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An Active Resonator Using Defected Ground Structure with Islands

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***Abstract*— A new resonator using active device and defected ground structure with islands (DGSI) is proposed. The active device is used for supplying the negative resistance which is one of key factors of the proposed active resonator. The negative resistance is realized by the series feedback circuit of the active device. The electrical**

characteristics of the proposed resonator with DGSI are improved by combining the negative resistance and the microstrip line with DGSI where the electric field is the most strong. It is shown that the measured improvement in S21 and S11 of the proposed active resonator with DGSI are 4.55dB and 0.32dB, respectively, at the resonant frequency compared to the previous DGSI resonator without active device.

Keywords-component; resonator, active resonator, DGS, DGSI, defected ground structure

I. INTRODUCTION

Passive resonators have been widely used in design high frequency filters. It has been one of interesting challenge to develop resonators of which size and loss are minimized. Especially, highly integrated resonators are required in RFIC and MMIC technologies. However, severely miniaturized resonators have relatively increased loss, which is the cause of degraded Q-factor. So it is required to compensate the loss and improve Q of passive resonators. One of methods is to adopt active devices in resonator circuits, which is called active resonators.

In this paper, a novel active resonator is proposed by combining the existing microstrip line with DGSI (defected ground structure with islands) and the negative resistance of active devices [1-3]. The microstrip line and DGSI forms a parallel line structure to which the negative resistance circuit having the series RLC feedback circuit of FETs are connected. Due to the combined active device, the loss and Q of resonators are improved.

The analysis for the negative resistance and measured frequency characteristics are presented to show the validity of the proposed resonator.

II. NEGATIVE RESISTANCE OF ACTIVE DEVICES

Fig. 1 and Fig. 2 show the RLC series feedback circuit of a common-source FET topology and its equivalent circuit, respectively. The impedances Z_1, Z_2 and Z_d in the equivalent circuit are expressed by eqs. (1)~(3) [3-5].

The input admittance, Y_{in}, is expressed by eq. (4). Y_{in} can be expressed by real and imaginary parts separately, and Fig. 2 is simplified as Fig. 3. The real part of Y_{in} is the negative resistance (R_{neg}) of the FET series RLC feedback circuit. R_{neg} is mainly dependent of L_d and C_d. The larger real part of Y_{in}, the smaller R_{neg} and the narrower bandwidth where the negative resistance exists.

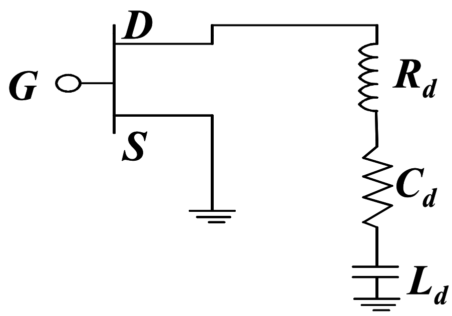


Fig. 1 FET series RLC feedback circuit

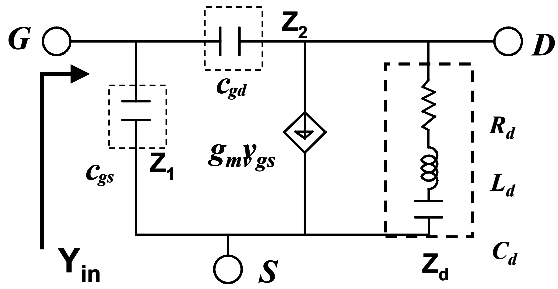


Fig. 2 Equivalent circuit of the FET series RLC feedback circuit

$$Z_1 = \frac{1}{j\omega C_{gs}} = -jX_1 \tag{1}$$

$$Z_2 = \frac{1}{j\omega C_{gd}} = -jX_2 \tag{2}$$

$$Z_d = R_d + j(\omega L_d - \frac{1}{\omega C_d}) = R_d + jX_d \tag{3}$$

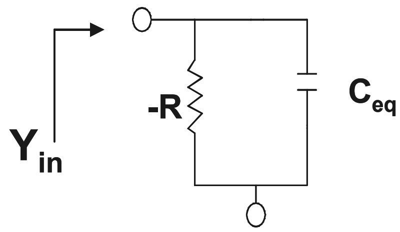


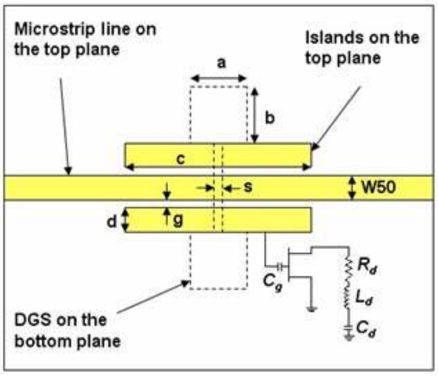
Fig. 3 Simplified equivalent circuit of Fig. 2

$$\begin{aligned} Y_{IN} &= \frac{R_d + g_m(R_d^2 + (X_d - X_2)X_d)}{R_d^2 + (X_d - X_2)^2} \\ &+ j(\frac{1}{X_1} - \frac{X_d - X_2 - g_m X_2 R_d}{R_d^2 + (X_d - X_2)^2}) \\ &= \frac{1}{R_{neg}} + j\omega C_{eq} \end{aligned} \tag{4}$$

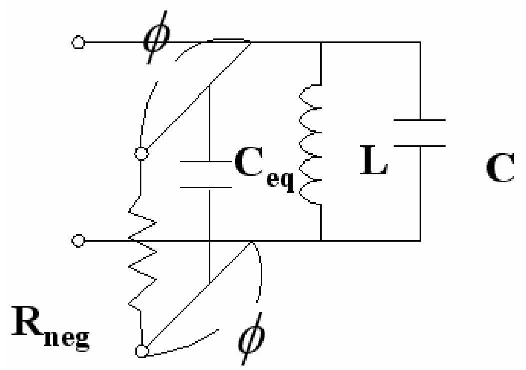
III. PROPOSED ACTIVE RESONATOR USING DGSI

Fig. 4(a) shows the proposed active resonator having DGSI and active part for the negative resistance. DGSI is composed of one dumb-bell shaped DGS on the ground plane and two islands at both sides of microstrip line on the top plane [1,2]. The negative resistance is realized by FET series RLC feedback circuit which is connected to one of islands on the top plane. The connection point of RLC feedback circuit is placed at the very high dense region of electric field.

Fig. 4(b) shows the equivalent circuit of the proposed active resonator with DGSI. ϕ represents the electrical length of islands, and L and C are the equivalent circuit elements of DGSI. R_{neg} and C_{eq} are determined using Fig. 3 and eq. (4). The loss of passive DGSI resonator is compensated through the active negative resistance.



(a)



(b)

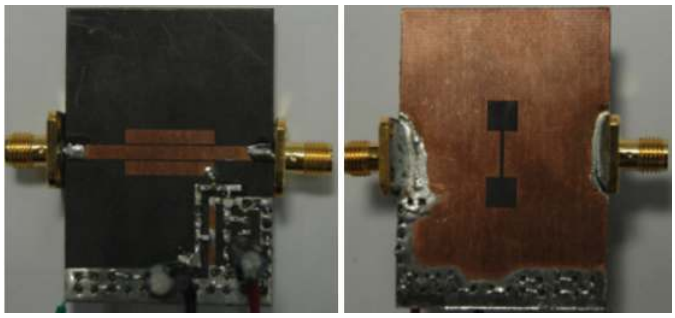
Fig. 4 Proposed active resonator using DGSI and active device (a) layout and schematic (b) equivalent circuit (ε_r=2.2, substrate thickness=31mils, a=b=5mm, c=15mm, d=W50=2.4mm, g=0.2mm, s=0.5mm)

Total capacitance of the active resonator, C_{total}, can be calculated by eq. (5). Here C_g is the DC block capacitor connected to the gate of FET. Therefore it is noted that the resonant frequency, Fo, of the active resonator shifts down from that of passive DGSI resonator, because the resultant resonator frequency depends on C_{total} rather than C, and C_{total} is greater than C.

$$C_{total} = C + \frac{C_{eq} C_g}{C_{eq} + C_g} \tag{5}$$

IV. SIMULATION AND MEASURED RESULTS

The proposed resonator composed of DGSI and active device has been fabricated, as shown in Fig. 5, measured and compared to the previous passive resonator realized by DGSI only. The FET device adopted is Fujitsu FHX35LG to which 2.5V of Vds and 10mA of Ids have been applied for biasing it. The element values of R_d, L_d, C_d, and C_g for the negative resistance circuit are 39Ω, 8.2nH, 3pF, and 1pF, respectively.



(a) (b)

Fig. 5 Photograph of the fabricated active resonator (a) Top view (b) Bottom view

Fig. 6 shows simulated S-parameters of two resonators, the passive resonator composed of only DGSI and proposed resonator having DGSI and active device. Agilent ADS momentum has been used for electromagnetic (EM) simulation, and the required Co-simulation between EM- and circuit-simulation has been performed on ADS. It is shown that the simulated S21 and S11 of the proposed active resonator are improved by 5.6dB and 0.62dB, respectively, at the resonant frequency compared to DGSI passive resonator.

Fig. 7 illustrates the measured S-parameters of the DGSI resonator and proposed active resonator. The measured improvement in S21 and S11 are 4.55dB and 0.23dB, respectively. Even though there are some minor discrepancies between simulation and measurement, it is definitely verified that the frequency response and fractional 3dB bandwidth versus Fo, which is the measure of Q, have been improved. The minor discrepancies are expected to be caused by the practically inserted additional lines in the negative resistance circuit for connecting of R_d, L_d, C_d, C_g, and FET device. Table 1 summarizes the simulation and measurement data.

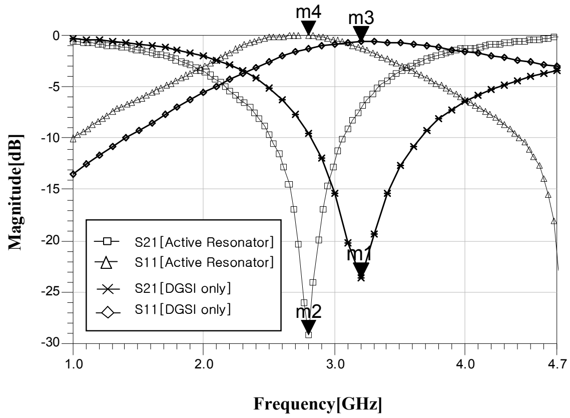


Fig. 6 Simulated S-parameters of the DGSI resonator and active resonator with DGSI and FET

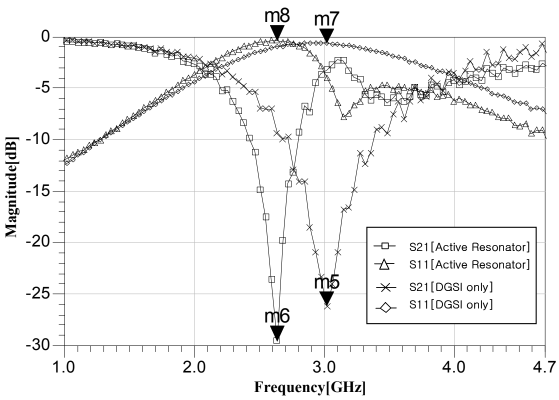


Fig. 7 Measured S-parameters of the DGSI resonator and active resonator with DGSI and FET

Table 1. Data of DGSI resonator and proposed active resonator

	DGSI only		Active Resonator	
	Simulation	Measurement	Simulation	Measurement
F_o [GHz]	3.2 (m3)	3.018 (m7)	2.8 (m4)	2.635 (m8)
S21[dB]	-23.614 (m1)	-25.024 (m5)	-29.219 (m2)	-29.577 (m6)
S11[dB]	-0.625 (m3)	-0.697 (m7)	-0.003 (m4)	-0.370 (m8)
$\frac{3dB\ BW}{F_o}$ [%]	71.9	53.5	56.25	33.85

V. CONCLUSION

A new active resonator using DGSI and FET negative resistance has been proposed and measured. It has been verified that the proposed active resonator has superior characteristics to the passive resonator composed of only DGSI. The measured improvement in S21 and S11 of the active resonator are 4.5dB and 0.3dB, respectively. The improvement has been caused by the compensation of the negative resistance of the FET series feedback circuit. It is expected that the proposed active resonator can be applied to microwave circuits such as oscillators and filters and so on, which require microwave resonators.

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