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Polarization Diversity Printed Dipole Antenna Using PIN Diode Switching For Wireless LAN Applications

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Abstract— In this paper, polarization diversity antenna system is implemented by using two orthogonally placed printed dipole antennas to achieve the vertical and horizontal polarization for ISM band applications. Simulation, fabrication & measurements are carried out for polarization diversity printed dipole antenna at 2.4GHz centre frequency. Here two orthogonal printed dipoles are simulated in HFSS simulation software and are fed by using via balun structure. A p-i-n diode (HSMP 1321) is used to switch between vertical and horizontal polarization for the respective antenna and the specified polarization is achieved. The simulation of PIN diode is done using ADS simulation software. The whole structure is fabricated on FR4 substrate having dielectric constant 4.4. The simulated results of antenna include VSWR, return loss and the radiation pattern.

***Index Terms*—Polarization Diversity, Printed Dipole Antenna, High Frequency PIN Diode, HFSS Simulation Software.**

I. INTRODUCTION

Today's requirement for the effective wireless communication is that the received signal should be without any fading and degradation in the signal components. Multipath propagation effect degrades usually the wireless system performances. Antenna Diversity in one of the several methods that have been studied to mitigate this phenomenon. This technique can overcome the multipath fading improving the overall performance of communication system. This will leads to design such an antenna which will provide the effective communication in complicated environment.

Due to the presence of large buildings or towers or any other obstacle in the signal path, wireless signal may get distorted from its original path. So, the characteristics of the signal such as polarization, SNR ratio get changed. The polarization diversity antenna will provide the best solution to this problem. The antenna will be designed at 2.4GHz centre frequency which is suitable for wireless LAN applications. The implementation of antenna diversity can increase the channel capacity and reduce the multi-path interference. The condition for diversity antennas is that they should be of the same type and gain [10].

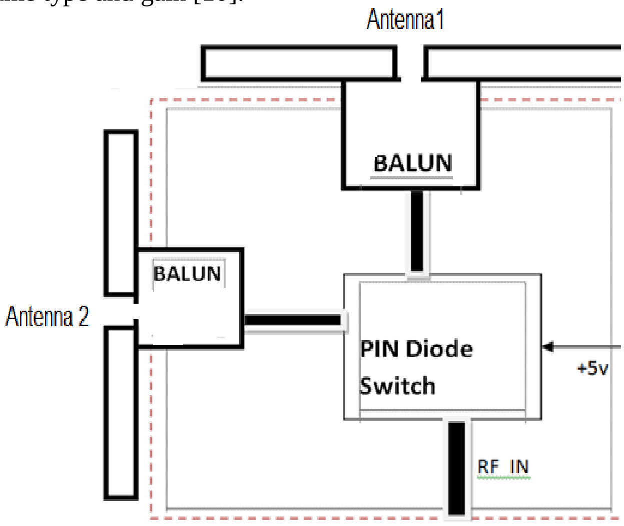

Fig.1.Block Diagram of Polarization Diversity System with P-I-N Diode Selection Circuit

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Antenna diversity involves the use of multiple antennas to receive multiple instances of the same signal. This allows the system to be more robust against the many factors that degrade signal reliability. A single antenna may not be able to receive a signal for several reasons. Two orthogonal printed dipole antennas are designed fed by using a via hole balun. A p-i-n diode selection ckt. is used to switch between two particular antennas to select the desired polarization, so that receiving the signal with minimum fading is possible. The basic block diagram of the system is shown above.

II. PRINTED DIPOLE ANTENNA DESIGN

The simulation part of printed dipole antenna is done by using HFSS simulator. A FR4 substrate with thickness of 1.6 mm and dielectric constant of 4.4 is selected for the design of whole circuit. The use of via hole balun helps to show the broadband nature of the dipole. The via-hole connects the microstrip line on the top layer to the right dipole arm on the bottom layer. This dipole arm will now have the same phase as the microstrip line. The dipole arm length and the microstrip feed line are approximately quarter-wavelength at the resonant frequency [1]. Figure.2. below shows the printed dipole antenna with via hole balun. The via hole balun structure is used to feed the current to the dipole structure on the another side. A microstrip via-hole balun acts as an unbalance-to-balance transformer from the feed coaxial line to the two printed dipole strips. The lengths of the dipole-arm strip and the microstrip balun are all approximately a quarter wavelength [5]. In particular, the microstrip line at the top layer feeds the dipole arms, and the integrated balun helps to cancel the current flowing on the outside part of the outer conductor at the coaxial line that is connected to the SMA connector [9].

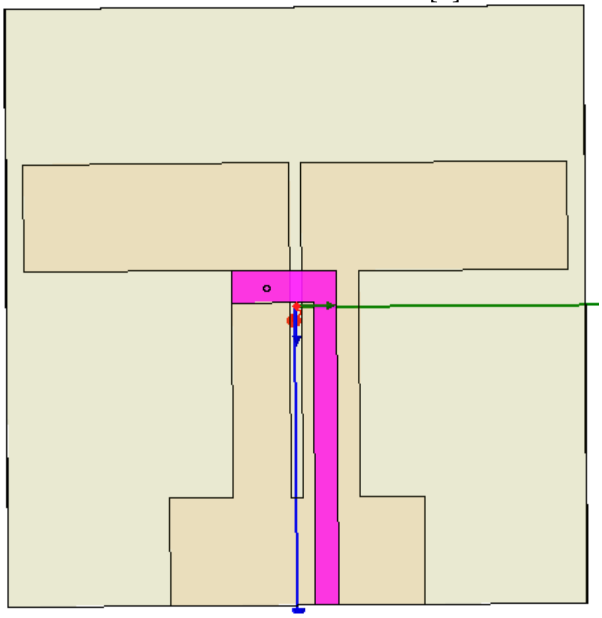

Fig 2. Printed dipole antenna with balun structure

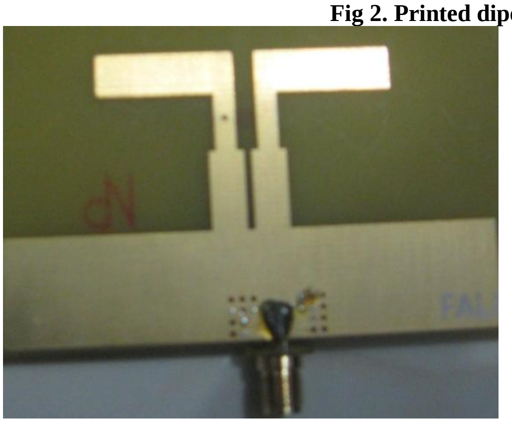

Fig.3(a)

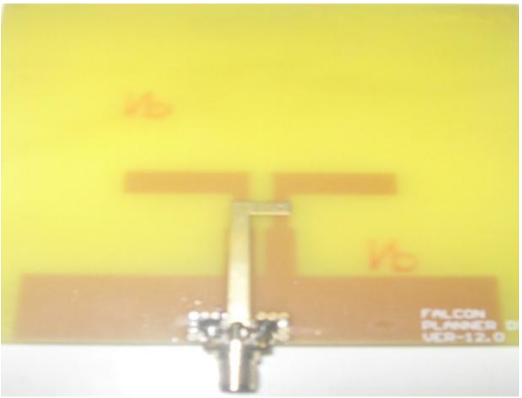

Fig.3(b)

Fig.3.Photographs of fabricated dipole antenna (a)Bottom layer (b)Top layer

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III. PIN DIODE SELECTION CRITERION

A SMP-1321 series PIN diode from Skyworks solutions is used for polarization switching between the vertical and horizontal components of the linearly polarized wave [11]. The terminals of the balun are connected to pin diode ckt. A bias voltage of 3V is fed through dc line. The bias ckt. Includes resistors, RF-choke inductors, and dc-block capacitors. A unique feature of the PIN diode is its ability to control large amounts of RF power with much lower levels of DC. When the control current is switched on and off, or in discrete steps, the device can be used for switching. In addition, the PlN's small size, weight, high switching speed, and minimized parasitic elements make it ideally suited for use in miniature, broadband RF signal control components. In the design of a strip line or microstrip SPDT PIN diode switch, bandwidth and physical construction are often important considerations.

The equivalent R-L-C circuit models of a p-i-n diode containing packaged parasitic effects can be extracted from the measured S-parameters. The p-i-n diodes are with self-protect resistors of forward-biased current, RF choke inductors, and dc block capacitors to isolate the dc bias from the RF signal. The dc block capacitors should have very low impedance at the RF frequency, while the RF choke inductors should have very high RF impedance. A quarter wavelength meander line can be on the PCB substrate to replace the RF choke inductors. Since the maximum forward-bias current of the p-i-n diode [5] (HSMP-1321) is I_f =10 mA (with a forward voltage V_f =0.85V), a self-protect resistor R=3Ω should be added for the forward-bias 5 V[5]. A dc block capacitors with C=0.25pF to have a very low impedance at the RF frequency is chosen. Figure below shows the simulated structure of two printed dipoles with p-i-n diodes and its bias circuit in ADS component library.

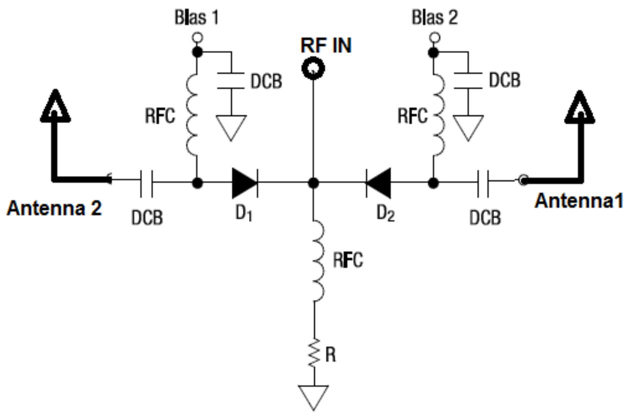

Fig.4. Circuit diagram of the p-i-n diode with two antennas simulated in ADS.

IV. POLARIZATION DIVERSITY PRINTED DIPOLE ANTENNA

The simulated model parameters of the printed dipole antenna in HFSS are used to fabricate the same model on FR4 substrate.The substrate thickness is 1.6mm with dielectric constant 4.4. The conductor thickness of the copper on patch side is 50μn. The dimension of each printed dipole is the same as the single dipole. The ground plane size is 35*30 mm. Each printed dipole has a microstrip via-hole balun as shown in fig.5 (a). The table below gives the structural parameters used for the antenna that will helps to achive good results.

Table 1.Specifications of proposed antenna

	ANTENNA 1 & ANTENNA 2
SUBSTRATE MATERIAL	FR -4(NAN-YA-PLASTIC)
SUBSTRATE THICKNESS	1.6 mm
LOSS tangent	0.002
Balun Size	0.23*λ
Ground size	0.7*λ
Dipole width	6mm

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Dipole length	23mm
via	0.5mm
Platting	Gold ENIG

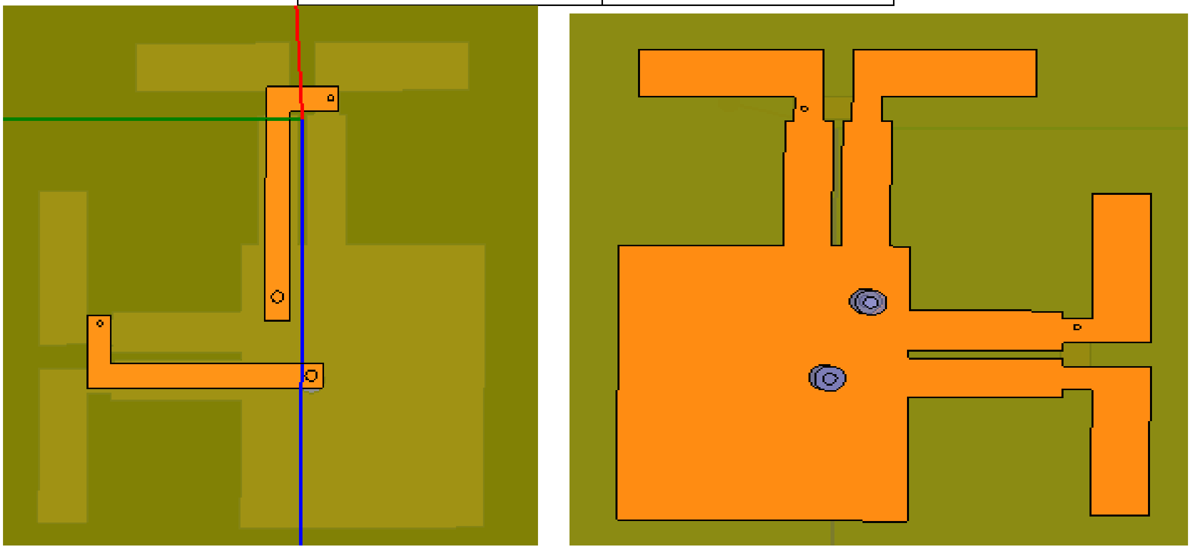

Fig.5(a) Fig.5(b)

Fig .5.simulated structure layout of printed dipole antenna (a)Top layer (b)Bottom layer

The parametric analysis is done for different sizes of balun as well as printed dipole structure for length and width variation.The radiated fields of the antenna are calculated by the effects on the balun and the dipole. It is essensial to cosider the length and width variations on both sides. Parametric analysis helps to find out the best results out of different simulation conditions. It can be used to calculate the change in specific output quantity. Here are some parametric variations tables showing the effects on resonance frequency, VSWR, return loss are presented for the variation in balun size and dipole size also.

Table 2:Parametric variations on dual printed dipole size

Dipole size variation (in mm)	Effect on resonance frequency	Effect on VSWR	Effect on return loss(S11 &S22)
15*21.2	2.2GHz	1.8	-13dB
20*25	2.2GHz	1.65	-13dB
30*25	2.4GHz	1.4	-14dB
35*30	2.4GHz	1.2	-25dB

Above table indicates that the there is no major change in the resonance frequency but VSWR and return loss are observed as a good agreement at 2.4GHz with return loss -25dB and VSWR 1.2.

Table 3:Parametric variations on balun size

Balun length variation (in mm)	Effect on resonance frequency	Effect on VSWR	Effect on return loss (S11)
54*34	2.4GHz	3.9	-4.4dB
54*25	2.4GHz	4.9	-3.5dB
40*35	2.32GHz	2.6	-7dB
54*40	2.6GHz	1.1	-31dB

VI. RESULTS AND DISCUSSIONS

By using the data obtained from simulation, the return loss and VSWR of the single printed dipole and dual printed dipole are calculated at centre frequency. The complete far-field radiation pattern or response at a specific frequency can be determined by the near-to-far-field transformation method [4].

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The VSWR of the printed dipole antenna with a via-hole balun is approximately lower than two from 2.2 to 2.9 GHz, with a bandwidth of approximately 80MHz. Figure below shows the computed and measured return loss with good agreement for single printed dipole. The mutual coupling effects between two adjacent printed dipole antennas can be calculated using S12 and S21 graph as shown in fig.7 (b). The minimum distance between two dipoles should be quarter wavelength to avoid the coupling.

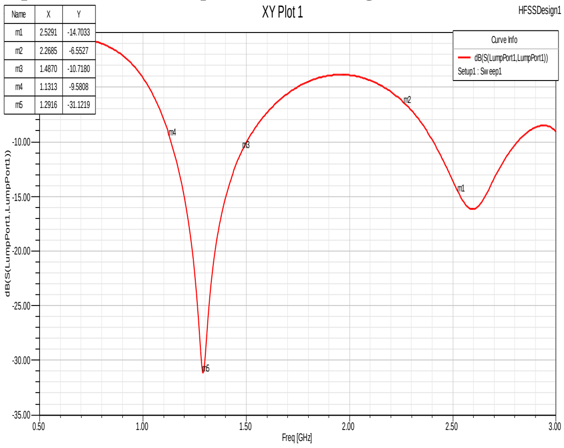
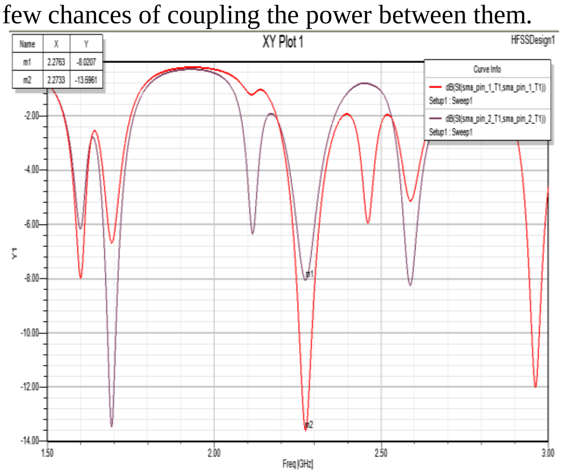


Fig.6(a) **Fig.6(b)**

Fig.6.The reflection coefficient S11 of the printed dipole (a) simulated (b) measured.

Figure below shows the return loss results for dual printed dipole at 2.38GHz as -43dB. The coupling effects between two antennas can be measured by S12 and S21 and it is observed as -11dB at 2.4GHz which indicates very few chances of coupling the power between them.



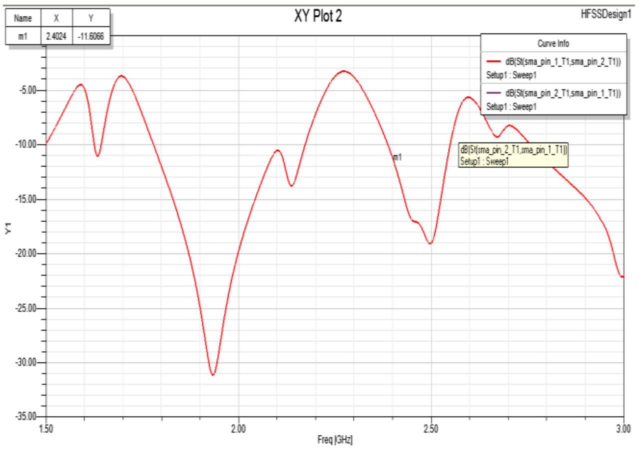


Fig.7(a) **Fig.7(b)**

Fig.7.Return loss of dual printed dipole antenna (a) S11 & S22 (S12 & S21).

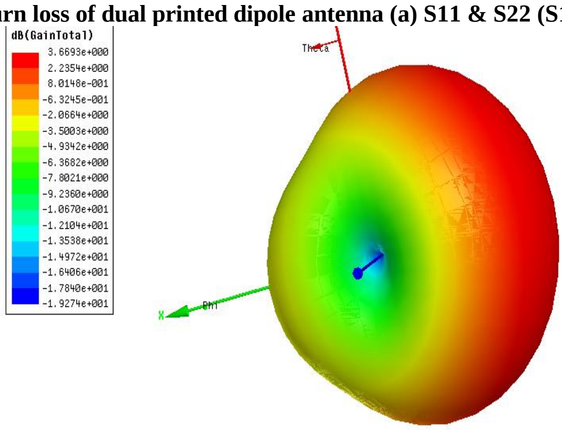


Fig 8. The 3D radiation pattern of the antenna

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The table below shows the comparison between the simulated and measured results obtained for the printed dipole at 2.4GHz.

Table 4: Comparison between simulated and measured results

Antenna without pin diode	Return loss	VS WR	R+JX	Band width	Gain
simulated	-18db	1.3	0.97+j0.02	80MHz	4dBi
Measured	-20dB	1.28	0.95+j0.08	50MHz	Not measured

VII. CONCLUSION

The proposed implementation represents a printed dipole antenna configuration for wireless applications at the frequency range of 2.4GHz. 60MHz impedance bandwidth is achieved practically with -25db return loss at center frequency. Parametric variations between balun size and dipole size helps to find out the good results. Variations on the radiation pattern are observed due to presence pin diode active circuit. PIN diode are biased using 3 V & 10 mA. The proposed antenna can produce linear polarization and switch According to bias condition. The insertion loss is -2.8dB the conversion efficiency get compromised. The insertion loss of pin diode circuit is -0.9db. The total size of antenna is compatible for portable wireless application with the diversity features.

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