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Analysis of Gunn Integrated Rectangular Microstrip Antenna

Manila Bhatnagar
Assistant Professor, IFTM University, Moradabad, India
Amar Sharma
Assistant Professor, IFTM University, Moradabad, India

Abstract:
The advancement of science and technology has accelerated the use of microwaves and millimeter waves in the area of communication engineering. Conventional microstrip antenna has a radiating patch on one side of a substrate and a ground plane on the other side. It has the attractive features like low profile, light weight, conformable to any shape, simple and inexpensive to manufacture using modern printed-circuit technology. In general, the patch conductors are made of copper or gold and can assume any shape. The analysis conducted on Gunn integrated rectangular microstrip antenna and evaluation of various parameters such as input impedance, voltage standing wave ratio (VSWR), return loss, radiation pattern, beamwidth, etc as a function of bias voltage and threshold voltage reveals that the Gunn loaded patch offers wider tunability, better matching, enhanced radiated power as compared to the patch alone.

Key words: *Active antenna, Rectangular microstrip antenna (RMSA), Gunn integrated microstrip antenna, voltage standing wave ratio (VSWR)*

1. Introduction

The patch can generally, be fed through a coaxial probe or microstrip line. The conformal property of such antenna makes it suitable, for military applications such as aircraft, missile, rocket, and other high speed vehicles, etc., as well as for commercial applications such as satellite communication, mobile communication, global positioning system, direct broadcast satellite (DBS), remote sensing, etc. In-spite of their numerous advantages, they inherently have low operational bandwidth, which puts constraints in number of applications in practice. The operational frequency range of the conventional microstrip antenna by applying some techniques, such as by changing geometry of the antenna, loading the patch with active devices (like Varactor diode, Gunn-diode, IMPATT, MESFET, HBT),etc.[1,2] These tunable antennas provide an alternative to wideband antennas, especially when a large bandwidth is required for encompassing several narrow band channel.

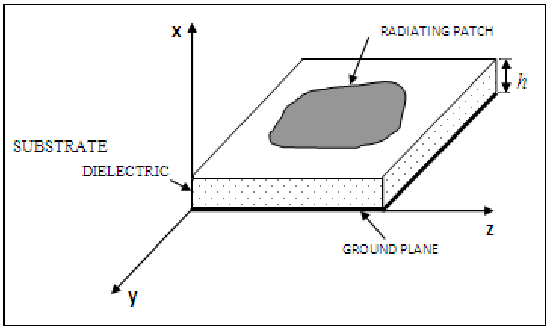


Figure 1: Geometry of microstrip antenna

2. Network Representation of Patch Antenna

The microstrip antenna generally has two-dimensional radiating patch of any planar geometry on one side of a dielectric substrate and ground plane on the other side. There are several methods which have been used to analyze and predict the radiation characteristics of microstrip antennas [3-8].The general network representation of the input impedance of a microstrip antenna is shown in Fig 2(a) & (b). The equivalent circuit for TM_{00} mode with $k_{00} = 0$ is the parallel combination of a static capacitance C_{00} and a resistance R_{00}, that represents loss in the substrate. The equivalent circuit for TM_{10} mode with

$k_{10} = \pi/\ell$, is represented by a Parallel $R_{10}\,L_{10}\,C_{10}$ network, where R_{10} represent radiation, substrate and copper losses, and C_{10} and L_{10} represent the static capacitance and inductance, respectively. The TM_{10} mode shows the dominant RF mode, which is identical to the transmission line model[7]. Fig. 1(a) shows a network model over a narrow band about an isolated TM_{10}^{x} mode, where the net series inductance is L_p. The feed probe diameter as expressed by the factor G_{mn} is the major factor in determining L_p. The values of C_{10}, L_{10}, and R_{10} are given as-

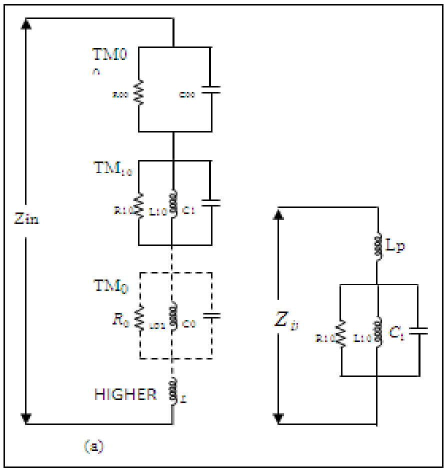


Figure: 2(a) General network model representing microstrip patch antenna,(b) Network model of microstrip antenna

$$\mathrm{L}_{10} = \frac{1}{\mathrm{C}_{10}\omega_{10}^{2}} \qquad (1)$$

$$C_{10} = \frac{\varepsilon_e \varepsilon_0\, \ell W}{2h} \cos^{-2}\left(\frac{\pi\, \mathrm{y}_0}{\ell}\right) \qquad (2)$$

$$R_{10} = \frac{Q_T}{\omega_{10} C_{10}}, \quad \omega_{10} = 2\pi\, f_{10} \qquad (3)$$

where (y_0, $W/2$) represent the feed-point co-ordinate, $f_{10} = f_r$ is the resonance frequency, ε_e is the effective dielectric constant, and Q_T is the total quality factor of the microstrip antenna and can be calculated as

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \qquad (4)$$

$$\frac{1}{Q_T} = \frac{1}{Q_r} + \frac{1}{Q_d} + \frac{1}{Q_c} \qquad (5)$$

where Q_r, Q_c and Q_d are the quality factors due to radiation, conduction and dielectric losses, respectively, and their values are given by [8]

$$Q_r = \frac{c\sqrt{\varepsilon_e}}{4 f_r h} \qquad (6)$$

$$Q_c = h\sqrt{\pi f_r \mu\sigma} \qquad (7)$$

$$Q_d = \frac{1}{\tan\delta} \qquad (8)$$

where $c =$ Velocity of light = 3×10^{8} m/s,

$\mu =$ Permeability = $4\pi\times10^{-7}$ N/Amp^2, and $\sigma =$ Conductivity of cupper = 5.8×10^{7} mho

Impedance of RMSA

$$Z_{in} = \frac{\omega_r^2 L^2 R R_d (R_d - R) + j\omega_r L R^2 R_d^2 (1 - \omega_r^2)}{\left[R R_d (1 - \omega_r^2 L C)\right]^2 + \left[\omega_r L (R_d - R)\right]^2} \qquad (9)$$

$\Delta\ell$ =Fringing length $= 0.412\,h\dfrac{(\varepsilon_e + 0.3)\left(\dfrac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\dfrac{W}{h} + 0.8\right)}$ (10)

and the resonant frequency is

$$f_r = \frac{\omega_r}{2\pi} \approx \frac{c}{2(\ell + 2\Delta\ell)\sqrt{\varepsilon_e}} \tag{11}$$

where VSWR is defined in terms of the reflection coefficient Γ as

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}\ . \tag{12}$$

The Γ is a measure of reflected single at the feed-point of the antenna. It is defined in terms of input impedance Z_{in} of the antenna and the characteristic impedance Z_0 of the feed line as given below:

$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}. \tag{13}$$

3. Theoritical Considerations

The Gunn diode operates in limited-charge accumulation (LSA) relaxation-oscillator mode [9,10]. The placement of the Gunn diode [1,2] is chosen such that the device impedance is matched to the input impedance of the patch. The diode placement location y_0 is given by -

$$y_0 = \frac{\ell}{\pi}\cos^{-1}\left(\frac{Z_{in}}{Z'_{in}}\right)^{1/2} \tag{14}$$

where ℓ is the length of the patch, Z'_{in} is the input impedance of the patch at the radiating edge, and Z_{in} is the input impedance of the antenna at the diode location (equal to the active-device dc resistance).

It is well known that the equivalent circuit of a resonant patch can be represented by a parallel combination of R, L, and C circuit (Fig. 2.(a)). The value of these parameters is calculated using modal-expansion cavity model as,

DC resistance	8 ohm
Threshold voltage	(2.9-4.4) Volt
Operating point I_0 at V_b mA/Volt	200 at 9.0 Volt
Oscillating Frequency (X-band)	(8.0-12.4 GHz)
Operating mode	LSA relaxation mode
Output power	10-25 mW at 10 GHz
Conversion efficiency	(2-5)%
Device capacitance (C_d)	0.1 pF
Typical value of low field resistance ($-R_0$)	-13.97Ω
Typical value of device negative resistance	-200Ω
DC bias voltage	(8.0-15.0) Volt

Table 1: Specifications of Gunn-diode (M/A Com 49104, GaAs, n)

Substrate material used	RT/Duroid 5880
Relative dielectric constant (ε_r)	2.2
Substrate thickness (h)	1.588 mm
Centre design frequency	10GHz

Table 2: Specifications of rectangular microstripe patch

A. Impedance of Gunn loaded RMSA-
The input impedance of Gunn-integrated patch is obtained according to Fig. 3 (c)

$$Zin = \frac{R}{2(R-} \qquad (15)$$

B. The reflection coefficient can be given by-

$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \qquad (16)$$

Where $Z_0 = 8\Omega$ (device dc resistance).

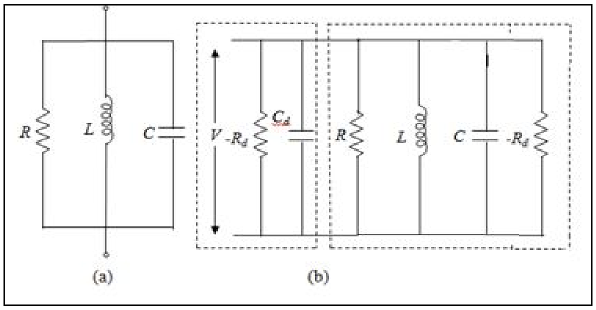


Figure 3: (a) Equivalent circuit of rectangular patch, (b) Equivalent circuit of two Gunn diode integrated microstrip patch

C. The voltage standing wave ratio

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (17)$$

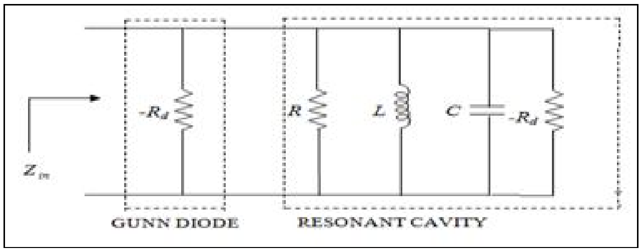


Figure 3.(c): Simplified equivalent circuit of two Gunn diode integrated microstrip.

D. Return loss

$$RL=20Log_{10}|\Gamma|. \qquad (18)$$

E. Radiation Fields

The theoretical radiated far field of the patch in **E**-plane ($-90^0 \le \phi \le 90^0$) is given by [11]

$$E(\phi) = \frac{-j2k_0\, hW\, E_0}{\pi\, r} e^{-jk_0 r} \left\{ \frac{\sin\left(\frac{k_0 h}{2}\cos\phi\right)}{\frac{k_0 h}{2}\cos\phi} \cos\left(\frac{k_0 \ell_e}{2}\sin\phi\right) \right\} \qquad (19)$$

Where ℓ_e the effective length of the patch and the value is is given as

$$\ell_e = \ell + 2\Delta\ell. \qquad (20)$$

4. Design Details

The Gunn loaded RMSA investigated were designed using various parameters of RMSA and Gunn diode the details of which are shown in Tables 1and 2.

5. Discussion of Results

The input impedance of Gunn loaded RMSA was calculated using equation 16.The calculated values of impedance, VSWR and return loss are shown in fig. Finally the radiation pattern for RMSA and Gunn loaded RMSA were using 9 and 15 the resulting data are shown in fig 1 and 4.

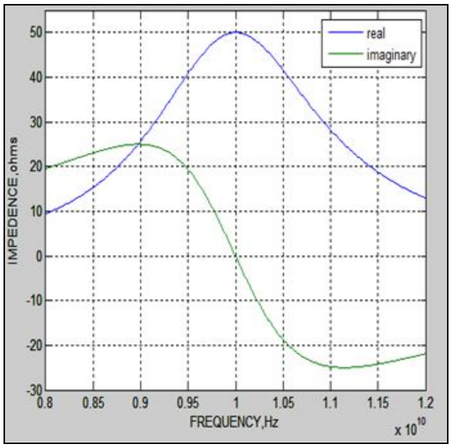


Figure 1: Impedance versus frequency

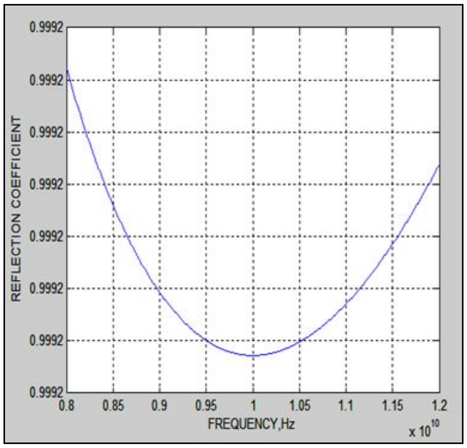


Figure 2: Reflection coefficient versus frequency

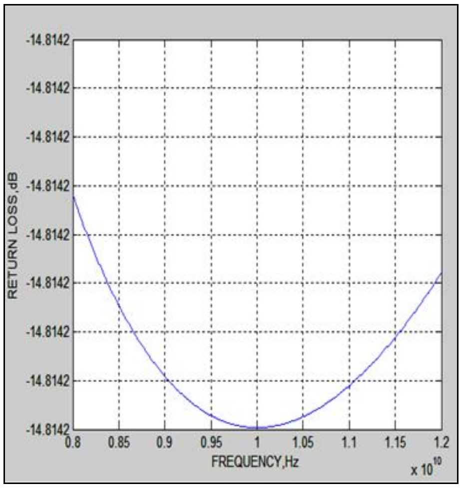


Figure 3: Return loss versus frequency

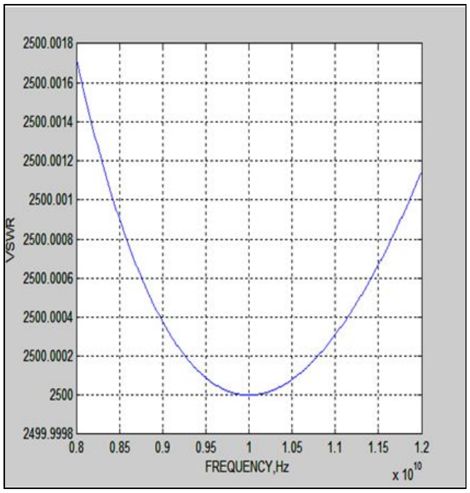
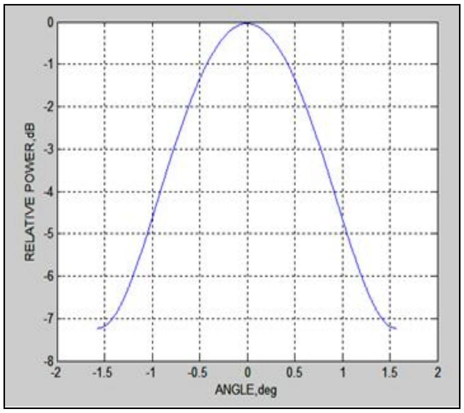


Figure 4: VSWR vesus frequency



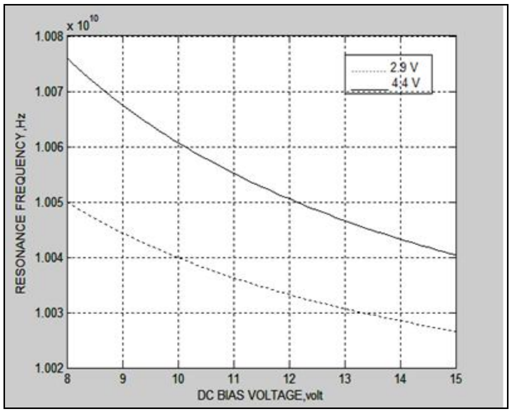
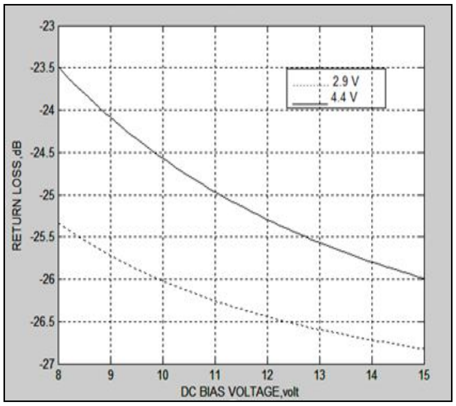


Figure 5: Single Radiation pattern

Figure 6: Variation of resonance frequency with dc bias voltage for two values of Vt.



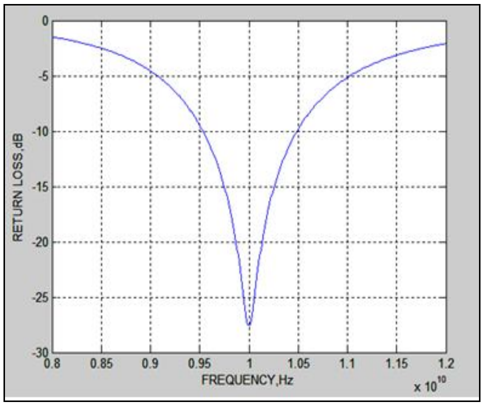


Figure 7: Variation of return loss with dc bias voltage for two values of Vt.

Figure 8: Return loss versus frequency

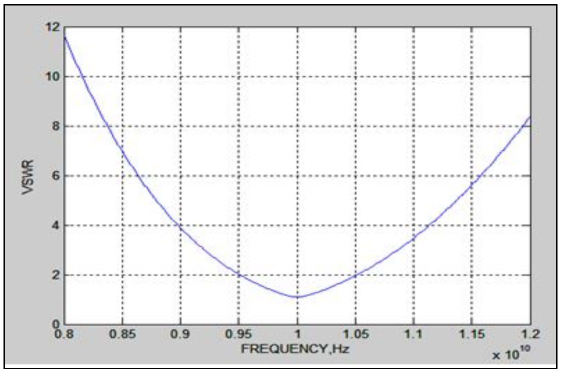


Figure 9: VSWR versus frequency

6. Conclusion

We design a rectangular microstrip antenna with the help of parameters and find the impedance, VSWR and return loss. This antenna has low operational bandwidth. In this section RMSA has been loaded with two Gunn diode and give results of input impedance, VSWR, return loss with different bias voltages and finally give the radiation pattern for electric field.

7. Future Scope

Future investigations may be conducted on antenna loaded with other active devices (IMPATT, HBT, TUNNEL DIODE, MESFET).

8. Refrences

1. H. J. Thomas, D. L. Fudge, and G. Morris, “Gunn source integrated with microstrip patch,” Microwave and RF, pp. 87-91, Feb. 1985.
2. J. A. Navarro, K. A. Hummer, and K. Chang, “Active integrated antenna elements,” Microwave Journal, pp. 115-127, Jan. 1991.
3. J. Bahl and P. Bhartia, Microstrip Antennas, Artech House, Inc., 1980.
4. R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook, Artech House, Inc., 2000.
5. P. Agrawal and M. C. Bailey, “An analysis technique for microstrip antennas,” IEEE Trans. Antennas Propagat., vol. AP-25, no. 6, pp. 756-759, Nov. 1977.
6. E. H. Newman and P. Tylyathan, “Analysis of microstrip antennas using moment methods,” IEEE Trans. Antennas Propagat., vol. AP-29, no. 1, pp. 47-53, Jan. 1981.
7. M. C. Bailey and M. D. Deshpande, “Integral equation formulation of microstrip antennas,” IEEE Trans. Antennas Propagat., vol. AP-30, no. 4, pp. 651-656, Jul. 1982.
8. P. Silvester, “Finite element analysis op planer microwave network,” IEEE Trans. Microwave Theory Tech., vol. MTT-21, no. 2, pp. 104-108, Feb. 1973.
9. J. T. Coleman, Microwave Devices, Reston Publishing Company, Inc., 1982, pp. 39.
10. S. K. Sharma and Babau R. Vishvakarma, “Gunn integrated microstrip active antenna,” Indian J of Radio & Space Phys, vol. 26, pp. 40-44, Feb. 1997.
11. Constantine A. Balanis, Antenna Theory Analysis and Design, Second Edition, John Wiley & Sons, Inc., 1997, pp. 728-746