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A Compound Reconfigurable Solid State Planar Plasma Antenna

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Abstract*: *In today's modern wireless era, reconfigurable antennas play a vital role for functioning under selective frequency bands, different polarizations and radiation patterns according to the users' application. This article, gives an insight on solid state plasma planar compound reconfigurable antenna for military radar applications at X-band by using array of Lateral PIN (LPIN) diodes. Silicon-dioxide (SiO_2) is used as substrate and proximity coupled feeding technique is chosen to avoid biasing problem in LPIN diodes and also to have compatibility with processing on a standard silicon process. The proposed antenna comprises of a square metallic patch placed above the substrate with linear array of LPIN diodes at adjacent sides of patch to provide fine and coarse tuning in frequency over the range of 8-12 GHz and LPIN diodes placed in the ground plane to provide pattern reconfiguration. Hence, the antenna with compound reconfigurability converges to a solution, where a single antenna satisfies the needs for multiple applications.

Index Terms*: *Compound Reconfigurable Antenna, Lateral PIN Diode, Plasma Antenna, Proximity Coupled Feed.

I. INTRODUCTION

The silicon-based plasma antenna has widespread of applications, which can be used in high-speed wireless communication networks, reconfigurable antennas and smart antennas. In traditional antenna systems, metal element is used as radiator. However, it has a ringing effect, which degrades the performance of radar, and more susceptible to electronic warfare. In recent years, many researches are going on plasma antenna due to its advantage over conventional metallic antenna in military applications, where stealth and electronic warfare are primary concerns.

Under forward bias, intrinsic layer of LPIN diode in plasma state has similar electrical performance as that of metallic conductor. In reverse bias, the intrinsic layer behaves as a high resistivity layer due to the depletion of charge carriers. [1]-[4] showed that, to achieve a metallic conductivity in silicon, the carrier concentration in an intrinsic layer must be very high, in the range of 10^{18}-10^{19} atom/cm^3 and also conductivity of LPIN diode depends on carrier lifetime and channel depth. To achieve reconfigurability in antenna functional characteristics by using solid state plasma, many models are proposed [1]-[6]. However, either frequency or pattern reconfigurable antenna is proposed with LPIN diodes with conductivity in range of 500-1000 S/m under forward bias. In this article, compound reconfigurable antenna is suggested in respect of frequency and pattern with LPIN diodes as switching devices.

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II. GEOMETRY AND DOPING CONCENTRATION OF LPIN DIODE

The LPIN diode is simulated in COMSOL MUTLIPHYSICS software. In the diode, length of intrinsic layer is 160 µm and length of P^+ and N^+ layers is 20 µm. And the doping concentration of P^+ and N^+ layers are in the order of 10^{20} atom/cm^3, and the intrinsic layer which has P type doped background concentration of 10^{12} atom/cm^3. And a metal contact is placed at edge of diode. The overall dimension of the LPIN diode is 5.4×0.2×0.01 mm^3 as shown in Fig. 1. Under forward bias of 5V, more charge carriers are injected into the intrinsic layer resulted in formation of plasma channel in the intrinsic layer. Therefore, conductivity of diode is achieved near to metallic conductivity of order $3x10^6$ S/m as shown in Fig. 2(a). Under reverse bias of -5V, more charge carriers move away from intrinsic layer and the conductivity of diode is achieved nearly to insulator of order $1x10^{-5}$ S/m as shown in Fig. 2(b). This conductivity value of simulated result is used to define a plasma material in HFSS software, which is used to design and simulate the proposed antenna.

III. RECONFIGURABLE ANTENNA DESIGN AND GEOMETRY

The proposed model comprises of a square patch with linear array of 5 LPIN diodes at each adjacent sides of patch to provide frequency reconfiguration and 2 LPIN diodes with dimension of 12.675×0.2×0.01 mm3 are placed in the ground plane to provide pattern reconfiguration. SiO2 is used as substrate and proximity coupled feeding is used for excitation as shown in Fig. 3. The overall dimensions of the antenna are shown in Fig. 3 and Fig. 4(a) – Fig. 4(b).

A. Frequency Reconfigurability

The operating frequency of antenna is reconfigured by changing the state of diodes, which are placed adjacent to patch. The diodes placed along y-direction are used to coarse tune and diodes placed along x-direction are used to fine tune the operating frequency of antenna. Fig.

5 shows the coarse tuning of operating frequency of antenna for variation in the length of plasma channel at adjacent side of patch along y-axis alone and Fig. 6 shows the fine tuning of operating frequency of antenna for variation in the length of plasma channel at adjacent side of the patch along x-direction with constant plasma channel length along y-direction.

Table 1 shows the frequency of antenna for various length of plasma channel along y-direction and x-direction at S1 = ON, S2 = ON.

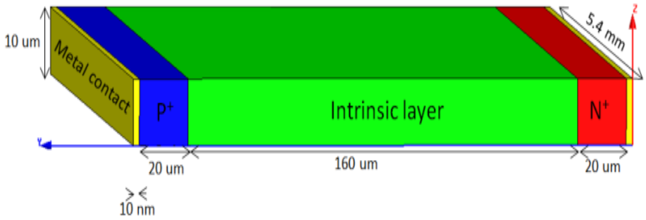
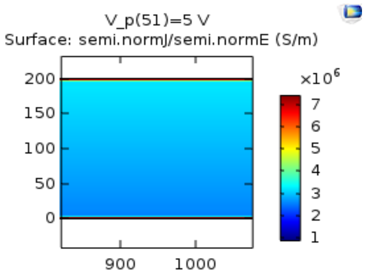
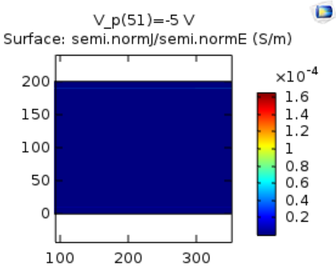


Fig. 1: Structure of Lateral PIN Diode [3].



(a) Forward bias



(b) Reverse bias

Fig. 2: Simulated conductivity value of LPIN Diode

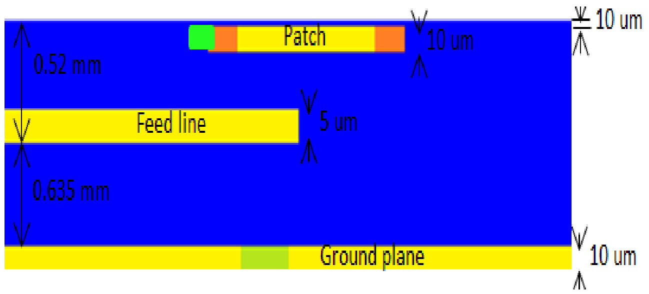
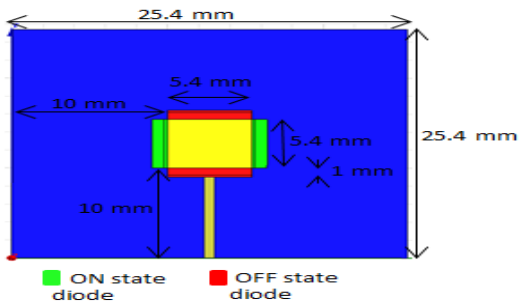


Fig. 3: Cross section view of proposed antenna model.

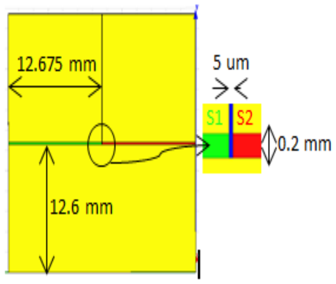
Fig. 7 shows the radiation pattern of antenna for various plasma channel length at adjacent side of patch along y-axis alone at diodes S1 and S2 in ON state. Other possible plasma channel length along x-axis and y-axis also produced unidirectional pattern with maximum radiation in 0°.

B. Pattern Reconfigurability

The radiation pattern of the proposed antenna is reconfigured by changing the state of diodes in ground plane without altering the operating frequency.



(a) Top view



(b) Bottom view

Fig. 4: Top and bottom view of proposed antenna model

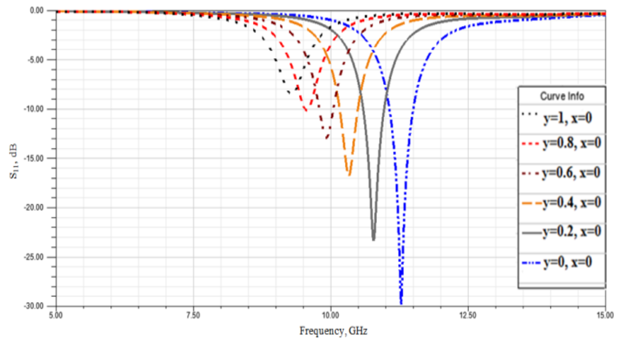


Fig. 5: Return loss characteristics of antenna for variation of plasma channel length along y-axis alone at S1 = ON, S2 = ON.

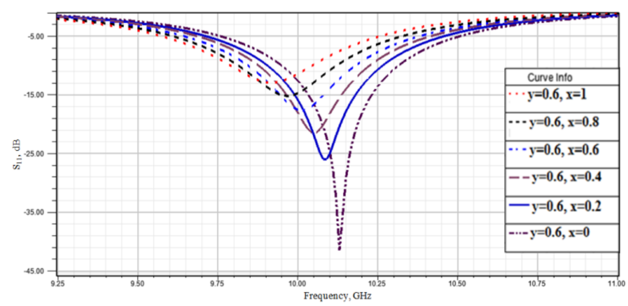


Fig. 6: Return loss characteristics of antenna for variation of plasma channel length along x-axis with constant plasma channel length along y-axis = 0.6 mm at S1 = ON, S2 = ON.

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Initially, antenna is capable of producing the radiation pattern towards 0°, as shown in the Fig. 7, when both diodes in ground plane are in ON state. If anyone diode becomes OFF, no current through it and changes the path

Table 1: Operating frequency of antenna for various length of plasma channel in y-axis and x-axis at S1=ON, S2=ON.

Plasma Channel Extension (mm)	Operating Frequency (GHz)					
	X=0	X=0.2	X=0.4	X=0.6	X=0.8	X=1
Y = 0	11.87	11.25	11.24	11.2	11.21	11.24
Y = 0.2	10.78	10.8	10.81	10.8	10.82	10.86
Y = 0.4	10.33	10.37	10.41	10.42	10.44	10.49
Y = 0.6	9.92	9.96	10.01	10.06	10.08	10.13
Y = 0.8	9.55	9.63	9.68	9.7	9.76	9.82
Y = 1	9.26	9.36	9.43	9.46	9.47	9.57

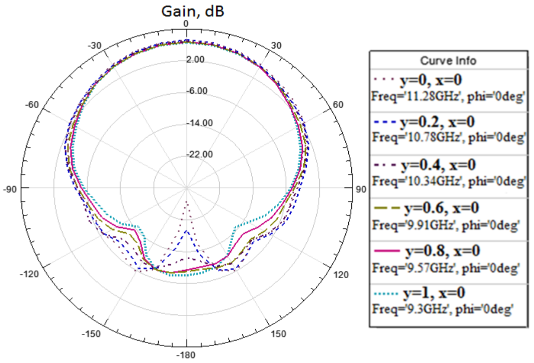

Fig. 7: Radiation pattern of antenna for variation of plasma channel length along y-axis at S1=ON, S2=ON.

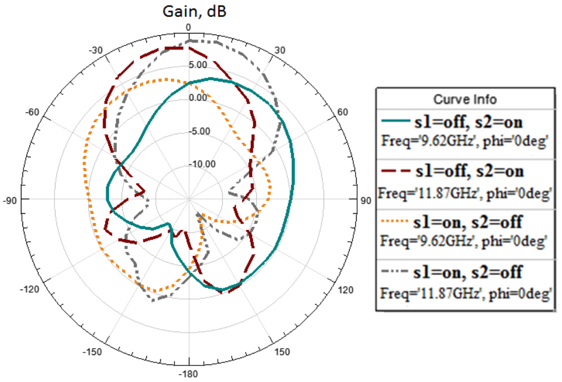

Fig. 8: Radiation pattern of antenna at plasma channel length along y-axis and x-axis is 0 mm at S1=ON, S2=OFF and S1=OFF, S2=ON.

Table 2: Radiation characteristics for variation of plasma channel length along y-axis alone at S1=ON, S2=OFF and S1=OFF, S2=ON.

Plasma Channel Extension (mm)	Operating Frequency (GHz)	Gain (dB)		Maximum Radiating Angle (degree)	
		S1=ON S2=OFF	S1=OFF S2=ON	S1=ON S2=OFF	S1=OFF S2=ON
Y=0	9.62	3.72	3.76	30	-30
	11.87	8.08	8.93	-10	10
Y=0.2	9.49	3.85	3.66	30	-30
	11.49	9.08	5.15	0	0
Y=0.4	9.31	4.12	3.69	30	-30
	11.2	7.71	7.76	-10	10
Y=0.6	9.21	4.22	4.13	30	-30
	10.99	7.31	7.28	-10	10
Y=0.8	8.98	4.65	3.31	20	-20
Y=1	8.62	4.83	4.58	20	-20

of current, therefore the radiation pattern of antenna also changes. The radiation pattern reconfiguration for various length of plasma channel along y-axis alone at S1=ON, S2=OFF and S1=OFF, S2=ON is shown in Fig. 8 and radiation characteristics are tabulated in Table 2.

IV. CONCLUSION

In this article, a solid state plasma compound reconfigurable antenna has been presented for 8-12 GHz frequency band. By controlling the state of LPIN diodes in ground plane and adjacent side of the square patch, pattern and frequency reconfiguration, respectively, have been achieved with high gain. Hence, the proposed compound reconfigurable antenna would be a suitable candidate for military radar applications.

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