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Frequency Agility using Gunn diode on a Rectangular Microstrip Antenna

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Abstract– With the advancement of science and technology in the field of wireless communication ,microstrip antenna is considered a versatile antenna .Apart from increasing its limitation of narrow bandwidth by active devices ,the operating frequency of loaded antenna can be controlled by the bias voltage of active devices .In this paper the active device is a Gunn diode and using equivalent circuit concept the analysis it on loading on Rectangular microstripantenna reveals that it offers wider tunability (9.9 GHz-10 GHz) for bias voltage from 8-15V for a given threshold voltage of 2.9 V.

***keywords** – Gunn diode,Rectangularmicrostrip antenna, frequency,bias voltage .*

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I. INTRODUCTION

Microstrip antenna is now a days a vast research are with different shapes of antenna finding its application in wireless communication. Among the various shapes of microstrip antenna ,the rectangular microstrip antenna is has found its application in various fields due to its simplicity in structure but its application is stricted due to limited bandwidth. Different techniques have been proposed till date and among it loading of active devices by various researchers to enhance its bandwidth.[1]-[2] is a good method .In present paper loading Gunn diode on RMSA is done with emphasis being done on its bandwidth enhancement and frequency agility

II. THEORETICAL CONSIDERATIONS

2.1 Analysis of Rectangular Microstrip Antenna.

The equivalent of Rectangular Microstrip Antenna is represented in figure 1 as a parallel combination of resistor R, inductor L, and capacitor C [3],[4]

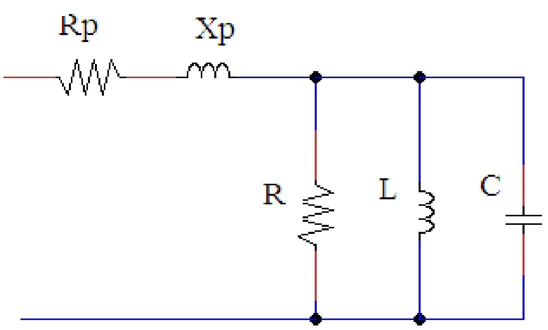


Fig.1. Equivalent circuit of resonant cavity (RMSA)

The impedance of RMSA is obtained from figure 1

$$Z_{in} = \frac{R\omega^2L^2 + jR^2\left(\omega L - \omega^3L^2C\right)}{X} \quad (1)$$

Where

$$X = R^2\left(1 - \omega^2LC\right)^2 + \omega^2L^2 \quad (2)$$

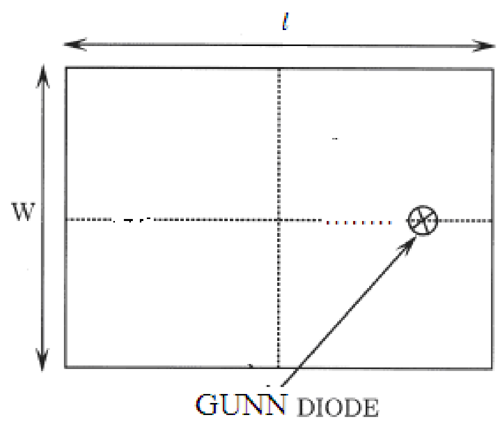
Separating the real and imaginary parts of the impedance of RMSA one gets

$$\mathrm{Re}\left(Z_{in}\right) = \frac{R\omega^2L^2}{X} \quad (3)$$

$$\mathrm{Im}\left(Z_{in}\right) = \frac{R^2\left(\omega L - \omega^3L^2C\right)}{X} \quad (4)$$

2.2 Rectangular microstripantenna loaded with Gunn diode

The Fig1 shows a Gunn diode loaded on rectangular microstrip antenna (RMSA) .Circuit theory has been used for analysis and details are given in the following sections.



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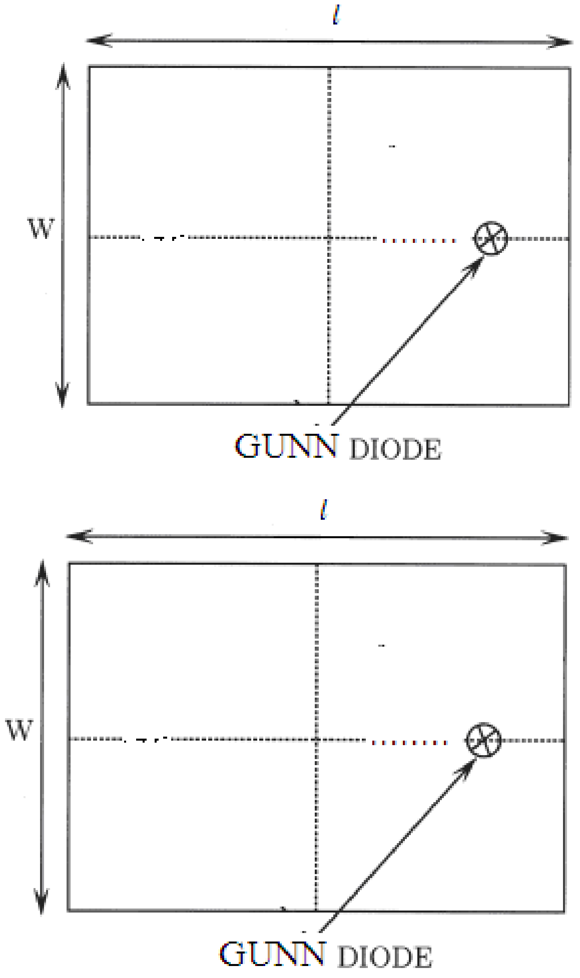

Fig.2. Top view of Gunn diodes loaded on RMSA

The equivalent circuit of RMSA and Gunn diode is shown in figure 3 respectively where R_p and X_p are coaxial probe feed resistance and reactance respectively [6]. R_d and C_d are negative differential resistance of Gunn diode [7] respectively. The values of R_p,X_p and C_d are small as compared to other components and hence are neglected. further simplified equivalent circuit is shown in figure 4

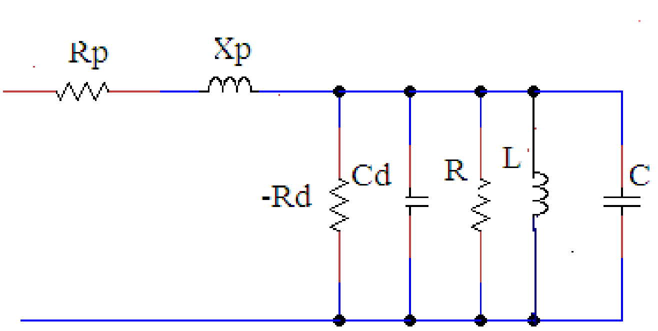

Fig.3: Combined equivalent circuit of RMSA with Gunn diode

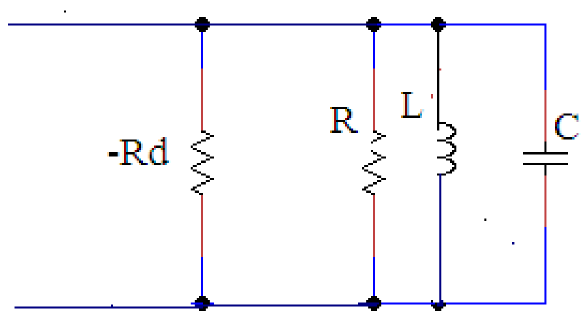

Fig.4: Simplified equivalent circuit of RMSA with Gunn diode

Impedance of Gunn loaded RMSA is derived from Figure 4

$$Z = \frac{(R_d - R)\omega^2 L^2 R R_d + j\omega L(1 - \omega^2 LC) R^2 (R_d)^2}{X_1} \quad (5)$$

Separating the real and imaginary parts of the impedance of Gunn loaded RMSA one gets

$$Re(Z) = \frac{(R_d - R)\omega^2 L^2 R R_d}{X_1} \quad (6)$$

$$Im(Z) = \frac{(1 - \omega^2 LC) R^2 (R_d)^2 \omega L}{X_1} \quad (7)$$

$$X_1 = (1 - \omega^2 LC)^2 R^2 (R_d)^2 + \omega^2 L^2 (R_d - R)^2 \quad (8)$$

The input impedance of the circuit is Z_{in} = Z. The reflection coefficient (ρ) can be calculated as

$$\rho = (Z_{in} - Z_0)/(Z_{in} + Z_0) \quad (9)$$

Where Zin is input impedance of RMSA symmetrically loaded with Gunn diodes,$Z_o$is impedance of the coaxial feed(50 Ω). Hence VSWR is calculated as

$$VSWR = \frac{1 + \rho}{1 - \rho} \quad (10)$$

The Return loss of antenna is given by

$$RL = -10\log\left(\frac{1}{\rho^2}\right) \quad (11)$$

2.3Operating frequency

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The Gunn diode operates in limited charge accumulation (LSA) relaxation oscillator mode [9]. It may be mentioned that when the bias voltage is less than the threshold voltage, the diode is ohmic with relatively small parallel capacitance and the current is exponentially limited L/Ro by time constant.[5] Thus, the time period T_1 can be written as

$$T_1 = L / R_0(V_b/V_t) \quad (12)$$

Where
R_o- low field resistance when
V_b -dc bias voltage;
V_t- threshold voltage;
L- inductance of the microstrip patch.

The RMSA resonator has its resonance frequency which is controlled by the *L* and *C* parameters of the patch and hence the time period for the patch can be written as

$$T_2 = 2\pi.\sqrt{LC} \quad (13)$$

Thus, the total time period *T* for the Gunn integrated RMSA can be given by

$$T_1+T_2 = T = (LV_t/R_0V_b)+2\pi(LC)^{1/2}$$
(14)

Therefore, the operating frequency of the active integrated RMSA is given by

$$f = \frac{1}{\frac{LV_T}{R_0 V_b} + 2\pi\sqrt{LC}} \quad (15)$$

III. III.DESIGN CONSIDERATIONS

In table 1 the parameters of RMSA is shown and the parameters of Gunn diode are shown in below table 2

Table 1PARAMETERS OF RMSA

Parameters	Values
Operating frequency	9Ghz
Length (l)	1.01cm
Width (W)	1.39cm
Thickness of substrate material (RT Duroid5870	0.159cm
relative permittivity of the substrate	2.32
Resistance	50.2Ω
Inductance	11.3 nH
Capacitance	2.756pF.

Table 2 PARAMETERS OF GUNN LOADED RMSA

Parameters	Values
Type	M/A COM 49104, GaAs, n
Threshold voltage (V_T)	2.9 – 4.9 volt
Operating point I_0mA/$V_b$volt	200 mA/ 900 volt
Oscillation frequency (x-band)	8.2 – 12.4 GHz
DC resistance	8 Ω
Operating mode	LSA relaxation mode
Output power mW(>25)	10-25 mW at 10 GHz
Device capacitance (C_d)	0.1 Pf
Packaging capacitance (C_e)	0.1 pF
Series inductance (L_s)	0.3 nH
Typical value of device negative resistance ($-R_d$)	-200 Ω
DC bias voltage	8.0 – 15.0 volt

IV. RESULTS AND DISCUSSIONS

The impedance of Gunn integrated RMSA is seen to vary with bias voltage of 8V -15V[8] for different threshold voltage as shown in figure 5, 6 and 7

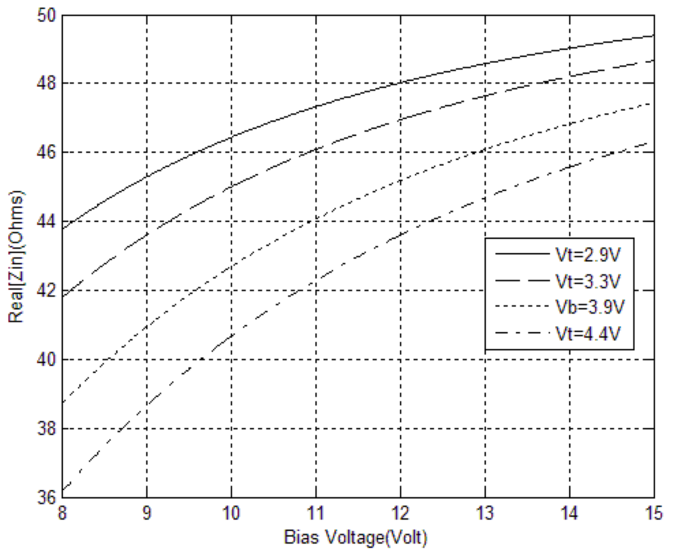

Figure 5: Variation of Real [Z_{in}] with bias voltage

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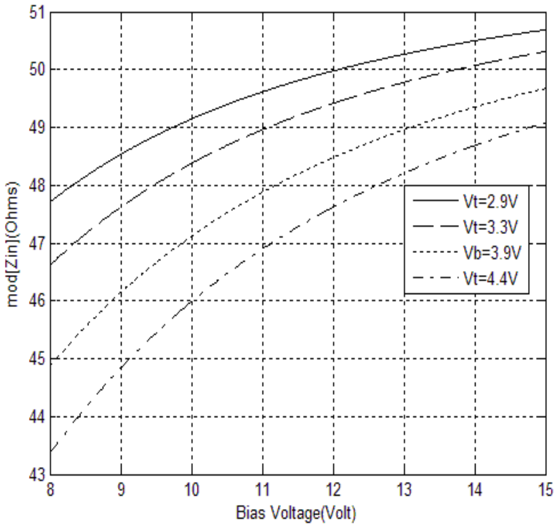

Figure 6: Variation of Imaginary [Z_{in}] with bias voltage

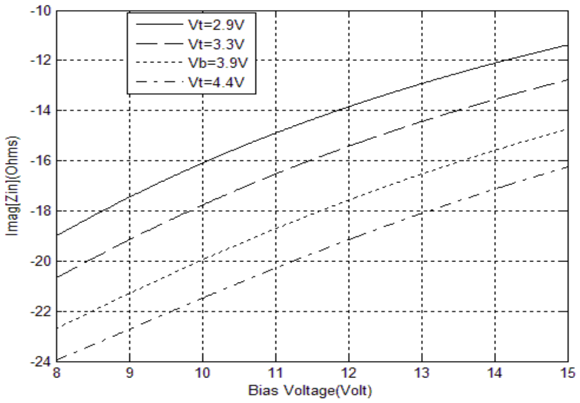

Fig.7: Variation of mod [Z_{in}] with bias voltage.

Variation of real part of with bias voltage for different threshold value is shown in Fig. 5. It is observed that real part of impedance increases with bias voltage for a given value of threshold voltage (V_t=2.9). It also increases with decreasing value of threshold voltage in which the increase is comparatively more in the lower bias as compared to higher biasing voltage.Variation of imaginary part with bias voltage is shown in Figure 6. It is seen that the imaginary part of the input impedance increases with increasing bias voltage for a given value of threshold voltage. From figure 7 it is observed that mod Z_{in} increases with bias voltage for a given value of threshold voltage, however, it depends inversely on the threshold voltage for a given bias voltage. It may be mentioned that the increase in mod Z_{in} is large (43.35Ω-47.7Ω) at lower bias (8V) as compared to higher bias (15V) where the increase is 49.08Ω-50.68Ω.This indicates that the Gunn loaded CMSA impedance is enhanced to a level where the matching is better at lower V_t as compared to higher value of V_t. This can be shown in tabular form as given below.

Table 3: COMPARISONS OF V_t AND MOD Z_{in} FOR DIFFERENT V_b

For V_b = 8V		For V_b 15V	
V_t	Mod Z_{in}	V_t	Mod Z_{in}
(in volts)	(in ohms)	(in volts)	(in ohms)
4.4	43.3	4.4	49.085
3.9	44.91	3.9	49.67
3.3	46.61	3.3	50.31
50.61	50.61	50.61	50.61

From figure 8 we observe that the operating frequency decreases with bias voltage for all the values of V_t, however the antenna operates at higher frequency range at higher value of V_t and at lower frequency range at lower value of V_t.

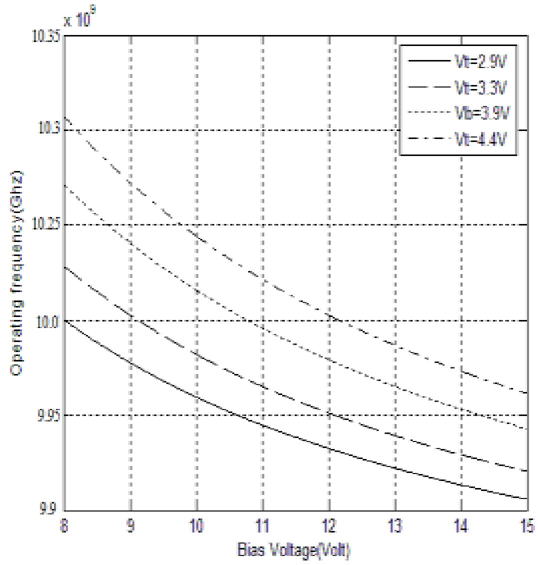

Fig.8: Frequency versus bias voltage.

It is observed that at constant V_t= 2.9, the operational frequency is 10 GHz at 8V bias voltage and 9.9 GHz at 15V bias voltageThis shows that frequency agility is achieved by loading of Gunn diode in which the operating frequency of the rectangular microstrip antenna is electronically controlled by the bias voltage of Gunn diode.

V. CONCLUSION

It is hence concluded that a Gunn loaded rectangular microstrip antenna offers wider tunability

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