Practical Considerations in the Design of a Bandpass Filter for the LWA Analog Receiver

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1 Introduction

In [1] a design for the LWA analog receiver was suggested. In Section 6.4 of that document, a design for a bandpass filter was proposed which provided the required 20-80 MHz bandpass. However, that design did not use standard (commercially available) components. In this document we (1) revise the design using standard values and (2) quantify the extent to which typical variations in component values may affect performance.

2 Design Proposed by Taylor

The design of the filter from [1] is shown in Figure 1.

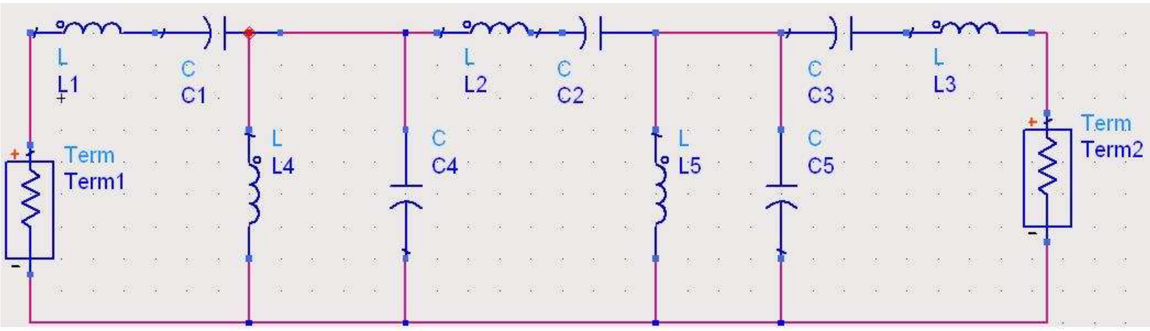

Figure 1: Fifth order Butterworth filter proposed in [1] .

The component values used in this design are listed in the following table.

component	value
L1	71 nH
L2	231 nH
L3	71 nH
L4	269 nH
L5	269 nH
C1	282 pF
C2	87 pF
C3	282 pF
C4	75 pF
C5	75 pF

The transfer function of the filter is shown in Figure 2. It is not intended that this be the sole filter in the LWA receiver chain, but rather it is anticipated that several such filters would be used distributed throughout the receiver chain, perhaps with additional filter(s) to provide increased rejection of the FM band if necessary.

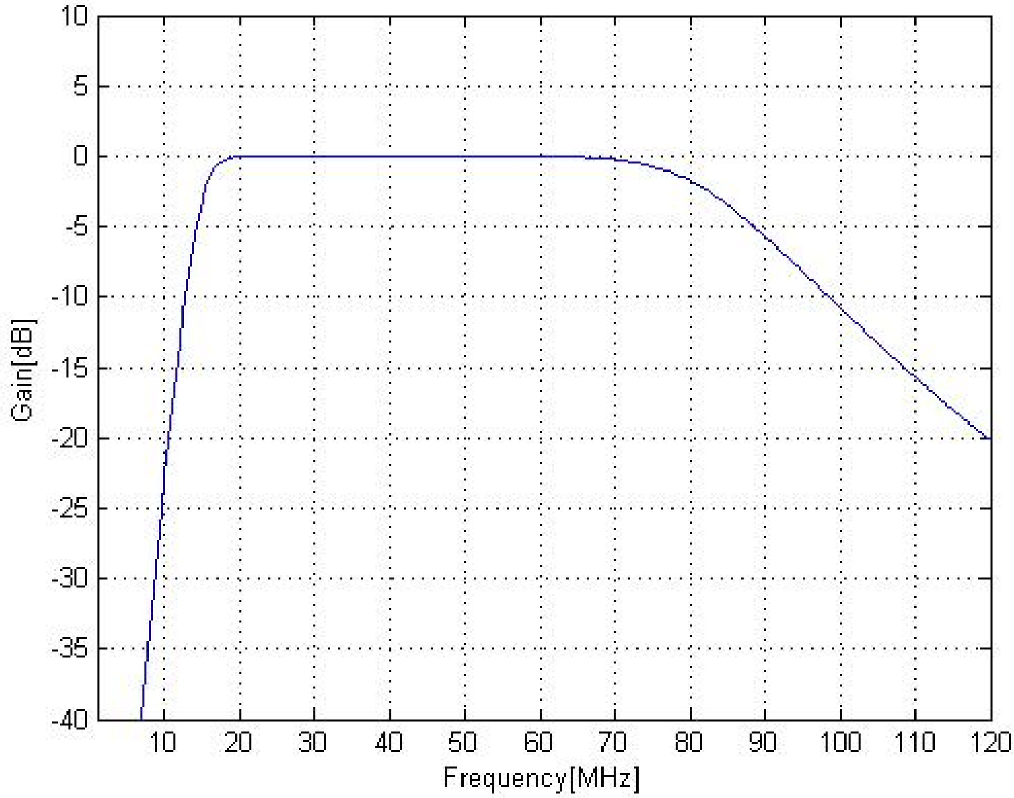

Figure 2: Frequency response of the filter using values specified in [1]

The next step was to consider the physical realization of the filter with standard value components.

3 Revised Design Using Standard Values

Revised values are selected from commercially available 0603 size SMT components available from the Digikey [1] and Coilcraft [2] catalogs. The selected values are :

Component	Value
L1	72 nH
L2	220 nH
L3	72 nH
L4	270 nH
L5	270 nH
C1	270 pF
C2	91 pF
C3	270 pF
C4	75 pF
C5	75 pF

The frequency response was generated using these values and is shown in Figure 3. The passband is shown in greater detail in Figure 4.

4 Effect of Non-Zero Value Tolerances

Commercially available SMT components typically have a tolerance (i.e., maximum error in value) of 5 percent. We used monte carlo simulation to study the effect of non-zero tolerance on performance. 100 trials were run using a uniformly-distributed random distribution to generate tolerance values within the specific range. These new values were then used to plot the transfer function of the filter. In Figure 5 the response due to 5% tolerance values is shown.

A plot was generated in the same manner for 1% tolerance. Figure 7 shows the response for components using 1% tolerance values.

In order to determine the effect of extreme errors in the component values, tolerance values as high as 10% and 20% were also considered. Figure 9 shows the response with 10% tolerance and Figure 11 shows the response with 20% tolerance.

[1] www.digikey.com
[2] www.coilcraft.com

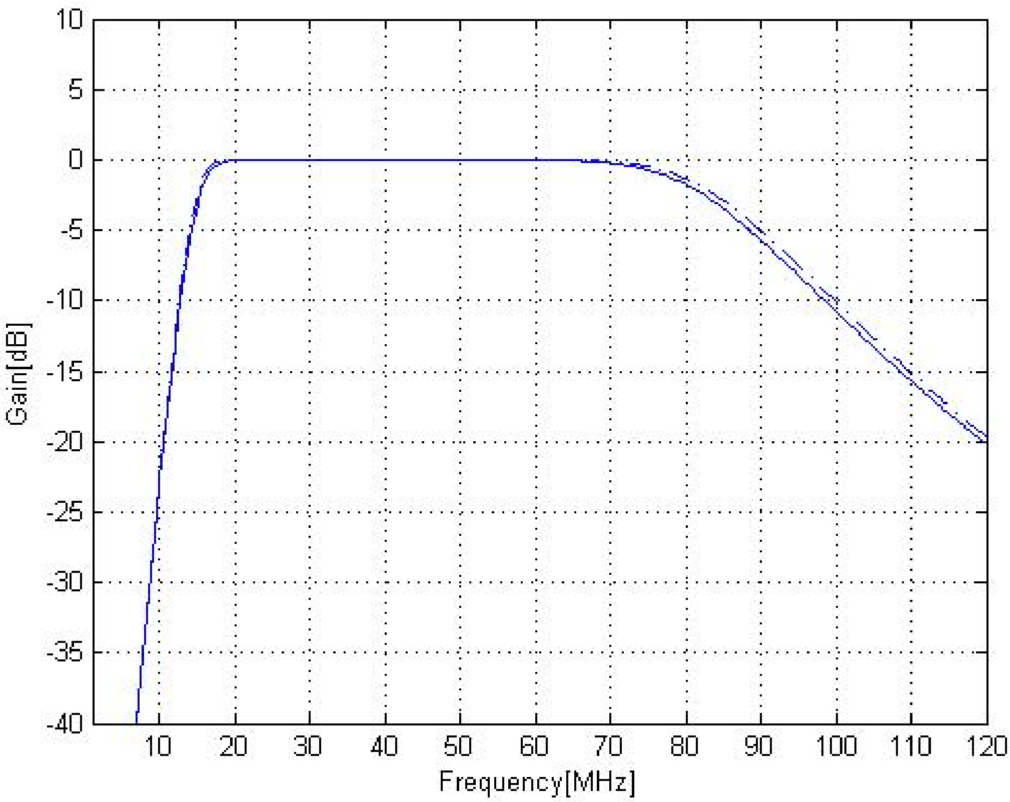

Figure 3: Frequency response using selected standard values (dashed line). Also shown is the response with values specified in [1] (solid line).

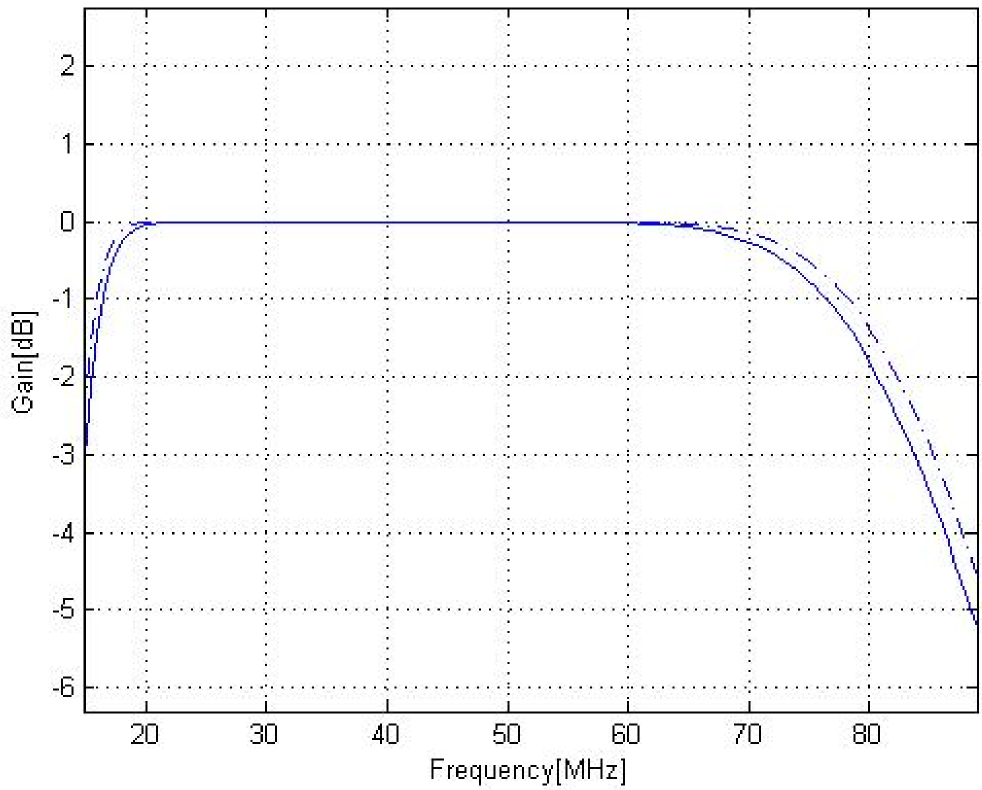

Figure 4: Same as Figure 3 zooming in to passband region.

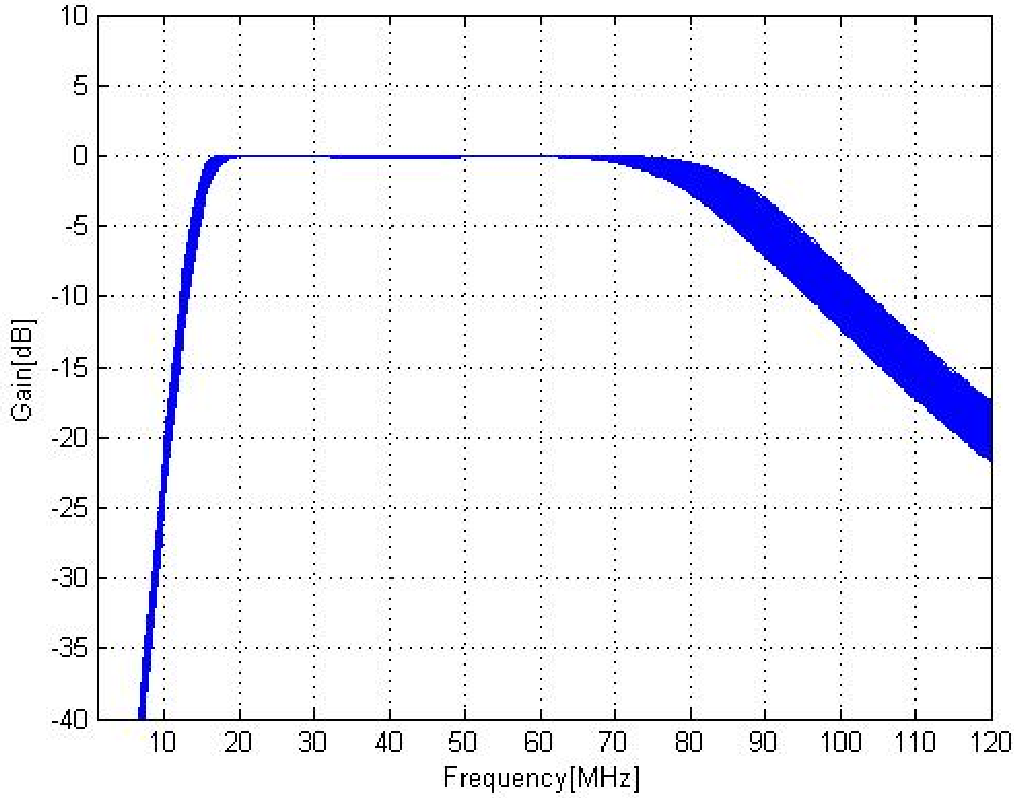

Figure 5: Frequency responses of 100 trials using components with tolerance of 5%.

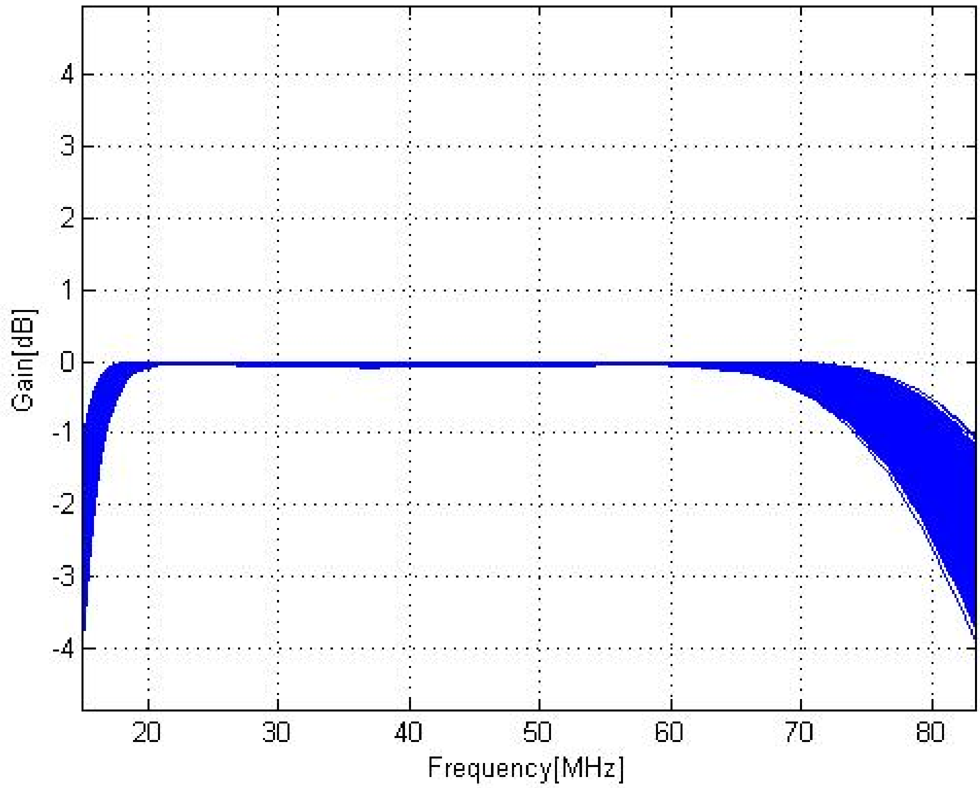

Figure 6: Same as Figure 5 zooming in to pass band region.

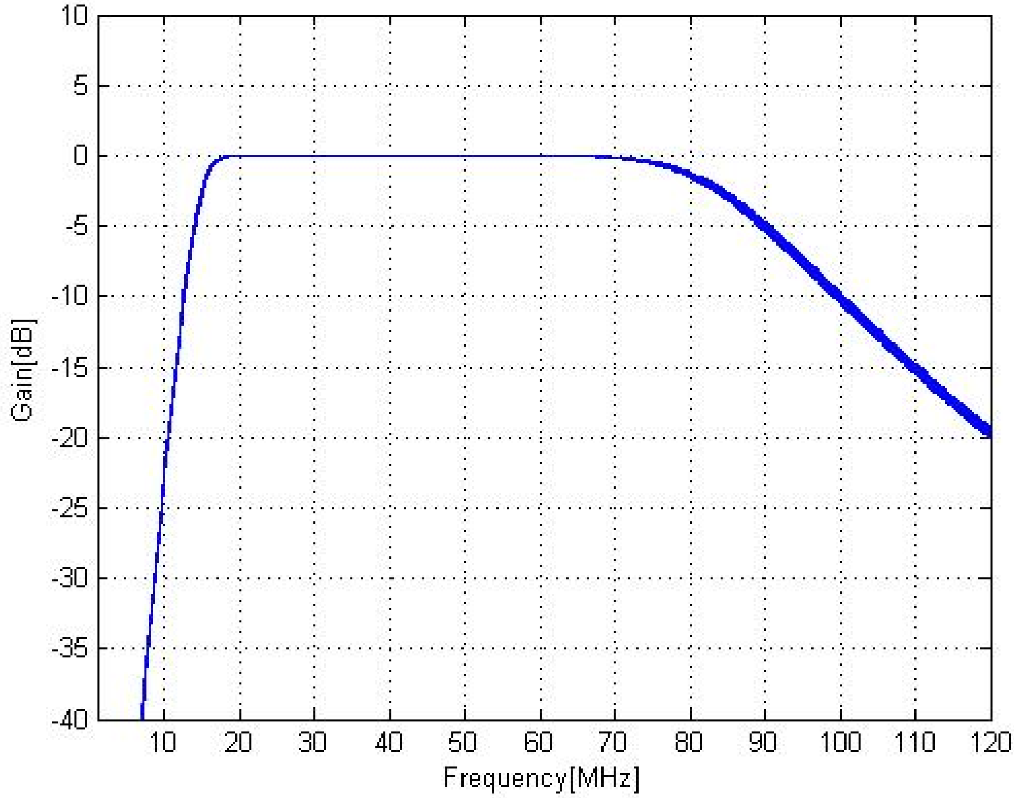

Figure 7: Frequency responses of 100 trials using components with tolerance of 1%.

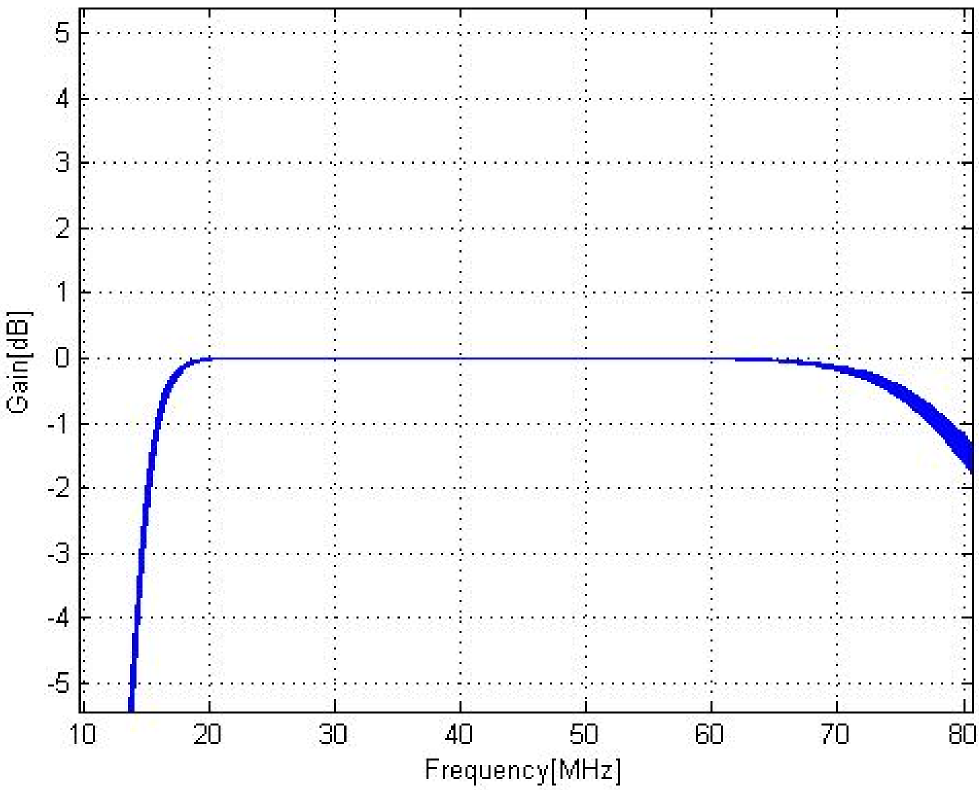

Figure 8: Same as Figure 7 zooming in to pass band region.

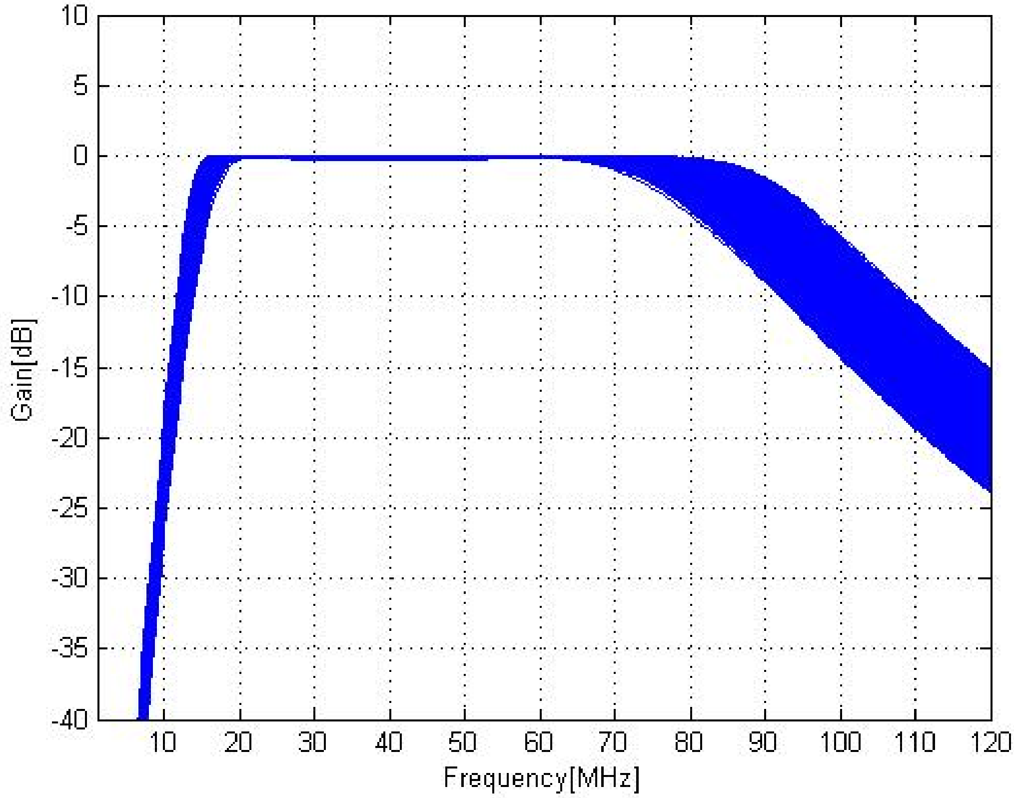

Figure 9: Frequency responses of 100 trials using components with 10% tolerance.

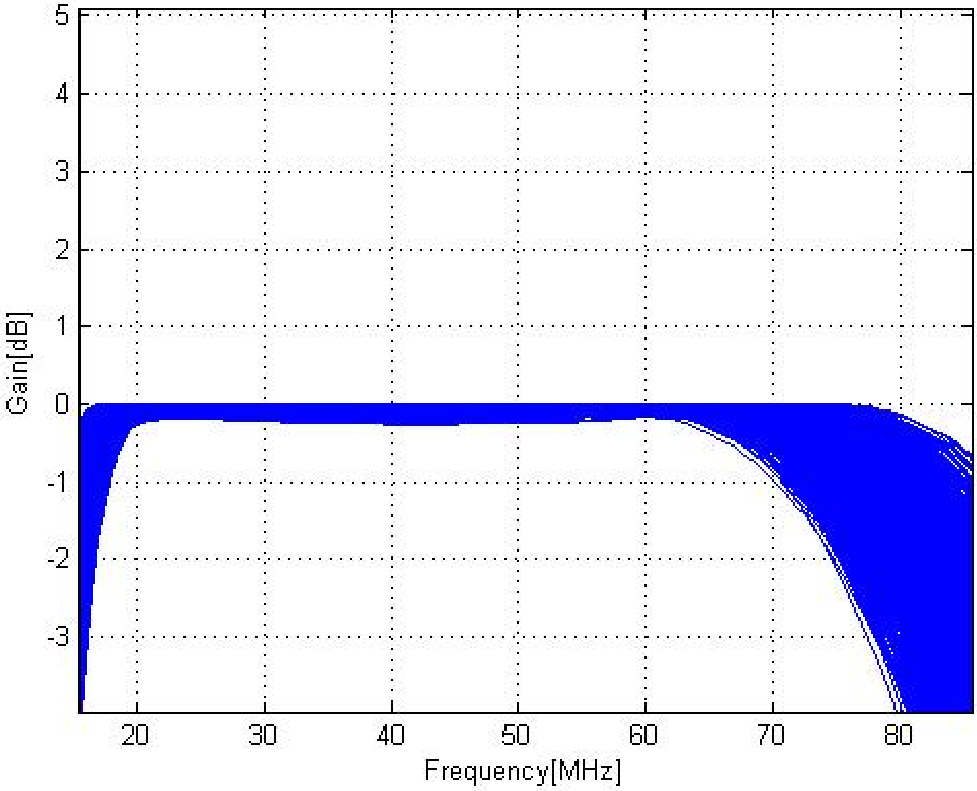

Figure 10: Same as Figure 9 zooming in to pass band region.

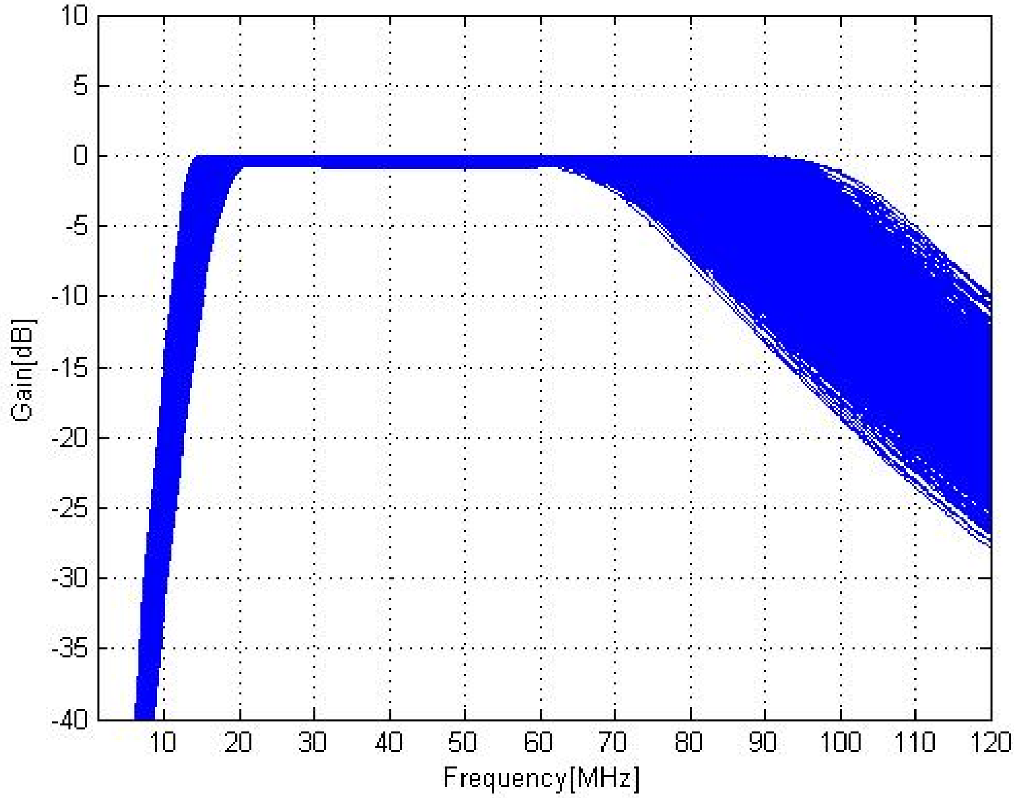

Figure 11: Frequency responses of 100 trials using components with 20% tolerance.

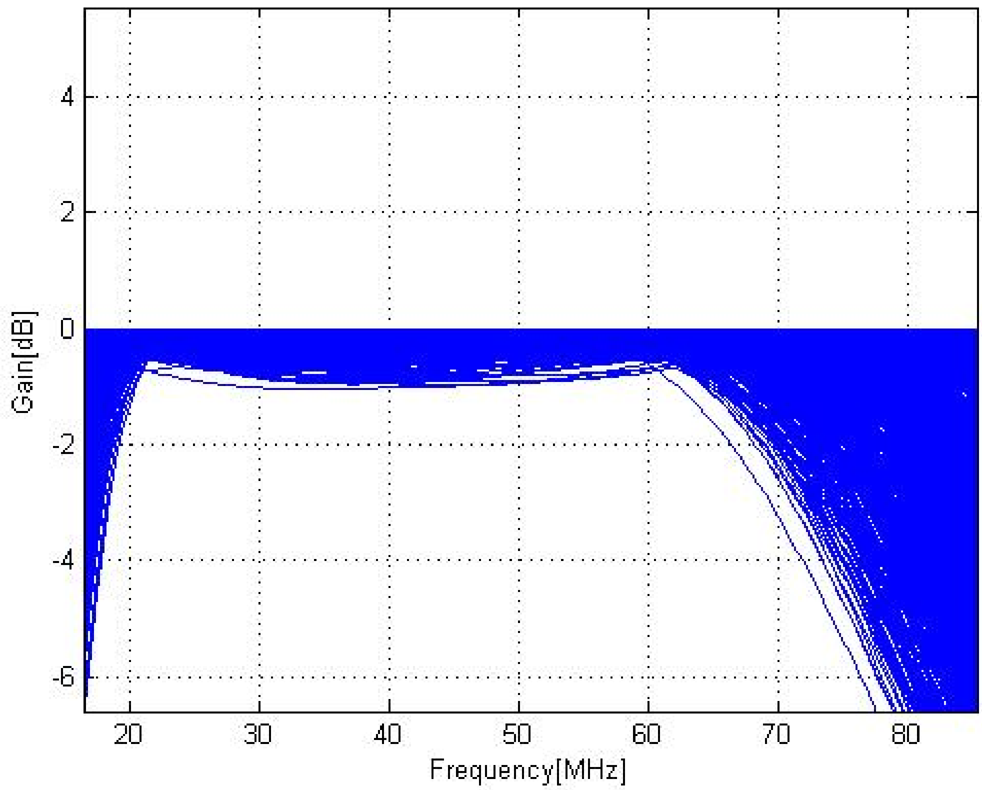

Figure 12: Same as Figure 11 zooming in to pass band region.

5 Conclusion

The following table summarizes the results of this study.

Component Values	Maximum deviation from [1] in 20-60 MHz	Maximum deviation from [1] in 60-80 MHz	Minimum attenuation at 10 & 90 MHz
From [1]	0 dB	0 dB	-23, -6 dB
Standard values, 0% tolerance	$<<$ 0.1 dB	$<$ 0.5 dB	-23, -5 dB
Standardvalues, 1% tolerance	$<<$ 0.1 dB	0.4 dB	-22, -5 dB
Standard values, 5% tolerance	$<<$ 0.1 dB	1.4 dB	-21, -3 dB
Standardvalues, 10% tolerance	$<<$ 0.1 dB	1.6 dB	-18, -2 dB
Standardvalues, 20% tolerance	$\sim$ 1 dB	4.5 dB	-14, $\sim$ 0 dB

Observing the results of this study we find that the use of standard commercially-available SMT components with typical 5% tolerance lead to deviations from the ideal design that are significant, and perhaps on the verge of becoming objectionable. Components with 1% tolerance, which are available but cost significantly more, are judged to be completely acceptable. The distribution of the errors in component values affects the results; we have used a uniform distribution but a Gaussian distribution may be a better model, and would likely yield deviations smaller than those seen here. Since this filter design is not unique (i.e., there are other topologies and value-sets that yield similar responses) it may be worthwhile to consider if a design exists which is more robust to deviations from ideal values than the design considered here.

References

[1] D.W.A. Taylor, “Design of Ultrawideband Digitizing Receivers for the VHF Low Band,” M.S. Thesis, Virginia Ploytechnic Institute & State University, 2006. http://scholar.lib.vt.edu/theses/available/etd-05162006-161217/.