A Varactor-Tuned RF Tunable Bandpass Filter with Improved Passband Flatness

Byung-Wook Kim · Du-Il Yun · Sang-Won Yun

Abstract

A RF tunable bandpass filter using dielectric resonators and varactor diodes is redesigned to improve the passband flatness. Since the tunable filters are generally of narrow bandwidth and the Q value of the varactor diode is usually very low, the passband flatness is strongly deteriorated by sizeable distortion loss. To remedy this problem, we construct modified Chebyshev type filter by use of network synthesis techniques. The key of modified Chebyshev type filter is the rearrangement of the passband poles to improve the passband flatness. To maintain the constant passband bandwidth, design techniques of input/output stage and coupling windows are also applied. Experimental results show that the passband flatness can be improved by purposed method without any additional RF amplitude equalizer.

Key words : Tunable Bandpass Filter, Passband Flatness, Modified Chebyshev Type Filter

Ⅰ. Introduction

Electrically tunable filters have wide applications in multi-band wireless communication system. Authors have suggested a design technique of a RF tunable bandpass filter using dielectric resonators and varactor diodes[1]. This filter shows that the constant bandwidth is maintained within tuning bandwidths with relatively low passband insertion loss. However, since the pass-band flatness (the difference between maximum and minimum insertion loss within passband) has been deteriorated by, so-called, sizeable distortion loss[2], a RF amplitude equalizer has been suggested[3] and adopted successfully[1]. In this paper, we construct the modified Chebyshev type polynomial to improve the passband flatness without any additional RF amplitude equalizer. The key of the modified Chebyshev polynomial is the rearrangement of the passband poles so that the passband flatness can be improved. A RF tunable bandpass filter has been designed using this modified Chebyshev polynomial by use of network synthesis techniques[4]. Experimental results will show that the passband flatness can be improved by the design method presented in this paper. The design technique which had already been suggested by authors to maintain the constant bandwidth within tuning bandwidths[1] was also employed.

Ⅱ. Modified Chebyshev Lowpass Prototype

Fig. 1 shows the general response of bandpass filter as a function of unloaded Q values of the resonators. Since the insertion losses due to finite Q values are generally increased at band edges, the passband flatness is deteriorated by finite Q values. One can also find that as the Q values of the resonators become worse, the passband flatness become worse too. Since RF tunable filters for wireless communication system are generally of narrow bandwidth and the Q values of the varactor diodes are usually very low, the flatness of the RF bandpass filter for wireless communication system is unacceptably poor[1]. This problem has been successfully resolved by application of RF amplitude equalizer[1],[3].

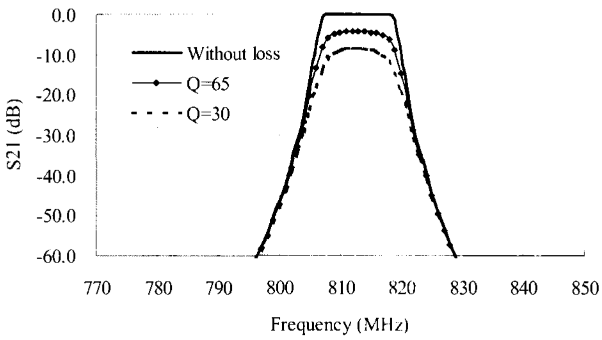

Fig. 1. Insertion loss as a function of unloaded Q.

In Fig. 2 the general characteristics of classical Chebyshev polynomial and modified Chebyshev polynomial where the passband poles are moved toward the band edges are compared. If a bandpass filter are designed using the modified Chebyshev polynomial where the passband poles are moved toward the band edges, the passband loss will be larger at the center of the passband than those at the band edges. However, if the losses of the resonators are considered, the passband flatness can be improved because insertion losses at the band edges will be affected strongly than those at the center of the passband.

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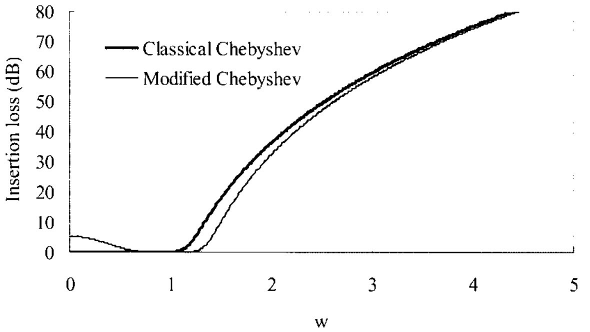

Fig. 2. Comparison between classical Chebyshev polynomial and modified Chebyshev polynomial; all passband poles are overlapped and move toward the band-edge.

Since we want to modify the Chebyshev polynomial in such a way that the insertion loss at the center of the passband is expected to be larger than that at the band edges, even order Chebyshev polynomial must be considered for modification. In this case, all the passband poles can be moved toward the band edges. Since the insertion loss due to finite Q values will be largest at the very end of the band edges, most effective method would be 'every passband poles are moved toward band edges.' Therefore, overlap all passband poles, then move it toward the band edges until insertion loss at center of the passband is equal to that of insertion loss at the band edges would be most effective method. Fig. 3 shows the comparison of the response of bandpass filter designed by use of classical Chebyshev polynomial and the response of modified Chebyshev polynomial as described. This result shows that the passband flatness can be improved by the method presented in this paper. Also, one can find that the bandwidth is enlarged as an effect of rearrangement of the passband poles. However, the overall skirt frequency characteristics are remained almost same. Since the transmission coefficient at the center of the passband is enforced to be low,

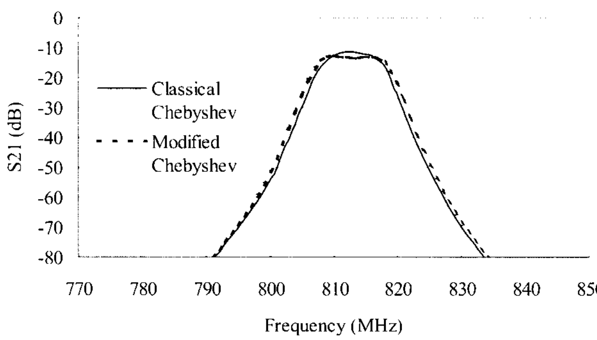

Fig. 3. Comparison bandpass filter response between classical Chebyshev and modified Chebyshev one; The resonator's losses are accounted for.

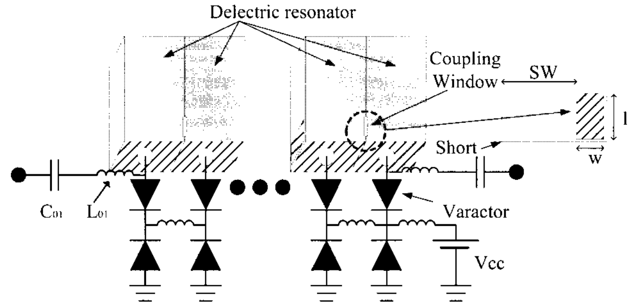

Fig. 4. A RF tunable bandpass filter.

the reflection coefficient at the center of the passband would be worse than that of the bandpass filter designed using classical Chebyshev polynomial. To remedy this problem, an additional matching section may be added[3].

Ⅲ. Practical Example

A varactor tuned RF tunable bandpass filter has been designed to the following specifications :

Frequency : 820 MHz ~ 855 MHz
Passband bandwidth : 8 MHz (W = about 1 %)
Type : 6 sections

Fig. 4 illustrates the tunable filter configuration[1] considered in this paper. This filter is composed of dielectric resonators and varactor diodes. Since the equivalent capacitance of the varactor diode has a dependency on the external bias voltages, this filter has a tunable capability. The series lumped L and C elements are used for input/output stage coupling and coupling windows are used for the coupling between resonators. The unloaded Q of the resonators were about 100. The simulated results designed by use of 0.01 dB classical Chebyshev polynomial shows that the passband flatness will be larger than 5 dB. To improve passband flatness, every passband poles are overlapped and

Table 1. Element values for modified Chebyshev filter.

g_0	1
g_1	1.08874629308957
g_2	0.76079230234706
g_3	3.88476807297075
g_4	0.34214425225670
g_5	8.63817418187220
g_6	0.09588945320525
g_7	11.35418189067268

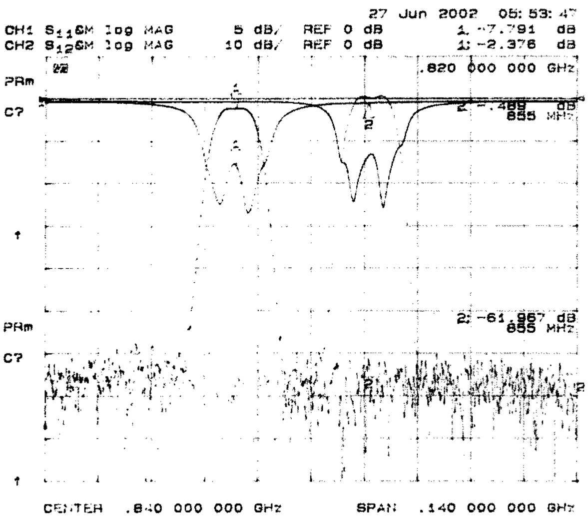

Fig. 5. Experimental results.

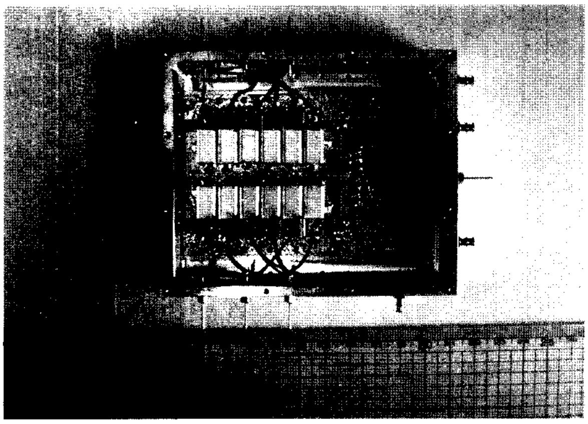

Fig. 6. Photograph of a 12 poles (6 poles filter + gain block + 6 poles filter) RF tunable bandpass filter.

moved at $w_c = 1$ as illustrated at Fig. 2. The network synthesis techniques are applied to obtain element values of the lowpass proto type. Table 1 shows the results obtained by this procedure. The simulated results shows that the passband flatness can be improved as illustrated at Fig. 3. To maintain the constant passband bandwidth, the design methods of the input/output stage and coupling windows by authors[1] have been applied. Fig. 5 shows the experimental results of overall 12 poles bandpass filter which is composed of two 6 poles filter based on the modified Chebyshev type filter plus gain block(low noise amplifier). These results are agreed well with predicted ones. The gain of the gain block are adjusted so that insertion losses of the overall 12 poles filter can be maintained to be constant. Fig. 6 shows the photograph of the constructed varactor-tuned RF bandpass filter.

Ⅳ. Conclusions

In this paper, a RF tunable bandpass filter using coaxial dielectic resonators and varactor diodes is redesigned to improve the passband flatness. The passband poles of the Chebyshev polynomial has been moved toward band edges so that passband flatness can be improved. Network synthesis techniques[4] along with design techniques of input/output section and the coupling windows[1] have been applied. Experimental results shows that the passband flatness can be improved by use of the techniques presented in this paper.

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