Microstrip Line Based RF Mixer Design for GSM 900 MHz Band

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Abstract – The main purpose of RF Mixer is the frequency translation to filter out a particular RF signal channel centered among many densely populated narrowly spaced neighboring channels would require extremely appropriate impedance matching networks. In such cases, one of the best known systems is down conversion process in heterodyne receivers. The BJT Model MMBR941 that has taken for designing of RF Mixer circuit with impedance matching network using smith chart utility model tool. The circuit has designed and simulated using Agilent’s ADS tool. The performance of a RF Mixer has evaluated using parameters like gain, 1db compression point and noise figure. The Gain has achieved as 13.067 dB, NF as 2.2 and 1.123 dB of 1 dB compression point has achieved in simulation.

Keywords – Heterodyne Receivers, MMBR941, Impedance Matching, Gain, Noise Figure, 1dB Compression Point.

I. INTRODUCTION

The portable wireless communication have a wide range of usage and it have experienced tremendous growth in today’s scenario, such a rapid growth has created demand in communication technology with smaller, lighter, cheaper and a low power consumption than ever for a portable devices. This triggers designers and engineers to innovate new system architecture and circuit topologies[2][7]. This paper focuses on the receiver architecture and in a communication era, already there are three architectures like heterodyne, homodyne and image reject are available. Each of these architectures has its own advantages and disadvantages. While designing the architecture, one should keep complexity, cost, and power consumptions should be primarily determined. One of such kind of architecture is heterodyne receiver for portable devices than other approaches[9][1]. Perhaps homodyne and image reject approach has also become a plausible solution for some kind of the design problems.

Fig.1 shows the architectural block of heterodyne receivers.

![Fig 1 Heterodyne Receiver Architecture](image)

The incoming signal which has been received from an antenna is amplified by LNA & suppresses the noise[3][11]. The suppressed signal is fed to RF Mixer block where the RF signal and LO signal combines each other either it can be frequency addition or subtraction and produces a translated frequency which is nothing but an IF signal. The translated frequency i.e., IF signal are used for the following reasons, i. At very high frequency, the signal processing circuitry results in poor performance ii. For convenient processing high frequency signal is converted into IF signal because ordinary circuits using lumped elements can be replace by cumbersome high frequency techniques such as striplines and waveguides[1]. The processed intermediate frequency can be used for the following applications such as Terrestrial Microwave Equipment, Radar, AM & FM Radio Receivers, Satellite UP & Downlink Equipments, Analogue Television receivers, and Long Wave Broadcast Receivers[4][10][8]. This paper has been framed as three chapters Chapter I discusses about introduction
II. RF MIXER DESIGN

The circuit has been designed based on the conventional method. The device that has been selected for designing this circuit is MMBR941 Motorola package from the RF transistor library. Based on the datasheet of the selected transistor the device has been biased and found the input impedance and output impedance. The input impedance value is 11.5-j*51.4 Ω and output impedance value is 2064.5-j*2010.5 Ω. The source impedance is 50 Ω and load impedance is 11.5-j*51.4 Ω at 900 MHz, by knowing these two values the input matching network has been designed. Similarly the source impedance on output side is 2064.5-j*2010.5 Ω and load impedance is 50 Ω at 45 MHz, now the load impedance can be matched with source impedance by using the maximum transfer theorem. The impedance matching network can be designed by two ways one is conventional smith chart method and another one is by using smith chart utility tool available in ADS. The dual matching transformation network has been adopted here which is as follows in Fig.2[6]

This configuration is applicable only when $R_L > R_S$ where $R_L$ is the load resistance and $R_S$ is the source impedance. By using the equation (1) & (2) the $X$ and $B$ has been found out. Based on the following equation (3), (4), (5) & (6) the dual elements of the matching network has been decided whether it is an inductor or capacitor.

i. When $X > 0$ it can be realized as an inductor

$$ L = \frac{x}{2\pi f_0} $$

(3)

ii. When $X < 0$ it can be realized as a capacitor

$$ C = \frac{1}{2\pi f_0|X|} $$

(4)

iii. When $B > 0$ it can be realized as a capacitor

$$ C = \frac{B}{2\pi f_0} $$

(5)

iv. When $B < 0$ it can be realized as an inductor

$$ L = \frac{1}{2\pi f_0|B|} $$

(6)

Choosing the appropriate condition based on X & B value of source impedance the input and output matching network has been designed with the complete RF circuit which has shown in Fig.3.
following expressions, height $H$ is 1.6 mm as the substrate is FR4 and dielectric constant $\varepsilon_r$ is 4.4.

When $\frac{W}{H} \leq 1$,

$$\varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + 12 \frac{H}{W}\right)^{-0.5} + 0.004 \left(1 - \frac{W}{H}\right)^{0.2}$$

(7)

$$Z_C = \frac{\eta}{2\pi\sqrt{\varepsilon_r}} \ln \left(\frac{3H}{W} + 0.25 \frac{W}{H}\right)$$

(8)

When $\frac{W}{H} \geq 1$,

$$\varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + 12 \frac{H}{W}\right)^{-0.5}$$

(9)

$$Z_C = \frac{\eta}{\varepsilon_r} \left(\frac{W}{H} + 1.393 + 0.677 \ln \left(\frac{W}{H} + 1.444\right)\right)^{-1}$$

(10)

Figure 4 shows the microstrip line based designed RF mixer circuit with matching network using the above mentioned expression.

III. RESULT ANALYSIS

The designed schematic has been simulated using Agilent’s Advance System Design tool. Figure 5 shows conversion gain of designed circuit with respect to the RF power.

At -29 dBm RF Power the conversion gain has been achieved as 12.974 dB. The next important terminology while evaluating the mixer design is 1dB compression point. 1dB compression point occurs when the input power of an amplifier is increased to a level that reduces the gain of the amplifier and causes a non linear increase in output power. Figure 5 shows the 1dB compression point.

The same circuit performance has been retains after converting the lumped components into microstrip line components. The following Figure 6 shows the converted stripline components from the circuit schematics, at a 900 MHz RF, 855 MHz LO and 45 MHz IF signal.
The same circuit performance retains in stripline components as compared to lumped components via matching techniques. Though the circuit gain is in good agreement, the scattering parameters of the circuit were not in good agreement. In order to overcome this, either filters can be included to reduce the transmission line losses or else the metamaterials concept can be included. This paper has to be extended in the analyses of RF mixer based on minimizing the losses which includes in transmission line and to enhance the $S_{21}$ value.

Figure 7 Pin Configuration of Microstrip Line Based Designed RF Mixer

Figure 8 Conversion Gain versus LO Power

Figure 9 $S$ Parameters of Designed Circuit

IV. CONCLUSION

In this paper, a microstrip line based mixer has been designed for GSM receiver. The conversion gain has been achieved as 12.974 dB at a RF power of -29 dBm and 1 dB compression point has been achieved at IF side. Though this prototype satisfies in all aspects of evaluating the performance metrics of a RF circuit, it cannot be able to minimize the transmission line losses. Further this paper can be extended as minimizing the scattering parameter losses by introducing either a filter concept or a metamaterials to overcome the drawbacks.

REFERENCES


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