A Miniaturized 2.4 GHz Band Multi-layer Bandpass Filter Using Capacitively Loaded λ/4 Slow-wave Resonator

Hee-Seok Song and Young-Shin Lee

Korea Electronics Technology Institute

#455-6 Masan-Ri, JinWi-Myon, PyoungTaek-Si, KyungGi-Do, R. O. Korea

Tel : +82-31-6104-130/ Fax: +82-31-6104-263

E-mail : mailto:songhs@nuri.keti.re.kr

Abstract —**In this paper, we proposed new multi-layer λ/4 slow-wave resonator, which is composed of strip-line and loading capacitance. Due to the slow-wave effect of the proposed resonator, it is possible to design and fabricate a compact bandpass filter with a wide upper stopband . Using LTCC multi-layer technology, we designed and fabricated 2.4 GHz ISM-band bandpass filter with a wide upper stopband and the size is 2.0 mmx1.2mmx0.8mm.**

I. Introduction

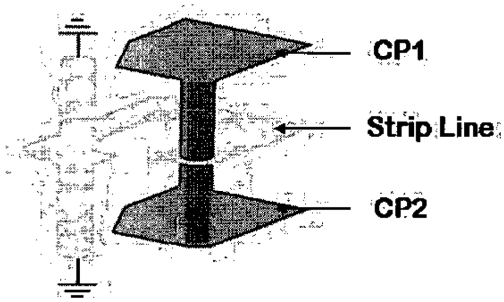
In order to reduce interference by keeping out-of-band signals from reaching a sensitive receiver, a wider upper stopband, including $2f_0$, where f_0 is the midband frequency of a bandpass filter, may also be required. However, many bandpass filter that are composed of half-wavelength resonators inherently have a spurious passband at $2f_0$. A cascaded lowpass filter or bandstop filter may be used to suppress the spurious passband at a cost of extra insertion loss and size. Bandpass filters using stepped impedance resonators[1], or slow-wave resonators such as end-coupled slow-wave resonators[2] and slow-wave open-loop resonators[3-4] are able to control spurious response with a compact filter size.

Recently, multi-layer technology using a low temperature cofired ceramics(LTCC) has become popular in high frequency application. Especially, as the demand for compact, highly integrated microwave circuits increases, the use of LTCC becomes desirable.

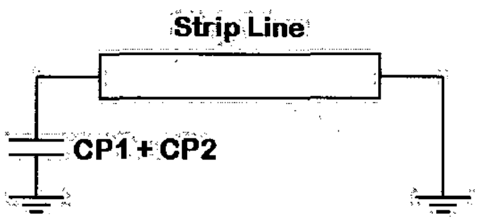
In this paper, new multi-layer slow-wave λ/4 resonator was proposed, and using the proposed resonators Chebyshev 2-pole bandpass filter was designed and fabricated with LTCC multi-layer process. Because the proposed resonator has slow-wave characteristic and LTCC multi-layer process was used to fabricate the physical circuit, the fabricated multi-layer filter has a wide upper stopband and the size is much smaller than conventional filter.

II. New Multi-layer λ/4 Slow-wave Resonator

Fig 1 is the 3-dimensional structure and equivalent circuit of the resonator proposed in this paper. The proposed resonator is made by adding loading capacitance to the conventional quarter-wavelength resonator in a strip-line structure. In order to increase the value of loading capacitance, we used two capacitance-patterns.



(a) 3-D structure



(b) equivalent circuit

Fig. 1 New multi-layer λ/4 slow-wave resoantor

In case of the conventional quarter-wavelength resonator, the first spurious resonant frequency(f_l) appears at $3f_0$, where f_0 is the fundamental resonant frequency. But, the proposed resonator can control the first spurious resonant frequency, depending on the loading capacitances. In order to get the effect of the loading capacitance, we investigated the resonance

0-7803-7695-1/03/$17.00 © 2003 IEEE

characteristics by circuit simulation. Equivalent circuit shown in Fig. 1(b) was used in simulations, and the used simulator is Agilent ADS2002. We assumed that the width and length of the strip line are 0.15mm and 4mm, and ground-to-ground height is 0.8mm. Fig.2 is the simulated results, and from the simulated results, without the loading capacitance, the first spurious resonant frequency, f_1 appears at $3f_0$, and so the ratio of the first spurious resonant frequency and the fundamental resonant frequency is 3. But, as the value of the loading capacitance is increased, both the fundamental and the first spurious resonant frequency are shifted down, and so the ratio is increased over 3.

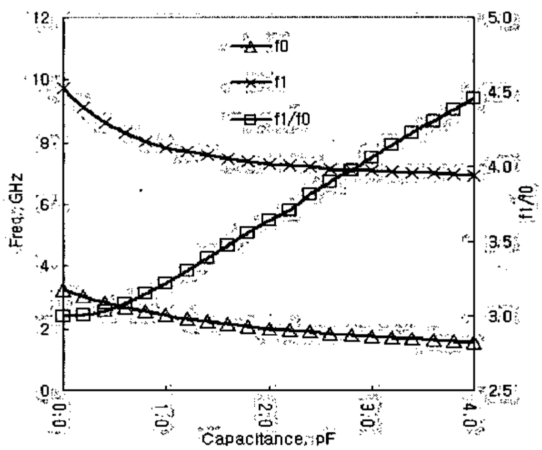


Fig. 2 Resonance characteristics according to the variation of the loading capacitance.

From the simulated results, we can see that it is possible to design and fabricate a compact bandpass filter with a wide upper stopband using the proposed multi-layer resonators.

III. DESIGN AND FABRICATION OF BANDPASS FILTER

A. LTCC Substrate Preparation

The employed LTCC material system is $ZnO-Nb_2O_5-TiO_2$ based dielectric ceramics with a small weight percent of glass frits. Dieletric and RF properties of LTCC substrate made of this ceramic powder was measured up to 6 GHz using microstrip ring resonator method [5]. The measured result is shown in Fig. 3. Dieletric constant of the substrate is 33 and the unloaded quality factor of the substrate at 2.5 GHz is about 1000. The total loss of the substrate system with screen-printed silver conductor is 0.002 dB/mm.

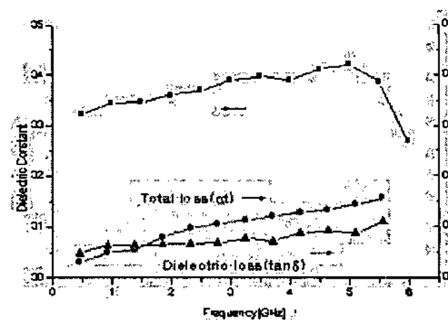
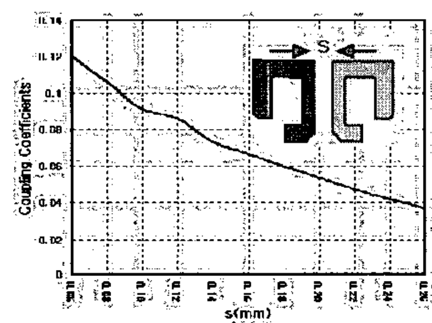


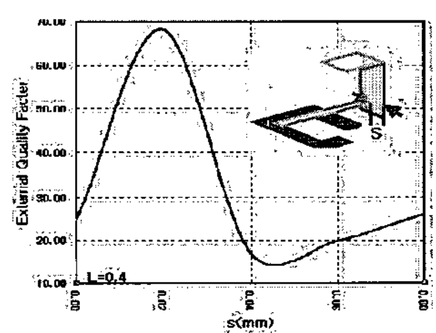
Fig. 3 Dielectric and loss properties fo the employed LTCC substrate

B. Design of Chebyshev 2-pole Bandpass Filter

Using the proposed resonator, Chebyshev 2-pole band-pass filter for ISM band was designed and fabricated. The filter was designed with the midband frequency of 2.44 GHz and 5% fractional bandwidth. 2-pole (n=2)



(a) Coupling coefficient

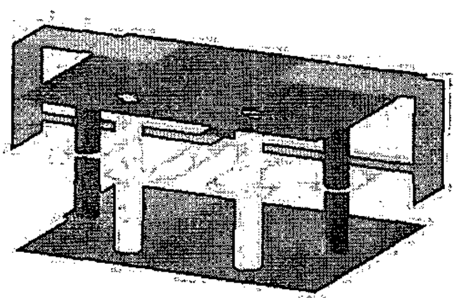


(b) External quality factor

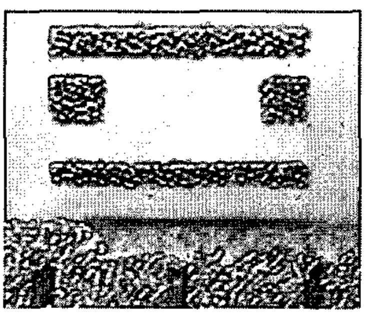
Fig. 4 Simulated design parameters

Chebyshev lowpass prototype with a passband ripple of 0.1 dB is chosen and the lowpass parameters (given for a normalized lowpass cutoff frequency $\Omega_c = 1$) are $g_0=1$, $g_1=0.8431$, $g_2=0.6220$ and $g_3= 1.3554$. The calculated bandpass design parameters are $Q_{e1}=Q_{e2}=16.862$, $M_{12}=0.07$, where Q_{e1} and Q_{e2} are the external quality factors of the coupled resonators at the input and output, and M_{12} is the coupling coefficient between the two resonators.

Using the EM simulation, the external quality factor and coupling coefficient was extracted. Commercial simulater, Ansoft HFSS was used for simulator. Fig. 4 is the simulated external quality facter and coupling coefficient. Using the simulated results, the 3-dimension structure was configured and simulated. Fig. 5 is the 3-dimensional layout and the fabricated physical circuit. Due to the advantage of the proposed resonator, the fabricated filter has a compact size, 2mm×1.2mm×0.8mm.



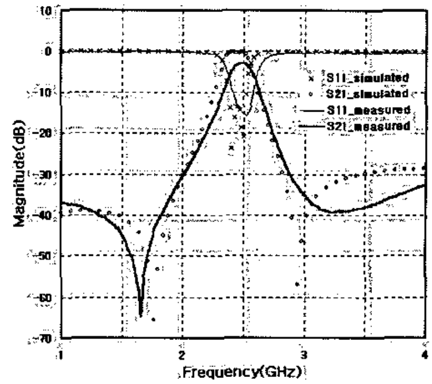
(a) 3-dimensional structure



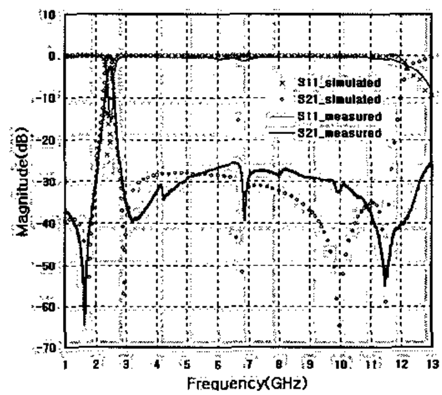
(b) the fabricated circuit

Fig. 5. The structure and physical circuit of the bandpass filter

Fig. 6 is the frequency response of the fabricated filter circuit. It is shown that the measured plot almost corresponds to the simulated plot. The fabricated filter has no spurious passband up to 13 GHz, and so it is demonstrated that the proposed filter has a wider upper stopband than the conventional filter. In the midband frequency, the insertion loss is about 3.2 dB and the return loss is about 15 dB.



(a) Passband characteristics



(b) Stopband attenuation characteristics

Fig. 6 Measured and simulated data of the fabricated bandpass filter

V. Conclusion

In this paper , the new multi-layer $\lambda/4$ slow-wave resonators was proposed. It is demonstrated by simulation that this resonator has the advantage over the size and the control of the spurious signal. Using the proposed resonators, we designed and fabricated a Chebyshev 2-pole multi-layer bandpass filter. Simulated and measured data shows that the filter using the proposed resonator has a wider upper stopband than the conventional filer and has a compact size.

REFERENCES

[1] M. Makimoto and S. Yamashita, " Bandpass filters using parallel coupled stripline stepped impedance resonators", IEEE Trans., MTT-28, 1980, 1413-1417.

[2] J. S. Hong and M. J. Lancaster, " End-coupled microstrip slow-wave resonator filter", Electronic Letters, 32, 16, 1996, 1494-1496.

[3] J. S. Hong and M. J. Lancaster, " Microstrip slow-wave resoantor filters", IEEE MTT-S, Digest, 1997, 713-716.

[4] J. S. Hong and M. J. Lancaster, " Theory and experiment of novel microstrip slow-wave open-loop resoantor filters", IEEE Trans., MTT-45, Dec, 1997, 2358-2365.

[5] Y. S. Lee, K. C. Kim, S. D. Park, J.C. Park, " A study on measurement for high frequency properties of LTCC substrate systems" IMAPS-Koreatech. Symposium, May, 2002, 264-269.