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FRONT END INTEGRATED RF UNIT FOR

Efficient Linear array Imager

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Abstract :

Efficient Linear array Imager (ELI)is a cross telescope capable of producing 64 beams simultaneously in the sky. It uses 16 receivers and each is likely to use 4 IF chains, making a total of 64 numbers. Clearly, such a large number of receiversrequire optimisation of volume, power and cost. Following the model of commercial LNBCs, we have made a prototype front end Integrated RF unit for use with ELI. This integrates front end filters, mixer section and postsamplifiers, all in a board size of 6 cm x 5 cm. This integrated RF units has avoided multiple SMA connectors and thereby improving reliability at the cost of inter-changeability. In this technical report, we describe the effort put in development of this prototype.

1. Introduction

Efficient Linear array Imager (ELI) is a cross telescope obtained by laying two fan-beam telescopes orthogonal to each other. It will form 64 simultaneous beams on the sky using 16 receivers. It is also envisaged that 4 spectral lines be simultaneously observedusing this. This implies that one needs 64 RF chains. Such a large number of IF chains will occupy large volume, be heavy, consume more power and overall cost more, owing to boxes and connectors. Therefore, it is desirable that one makes an integrated Rf board that is compact,economical and consumes less power. In this technical report, we describe our effort in developing an integrated Front end RF boards which receives the RF signal from the LNA anywhere in the frequency range 7000-14000 MHzto generate 1st IF output with sufficient power from 0 to 3500MHz which is further channelized to different frequency bands as input to the 2nd IF processor unit. The motivation in building an Integrated Front RF unit is given in Section 2. Integrated Front RF unitis described in section 3. Development of FRONT end RF filters and Fabrication details are given in section 4 and the measurement results are in section 5.Developpment of high frequency multi way powers Splitter for local oscillator distribution for 16 RF units are given in section 6.Section 7 concludes with the summary of work carried out.

2.Motivation

As mentioned, ELI requires a large number of RF units and it is necessary to reduce the overall weight, cost, power consumption while improving reliability. Thus, the motivation for building anintegratedRFunit is toI) minimize the number of connectors and cables ii) make the system compact, light weight, efficient andreliable for using it in the ELI receiver system.

3.Description of the RF UNITS

The basic purpose of the RF unit is toi)band limit the received RF signal from the LNA, ii) converts the RF signal to first IF signal and iii)amplify the signal to the level required for2nd IF processor unit iv) avoid aliasing and minimise additional noise and insertion losses.

Our receiver is a super heterodyne receiver converting the RF signal (7-14GHz) into an IF output centred at 1750MHz. The instantaneous bandwidth of the receiver is about 3500MHz. The RF BAND 7-14GHz is divided into two bands i.e Lower side band conversion unit which converts 7 to 10.5GHz to desired IF from 0 -3.5GHz using appropriate LO and upper side band conversion unit which converts 10.5GHZ to 14GHz into desired IF from 0 - 3.5GHz using appropriate LO. The block diagram of the receiver is shown below.

Ku FRONT END RECEIVER BLOCK DIAGRAM

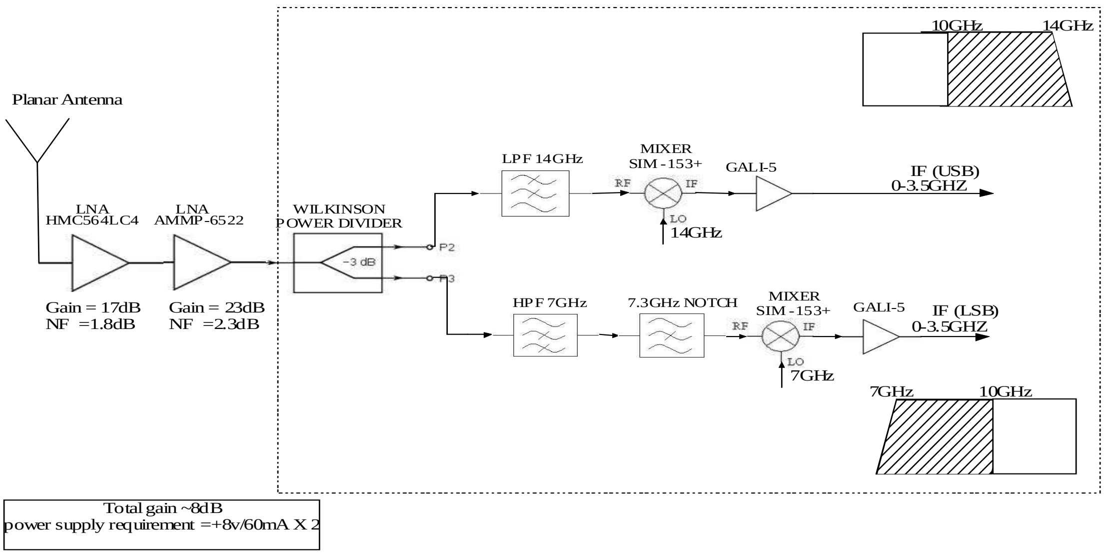


Fig 1. Block diagram of the RF units

Lower side band conversion card (LSB) and Upper side band conversion card (USB) are developed to convert the RF signal (7GHz to 14GHz) from LNA. The output of LNA is divided into two bands (7 to 10.5GHz) LSB and (10.5 to 14GHz) USB bands.LSB card contains 10.5GHz microstrip stub low pass filter and USB card contains 10.5GHz microstrip stub High pass filter as input section. The suceeding sections in the cards are Mini circuit Mixer SIM 153+ Mixer for down conversion using appropriate local oscillator signal and Mini circuits Gali 5+ post amplifier with typical gain of around +18dB.The transmission trace width for interconnection is matched to 50Ω. ThesePCB's are designed in Genesys software on Ultralam substrate having dielectric constant of 2.55.

3.1 Development of FRONT end RF filters and fabrication details:

Design and development of 10.5GHz low pass filter

Stub Microstrip low-pass filters can be designed as shown in Figure 2, which is made of shunt short-circuited stubs that are lamda/4 long with connecting lines that are also lamda/4 wavelength long, where lamda is the guided wavelength in the medium of propagation at the cutoff frequency Fc. For a filter of degree n, the stub low-pass filter characteristics depend on the characteristic impedance of the stub lines.

The stub low pass implements the series inductors of the low pass prototype as high-impedance lines and the shunt capacitors as open-end stub lines. This topology enhances the stop band performance at particular frequencies.

Required specification of the Low pass filter (LPF):

- Cut off frequency =10.5GHz
- Order=19
- Pass band ripple=0.1dB
- Insertion loss=<-0.5dB
- Return loss= <-20Db
- Out off band rejection =<-40Db.

This filter is designed and fabricated on Ultralam substrate of dielectric constant of 2.55 and substrate thickness of 0.762mm. The 3dB cut-off frequency of the filter is optimized to achieve 3db cut off at 13GHz with reasonably good VSWR over the band. Since we expect 15 -20% frequency shifts in cut off frequency from simulation to practical results due to etching tolerance and fabrication accuracy, this filter is designed at 13GHz in simulation. The filter is simulated and optimized for minimum insertion loss and better VSWR over the frequency range.

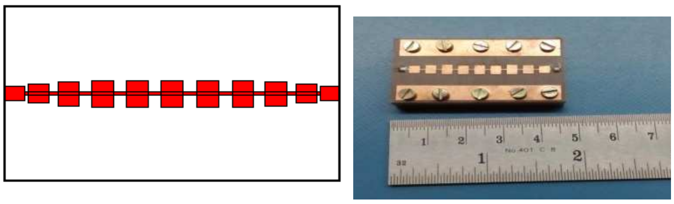


Fig 2. PCB layout and fabricated filterof LPF

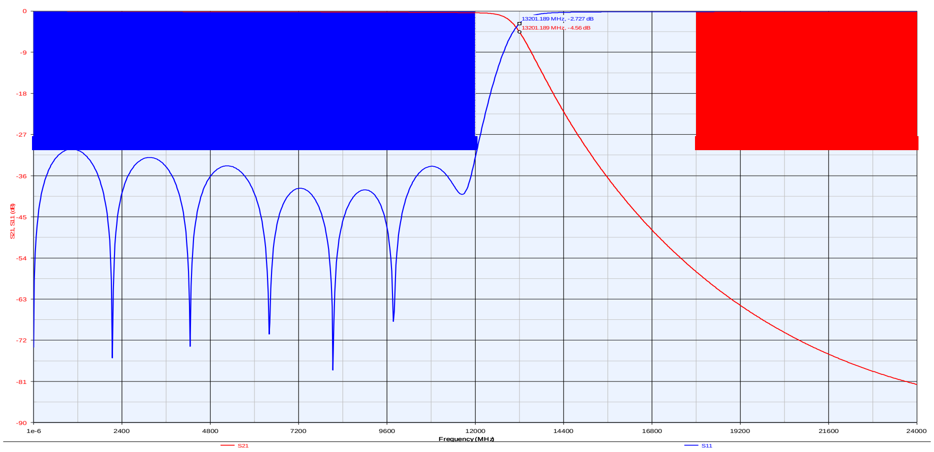


Fig 3 Simulation results of LPF

This filter was simulated using Genesys Software and fabricated on an ultralam2000 from Rogers. This filter was Assembled, and tested, it required a small amount of tuning to achieve the specified cut off frequency.

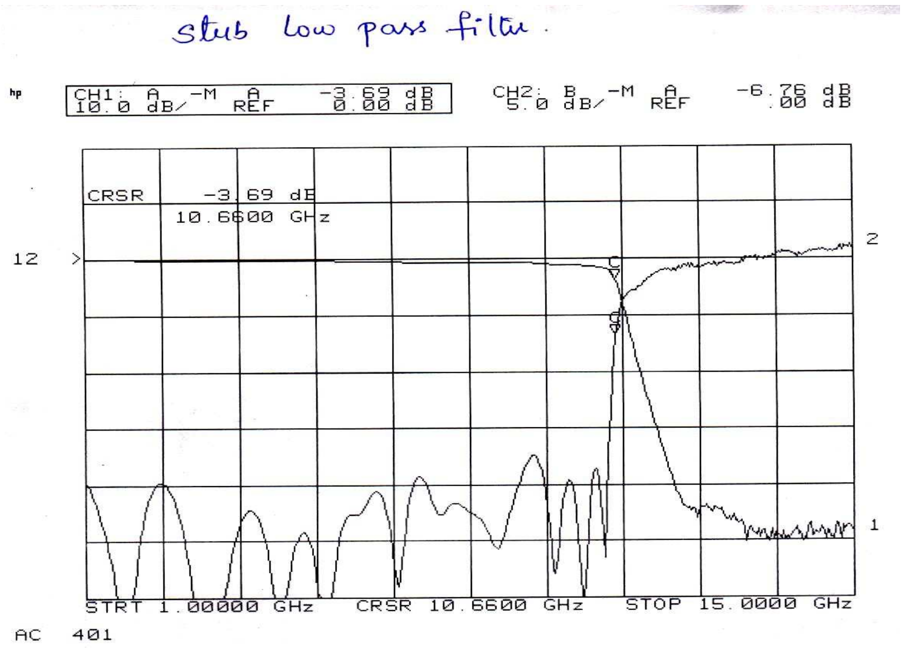


Fig 4.Measured results of LPF

	Expected	Achieved
Cut off freq	10.5GHz	10.66GHz
Insertion Loss	<0.5dB	0.4dB
Return Loss	25dB	20dB
Roll off	1.3	1.33

<u>Design and development of 10.5GHz High pass filter.</u>

High pass filter (HPF) 10.5GHz is the first section of the upper side band conversion unit. Microstrip high pass filter is a 7 order Chebyshev characteristics filter with 0.1 ripple in the pass band with cut off at 10.5GHz.

Microstrip short circuited stub topology is implemented in this design. In design and realization of Microstrip filter, short section of transmission line or stub, whose length is much smaller than a quarter of guided wavelength are the most common components in design.The short circuited stub is considered to achieve a high pass filter response. The short circuited stub behaviour resembles to the shunt inductor.

This filter design is simulated and optimized to achieve desired response in Genesys software. This filter is realized on an ultralam substrate with dielectric constant of 2.55 and thickness of 0.762mm.

Required specification of the High pass filter:

- Cut off frequency =10.5GHz
- Order=7th
- Pass band ripple=0.1dB
- Insertion loss=<-0.5dB
- Return loss= <-20Db
- Out off band rejection =<-40Db.

Fig 5 .Fabricated filter of HPF

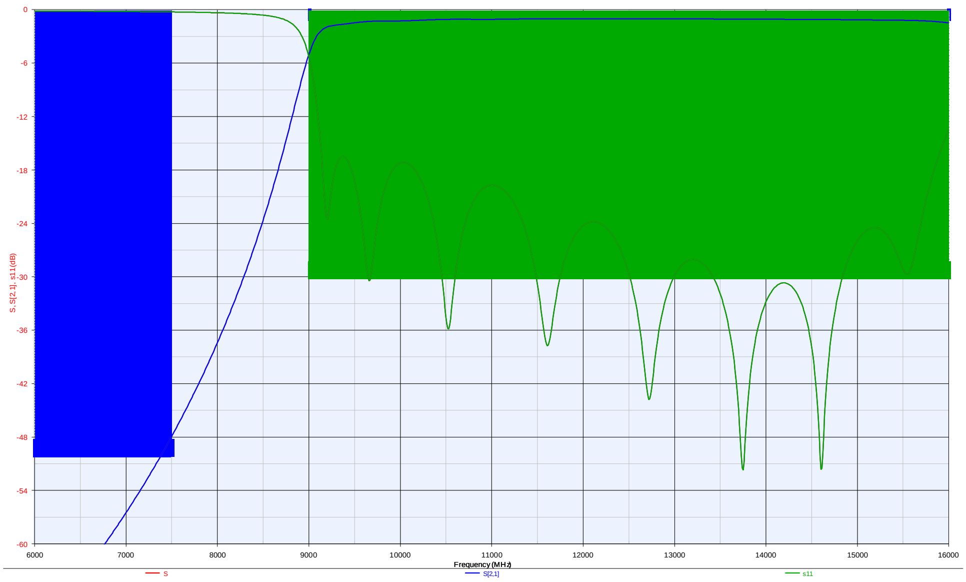


Fig 6. Simulation results of HPF

This filter was Assembled, and tested, it required a small amount of tuning to achieve the specified cut off frequency.

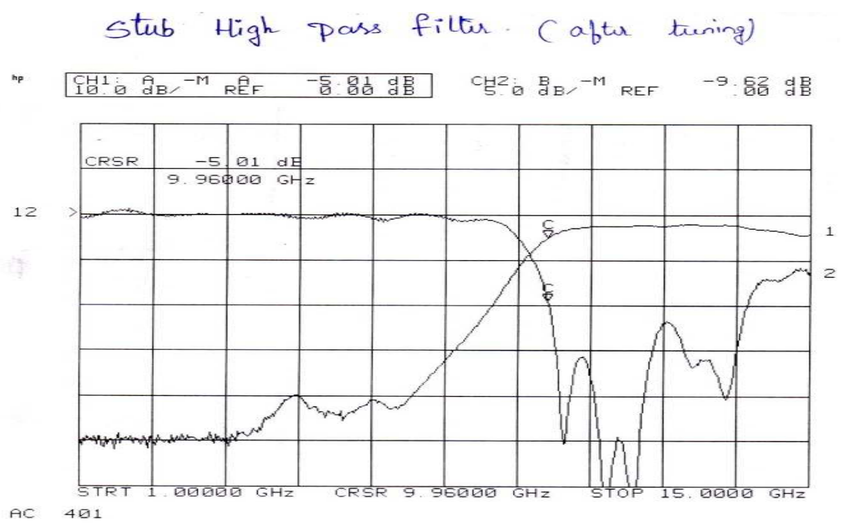


Fig 7.Measured results of HPF

	Expected	Achieved
Cut off freq	10.5GHz	10.66GHz
Insertion Loss	<0.5dB	1.8dB
Return Loss	25dB	10dB
Roll off	1.3	1.4

3.2 <u>Development of USB AND LSB with fabrication details:</u>

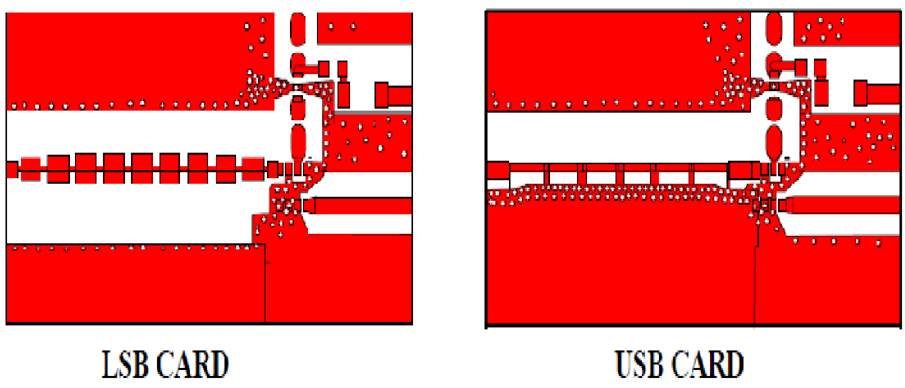


Fig8.PCB LAYOUT PATTERN.

Fig 6 shows a printed circuit board of the RF chain. Top layer carries RF components and transmission line with a ground on the bottom side. Sufficient numbers of vias are provided on the pub to ensure good grounding. This also helps minimize parasitic ground inductance. Care is taken to provide good isolation between the RF and DC by providing RF choke in the dc path.This compact intermediate RF chain is assembled in a milled box. Smaller package of SMD components are used to reduce the PCB size.

SMA connectors are provided for the RF input and IF output, LO input. A feed thru filter is used at the output for providing the DC bias for the amplifier and to minimize RF leakage into the power supply line.

4.Measurement of USB AND LSB:

Characterisation of LSB CARD:

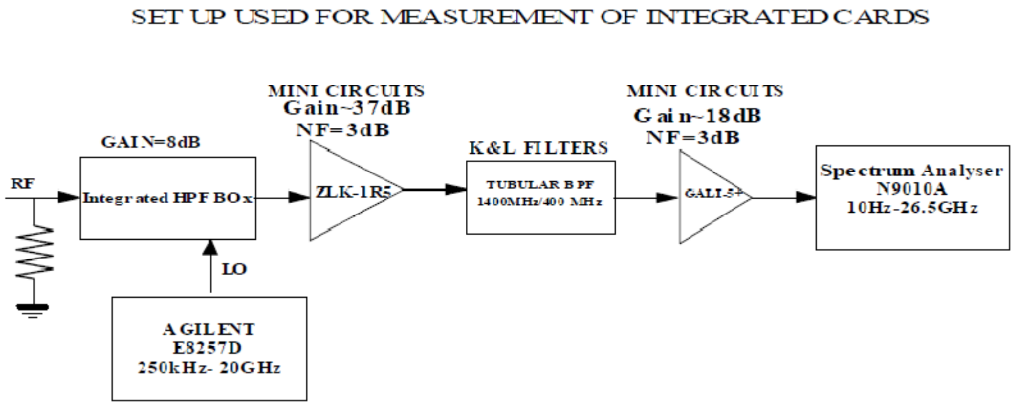


Fig 9. Setup for testing integrated cards.

Instruments used:

LO SIGNAL Generator= Agilent Technologies E8575D,

INPUT SIGNAL GENEATOR: EXG Analog generator N5173B

Spectrum analyser KEYSIGHT N9010A EXA signal Analyser 10HZ-26.5GHz.

Above setup is made to evalute the Integrated cards. The required LO is fed externally from Agilent E8257D signal source and ouput IF is measured on spectrum analyser N9010 A .

The Integrated IF card input is terminated with 50ohms. The down converted IF with appropriate LO from Integrated box is amplified by ZLK-1R5 which has gain of ~37Db followed by K&L Tubular filter as IF filter centered around 1.4GHz with Bandwidth of 400MHz .The IF filter output is further amplified by Gali 5+ post amplifier.

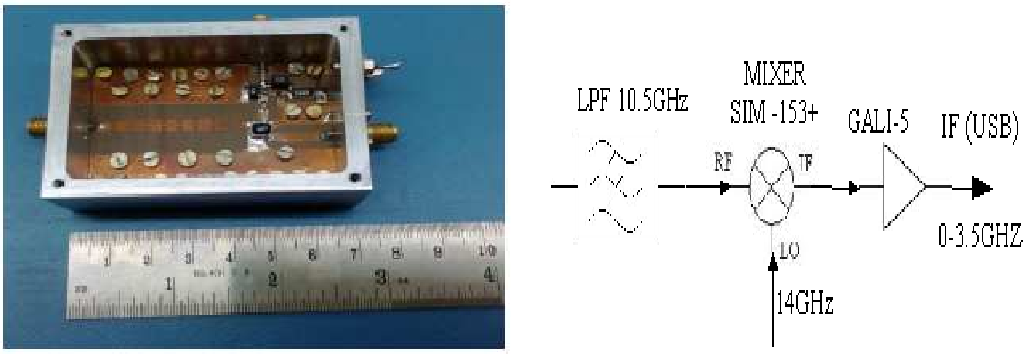


Fig 10.Lower side band conversion card assembled in Milled box.

1db compression measurement of LSB CARD @RF =8200MHz and with LO=7000MHz .IF measured is 1.2GHz

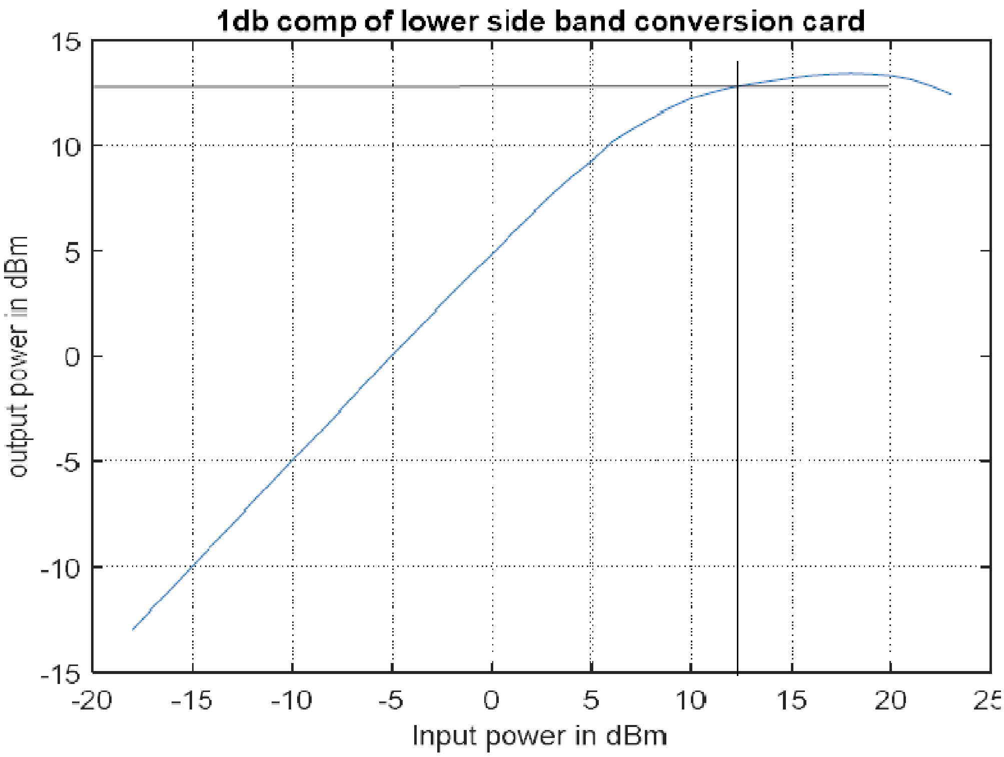


Fig 11 .1dBcompression of LSB Card

From the graph above the input 1db compression point of the LSB card @IF 1.2GHz is found to be +6dBm.

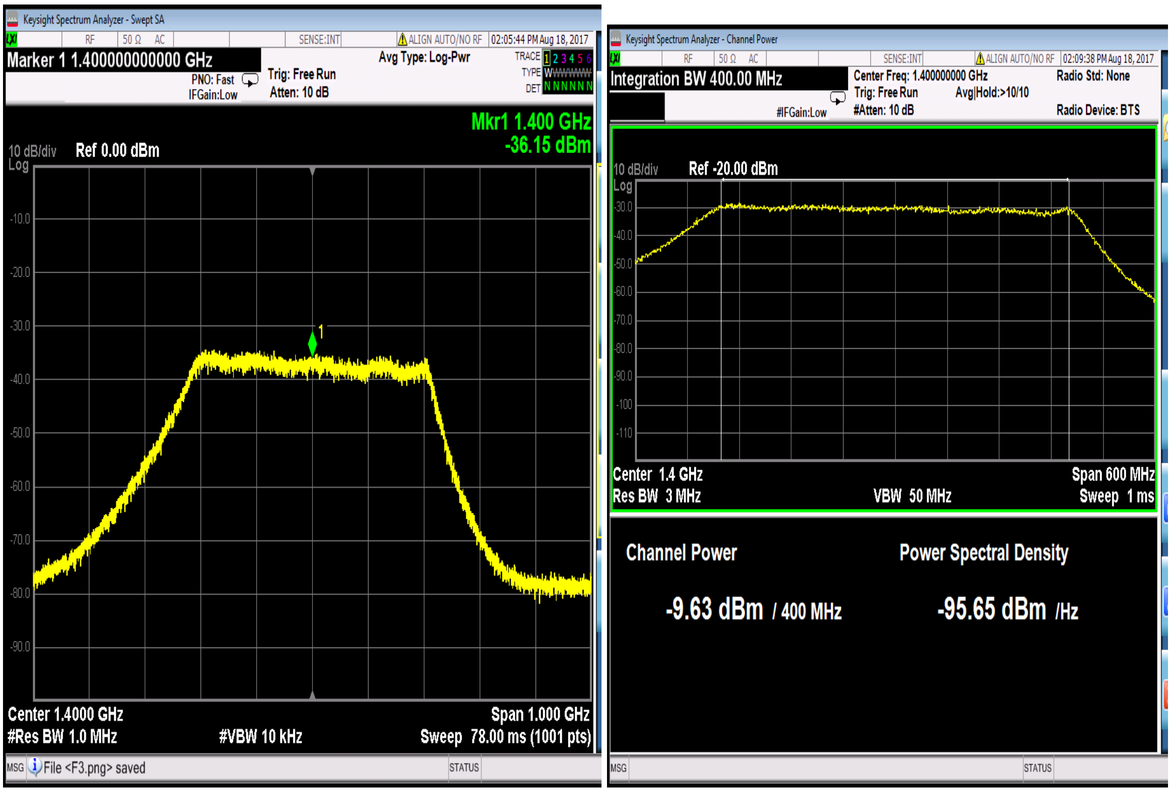


Fig 12. Output results of LSB card on Spectrum analyser

Characterization of USB CARD:

1db compression measurement of USB CARD @RF =12500MHz and with LO=14000MHz .IF measured is @ 1.2GHz.

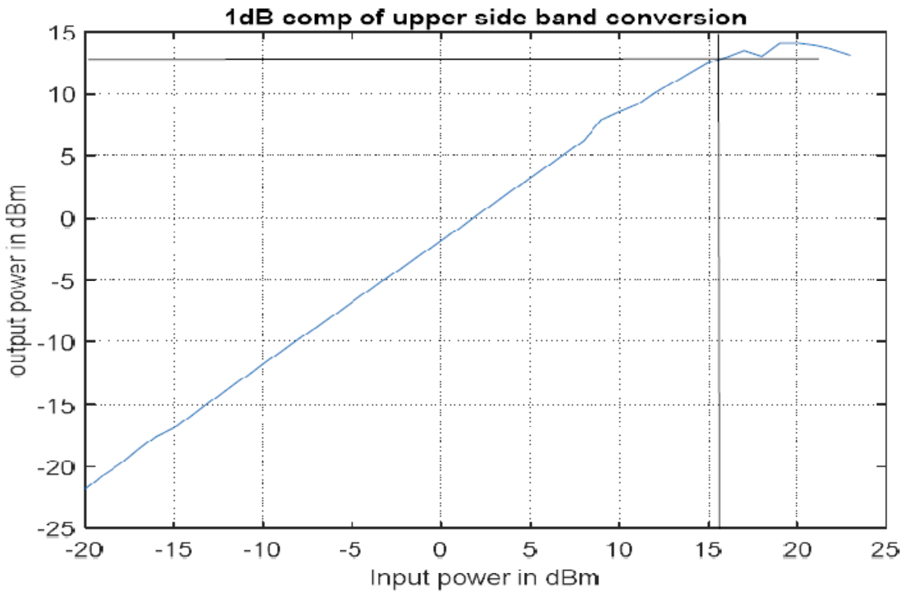


Fig 13. 1dB compression of USB Card.

From the graph above the input 1db compression point of the LSB card @IF 1.2GHz is found to be +10dBm.

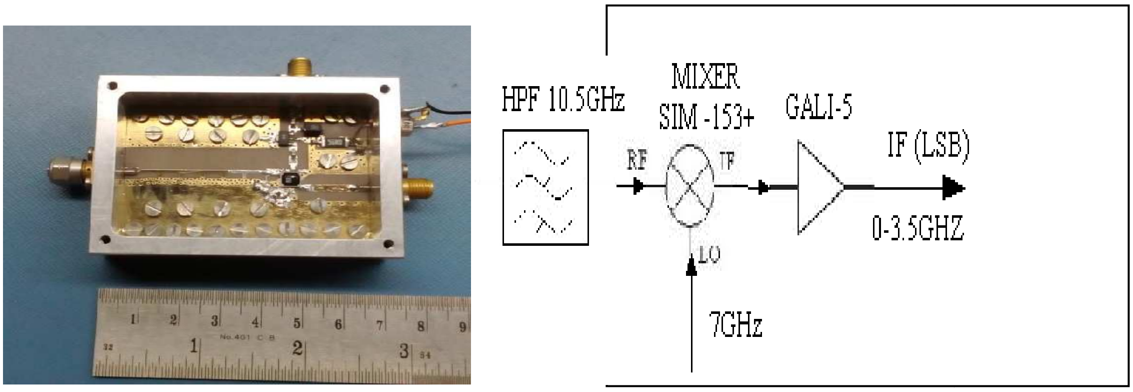


Fig 14 .upper side band conversion card assembled in Milled box.

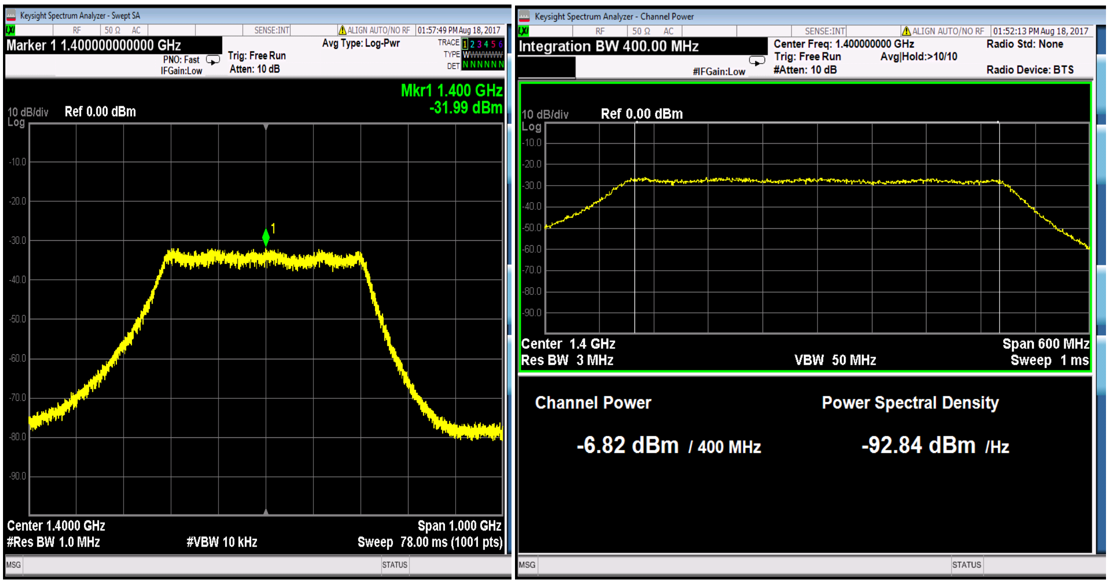


Fig 15. Output results of USB card on Spectrum Analyzer.

Gain of the Integrated RF units (LSB and USB) is measured around 8dB across the band.

5. Development of 3GHz to 7 GHz high frequency powers splitters.

The LO distribution network distributes Local oscillator signal for 16 RF units which converts the RF signal anywhere from 7000 to 14000MHz to 0 to 3500MHZ IF signals.

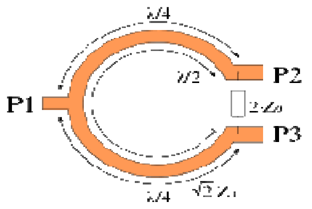
ADF 5355 Synthesizer Evaluation board has integrated VCO with a fundamental output frequency ranging from 3400 MHz to 6800 MHz as LO signal to Lower side band conversion unit.VCO frequency is connected to divide by 1, 2, 4, 8, 16, 32, or 64 circuits that allow the user to generate RF output frequencies as low as 54 MHz This board also has frequency multiplier which can produce the frequencies upto 13.9GHZ which can be used as LO signal for Upper side band conversion unit. The 8way power splitter distributes the LO signals to 8 individual RF units after sufficient amplification by a power amplifier to the Mixer input (+7dBm).

This power division is mainly for LO distribution for 16 channels Receivers.

The Wilkinson power divider concept can be used for an N-way power division system.

, it is easiest to see how it operates as a two way system, and later expand it out to see how the Wilkinson power splitter can be used as an n-way device.

The Wilkinson power divider / Wilkinson combiner uses quarter wave transformers to split the input signal to provide two output signals that are in phase with each other.



DESIGN OF WILKINSON POWER DIVIDER

1.Select an appropriate substrate of thickness (h) and dielectric constant (εr) for the design of the power divider.

2. Calculate the wavelength λg from the given frequency specifications as follows:

Where, c is the velocity of light in air.

F is the frequency of operation of the coupler.

Er is the dielectric constant of the substrate.

3. Synthesize the physical parameters (length & width) for the λ/4 lines with impedances of Z0 and √2 Z0 (Z0 is the characteristic impedance of microstrip line which is = 50 Ω)

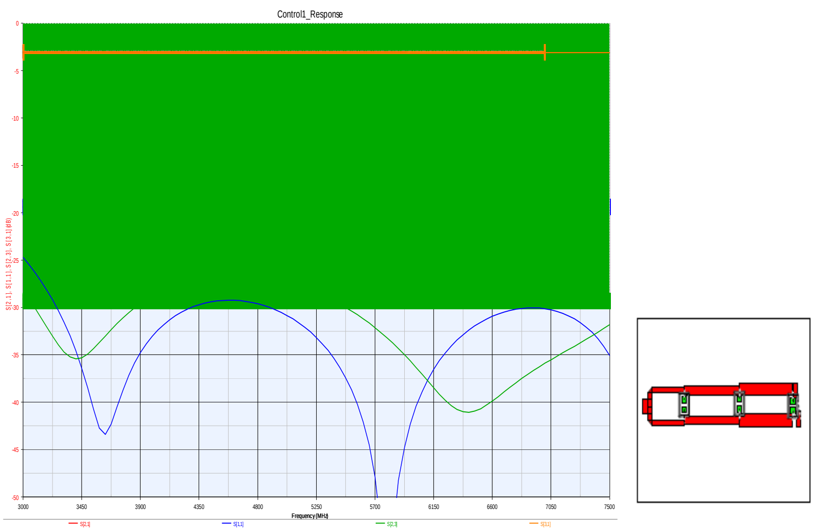


Fig 16.Simualtion and layout of two way 3sec wilkinson power splitter

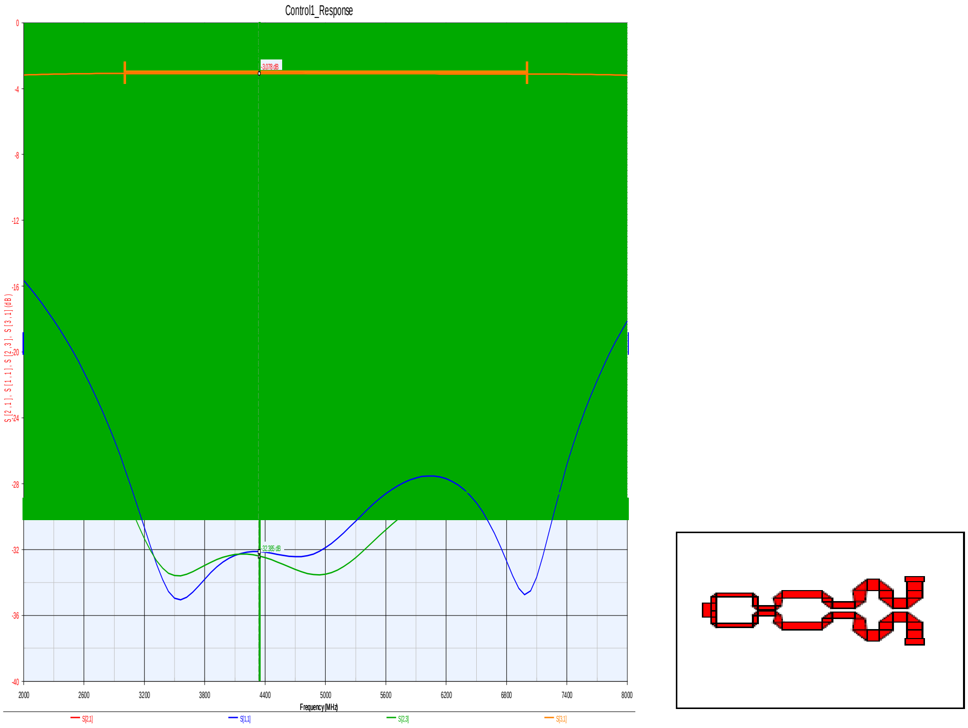


Fig 17.Simualtion and layout of two way 3sec MEANDER wilkinson power splitter

The plan was to design 8 way power division networks. To start with, we have designed 4way Wilkinson power division network cascading 2 way power splitters.

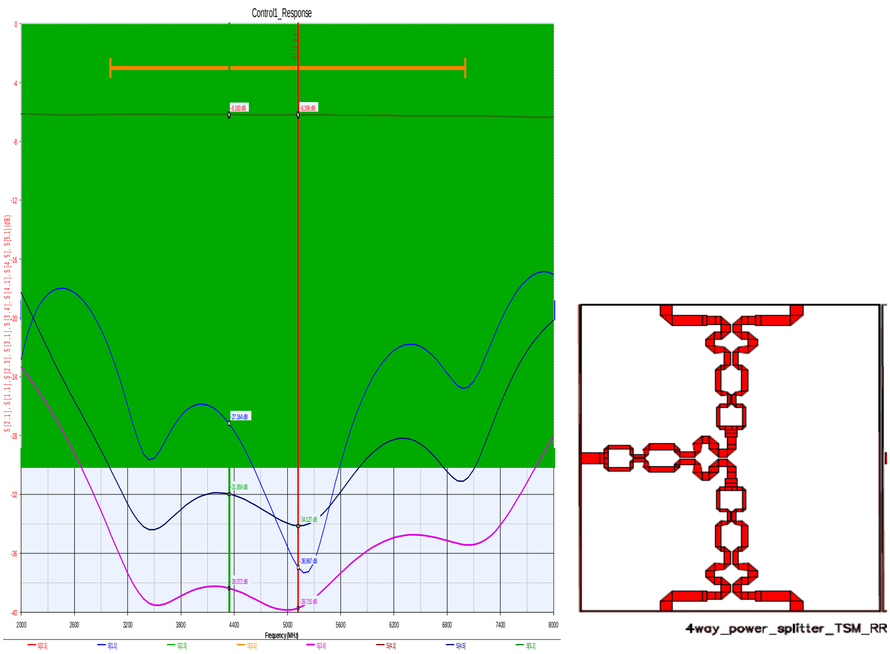
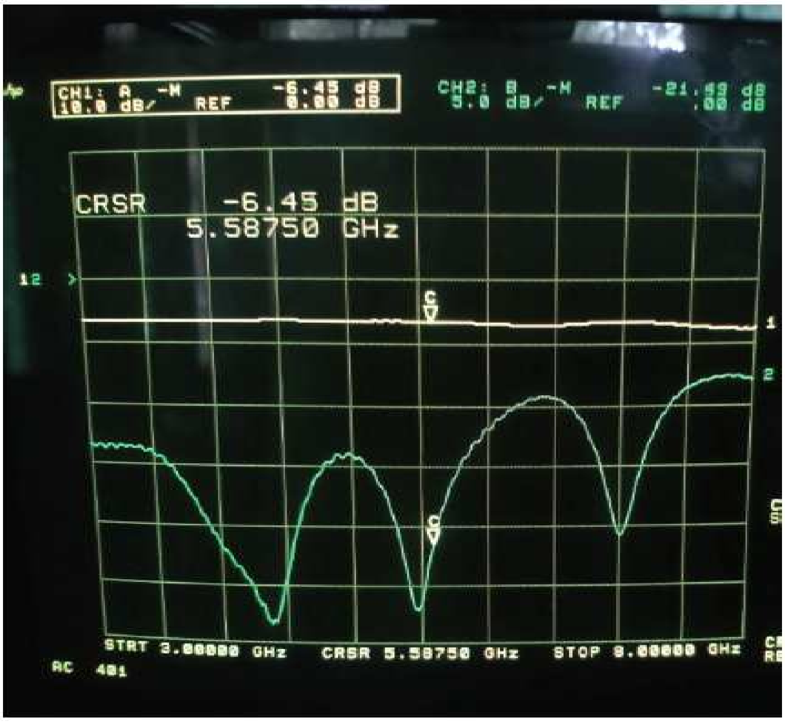


Fig 18.Simualtion and layout of four way 3sec MEANDER wilkinson power splitter



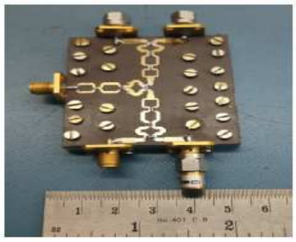


Fig 19. Layout of 3 sec 4 way power divider and fabricated PCB

- **3000MHz to 7000MHz EIGHT WAY POWER SPLITTER DESIGN**

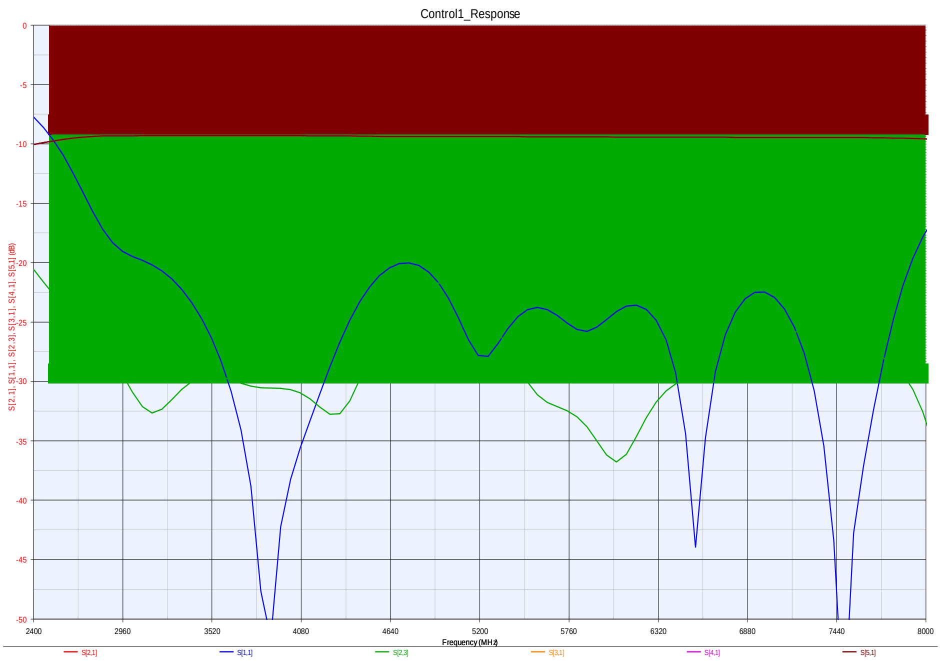


Fig 20. Simulation of 8 way power divider.

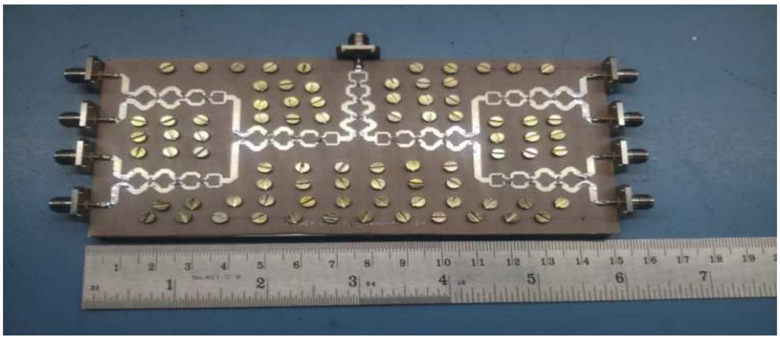


Fig 21.fabricated 8 way power splitter

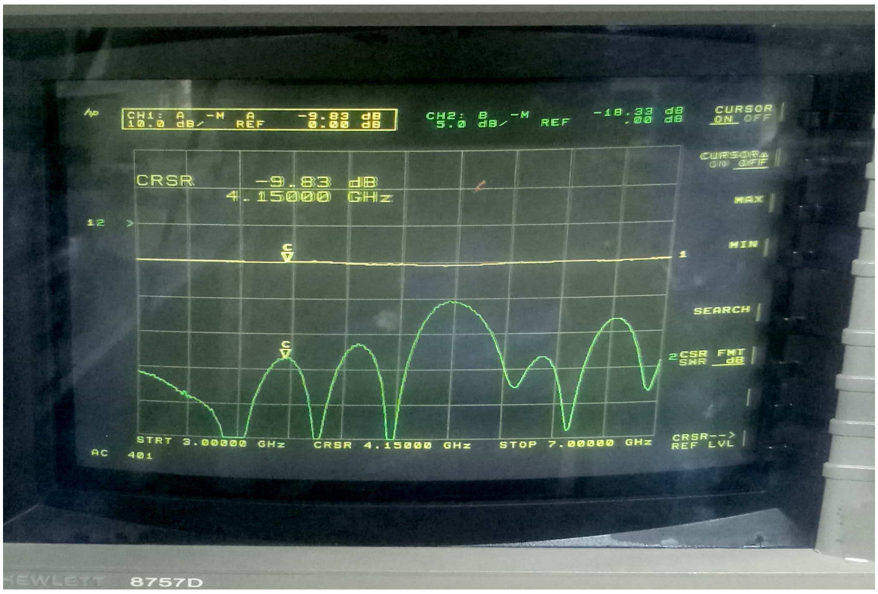


Fig 22. Measurement results of 8 way power splitter.

6. Conclusions

We have successfully built the IntegratedFront end RF unit which could meet the expected results. The performance is found repeatable over many measurement cycles. Both Integrated cards are tested and they found to be stable.

The total gain of the RF unit is around ~8dB. Further amplification is needed before cascading with the 2^{nd} IF processor unit and with the digitizer for sampling.

3 to 7 GHz power splitter is successfully built and tested. This power splitter output should be cascaded with a power amplifier to boost the boost LO power to a sufficient level required for mixer operation in RF conversion units.

Acknowledgement

We thank Nagaraj H N for helping us with PCB fabrication process and Mohamed Ibrahim for providing us with milled boxesfor the RF UNTIS.

References

1.Reinhold Ludwig and Pavel Bretchko, “RF Circuit Design”.

2.G. Mathieu, E.M.T. Jones, L. Young, “Microwave Filters, Impedance-Matching networks, and Coupling Structures (Bartech Microwave Library)”.