Study and Investigation of Metamaterial Losses free Resonator For Nanotechnology Applications

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Abstract— This paper presents analysis of the Metamaterials parameters and its dependence on its nanostructure and shows that such materials has nonlinear Electric permittivity and magnetic permeability. These parameters affect functionally the energy propagation and losses. It also investigates that these materials need to employ a controllable negative resistance to control the above mentioned parameters and compensate for the nanometric resonator losses. A new nonnumeric negative resistance MOSFET (NR-MOSFET) has been proposed, designed and examined for this reason. These losses results from metallic sub wavelength Split-Ring Resonator (SRR) and the metamaterial itself is constructed of arrays of these SRR cells. The basic idea of the negative resistance MOSFET depends on contracting the channel width proportionally as increasing the drain voltage. The new device is expected to have a speed of response which is higher than any of the known traditional techniques, a very low power consumption and a wide dynamic range of resistance variation . These good performance serve to have the desired functionality of the metamaterial.

I. INTRODUCTION

METAMATERIAL Metamaterials are nanostructure materials fabricated from repetition of dielectric and / or metallic elements to produce the desired electromagnetic behavior and it is characterized by negative electric permittivity -ε And magnetic permeability -μ which makes it to have negative refractive index n and energy propagating in the opposite direction [1-3]as shown in Figure (1) .

If the frequency of the incident light lies within a spectral band slightly above the LC-resonance frequency, the effective magnetic permeability of the SRR array can indeed be negative. These cells act as electric dipoles whose electric response can lead to a negative permittivity. As well known, in order to obtain a magnetic response from a metal nanostructure the incident light has to excite local currents circulating in loops (solenoid currents). These currents in turn give rise to a magnetic dipole-moment. By properly designing the metal nanostructure, one can obtain a resonant enhancement of the local currents leading to strong magnetic response, and if a current is excited and circulated in a monomolecular loops, It gives rise to a magnetic dipole moment, which in turn give a current which circulates in the same direction as that creating the magnetic dipole moment. This latter current enhances by the same manner the magnetic dipole moment and so on. Leading to strong magnetic response with negative permeability and does the same w.r.t. the electric response and gives rise to negative permittivity [4-7]. As shown in Figure (3) I\ meta assists I and B\ meta assist B.

This property is very needed in many applications such as antenna where the radiation is noticeably increased and waveguides where neither energy reflection nor losses occur. Several advantages of such nanostructure materials are gained. Size reeducation, high directivity, increased power radiability, novel functionalities are examples of these advantages [8-9].

Section 2 illustrate the Electric / magnetic response enhancement, negative resistance MOSFET (NR-MOSFET) is presented in section 3, theory and modeling in section 4 , and Measurement technique is presented in section 5. the conclusions of this work are is finally given in section 6.

Figure (3) The circulated currents and the magnetic dipole moments

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II. ELECTRIC AND MAGNETIC RESPONSE ENHACEMENT

Knowing that an array of metmaterial SRR can be modeled or equivalent to a series of array of LC sections(see figure (4)), then the enhancement of the electric and magnetic response can be further enhanced by decreasing the nanostructure resonator losses, which can be fulfilled by inserting a nano structure negative resistance element such as a nanometer negative resistance MOSFET(NR-MOSFET) in series with each array of SRR .

Where $\frac{1}{2}R_{meta}$, $\frac{1}{2}L_{meta}$ and C_{meta} are metamaterial equivalent circuit and $NRMOSFT$, $C_{parasitic}$ are the negative resistance compensation.

III. NEGATIVE RESISTANCE MOSFET (NR MOSFET)

The idea and construction of the proposed voltage controlled negative resistance MOSFET (NR-MOSFET) is shown by figure (5). It is realized using the polysilicon gate N type short channel MOSFET technology. It consists of a MOSFET

(T_{NR}) with channel length L_N, width Z_N and oxide thickeners h_{ON}, the channel width contraction is achieved using two additional auxiliary Al long deposited over the oxide. The potential of which is maintained negative with respect to the channel well potential and its amplitude kept varying proportionally with the drain voltage V_{DS} then when its potential is zero, the channel remains un contracted. When its potential is negatively increased the channel is depleted beneath these Al langue and laterally besides them which makes the channel to contract. In this case it can be observed that the drain current IDS decreases as the drain voltage VDS increases which means that the MOSFET has a negative channel resistance [10].

A MOSFET operational amplifier see Figure (6) is designed so as to reverse the polarity and have the desired amplitude needed to elaborate the wanted contraction and it's biased between the control voltages $+V_R$, $-V_R$. The equivalent circuit of the controlled negative resistance as shown in Figure (6) . The op amp is designed so as the control voltage V_C obeys the behavior shown in figure (7), and goes negative as V_{DS} goes positive. Since the channel well potential is always negative this design guarantees a strong depletion of the N^+ version layer of the channel well. This leads to a depletion layer width W which increases steeply as V_{DS} increases, thus controlled decrease of the channel width and consequently channel current I_{DS} decrease as V_{DS} increases, we notice that the decrease of I_{Ds} becomes more noticeable in the saturation region where IDS should remain constant and cause more observable negative resistance behavior.

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IV. THEORY AND MODELING

The energy band diagram of the proposed negative resistance NR-MOSFET is shown in Figure (8)

The variation of the potential V_Z with distance, when the Al Langue potential is made zero and the surface potential V_S :

$$V_S = V_C + \frac{C_{ox}}{2d_o\,\varepsilon_s}(V_{GS} - V_T - V_x)\ Z^2 \ldots\ldots.(1)$$

and the control voltage is :

$$V_C = -\eta V_{DS} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

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$$V_C = -\eta V_{DS} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

where:

C_{ox} *the MOSFET oxide capaci* tan *ce per unit surface*

$(\sim 8.85\times10^{-4}\ F/m$ *with oxi* det *hickness* $h_o = 400A^o\ )$

d_o *the MOSFET channel depth* $(\sim 100A^o\ )$

V_{GS} *the gate to source voltage* (V)

V_T *the threshold voltage* $(\sim 0.5V)$

V_x *the channel potential taken , longitudinally, at postionx* (

The amount of channel contraction can be calculated by equating the channel width Z to W:

$$W = \sqrt{\frac{2d_0\varepsilon_s\,(V_s + \eta V_{DS})}{C_{ox}\,(V_{GS} - V_T - V_X)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Where $V_{DS} \geq V_{DSS}$

and

$$V_{DSS} = (V_{GS} - V_T)[1 - \sqrt[4]{\frac{\varepsilon_s d_o h_o}{4\varepsilon_o L^2}}\ ] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where $\eta\ \zeta$ is the ratio of the P^+ region potential VC to the drain voltage VDS of the NR - MOSFET. is obtained as follows:

$$\eta = \frac{dV_x}{dV_{ds}} = \sqrt{\frac{Z_1/L_1}{Z_2/L_2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \ldots \qquad (6)$$

We notice that the best value of η is unity and I_{DS} remains constant and independent of V_{DS} as long as η is zero . when η is increased I_{Ds} decreases as V_{Ds} is increased. The rate at which I_{Ds} decreases is increasing V_{Ds} increases as η in creases. This indicates that the NR-MOSFET acquire a negative resistance in saturation region of operation. Controlling the geometrical ratio of the NR controls this resistance. MOSFET device. it be comes also externally controlled by controlling the value of η.

To realize a nano geometric NRMOSFET advanced fabrication process based on ion implantation will be used instead of the traditionally known photolithographic technique to implement all drain, source and gate regions [11- 12].

V. MEASUREMENT TECHNIQUE

Experimental test MOSFETs has been prepared by Thomson microelectronics /DRD of Grenoble / France. The source channel-width z = 10 micron, the drain channel-width Z` ranges from 5 to 10 micron, channel length L = 5 micron and oxide thickness h0 are 40 A and 1200 A. Measurements are performed on these test specimens to obtain the value of the effective MOSFET geometrical ratio $\left(\frac{Z}{L}\right)_{eff}$ and its dependence on the device geometry (Z, L, β) and biasing (VDS, VGS). Measurement and characterization are achieved using the experiential net up shown in Figure 9. Hundreds of measurements have been performed to specify the device parameters . Figure 10. shows the dependence of the IDs/VDs characteristics on the value of the parameter η. and Geometries. We observe that IDs still increasing proportionally in the ohmic region with VDs but at smaller rate. Then IDs begins to decreases as increasing VDs in the saturation region. The rate of decreases becomes more important at greater values of η. This behavior is attributed to the increase of the depletion region width as VDs. It becomes more noticeable of at greater values of VGs .

VI. CO)NCLSIONS

The presented nanotechnology losses free resonator metamaterial cell which composed of SRR cell and a nanometer negative resistance NR-MOSFET is reliable and has many applications in microwave smart antenna and nanotechnology which is very important nowadays in mobile communication systems.

ACKNOWLEDGMENT

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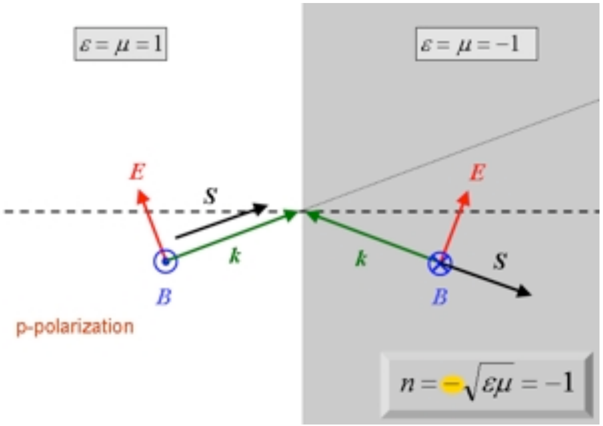

Figure (1) Negative refraction at the interface between vacuum and metamaterial

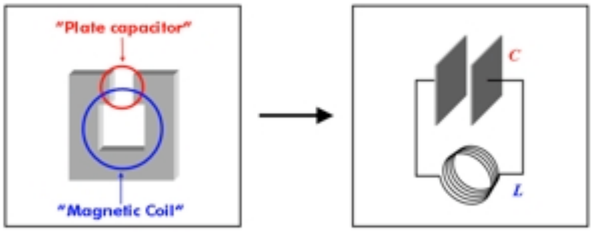

Figure (2). The basic physics of a SSR simulated as an LC oscillator

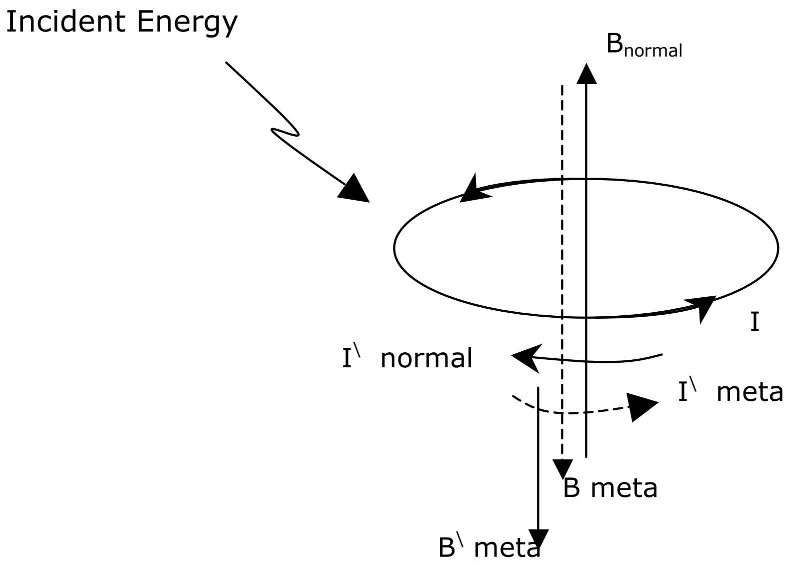

Figure (3) The circulated currents Magnetic Dipole moments

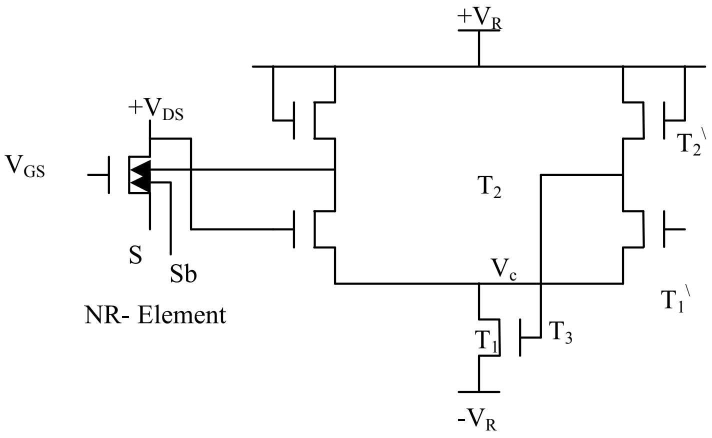

Figure 6. NR MOSFET equivalent circuit

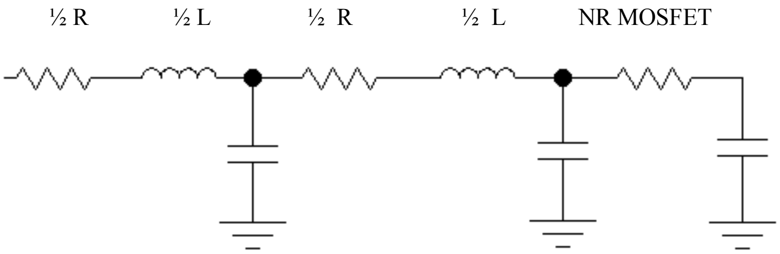

Figure (4) The proposed equivalent circuit for an array of SRR and compensated negative resistance

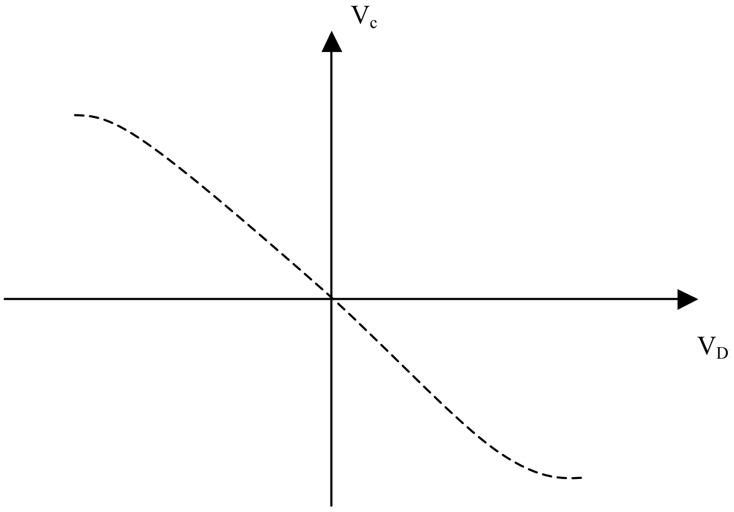

Fig.(7) Variation of V_c with V_{DS}

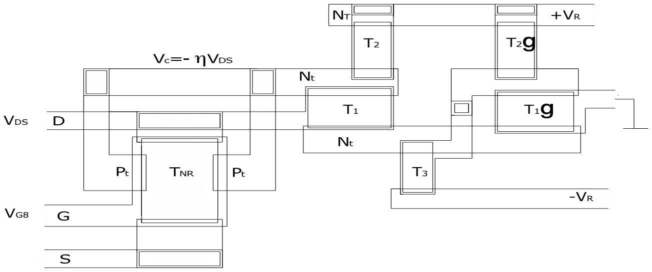

Figure (5) The construction of the proposed voltage controlled negative resistance

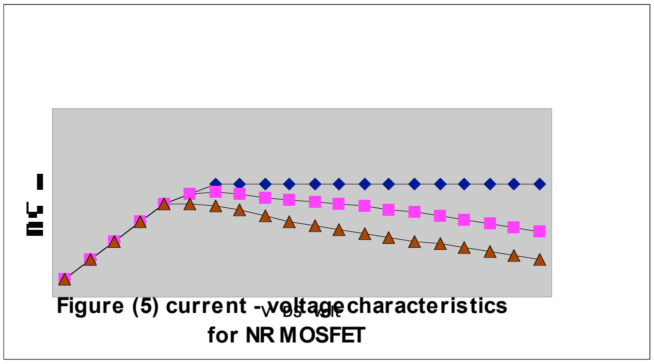

Figure 10. Current –Voltage characteristics for NRMOSFET

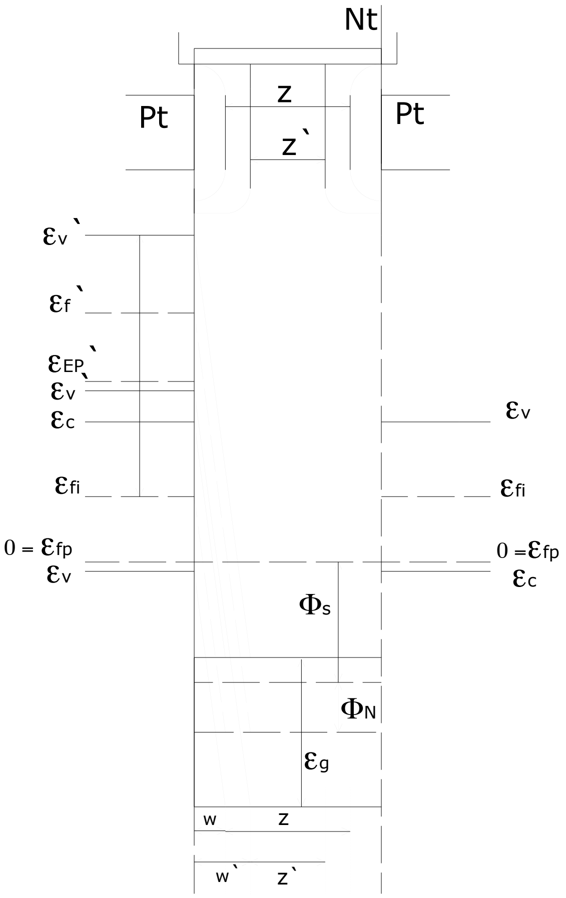

Figure 8. the energy band diagram for NR MOSFET

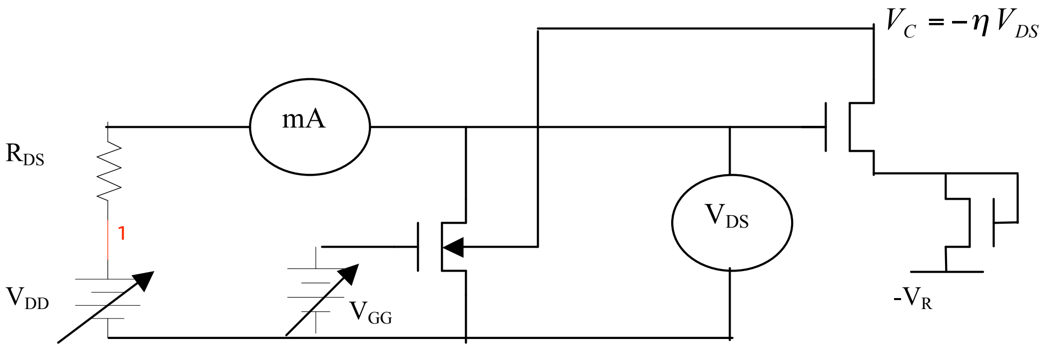

Figure 9 Experimental Setup