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Comparison of Bandwidth Enhancement of a Microstrip Antenna With Negative Capacitor, Negative Inductor And Negative Resistor

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Abstract: - **Now a days 4G communication requires high gain and easy integrated array circuits. Various communication systems require single radiating element operating in wide band. Microstrip antenna has all these advantages but it has some limitations, like low gain, low bandwidth and surface wave propagation. Use of negative inductor, negative capacitor or negative resistor overcomes this disadvantage of Microstrip antenna. In this paper, we will see how the bandwidth of a Microstrip antenna is enhanced with the use of negative inductor, negative capacitor and negative resistor separately. A comparison will be made based on the results obtained so that we can find out that out of negative inductor, negative capacitor and negative resistor which one provides the maximum bandwidth enhancement for a Microstrip Antenna.**

Keywords: 4G, Antenna, Bandwidth, Capacitance, EIRP, FET, Microstrip, MICS, Negative Inductance.

I. INTRODUCTION

Microwave integrated circuits (MICS) have received great deal of interest for many application systems in today's life. They are easy to produce and more reliable with improved performance at low cost. The radiation pattern of a rectangular patch antenna can be controlled by inductive loading. For these reasons, integrated antennas are to be used as RF (Right Front) at antenna terminals. The purpose of this study is to investigate the effects on radiation performances of loading a microstrip element with active inductive load.

II. EVALUATION

A. Microstrip Patch Antenna

MPA (Microstrip Patch Antenna) consists of metallic patch on one side and dielectric substrate on another side. The length of the patch (L) is equal to one half of the dielectric wavelength which corresponds to the resonant frequency. The dielectric substrate material determines the size and bandwidth of an antenna. Larger the dielectric constant smaller is the size of antenna but it reduces the bandwidth and efficiency of the antenna while decreasing the dielectric constant increases the bandwidth and thereby increasing the size of the antenna. But there is limit on increasing the value of dielectric constant. The width W of the Microstrip antenna determines the input

impedance and radiation pattern. Larger width indicates an increase in bandwidth. As shown in Figure 1. "h" is the height of substrate. Here rectangular patch antenna is used. There are various methods for improving the bandwidth and gain MPA like changing the shape of patch, using multilayer structures, different feeding techniques, array method, using different dielectric substrates etc.

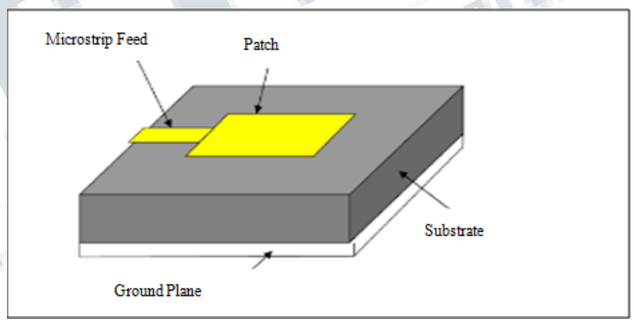

Fig 1: Microstrip Patch Antenna top view

$$Z = \frac{R_{max}}{1 + jQ} \qquad (1)$$

Where, R_{max} is the resonant resistance. Q = Quality factor

$$v = \frac{f}{f_r} - \frac{f_r}{f} \qquad (2)$$

Where f_r = resonant frequency
For lower and upper band edge frequencies f_1 and f_2 = S
And relative bandwidth (BW) can be written as:

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$$BW = \frac{f_2 - f_1}{f_r} \tag{3}$$

The quality factor can be expressed as:

$$Q = \frac{1}{BW}\sqrt{\frac{(SR_{norm}-1)(S-R_{norm})}{S}} \tag{4}$$

It can be shown from (4) that decreasing the quality factor is also effective way to enhance the antennas impedance bandwidth.

Equation (4) reduces to well known expression for Rnorm=1.

$$BW \Big| R_{norm=1} = \frac{1}{Q}\frac{S-1}{\sqrt{S}} \tag{5}$$

The admittance of a parallel RLC circuit about a narrow band frequency can be written as:

$$Y_{ant}(f_r+\Delta f) = G_{ant} - jB_{ant} \cong \frac{1+4Q^2\left(\frac{\Delta f}{fr}\right)^2}{R_{norm}-2jR_{norm}Q\left(\frac{\Delta f}{fr}\right)} \tag{6}$$

Where the frequency shift from resonance (Δf_{max}) is:

$$\Delta f_{max} = f - f_r$$

And,

$$\frac{\Delta f_{max}}{f_r} = \frac{1}{2Q}\sqrt{2R_{norm}-1} \tag{7}$$

For parallel type resonance, the bandwidth (BW) is –

$$BW = \frac{2G_{ant}}{\omega_0 \frac{dB}{d\omega}\Big|_{\omega 0}} \tag{8}$$

The calculated return loss level is increased by using reactive matching network. This compensation network could transform the frequency dependent complex antenna impedance Z_0 over a large bandwidth which is the requirement here. Thus, it is important to select suitable components for optimizing the matching levels which will maximize the bandwidth. This resonant load can be realized by a cascade of negative inductor or capacitor segments connected to an appropriate point of the patch antenna.

B. Proposed Active Compensated Antenna

The 50 input impedance of the antenna is obtained. TLYA – 5CH200 which has permittivity of 3.20 and thickness of 0.78 mm has been used as a substrate material.

The patch dimensions of width w = 16 mm and length L= 9 mm have been selected with ground plane dimensions of 50×50 mm used. The designed antenna operates at 10.5GHz with -21.5 dB at resonant frequency.

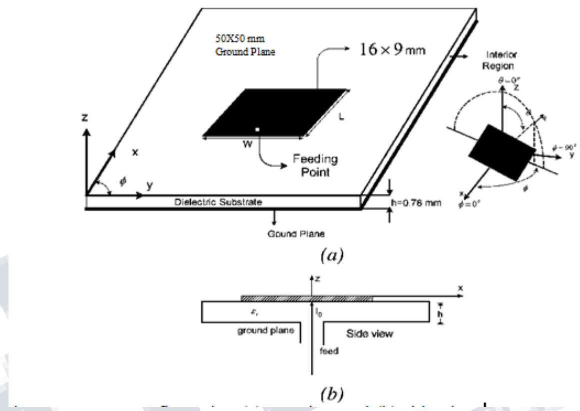

Fig 2: Antenna Configuration (a) top view and (b) side view

III. COMPARISON OF USING NEGATIVE INDUCTOR, NEGATIVE CAPACITOR AND NEGATIVE RESISTOR

A. Negative Inductance

The equivalent inductance (L_{eq}) and equivalent capacitance (C_{eq}) can be written as:

$$L_{eq} = \frac{C_{gs}}{g^2 m} \tag{9}$$

And,

$$C_{eq} = C_{gs} \tag{10}$$

The negative inductance compensation circuits having two FETs of same type have been simulated.

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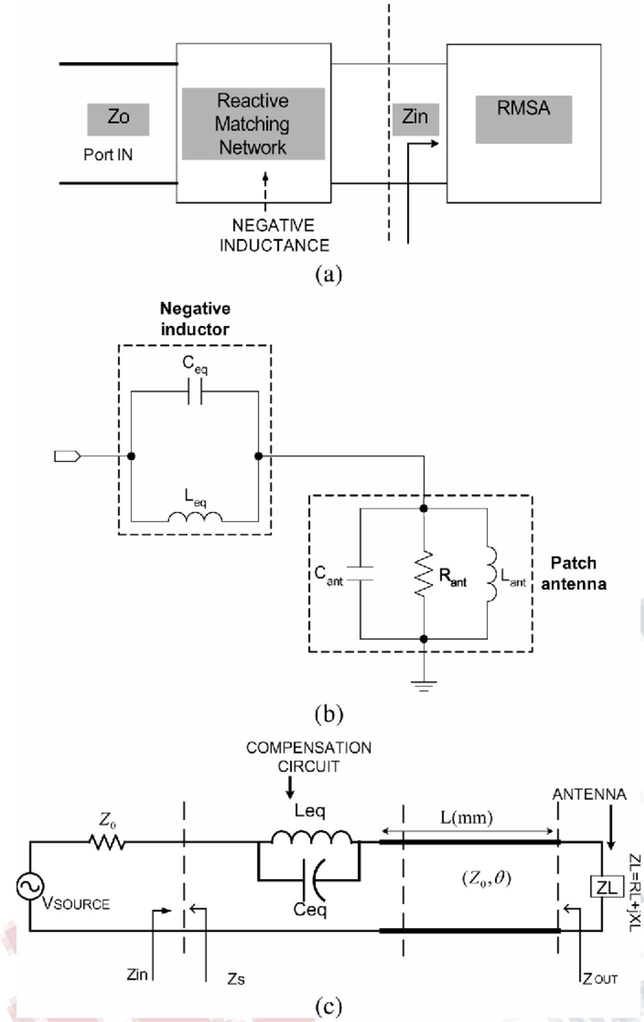

Fig 3: (a) Broadband matching block diagram, (b) the equivalent circuit of the compensated patch antenna with negative inductance (c) equivalent circuit model both matched to source and the antenna.

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From comparative analysis we observe that use of negative inductance in MPA can improve the bandwidth from 13.1% to 25.2% with a minimum deep point of -36. 33 dB.

B. Negative Capacitance

Two same type of FETs with identical transconductance (i.e.

$g_{m1}=g_{m2}=g_m$) and gate source capacitance (C_{gs}) parameters are chosen so that the value of LCR is given by:

$$R_N = \frac{1}{{g_m}^2 R_{ds}}$$

(10)

$$L_N = \frac{C_{gs}}{{g_m}^2}$$

(11)

$$C_N = {g_m}^2 L$$

(12)

Second loading port is selected near the radiating edge and opposite to the feeding port. When the negative capacitor is connected to output of antenna, the resulting equivalent circuit obtained as in fig (4):

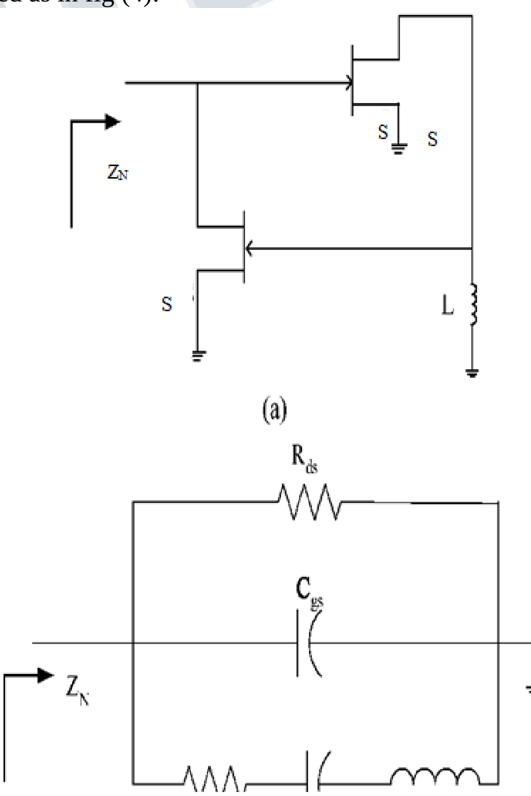

Fig 4: (a) Principle scheme of the negative capacitance circuit, (b) equivalent circuit of the negative capacitance circuit, and (c) simplified equivalent circuit of the negative capacitance circuit.

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With the utilization of negative capacitor and chip resistor loading circuit antenna gain has been increased to 9.2 dB and return loss level decreased from -18dB to -42 dB.

C. Negative Resistance

In this mechanism common collector configuration of NPN bipolar transistor is used. Inductive short circuited stub connected to transistor base terminal, optimized to obtained negative resistor at the emitter in frequency band around 2.3 GHz. The emitter terminal is used as a oscillator output and it is connected to patch antenna.

As the Microstrip radiator and oscillator circuit are integrated together, its equivalent isotropic power (EIRP) is given by:

$$EIRP = \frac{\Pr}{Gr}\left(\frac{4\pi R}{\lambda}\right)^2$$

(13)

Where we have:
λ = wavelength of measured signal.
Pr = oscillator output power, R = radius.
Gr = Antenna gain

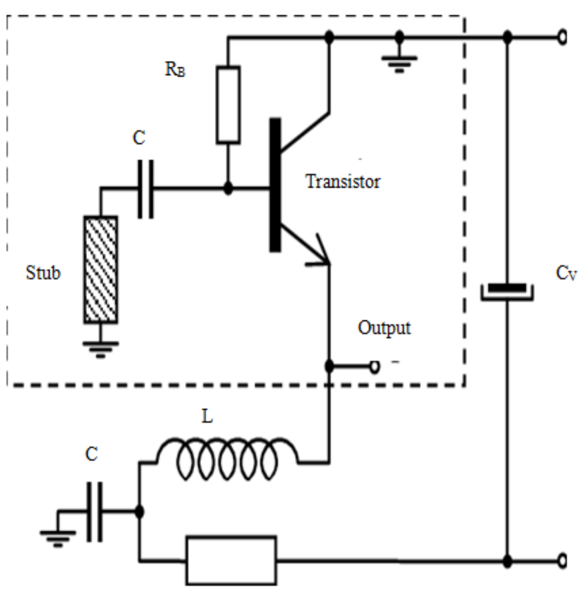

Fig 5: Transistor oscillator circuit with antenna loaded.

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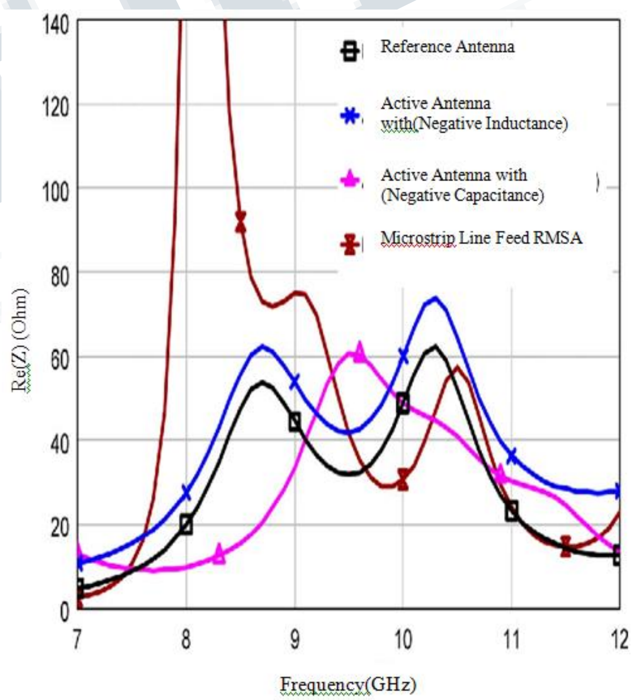
9 v of linear voltage used .The maximum EIRP of 19.4 dBm is measured and a dc to RF conversion efficiency of 33% achieved.

IV. CONCLUSION

From comparison of the results of the experiments in the table below we see that by using negative inductor we achieved more gain bandwidth as compared to use of negative conductance and negative resistance respectively.

TABLE I

Comparison of results	***Negative inductance***	***Negative Capacitance***	***Negative resistance***
Bandwidth enhancement	13.1% - 25.3%	16.2%	23.2%
Return loss(dB)	-36.33	-31.4	-35.2



Frequency(GHz)

Fig 6: Variation of the real parts of the antenna impedances for all configurations.

Hence, with respect to the benefits achieved, the use of negative inductor for the bandwidth enhancement of a microstrip antenna is recommended.

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TABLE II
Units For ELECTRONICS

Unit Name	Unit Symbol	Quantity
Ampere (amp)	A	Electric current (I)
Volt	V	Voltage (V, E) Electromotive force (E) Potential difference (Δφ)
Ohm	Ω	Resistance (R)
Watt	W	Electric power (P)
Decibel-milliwatt	dBm	Electric power (P)
Decibel-Watt	dBW	Electric power (P)
Volt-Ampere-Reactive	var	Reactive power (Q)
Volt-Ampere	VA	Apparent power (S)
Farad	F	Capacitance (C)
Henry	H	Inductance (L)
siemens / mho	S	Conductance (G) Admittance (Y)
Coulomb	C	Electric charge (Q)

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