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A novel Method for mounting Gunn Diode in Active Slot-Ring Antenna

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Abstract

An Active Slot-Ring Antenna (ASRA) has been studied through experiments and analysis in order to find the optimum location of the active device so that the best performance in antenna characteristics is realized in terms of power radiated and power received. Analyses have been carried out in terms of equivalent {ABCD} matrix parameters. Radiation pattern and locking characteristics of the ASRA have been measure and presented in support of the analytical methods.

Keywords: Active Slot-Ring Antenna (ASRA), Gunn diode, Bias tuning, Radiation pattern.

1. Introduction

One of the most inspiring quests of the present century is to establish connectivity to anyone anytime and anywhere, of course through communication systems. And an Antenna is the port through which it is done. Antenna converts the electrical information-bearing signal into electromagnetic radiation that spreads all over the communication space. This is transmission property of an antenna. But an Antenna also acts for the reception of electromagnetic waves, which shines on it. After reception, it converts into the corresponding information bearing signal for further processing of data recovery.

An *Active Microstrip Patch or Slot Antenna*, sometimes also called *Quasi-optical Transmitter* is capable of performing the functions of generation, radiation, and reception. Further, at microwave and millimeter wave frequencies microstrip patch or slot antennas have some well known advantages, such as, low profile, small size, lightweight, low cost, compact, and conformable. It is worth mentioning that simultaneous optimization of oscillator and antenna performance is sometimes self-defeating since antennas require loosely bound fields while oscillator circuitry needs tightly bound fields to prevent undesired coupling or radiation. That is, microstrip antennas operate best with a substrate having low dielectric constant whereas a substrate with higher dielectric constant is preferred for microwave circuitry. The Microstrip Ring Resonator was first proposed by P Traughton in 1969 for the measurements of the phase velocity and dispersive characteristics of a microstrip line. In the 1980s, applications using ring circuits as antenna and frequency-selective surfaces emerged. The concept of Microstrip slot antennas has evolved from slot antenna excited by a strip line. An Active Slot-Ring Antenna (ASRA) i.e. a microstrip slot antenna integrated with active device performs both the function of generation and radiation simultaneously [1-6]. It is an active device mounted slotted ring antenna coupled to the free space through an output port matched to the free space. These types slot antennas have been extensively discussed in the literature [7-9]. Till now literatures was silent to the fact that where will be the exact position of the Gunn diode and how the exact position will be find out. In this paper a detailed procedure using A, B, C, D parameters, for finding the exact position of the Gunn for mounting on the active slot antenna have been present. A detailed study on the design and radiation poperties of active slotted ring antenna has been performed in this paper.

2. Active Slot-Ring Antenna

An Active Slot-Ring Antenna (ASRA) i.e. a microstrip slot antenna integrated with active device performs both the function of generation and radiation simultaneously. It is an active device mounted slotted ring antenna coupled to the free space through an output port matched to the free space. Existing literature [2-7] gives the following procedure for calculating the dimension of the slot ring antenna in terms of the desired frequency of oscillations (f_o)

$$r = \frac{c}{2\pi f_o \sqrt{\varepsilon_{eff}}} \qquad (1)$$

where r is the mean radius of the ring, f_o the desired frequency of oscillation, c velocity of electromagnetic wave in free space and ε_{eff} is the effective dielectric constant. This is the ideal situation when an unpackaged negative resistance device is used. And as such the experimental value differs. When the parasitic elements of the packaged device is taken into consideration the frequency of oscillation is obtained as

$$f = \frac{f_o}{\sqrt{\left[\left(1+\left(C_g/C_1\right)\right)\cdot\left(V_0/V_s\right)^2\right]}} \qquad (2)$$

This suggests: "*choose f, find f_o and use (1) to find the dimension of the antenna*". C_g and C_1 are respectively the capacitances of the package and effective tuning capacitance of the resonant slot ring. Vo and Vs are respectively the amplitudes of oscillations without and with the package parasitic elements. For good packages these voltages are almost equal. This suggests that the actual size of the slot-ring is smaller than that prescribed by the earlier workers. Theoretical and numerical techniques for calculating the size of the antenna have been developed with experimental supports.

3. Methodology

An Active Slot-Ring Antenna (ASRA) i.e. a microstrip slot antenna integrated with active device performs both the function of generation and radiation simultaneously. It is an active device mounted slotted ring antenna coupled to the free space through an output port matched to the free space. Any transmission line of finite length may be represented by the so called A, B, C, D parameters of a (2 X 2) matrix. The A, B, C, D parameters will be calculated from the value of intrinsic parameter. The input impedance of a two-port network with load impedance Z_L can express as

$$Z_{in} = \frac{AZ_L + B}{CZ_L + D} \qquad (3)$$

Now the tow port networks can be interconnected in different ways among which the cascade connection is the simplest one.

In case of two-cascade connection the overall transmission parameters will be expressed as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \qquad (4)$$

For N no of cascade connection the transmission parameters will be expressed as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \prod_{i=1}^{N} \begin{bmatrix} A_i & B_i \\ C_i & D_i \end{bmatrix} \qquad (5)$$

The above transmission line model is to be used to calculate the input impedance at different position of the slotted ring in order to find out the exact position of the Gunn diode for mounting in the ring. To calculate the input impedance using transmission line model the slotted ring will be analyzed as a polygon of N sides. As N i.e. the number of side increases, the angle between two sides also increased which gives better approximation of the ring as a connected transmission line. Having represented the ring resonator as a cascade of sections of transmission lines, each section is modeled by its equivalent A B C D matrix. Now consider the diode is mounted at position AB as shown in Fig.1. If the length of the ring is L then the length of the each section will be $l = L/N$. Let the input impedance of the diode will be Z_d ohm where $Z_D = 2Z_d$. Let the power coupled to the impedance matching network is m^2 % of the total power generated, where m is the coupling factor and its range is $0 < m \leq 1$.

Thus it can written as

$$Z_R = m^2 Z_0 \quad (6)$$

Where Z_0 = Characteristics impedance of the ring. The equivalent circuit is shown in Fig.2.

Now if we consider the portion of the transmission line AB-M-EF as network N_a and portion EF-N-AB as a network N_b, then the two port network representation will be as shown in Fig. 2.

Now for N_a, the transmission parameters can be expressed as

$$\begin{bmatrix} A_a & B_a \\ C_a & D_a \end{bmatrix} = \prod_{i=1}^{n} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad (7)$$

Similarly for N_b, the transmission parameters can be expressed as

$$\begin{bmatrix} A_b & B_b \\ C_b & D_b \end{bmatrix} = \prod_{i=n+1}^{N} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad (8)$$

Where A, B, C, D are transmission parameters for each length l of transmission line and expressed as

$$A = \cosh(\gamma l) \qquad B = Z_o \sinh(\gamma l)$$
$$C = \sinh(\gamma l)/Z_o \qquad D = \cosh(\gamma l) \quad (9)$$

Where l = length of each division and γ is the propagation constant and can be represented as $\gamma = \alpha + j\beta$

So the input impedance of the slotted ring can be expressed as

$$Z_{in} = \frac{E_i}{I} = \frac{A_a . Z_R (1+x) - B_a}{(C_a + C_b) . Z_R (1+x) - (D_a + x D_b)} \quad (10)$$

where $$x = \frac{(A_a - A_b) Z_R - B_a}{(A_b - A_a) Z_R - B_b} \quad (11)$$

Now the input impedance at different position of the slotted ring can be evaluated with help of MathCAD by changing the values of n from one to N-1.The Fig.3 shows the variation of input impedance with different position of the slotted ring. From the Fig it is seen that the input resistance of the slotted ring will be matched with the dynamic resistance of Gunn diode near the $\gamma/2$ distance from the point of power coupling to the impedance matching network.

4. Experimental Result

Microstrip slot antenna (Fig.4) is fabricated by using a 0.787mm thick Takonic TLY-5-0310-CH/CH substrate with ε_r = 2.2 and the active device used is commercially available low power MA/COM packaged Gunn diode (MA 49104) with typical dc to rf conversion efficiency of approximately 1.5%. The slot line ring resonator was designed for 10 GHz has a mean radius 4.216 mm and a line width of 1 mm [9-12]. The slot line ring resonator was designed for characteristic impedance of 158.057 Ω. The slot line notch antenna uses an exponential taper to match the impedance of the ring to free space. The gap at the feed point is 1mm and the gap at the mouth of the antenna is 11.894 mm. The Gunn diode is mounted on a piece aluminum that serves as the heat sink required by the low dc-to-RF conversion efficiency of the diode. The dc bias to the Gunn diode is provided directly to the center ring by a thin wire. The experimental setup for the measurement of the bias tuning of active microstrip antenna is shown in Fig 6. The active slot shows a 5.4 dB bias tuning range of 479 MHz over a bias voltage variation of 3.7 V as depicted in Fig.7. The E plane and H plane radiation pattern of the active antenna are measured in free space as shown in Fig.8 and Fig. 9 respectively.

5. Conclusion

From the theoretical and experimental results we can conclude the following points-

I. there is a definite point on the ring for connecting the active device
II. as the ASRA is an oscillator so it is bilateral coupling between the device and the load,
III. the dimension of the slotted ring should be chosen according to the frequency of oscillation of the ASRA,
IV. the second harmonic generation depends on the location of the active device.

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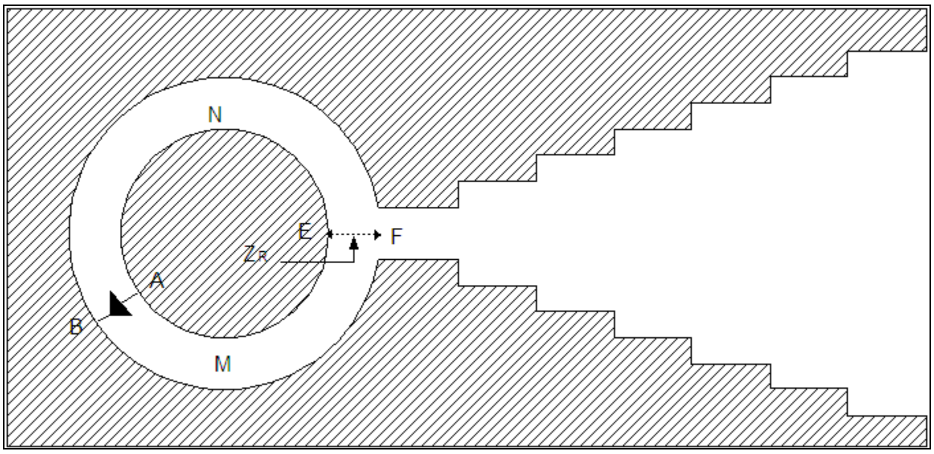

Fig.1 Schematic Arrangement of an Active Slot Ring Antenna

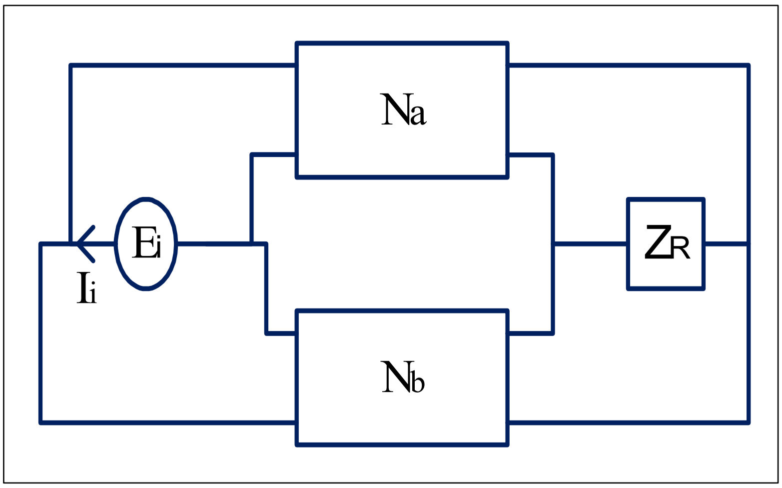

Fig. 2: Two port network representation

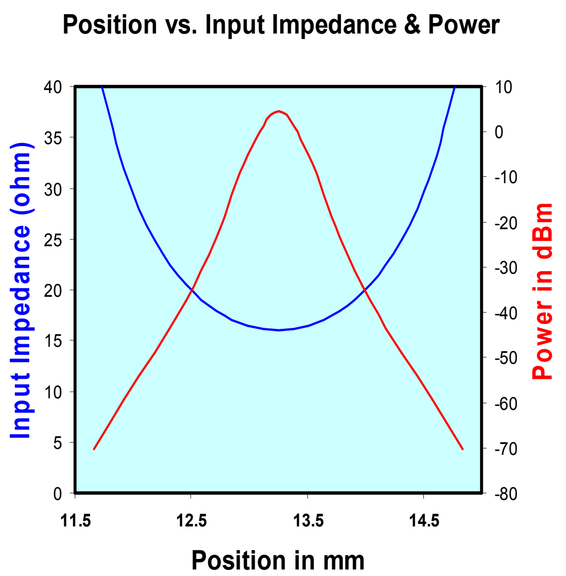

Fig 3: variation of input impedance with position of the Slot Ring Antenna

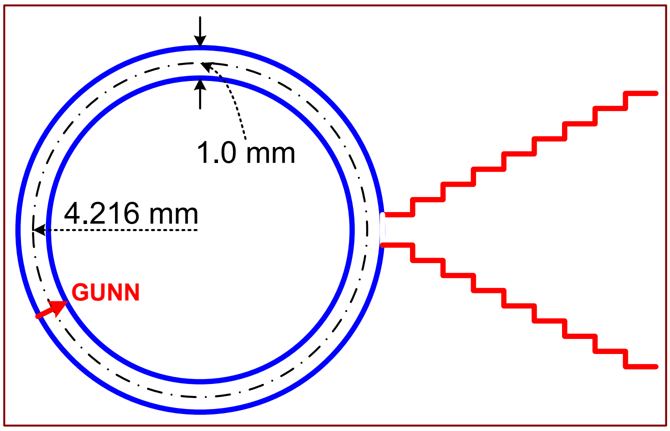

Fig 4: - Active Microstrip Slot Ring Antenna

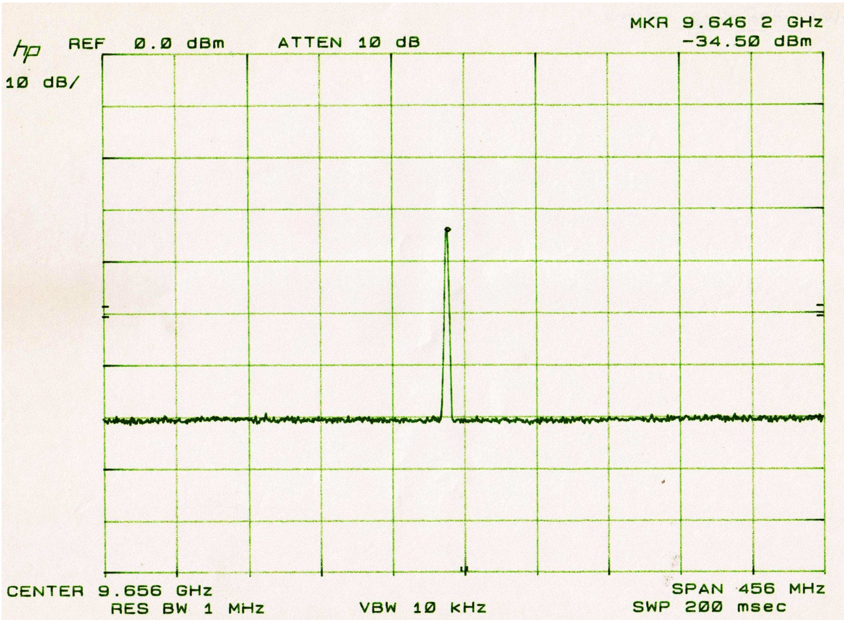

Fig 5- Free running power spectrum of the active slot ring antenna

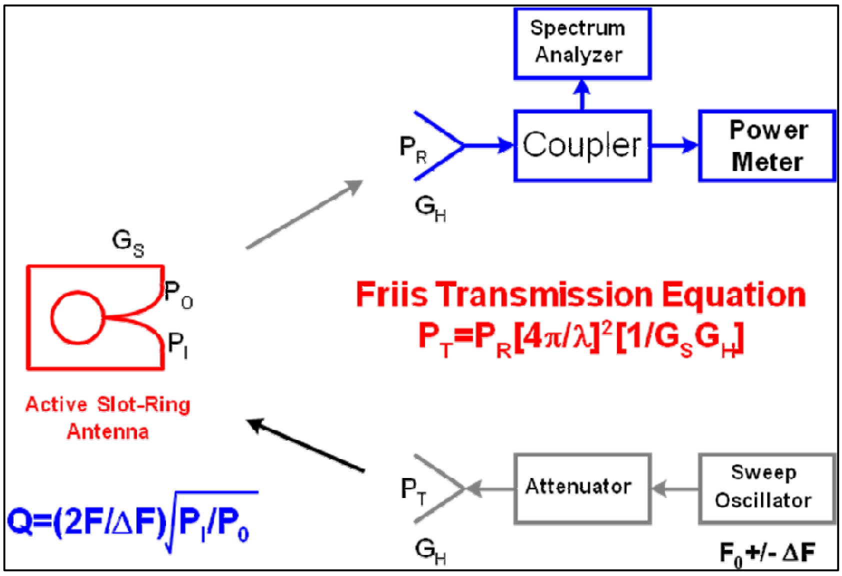

Fig 6: - Experimental setup for the measurement of the bias tuning characteristics of active microstrip slot-ring antenna

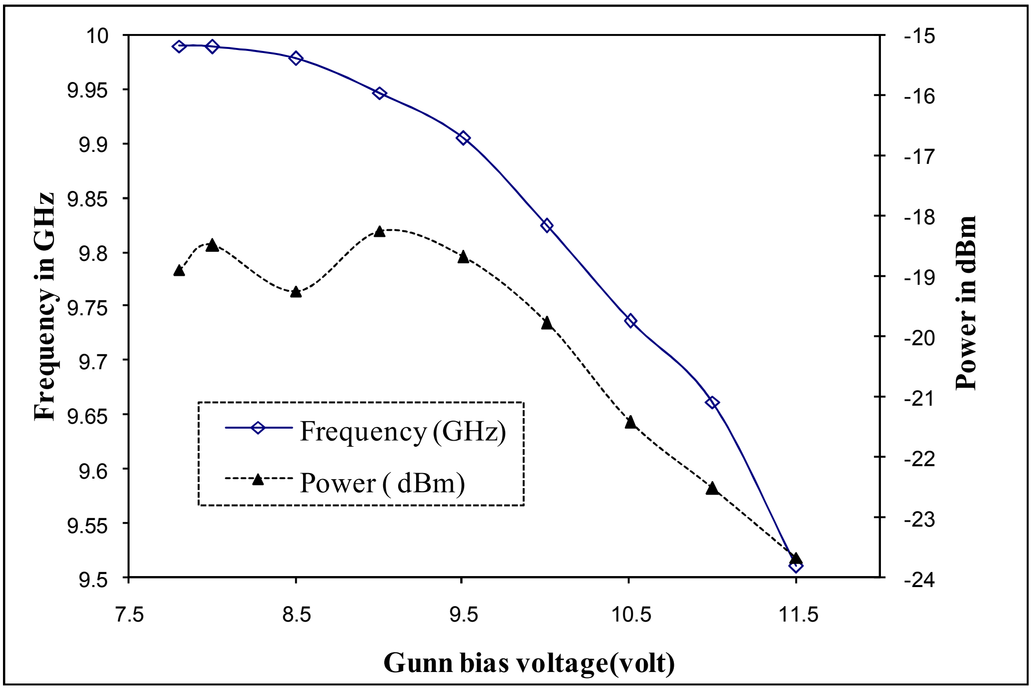

Fig. 7: - Bias Tuning Characteristics of ASRA

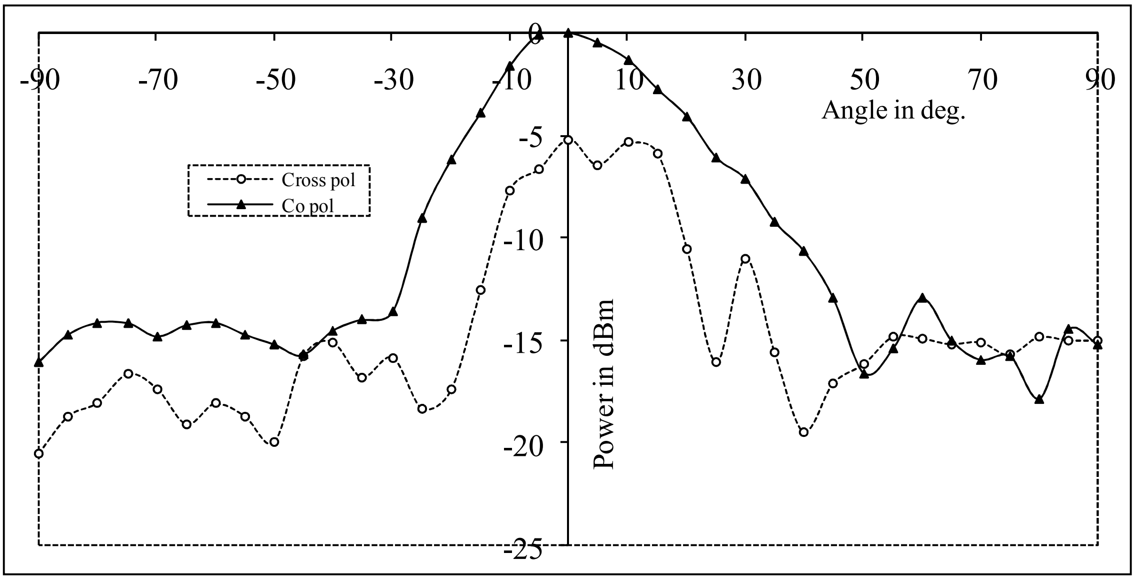

Fig 8:

E plane radiation pattern of the Active Slot Ring Antenna

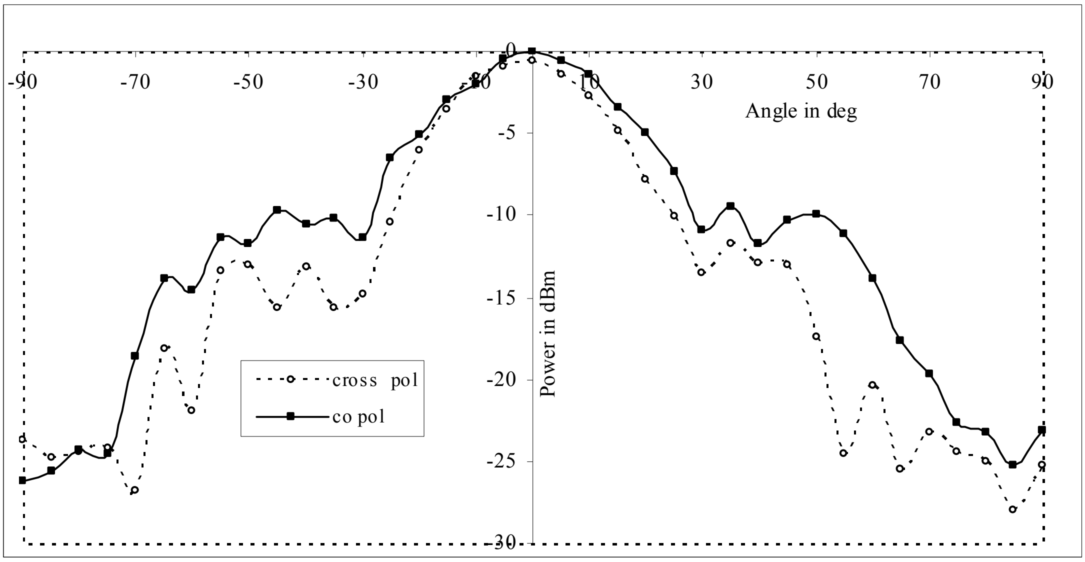

Fig 9: H plane radiation pattern of the Active Slot Ring Antenna