Deviation Tolerance Analysis For Backlink Frequency Of Eight-Order-R Bandpass Filter Using Biquadratic Topology UHF RFID System

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Abstract*—In this paper, the deviation tolerance for the backlink frequency of 320kHz and 640kHz for eighth-order Active-R bandpass Biquadratic filter to be used for UHF RFID Systems was investigated. The filter was designed with center frequencies of F_o=320 kHz and F_o=640 kHz at a quality factor of Q=30. The simulated response characteristics show that both filters have their midband gains decreasing with each section (stage), in the range of −0.191dB to −3.673dB for F_o=320 kHz while F_o=640 kHz had from −1.433dB to −8.820dB. The bandwidths also decreased monotonically from 8.820 kHz to 4.478 kHz at F_o=320 kHz and 16.206 kHz to 8.820 kHz at F_o=640 kHz. Results also showed that there was a very slight shift from the center frequency with deviation ranging from −0.938% to −1.116% at F_o=320 kHz and −0.969% to −0.936% at F_o=640 kHz. From the results, the filter frequency deviation is within that specified by EPC Standard of ±22%. Therefore, the filter can be used for UHFRFID Systems.

— *Keywords— Deviation, Tolerance, Backlink Frequency, Eight-Order, Active-R Filter, Bandpass, UHF, RFID*

I. INTRODUCTION

The radio frequency identification system (RFID) works by communication from a tag to a reader or vise-versa. These tags can be active or passive. The RFID reader, also known as an interrogator, has to defect a very small received signal strongly interfered by the signal it transmits to supply the tag with energy and that leaks into the receiver being several magnitudes stronger.

The RFID system is comprised of the following components [4]; one or more tags or transponders with uniqueidentification codes and a small antenna embedded within each tag. A reader orinterrogator with one or more antennas that are connected to a host computer through various kinds of interfaces.Application software on a host computer. A tag has an identification number (ID) and a reader recognizes an object through consecutive communications with the tag attached to it. The reader sends out signal which supplies power and instructions to a tag. The tag transmits its ID to the reader and the reader consults an external data base with received ID to recognize the object [1-3]

A filter is defined as a network which passes a certain portion of a frequency spectrum and blocks the remaining portion of the spectrum [6]. By "Blocking", we mean the magnitude response ($|H(Jw)|$) of the filter is approximately zero for that frequency-seductive device or system.

Filters are divided into two types according to circuit components viz: Passive and Active filters. A passive filter is simply a filter that uses no amplifying elements (transistors, operational amplifiers, etc). Since there are no active components, passive filters require no power suppliers. Active filters use amplifying elements especially operational amplifiers (Op. amps) with resistors and capacitors in their feedback loops to synthesis the desired filter characteristics [2, 7]. According to frequency response, filters are divided into five classes as: Low pass filters which passes all signals that are less than or equal to the cut-off frequency while eliminating signals that are above the cut-off frequency (fc). High pass filters which pass all signals that are greater than the cut-off frequency while eliminating signals that are less than the cut-off frequency (fc). Band pass filters are characterized by both the high pass response and low-pass response. Band-stop filters pass all the signals that are outside the frequency range, while eliminating those that are within the frequency range. It is the direct opposite of a band pass filter. All pass filters pass all signal responses with unchanged magnitude, only the phase's change. Active band pass filters are used for the RFID system reader to reject all signals outside the ultra-high frequency (UHF) signals (40 kHz-640 kHz) and to amplify the low antenna signal.

RFID systems operate in three frequency bands: in the low-frequency (LF) domain at around 125 kHz, in the high-frequency (HF) domain at 13.56 mHz and in the ultrahigh-frequency (UHF) domain at 870-960 and 2.4 GHz [2]. The passive RFID tags apply backscatter modulation for communication. The signals defined by the EPC standards for UHF use either the FMO or the miller coding. Theses involve modulating a subcarrier by means of inverting its phase. The Frequency of this subcarrier is called backscatter link frequency (BLF). The EPC standard for UHF determines that the BLF that the tags use is freely chosen by the RFID reader in the range from 40 kHz to 640 kHz and transmitted to the rag at the beginning of the communication. The UHF standard determines the BLF deviation allowed for the received signal over the indicated by the RFID reader. This deviation can be up to ± 22% on average.

Therefore, taking into account the wide range of link frequencies that the EPC for UHF RFID allow to use, it is necessary to develop a filter whose bandwidth is tight a possible to the spectral width of the received RFID signal. In addition, the EPC standards for UHF permits a frequency tolerance that depends on the link frequency requested by the transmitter. These values are listed in the table 6.9 of the EPC standard for UHF. This table shows that the allowed tolerance is assigned by frequency interval especially for BLF 640 kHz and 320 kHz. The link deviation tolerance allowed is more restricted. Therefore, it is meaningful that the filter is equipped with filter optimized to these concrete frequencies [2].

Recently, compensated operational amplifiers (op. amps) have been made available where the Gain bandwidth product (GBW) varied and kept within a right tolerance, one could utilize this parameter to obtain tightly controllable frequency variation in the filter without using capacitors, hence the active-R configuration. In a high-order filter design, usually multiple-loop feedback techniques are used. Therefore, there are several configurations that can be chosen as active blocks (blocks with second-order voltage gain transfer function). In choosing an active block, one important consideration is low sensitivity. An attractive configuration from the cost and sensitivity point of view is the [5] configuration. This configuration can be used as cascade to achieve low sensitivity and high order. This infirmed the choice of biquadratic topology to be used to achieve a tightly controllable frequency to match the BLF deviation tolerance allowed for 320 kHz and 640 kHz as specified in the EPC standard class 1 generation 2 for UHF RFID systems.

This paper investigates the Eighth-order active-R Bandpass filter using Biquadratic topology at centre frequencies of 320 kHz and 640 kHz at a quality factor of Q=30 using multisim work bench version 11.0 software.This also studies the frequency at which it functions so as to ascertain that it meets the deviation tolerance specified in the EPC standards at the said frequencies.

II. METHODS

A. *Design Specification*

The architecture that has been used to implement the eighth-order bandpass filter is the biquadratic topology because of its advantages of in terms of mid-frequency stability, high-Q factor, independent gain and Q values and high-roll-off. The second-order Bandpass filter is shown in Figure 1. Table 1 illustrates specifications for the desired bandpass filter. By using the following filter parameters, the required filter can be designed and simulated with MULTISIM work bench version 11.0.

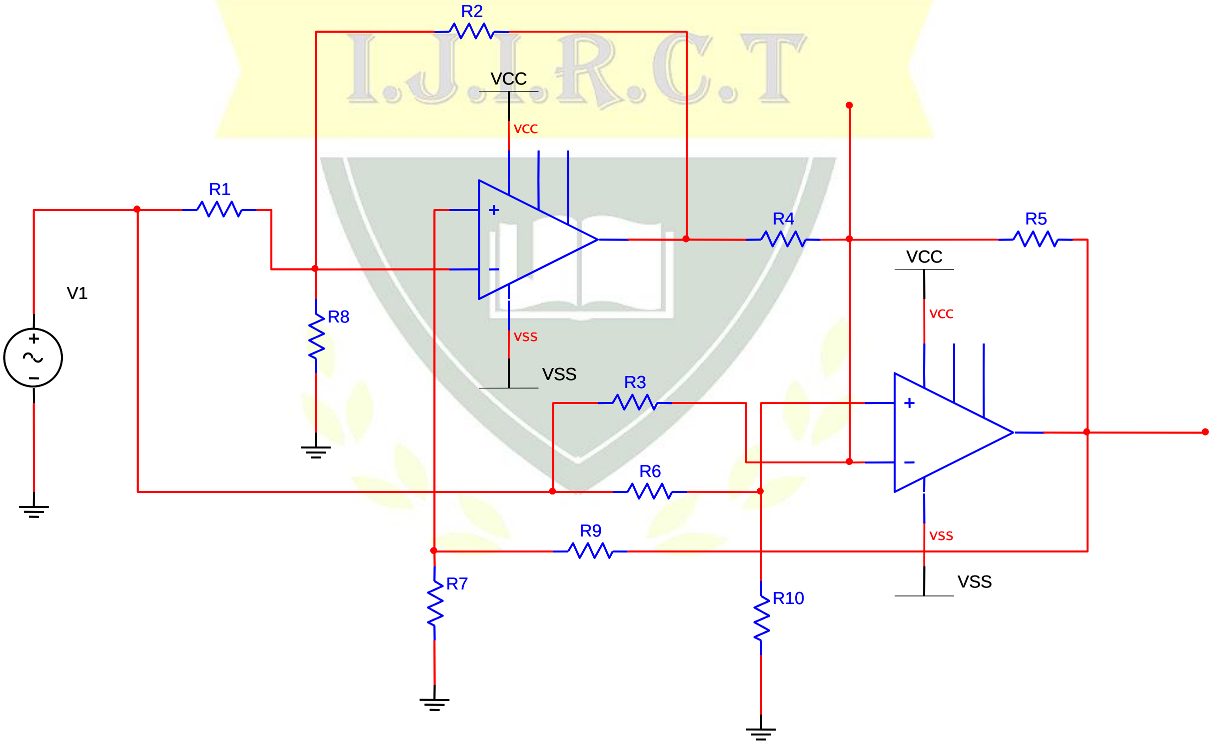

Fig. 1. Second-order Active Biquadratic Filter.

B. *Design Implementation*

Fig. 1 shows the second-order Band pass R-filter used in this work to design eight-order Band pass configuration presented by Hyong, K.K, Ra, J.B. (1977) has a voltage transfer function;

$$\frac{V_2}{V_1}=\frac{(\alpha-\beta)s+(\gamma-\delta)}{s^2+(\omega_1+\omega_2)s+(1+K)\omega_1\omega_2} \qquad (1)$$

The band-pass function is obtained with γ= δ, giving the transfer function from equation 1 to be

$$\frac{V_2}{V_1}=\frac{(\alpha-\beta)s}{s^2+(\omega_1+\omega_2)s+(1+K)\omega_1\omega_2} \qquad (2)$$

Where; S=Jω (3)

and the transmission parameters of the filter are given as;

$$\alpha = \frac{R_{6b}}{R_{6a}+R_{6b}}\left(1+\frac{R_5}{R_4}+\frac{R_5}{R_3}\right)\omega_2 \qquad 4$$

$$\beta = \frac{R_5}{R_3}\omega_2 \qquad (5)$$

$$2\omega_1 = \frac{\omega_Q}{\omega_p} = 2\omega_2 \qquad (6)$$

$$\omega_p = \text{pole frequency} = \sqrt{(1+k)\omega_1\omega_2} \qquad (7)$$

$$Q_p = \text{pole quality} = \frac{\sqrt{(1+k)\omega_1\omega_2}}{\omega_1+\omega_2} \qquad (8)$$

$$\omega_1 = frquency\ of\ first\ op - amp$$

$$\omega_2 = frquency\ of\ second\ op - amp$$

The alternator, k of the filter is given as;

$$k = \left(1+\frac{R_2}{R_{1a}//R_{1b}}\right)\frac{R_5}{R_4}\frac{R_{7b}}{R_{7a}+R_{7b}} \qquad 9$$

The Gain (G) of the filter is;

$$Gain\ (G) = \frac{\alpha-\beta}{\omega_1+\omega_2} \qquad (10)$$

For convenience, he assumed $\omega_1 = \omega_2$ in the equation

$$\omega_1 = GB_1/\left(1+\frac{R_2}{R_{1a}//R_{1b}}\right) \qquad (11)$$

$$\omega_2 = GB_2/\left(1+\frac{R_5}{R_4}+\frac{R_5}{R_3}\right) \qquad (12)$$

And then identify equation 6 together with equation 11 for ω_1 yields;

$$1+\frac{R_2}{R_{1a}//R_{1b}} = \frac{2\omega_Q}{\omega_p} = 2GB_2 \qquad (13)$$

Where the values of the resistors are determined by ratios. Similarly, using equation 12 for equation 6 for ω_2, then substituting

$$1+\frac{R_5}{R_4}+\frac{R_5}{R_3} = 2\frac{Q_p}{\omega_p} = GB_2 \qquad (14)$$

and using $\omega_p^2 = (1+k)\omega_1\omega_2$, we express resistance ratios as;

$$\frac{R_2}{R_{1a}//R_{1b}} = \frac{2\omega_Q}{\omega_p}GB_2 - 1 \qquad (15)$$

$$\frac{R_5}{R_3} = \eta\frac{2\omega_Q}{\omega_p}GB_2 \qquad (16)$$

$$\frac{R_5}{R_4} = (1-\eta)\frac{2\omega_Q}{\omega_p}GB_2 - 1 \qquad (17)$$

And

$$\frac{R_{7b}}{R_{7a}+R_{7b}} = \frac{2Q_p\frac{\omega_p}{GB_1}\left(1-\frac{1}{Q_p^2}\right)}{(1-\eta)\frac{2Q_2}{\omega_p}GB_2-1} \qquad (18)$$

Using $\gamma = \frac{R_2R_5}{R_{1a}R_4}\omega_1\omega_2$, $\delta = (\beta-\alpha)\omega_1$ together with equation 4 and 5, we have;

$$\frac{R_{6a}}{R_{6b}} = \frac{1+2\frac{R_5}{R_3}+\frac{R_5}{R_4}\left(1+\frac{R_2}{R_{1a}}\right)}{\frac{R_5}{R_4}\frac{R_2}{R_{1a}}-\frac{R_5}{R_3}} \qquad (19)$$

$$R_{1a} \geq \frac{R_2R_3}{R_4} \qquad (20)$$

Where $0<\eta<1$ (21)

Given the pole parameters and the Gain Bandwidth product of the operational amplifiers GB_1 and GB_2 we determine the resistance ratios from the equations above for a chosen η. For $4Q^2>>1$, it can be seen from equation 18 that the tuning of the pole frequency (ω_p) is attainable by R_{7b}/R_{7a}, while the pole frequency (Q_p) is tuned by R_4.

First, we considered the design of second-order active-R bandpass filter (stage 1) with resonant frequency (ω_p) of 320 kHz and Q=30. $GB_1=GB_2=10\times10^6$Hz. Choosing R_{1a}=1.0MΩ, R_2=40 kΩ from equation 15 we have R_{1b}=21.33Ω. From equation 16 choose η=0.1 and taking the value of R_5=40 kΩ, yield R_4=23.72Ω. Also from equation 17, R_5=40 kΩ, R_4=21.10Ω. From equation 19, the ratio of the resistors R_{6a}=320 kΩ, R_{6b}= 14.62Ω. Finally, using equation 18, the ratios are R_{7a}=1.69 MΩand R_{1b}=1.92 kΩ. The same process was repeated for F_o= 640 kHz at a quality factor of Q=30 and the results presented in Table 1.The value of the filter Gain calculated from equation 10 is -0.191 dB for the second-order and -3.673 dB for the Eighth-order. All calculated resistor values are presented in Table 1. The eighth-order active-R bandpass filter was then realized from the cascade of four of the second-order stages as shown in Figure 2.The deviations in the centre frequencies at F_o=320 and F_o= 640 at a constant Q=30 were calculated together with their percentage tolerance and recorded as shown in Tables 2 and 3 respectively.

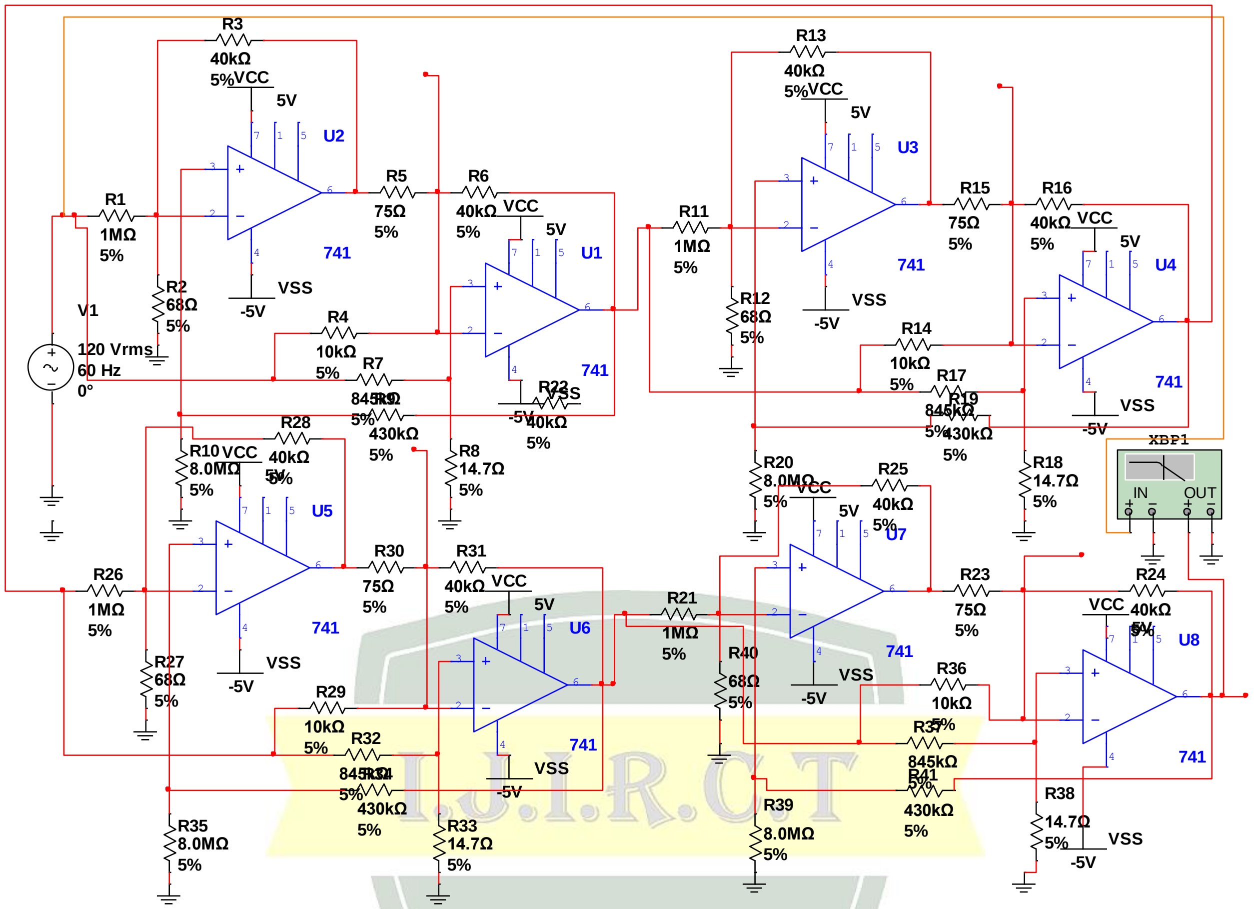

Fig. 2. Eighth-order Active-R Biquadratic filter.

TABLE I. RESISTOR VALUES FOR EIGHTH-ORDER ACTIVE- R BAND PASS BIQUAD FILTER NETWORK AT Q=30

			Calculated Resistor Values										Experimental Resistor Values									
S/N	FLF (MHz)	BLF (KHz)	$R_{1a}(\Omega)$	$R_{1b}(\Omega)$	$R_2(\Omega)$	$R_3(\Omega)$	$R_4(\Omega)$	$R_5(\Omega)$	$R_{6a}(\Omega)$	$R_{6b}(\Omega)$	$R_{7a}(\Omega)$	$R_{7b}(\Omega)$	$R_{1a}(\Omega)$	$R_{1b}(\Omega)$	$R_2(\Omega)$	$R_3(\Omega)$	$R_4(\Omega)$	$R_5(\Omega)$	$R_{6a}(\Omega)$	$R_{6b}(\Omega)$	$R_{7a}(\Omega)$	$R_{7b}(\Omega)$
1	920	320	1.00M	21.33	40k	213.33	18.97	40k	320k	14.62	1.69M	959.62	1.00M	21.50	40k	10k	23.70	40k	324k	14.70	13.5k	1.60k
2	940	640	1.00M	42.67	40k	426.67	23.72	40k	640k	14.62	845k	1.54k	1.00M	43.00	40k	10k	47.50	40k	649k	14.70	13.5k	10k

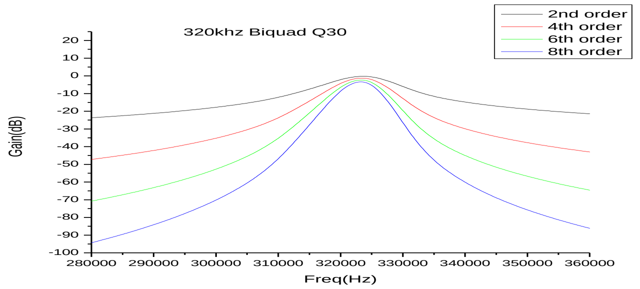

Fig. 3. Simulated Results of Magnitude Response of Eighth-Order Active-R Bandpass Filter at F_o=320 kHz and Q=30.

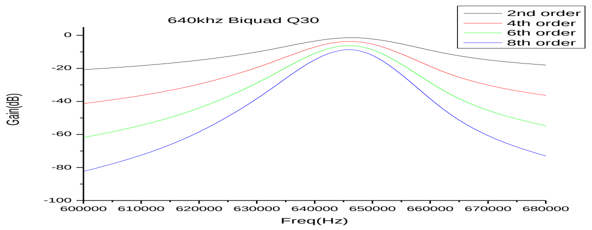

Fig. 4. Simulated Results of magnitude response of Eighth-Order Active-R Bandpass Filter at F_o=640 kHz and Q=30.

TABLE II. DEVIATION TOLERANCE FREQUENCY FOR F_0=320 KHZ

Stage	**Centre freq shift (kHz)**	**% shift of Centre freq. (F_o)**	**Bandwidth (kHz)**	**Midband Gain (dB)**
1	323.571	−1.116	8.743	−0.191
2	323.607	−1.127	7.463	−1.352
3	323.003	−0.938	5.971	−2.512
4	323.216	−1.005	4.478	−3.673

TABLE III. DEVIATION TOLERANCE FREQUENCY FOR F_o=640 KHZ

Stage	**Centre freq. shift (kHz)**	**% shift of centre freq. (F_o)**	**Bandwidth (kHz)**	**Midband gain (dB)**
1	646.202	−0.969	16.206	−1.423
2	646.202	−0.969	11.947	−4.003
3	646.202	−0.969	10.022	−6.584
4	645.989	−0.936	8.316	−8.820

III. RESULTS AND DISCUSSION

Figure 3 shows the magnitude versus frequency response plot obtained from the output of the four cascading sections (i.e. stage 1,2,3 and 4) for the eighth-order active-R bandpass filter using Biquadratic topology at Quality factor (Q)=30. The plot shows a gradual decrease of the mid-band gain from stage 1 with a value of −0.191dB, stage 2 has −1.352dB, stage 3: −2.511dB and the last stage 4: −3.673dB. Also the plot shows that bandwidth decreases from stage 1(8.743 kHz), stage 2 (7.463 kHz), stage 3 (5.971 kHz) and stage 4 (4.478 kHz). The filter at this quality factor of Q=30 and centre frequency F_o=320 kHz has its centre frequency shifted a little to the right at the various stages from 1 to 4 (Table2). Stage 1 (323.471 kHz), stage 2 (323.607 kHz), stage 3 (323.003 kHz), and stage 4 (323.216 kHz). More so, the frequency deviation at the stages in percentage are: stage (−1.116%), stage 2 (−1.127%), stage 3 (−0.938%), and stage 4 (−1.005%). From the results, (Table 2) it is observed that the frequency deviation tolerance is very low and nearly negligible since the frequency deviation tolerance allowed by the EPC standard is ± 22%. The filter therefore is deemed to meet its specification. However, the deviation experienced by the filter at this centre frequency of 320 kHz is suspected to be as a result of parasitic effect.

Figure 4 shows the magnitude versus frequency response plot obtained from the output of the four cascading sections (stage 1,2,3 and 4) of the Eighth-order active-R bandpass filter with Q=30 and centre frequency F_o=640 kHz. The plot shows a gradual decrease in the midband gain and bandwidth of the filter network obtained from the output of the first cascading section (stage 1) to the fourth section (stage 4). From the results presented in Table 3, it seems each cascading section is providing the same percentage deviation of the centre frequency (−0.969%) up until the fourth section (stage 4) which increased to (−0.936%). From the results presented (Table 3), it is clearly observed that the centre frequency deviation is about −0.969% and −0.936% within the range of the allowed tolerance frequency for UHF RFIDs. Therefore the filter performs to specification.

The results presented in Tables 2 and 3 show that the Biquadratic filter at a centre frequency of 640 kHz has a tighter frequency compared to F_o=320 kHz. But they all conform to the EPC standards for UHF RFIDs and therefore perform according to the specification. However, the little shift experienced could be as a result of approximated values of the resistors used in the designs (Attri 2005). The restriction to the commonly available resistor informed these approximations.

CONCLUSION

We have successfully designed and investigated the deviation tolerance frequency for the Eighth-order active-R Bandpass filter using Biquadratic topology at centre frequencies F_o=320 kHz and F_o=640 kHz. We observed that both centre frequencies maintained a deviation tolerance of −1.005% and −0.936% respectively which is very low compared to the ±22% set by the EPC standard.

We also observed that they have tight bandwidth even though the midband gain is low. More so they can be used for higher-order filter networks. The Biquadratic topology is designed to meet the standard for the UHF RFID systems since they conform to the EPC standard class 1 Generation 2 protocol 4 UHF RFID systems.

REFERENCES

[1] Abdul, H.A.Z.A. (2014). Design and Simulation of 4th Order Active Band-pass Filter using Multiple Feedback and Sallen-key Topologies.Journal of Babylon University/Engineering Sciences.22(2).235-346.

[2] Carlos,F.C. (2009). Development of Receiver Algorithms for Radio Frequency Identification (RFID).Diploma thesis.Institute of communications and Radio Frequency Engineering, Vienna, Austria 95pp.

[3] EPC Global Class-1 Generation-2 UHF RFID Protocol For Communications at 860MHz to 960MHz Version 1.0.9 2004.

[4] Farunak, N. and Farid, D. (2011). Ultra-Wide Band Radio Frequency Identification Systems. Springer Science and Business Media, LLC. 26(4).338-345.

[5] Hyong, K.K., Ra, J.B. (1977). An Active Biquadratic Building Block without External capacitors. IEEE Transaction on Circuits and systems. 24(12):689-694.

[6] Igwue, G.A. (2007). Basic Circuit Theory and Industrial Electronics for Physicist, Aboki Publishers, Makurdi, Nigeria.1.P.35.

[7] Kugelstadt, T. (2008). Active Filter Design Technologies, Texas Instruments Publishers, Dallas, USA.