MICROWAVE LUMPED AND TRANSVERSAL BANDPASS FILTER USING UNEQUAL SOURCE DEGENERATION INDUCTORS FOR NOISE AND SELECTIVITY IMPROVEMENT

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For the modern mobile communication transceiver design, high selectivity of the RF front-end filter is usually required. But the low Q-factor and components losses of the passive filter degrade the performance significantly. Numerous active filter topologies have been proposed to overcome such limitations as well as offering the monolithic integration capability [1-3]. Among these filtering techniques, the conventional lumped and traversal filter structure using large number of transversal elements provides high selectivity and stable operation. Recent research on the source degeneration inductor added to the transversal element has also demonstrated that the filter noise performance can be improved. But the filter size is still the main laggard for practical usage. Against this background, the lumped and transversal filter using unequal source degeneration inductor as depicted in Fig. 1 is explored. The emphasis is placed on the passband edge transmission zeros introduction to improve the selectivity with least number of transversal elements used; maintaining the overall good noise performance.

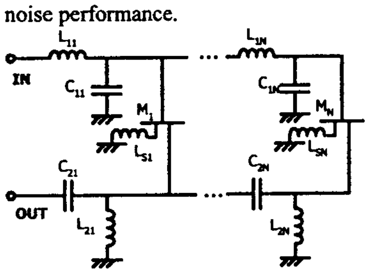

Fig. 1 Lumped and transversal filter with N source degeneration inductors (L_{SN}).

In [4], the conventional lumped and transversal filter using equal source degeneration inductors was studied as illustrated in Fig. 2. It was reported that noise figure can be reduced but the filter selectivity is still poor. As such, the lumped and transversal filter using unequal source degeneration inductor added to different transversal elements is proposed to sharpen the filter response whilst the noise figure reduction advantage is kept by using the main signal path transversal element (M_N) source degeneration inductor. In order to verify the proposed method, a 1.6GHz lumped and transversal filter with two sections (N=2) is designed and implemented. By proper selection of the unequal source degeneration inductors L_{S1} = 3.3nH and L_{S2} = 1nH (L_{S1}/L_{S2} is about 3) the noise figure of the filter can be reduced by about 3dB when compared with the ones without source degeneration inductor as shown in Fig. 3.

The S-parameters of the above lumped and transversal filter using unequal source degeneration inductors is illustrated in Fig. 4. Comparing to the filter structure using equal inductor, it is obvious that the filter BW is reduced to about 49.6 MHz (about 3%) and the band edge is significantly sharpen by transmission zeros at -51.5dB @1.53GHz, -35.3dB @1.57GHz, -40dB @1.78GHz and -54dB @1.94GHz respectively.

[1] K. W. Tam, P. Vitor and R. P. Martins, "MMIC active filter with tuned transversal element," *IEEE Trans. Circuits Syst. II*, vol. 45, pp. 632-634, May 1998.

[2] W. Mouzannar, L. Billonnet, B. Jarry and P. Guillon, "Highly selective novel MMIC microwave active recursive filter," in Proc. *IEEE Radio Frequency Integrated Circuits Symp.*, Jun. 1998, pp. 39-42.

[3] E. C. Krantz and G. R. Branner, "Active microwave filters with noise performance consideration," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 1368-1378, July 1994.

[4] K. V. Chiang, W. W. Choi and K. W. Tam, "Source Degeneration Inductor Based Noise Suppression Scheme for Microwave Lumped and Transversal Bandpass Filter," in Proc. *Asia-Pacific Microwave Conference (APMC2003)*, Nov. 2003, Seoul, Korea, vol. 3, pp. 1961-1964.

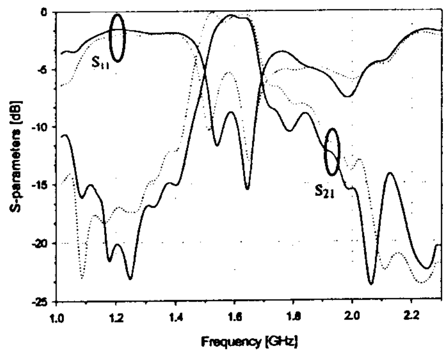

Fig. 2 Measured S-parameters of the lumped and transversal filters (dotted-line – without source inductors; solid-line – with equal source inductors).

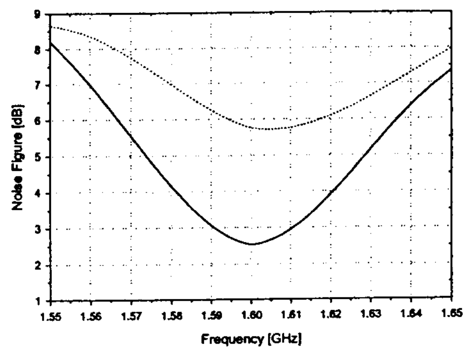

Fig. 3 Measured noise figures at mid-band of the filters (dotted-line – without source inductors; solid-line – with unequal source inductors).

By varying the ratio of L_{S1}/L_{S2} from 1 to 5, it is reported that the optimal band edge rejection is yielded when L_{S1}/L_{S2} about 3 and -30dB of S_{11} matching in passband is obtained. In the inset of Fig. 4, 49.6 MHz as 3dB BW is kept for the above ratio variation.

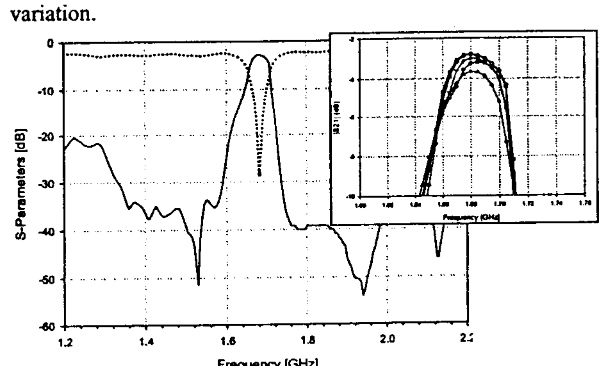

Fig. 4 Measured S-parameters of the lumped and transversal filters with unequal source degeneration inductors (dotted-line – S_{11}; solid-line – S_{21}. ◇– L_2/L_1 = 1; △– L_2/L_1 = 2; O– L_2/L_1 = 3; □ – L_2/L_1 = 4; ▽ – L_2/L_1 = 5).

The above shows that the lumped and transversal filter using unequal source degeneration inductor is capable of offering both noise reduction and high selectivity. This indeed provides additional design feasibility for the conventional lumped and transversal filter.

Microwave Lumped And Transversal Bandpass Filter Using Unequal Source Degeneration Inductors For Noise And Selectivity Improvement

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Abstract

A new lumped and transversal filter using unequal source degeneration inductors are proposed in this work. By proper selection for the source degeneration inductor of the auxiliary transversal elements, the selectivity improvement is obtained whilst the noise reduction is kept. In order to verify the proposed structure, a 1.6GHz two transversal sections lumped and transversal filter is designed and implemented. In this work, by selecting the source degeneration inductor ratio for the auxiliary to main signal path transversal element to 3, the 3dB BW of the filter is greatly reduced to 50MHz (about 3%) whilst the ~3dB noise figure improvement is kept.

1. Introduction

For the modern mobile communication transceiver design, high selectivity of the RF front-end filter is usually required. But the low Q-factor and components losses of the passive filter degrade the performance significantly. Numerous active filter topologies have been proposed to overcome such limitations as well as offering the monolithic integration capability in the past years [1-4]. Among these active filter structures, the conventional lumped and transversal structure is one of the active filtering techniques that can provide high selectivity with stable operation, but its dynamic performance likes noise figure (NF) is degraded in general by the presence of large number of active transversal elements. Although the noise reduction scheme by adding the source degeneration inductors to the transversal elements is proposed to improve the noise performance of the conventional lumped and transversal filters recently [5]. But the filter size is still the main laggard for practical usage. Against this background, the lumped and transversal filter using unequal source degeneration inductor is explored in this work. The emphasis is placed on the passband edge transmission zeros introduction to improve the selectivity with least number of transversal elements used; maintaining the overall good noise performance.

Besides this introductory section, the structure the lumped and transversal filter with unequal source degeneration inductors will be addressed in section 2. To demonstrate the performance of the proposed filter structure, a two sections lumped and transversal filter with source degeneration inductors is implemented and its measurement results are presented in section 3. Finally, the conclusion is then drawn in section 4.

2. Lumped and Transversal Filter with Unequal Source Degeneration Inductors

An N-section lumped and transversal filter with source degeneration inductors is depicted in Figure 1 where N inductors L_{s1}-L_{sN} are added to the source terminals of the transversal elements M_1 to M_N respectively.

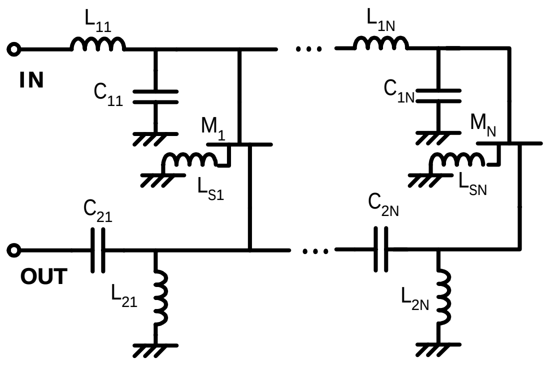

Figure 1. Lumped and transversal filter with N source degeneration inductors (L_{SN}).

In [5], a 1.6GHz conventional lumped and transversal filter with two transversal sections (N=2) using equal source degeneration inductors was studied ($L_{s1}=L_{s2}$). With these source degeneration inductors, it was reported that the noise figure of the filter can be improved by reducing the noise generated by the transversal element whilst the transfer characteristics of the filter is kept. But the filter selectivity is still poor. As such, new lumped and transversal filter using different source degeneration inductors are proposed to obtain noise reduction and selectivity improvement. Similar to the above approach, source degeneration inductors are added to the source terminals of the transversal elements M_i (i = 1 to N) with unequal inductance values ($L_{si} \neq L_{sj}$, where $i \neq j$). It is reported that the major noise contribution is from the transversal element of the main signal path (M_N) [6]. In unequal source degeneration inductors approach, different inductance value inductors are used for the auxiliary transversal and main transversal elements ($L_{si} \neq L_{sN}$, where $i \neq N$) whilst the inductor in main signal path (L_{sN}) is kept. By proper selection of the unequal source degeneration inductors L_{S1} = 3.3nH and L_{S2} = 1nH (L_{S1}/L_{S2} is about 3), the filter band edge can be sharpen by the unequal source degeneration inductors whilst the overall noise figure of the filter can be kept at the similar level. In order to verify the proposed method, a 1.6GHz lumped and transversal filter with two sections (N=2) is designed and implemented.

3. Experimental Results

The designed lumped and transversal filter with unequal source degeneration inductors are implemented and measured. The measured results of the filters using equal and unequal source degeneration inductors are illustrated in Figure 2 and Figure 3 respectively. Comparing to these results, it is obvious that the BW of filter using the unequal source degeneration one is reduced to about 49.6 MHz (about 3%) and the band-edge is significantly sharpen by transmission zeros at -51.5dB @1.53GHz, -35.3dB @1.57GHz, -40dB @ 1.78GHz and -54dB @1.94GHz respectively. Like the equal inductor case, the filter's noise figure can also be reduced by around 3dB when compared with the ones without inductor as shown in Figure 4. By varying the ratio of L_{S1}/L_{S2} from 1 to 5, it is reported that the optimal band edge rejection is yielded when L_{S1}/L_{S2} is about 3 and -30dB of S_{11} matching in passband is obtained. In Figure 5, it shows the passband measurement, where 49.6 MHz as 3dB BW is kept for the above ratio variation.

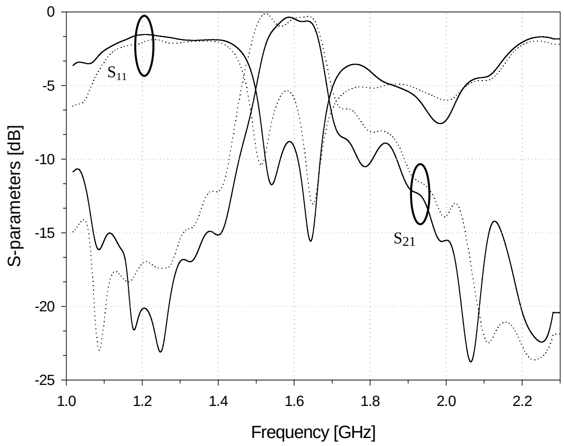

Figure 2. Measured S-parameters of the lumped and transversal filters (dotted-line – without source inductors; solid-line – with equal source inductors).

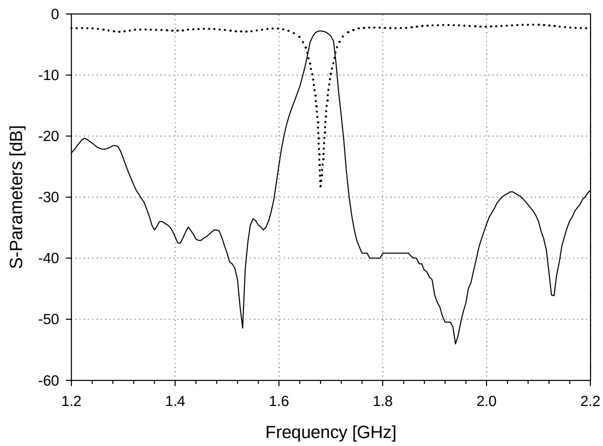

Figure 3. Measured S-parameters of the lumped and transversal filters with unequal source degeneration inductors (dotted-line – S_{11}; solid-line – S_{21}).

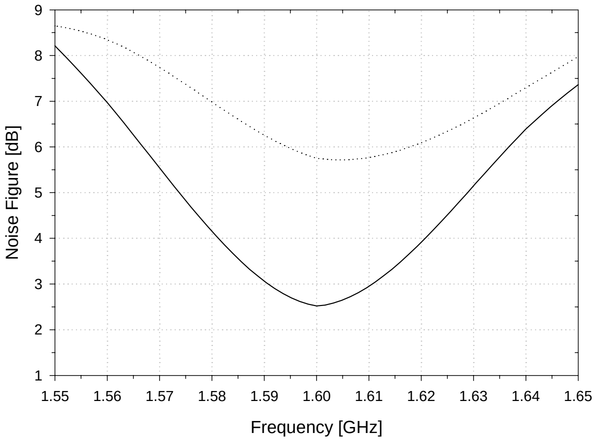

Figure 4. Measured noise figures at mid-band of the filters (dotted-line – without source inductors; solid-line – with unequal source inductors).

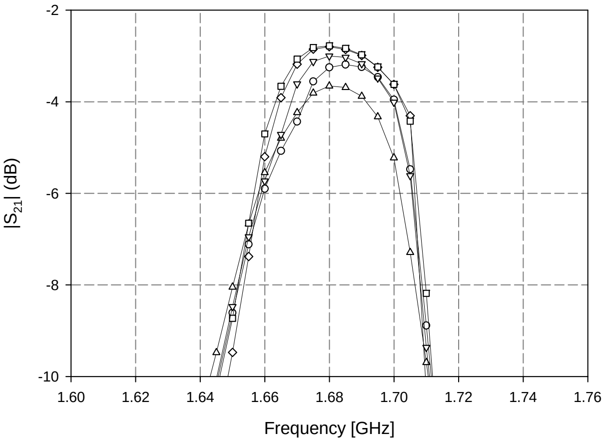

Figure 5. Passband measurement of the lumped and transversal filters using unequal source degeneration inductors with different inductor ratio (◇– L_{s1}/L_{s2} = 1; △– L_{s1}/L_{s2} = 2; ○– L_{s1}/L_{s2} = 3; □ – L_{s1}/L_{s2}= 4; ▽ – L_{s1}/L_{s2} = 5).

4. Conclusions

This paper shows that the lumped and transversal filter using unequal source degeneration inductor is capable of offering both noise reduction and high selectivity. This indeed provides additional design flexibility for the conventional lumped and transversal filter.

Acknowledgements

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References

[1] M. J. Schindler and Y. Tajima, "A novel MMIC active filter with lumped and transversal elements," *IEEE Trans. Microwave Theory Tech.*, vol. 37, pp. 2148-2153, Dec. 1989.

[2] U. Karacaoglu and I. D. Robertson, "MMIC active bandpass filters using varactor-tuned negative resistance elements," *IEEE Trans. Microwave Theory Tech.*, vol. 43, pp. 2926-2932, Dec. 1995.

[3] K. W. Tam, P. Vitor and R. P. Martins, "MMIC active filter with tuned transversal element," *IEEE Trans. Circuits Syst. II*, vol. 45, pp. 632-634, May 1998.

[4] W. Mouzannar, L. Billonnet, B. Jarry and P. Guillon, "Highly selective novel MMIC microwave active recursive filter," in Proc. *IEEE Radio Frequency Integrated Circuits Symp.*, Jun. 1998, pp. 39-42.

[5] K. V. Chiang, W. W. Choi and K. W. Tam, "Source degeneration inductor based noise suppression scheme for microwave lumped and transversal bandpass filter," in Proc. *Asia-Pacific Microwave Conference (APMC2003)*, Nov. 2003, Seoul, Korea, vol. 3, pp. 1961-1964.

[6] K. V. Chiang, K. W. Tam, W. W. Choi and R. P. Martins, "Noise performance of CMOS transversal bandpass filters," in Proc. *IEEE International Symposium on Circuits and Systems (ISCAS2002)*, vol. 3, pp. 871-874, May 2002.