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MEASUREMENT OF RF SIGNAL POWER IN RF MEMS SWITCH

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ABSTRACT:

A Radio Frequency Micro Electro Mechanical System (RF MEMS) is a miniaturized mechanical system with electronic components. The RF power sensors are the key component of any RF power meter. RF power sensor based on MEMS technology works with a innovative sensing principle that is to measure the RF signal power. RF MEMS power sensor technology is based on detecting the electrostatic force between the RF signal line and a suspended membrane. RF MEMS switch has two states namely ON state and OFF state. In the ON state it exhibit R, L, C characteristics where as in the OFF state exhibit only capacitance characteristics. The RF power is measured for the desired frequency of 15GHz.

I. INTRODUCTION

Modern communication systems require low weight, volume and power consumption and a high level of integration with electronics. Wide band 100 kHz-4GHz power sensors are presented which are based on sensing the electrostatic force between the RF signal line and the suspended membrane. Electrostatic force is directly proportional to RMS signal voltage, which results in the displacement of the suspended membrane. It is capacitive allowing signal power with low dissipative losses. Design optimization results in measured insertion and reflection losses better than -30dB and -0.15dB respectively up to 4GHz and a sensitivity of 90FmW^-1 [1]. The use of the power sensor is to measure a certain percentage of the incident RF power coupled by a MEMS membrane, During the RF power detection, an undesired phase shift is generated by the MEMS membrane. Using this model, the additional phase shift is analyzed to show the phase change of the detected RF signal [2].The power sensor measures the microwave power coupled from the CPW line by a MEMS membrane. The experimental results show that the sensor has a reflection of about -17 dB and insertion loss of less than -0.083 dB up to15 GHz [3]. In this paper, a power sensor for RF signals realized in MEMS technology is presented. The power sensor is based on a sensing principle proposed for measuring RF signal power in RF and microwave devices.

II. CPW BASED POWER MEASUREMENT

Conventional microstrip transmission line has high dispersion and low losses where as the CPW transmission line has low dispersion and high losses which is required for the better performance and efficient transmission of the RF signal through the device. The CPW has design flexibility and small circuit size which reduces the area. Due to these reasons CPW is considered to be an optimum transmission line for power sensing. The RF MEMS power switches are very small in size and are of low cost when compared to that of conventional switches.

A. RF MEMS SWITCH:

The basic structure of RF MEMS switches consists of three layers It has two ground plane on either side of the CPW plane and a single center conductor to transmit the RF signal. The RF MEMS switch consists of two states they are ON state and OFF state. A capacitance effect is realized between the two electrodes (fixed electrode and movable electrode). When a voltage is applied between two electrodes an electrostatic force is produced between them .when the driving voltage is stopped the electrostatic force will disappear.

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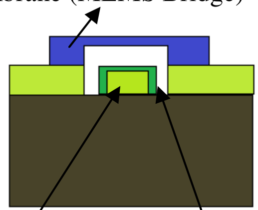

Fig 1. RF MEMS Switch in OFF state

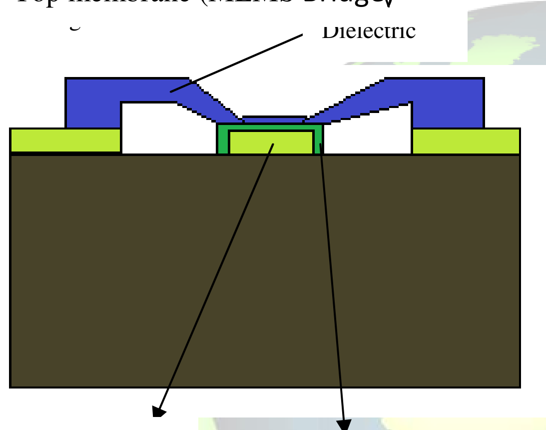

Fig 2. RF MEMS Switch in ON state

B. DESIGN FORMULA:

Formula for capacitance: The up-state capacitance is given by

$$C_{up} = \frac{\varepsilon_0 A}{g_0 + \frac{t_d}{\varepsilon_r}}$$

The down-state capacitance is given by

$$C_{dn} = \frac{A\varepsilon_0\varepsilon_r}{t_d}$$

Formula for inductance: The up-state inductance is given by

$$L_{up} = \frac{1}{4\pi^2 C_{up} f_{0^2}}$$

The down-state inductance is given by

$$L_{dn} = \frac{1}{4\pi^2 C_{dn} f_{0^2}}$$

III. RF PERFORMANCE MEASUREMENTS

The performance of any RF or microwave device is studied by the RF measurements. The performance measures are the S-Parameters and their phase characteristics. The S- Parameters are the scattering matrix parameters which are used to analyze the insertion loss, reflection loss, VSWR, reflection coefficient and characteristic impedance of the device. The important S-Parameters are insertion loss and reflection loss. . [6] discussed about amplifier power relation, impedance , T π and microstripline matching networks.

A. REFLECTION LOSS:

Reflection loss of any RF or microwave device is defined as the ratio of reflected power wave at port 1to the incident power wave at port 1.It is given by S (1, 1) and is measured in dB.

$$S_{11} = \frac{\text{reflected power wave at port 1}}{\text{incident power wave at port 1}}$$

B. INSERTION LOSS:

Insertion loss of any RF or Microwave device is defined as the ratio of transmitted power wave at port 2 to the incident power wave at port 1.It is given by S (2, 1) and is measured in dB.

$$S_{21} = \frac{\text{transmitted power wave at port 2}}{\text{incident power wave at port 1}}$$

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C. SENSITIVITY:

The sensitivity is defined as the ratio of output voltage to the total power in the RF or microwave device.

$$S_{total} = \frac{V_{out}}{P_{total}}$$

$$= \alpha \sum_{i}^{N_i} (T_h - T_c)/P_{total}$$

B. RF MEMS POWERSENSOR IN ON STATE:

In the ON state the power sensor has all the R, L and C characteristics. Figure 3 shows the equivalent circuit modeling for the ON state of RF MEMS power sensor. The resistor in the circuit acts as the power sensing component and senses the RF power in the device

C. EQUIVALENT CIRCUIT:

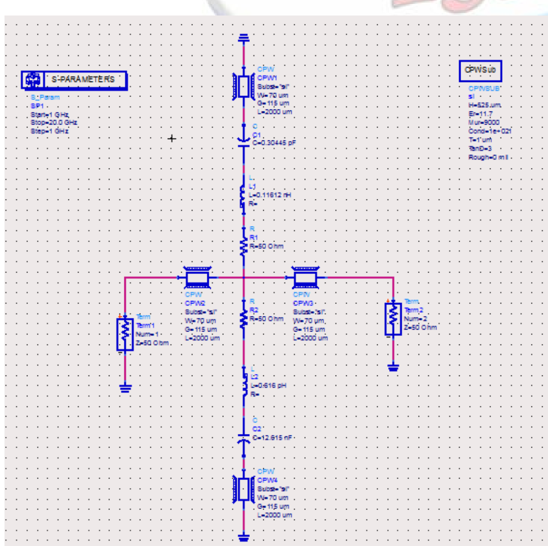

Figure 3 Equivalent circuit modeling in ON state

D. EXPERIMENTAL RESULTS

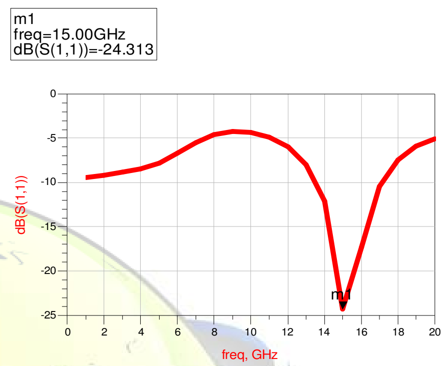

Figure 4 Return loss in ON state

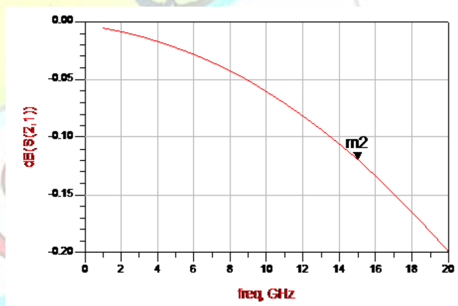

Figure 5 Insertion Loss in ON state.

m3
freq=15.00GHz
phase(S(2,1))=102.826

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Figure 6 Phase characteristics in ON state

E. RF MEMS SWITCH IN OFF STATE:

In the OFF state the power sensor has only capacitance characteristics. Figure 7 shows the equivalent circuit modeling for the OFF state of RF MEMS power sensor. When the metal bridge loses its contact with the dielectric layer the power sensor comes into OFF state

F. EQUIVALENT CIRCUIT:

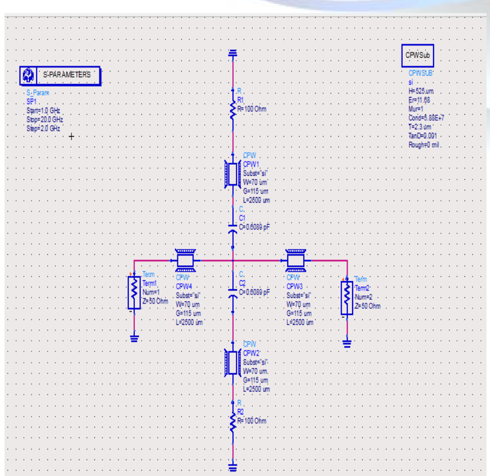

Figure 7 Equivalent circuit modeling in OFF state

G. EXPERIMENTAL RESULTS:

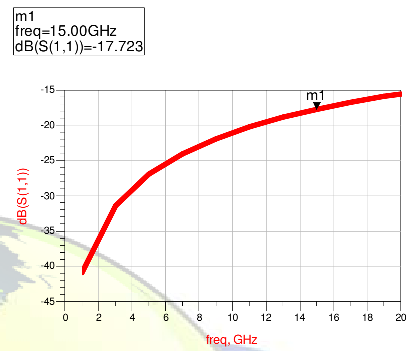

Figure 8 Reflection loss in OFF state

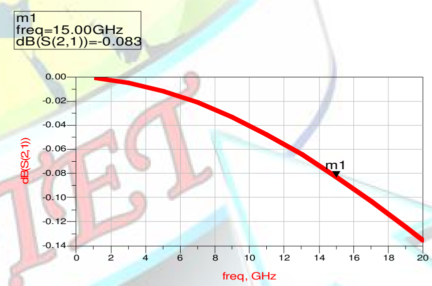

Figure 9 Insertion Loss in OFF state.

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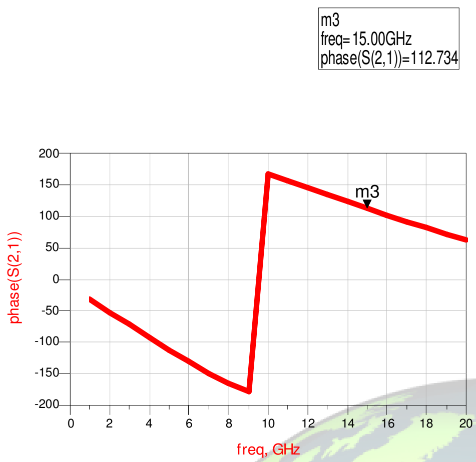

Figure 10 Phase characteristics in OFF state

TABLE 1. ANALYSIS OF S-PARAMETERS OF RF MEMS POWER SENSOR IN ON AND OFF STATE

FREQUENCY	***S-PARAMETERS***	***ON STATE***	***OFF STATE***
	REFLECTION LOSS	-24dB	-17.8dB
15 GHZ	INSERTION LOSS	-0.12dB	-0.08dB
	PHASE CHARACTERISTICS	102º	112º

From figure 4 and figure 5 the insertion loss and reflection loss of the RF MEMS power sensor in ON state are observed and analyzed. Similarly from figure 8 and figure 9 the insertion loss and reflection loss in OFF state are observed and analyzed. In this power sensor the insertion loss in ON state is -0.12dB where as in OFF state it is -0.083dB. Similarly, the reflection loss in ON state is -24dB where as in OFF state is -17.83dB.

IV. CONCLUSION

.A lumped model RF MEMS power sensor has been presented in this paper. The power sensor is designed using silicon (Si) substrate. S-Parameters and phase characteristics of the power sensor are analyzed in both ON and OFF state. The designed RF MEMS based power sensor is capable of measuring the power coupled in MEMS membrane more effectively than the conventional power sensors.

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