Improved Model to Compute Resonant Frequency of Right Angle Isosceles Triangular Patch Antenna with and without Suspended Substrate

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Abstract—**An improved CAD model based on cavity model analysis has been proposed to compute the resonance frequency of a right angle isosceles triangular patch antenna (45^0-45^0-90^0) with and without suspended substrate. The model is found to be valid for wide range of antenna parameters like patch side length, substrate thickness and dielectric constant. A standard electromagnetic simulator (HFSS) has been employed to validate the present model. Better agreement (average % error 1.17) is observed between theoretical and simulated values compared to other model available in literature.**

Keywords— resonance frequency, CAD, right angle isosceles triangular patch, suspended substrate.

I. Introduction

The triangular microstrip patch antenna is physically smaller than rectangular patch antenna without any change in radiation characteristics. It is a well-known microwave network element due to its extensive application in the design of many useful microwave circuit components like circulator, resonators and filters [1]. High Q geometry of triangular microstrip patch antenna supports its application in array configuration with reduced coupling [2]. It is also suitable for used in curved surface due to its conformability.

Among all triangular geometry only equilateral shape has been widely investigated by the researchers [1-7]. Other geometry like right angle isosceles triangular patch antenna (RAITPA) is least investigated till now. The isosceles triangular patch antenna can provide better flexibility compared with equilateral triangular patch antenna in the design of microwave integrated circuit [6]. Only a very few investigations are available in open literature for RAITPA [6, 8]. Among them only Olaimat [8] has predicted theoretically the resonant frequency of RAITPA for dominant and higher order mode. The effect of fringing field is not included in the theoretical model proposed by Olaimat [8]. So, large discrepancy exists between the simulated and theoretical values. Full wave analysis [7] and other commercial software

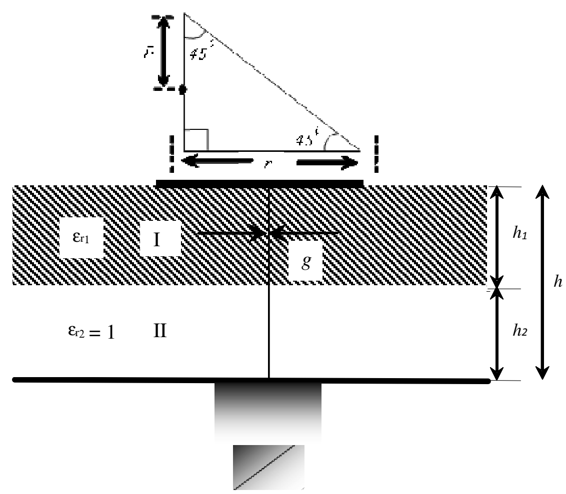


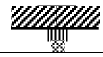
Fig. 1. A schematic diagram of probe-fed right angle isosceles triangular patch antenna on suspended substrate.

[9] are not efficient for direct synthesis of antenna due to their complexity and large time requirement.
We have addressed these issues and proposed a very simple and accurate CAD model based on cavity model analysis to compute the resonant frequency of RAITPA with and without suspended substrate. The present model is valid for wide range of antenna parameter. A standard electromagnetic simulator [9] has been employed to validate the present model. Good correlation has been found between theoretical and simulated values compared to other model available in open literature. For designing the MIC on semiconductor materials with $\varepsilon_r \approx 10$, this model will be widely applicable.

II. Theory

Based on cavity model the resonant $f_{r,nm}$ of T_{nml} modes for a RAITPA with and without suspended substrate as shown in

TABLE I
THEORETICAL AND SIMULATED VALUES OF RESONANT FREQUENCIES OF AN RITPA OPERATED IN DIFFERENT MODES WITH AND WITHOUT SUBSTRATE.
$\varepsilon_r = \varepsilon_{r1} = 2.4$, $h_1 = 1.58$ mm, $r = 60$ mm



h_2 (mm)	Mode	Resonant frequency(GHz)		
		Simulated [9]	Computed	
			Present	Olaimat [8]
0.0	TM_{10}	1.526	1.566	1.614
	TM_{11}	2.164	2.214	2.282
	TM_{20}	3.505	3.131	3.227
	TM_{21}	4.360	3.501	3.608
	TM_{30}	4.621	4.697	4.841
Avg. %Error			1.066	4.058
0.25	TM_{10}	1.711	1.682	1.761
	TM_{11}	2.375	2.379	2.491
	TM_{20}	3.322	3.364	3.522
	TM_{21}	3.768	3.761	3.938
	TM_{30}	4.94	5.046	5.284
Avg. %Error			10092	5.06
0.50	TM_{10}	1.751	1.756	1.866
	TM_{11}	2.468	2.483	2.638
	TM_{20}	3.447	3.512	3.731
	TM_{21}	4.067	3.926	4.172
	TM_{30}	4.998	5.268	5.597
Avg. %Error			1.641	7.994
Total Avg. %Error			1.170	5.704

Fig.1 can be computed using a simple and accurate closed form expression [8, 10-11] as

$$f_{r,nm} = \frac{c}{2 r_{eff} \sqrt{\varepsilon_{r,eff}}} \left(n^2 + m^2 \right)^{1/2} \tag{1}$$

where, c is the velocity of light in free space, $\varepsilon_{r,eff}$ is the effective permittivity of the medium below the patch and r_{eff} is the effective side length of the patch, m, n, l are integers which are never zero simultaneously satisfying the condition $n+m+l=0$.

The effective side length of the RAITPA can be computed as

$$r_{eff} = r(1+q) \tag{2}$$

In equation (2), q arises due to the fringing fields at the edge of patch. The q is obtained from [12] taking equivalence relation between circular and triangular geometry considering equal area as [12]

$$q = q_1 + (1+q_1)(q_2+q_3) \tag{3}$$

$$q_1 = \left(1+\varepsilon_{re}^{-1}\right)(4h/\pi a)$$

$$q_2 = (2/3)\left\{\left(0.37+0.63\varepsilon_{re}\right)^{-1}(8+\pi a/h)^{-1}\right\}$$

$$\ln\left[\left\{1+0.8(a/h)^2+(0.31a/h)^4\right\}(1+0.9a/h)^{-1}\right]$$

$$q_3 = (4+2.6a/h+2.9h/a)^{-1}\left\{(0.37+0.63\varepsilon_{re})^{-1}-1\right\}$$

In equation (3), a is the radius of equivalent circular patch and other variables have usual meaning.

The expression for computing the $\varepsilon_{r,eff}$ can be proposed as [3]

$$\varepsilon_{r,eff} = \frac{\varepsilon_{re}+1}{2} + \frac{\varepsilon_{re}-1}{2}\left(1+\frac{12h}{r}\right)^{-1/2} \tag{4}$$

where, ε_{re} is the relative permittivity of the medium below the patch can be computed as

$$\varepsilon_{re} = \frac{\varepsilon_{r1}\,\varepsilon_{r2}\,h}{\varepsilon_{r1}\,h_2 + \varepsilon_{r2}\,h_1} \tag{5}$$

III. RESULT

Table I shows a comparative study of theoretical and simulated values of resonant frequencies of a right angle triangular patch antenna operated in different modes for different suspended thickness. Here close agreement (avg. % error 1.17) is observed with respect to simulated values compared to Olaimat [8]. The variation of dominant mode resonant frequency of a RAITPA having substrate thickness $h = h_1 = 0.8265$ mm and dielectric constant $\varepsilon_r = \varepsilon_{r1} = 2.4$ as a function of side length is visualized in Fig.2. Theoretical curve employing present model is compared with simulated [10] data and it reveals good agreements between them.

The variation of resonant frequency of a RAITPA on single substrate with substrate thickness ($h = h_1$) for different dielectric constant ($\varepsilon_r = \varepsilon_{r1}$) is visualized in Fig. 3. Here we have compared theoretical curve employing present model with simulated values [10] and it exhibits close correlation for total range of substrate thickness.

Theoretical and simulated variation of TM_{10} & TM_{11} mode resonant frequency as a function of suspended substrate thickness h_2 of RAITPA with fixed upper substrate thickness

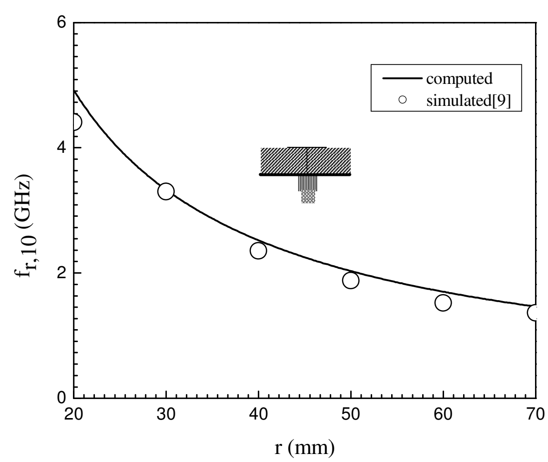


Fig.2. Theoretical and software computed variation of dominant mode resonant frequency of a right angle isosceles triangular patch antenna as a function of side length with substrate thickness $h = h_1 = 0.8265$ mm and $\varepsilon_r = \varepsilon_{r1} = 2.4$.

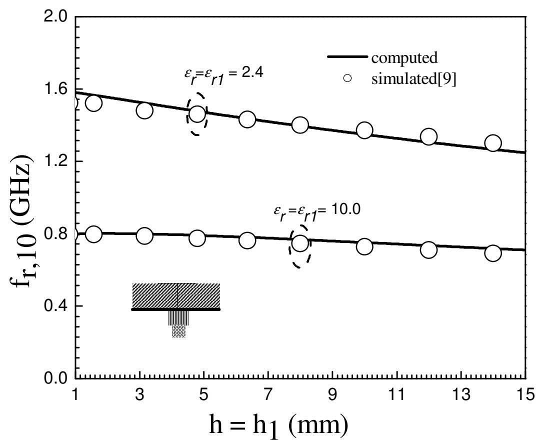


Fig. 3. Theoretical and simulated variation of dominant mode resonant frequency as a function of substrate thickness $h = h_1$ of a right angle isosceles triangular patch antenna with side length $r = 60$ mm.

$h_1 = 1.58$ mm, $r = 60$ mm, $\varepsilon_{r1} = 2.4$, $\varepsilon_{r2} = 1.0$ is shown in Fig.4. Comparison show good proximity between theoretical curve and simulated values [10].

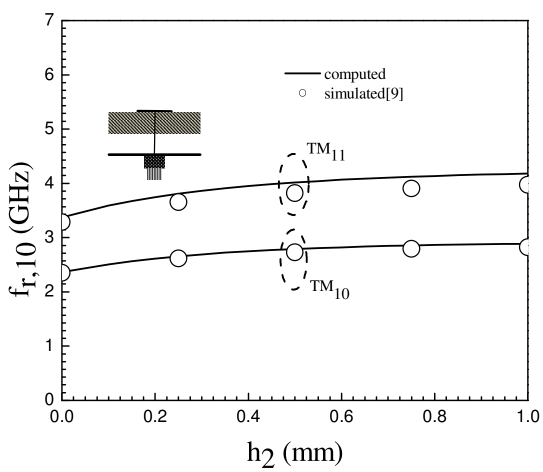


Fig.4. Theoretical and simulated variation of dominant mode resonant frequency as a function of air gap thickness h_2 of a right angle isosceles triangular patch antenna with fixed upper substrate thickness $h_1 = 0.8265$ mm, $r = 40$ mm $\varepsilon_{r1} = 2.4$, $\varepsilon_{r2} = 1.0$.

IV. Conclusion

A very simple and accurate CAD model based on cavity model analysis has been proposed to predict accurately the resonant frequency of a RAITPA with and without suspended substrate. An accurate expression for the effective side length and permittivity of RAITPA is proposed. Computed resonant frequencies of an RAITPA employing present model are compared with simulated. The present model shows very close agreement (average % error 1.17) with simulated values compared to other model. The present model is valid for wide range antenna parameter. For designing the MIC on semiconductor materials with $\varepsilon_r \approx 10$, this model will be widely applicable.

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