Improved Impedance Matching of Dual-Frequency Microstrip Printed-Dipole Antenna with Conductor Back

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Abstract: A novel dual-frequency microstrip printed-dipole antenna operating at 5 GHz and 10 GHz is presented. This antenna is designed for wireless and mobile communication. The balance step coplanar strip is used to be a transmission line at the center of dipole with matching impedance at 50 ohm. Using the conductor strip align on the other side of antenna and adjust the width of step coplanar strip line to improved input impedance matching. By modification for matching impedance of dual frequency antenna are not affected to the radiation patterns. The Finite Difference Time Domain (FDTD) technique is applying to analyze the basic characteristic properties such as S_{11} , input impedance , VSWR and radiation patterns. And these parameters are discussed. The analyze problem space are 51 x 197 x 175 cells and cell dimension are Δx = 0.3 mm and $\Delta y = \Delta z$ = 0.15 mm.

Keywords: microstrip, dipole, antenna, dual-frequency, matching, FDTD

1. INTRODUCTION

Over the past decade microstrip antenna are very useful because of their advantages over the conventional antennas such as light weight, low cost and low profile. One of its well-known is printed-dipole antenna. Their attractive elements owing to desirable properties such as small size, linear polarization, higher input resistance (easier to match) and attain significant bandwidth. The choice of feed line is very important in the microstrip dipoles and should be include in the analysis. Coplanar strip (CPS) line is an attractive uniplanar transmission line for solid-state device integration. It comprises two adjacent conductive strips on one face of a dielectric substrate. Its useful in printed dipole antenna because of their properly structure and feeding characteristic are satisfaction.

2. ANALYTICAL METHOD

The Finite Difference Time Domain (FDTD) technique was used to analyze this antenna. A novel numerical algorithm was presented by K.S Yee. FDTD method is very useful in analytical the complex antenna, high-frequency circuit and wireless application system. Due to its advantages like extreme simplicity, flexibility, reduce the computation time compare with frequency-domain technique and can applying to all types of electromagnetic problems from simple structure to complicated structure. This method solve electromagnetic problem in time domain. It divides the problem space into small rectangular cells call 'Yee cell'. The properly time step (Δt) that relative to the space increments (Δx, Δy and Δz) is required to derive the Maxwell's equation. To ensure the numerical stability of the leap-frog algorithm. The following equation show the time step expression.

$$\Delta t \le \frac{1}{c}\sqrt{\frac{1}{(\Delta x)^2}+\frac{1}{(\Delta y)^2}+\frac{1}{(\Delta z)^2}} \qquad (1)$$

Where c is the light velocity and Δx , Δy , Δz are cell dimension. The analysis problem space of 51 x 197 x 175 cells with the cell dimension are Δx = 0.3 mm and Δy = Δz = 0.15 mm.

3. ANTENNA GEOMETRY

3.1 Antenna design

This paper presents a new dual-frequency microstrip printed-dipole antenna shown in Fig 1. Glass bonded-mica was used as a substrate with a dielectric constant and thickness of 7.5 and 2.4 mm, respectively. By use the FDTD software to simulate electromagnetic problem. The basic characteristics are discussed.

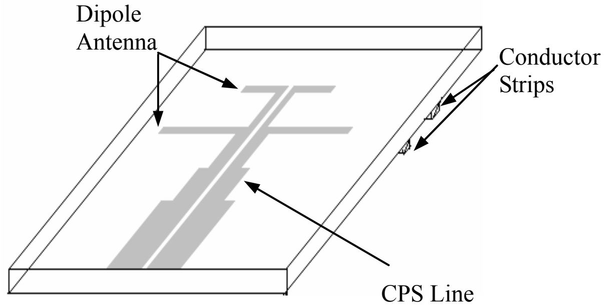

Fig 1. Antenna Structure

The layer thickness is a thin plate compare with the wavelengths of the design dual-frequencies (5 GHz and 10 GHz). An antenna consists of two different wavelengths dipole parallel strip aligned on the surface of substrate. The step coplanar strip line is used to be a feed line at the center of half wavelength dipole on the same plane. The dipole antennas are designed for dual frequencies at 5 GHz and 10 GHz. Each dipole antenna independent according to their operating frequency with 50 ohm input impedance. The short dipole is designed for 10 GHz and the long dipole is designed for 5 GHz. Both dipoles are long approximate to half wavelength of their frequency. The length of antenna can define from following equations, Eqs. (2) ~(3).

$$\lambda_g \approx \frac{c}{f\sqrt{\varepsilon_{eff}}} \quad (4)$$

where

$$\varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2} \quad (3)$$

where

- f is a design frequency
- λ_g is a design frequency wavelength
- ε_{eff} is an effective permittivity
- ε_r is a relative permittivity

The pulse signal source, Gaussian pulse, was used to excite along the feed line at input port of the circuit. The input voltage $v(t)$ of signal source can express as Eq. (4)

$$v(t) = e^{-\left(\frac{t-t_0}{T}\right)^2} \quad (4)$$

Where t_0 is the center of the pulse
T is the pulse width at its $1/e$ characteristic decay point

When operating, current flow along CPS line and flow to long dipole and short dipole, respectively and induces the radiation. Hence, careful design of the distance between long and short dipole is required to avoid the current coupling. And improved the matching impedance by align conductor strip on the other side of substrate at the antenna located and adjust the properly width of CPS line.

3.2 Antenna configuration

Fig 2. shown the configuration of the proposed dual-frequency microstrip printed-dipole antenna with conductor back fed by step CPS line. This antenna is printed on a substrate of thickness h =2.4 mm and relative permittivity, ε_r = 7.5. The configurations of antenna are as follows;

The length of long dipole (L_1)	=	0.49 λ_g of 5 GHz (f_1)
The length of short dipole (L_2)	=	0.45 λ_g of 10 GHz (f_2)
The width of long dipole (w_1)	=	0.45 mm
The width of short dipole (w_2)	=	0.6 mm
The distance of step CPS line d_1	=	0.25 λ_g of f_1
The distance of step CPS line d_2	=	0.125 λ_g of f_1
The distance of step CPS line d_3	=	0.125 λ_g of f_1
The distance of step CPS line d_4	=	0.125 λ_g of f_2
The width of step CPS line w_3	=	1.5 mm
The width of step CPS line w_4	=	1.2 mm
The width of step CPS line w_5	=	adjust
The width of step CPS line w_6	=	adjust
The gap (g) between dipole legs	=	0.15 mm

And the width of conductor strips that align on the other side of design dual-frequencies (5 GHz and 10 GHz) are equal to the width of antenna at their located.

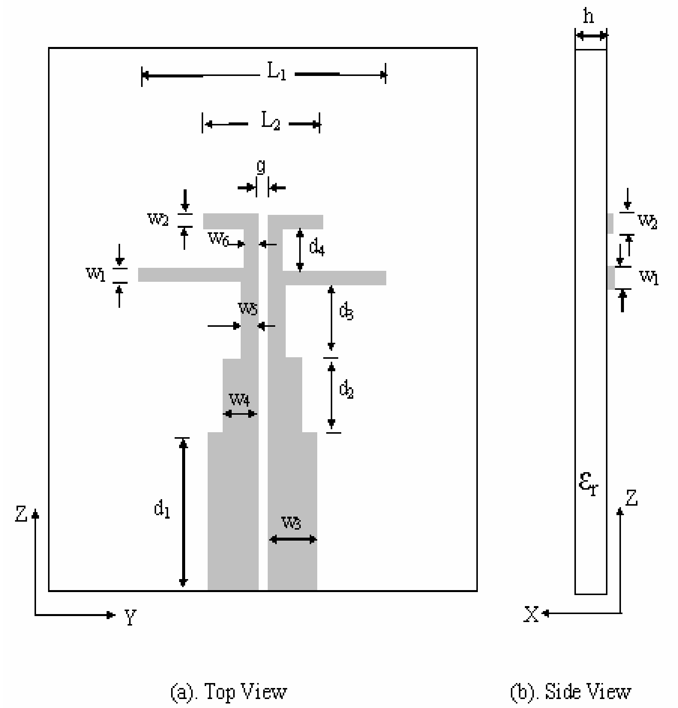

Fig 2. Antenna Configuration

3.3 Simulation

The antenna was designed for two frequencies at 5 and 10 GHz. And the conductor strip is used to improve matching impedance by aligned at the backside of antenna plane. After that the width of CPS line (w_5 or w_6) is adjusted for the best matching impedance of two frequencies. By FDTD software program, the antenna was tried to simulate in 4 cases.

I. Antenna has not conductor located at backside.
II. Conductor strip located at the backside of long antenna.
III. Conductor strip located at the backside of short antenna.
IV. Conductor strip located at the backside of both antennas.

And the basic characteristic results are discussed.

4. SIMULATION RESULTS

The basic characteristic results from FDTD simulation are shown in table1. And discussed in the below section.

Table 1. The basic characteristics of printed-dipole antenna.

Characteristics / Frequency resonant (GHz)		S_{11} (dB)	Z_r (Ω)	Z_i (Ω)	VSWR
CASE I	f_1 = 5.07	-13.39	74.72	-10.31	1.54
	f_2 = 10.06	-24.26	56.51	0.296	1.13
CASE II	f_1 = 5.03	-27.87	54.07	-1.04	1.08
	f_2 = 10.06	-29.56	52.31	-2.53	1.06
CASE III	f_1 = 4.98	-35.18	51.72	0.41	1.035
	f_2 = 9.97	-34.07	49.19	1.799	1.04
CASE IV	f_1 = 5.03	-19.38	41.29	4.55	1.24
	f_2 = 9.97	-24.39	44.93	2.67	1.13

4.1 Return Loss (S_{11})

The return losses of the dual-frequency microstrip printed-dipole antenna are depicted in Fig 3. and Fig 4. And the results are shown in table 1. Fig 3. shown the S_{11} parameters compare between the antenna without conductor strip at backside and the antenna with conductor strips at backside of both antennas place. The results of S_{11} parameters of the antenna with conductors back are better than the other case. In case IV, the conductor strips at the backside should be improved the impedance matching and for the better result the width of CPS line (w_5 and w_6) was adjusted. The figure below shown the distinguish result between case I and case IV at f_1, the S_{11} of case IV was down more than case I clearly, but their are not at f_2 the S_{11} of two case are close to -25 dB. Even though the results are improved but it's not good enough.

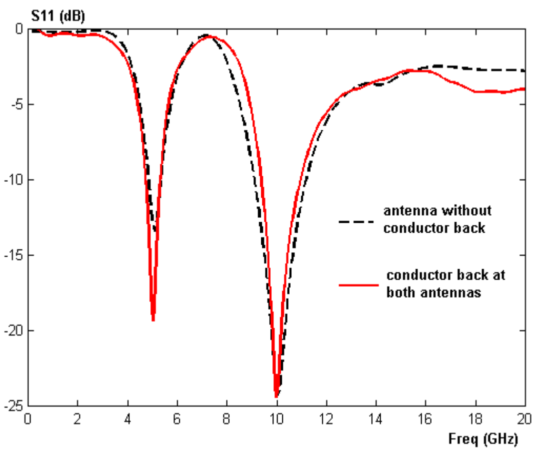

Fig 3. Return Losses compare with cases I and case IV

To consider in case of antenna with conductor located at backside for case II and III show in Fig 4. Case II, when located the conductor strip at the backside of long dipole place. The return loss of high frequency (10 GHz, L_2) was down more than the return loss of low frequency (5 GHz, L_1). By adjust the properly width of CPS line (w_5) the return loss of low frequency was improved. On the contrary, in case III, when located the conductor strip at the backside of short dipole place. The return loss of low frequency was down more than the other one and improve the return loss of high frequency by adjust the properly width of CPS line (w_6).

From the simulation results in case of conductor located at backside of antenna and compare them. The S_{11} parameters of case III has received the best result and the values between f_1 and f_2 are nearly to -35 dB. So the next section should be shown only detail in case III.

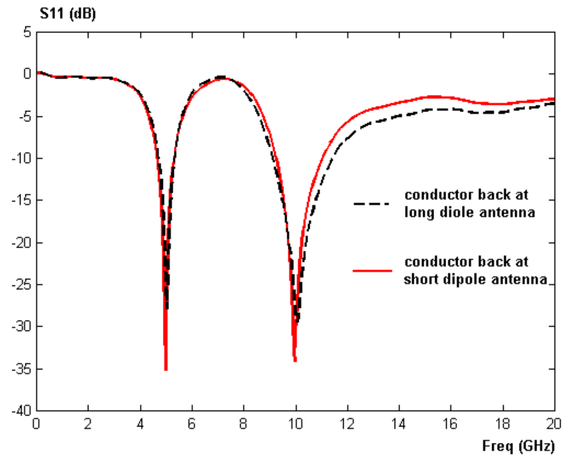

Fig 4. Return Losses compare with cases II and case III

4.2 Input Impedance (Z_{in})

The input impedance is one of the most significant characteristics. It relative with the S_{11} parameter for the less reflected wave the impedance should be matched. The input impedance at input port must be matched with source and load because of the impedance value change along feed line. So the matching impedance is necessary for design antenna.

From table 1. the best of input impedances of two frequencies are occurred at case III shown in fig 5. The input impedance of f_1 and f_2 in real and imaginary parts are 51.72, 0.41 Ω and 49.19, 1.799 Ω, respectively. Which they close to 50 Ω for real part and close to 0 Ω for imaginary part at the resonance frequency.

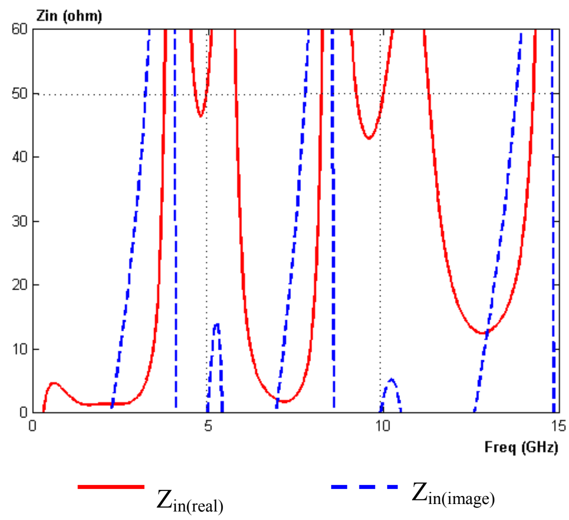

Fig 5. The input impedance

4.3 VSWR

VSWR characteristic show the antenna performance that relative with reflected wave. The VSWR , denoted by ρ, can define by the ratio between the maximum voltage V_{max} and the minimum voltage V_{min} as Eq. (5).

$$\rho = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{5}$$

Where Γ is the reflection coefficient and it defined according to the following equation:

$$\Gamma = \frac{Z_i - Z_o}{Z_i + Z_o} \tag{6}$$

Where Zi is input impedance

Z_o is characteristic impedance

From table 1. The best of VSWR characteristic is in case III shown in Fig 6. These figure shown the nearly values of VSWR between f_1 and f_2 are 1.035 with 12.8% bandwidth and 1.04 with 18.29% bandwidth, respectively. These values are in the maximum mismatch value to be expected for standard communication system.

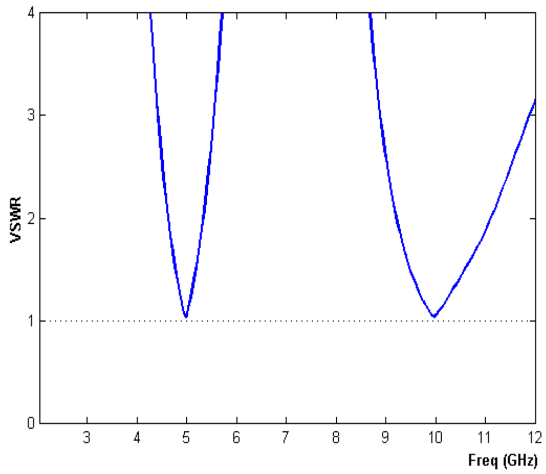

Fig 6. VSWR of the antenna in case III

4.4 Radiation Patterns

The radiation patterns should be affected from the modify design antenna for matching impedance of dual frequency antenna but it's not significant. So all cases of antennas simulation have the same shape of radiation patterns. The radiation patterns at dual frequencies are shown in Fig 7. and Fig 8., respectively. A center-fed coplanar strip dipole radiate wave propagation in forward directional from center of antenna and cross polarization is very low. Fig 7. shown the radiation patterns on electric field of two frequencies are likeness and their shape are base on ordinary shape of dipole pattern. Fig 8. shown the radiation patterns on magnetic field of two frequencies. The shape of low frequency is similar to the ordinary shape. But the shape of high frequency should be some affected from the strip of long dipole so its pattern is not omni.

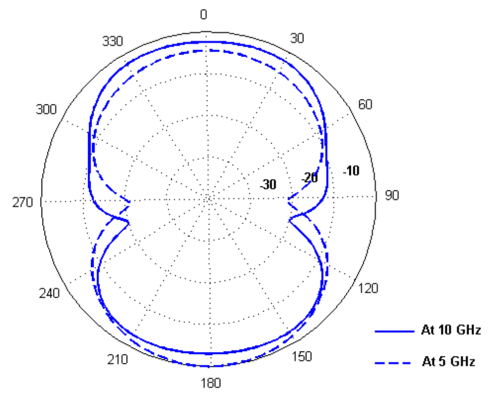

Fig 7. Radiation Patterns on electric field

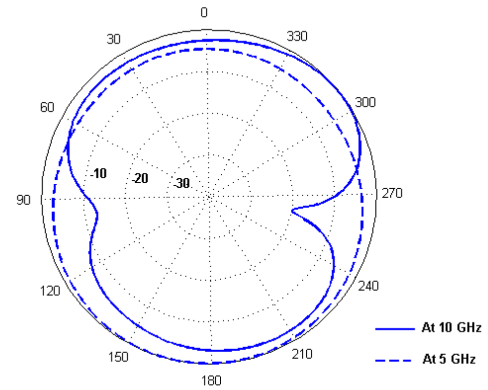

Fig 8. Radiation Patterns on magnetic field

5. CONCLUSION

A novel microstrip antenna has been proposed to operate at dual frequencies. The microstrip is a single layer printed-dipole antenna fed by coplanar strip line. Improve matching impedance with conductor at backside of the dipole antenna and adjust the width of CPS line.

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