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SECOND ORDER CURRENT FEEDBACK OPERATIONAL AMPLIFIER (CFOA) ACTIVE-R BANDPASS FILTER FOR AERONAUTICAL MOBILE APPLICATIONS

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Abstract: Aeronautical mobile communication systems utilize Digital broad band data link technology between space and ground to achieve the interconnection and networking between plane and the ground during flight (Guo, 2013). This technology utilized i.e. Digital broad band data link between the space and ground at link layer need to solve that the problem of multiple planes, a variety of crafts sharing limited radio resource between space and ground. Therefore the need for filter comes into play to solve the problem of interference, in this respect, using mechanism of bandwidth dynamic allocation and demand to solve the contradiction between resource utilization and service quality is an important research aspect, hence the second order CFOA Active-R Bandpass filter was designed, simulated and results presented. Results showed good agreement with filter specification; therefore it can be used in the implementation in Aeronautical Mobile Communications system.

Keywords: *second order, CFOA,Bandpass, filter, Aeronautical mobile, Communications, Active-R. (Paper received: 10/08/2022, Accepted: 5/9/2022)*

I. INTRODUCTION

Several years now has witnessed analogue filters as one of the main components in every electronic and communications systems. Analogue filters apart from a few active circuits elements, consists of components like resistors, capacitors and inductors. It is even customary to assume that the components are ideal i.e. they have no parasitic elements, the usual components and active Circuits are far away from ideal behaviour. Therefore getting a correct analysis and synthesis of analogue filters is difficult without the use of computers, (Rusu, Kovacs &Grama, 2009). Today's engineers find it easy to carry out computers simulations to calculate the gain and phase responses of any analogue filter before implementation of any design they want to carryout. (Mitra, 2006).

Aeronautical mobile communication systems utilize Digital broad band data link technology between space and ground to achieve the interconnection and networking between plane and the ground during flight (Guo, 2013). This technology utilized i.e. Digital broad band data link between the space and ground at link layer need to solve that the problem of multiple planes, a variety of crafts sharing limited radio resource between space and ground. Therefore the need for filter comes into play to solve the problem of interference, in this respect, using mechanism of bandwidth dynamic allocation and demand to solve the contradiction between resource utilization and service quality is an important research aspect.

Digital filters have been for many years the most common application of digital signal processors (DSP). It has been known that the digitizing any design, one can ensure that we can reproduce it time and time again with exactly the same characteristics. There is also a significant advantage with respect to analogue filters. It is possible to reprogram the DSPS and drastically alter the filter's gain or phase response. For example, we can reprogram a system from low pass to high pass without throwing away our existing hardware. It is common knowledge that traditionally IIR digital filters are designed using some analogue filters describe in time domain or transform domain; then analogue filters can be converted to digital filters using appropriate transformation from S-domain to Z-domain (Whitaker, 2001). For many engineers, analogue filters mean certain circuits or a net list of components, and digital filters are set of statement in certain software (Rusu et. al., 2009).

There is a fundamental need for communication between aircrew and ground controllers, among the aircrew and between aircrew passengers. External Communication is achieved by means of radio-telephone (R/T) link. The first items of radio equipment's to appear on aircraft were low frequency (LF) communication sets in the World War 1 days of spark gap transmitters. Intercom was by means of a Gosport (speaking) tube. By 1930s the early keyed continuous of wave (C.W) (radio –telegraphy) was beginning to be replaced by radio telephone although "key – bashing" had its place as long as aircraft carried radio operators. Early Radio-telephone was within the low frequency (LF) and High frequency (H.F) bands, the sets operating on only one or very few frequencies. With airfields widely spaced and low-powered transmission, there was little interference and so the need for many channels did not arise.

The situation has drastically changed since World War II; air traffic and facilities have increased with the consequent demand for extra channels which cannot be provided in the Intermediate Frequency (I.F), Medium Frequency (M.F) or High Frequency (H.F) bands. Fortunately, very high frequency (VHF) equipment has been successfully developed from early beginning in World War II fighter control.

The current situation is that, the VHF is used for short range communication, while HF is used for long-range. A large air-liner, such as Boeing 747, carries three VHF's and dual HF. In addition, in such aircraft, selective calling (Selcal) facilities are provided by a dual installation such that a ground station can call aircraft either singly or in groups without the need for constant monitoring by the crew (Powell, 1981).

The highest concentration of sources, users and stakeholders of information required for safe and regular flight operations occur at a nation's airports. Flight domains within the nation's airspace system (NAS), the airport domain is one where aircraft are in close and operational support vehicles, personnel and infrastructure. Air traffic controllers, aircraft pilots, airline operators, ramps operators, aircraft services providers, and security, emergency, construction, snow removal, and dicing personnel all contribute to the safe and efficient operation of flights (Budinger, & Hall, 2011). A typical wireless communication system is shown in Figure 1. It consist of a source of information, a hardware subsystem called the transmitter, the channel or means by which the signal travels, another hardware subsystem called the receiver, and a destination of the information (sink).

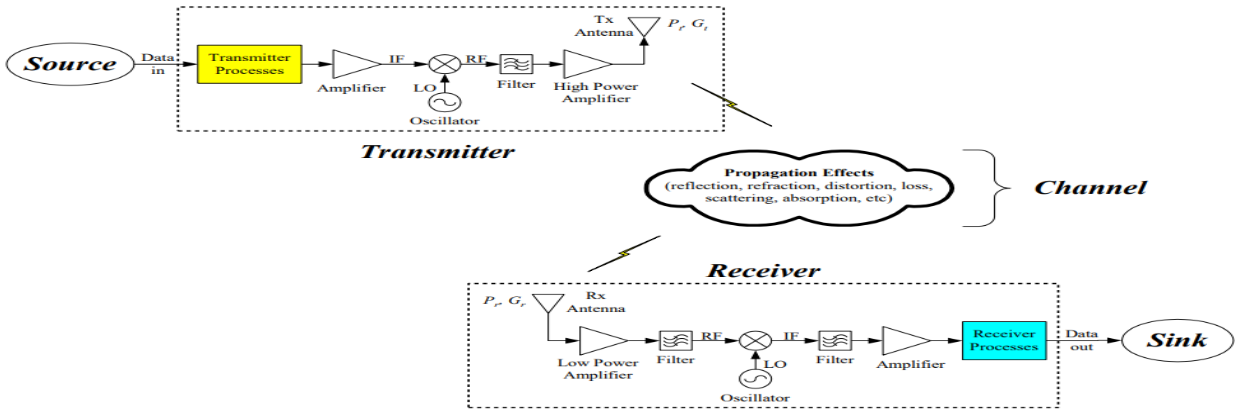

Figure 1. A Simplified Model of Wireless Communications System

As communications, navigation, and surveillance (CNS) facilities for air traffic management (ATM) at an airport grow in number and complexity, the need for communications network connectivity and data capacity increases. Overtime, CNS infrastructure ages and requires more expensive and extensive monitoring maintenance, repair or replacement. Airport construction and unexpected equipment voltages also require temporary communications alternatives (Budinger, & Hall, 2011).

In view of the above reason, this research is an effort to design and simulate a second order CFOA active-R Band pass filter to be used in these communication systems in Aeronautical mobile. This will in no little measure reduce the cost of replacing the equipment's as stated by Bundinger& Hall (2011).

1.1 A BASIC VERY HIGH FREQUENCY (V.H.F) COMMUNICATIONS PRINCIPLES.

An aircraft V.H.F communications transceiver is compressed of either a single or double conversion super het receiver or a transmitter. A modem set provides 720 channels at 25 kHz spacing between 118MHz and 135.795MHz; until recently the spacing was 50 kHz giving only 360 channels. The mode of operation is single channel simplex (S.C.S) that is, one frequency and one antenna for both receiver and transmitter. If provision for satellite communication is included in accordance with Aeronautical Radio Incorporated (ARINC) 566 then in addition to A.M, S.C.S we will have F.M double channel simplex (D.C.S), that is different frequencies for transmitters and Receivers (Powell, 1981).

Communication by V.H.F is essentially "Line of Sight" by direct space wave. The range available can be approximately by 1.23 $(\sqrt{hg} + \sqrt{ht})$nM where $h\gamma$ is the height, infact, above sea level of the receiver while ht is the same for the transmitter. Thus with the ground station at sea level, the approximate maximum range for aircraft at 10,000 and 1000ft (30,000 and 3000M) would be 123 and 40nm respectively.

The receiver is a single conversion super het. The R.F stage employs varactor diode tuning utilizing the tuning voltage from the stabilized master oscillator (S.M.O). Both the R.F amplifier and mixer are dual gate field effect transistors (F.E.T) the R.F amplifier FET has the input signal applied to gate 2. The mixer connections are: gate 1, signal; gate 2, S.M.O. The difference frequency from the mixer, 11.4MHz is passed by a crystal filter, providing the desired narrow bandpass to the I.F amplifiers. Two stages of A.G.C controlled I.F amplification are used; the first of which is a linear integrated circuit the simplified King Kγ 196 receiver block diagram is shown in figure 2. (Powell, 1981).

(Powell, 1981) Aircraft Radio Systems (multi loop filters)

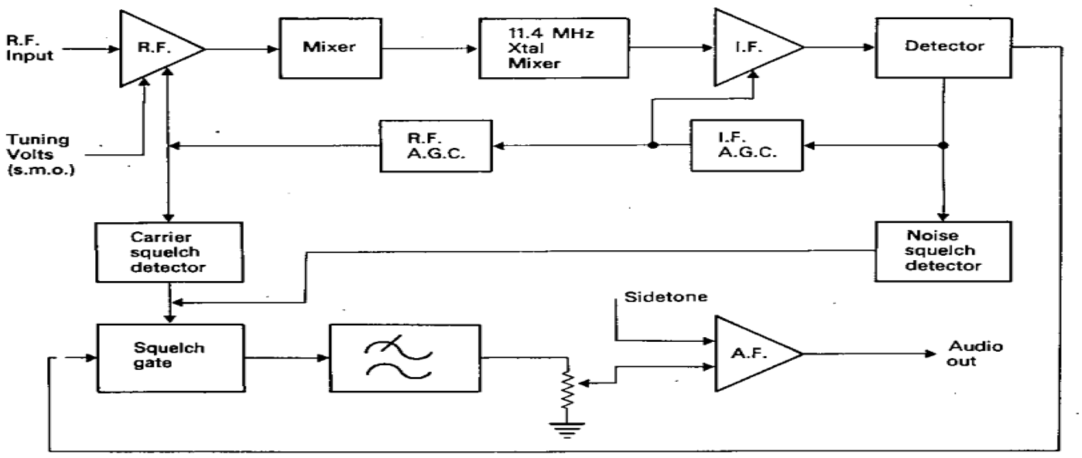

Figure 2. King KY 196 simplified receiver block diagram showing the 11.4MHz external mixer

Figure 2 shows the linear were a filter is utilized at frequency of 11.4MHz. This paper therefore is on the design and simulation of a current Feedback Operational Amplifier (CFOA) Bandpass filter for use in the Aeronautical Mobile communications. The CFOA has a variable – gain and constant bandwidth. It has a variable gain and constant bandwidth. It has higher slow-rate and operates on a higher frequency range. They do not have a gain bandwidth product conflict. When signals amplitudes increases, it shows a very small loss in bandwidth. Since large signals can be accommodated with minimal distortion therefore, these amplifiers have good linearity at very high frequencies. These qualities make it suitable for implementation in Aeronautical Mobile Communications systems.

The AD 844AN is a CFOA based IC. It is has high speed and is a monolithic IC. It has high bandwidth around 60MHz and provides very fast large signal response with excellent DC performance. It has very high slew rate of 2,000.

II. MATERIALS AND METHODS

The research made use of a second order Active R Bandpass filter coupled with two current feedback operational Amplifiers (CFOA) of AD844AN type of Gain Bandwidth product 60MHz. also, 7 resistors of different resistances were calculated, input power source, an output connector, grounded connectors and Multisim version 14.2 software for simulation.

The operational Amplifiers were first mounted on the circuit board and the resistors after calculating and determining their values. Furthermore, the input power source was mounted together with the output connector. The components were finally joined together with the aid of wires. The Band pass filter designed is presented in Figure 3.

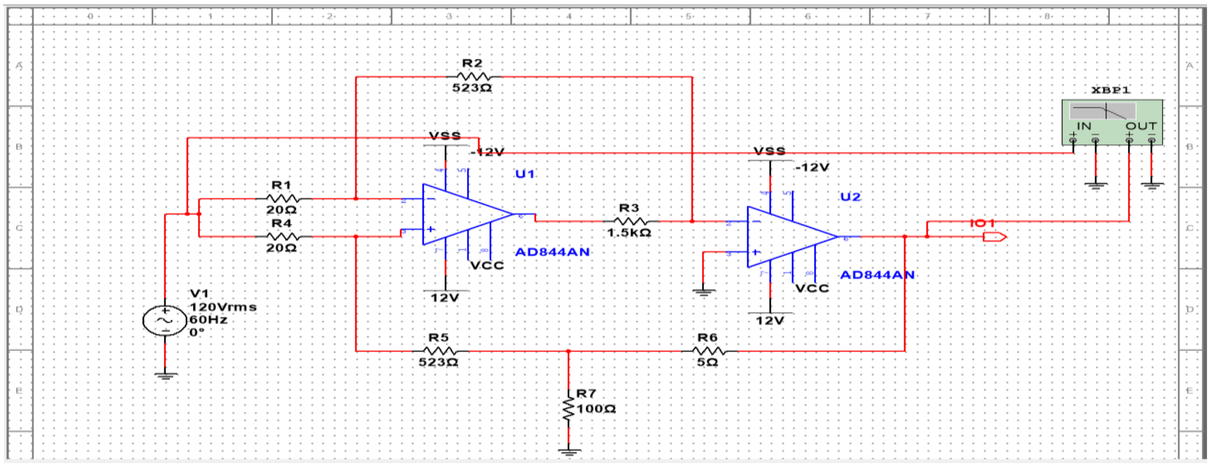

Figure 3. Second Order CFOA Active-R Bandpass Filter

2.1 DESIGN SPECIFICATION

The filter utilized only Active-R type with centre frequency ω_o of 11.4MHz, Quality Factor, Q=5 and a gain factor K of 10. The resistor values were calculated using design equations 12, 13 and 14.

2.2 DESIGN EQUATION

Figure 3 represents a new active-R Bandpass filter which uses two op. amp (OA's) and seven resistors. By direct analysis of the network assuming

$$A_i = \frac{GBi}{S} \qquad (1)$$

Where Gb is the gain bandwidth product of the OA, and assuming $R_5 \gg R_7$, the transfer function is given by:

$$\frac{V_3}{V_1} = \frac{-GB_2R_3}{(R_1+R_2+R_3)S} \times \frac{S^2+SGB_1\left(\frac{R_1+R_2}{R_3}\right)\left(\frac{R_5}{R_4+R_5}-\frac{R_2}{R_1+R_2}\right)}{S^2+S\left(\frac{GB_1R_1}{R_1+R_2+R_3}\right)+\frac{nGB_1GB_2R_4(R_1+R_2)}{(R_4+R_5)(R_1+R_2+R_3)}} \qquad (2)$$

Where $n = \frac{R_7}{R_6+R_7}$ (3) Taking $\frac{R_5}{R_4} = \frac{R_2}{R_1}$ (4)

And defining $a = \frac{R_3}{R_1}$ (5) $b = 1 + a + \frac{R_2}{R_1}$ (6)

$$M = \frac{R_4}{R_4 + R_5} \qquad (7)$$

The transfer function reduces to

$$\frac{V_3}{V_1} = \frac{-\frac{a}{b}GB_2S}{S^2 + S\left(\frac{GB_1}{b}\right) + m.n.GB_1.GB_{2.}\left(\frac{b-a}{b}\right)} \qquad (8)$$

Which realizes an inverting band pass characteristics having?

$$\omega_o = \sqrt{\left[m.n.GB_{1.}GB_{2.}\left(\frac{b-a}{b}\right)\right]} (9)$$

$$Q = \sqrt{\left[m.n.\frac{GB_{2.}b(b-a)}{GB_1}\right]} (10)$$

$$K = |gain|\omega_o = a.\left(\frac{GB_2}{GB_1}\right) \qquad (11)$$

It is seen that the gain K can take any arbitrary value.

For a specified ω_o, Q and K, the design equations of the band pass filter are given by:

$$\frac{R_3}{R_1} = K.\frac{GB_1}{GB_2} \qquad (12)$$

$$\frac{R_2}{R_1} = \frac{R_5}{R_4} = Q.\frac{GB_1}{\omega_O} - \left(1 + K.\frac{GB_1}{GB_2}\right) \quad (13)$$

$$\frac{R_6}{R_7} = \frac{GB_2}{\omega_O Q} - 1 \quad (14)$$

Therefore resistor values were calculated using equations 12, 13 and 14 as follows;

$$\frac{R_3}{R_1} = K.\frac{GB_1}{GB_2} = 10 \ \rightarrow R_3 = 10R_1 \ \rightarrow 200 = 10R_1 : R_1 = \frac{200}{10} = 20\Omega$$

$$\frac{R_2}{R_1} = \frac{R_5}{R_4} = 5 \times \frac{60 \times 10^6}{11.4 \times 10^6} = (1 + 10 \times 1) = 26.30 \rightarrow R_2 = R_5 = 26.30 \times 20 = 526\Omega$$

$$\frac{R_6}{R_7} = 0.05 \quad let\ R_7 = 100\Omega \ \ \rightarrow R_6 = 5\Omega$$

$R_1 = R_4 = 20\Omega$
$R_2 = R_5 = 526\Omega$
$R_3 = 200\Omega$
$R_6 = 5\Omega$
$R_7 = 100\Omega$
Under the condition;$R_3 \gg R_1 R_4$

Table 1. Calculated and preferred resistor values

		Resistor Values(Ω)							Prefered Values		
s/n	Quality factor	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_2	R_3	R_5
1	5	20.00	526.00	200.00	200.00	526.00	5.00	100.00	526.30	1.50K	526.30

R_2 Can be tuned to realize the desired cut off frequency
R_7Can be tuned to realize the gain.

III. RESULT AND DISCUSSION

The CFOA Active-R Bandpass filter presented in Figure 3 was simulated and the Magnitude and Phase response curves obtained through Bode Plotter as presented in Figures 4 and 5which aided results to be read and recorded as presented in Table 2.

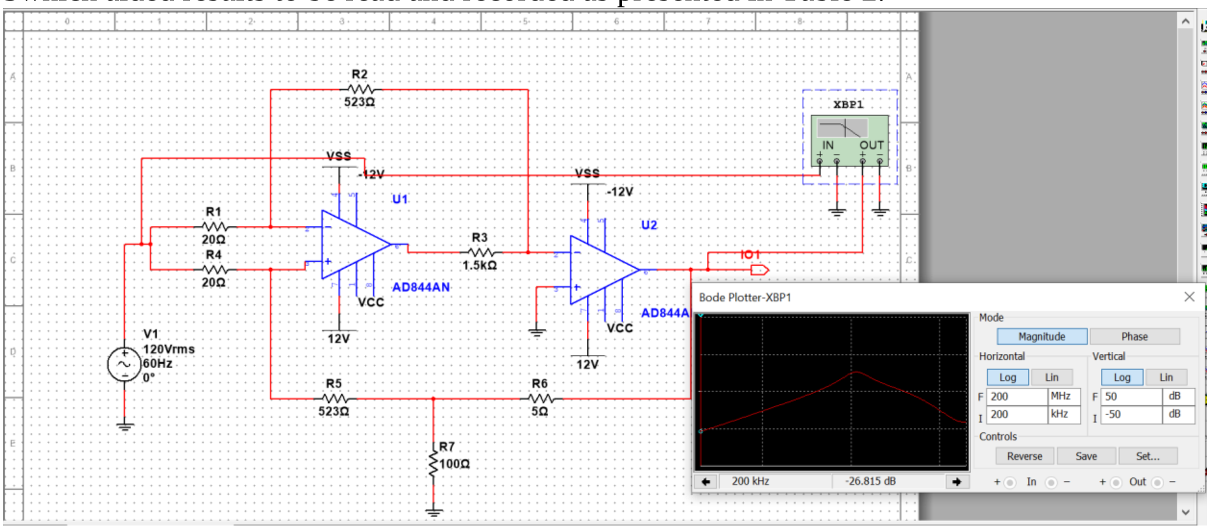

Figure 4. Shows Schematic Circuit Diagram of CFOA Active-R Bandpass Filter with its output

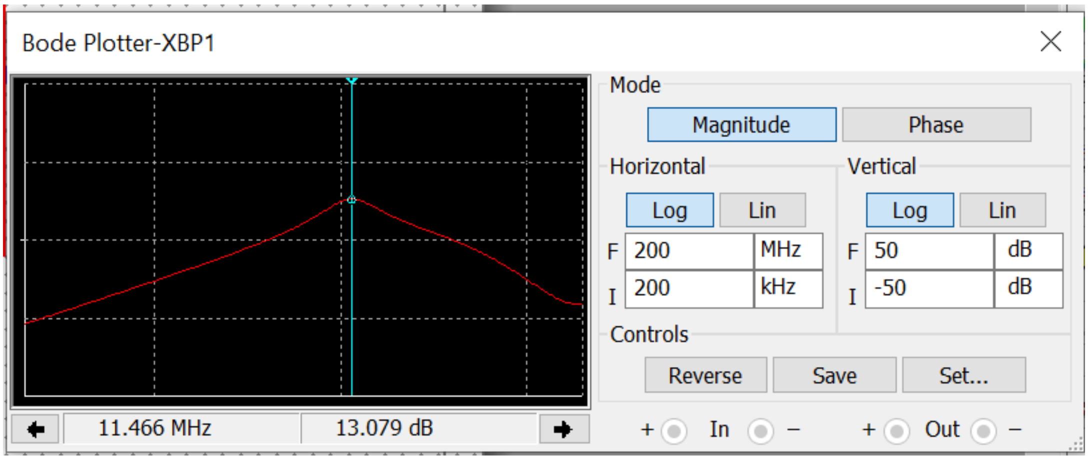

Figure 5. Shows Schematic Circuit Diagram of Response Curve

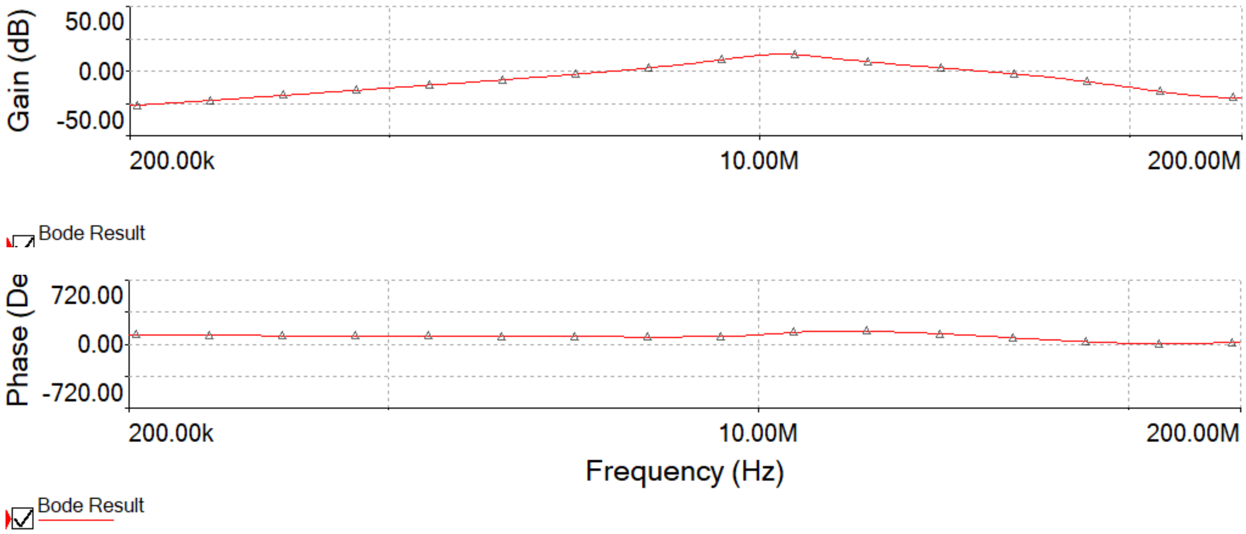

Figure 6. Magnitude and Phase Response of Second Order CFOA Bandpass filter

Table 2.Simulated Filter parameters of CFOA Active – R Bandpass Filter.

S/N	Quality factor	Centre freq. ω_o (MHz)	Mid band gain (dB)	-3dB Gain	Higher cut off frequency (MHz)	Lower cut off freq. (MHz)	Bandwidth (BW) (MHz)	Roll-off rate dB/ decade
1	5	11.466	13.079	10.079	15.70	8.66	7.04	-39.92

The magnitude and phase response curves of the simulated Second Order Active-R Bandpass Filter is presented in Figures 5 and 6,While measurement was carried out with the aid of Bode plotter in terms of filter parameters like centre Frequency ω_o, Midband gain G, - 3dB gain, Bandwidth (BW) and roll off rate (ROR) and result presented in Table 2. The result shows a centre frequency of 11.466 MHz and the Midband gain of 13.079dB. The filter recorded a Bandwidth of 7.04MHz and a roll-off rate of -39.92dB/decade which approached a second order double pole filter. Theoretically the second-order filter with double pole approaches -40dB/decade.

The above result is in agreement with the set specification with a slight variation which could be solved when proper tuning is carried out on the filter resistor R_2that controls the ω_o.

IV. CONCLUSION

The second order CFOA Active-R Bandpass filter was designed simulated and results presented. Results show good agreement with filter specification; therefore it can be used in the implementation in Aeronautical Mobile Communications system.

V. ACKNOWLEDGEMENT

I want to appreciate Assoc. **professor Joseph Mom** for putting me through some electrical theories when I needed it. Also to my mother Mrs **Esther KasevhembaAtsuwe** for her support during the period of research .Finally to my Lovely wife, Mrs AemberAtsuwe and Children;Nenguen, Mneuter, Nanenter and Kuranseter.

VI. DECLARATION OF INTEREST

I would like to state that there is no clash of interest from anywhere since this research is a privately sponsored one by one my humble self and family.

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