Multi-Application PIN Diode

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***Abstract* - In this paper, a multi-application PIN diode is presented. The PIN diode structure is similar to conventional PIN diodes, but only difference is that a layer is used in the middle of layers. The diode has 4 pins. Proportional to the applied voltage to the two control pins, it can be achieved a value arbitrary of series capacitance and resistance. This feature of the PIN diode can be used a good way in the resonators, amplifiers and high frequency multiplier, modulator and demodulators circuits. And also by using these elements rather than complex circuits in telecommunication systems, the circuit size and number of elements are reduced.**

Index Terms – PIN diode. Multi-Application PIN diode. Control pins. Modulator with PIN diode.

I. INTRODUCTION.

Today, the necessity of design and use of high frequency communications equipment has been evident than before. In high frequencies, the carbonic resistance and electronic capacitance, show different behavior in ideal case. Therefore this false and non-ideal performance of elements cause distortion to the output signal and will affect on the performance of system. For resolving this problem, a object must be used in high-frequency instead of these elements that output to be close to the ideal case. PIN diode is a semiconductor element that can act as a variable resistance in RF and microwave frequencies. If the PIN diode to be in forward bias, it is equivalent to a series resistance (R_s) with a small inductance. If the PIN diode is in reverse mode it is equivalent to a capacitor in parallel with a resistance (R_p)[1]. A multi-layer PIN diode structure is presented by adding an N type layer to the common PIN diode [2]. N layer is added to increase capacitances of discharge to the non-discharge area. Thus, compared with a conventional PIN diode it has a more reverse voltage.

In this paper, by adding a $N^+ - P^+$ layer to the conventional PIN diode, a multi-application PIN diode has been presented. Proportional to the applied voltage to the pins control, it can be used a good way in the resonators, amplifiers and high frequency multiplier, modulator and demodulators circuits. In this paper, the MATLAB software is used to simulate.

II. MULTI-APPLICATION PIN DIODE.

The layer structure of multi-application PIN diode is shown in Fig.1. As can be observed, one $N^+ - P^+$ layer is

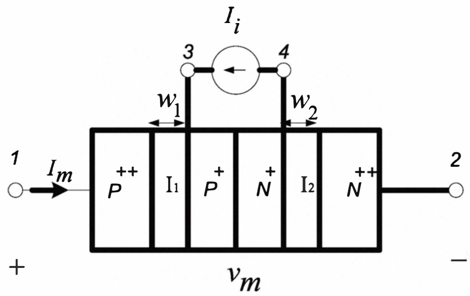

Fig.1 The layer structure of multi-application PIN diode.

added into the I layer and this layer with a thickness W is divided in two layers with a uniform thickness of w_1 and w_2. This element has 4 pins. Pins 1 and 2 for general bias and pins 3 and 4 for control of the $N^+ - P^+$ layer are used. For surveying element it supposed that if the PIN diode to be in direct bias, the current passing from the pins 1 and 2 is constant and equal to I_m. I_i is the input current to pins 3 and 4. Depending on the voltage, v_m and current, I_i are positive, negative or zero, the element is equivalent to 3 models as following:

model 1: Assume that both the I_i and v_m are positive. With regardless to the small capacitors and Inductors created in layers,C,C_1,C_2 and L_1, L_2 in direct mode, element serves as a constant resistance and a variable resistance to I_m. The PIN diode equivalent circuit is given in Fig.2. R_1 and R_2 are equivalent resistance of layers I_1 and I_2, respectively and R_v is equivalent resistance of layer $N^+ - P^+$ and are as follows[3]:

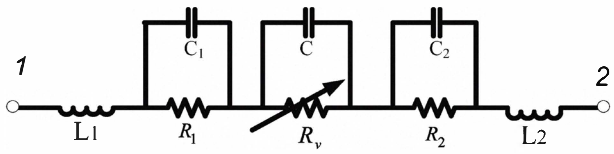

Fig.2. PIN diode equivalent circuit when I_i and v_m are positive.

$$R_1 = \frac{w_1^2}{\mu_p I_m \tau_l} \quad (1)$$

$$R_2 = \frac{w_2^2}{\mu_p I_m \tau_l} \quad (2)$$

$$R_v = \frac{v_t}{I_i + I_m} \quad (3)$$

τ_l is the recombination time at the depletion region.

model 2: If the applied voltage to the pins 1and 2 is negative and the applied current to the pins 3 and 4 is positive then the $N^+ - P^+$ layer acts as a variable resistance with voltage and two layers I_1 and I_2, act as a capacitor. The resistance of these layers are R_{c1} and R_{c2}, respectively. PIN diode equivalent circuit with these conditions is shown in Fig.3. C_1,C_2 and R_v can be defined as follows[4] :

$$R_v = \frac{v_t}{I_i} \quad (4)$$

$$c_1 = \frac{\varepsilon A}{w_1} \quad (5)$$

$$c_2 = \frac{\varepsilon A}{w_2} \quad (6)$$

C_1,C_2 are equivalent capacitors for I_1 and I_2 layers, respectively.

model 3: If the pins 3 and 4 are short circuit then the element acts as a ordinary PIN diode. The circuitry model of multi-application PIN diode is given in Fig.4.

The current-voltage curve and the total resistance of PIN diode per flow changes I_i are shown in Fig. 5 and Fig. 6, respectively. As shown in Fig.5 and Fig.6 by increasing I_i, resistance will reduce also threshold voltage will increase.

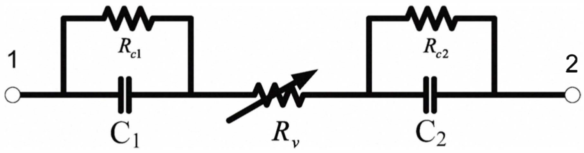

Fig.3. PIN diode equivalent circuit when I_i is positive and v_m is negative.

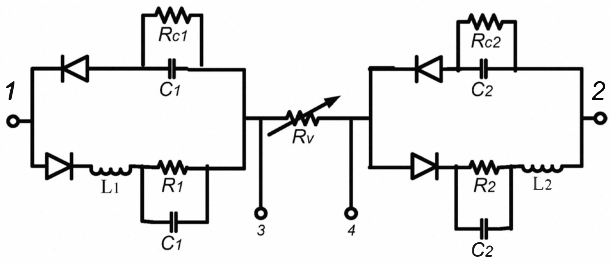

Fig.4. The circuitry model of multi-application PIN diode.

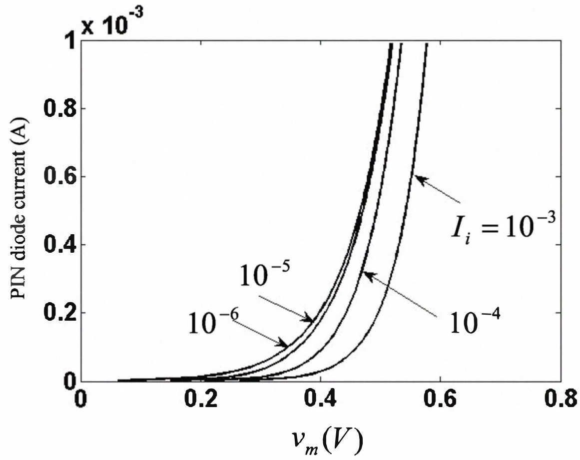

Fig.5. The current-voltage curve of PIN diode Per flow changes I_i.

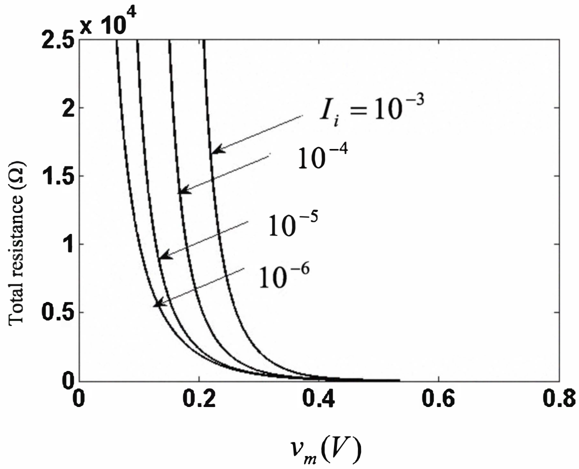

Fig.6. The total resistance curve of the PIN diode, Per flow changes I_i.

III. MODULATOR WITH MULTI-APPLICATION PIN DIODE

Here, an example for proper performance of PIN diode that presented above is given. The PIN diode is located in part of modulator transmitter system. For escaping of non-linear analysis, it has been used. Fig.7 shows the modulator stage. x_c is message signal. The interface circuit has been used to convert this signal to input current for PIN diode control pins. Fig.8 shows the modulator small signal circuit. R_v is defined as:

$$R_v = R'(1-\frac{x_c}{V_t}) \tag{7}$$

Where that $R' = \frac{V_t}{I_s}$. (8)

The output signal is obtained according to following equation.

$$V_o = g_m.\cos(w_c t).(R_1 + R_2 + R_v) =$$

$$g_m.\cos(w_c t).(R_1 + R_2 + R' - \frac{R'x_c}{V_t})$$

μ is defined as follows:

$$\mu = \frac{-R'}{V_t(R' + R_1 + R_2)} \tag{9}$$

$$V_o = g_m.(R_1 + R_2 + R')(1 + \mu.x_c \cos(w_c t)) \tag{10}$$

Modulator output signal is given in Fig.9. The modulation frequency is 80×10^6 Hz.

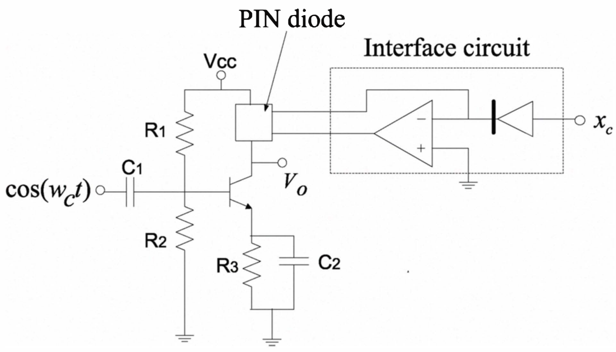

Fig.7. Modulator stage.

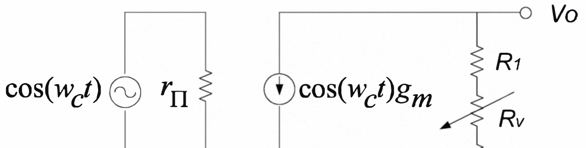

Fig.8. Modulator small signal circuit.

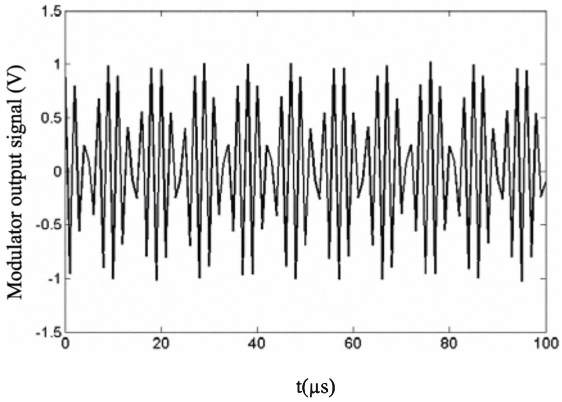

Fig.9. Modulator output.

IV. CONCLUSION

In this paper, a multi-application PIN diode is designed. This PIN diode by adding a layer to the middle layer is obtained. With respect to input voltage and the also applied voltage to control pins, the element is presented for three types with difference impedance. By using of this feature of the PIN diode, it can be used in the resonators, amplifiers and high frequency multiplier, modulator and demodulators circuits. Multi-application PIN diode has a higher breakdown voltage to the common PIN diode.

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