© 2017 IJEDR | Volume 5, Issue 4 | ISSN: 2321-9939

Design and Simulation of Transmitter and Receiver sections for C-band FMCW Radar

[1]M.Krishnaveni, [2]R.Hemalatha, [3]K.Balajyothi
[1]Student, [2]Associate Professor, [3]Scientist 'E'
[1,2]Department of ECE,
[1,2]University College of Engineering, Osmania University, Hyderabad, India
[3]Directorate of Radar Seekers & Systems, RCI, DRDO, Hyderabad, India

***Abstract*—This paper presents the design and simulation of transmitter and receiver sections for C-band FMCW radar which is mainly used in Altimeters. FMCW radars have advantages over pulsed radars which include low transmitter power and low probability of interception. The transmitter section consists of upconversion, filtering, frequency multiplication, amplification and power divider blocks. Receiver section includes down conversion, filtering and amplification blocks. The transmitter and receiver block level simulation has been done using Keysight SystemVue software. The dynamic range of the receiver has been achieved up to 80 dB using Variable Gain Amplifier. With high dynamic range, additional long or short distance targets can be detected.**

***Index Terms*— Frequency Modulated Continuous Wave (FMCW), power divider, receiver, dynamic range, Variable Gain Amplifier (VGA)**

I. INTRODUCTION

Radar system consists of a transmitter, transmitting antenna, receiving antenna, receiver and signal processor. Based on the type of transmitting waveform, Continuous Wave (CW) and Pulsed radar are present. Due to the absence of timing marking reference, unmodulated CW radar measures only velocity and is unable to obtain the measurement of the target range. With Frequency Modulation of the CW, timing reference is possible so that the delay between the transmitted and received signals can be measured which is directly proportional to the target range (R) [1]. The advantages of FMCW radar are its low transmitter power and accurate height measurement. It can detect both close and long distance targets with transmitter power of milli watts.There are many applications which basically operate on the principle of FMCW radar. FMCW Radars are widely used in altimeters, proximity sensors, surface penetrating radars, park sensors in the cars, military applications and many more [1]. C-band FMCW radars are widely used in altimeters [1], [2]. The basic parameters considered to design the receiver are taken from [3].

Basic configuration and specifications of the system have been presented in section II. Amplifiers are taken from different vendors in order to achieve system performance. Filters and Coupled Line Coupler are designed and simulated in Advanced Design System (ADS) software. The transmitter and receiver chains have been designed and simulated in SystemVue software as given in section III.

II. CONFIGURATION

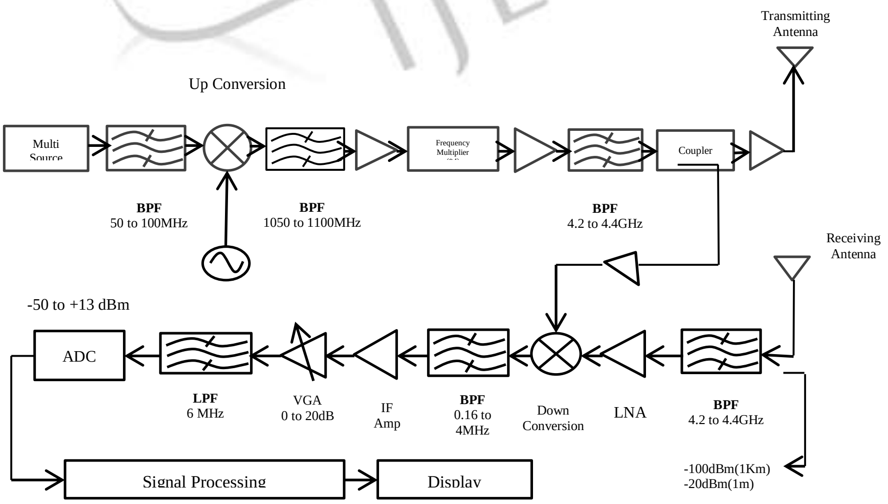

Figure 1. Block diagram of FMCW Radar

Table 1 System Specifications of FMCW Radar

Parameter	Value
Transmission Frequency	C band(4.2G to 4.4 GHz)
Transmitter power	+30dBm (1Watt)
Transmitter bandwidth	200MHz
Receiver input power (for 1Km)	-100dBm
Receiver input power (for 1m)	-20dBm
Dynamic range	80dB
Beat frequency range (Rx bandwidth)	0.16MHz to 4MHz
Receiver gain	50dB
Rx noise figure	5dB
ADC input power	-50 to +13 dBm

Basic configuration of the FMCW radar transmitter (Tx) and receiver (Rx) is given in Fig. 1. The transmitter chain starts with a 75 MHz chirp signal. And it is upconverted to Radio Frequency (1.05G to 1.1GHz) by using Mixer-LO (Local Oscillator) operation. The signal gets amplified and is given to a frequency multiplier whose multiplier factor is 4 in order to generate C-band frequency range as per the system specifications given in Table 1. The signal is passed through a parallel coupled microstrip BPF whose bandwidth is equal to the transmitter bandwidth of 200MHz. Coupled Line Coupler acts as a power divider to pass the Tx power signal to Rx. The Tx signal is amplified to required output power of +30 dBm and transmitted through an antenna. After some delay target gives an echo to the Rx which is amplified by the Low Noise Amplifier (LNA) in order to improve the Signal to Noise Ratio. The echo signal has the power based on the relation $P \propto \frac{1}{R^4}$. If the target is moving towards the radar, the received signal frequency is higher than the Tx frequency and is low when the target is moving away.
Received echo signal is down converted to Intermediate Frequency (IF) is also called beat frequency (f_b) using the mixer-Tx signal. Beat frequency is directly proportional to the target range and velocity. The signal is given to IF amplifier and processed. For 1Km distance, the received signal power is -100dBm with f_b of 2MHz and for 1m range, power is -20dBm with f_b 4MHz. Low Pass Filter is placed to pass only the required f_b and reject all other frequencies. This signal is given to a 12-bit ADC whose dynamic range is 60dB (-50 to +13dBm). If the receiver output power is beyond the ADC drive power VGA adjusts its gain and gives sufficient power to ADC. The digital signal is further processed and the target range and velocity is displayed in display unit.

III. Simulation And Results

The transmitter and receiver for C-band FMCW radar are modeled and simulated using Keysight SystemVue software. Filters have been designed and simulated ADS software. Inductors and capacitors which are used in filter design are taken from Coilcraft and American Technical Ceramics Corporation (ATC) 100 series. Amplifiers are taken from vendors like Hittite technologies and minicircuits based on the gain requirement at different frequencies. Designed filters and their responses are shown in figures from 2 to 13 and coupler is shown in Fig. 14.

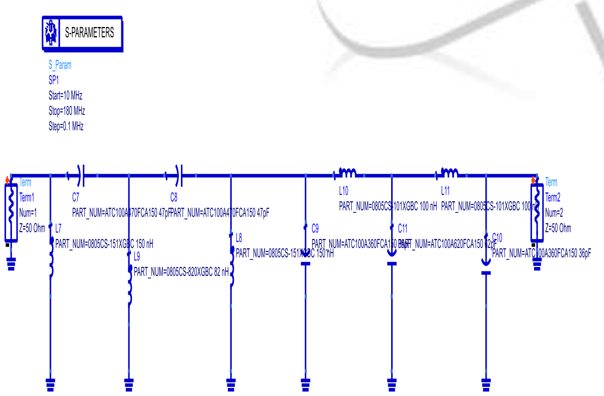

Figure 2. Schematic of 50 to 100 MHz BPF

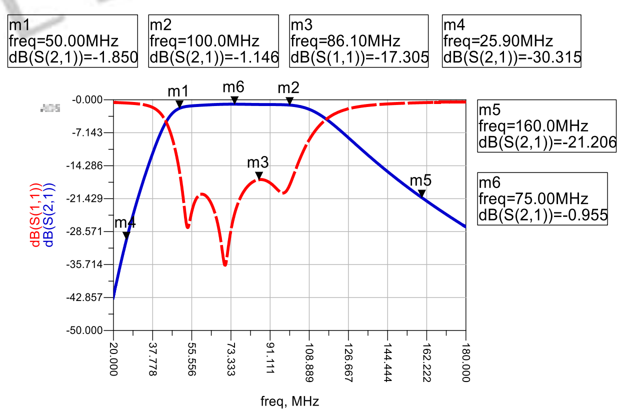

Figure 3. S-parameter response of 50 to 100 MHz BPF

In Fig. 3 the solid line shows the insertion loss (S_{21}) and the dashed line shows the return loss (S_{11}). This is applicable for all s-parameter response of filters.

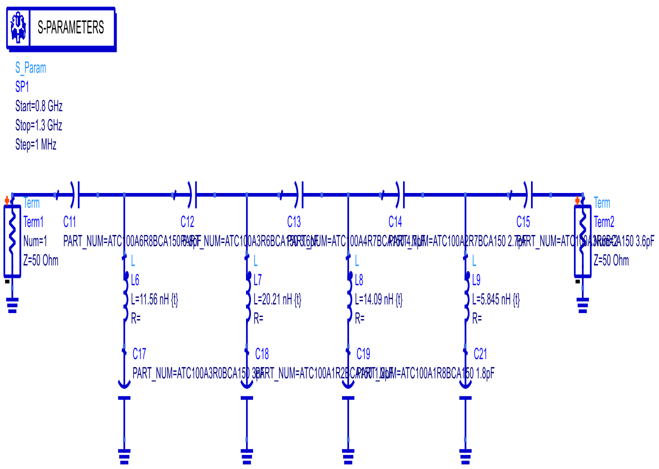

Figure 4. Schematic of 1050MHz HPF

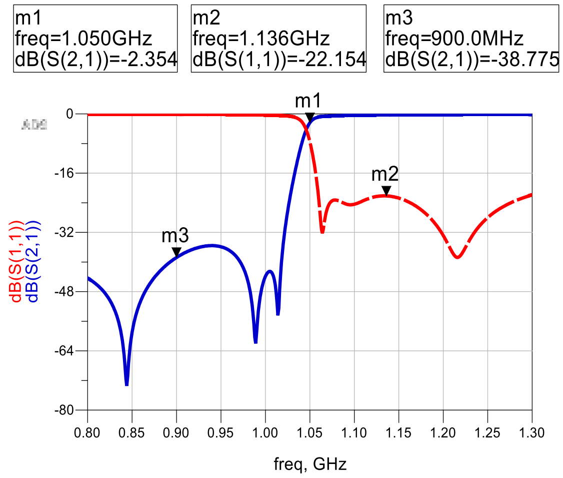

Figure 5. S-parameter response of 1050MHz HPF

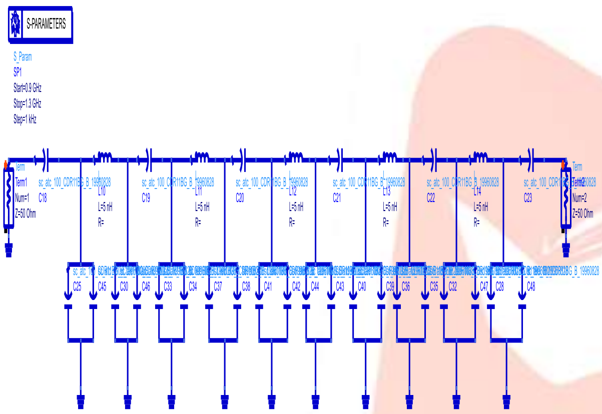

Figure 6. Schematic of 1050 to 1100MHz BPF

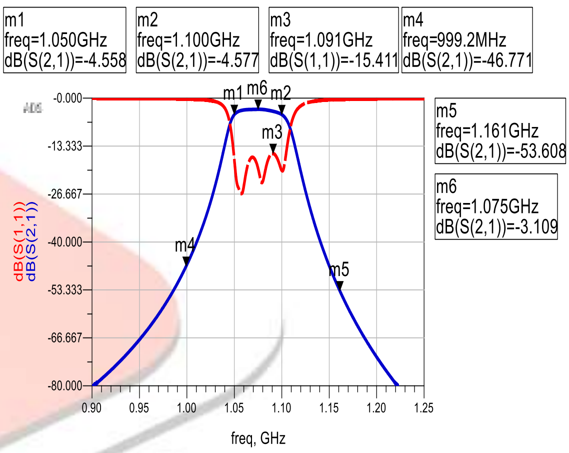

Figure 7. S-parameter response of 1050 to 1100MHz BPF

The calculated width, space and length of the coupled sections are given in Table 2. RT/Duroid whose dielectric constant is 2.2 has taken as the substrate with thickness of 0.508mm and copper conductor thickness is 0.035mm.

Table 2 Parameters of Coupled line sections used in parallel coupled microstrip BPF.

Coupled section	Width W(mm)	Space S(mm)	Length L(mm)
1	1.43	0.114	12.67
2	1.72	0.99	12.48
3	1.73	1.29	12.47
4	1.72	0.99	12.48
5	1.43	0.114	12.67

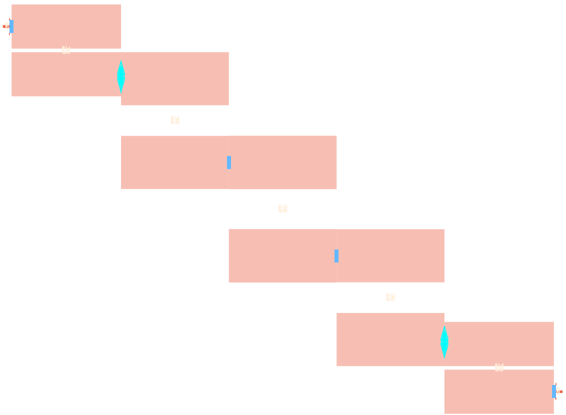

Figure 8. Layout of parallel coupled microstrip BPF

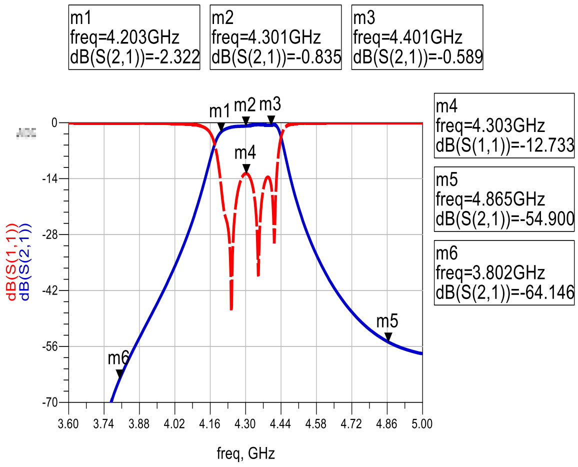

Figure 9. S-parameter response of 4200 to 4400MHz microstripBPF

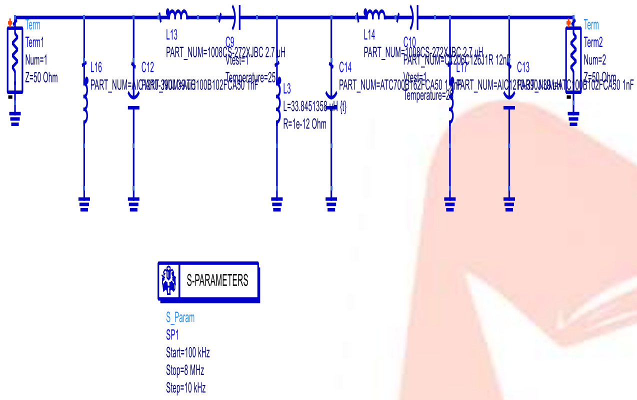

Figure 10. Schematic of 0.16 to 4MHz BPF

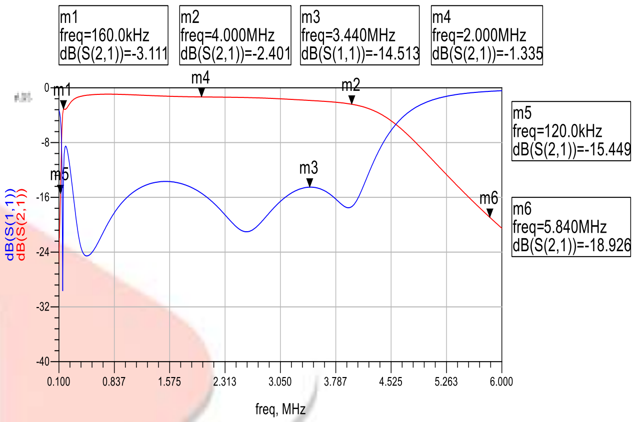

Figure 11. S-parameter response of 0.16 to 4MHz BPF

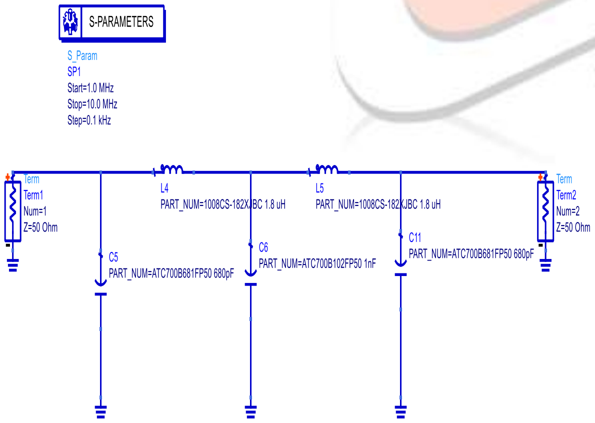

Figure 12. Schematic of 6MHz LPF

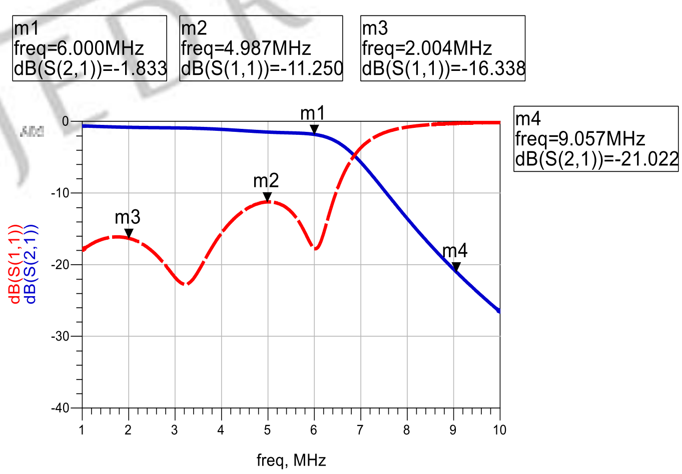

Figure 13. S-parameter response of 6MHz LPF

The width, space and length of the coupled line coupler are

W= 1.487 mm, S= 0.685 mm and L= 12.79 mm.

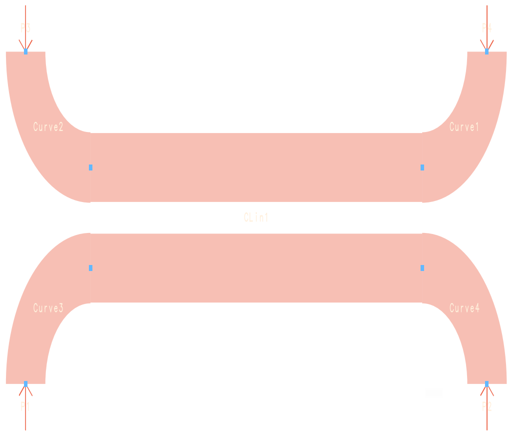

Figure 14. Layout of Coupled line coupler

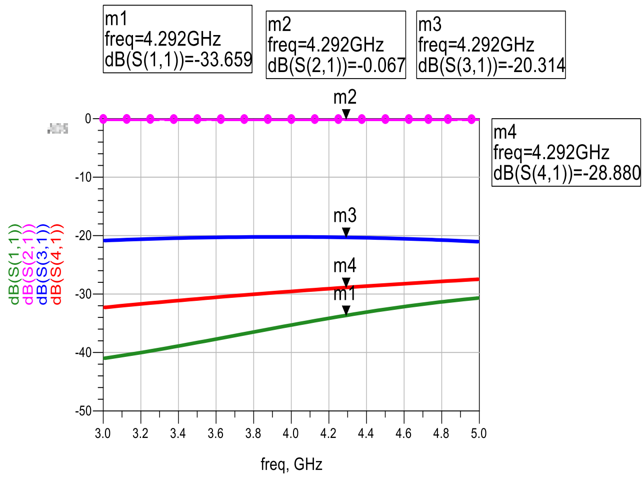

Figure 15. Characteristics of Microstrip Parallel coupled directional coupler

After simulation of all filters and coupler, S2P files are taken for them. All modules are integrated to form transmitter and receiver sectionss for FMCW radar. Simulation has been done in SystemVue software and results are achieved as per the system specifications.

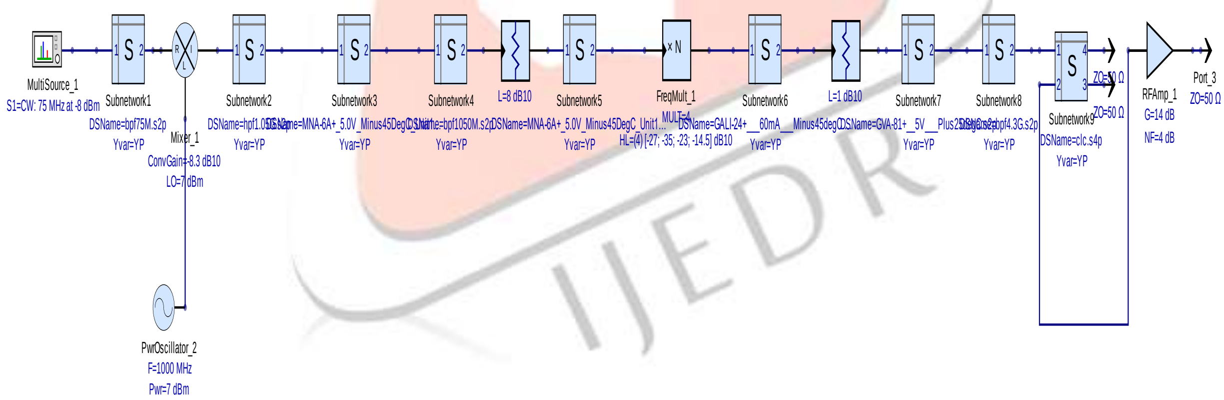

Figure 16. Schematic of the Transmitter in Keysight SystemVue

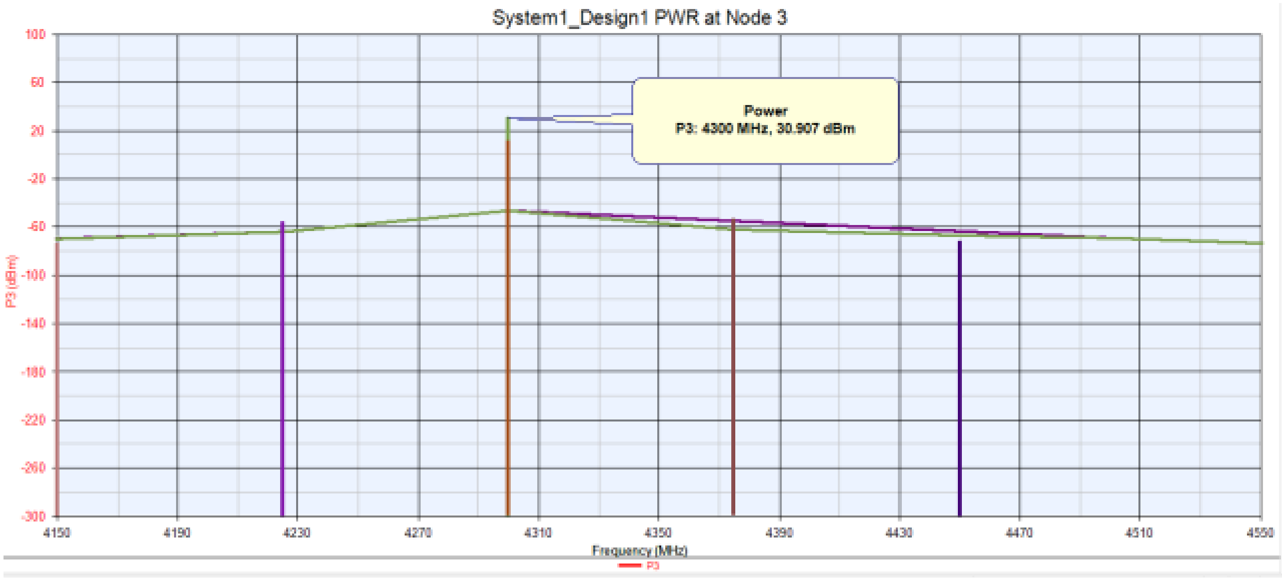

Figure 17. Transmitter Power

For 1Km range, the received power is -100dBm at 4302MHz and the Rx gain is 50dB when VGA is ‘ON’. So, the Rx output power is -100+50= -50dBm, can be processed by ADC. For 1m range, received power is -20dBm at 4304MHz. This signal can be processed by ADC only when VGA is ‘OFF’. In OFF condition, VGA reduces its gain to 0dB and gives the required output power (10dB) signal to ADC. Therefore, the dynamic range of the Rx has been achieved up to 80dB.

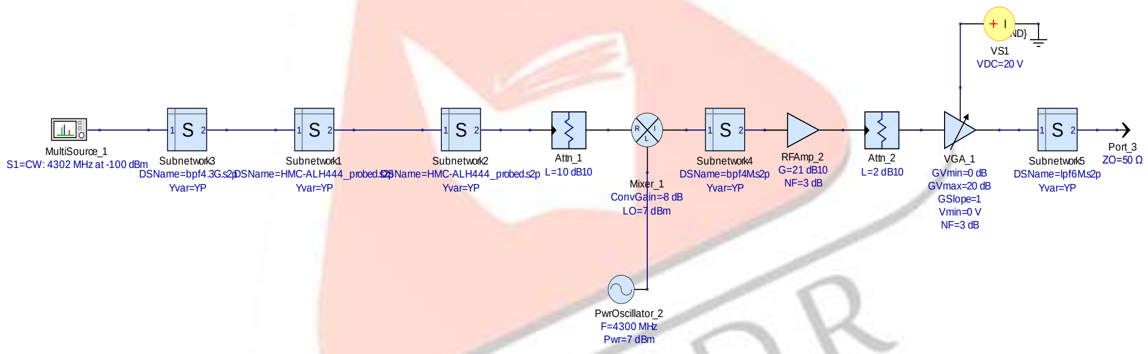

Figure 18. Schematic of Rx in Keysight SystemVue when VGA is ‘ON’

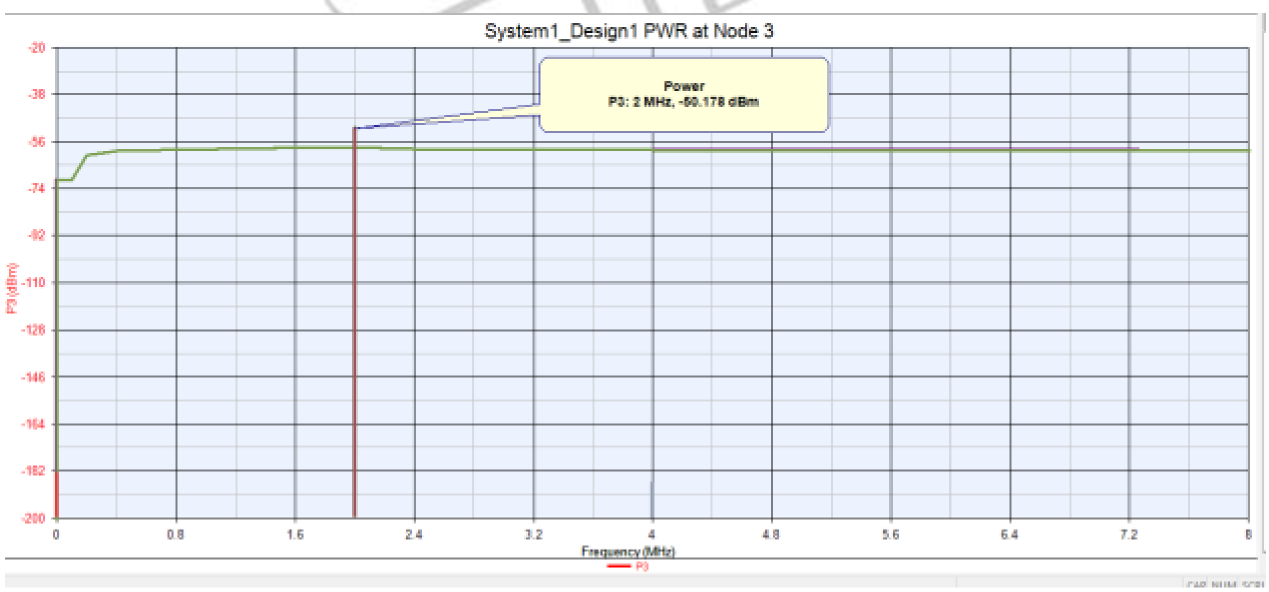

Figure 19. Rx output power when VGA is ‘ON’

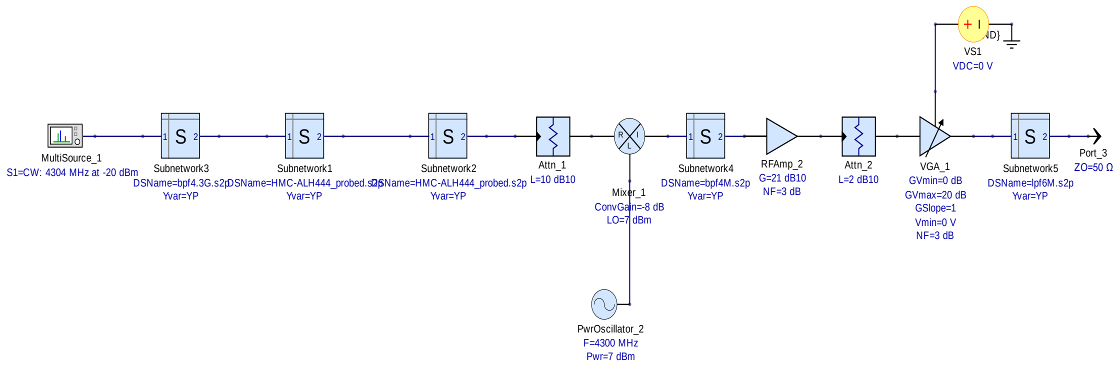

Figure 20. Schematic of Rx in Keysight SystemVue when VGA is 'OFF'

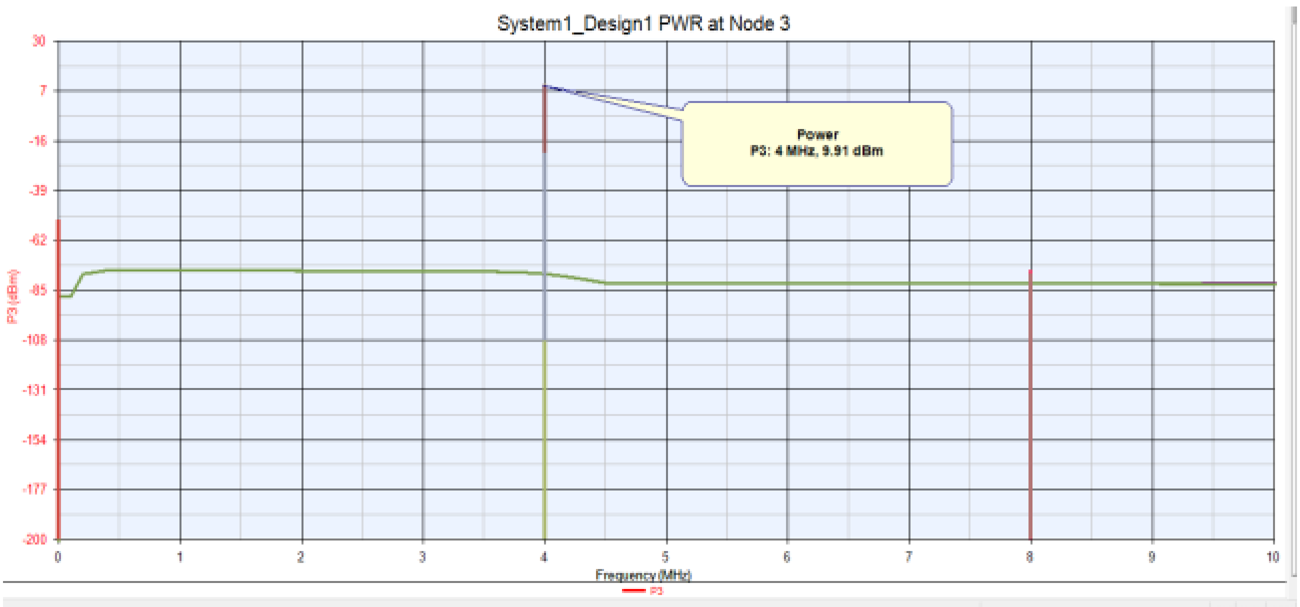

Figure 21. Rx output power when VGA is 'OFF'

Figure 22. Rx Cascaded Gain

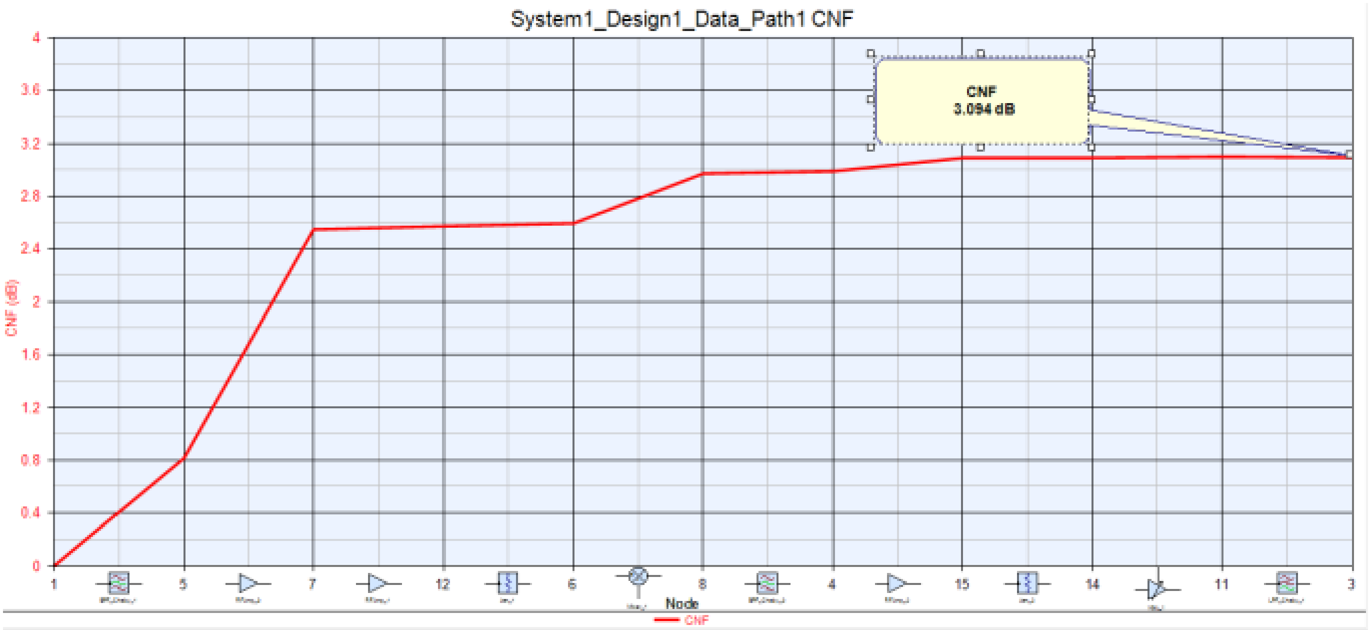

Figure 23. Rx Noise Figure

The fabricated 50 to 100 MHz BPF results are presented below.

Figure 24. Fabricated filter of 50 to 100 MHz BPF

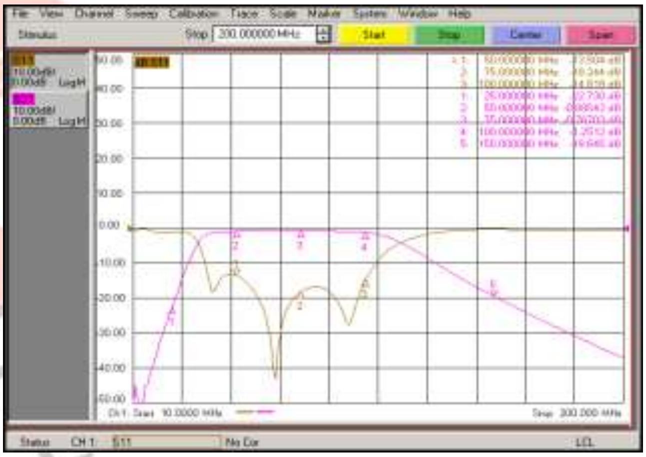

Figure 25. Test results in Vector Network Analyzer

Table 3 Comparison of simulated and tested results of fabricated 50 to 100 MHz BPF

Frequency	**Simulated results**		**Tested results**	
	S21(dB)	**S11(dB)**	**S21(dB)**	**S11(dB)**
25 MHz	-30		-22.7	
50 MHz	-1.85	-18.1	-0.88	-13.5
75 MHz	-0.95	-24.6	-0.76	-18.2
100 MHz	-1.1	-18.0	-1.2	-14.8
150 MHz	-21.2		-19.6	

The simulated results are achieved as the expected system specifications. The remaining modules are under fabrication process.

IV. CONCLUSION

Design and simulation of transmitter and receiver sections for FMCW Radar have been presented. The Tx and Rx systems are simulated in Keysight SystemVue software. For 1m range, beat frequency 4MHz signal is detected and processed by using VGA. Hence the Rx dynamic range is achieved up to 80dB. The fabricated results of 50 to 100 MHz filter has been given and compared with the simulated results.

V. ACKNOWLEDGMENT

This work was supported by the RCI (Research Center Imarat), DRDO (Defence Research and Development Organization), Hyderabad, Telangana. The authors wish to thank Mr. M.Gangadhara, Scientist 'G', RCI, DRDO, Hyderabad for his valuable discussions and technical support throughout the project. We extend our sincere gratitude and heart full thanks to him. Authors also wish to thank Mr. M.Rambabu, TO 'A', RCI, DRDO, Hyderabad for his motivation throughout the submission of paper and for his valuable discussions during the project.

REFERENCES

[1] D. R. Jahagirdar, "A High Dynamic Range Miniature DDS-based FMCW Radar" 2012 IEEE Radar Conference, May, 2012.
[2] Merril I. Skolnik, "Introduction to Radar Systems", Second Edition, McGraw-Hill Book Company, Singapore, 1980.
[3] B. Someswara Rao, Rajatendu Das, and C.G.Balaji, "High Dynamic Range Monopulse Microwave Receiver Front-end", Proceedings of Asia-Pacific Microwave Conference, 2007.
[4] Soufiane Matah, Lahbib Zenkouar, "A practical approach for RF system design of an S-band modern digital radar receiver", Proceedings of 2014 Mediterranean Microwave Symposium (MMS2014), 2014.
[5] David M. Pozar, "Microwave Engineering", Second Edition, John Wiley & Sons, inc., New York, 1999.
[6] M. J. LANCASTER, "Microstrip Filters for RF/Microwave Applications" A Wiley-Interscience Publication John Wiley & Sons, Inc, New York, 2001.

BIO DATA OF AUTHOR(S)

1. Marepalli Krishnaveni was born in Khammam, Telangana in 1993. She has completed her SSC from Board of Secondary Education in APSWERS School, kallur, Khammam in 2009. She has completed her B.E. in Electronics and Communication Engineering from Chaitanya Bharathi Institute of Technology, Gandipet, Telangana, in 2015. At present, she is pursuing her Master's degree in Microwave and Radar Engineering from Osmania University, Hyderabad. Currently, she is doing her project work in RCI (Research Center Imarat), DRDO (Defence Research and Development Organization) in Hyderabad as a part of her M.E academics.

2. Hemalatha Rallapalli was born in 1970. She received the B.Tech degree in Electronics and Communication Engineering from Sri Krishna Devaraya University, Anantapur, India in 1992, and the M.Tech and Ph.D. degrees in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Hyderabad, India in 2006 and 2012, respectively. She has a versatile industrial experience of around ten years in various industries like Telecommunication, Information technology, to name a few. Further she pursued her career in teaching as her passion was in teaching. She has been in the teaching field for around 15 years now and is presently working in Osmania University, Hyderabad, India. Her areas of interest include Embedded Systems, Wireless Communications etc. Dr.R.Hemalatha is a Fellow of the Institution of Electronics and Telecommunication Engineers (IETE) and a member of the Institute of Electrical and Electronics Engineers (IEEE).

3. Balajyothi Kasi has done her graduation from Andhra University, Andhra Pradesh, India in 2001. She has joined in Defence Research and Development Organization in January, 2002. She has completed her Master of Engineering in Digital Systems Engineering from Osmania University, Hyderabad in 2016. She has an experience of 15 years in the field of Radar Systems.