(\frac{\beta L}{n})}{Z_{o1k} + jZ_{Lk1}\tan(\frac{\beta L}{n})} \tag{3}$$

where Z_{ok} and Z_{Lk1} are the characteristic and load impedances for that particular section. Z_{ok} may be obtained by [19]

$$Z_{ok} = \frac{60\log\left[\frac{8h}{W_k} + \frac{W_k}{4h}\right]}{\sqrt{\varepsilon_{eff}}} \quad if \quad \frac{W_k}{h} \le 1$$

otherwise (4)

$$\frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W_k}{h} + 1.393 + 0.667\log(\frac{W_k}{h} + 1.444)\right]}$$

where W_k is width of k^{th} transmission line section and L is distance between vertex and bottom of the patch

$$W_k = \frac{d_{eff}\left(n-k\right)}{n}, \tag{5a}$$

$$L = \frac{2d_{eff}}{\sqrt{3}} \tag{5b}$$

$$d_{eff} = d + 3.15\Delta \tag{5c}$$

where Δ and ε_{eff} are fringing field width and effective permittivity respectively [19].

Z_{Lk1} for any section is equal to the input impedance of the previous section and may be written as

$$Z_{Lk1} = \begin{cases} \eta / \sqrt{\varepsilon_{eff}} & if \quad k = 1 \\ Z_{in1(k-1)} & otherwise \end{cases} \tag{6}$$

On the other hand Z_{in2} is the input impedances at probe towards vertex and may be given by

$$Z_{in2} = Z_{in2k} \big| k = p \tag{7}$$

where Z_{in2k} is the input impedance of k^{th} section looking towards vertex ($s \ge k \ge p$), and is defined by

$$Z_{in2k} = Z_{ok} \frac{Z_{Lk2} + jZ_{ok}\tan(\frac{\beta L}{n})}{Z_{ok} + jZ_{Lk2}\tan(\frac{\beta L}{n})} \tag{8}$$

where Z_{LK2} for any section is equal to the input impedance of the previous section and may be written as

$$Z_{Lk2} = \begin{cases} Z_{in3} \| j\omega L_s & if \quad k = s \\ Z_{in2(k+1)} & otherwise \end{cases} \tag{9}$$

Z_{in3} is the impedance at shorting pin position, looking towards vertex and may be written as

$$Z_{in3} = Z_{in3k} \big| k = s \tag{10}$$

where Z_{in3k} is the input impedance of k^{th} section looking towards vertex ($k \ge s$), and is defined by

$$Z_{in3k} = Z_{ok} \frac{Z_{Lk3} + jZ_{ok}\tan(\frac{\beta L}{n})}{Z_{ok} + jZ_{Lk3}\tan(\frac{\beta L}{n})} \tag{11}$$

Z_{Lk3} for any section is equal to the input impedance of the previous section and may be written as

$$Z_{Lk3} = \begin{cases} \eta / \sqrt{\varepsilon_{eff}} & \text{if} \quad k = n \\ Z_{in1(k+1)} & \text{otherwise} \end{cases} \tag{12}$$

Similarly one may obtain the patch impedance if shorting pin is connected between probe and bottom of the patch as shown in Fig. 5.

III. RESULTS AND DISCUSSION

Resonant frequency (which is indicated by the zero input reactance value) and frequency ratio are calculated at different shorting-pin and probe positions for different values of n for the antenna designed parameters: ε_r = 4.4, h = 1.6 mm, d = 50 mm, and r_s = 0.32 mm. These are also calculated for different substrate permittivities having other parameters remain same. The results are plotted and shown in Figs. 6-11.

It is evident from Fig. 6 that at d_s/d_h =0.33, the first resonant frequency (f_{r1}) has a maximum value, while the second resonant frequency (f_{r2}) has a minimum value consequently frequency ratio (FR) is minimum. The minimum FR varies from 2.81–1.68, and it is also observed that it decreases if substrate permittivity increases. While the FR increases if the distance from that point (d_s/d_h =0.33) increases. Maximum FR is observed at the triangle tip. The maximum FR varies from 5.43–5.07, and it is also observed that it decreases if substrate permittivity increases.

Fig. 7, revels that the obtained theoretical results are in good agreement with experimental results obtained by Pan and Wong [27]. It is also observed that the resonance frequencies are almost constant with probe position as shown in Fig. 8.

From Figs. 9-11, it is observed that the nature of graph for variation of resonant frequency with

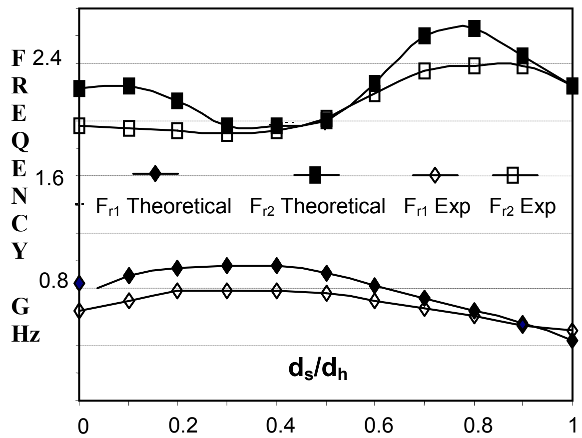

Fig 6: Comparison of theoretical and experimental results [27]

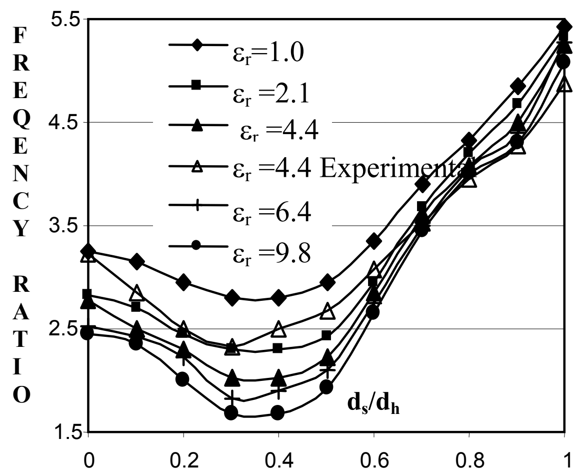

Fig 7: Variation of Frequency Ratio with shorting pin position.

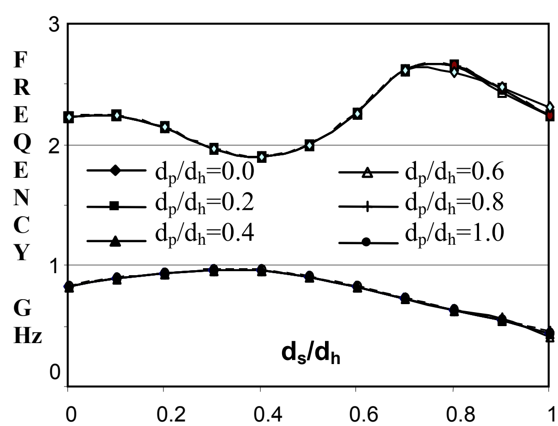

Fig 8: Variation of resonance frequencies with shorting pin position for different probe positions (ε_r=4.4 and d= 50 mm).

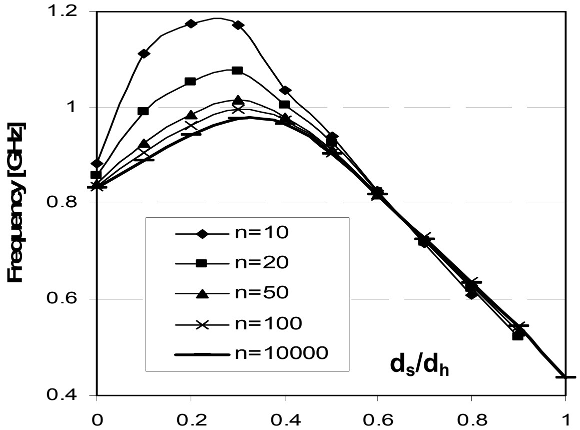

Fig 9: Variation of lower resonant frequency with shorting pin position for different values of n.

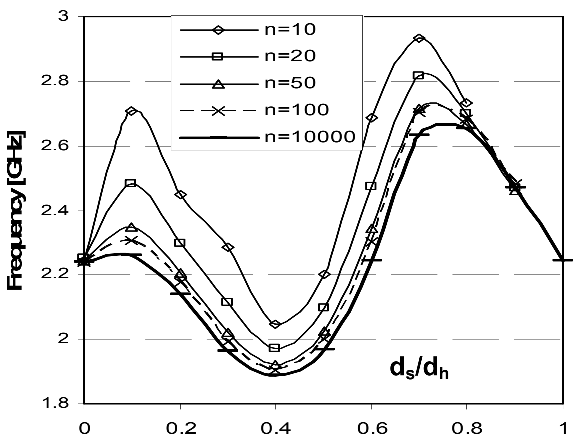

Fig 10: Variation of upper resonant frequency with shorting pin position for different values of n.

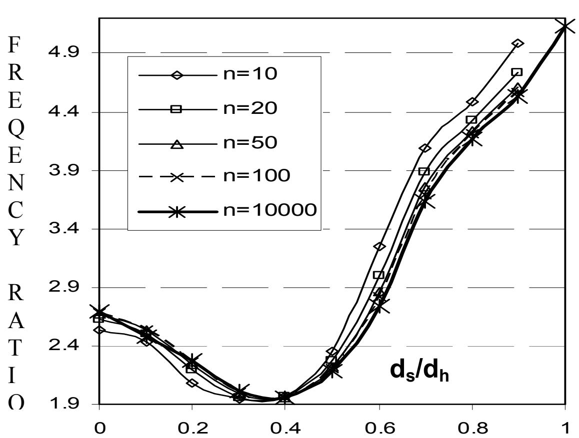

Fig 11: Variation of Frequency Ratio with shorting pin position for different values of n.

shorting pin position for values as small as n=10 is similar to higher values of n such as n=10000 and it is also observed that the graph is in good approximation for n=100. The error between n=100 and n=10000 is less than 3%.

IV. CONCLUSION

In this study we have presented an approximate but computationally very fast method for solving the problem of probe fed ETMSA with a shorting pin. The Transmission Line model is used for the calculation of input impedance. Comparison with the measured results demonstrates the accuracy of the proposed method.

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