A VARIETY OF ACTIVE PATCH ANTENNA WITH A NEW DESIGN PHILOSOPHY

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INTRODUCTION

Microwave systems like radar, missile guidance and communication equipment which require large amplifiers to produce high power beam, wave-guides for its low loss and higher power capabilities and motors for scanning are bulky, occupy large space and are not easily routed. Most efficient replacements have been found in the active antenna array where active devices are integrated directly into the antenna platform. Whenever an active device, either a Gunn, IMPATT or a FET is integrated within a microstrip patch antenna, the assembly is commonly called active microstrip patch antenna (AMPA). AMPA serves both the purpose of radiation and power generation. In an active antenna there are two ways of integrating the Gunn diode within the patch e.g. i) direct integration of the device within the patch(AMPA-I), ii)device is connected to the patch through a microstrip transformer (AMPA-II). The central idea is obviously, to realize maximum power output from an antenna. In the first instance, position of the diode on the patch [1] is of importance whereas in the second it is related with the appropriate design of the quarter wave transformer.
An antenna where the diode is placed within the patch is capable of producing high power output with spectral purity, yet suffers certain difficulties: (a) Whenever a device is integrated within the patch it affects the field equations as well as the resonant frequency.(b)When desired frequency of oscillation is high , patch dimension become comparable to the active device and is difficult to design in practice.(c) Diode has a finite dimension, which limits the placement of it in the exact location on the patch. To overcome these limitations an excellent way of integrating a two/three terminal device within the patch through a microstrip transformer is proposed in this paper.

Fig 1 shows the way of placing the active device (Gunn diode) within the patch. The central idea is to obtain

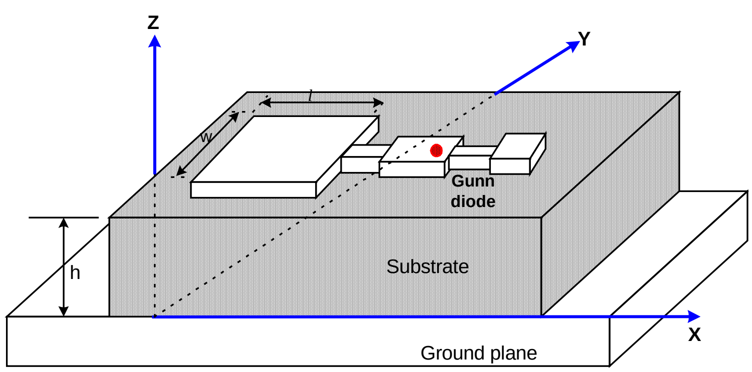

Fig.1: Gunn Mounted Active Microstrip Patch Antenna

perfect matching between antenna and the device so that maximum power output, stable oscillation, uniform radiation pattern and pure spectrum can be achieved. To fulfill the above conditions the transformer sections are designed properly so that device-antenna impedance matching is realized not treating the patch and diode as equivalent passive impedances, but considering them as a part of an oscillating system. This is not done by earlier workers. This leads to a completely new design equation.

THEORY & DESCRIPTION

Fig 1 depicts the schematic diagram of an active rectangular microstrip patch. The patch element is followed by two sections of quarter wave transformer and proper bias line. A microstrip patch can be viewed as a parallel plane transmission line or a parallel plate wave-guide. The resonant frequency of a microstrip patch antenna of length L and width W without diode is same as the cut-off frequency of a rectangular wave-guide and is given by

$$f_r = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m}{W}\right)^2+\left(\frac{n}{L}\right)^2} \tag{1}$$

Where ε_r is the relative dielectric constant of the substrate; m, n denotes the mode of operation. The resonant frequency for the lowest order mode, viz. m=1 and n=0 is obtained from "(1)" as

$$f_r = \frac{c}{2\sqrt{\varepsilon_r}}\left(\frac{1}{L}\right) \tag{2}$$

Based on transmission line model, the input impedance of a patch can be written as

$$Y_{in} = G_{in} + jB_{in}$$

The real part of *Yin* gives the input conductance *Gin*

$$G_{in} = [2G + 0.5(G_i + R_1^{\,2} Y_0)L]\sec^2 \beta L \tag{3}$$

Where G = Gr-Gm represent radiation conductance (*Gr*) and conductance due to the mutual coupling between the conductance opposite ends of the patch [2].*Gi* is the intrinsic conductance and R_1 is the series resistance[2], Y_0 is the characteristic admittance. While the imaginary part gives the value of resonant frequency.
Fig 2 shows the configuration of an active microstrip patch antenna where the Gunn diode is located outside the patch.

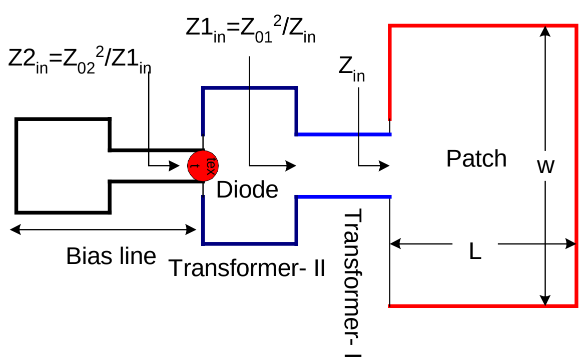

Fig.2: Active Microstrip Patch Antenna, Gunn diode being placed outside the patch

The relations for the various impedances as shown in Fig 2 are related according to the following relations:

$$Z2_{in} = \frac{Z_{02}^2}{Z1_{in}}, \quad Z1_{in} = \frac{Z_{01}^{\;2}}{Zin} \tag{4}$$

Where Z_{01} and Z_{02} are the characteristic impedances of the first and second transformer respectively.

We put

$$n^2 = \frac{Z_{02}^2}{Z_{01}^2}, \qquad Y2_{in} = \frac{Y_{in}}{n^2} \tag{5}$$

Current-voltage relation of a diode is written as $i = -\alpha v + \beta v^2 + \gamma v^3$ where α, β, γ are constants. Steady state output from an antenna is written as $V_s^2 = \frac{4}{3\gamma}\left(\alpha - G_{in}\right)$ [3]

We know that for sustained oscillation $\alpha > \left[2G + 0.5(G_i + R_1 Y_0^2)\right]\sec^2 \beta L$

Here , $V_s^2 = \frac{4}{3\gamma}\left(\alpha - G2_{in}\right)$ i.e., $V_s^2 = \frac{4}{3\gamma}\left(\alpha - \frac{G_{in}}{n^2}\right)$

Power output $P_r = 2V_s^2 G_r = \frac{8}{3\gamma}\left[\alpha - \frac{1}{n^2}\left\{2\left(G_r - G_m\right) + 0.5\left(G_i + R_1 Y_0^2\right)L\right\}G_r\right]$

Maximising output power i.e., putting $\frac{dP_r}{dG_r} = 0$ we get

$$\alpha = \frac{1}{n^2}\left\{\left(4G_r - 2G_m\right) + 0.5\left(G_i + R_1 Y_0^2\right)L\right\}$$

$$\text{i.e., } n^2 = \frac{\left\{\left(4G_r - 2G_m\right) + 0.5\left(G_i + R_1 Y_0^2\right)L\right\}}{\alpha}$$

Knowing the values of r.h.s n^2 can be found out. Using formula (4) quarter wave transformers can be designed. Characteristic impedance of a transformer depends on its width.

DESIGN:

An active patch working nearly at 9.5 GHz has been designed and fabricated by using 0.787mm thick Takonic TLY-5-0310-CH/CH substrate with ε_r=2.2. The conducting material has 0.502/sq ft copper metalization with a metal thickness 0f 0.018mm.The antenna is supported from the other side by a thick aluminium plate, which serves the purpose of heat sink as well as provides mechanical support for experimental observation. A screw type low power MA/COM-49104 diode has been used as an active device.

Antenna dimensions:

Design frequency (GHz)	Length (mm)			Width(mm)			Characteristic Impedance(ohm)		
	Patch	Transf-ormer I	Transf-ormer II	Patch	Transf-ormer I	Transf-ormer II	Patch	Transf-ormer I	Transformer II
9.5	10.198	5.405	5.405	14.57	1.011	6.0714	12.95	90.123 (Z_{01})	27.142 (Z_{02})

The transformers are designed so that $\frac{Z_{02}}{Z_{01}} = n$ is nearly equal to 0.31 taking dynamic impedance of diode as 0.1.

EXPERIMENTAL OBSERVATION:

The patch is biased by using a broad band bias T (A 391001from Anritsu).The antenna oscillates at 9.731GHz with bias voltage 10.8 volt. The free running spectrum of the patch is observed in a spectrum analyzer (HP 6566B) and shown in

Fig 3. Power outputs from the antenna (both E and H plane) are observed with a 18 dB horn (Vidyut Y and Udyog X 5041).

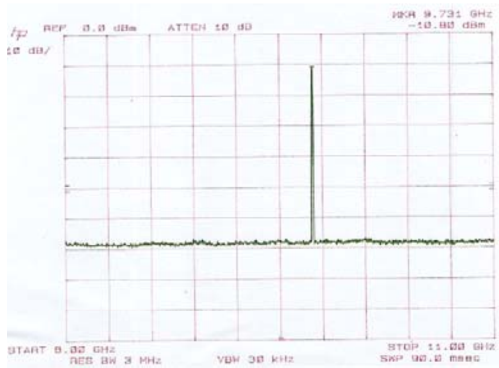

Fig.3: Spectrum of Active Patch Antenna Output

Measured active antenna power

f_0 GHz	λ_0 GHz	R mm	P_0 mW	G_H	G_P	P_PG_P(mW) EIRP	P_P(Mw)
9.731	30.83	820	0.138 (E plane)	63.095 (18dB)	6.26	244.33	39.031
			0.100 (H plane)			177.05	28.283

A voltage tuning range of 200 MHz with power variation ~3dB is obtained when the bias voltage is varied from 10.2 to 14 volt. Qext of the patch is calculated using Adler's equation [4] as 150. Radiated power (both E and H plane) at different directions is observed in a power meter.

One noticeable difference observed is: In an antenna where the diode is placed within the patch free running frequency increases from 9.17 to 9.35GHz with increasing bias voltage (from 7 to 11 volt) whereas in AMPA-II of antenna frequency decreases from 9.8 to 9.6 GHz with bias a variation of 10.2 to 14 volt.

CONCLUSION:

Excellent agreement between proposed theory and experiment has been observed. With this new design the free running spectrum of AMPA is very pure and free from side bands shows stability of oscillation. With the same low power diode, power output observed in an antenna where the diode is placed within the patch (AMPA -I) is 35.83 mW in contrast to 39.031mW in AMPA-II. Far field radiation pattern is almost regular as shown in Fig.4 also shows a very low cross polarization (more than 20dB) level for both and H plane. However, due to the realization of high Qext, locking band width decreases is a disadvantage of this antenna. Injection locking characteristics suggests that an injection locked active antenna can be used as a tracking demodulator for an angle modulated signal [5].

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REFERENCES

[1] A Bhattacharya, '*Studies on active microstrip patch antenna'* Ph D Thesis, Burdwan University, West Bengal, INDIA, 2001

[2] I J Bhal and P Bhartia , *Microstrip antennas*, Artech House,MA 1980

[3] B N Biswas, A Bhattacharya, D Mondal, P Lahiri, A Bose and S Pal, 'Rectangular Active Microstrip Patch Antennas Revisited', *IETE J of Research,* vol 45,no.2, pp.135-145,March –April 1999

[4] R A Adler 'A Study of locking phenomena in oscillators' Proc. IRE, vol.34, pp.833-835,April 1998.

[5] B N Biswas, A Bhattacharya, D Mondal and P Lahiri, 'A novel scheme for reception using an active microstrip antenna', IEEE Trans. Microwave Theory Tech., vol MTT-48,no 10,pp.1765-1768, Oct2000