

Design and Development of Wideband Up/Down Converter for Sigint Receiver

M.Sowmyasri¹, S.Aruna², K.Srinivasa Naik³, Ch.Viswanadham⁴

¹Student, Department of ECE, AUCE (A), Andhra University, Visakhapatnam, India-530003.

²Assistant Professor, Department of ECE, AUCE (A), Andhra University, Visakhapatnam, India-530003.

³Associate Professor, Department of ECE, VIIT, JNTUK, Visakhapatnam, India-530049.

⁴Senior Deputy General Manager, Bharat Electronics, IE, Nacharam, Hyderabad, India – 500076.

Abstract — A typical ELINT system consists of Antenna subsystem, Receiver subsystem, Processor subsystem and Display subsystem. Receiver measure, the radar parameters in parallel hardware and ensure the entire measured data of radar signals are available within 100ns for further processing. The receiver is built with analog, Radio Frequency, Microwave, digital hardware and software. In current systems, the antenna system is built with an array of antennas, front end RF and microwave components, interface hardware, etc.. The antenna subsystem processes the received signal from antennas and transfers to receiver subsystem for parameter measurements. The processing in antenna subsystem includes reception, front end amplification for SNR improvements, conversion to a suitable frequency range, detection, etc., One of the front end processing is a conversion of the incoming RF frequencies to upper or lower bands. In the present project, the incoming RF signals in the frequency range of 2-18 GHz need to be converted to 8-11 GHz band, i.e. 3 GHz IBW.

Keywords — EW System, Electronic Intelligence (ELINT), Signal Intelligence (SIGINT), Advanced Design System (ADS).

I. INTRODUCTION

Electronic warfare is defined as, “A military action involving the use of electromagnetic energy to determine, exploits, reduce, or prevent the antagonistic use of the electromagnetic spectrum and action which retains friendly use of the electromagnetic spectrum space” [1].

Functionality electronic warfare system is classified into three groups Electronic Support (ES), Electronic Attack (EA), Electronic self Protection

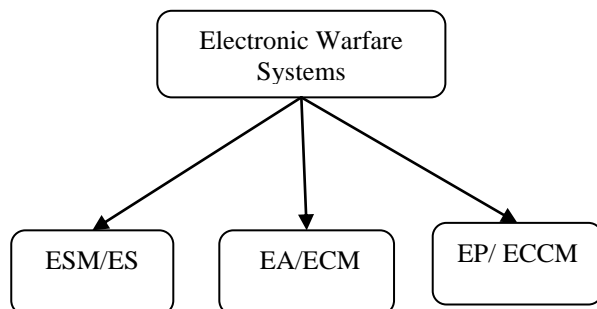


Fig 1: EW system Classification

(EP), these are generally regarded as Electronic Support Measures (ESM), Electronic Counter Measures (ECM), Electronic Counter-Counter Measures (ECCM) respectively as shown in figure 1.

A. Electronic Support Measures (ESM)

ESM is “actions taken to search for, intercept, locate and analyze radiated electromagnetic energy for the purpose of exploiting measured quantities in support of military operations”. ESM is based on the use of intercept or warning receivers and relies heavily on a previously compiled directory of both tactical and strategic electronic intelligence (ELINT): this covers information gathering on tracking and guidance radars for analysis of potential weapon threats and includes the intercept and analysis of the associated communications traffic. The acquisition of signal intelligence (SIGINT), i.e. the parameters and purposes of signals, permits the definition of the requirements for ESM systems, e.g., bandwidth, amplitude (power), angle of arrival (AOA), time of arrival (TOA), pulse width (PW), and pulse repetition time (PRT), PRI type, scan type and rate, lobe duration (Beam width) etc. ESM is entirely passive, being confined to the identification and location of enemy signal [2].

B. Electronic Counter Measures (ECM)

ECM is “the division of electronic warfare involving actions taken to prevent or reduce an enemy’s effective use of the electromagnetic spectrum”. ECM includes passive techniques, such as the firing of chaff, and active techniques, such as jamming and deception, both manipulative and imitative [2-3].

C. Electronic counter-Counter Measures (ECCM)

ECCM is “actions taken to retain the use of the electromagnetic spectrum, despite a hostile force’s use of ECM techniques”. This includes coding techniques which spread the signal energy over a wide bandwidth and null-steering processing in the receiver antenna to minimize the effect of enemy jamming and interference. These are measures taken in the design or operation of radars or communication systems to counter the effects of ECM [1-3].

II. UP/DOWN CONVERTER

An up-down converter is an assembly, which consist of up converter and down converter in a single package. The incoming signal is either unconverted or down converted depending upon the requirement. They are typically used in receiver front-ends or in the transmitted signal path to generate the RF signal for subsequent amplification/processing. In this paper design of up/down converter is considered.

Table 1
Target Specifications of Up/Down Converter Module

S NO	Parameters	Specifications
1	Input Frequency Range	2-18 GHz
2	Output Frequency	8-11 GHz
3	Conversion Loss/Gain	0 dBm
4	Maximum Input	0 dBm
5	Dynamic range	65 dB
6	Harmonics	<-10dBc
7	Image Rejection (min)	<-50dB
8	VSWR	2:1 (Max)
9	RF Impedance	50Ω
10	Noise Figure	8 dB (Max)
11	LO Radiation	≤-90 dBm
12	Video Specifications	
A	Frequency Range	8 – 11 GHz
B	DLVA Type	DC Coupled
C	Dynamic Range	68 dB (min)
D	TSS	-76 dBm Min measured with 20 MHz BW
E	Noise Figure	8 dB (max)
F	Log Slope	15 mV/dB
G	Log Linearity	±1.5 dB for 100% points
H	Logging Range	-68 to 0 dBm
I	Frequency Flatness	±1.5 dB for 100% points
J	RF Gain	25 dB min
K	Max RF Input	+10dBm
L	Harmonic level	Better than -14 dBc
M	No. of inputs	1 (normal)
N	VSWR	2:1 Max into 50 Ω load
O	Min & Max Video Amplitude	200 mV at -68dBm & 1.22 V at 0 dBm into 50 Ω 80 mV at -76 dBm into 50 Ω
P	Output Response	Should always be monotonic
Q	Video Polarity	Single
R	Rise Time	25 ns (typical)

S	Settling Time	30 ns (typical)
T	Recovery Time	200 ns
U	Base Noise	<30 mV
V	DC Offset measured for no input and CW over the dynamic range	±20 mV max
13	Power Supply	+15V±1V
14	Connectors: J1(SMA Jack) J2(SMA Jack) J3(Micro D)	RF In RF Out Power supply & Control signal

These devices usually have a low noise amplifier to modify the strength of a received signal. Low noise is important because any noise generated by the amplifier itself has added to the noise already present on the received signal and will be amplified by the device, thus increasing the noise figure. The amplifier may have adjustable gain. The signal then passes into a mixer element, usually an active component in a double balanced topology. The mixer mixes the incoming RF signal in the time domain with a reference frequency from the local oscillator (LO). As a result two frequency products (the difference and sum) are produced. In double balanced topology, the sum product is suppressed, and the difference product is the output. This difference product is either at a lower frequency called an intermediate frequency (IF) for additional down-conversion or it is converted down to the origin (base-band, or zero Hz). The output is typically differential and passes into a matching network in the case of an IF where it is then filtered with a band pass filter before passing onto to the demodulator.

RF front end has two channels, namely frequency channel and direction channel. This Up/Down converter falls into frequency channel. Frequency up/down converters provide frequency translation of the input signal to a desired frequency band. They support both up and down frequency translations with either fixed local oscillators (block converters), or tunable local oscillators (agile converters). In the present project, the incoming RF signals in the frequency range of 2-18 GHz need to be converted to 8-11 GHz band, i.e. 3 GHz IBW. This is required due to the limited bandwidth of the DIFM receiver for obtaining high sensitivity.

III. BLOCK DIAGRAM

The 2-18 GHz signal is fed to the input port of the Up/Down Converter module. The signal is amplified by the Low Noise amplifier (LNA) and fed to the SP4T switch. Out of 2-18 GHz, 2-11 GHz signal will pass through the second SP4T switch and 11-18 GHz signal will pass through three Band Pass Filters (BPF) with bandwidth of 11-14GHz, 14-15 GHz &

15-18 GHz, respectively. The 2-11 GHz signal after passing through SP4T switch, passes through 3 Band Pass Filters (BPF) with a bandwidth of 2-5 GHz, 5-6 GHz & 6-8 GHz, respectively. The 8-11 GHz signal directly passes through 8-11 GHz & then to SP4T switch. All the signals which pass through BPFs (except 8-11 GHz signal) are mixed with Local Oscillator (LO) frequency in the mixer and down or up converted to IF frequency of 8-11 GHz. There are six LO frequencies- LO1 (13 GHz), LO2 (14 GHz),

LO3 (16.5 GHz), LO4 (3 GHz), LO5 (6 GHz) & LO6 (7 GHz) all operated at power levels of 10 dB. All the signals of 8-11 GHz are amplified and then pass through SP4T switches & power divider. One output of the power divider goes to the first output RF port 8-11 GHz P_{out} and second output is passed through the RF detector or EDLV A (extended dynamic range log video amplifier) to get the video output V_{out} .

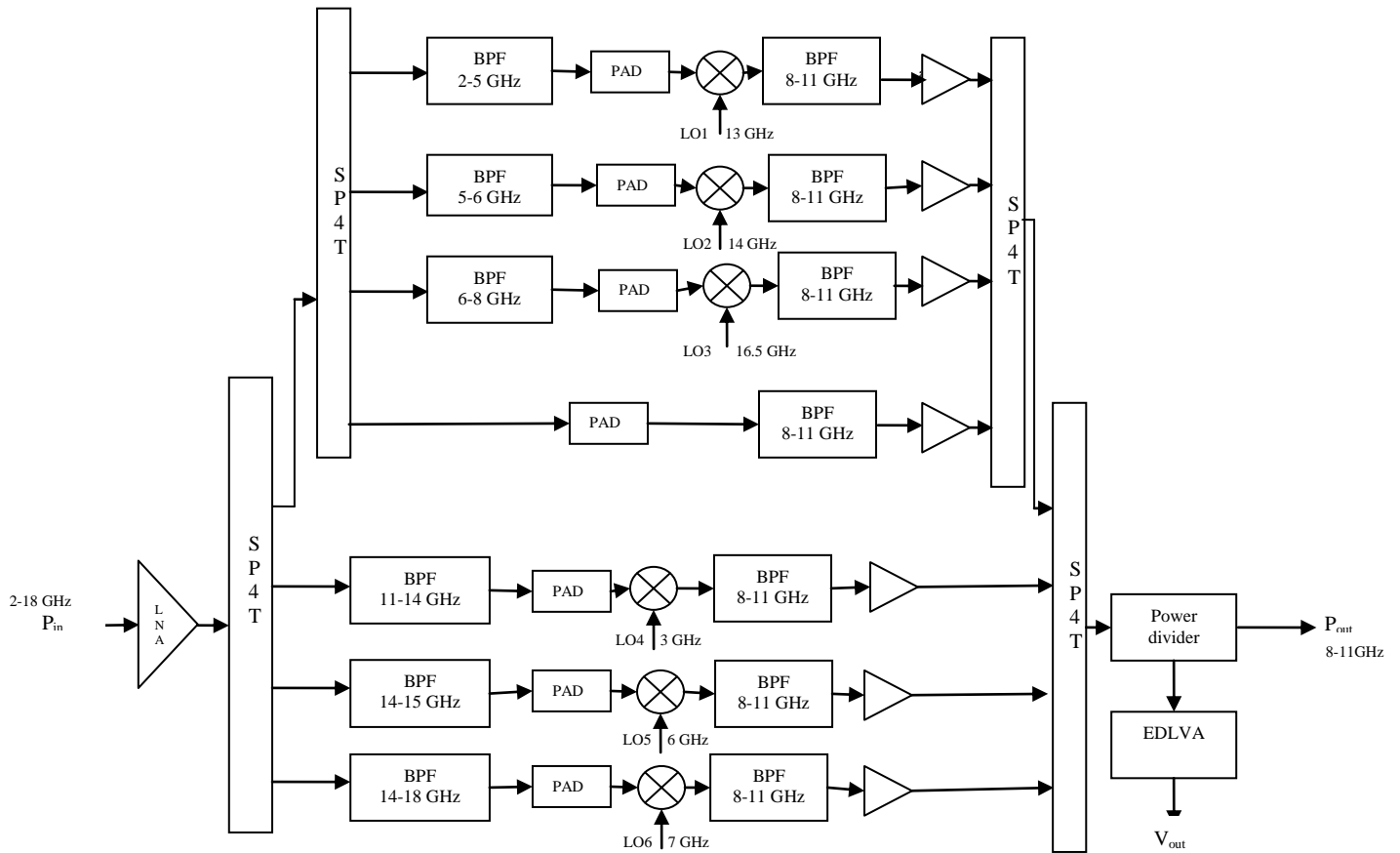


Fig 2: RF Up/Down Converter Block Diagram

IV. SIMULATION USING ADS AND CST

In this project, most of the design is done using ADS except filters and the power divider. Filters and power divider modules are designed using CST design studio and touchstone files generated & loaded in ADS for block simulation.

Advanced Design System (ADS) is the flagship product from Keysight EEsof EDA, the technology and innovation leader in high-frequency, mixed-signal electronic design automation (EDA). It is the only design, simulation platform that enables the co-design of IC, package and board in high-frequency and high-speed applications [7]. In this project design, we used harmonic balance simulation, s-parameter simulation and EM simulation of the

software. ADS contains a much larger library of transmission line and passive component models that include non-ideals of these components as it is oriented toward microwave applications.

CST (Computer Simulation Technology) is a fully featured software package for electromagnetic analysis and design in the high frequency range. It simplifies the process of creating the structure by providing a powerful graphical solid modeling front end. The program is especially suited to the fast, efficient analysis and design of components like antennas (including arrays), filters, transmission lines, couplers, connectors (single and multiple pin), printed circuit boards, resonators and many more. In this project CST design studio is used for

designing filters and power divider as it is a powerful and an easy-to-use schematic design tool that radically speeds up the analysis, synthesis and optimization of complex structures and electromagnetic systems [8].

We have optimization and tuning available in both ADS and CST to get the desired output in case our design not providing required output [7-8].

A. Tuning and optimization

In most cases, parameters calculated by us may not meet the desired performance, so the design software generally contains options tuning and optimization to get the optimum performance by changing the parameter values [7-8].

1) **Tuning:** In Tuning variables set by us can be varied within maximum and minimum limits to achieve the desired response and the changes can be viewed in the graphical window simultaneously. So by changing different parameter values in a trail and error, we can find the best result.

2) **Optimization:** Optimization is different from tuning, here a set of parameter values was modified to meet predefined performance goals using some optimization technique to reduce the difference. Optimization technique compares the computed an desired response and modify design parameter value accordingly to meet specific optimization goals. Predefined goals set by us should be practically possible and realizable otherwise optimization is not possible to meet the goals..

B. RT Duroid 5880

Here the material used for constructing the components is RT/Duroid 5880. RT/Duroid 5880

laminates are Poly Tetra Fluoro Ethylene (PTFE) composites reinforced with glass microfibers for high frequency applications. The dielectric constant of RT/Duroid 5880 is the lowest of all products, and low dielectric loss of 2.2 make them well suited for high frequency/broad band applications. These laminates provide uniform electrical properties over frequency and provide isotropic behavior. As it is of reinforced PTFE material it provides lowest electrical loss which extends the usefulness of RT/Duroid 5880LZ to Ku-band and above. RT/Duroid 5880LZ laminates have low moisture absorption and excellent chemical resistance so they are resistant to all solvents and reagents used in etching printed circuits or in plating edges and holes.

C. Simulation and Results of Modules

Up to 8 GHz frequency range need to be up converted, 8-11 GHz no need for any conversion and above 11 GHz they should be down converted. In the block diagram we have designed every component, i.e., Low noise amplifier, BPF, Switch, up converter mixer, power divider according to the given specifications and the response of the each simulated block was verified for the results. After designing each component, all the components were connected as per the block diagram shown in figure 2 and the full module response is compared over specifications in table 2. As the simulation results of all the modules is not possible to present in this paper, here we presented response for up converted RF channel of 5-6 GHz in the Fig. 3 – 13.

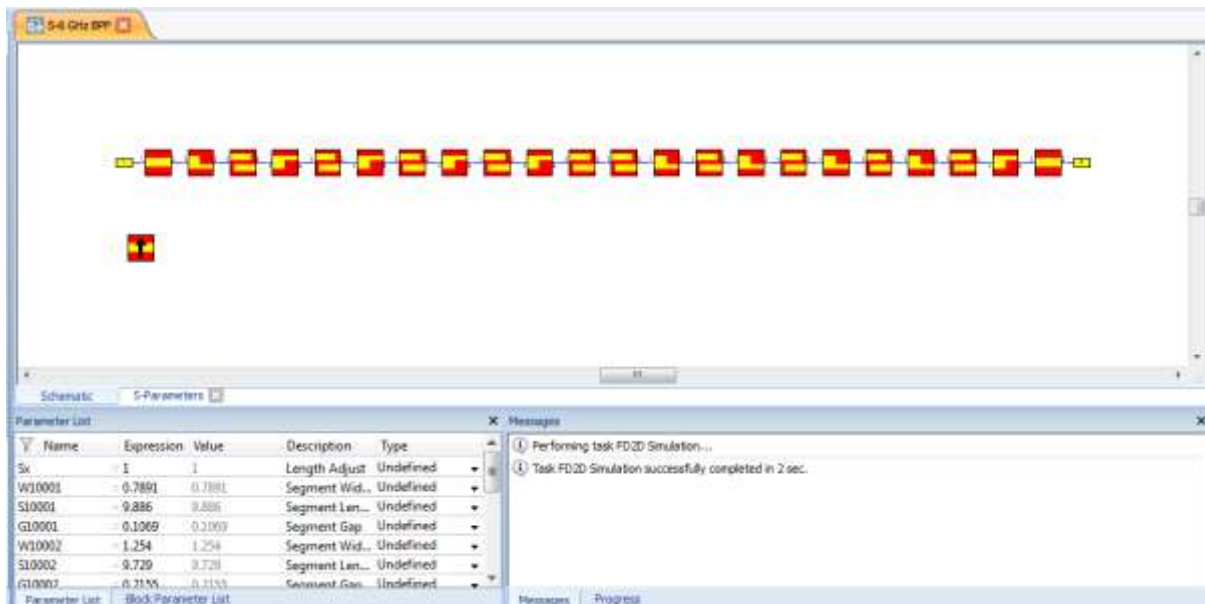


Fig 3: CST schematic diagram of 5-6 GHz Bandpass filter

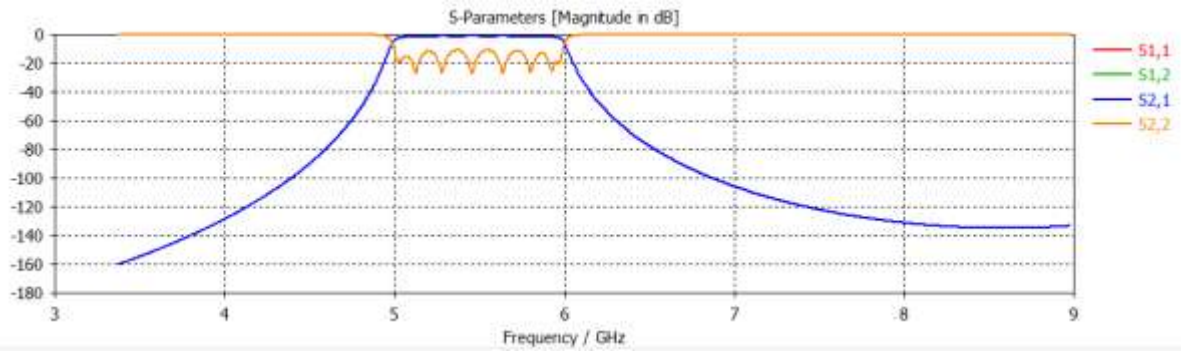


Fig 4: S-Parameter Response for 5-6 GHz Bandpass filter

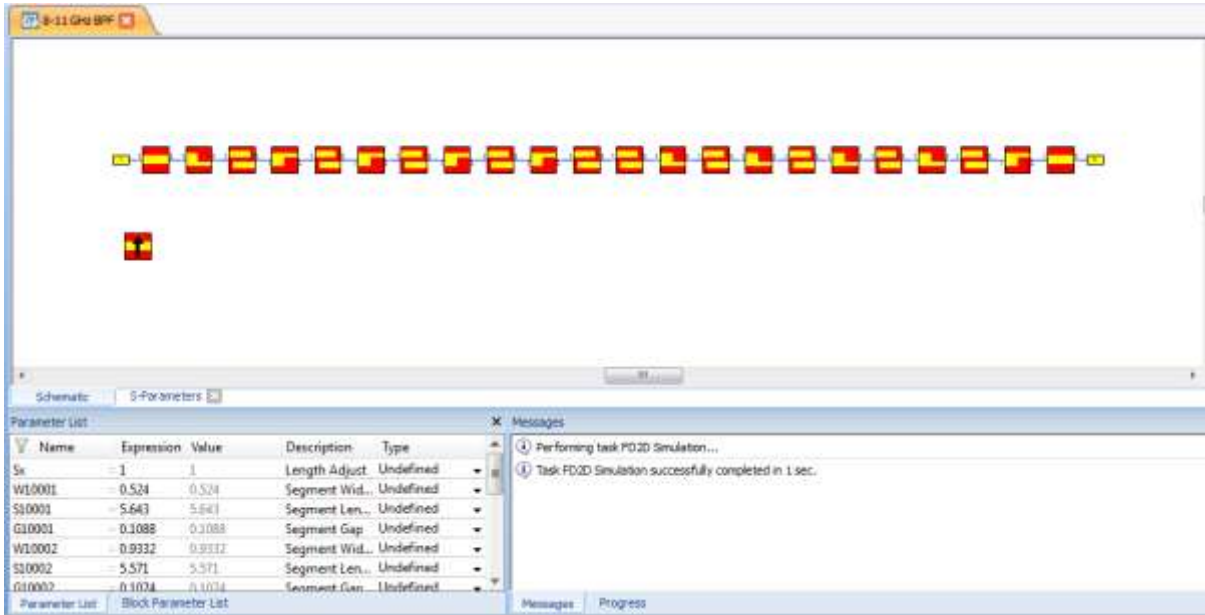


Fig 5: CST schematic diagram of 8-11 GHz Bandpass filter

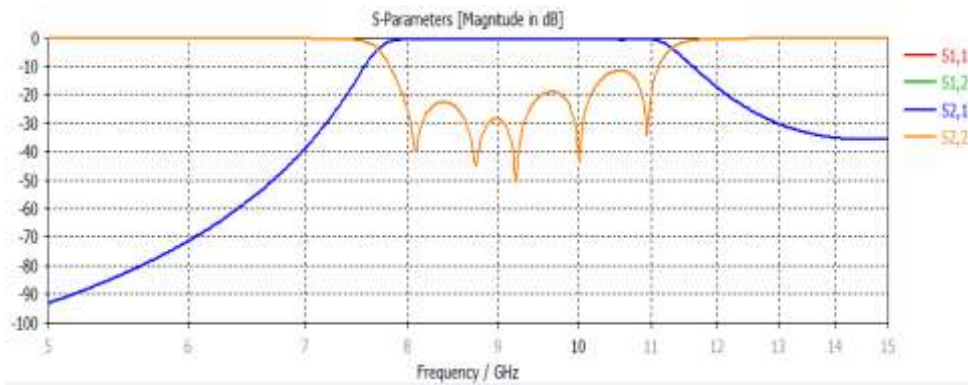


Fig 6: S-Parameter Response for 8-11 GHz Bandpass filter

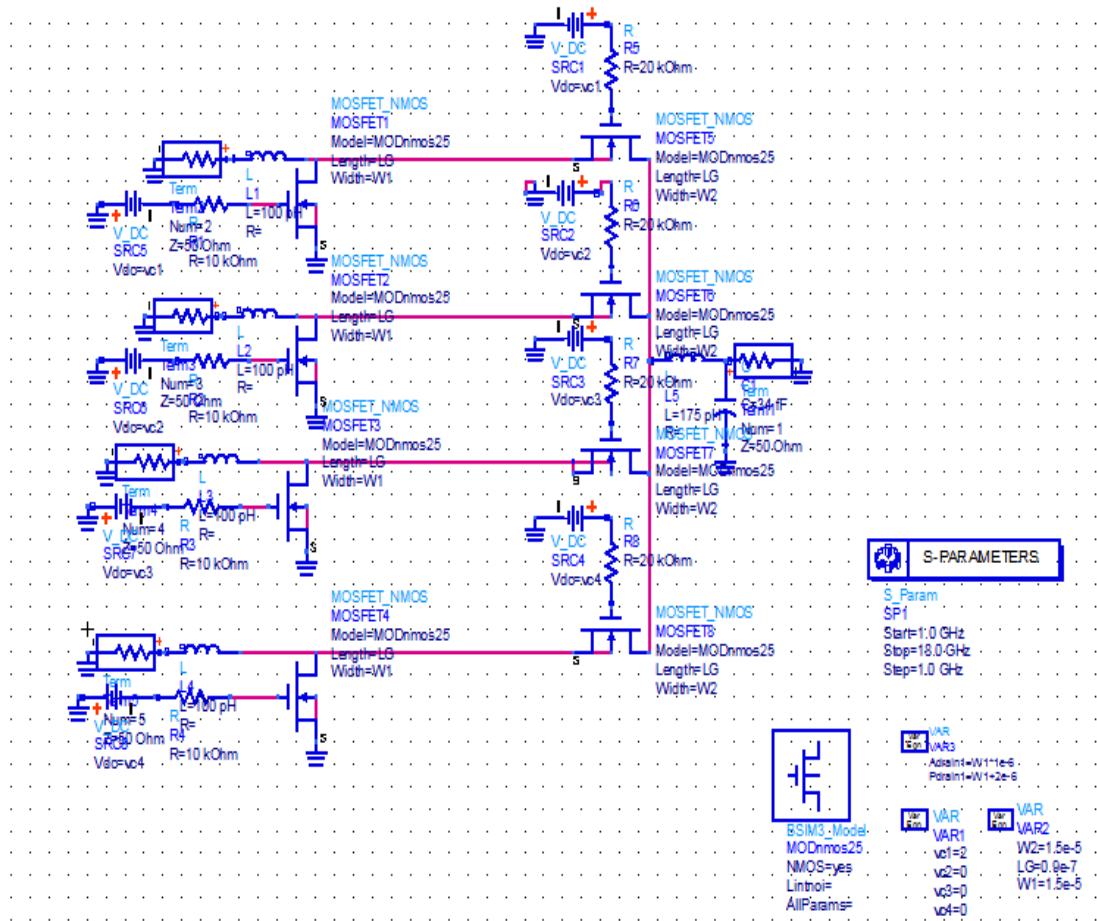


Fig 7: ADS schematic diagram for 2-18 GHz SP4T switch

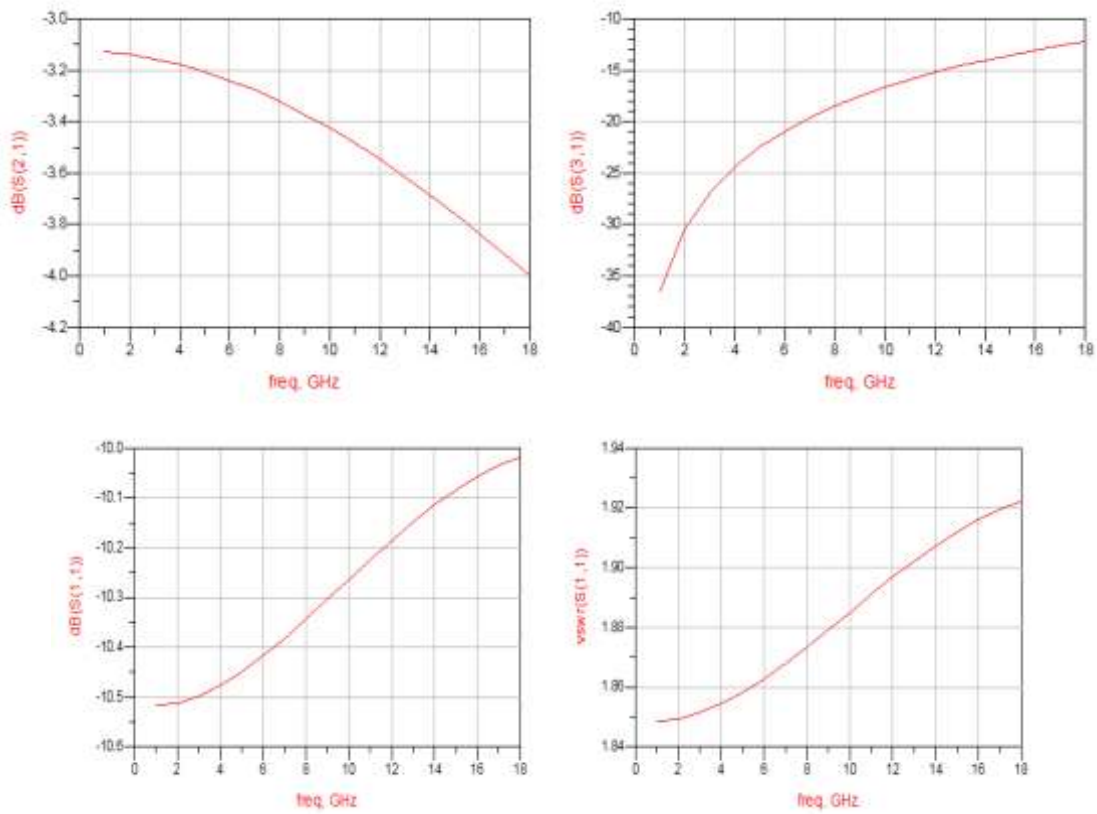


Fig 8: S-parameter response for 2-18 GHz SP4T switch for second port 'on'

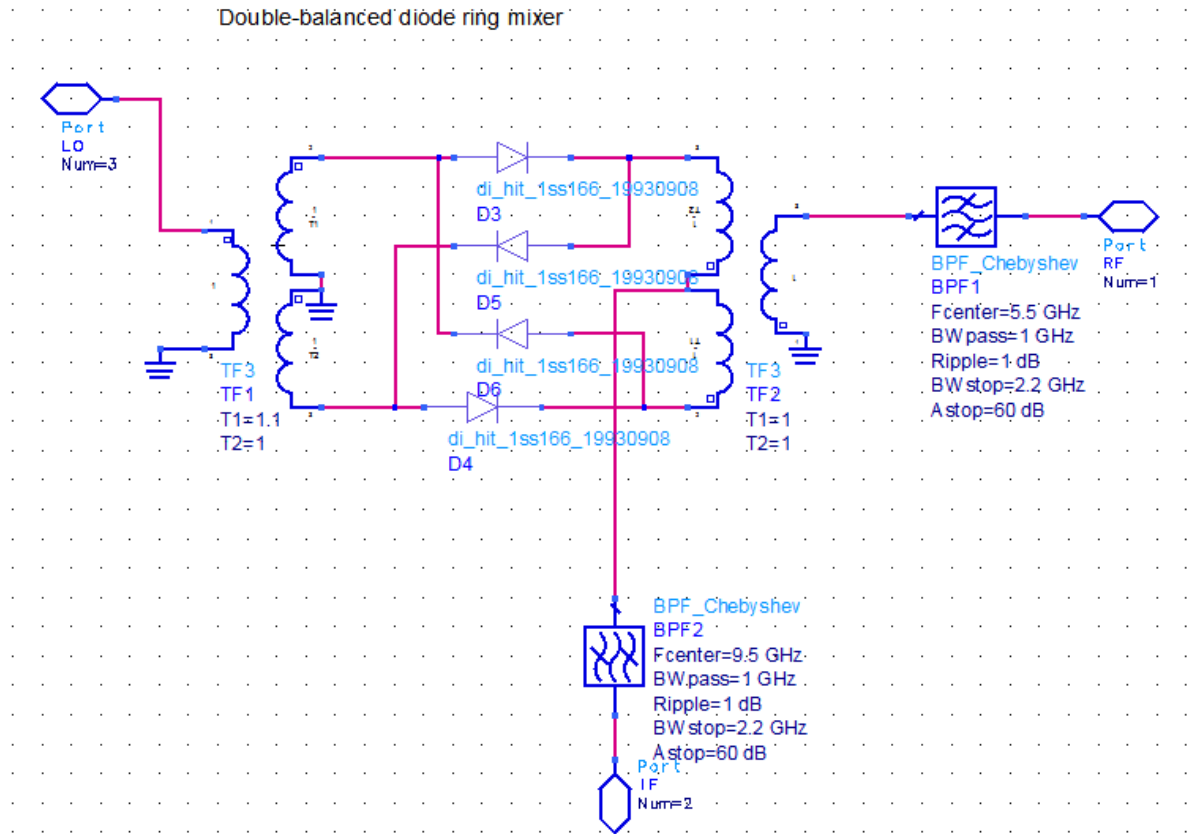


Fig 9: ADS schematic diagram for 5-6 GHz Mixer

Table 2

5-6 GHz Mixer response

Mixer (LO at 13GHz, 10dB)	Input at 5 GHz and -30 dB	Input at 6GHz and -30 dB
Output frequency	9 GHz	10 GHz
Conversion Loss	-16.72 dB	-15.1 dB
Harmonic Rejection	-150 dB	-160 dB

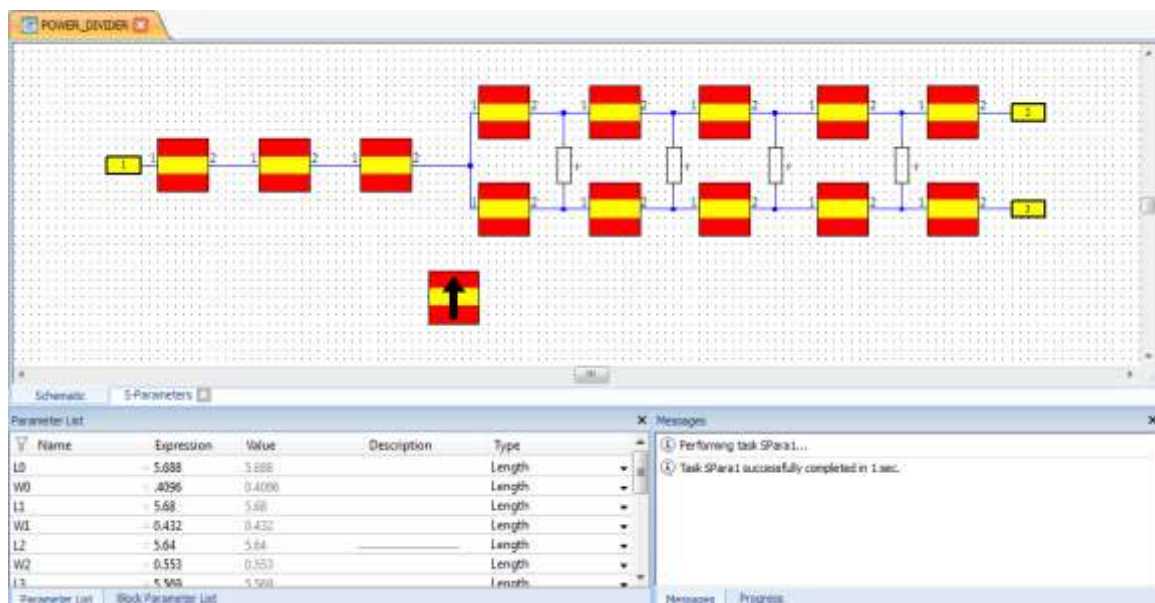


Fig 10: CST schematic diagram of 2-way Power Divider operating in the frequency range of 2-18 GHz

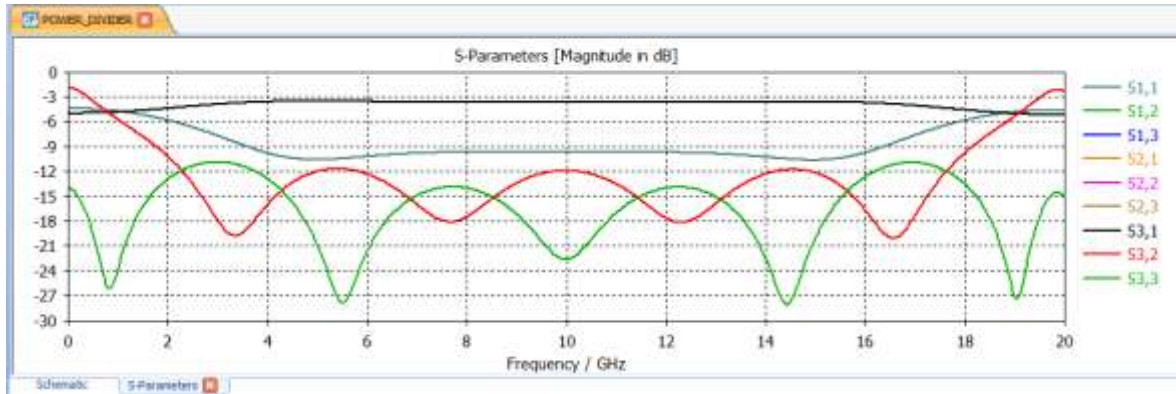


Fig 11: S-parameter response of 2way power divider

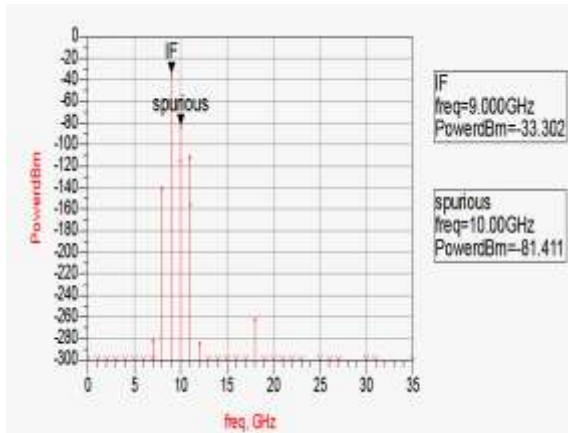


Fig 12: Output Power response of Up/Down converter for 5 GHz and -35dBm input

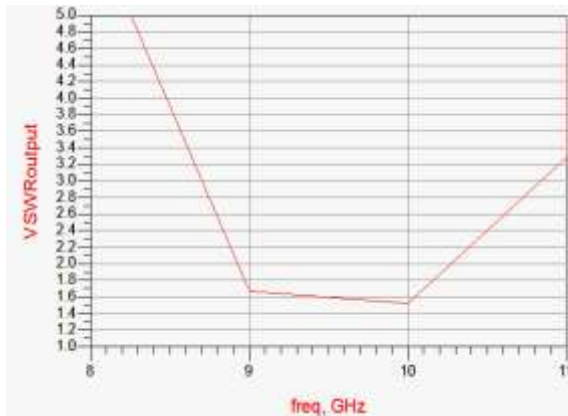


Fig 13: Output VSWR of Up/Down converter for output between 9 -10 GHz

V. CONCLUSION

In RF channel the received signal from the antenna need to be converted to a desired frequency band (8-11 GHz) for improved sensitivity of the digital receiver. For this action here a frequency converter is designed to work in 2-18 GHz range. Each component of the 5-6 GHz channel of block diagram is designed and simulated using ADS software. In this project Filters, Mixers, Switches

and LNA design schematics and their responses using ADS were shown. The components needed for the design were taken from the component library. After simulating each component, all components were connected and simulated. The combined response has met all the specifications with respect to the design specifications.

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