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Switch Limiter for High Power Radar Application

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***Abstract*-Receiver protector is necessary requirement of Front End Radar Receivers from intentionally transmitted high power. Switch Limiter can offer one of such protections to Receiver circuits. The sizes of solid state switch limiters are very smaller with respect to traditional high power cavity duplexer/diplexers. These solid state switch limiters can also be integrated in planar PCB assemblies of Receivers. This paper gives design of switch limiter with power handling of 2KW (3.2% duty cycle.) in S Band with discrete components. This design has been implemented to achieve better than 40dB attenuation. Limiter is included in design to protect Low Noise Amplifiers, which is prone to damage if exposed to high level RF signals. Same design can offer protections for Secondary Surveillance Radars (IFF systems in multiple mode of operations) with little optimization of components.**

Keywords- PIN diode, Switch Limiter, Radar, IFF etc.

I INTRODUCTION

A switch is an electrical component for opening and closing the connection of a circuit or for changing the connection of a circuit device [1]. The switch-limiter's has to perform the function of receiver protector from high level signal while maintaining very low loss. This requires the use of a non-linear device like PIN diodes, as they can handle high power RF signal and provide reasonable leakage [2].

The use of PIN diodes as the switching element in microwave circuits is completely depend on the difference between the PIN diode's reverse and forward bias characteristics. At lower microwave frequencies, the PIN diode appears to be very small impedance under forward bias and very large impedance under reverse bias. It is the difference in performance between forward and reverse bias states upon which switch operation relies.

In the design of switch limiter switching time & power handling are the critical parameters. The PIN Diode characteristically has relatively wide I-region and can therefore withstand larger RF Voltages than varactors or microwave schottky diodes. The forward and reverse bias conditions, necessary to insure safe high power switch operations [3]. The switch's Power Dissipation is considered as another limiting factor in determining the maximum RF power level that the PIN diode switch can control without overheating. Power Dissipation depends on Rs (which is a function of the forward bias current) relative to Zo, on the input power to the switch, Pa, as well as on the switch connection chosen.

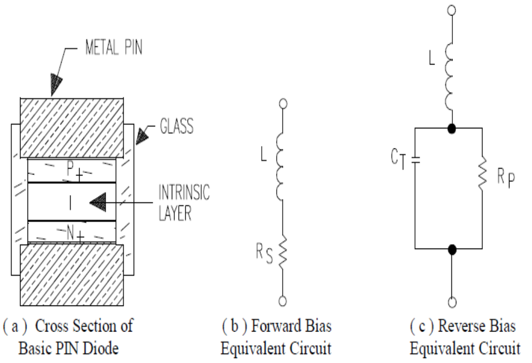

Fig. 1 PIN Diode internals & equivalent circuit

Finally, the maximum RF power that the PIN diode is capable of switching depends on the incident power, Pa, Zo, the switch connection type, average Dissipated Power (Pd), and on the Reverse Breakdown Voltage (VBR) rating.

II. DESIGN APPROACH

Isolation is a measure of the microwave power through the switch that is not transferred to the load, both from Attenuation Loss and Reflection Loss, when the switch is OFF. It is a measure of how effectively a PIN Diode Switch is turned OFF. Insertion Loss (IL) is the Transmission Loss through the physical structure of a PIN diode switch. In the forward biased case (the ON state), large values of bias current plus microwave current may flow through the switch structure, causing significant Ohmic Loss.

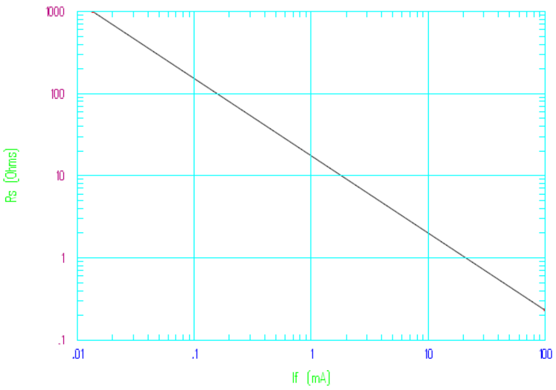

Fig. 2 Series resistance Vs current in PIN Diode

Rs = W2 / (μn+ μp)Q(Ω) or Rs = w2 / (μn+ μp) IF τ (Ω)

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Where W = I- region Width , IF = Forward Bias current , τ = Minority Carrier Lifetime , μn = Electron Mobility , μp = Hole Mobility.

In the reverse bias case (the OFF or Isolation state), only small values of leakage current flow through the switch, so the reverse bias loss is small. Insertion Loss of switch limiter causes the system's Noise Figure to increase by the amount of the Insertion Loss.

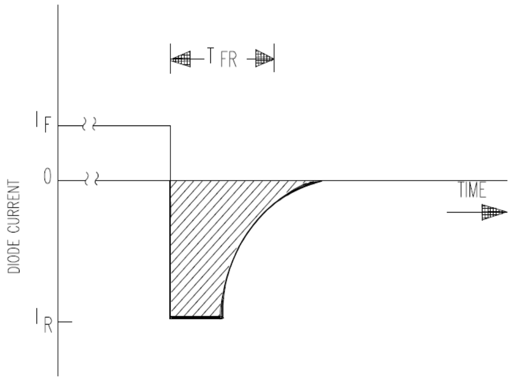

Fig. 3 Transition time in PIN diode

$$TFR = \ln(1 + IF/IR)\,\tau \text{ (SEC.)}$$

Time for the forward – to – reverse switching

The Shunt SPST Switch offers high isolation over a broad frequency range (approximately 20 dB for a Singled diode switch). Insertion Loss is low because there are no switch elements in series with the transmission line. The diode is electrically and thermally grounded to one side of the transmission line and has higher Pd capability than the SPST circuit. ISO and Pd are functions of Rs[4]. IL primarily depends on Ct. the design equations are given below.

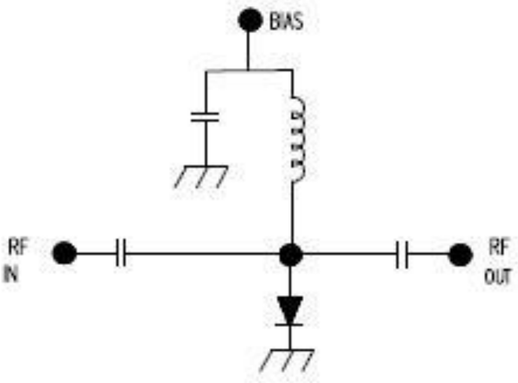

Fig. 4 Shunt SPST Switch

For Shunt SPST Switches [5]:

$IL = 10 \log \{1 + (\pi f\, Ct\, Zo)^2\}$ dB

$ISO = 20 \log \{1 + Zo / 2 Rs\}$ dB Power Dissipation (Forward Bias)

$Pd = 4 Rs Zo / (Zo + 2 Rs)^2 Pav$ watts Power Dissipation (Reverse Bias)

$Pd = \{Zo / Rp\} Pav$ Watts

(Where Pav is the maximum available power) Peak RF Current (Shunt Switch)

$Ip = \sqrt{(8Pav / Zo)}$ Amps

Peak RF Voltage (Shunt Switch) $Vp = \sqrt{(2\, Zo\, Pav)}$ Volts

If the shunt switch circuit is not matched, multiply the above equations by the "sigma" factor [5]. ADS Simulation file of designed SPDT switch is shown in fig 5.

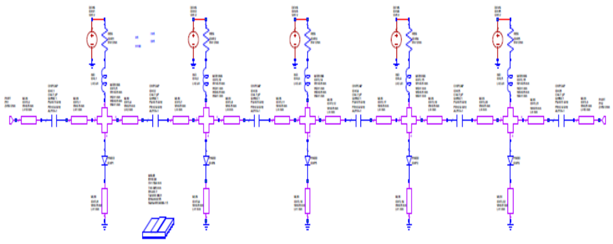

Fig. 5 simulation of designed Shunt SPST Switch

Results of simulation shown in fig 6 & 7

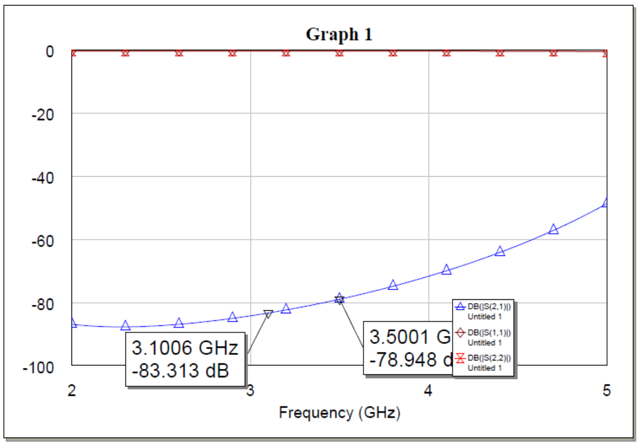

Fig. 6 Simulation results of Pin Diode Switch

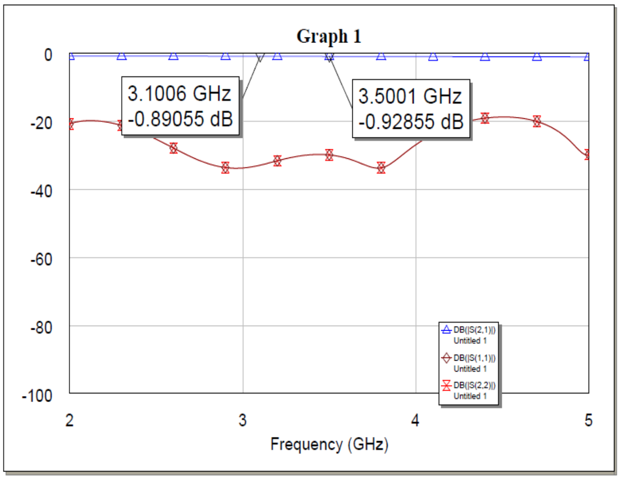

Fig. 7 Simulation results of Pin Diode Switch

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III. DESIGN METHOD

Maximum input peak power level to the Limiter is 2KW. MSWSH-100-30 PIN diode is chosen for this purpose which is having a breakdown voltage of the order of 700 V much higher than 316V. The diode supports up to 100 Watt CW when hot switched while actual power at the system is 64 W CW. Two diodes is being used to have better than 40dB attenuation. Two more Limiter diodes MLP7122 and MLP7112 are used after this. So it will give limiting action as well as attenuation when biased. In the last stage MLP7130 is used as fine limiter so that power is limited which LNA can handle safely. Fig 8 shows the circuit of developed switch limiter.

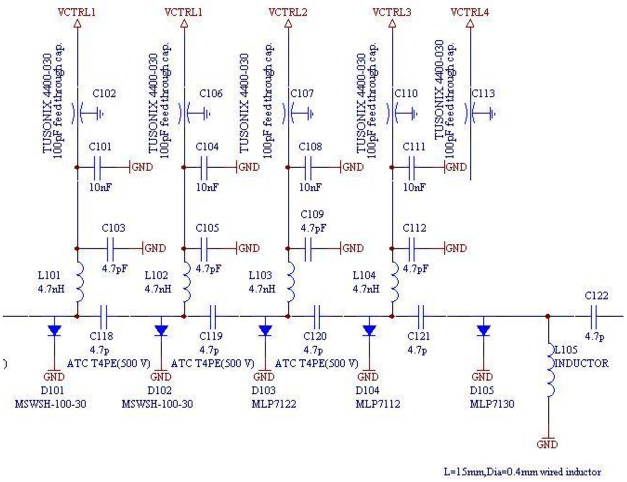

Fig.8 Developed Switch Limiter Circuit

The switch limiter's PCB was fabricated with Rogers 4003C of 1.6mm thickness, 1 onze cu substrate. Proper filtering & isolation has been taken care in design with capacitors & inductors.Fig.9 shows the designed & developed switch limiter assembly.

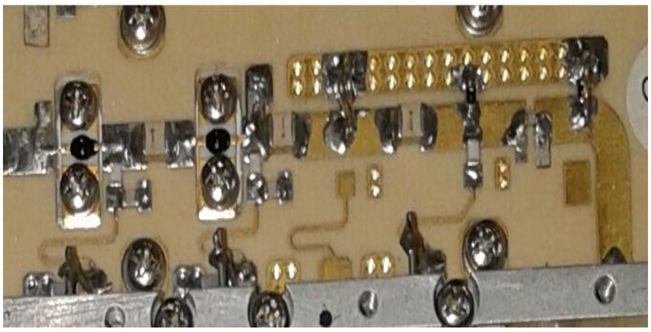

Fig.9 Shunt SPST Switch

IV. EXPERIMENTATION

The switch limiter was developed for Frequency Range from 3.1 to 3.5 GHz with insertion loss less than 0.5dB, amplitude flatness ±0.25dB, attenuation of Min 48dB, with permissible i/p peak power level up to 2KW. Isolation graph of developed Switch Limiter is shown in fig 10.

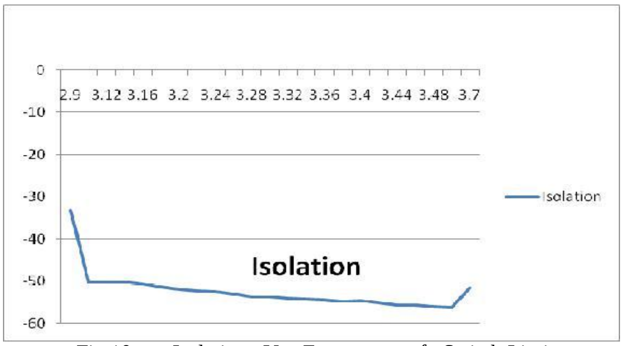

Fig.10 Isolation Vs Frequency of Switch Limiter

In actual Radar Receiver system Switch Limiter along with configurable memory has been used to characterization of temperature behavior of Switch limiter as well as complete receiver line up.

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Amit Tiwari has graduated his Bachelor in Engineering in Electronics & Communication & Master of Technology in Microwave Engineering from IT-BHU. He served MITS & Institute of Engineering, Jiwaji University Gwalior as a assistant professor. He is currently working as Deputy Manager, in Development & Engineering-Microwave Components of Bharat Electronics Limited, Ghaziabad. He has designed & developed Airborne RF Transceivers for AEW&CS (DL), IFF Transmitters for Radars, SSPA, Receivers & its components etc for Data link & radar applications.

R. C. Yadav did his Master of Technology in Microwave Engineering from South Campus, Delhi University, in 1992. He served various organization for more than 23 years out of which 5 years in Institute of Microelectronics, Singapore, He is currently working as Sr. Deputy General Manager, Development & Engineering-Microwave Components of Bharat Electronics Limited, Ghaziabad. He is recipient of Rakshamantri award for R&D efforts. He has been involved in design of IFF Radar transmitters & Receivers etc.