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Designing Tunable Narrowband Bandpass Filter Utilizing Neural Network And Converting It To Wideband Filter

[1]A. Alahyari, [2]M. Shahrjerdi, [3]A. Habibzadeh, [4]M. Dousti

[1]Islamic Azad University Broujerd Branch, Broujerd Iran.
[2]Islamic Azad University Arak Branch, Arak Iran.
[3]Islamic Azad University- Hashtgerd Branch, Karaj, Iran.
[4]Dept. of Electrical Engineering, Science and Research branch, Islamic Azad University, Tehran, Iran.

Abstract: In this study we aim at adjusting the singleband and dualband bandpass filter designed in a ED02AH technology. The quality factor and center frequency of the filter will change by varactor diodes. Here, we use a neural network to acquire the proper biasing voltages of varactor diodes in order to obtain specific gain and quality factor. Moreover, using the filter structure and only one varactor diode, we achieved wideband bandpass filter. Amplitude and bandwidth of the filter could be tuned by a change in the biasing voltage of varactor diode.

Key words: *ultra wideband, neural network, ED02AH.*

INTRODUCTION

Ultra-wideband (UWB) communications technology provides a practical means of low-power, high-data-rate transmissions over short distances, such as in personal-area networks (PAN). The technology is also suitable for longer-range applications, such as radar systems. High-performance filters with adequate bandwidths are essential in order for UWB systems to co-exist with current wireless communications systems. The design of such filters is not trivial, although a number of approaches have been developed. For example Two types of suspended strip line ultra-wideband bandpass filters are described in Menzel *et.al.,* (2005), one based on a standard lumped element (L-C) filter concept including transmission zeroes to improve the upper passband slope, and a second one consisting of the combination of a low-pass and a high-pass filter. Another approach is the design utilized embedding individually designed highpass structures and lowpass filters (LPF) into each other, followed by an optimization for tuning in-band performance, Luh Hsu *et. al.,* (2005). In this study, we applied neural network to adjust the gain and quality factor of narrowband filter, because of its ability to represent RF and microwave component behaviors. Once trained to model the electrical behavior of passive and active components/circuits (Fang *et. al.,* 2000; Xu *et. al.,* 2002. They often referred to as neural-network models, can then be used in high-level simulation and design, providing fast answers to the task they have learned Gupta, 1998; Devabhaktuni *et al*., 2001). Moreover, they are efficient alternatives to conventional methods such as numerical modeling methods, which could be computationally expensive, or analytical methods, which could be difficult to obtain for new devices, or empirical models. This paper organized as follows:

First, we adjust the two-stage bandpass filter. Then training of neural network will be discussed in section III. Afterwards, tuning the dual band bandpass filter using desired neural network will be addressed in section IV. Finally, we will explain how to realize a dual band bandpass filter by using only one varactor diode.

Tuning Two-Stage Bandpass Filter By Neural Network:

Alternatively, a narrowband BPF can be constructed by two low-pass filters in a negative feedback loop (Alahyari *et al*., 2011). The overall structure of a two-stage dualband filter is shown in Fig.1a. It is important to notice that, in a single band filter there are only two varactor diodes in the second stage (V_{a2} and V_{f2}) whose biasing voltages can control the center frequency as well as quality factor. Frequency displacement is illustrated in Fig.1b. It is prominent that the gain is constant

In this section we consider the center frequency, quality factor, and desired gain as the neural network inputs. The network output specifies the voltages that are appropriate to adjust above parameters. The structure of neural network includes three inputs and two outputs. F_0 , Q, and A, are perceived as inputs. Network outputs are V_a and V_f such that the center frequency and quality factor can be controlled simultaneously using them (Fig.2).

Corresponding Author: A. Alahyari, Islamic Azad University Broujerd Branch, Broujerd Iran.

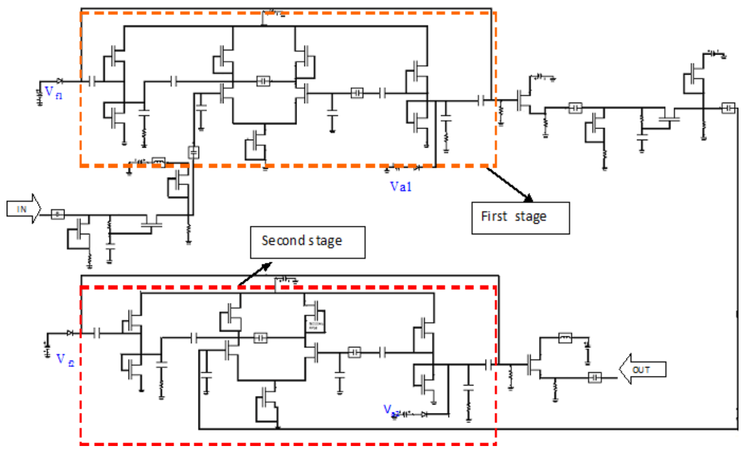

Fig. 1a: The circuit of dual band bandpass filter.

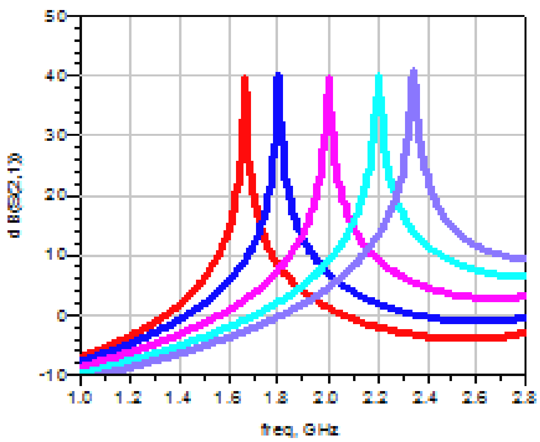

Fig. 1b: Frequency displacement in Two-stage filter.

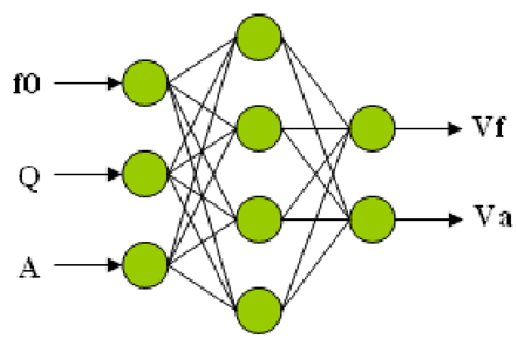

Fig. 2: Neural Network structure.

Network Training:

Several samples (from circuit of the filter) are obtained by ADS software in order to design and train the neural network. In fact, These samples are the values of center frequencies and quality factors and gain as a function of V_a and V_f. That means, we applied V_f and V_a (the number of voltages is the number of samples used to neural network training) to the circuit and we measured the center frequency and quality factor generated by the filter. This sample is used to neural network training via levenberg marquardt algorithm. Three layers of the network includes; sigmoid function in the first and second layer and hyperbolic tangent in the third layer. After training the' b 'and 'w' factors will be determined using levenberg marquardt algorithm.

In order to verify the network performance, some data is applied as a test data. We choose ten numbers of V_f and V_a as a real values to design the specified filter. The data in the First group in Table. 1 shows them. Then, we applied these random data to ADS and new values for center frequency, quality factor, and gain are achieved (second group). These values are different from those which are utilize to network training.

Now in order to test a network, the value of center frequencies and quality factors obtained in previous step are entered as inputs. The output of this network determines the V_f and V_a (third group) and verifies that they are close to the first group. The diagrams of V_f and V_a as a result of ten samples of center frequency and quality factor are illustrated in Fig. 3a and Fig. 3b.

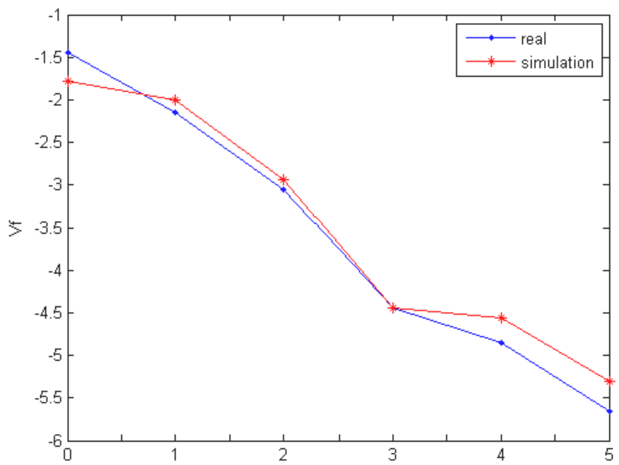

Fig. 3a: Compassion diagram of real V_f and network output V_f.

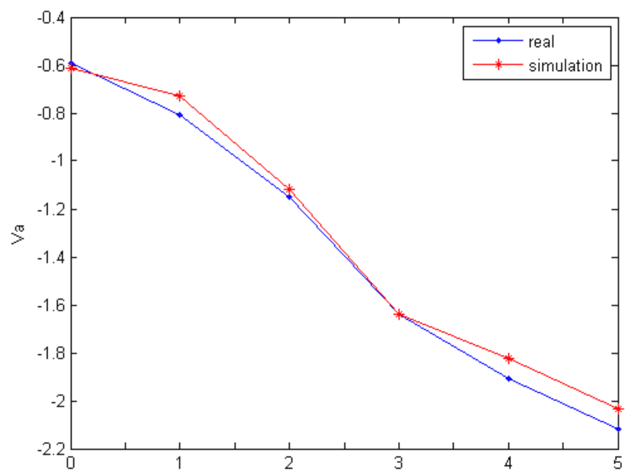

Fig. 3b: Compassion diagram of real V_a and network output V_a.

Table. 1: Real data and obtained data from neural network

First group		Second group			Third group		Fourth group		
V_f	V_a	f_0	Q	A	V_f	V_a	f_0	Q	A
-1.45	-0.59	2.09	70	38.95	-1.7844	-0.6129	2.11	75	44.74
-2.15	-0.81	2.145	72	41.73	-2.0032	-0.7302	2.13	72	43.67
-3.05	-1.15	2.206	75	40.30	-2.9437	-1.1180	2.22	78	41.6
-4.45	-1.64	2.280	72	41.21	-4.4487	-1.6409	2.28	70	41.29
-4.85	-1.91	2.300	70	39.60	-4.5587	-1.8248	2.29	68	38.75
-5.65	-2.12	2.325	70	40.30	-5.3071	-2.0343	2.32	72	41.12

As a case of comparison, we apply one real voltage (first group) and obtained voltage from neural network (third group) to desired filter. Simulation results depict that two filters are similar to each other (Fig. 4).

Line color	V_f	V_a	f_0	Q	A
	-3.05	-1.15	2.206	75	40.30
	-2.9437	-1.1180	2.22	78	41.6

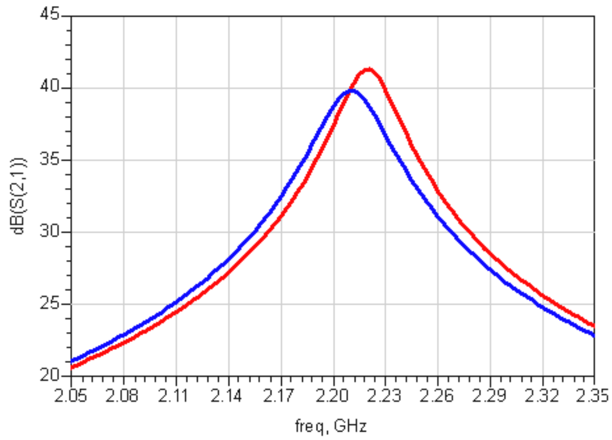

Fig. 4 : Compassion result of a real filter and its counterpart achieved by neural network

Tuning Two-Stage Dual Band Bandpass Filter By Neural Network:

The structure of a dualband bandpass filter is introduced in section II (see Fig.1). It includes two varactor diodes in the first and second stage respectively. As mentioned in section II, biasing voltages variation is applied to adjust f_0 and Q. Frequency displacement is depicted in Fig.5

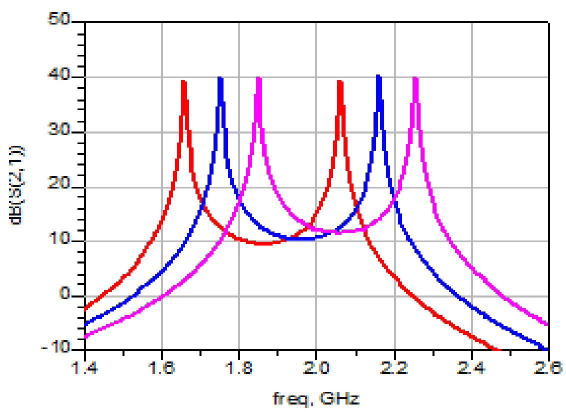

Fig. 5 : Frequency displacement in dual band bandpass filter.

Since each stage works separately and biasing voltage variation in one stage does not affect on the second, the neural network for each stage is designed independently. Similar structure is employed as discussed in two-stage filter. In this case, we train the neural network using achieved samples from ADS and finally we will test the network with seven new data. Fig.6a and Fig.6b show the behavior of the first stage dual band filter. Values of V_a and V_f from network output; seven samples of center frequency, quality factor and gain used as testing input; are compared with real V_a and V_f.

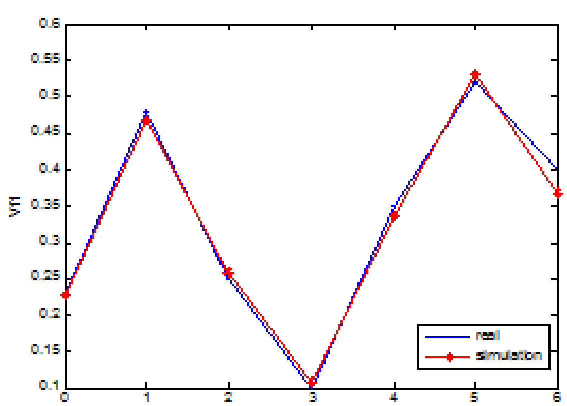

Fig. 6a: Diagram of V_{f1} of the first stage dual band filter.

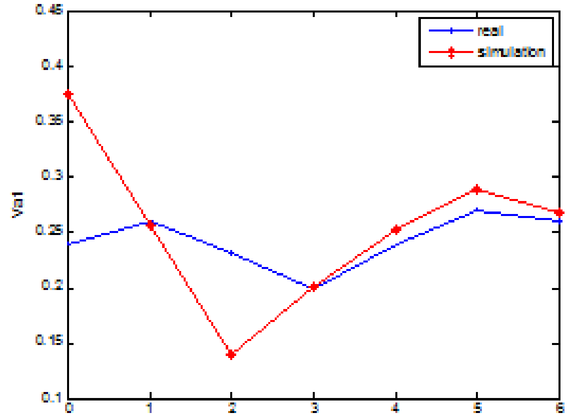

Fig. 6b: Diagram of V_{a1} of the first stage dual band filter.

Table.2: Real data and obtained data from neural network.

First group		Second group			Third group			Fourth group	
V_{f1}	V_{a1}	f_1	Q_1	A_1	V_{f1}	V_{a1}	f_1	Q_1	A_1
0.23	0.24	1.780	95	50.19	0.2258	0.3757	1.755	60	28.95
0.48	0.26	1.7	85	40.00	0.4687	0.2563	1.69	80	42.00
0.25	0.23	1.775	80	44.24	0.2585	0.1391	1.795	65	33.45
0.10	0.20	1.820	90	63.41	0.1073	0.2003	1.820	90	63.56
0.35	0.24	1.745	85	42.06	0.3358	0.2529	1.750	90	46.38
0.52	0.27	1.665	80	41.12	0.5308	0.2885	1.675	80	39.96
0.40	0.26	1.720	90	45.31	0.3686	0.2688	1.735	110	54.40

The same test method is exerted on the second stage of a dualband filter. Fig.7a and 7b illustrate the comparison results.

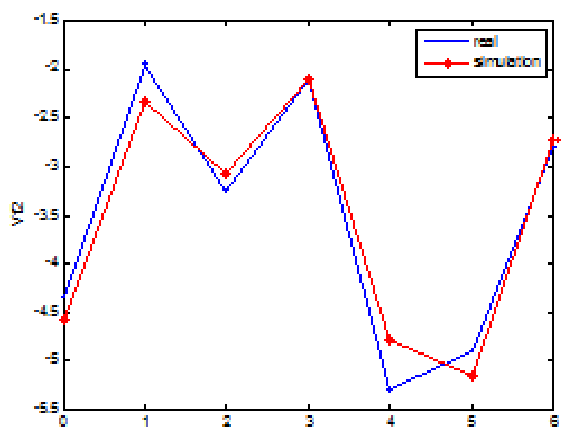

Fig. 7a: Diagram of Vf2 of the second stage dual band filter.

In the following of this study, two samples of both Table 2 and Table 3 are applied to the filter. One real voltage value (first group) and one value obtained from neural network (third group). As Fig. 8a and Fig. 8b imply, the diagrams are adjacent to each other.

	Va1	Vf1	Va2	Vf2
Real value (blue)	0.26	0.48	-0.52	-1.95
Network output (red)	0.2563	0.4687	-0.58	-2.34

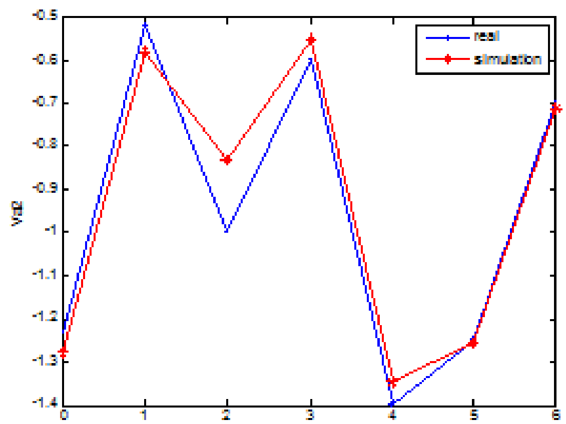

Fig. 7b: Diagram of Va2 of the second stage dual band filter.

Table 3: Real value and neural network output value.

First group		Second group			Third group		Fourth group		
V_{f2}	V_{a2}	f_2	Q_2	A_2	V_{f2}	V_{a2}	f_2	Q_2	A_2
-4.35	-1.23	2.21	60	32.02	-4.5737	-1.2786	2.215	65	32.30
-1.95	-0.52	2.095	90	49.80	-2.3407	-0.5803	2.075	110	47.50
-3.25	1.0	2.145	110	54.23	-3.0726	-0.8318	2.145	85	42.60
-2.10	-0.60	2.09	85	43.33	-2.0864	-0.5517	2.085	85	45.95
-5.30	-1.40	2.23	85	43.90	-4.7897	-1.3455	2.225	65	33.20
-4.90	-1.25	2.22	75	39.22	-5.1536	-1.2578	2.225	75	38.88
-2.80	-0.70	2.125	85	44.01	-2.7244	-0.7112	2.120	85	42.34

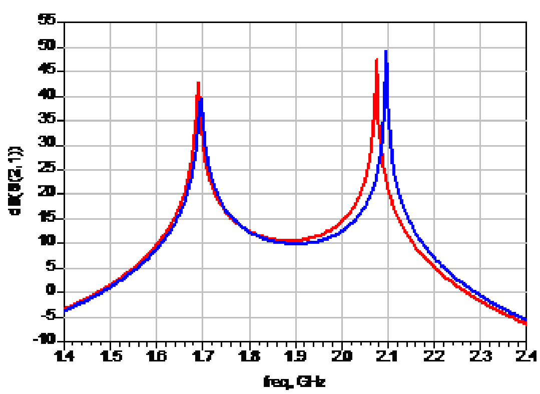

Fig. 8a: Comparison of real filter and obtained filter from neural network (data of Table 2).

	Va1	Vf1	Va2	Vf2
Real value (blue)	0.27	0.52	-1.25	-4.90
Network output (red)	0.2885	0.5308	-1.2578	-5.1536

Wideband Bandpass Filter:

Referring to the dual band bandpass filter, we can realize wideband bandpass filter by removing 3 varactor diodes and only using one varactor diode in the first stage with biasing voltage Vf1 (Fig.1). The scattering parameter of wideband filter is shown in Fig.9a. Bandwidth and Noise figure are 2GHz and 5 respectively. Vf1 responsible to qualify the bandwidth and gain of the filter (Table.4). Also Gain and bandwidth variations are shown in Fig. 9b. Scattering parameters, S11 and S22, are shown in Fig.10a and Fig.10b.

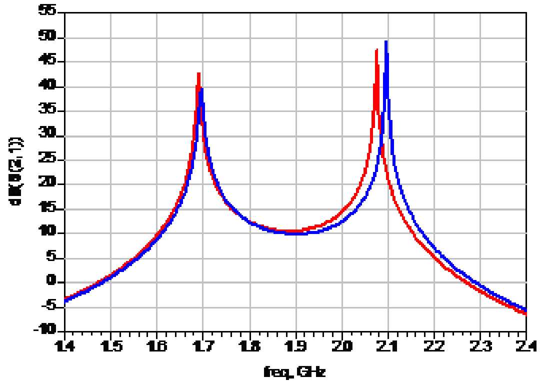

Fig. 8b: Comparison of real filter and obtained filter from neural network(data of Table 3).

Table 4: Controlling Bandwidth and Gain by Vf.

Vf(volt)	B.W(GHz)	A(dB)
-1.13	3.5	10
0.00	2.1	20
1.13	1.9	22
2.26	1.8	23
3.39	1.7	24
4.52	1.6	25
5.65	1.5	25
6.78	1.4	26

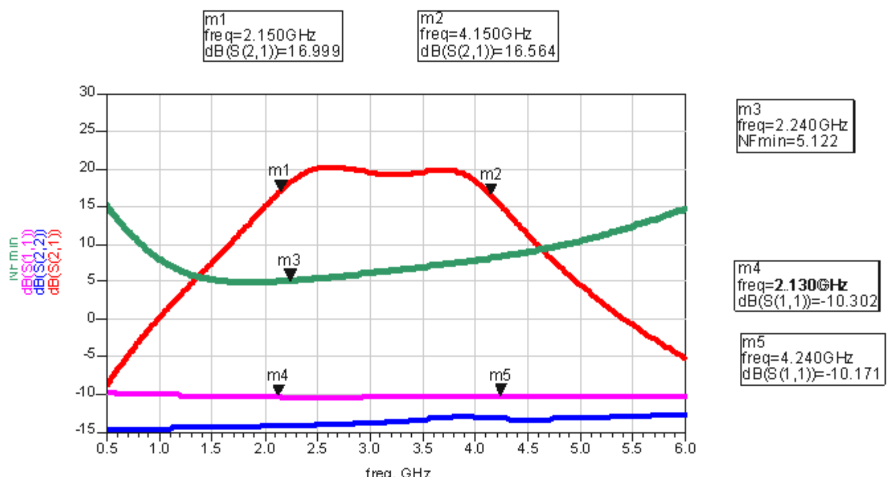

Fig. 9a: Wideband filter of 2GHz bandwidth.

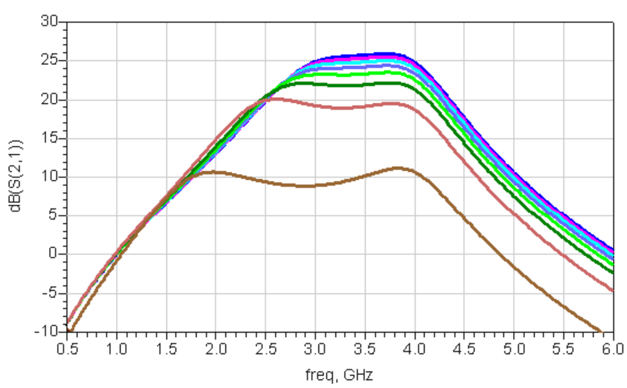

Fig. 9 b: Variation of bandwidth and gain of wideband filter.

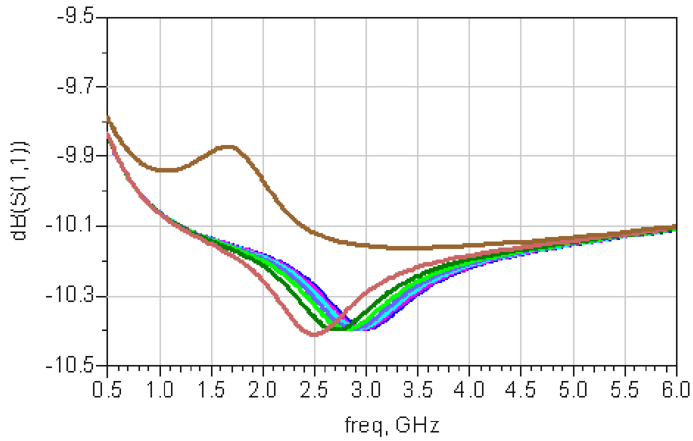

Fig. 10a: Input impedance matching of wideband filter.

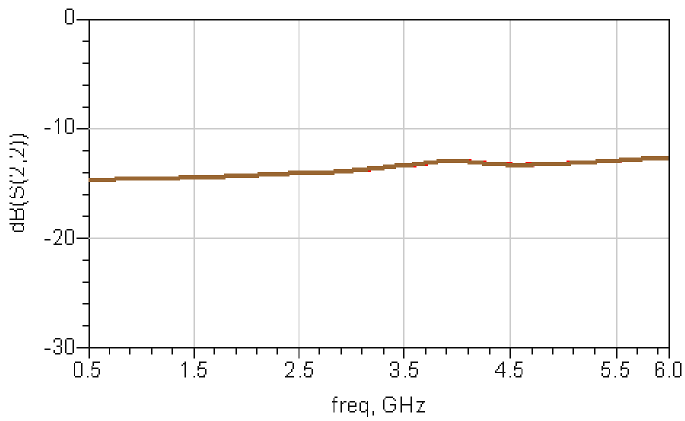

Fig. 10 b: Output impedance matching of wideband filter.

Conclusion:

As depicted in this study, we could control the center frequency in addition to quality factor using varactor diode biasing voltages. The filter behaviour obtained from neural network output is very similar to a real filter. In further works, we can do similar estimation utilizing fuzzy systems and comparing the results with neural network. Also using one varactor diode and changing the biasing voltage of it, bandwidth and amplitude of wideband bandpass filter can be adjusted. We used ED02AH technology in this paper. We aim to achieve filters whose bandwidth is more while applying other technologies such as BICMOS or RFCMOS in the same structure.

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