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A SINGLE TO BALANCED BANDPASS LOW NOISE AMPLIFIER WITH 0.6 dB NOISE FIGURE FOR CELLULAR BASE STATION

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Abstract — *The low noise amplifier is used for the cellular base station if the parameters are fulfilled. The noise figure needs to be below 1 dB, and gain should also be high. These both should be accomplished at the same time along with linearity. Low noise figure is designed using the common source inductive source degeneration technique as it provides good matching and the losses are reduced. The filter and balun are designed using the microstrip type. The overall integrated circuit should have low noise figure and high gain at a time. Insertion loss is to be reduced in the proposed design. Filter, amplifier and balun need to be designed in such a way that their loss does not affect the next stage of the design. The sensitivity of the receiver is also very important and need to be maintained. The receiver should be such that it should receive the signals in proper form as sent. In the below design the noise figure is reduced to 0.6 dB for the base station application.*

Keywords— cellular base station, low noise amplifier, noise figure,microstrip, transmission line

I. INTRODUCTION

Low noise amplifier is an important block at the receiver side. The low noise amplifier needs to amplify weak signals without disturbing its characteristics. Noise is a type of signal. It gets added at any block in the transceiver. So it needs to be controlled and minimized at every stage. Low noise amplifier tries to minimize the noise at its level best. At the cellular base station the received signal should be received and worked upon properly. Base station has the receiver which is sensitive to the incoming signals. So the removal and reduction of unwanted signal is necessary. Selectivity and sensitivity play an important role in the receiver [2].

Present generation cellular/GSM base stations require good performance from low noise amplifier. The receivers want high gain, low noise figure, good linearity all together. As the receiver receives wanted and unwanted signals both from the antenna it's highly influenced by noise figure and noise factor. Low noise amplifier has applications in base station preferably when noise figure

is below 1 dB. Noise figure parameter should not affect the overall performance and so should be as less as possible [1].

Noise at every stage of circuit needs to be considered. The impedance matching is important for the noiseless circuit. Impedance matching issue should be taken into account by considering the return loss parameter. It is necessary to minimize the noise degradation. The impedance matching should be good between antenna and the input port. If one parameter is good enough then the other parameters get affected and it is due to trade off between them. All the parameter need to be good at a time is a big challenge. For this purpose the circuits used all need to be tested and noise free. Or else one circuit has effect of loss on the next circuit.

The selection of low noise amplifier should be done by considering the trade off between gain and noise figure. Low noise amplifier can be implemented by various topologies. Common gate, common source are some of its topology. Complementary Metal Oxide Substrate (CMOS), Bipolar Junction Transistor (BJT) and Field Effect Transistor (FET) can be used for designing of amplifier. Here the transistor is used. The further blocks consist of block diagram, working, implementation and results.

II. CONSTRUCTION AND WORKING

The blocks considered for designing are bandpass filter, low noise amplifier and balun.

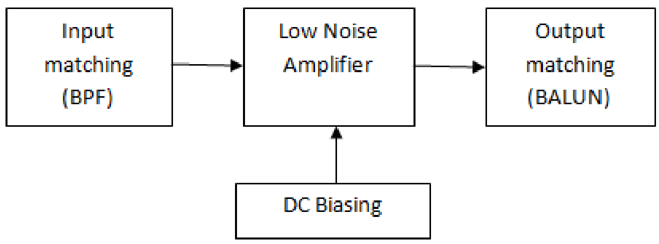

Fig. 1 - Block Diagram of System

A. Bandpass filter- filters are used for the selectivity process. There are two types of filters as active and passive filters. The passive filter has types as high pass filter, low pass filter and band pass filter. These configurations are always used. The passive filters are lossy as compared to active filters. Active filters have very less insertion loss. They are designed using the negative resistance circuit along with the passive filter. Due to this technique the insertion loss is 0. But the noise figure does not become completely 0, as the passive part affect the active circuit. So there is a trade off between the loss and noise figure, it's important that both should be minimum at a time [2]. In this design we are using the bandpass filter and hairpin configuration. Bandpass type is preferred for the frequency selectivity. Microstrip configuration is selected as it has fewer losses over the lumped components design.

The bandwidth of the filter is from 870 MHz to 930 MHz and this range can be used for the base stations. As we require compact size according to the present scenario, the hairpin filter configuration is chosen. At the first stage the parallel coupled filter was designed. But later the size constrain became into account so the edged of the coupled filter were bent into the 'U' shape which made the design as the hairpin filter. All the simulation part of the system is carried out in the ADS (Advance Design System) software by the Agilent Company. In this the design can be done by using lumped components, microstrip and mixed also. Microstrip option is selected then MLIN, MACLIN, Curve are these component are used for the filter design.

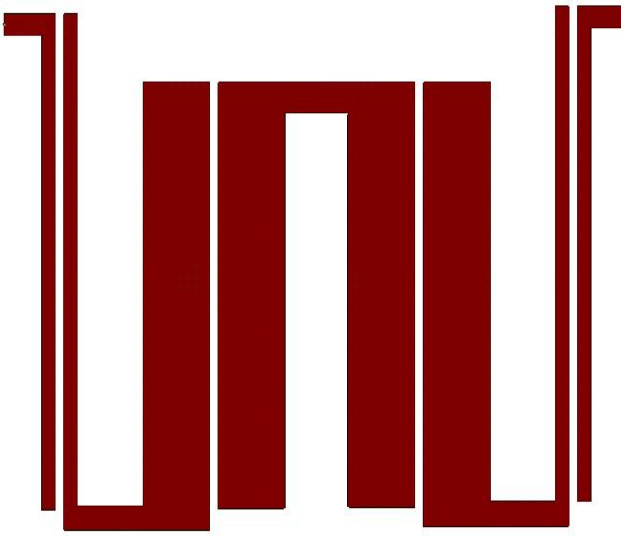

Fig. 2- Hairpin filter

B. Low Noise Amplifier (LNA) - the LNA is designed by using the transistor. ATF 54143 transistors is selected as it is highly linear and also the noise figure is minimum. Operating voltage is 3 volts and current is 60 mA. The topology used is the common source inductive source degeneration. It is preferred as it has less loss than the resistive feedback, so the inductive is used. The input and output impedance matching is provided by the inductor. The source inductor which has the voltage series feedback is responsible for the stability of the circuit. The stability factor is important for the overall design. Stability shows that the circuit is stable for that particular frequency range. It should be above 1 and if it's exactly 1 then it's marginally stable.

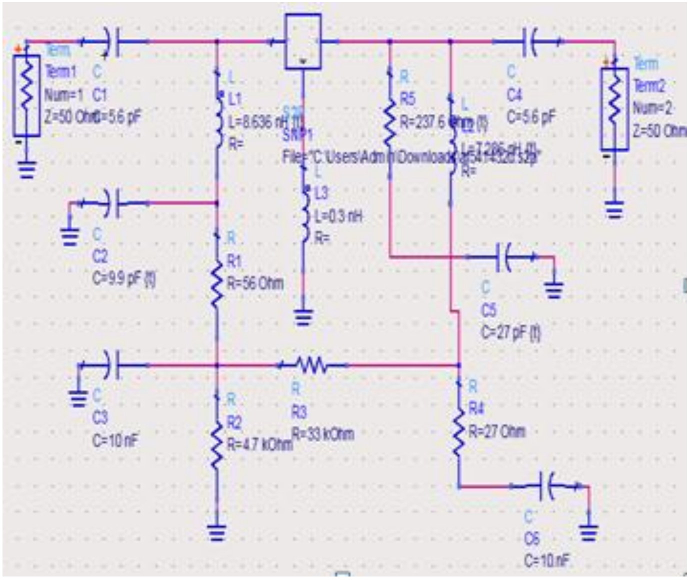

Fig. 3- Low noise amplifier design

The transistor is provided voltage divider biasing by the 2 resistor R2 and R3. DC blocking capacitors are used at input and output. Gate biasing is given by the resistor R1 and R2. Capacitor C2 at the gate terminal is used to reduce the power supply noise. All the source of noise is controlled at this stage so that they don't affect the overall noise figure. The s2p parameters are considered for the transistor [5]. Touch stone format is used in the software.

C. Balun- it is balance-unbalance. It is used at the receiver to split one input into two phase shifted output. Balun has unbalanced input and balanced output. Outputs are 180̊ phase shifted. Here in this design microstrip Marchand balun is used. Marchand is more tolerable to the even mode impedances then the parallel plate. Transmission line is an option in ADS. The transmission lines of length λ/2 and λ/4 are designed for balun. Two parallel lines are chosen there width and length is decided according to the frequency i.e. 900MHz. The spacing between the parallel lines is very less its 2 mm. These lines are of 90̊ phase shift towards each other. The two 90̊ phase shift will give 180̊ phase shift at the output.

$$S11= 0 \tag{1}$$
$$S21= -S31 \tag{2}$$

1= input port

2 and 3= output ports

The balun can simply be designed using the lumped components. But the losses are added due to inductor and capacitor. Also the balun is made bulky due to the inductor. As we have used here the transmission line even the co-axial cable is used. The microstrip is preferred as they are inexpensive and can be realized in the printed circuit board.

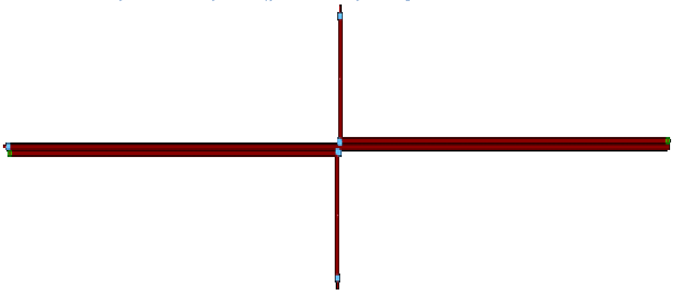

Fig. 4- Marchand Balun

III. SIMULATION

The designing of the bandpass filter, low noise amplifier and balun are done in the ADS software. This software is of Agilent Company. This software is used for mixed type of design as it has the option of lumped, transmission line etc. The linear design is supported in this. Simulation can be done for all parameters as S, Z, and Y. The EM simulations can be carried out in this software; it creates meshes in the design and then simulates it. It requires some time for simulations. The software simulations of the integrated circuit are presented. Also the hardware measurement is done. The power supply of 12volts is required and the network analyzer. The outputs are plotted on the network analyzer. Calibration is carries out for the analyzer.

The PCB layout is carried out in the Express PCB software. The measurements are taken from the simulation part and then it is symmetrically designed in the express PCB software.

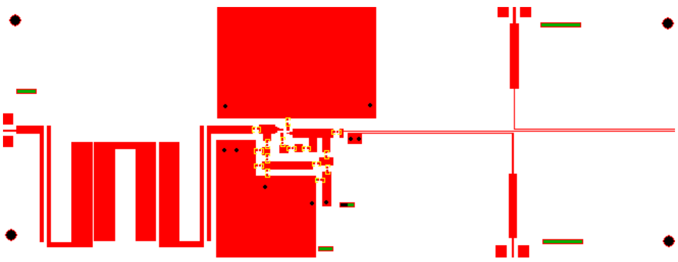

Fig. 5- PCB layout

IV. RESULTS

The S parameters are simulated. The S parameters are carried out to calculate the amount of reflected signal. It is a ratio of the reflected wave to the input wave. So it's a form of calculation of 2 port network. If the load absorbs the entire incident wave then there will be 0 reflected waves. This is possible if the impedance is completely matched. So the matching plays an important role. Here the S11 (input return loss), S21 (gain), noise figure and the phase angle is measured.

Also stability is plotted for the robust performance. The noise figure is only simulated not measured.

Below graph is of the noise figure of the overall circuit consisting of the filter, balun and amplifier. The noise figure is 0.47 dB which is much less and acceptable.

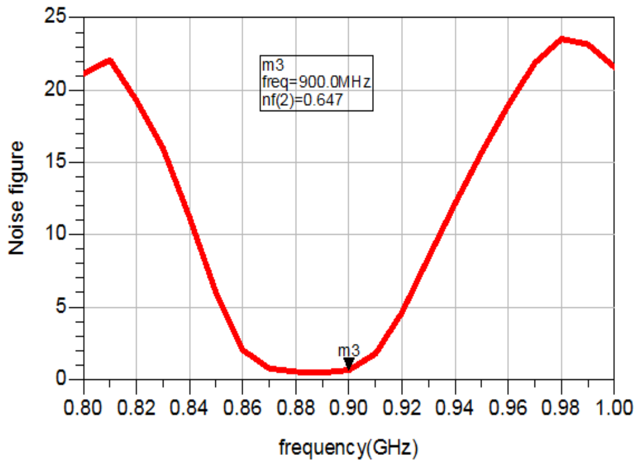

Fig. 6- Noise figure

The S11 is the input return loss plot. Simulated S11 and measured is -17 dB. The figure 7 shows the measured S11 parameter.

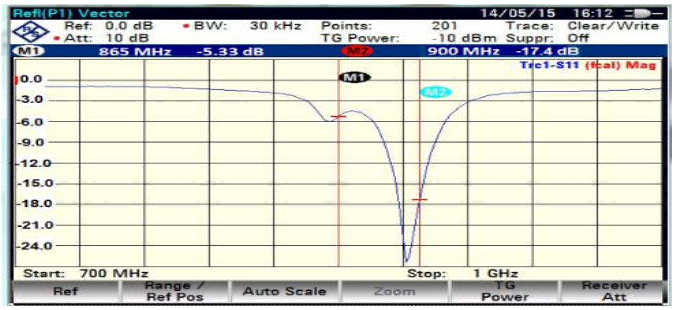

Fig.7- S11 Input return loss Vs frequency

Gain is an important parameter it calculates the ratio of output to input. The simulated gain S21 is -15 dB and the measured is 13.2 dB.

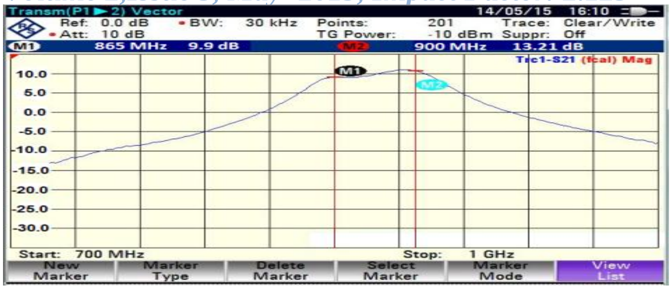

Fig. 8- S21 gain vs. frequency

Balun has the 180̊ phase shifted output. The 2 port output is simulated of the balun. Figure 9 shows the phase angle. The measured result shows 168̊ it's not up to 180̊ due to the losses of the overall circuit.

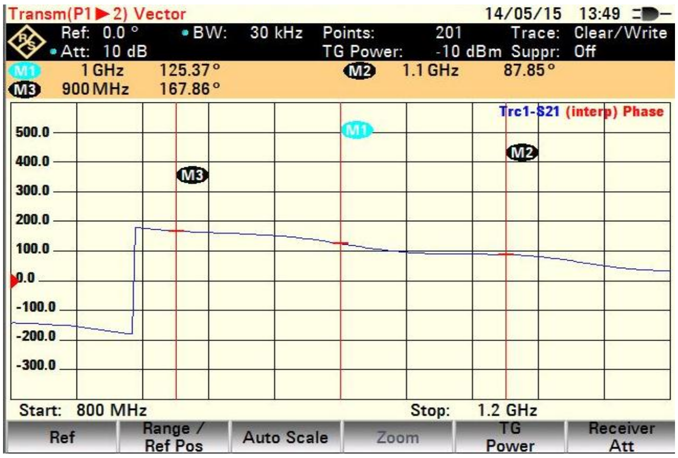

Fig. 9- Phase angle vs. Frequency

V. CONCLUSION

Low noise amplifier is designed using transistor ATF 54143. the filter is designed using microstrip and balun is designed using transmission line. The proposed work integrates the three blocks of an RF front end. Noise figure of the whole integrated circuit is 0.647 dB. The overall gain is improved. This low noise amplifier has applications in cellular base stations as the noise figure is below 1 dB.

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