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Simulated Study of Printed Dipole Antenna in Various Orientations

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Abstract—*This paper investigates the problems for analysis of microstrip dipole antenna on substrate materials and studies the antenna performance in array configuration. In our design we have transformed conventional wire dipole antenna configurations to corresponding microstrip version. The microstrip dipole antennas mounted on substrate materials have been simulated and the radiation characteristics of the antenna are analyzed. We have also presented the simulated results of 2-element array of center-fed microstrip printed dipole antennas in side by side, echelon and collinear configuration. Our study includes (i) the effect of dielectric material on resonance frequency,(ii) self and mutual impedance, and (iii) bandwidth at center frequency 3GHz. The printed dipole array may be used in satellite communication at higher frequencies*

Keywords*: Bandwidth, Input impedance, Microstrip dipole antenna, Radiation resistance.*

1. INTRODUCTION

Printed dipoles are low-profile planar structures similar the rectangular patch antennas, so their radiation characteristics may be assumed to be similar except for those features that depend on the aspect. Compared to traditional wire antennas, printed dipole antennas have additional advantages including small volume, light weight and low cost, these features made them suitable for space and satellite applications, where size and weight are major considerations. The two element arrays, in side-by-side, collinear and parallel in echelon may be considered as the basic block of larger arrays.

The Microstrip Dipole in arrays configuration and effect of mutual coupling have been studied by number of authors [Yen Hun Yu et. al., 1990; Nesic, Jovanovic S., and Brankovic V,1998; Scoot M. 2001; Prasad Maria Roshini et al. 2012 ; Poongodi C. , Shanmugam A. ,2013].

The objective of our propose work is to simulate parameters of printed dipole and study namely: (a) effect of dielectric materials on resonant frequency,(c) driving point impedance (self & mutual) and (d) bandwidth using simulation software Matlab version-7.9.

2. THEORETICAL FORMULATION

Printed version of Dipole antenna is characterized by narrow strip width in the range of $0.05\lambda_0 \leq W \leq 0.1\lambda_0$ and overall length is about half the wavelength in dielectric medium. The radius of conventional wired dipole can be transformed into equivalent radius which is about one fourth of strip width for zero metallization thickness [6].

2.1 Effective dielectric constant and fringing length extension

The effective dielectric constant (ϵ_{ef}), fringing length extension ΔL, of printed dipole can be expressed as [6]:

$$\epsilon_{ef} = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon_r-1)}{2}\left[1 + \frac{12L}{h}\right]^{-1/2} \tag{1}$$

$$\Delta L = 0.412h\frac{(\epsilon_{ef}+0.3)\left(W/h+0.264\right)}{(\epsilon_{ef}-0.258)\left(W/h+0.8\right)} \tag{2}$$

Where ϵ_r is relative permittivity, **L**, **W** & **h** are dipole length, strip width and substrate height respectively.

Similarly equivalent radius (a_e), length, width, resonant frequency (f_r), input impedance (Z_{in}) and VSWR bandwidth (BW) of printed dipole can be expressed as [7]:

$$a_e = \frac{w}{4} \tag{3}$$

$$f_r = \frac{c}{2L\sqrt{\epsilon_{ef}}} \tag{4}$$

$$L = c/2f\sqrt{\varepsilon_{ef}} - 2\Delta L \tag{5}$$

$$W = c/20f \tag{5a}$$

$$Z_{in} = R_{in} + jX_{in} \tag{6}$$

The bandwidth (BW) of the center-fed dipoles for the **VSWR ≤ 2** can be expressed as:

$$BW = \frac{1}{\sqrt{2}}\frac{W}{\lambda_0}\frac{h}{\lambda_0}\frac{4\pi^2}{5\sqrt{\epsilon_{ef}}} \tag{7}$$

The expressions for self (Z_{11}) and mutual (Z_{21}) impedance for wired dipole in free space as given in [6] have been modified for printed dipole in substrate with the concept of equivalent radius and guided wavelength ($\lambda_d = \lambda_0/\sqrt{\varepsilon_r}$). The driving point impedance (Z_d) includes effect of mutual coupling and it is a sum of self and mutual impedance and can be expressed as:

$$Z_d = Z_{11} + Z_{21} \tag{8}$$

3. SIMULATION

Simulations of eqn. (1)-(8) are carried out in MATLAB Platform to study the various characteristics of the printed dipole. First we simulate fractional change in resonant frequency with different dielectric substrate and height as a function of frequency and response is shown in **Fig.1.** We have carried out simulation for radiation efficiency as a function of observed frequency as shown in **Fig.2.** Similarly, self-resistance, reactance and bandwidth of printed dipole with various strip width are also simulated and the responses are shown in **Fig.3-Fig.4.** The two-element identical array of printed dipole in side-by-side, collinear and Parallel in Echelon configuration is simulated for mutual resistance, reactance as a function of frequency with different element spacing and also mutual impedance and driving point impedance as function of element spacing at fixed frequency is carried out and responses are shown in **Fig.5-Fig.16**. At last we simulate the return loss & VSWR for single element printed dipole and responses are shown in **Fig.17-18**.

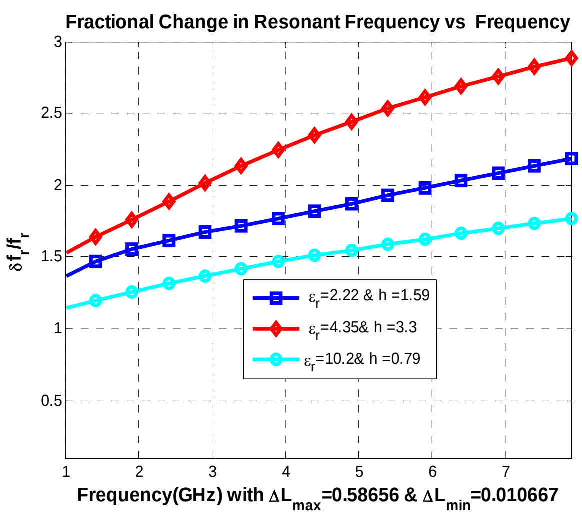

Fig. 1: Fractional change in resonant frequency with different substrate material and heights

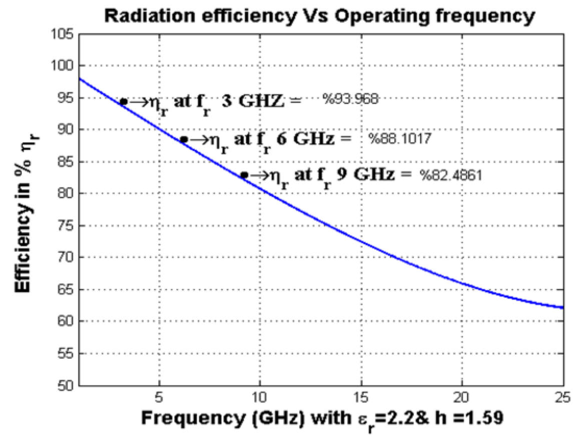

Fig. 2: Radiation efficiency as a function of frequency with ϵ_r=2.2 & h=1.59 mm

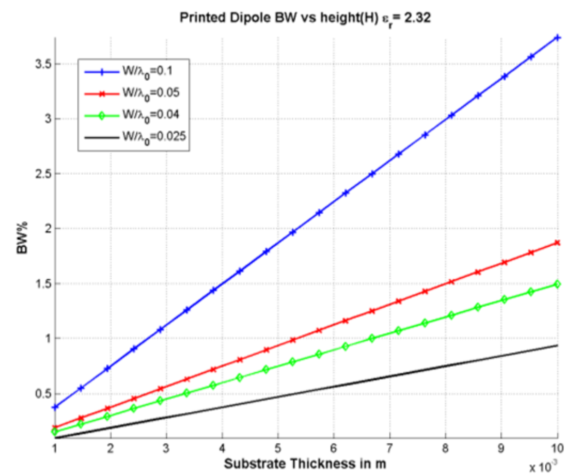

Fig. 4: BW with different strip width as function of substrate height

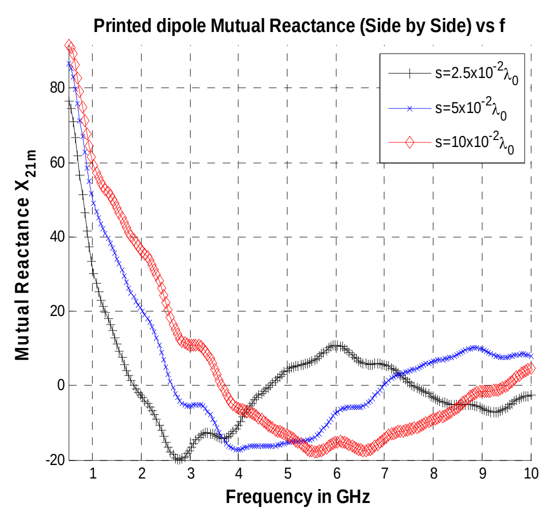

Fig. 6: Mutual Reactance as a function of frequency with different element spacing (side-by side)

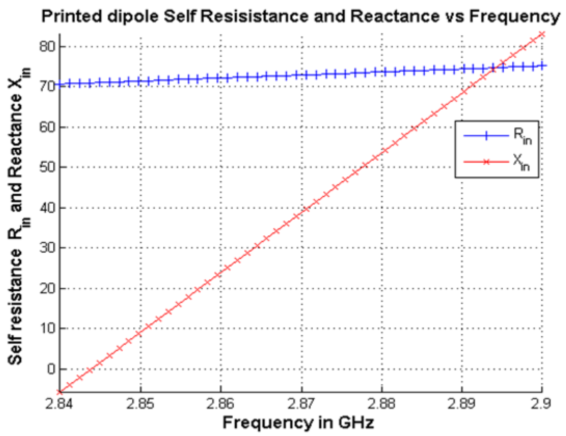

Fig. 3: Self-Resistance & Reactance of Printed dipole as function of frequency

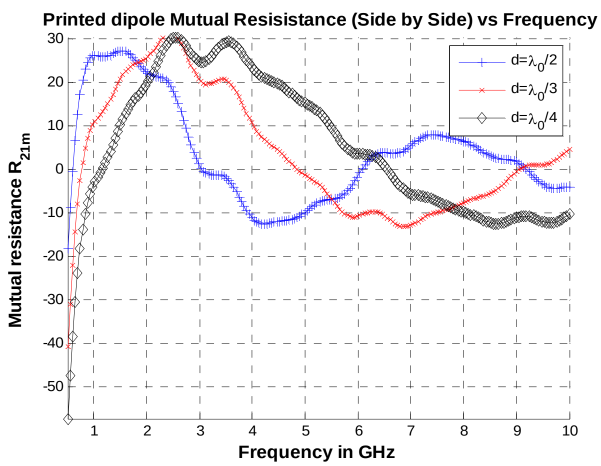

Fig. 5: Mutual Resistance as a function of frequency with different element spacing (side-by side)

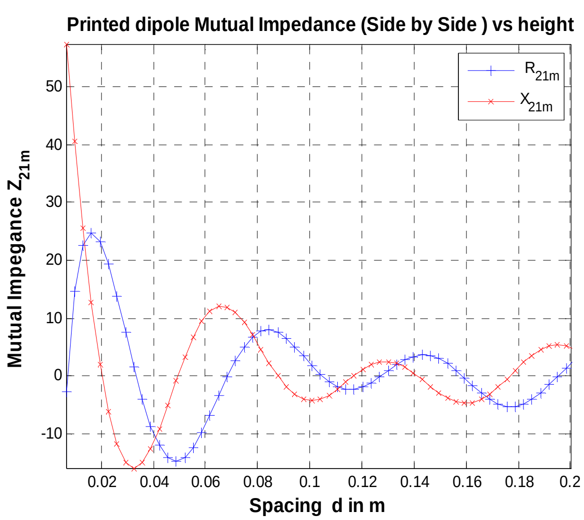

Fig. 7: Mutual impedance as a function of element spacing (side-by side)

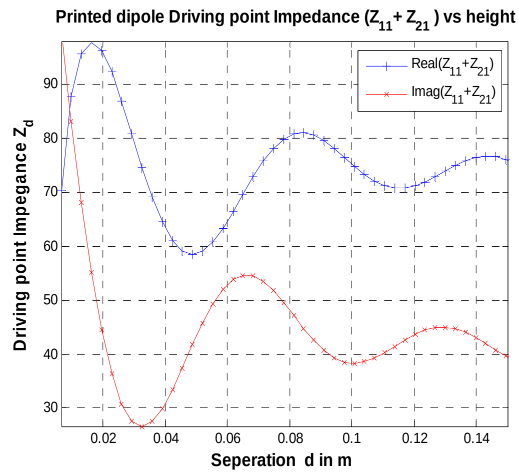

Fig. 8: Driving Point impedance as a function of element spacing (side-by side)

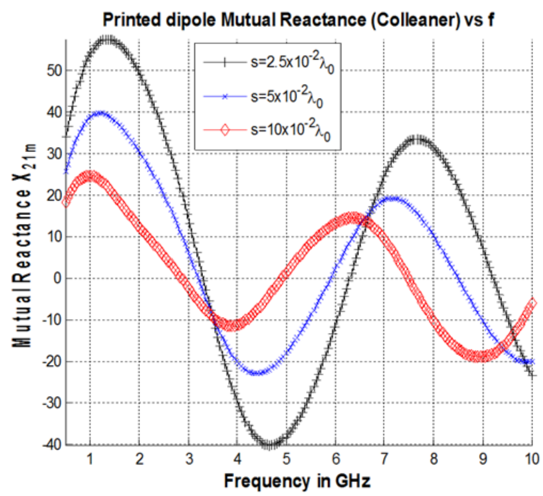

Fig. 10: Mutual Reactance as a function of frequency with different element spacing (Collinear)

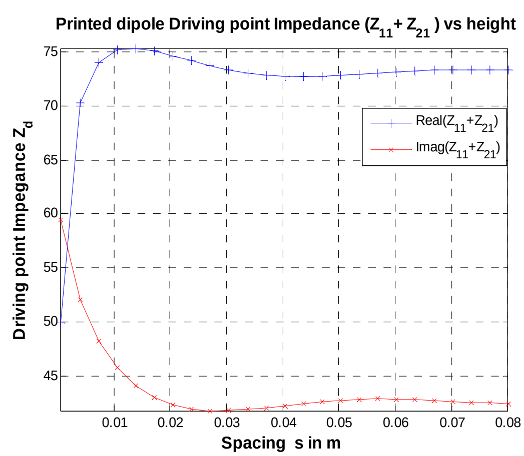

Fig. 12: Driving Point impedance as a function of element spacing (Collinear)

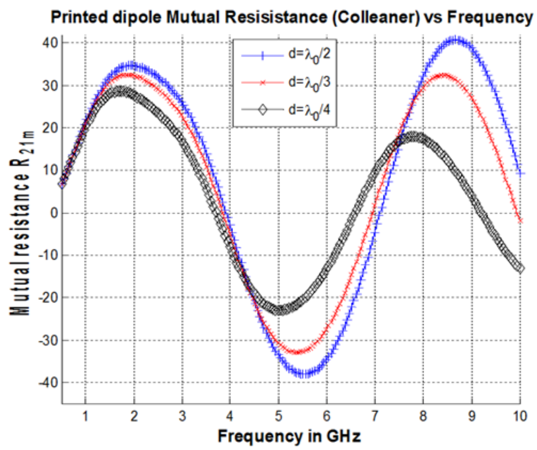

Fig. 9: Mutual Resistance as a function of frequency with different element spacing (Collinear)

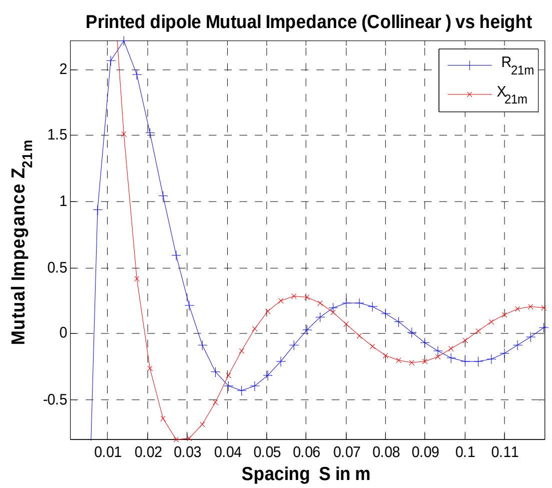

Fig. 11: Mutual impedance as a function of element spacing (Collinear)

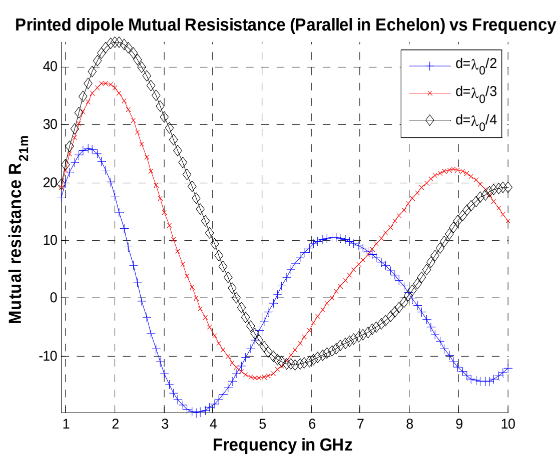

Fig. 13: Mutual Resistance as a function of frequency with different spacing (Echelon)

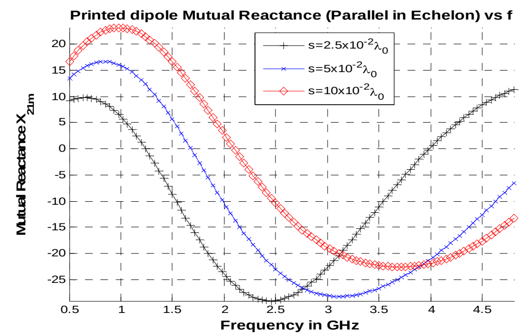

Fig. 14: Mutual Reactance as a function of frequency with different spacing (Echelon)

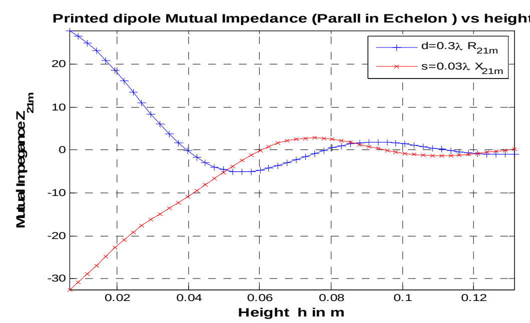

Fig. 15: Mutual impedance as a function of separation (Parallel in Echelon)

4. RESULTS AND DISCUSSION

The geometrical shape of the printed dipole and the rectangular patch are similar but their BW and driving point impedance are significantly different. The resonant frequency and efficiency depends on relative permittivity and substrate height, for thick substrate fractional change in resonant frequency increased and efficiency decreases. The **BW** increases with increase in strip width and substrate height. In order to achieve large **BW** efficiency has to be sacrificed. Computed **BW** in percentage and maximum efficiency ($\boldsymbol{\eta_{max}}$) is shown in **Table-I.** The simulated **BW** for single element printed dipole (**Fig.18**) is about **600MHz** or **24.2%** with centre frequency **2.5 GHz** for **VSWR** $\leq$ **2**. The self-resistance and reactance values are nearly equal to wire dipole. Comparative study of two element printed dipole array in side by side, collinear and parallel in Echelon configurations is performed by simulating antenna parameters and the results are shown in the **Table-II-III**. Maximum mutual Coupling occurs in side by side configuration. It can be seen that minimum coupling occurs in parallel in Echelon configuration where driving point impedance (sum or difference of self and mutual impedance) attains minimum value for about **4mm** element spacing. The return loss and VSWR are within the measured values (-20dB and 1.1).

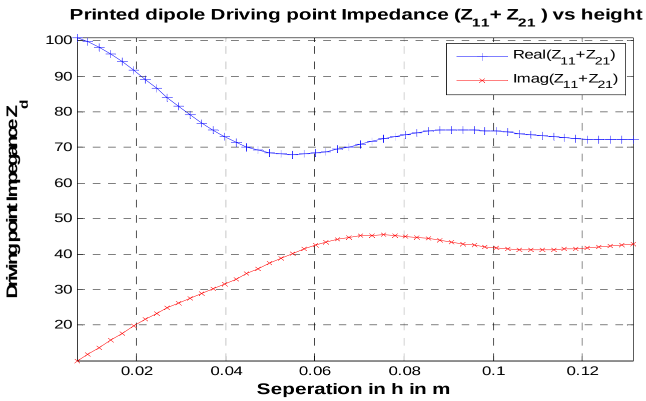

Fig. 16: Driving Point impedance as a function of separation (Parallel in Echelon)

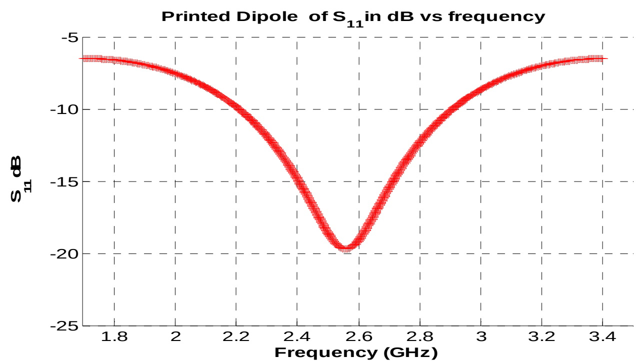

Fig. 17: Return loss (dB) as a function of frequency

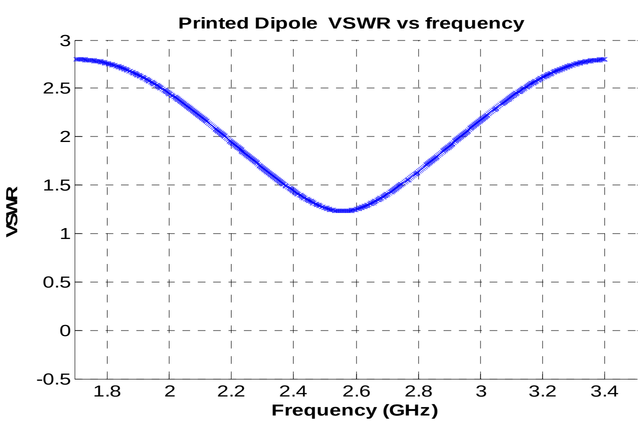

Fig. 18: VSWR as a function of frequency

Table I: Comparison of BW and efficiency of printed dipole with different width

ϵ_r	h mm	W mm	L mm	BW% Dipole	η_{max} %	ε_{ef}
2.32	5	8.9	36.7	5	82.5	1.94
3.7	5	8.5	29.5	4.1	72.5	2.9
6.15	5	8.3	23.4	3.26	66.1	4.57

Table-II

Self, mutual and driving point impedance of printed dipole in side-by-side configuration

L mm	Z_{11} Ω	d mm	Z_{21} Ω	$Z_d=Z_{11}+Z_{21}$ Ω
32.8	73.13 +42.54i	6.6	-2.63 +57.41i	70.5+99.95i
32.8	73.13 +42.54i	23	19.02 - 6.5i	92.15 +36.04i

Table-III

Self, mutual and driving point impedance of printed dipole in collinear configuration

L mm	s mm	Z_{11} Ω	Z_{21} Ω	$Z_d=Z_{11}+Z_{21}$ Ω
32.8	0.49	73.1 +42.5i	25.4+15i	98.6 +57.5i
32.8	4.9	73.1 +42.5i	17.4 -1.3i	90.54 +41.2i

5. CONCLUSION

On the basis of theoretical and simulated analysis of the Printed microstrip dipole antenna with three dielectric substrates, design parameters of the antenna have been calculated and are tabulated. The printed antenna can perform well in array configuration when the real part of driving point impedance is maximum. The antenna can be made to operate in the frequency range of 1-10 GHz with proper adjustment of antenna orientation to radiate in end fire or in broad side direction. The Return loss and VSWR values are of the order of standard experimental values.

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