BALANCED LOW-LOSS SAW RING AND THREE-TRANSDUCER FILTERS WITH IMPEDANCE CONVERSION

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1. ABSTRACT

This paper presents the balanced low-loss SAW filters with impedance conversion from 50–75Ω to 150–250Ω in a wide fractional bandwidth of 1.5–7%. The ring SAW filter on 128°YX $LiNbO_3$ and wideband three-transducer SAW filters with unidirectional IDTs on U-shaped MSCs on 128°YX, 64°YX, 41°YX $LiNbO_3$ are used for this purpose. The optimization of the SAW filters is provided with computer simulation using the equivalent circuit model. The 45–52 MHz samples of the balanced SAW filters have shown an insertion loss of around 2 dB, stopband attenuation of 30–50 dB. Two cascaded filters provided an insertion loss of around 3 dB and stopband attenuation of 60–100 dB.

Keywords: balanced SAW filters, impedance conversion.

2. INTRODUCTION

The development of the low-loss SAW filters having the specified frequency response in combination with additional features like balanced operation and impedance conversion meets the advanced direction of the SAW technology progress – expansion of the functionalities of SAW devices [1]. The balanced operation allows to combine the SAW filter with the modern balanced ICs of the low noise amplifiers, mixers without using cumbersome baluns. The low impedance conversion to high impedance is highly suitable for matching the low impedance antennas, low noise amplifiers with high impedance mixers. This paper presents the new balanced low-loss SAW filters with impedance conversion from 50–75Ω to 150–250Ω in a wide fractional bandwidth of 1.5–7%. The self-matched low-loss ring SAW filter with reflective multistrip couplers (RMSCs) and wideband low-loss three-transducer SAW filters with unidirectional interdigital transducers (IDTs) on U-shaped MSCs are used for this purpose.

3. BALANCED LOW-LOSS SAW RING FILTERS WITH IMPEDANCE CONVERSION

For a fractional bandwidth of 1.5% we used previously developed self-matched low-loss SAW ring filters on 128°YX $LiNbO_3$ [2] (Fig. 1). As will be seen from Fig. 1 the input/output IDTs of the ring filter have not a common grounded busbar. So the symmetrical connection of the input/output IDTs to the loads is possible. Consequently, the ring filter can be both the balanced/unbalanced structure similar to a transversely coupled resonator filter with a split center busbar [4]. In order for the 50Ω input impedance to be converted to the 200Ω output impedance in the ring filters we used a sectional output IDT with a series electrical connection of the 2 sections [5] (Fig. 1). Then theoretically an output IDT impedance increases by a factor of 4. The theoretical analysis of the balanced SAW ring filter was provided using a computer simulation on a basis of an equivalent circuit model. The calculation for the entire device reduces to multiplying "the real RMSC response" (i. e., the experimental RMSC frequency response entered into the computer) by the frequency response of the ring filter containing only the input/output IDT [2]. The equivalent circuit of the balanced ring SAW filter is shown in Fig. 2. Here $[P_1]$ is a mixed matrix of the input IDT, $[P_2]$ — a mixed matrix of sectional output IDT, Z — characteristic impedance of the medium between IDTs, V — SAW velocity. Fig. 3 shows a simulated frequency response of the balanced SAW ring filter on 128°YX in a 75Ω–250Ω system. The filter has shown a 3-dB fractional bandwidth of 1.87% with minimal insertion loss and ripple, stopband attenuation of above 30 dB. The measured frequency response of the balanced SAW ring filter is shown on Fig. 4. The filter has been symmetrically connected to a 75-Ω input load and to a 250Ω output load. Measurements were carried out by a standard frequency response meter and balanced transformers. The losses of the balanced transformers were eliminated from the measured insertion loss of the filter. At the 45.42 MHz the filter has shown an insertion loss of less than 2 dB, 3-dB fractional bandwidth of 0.85 MHz with a very low ripple of 0.1 dB and stopband attenuation around 30 dB at ±5% offset from the center frequency. Fig. 3 and Fig. 4 show good agreement between the simulated and measured responses.

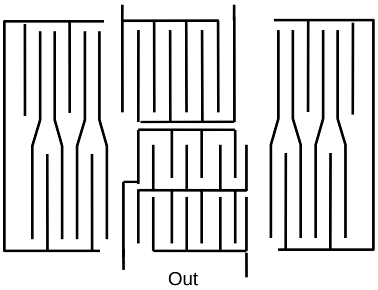

Fig. 1. Balanced SAW ring filter with impedance conversion

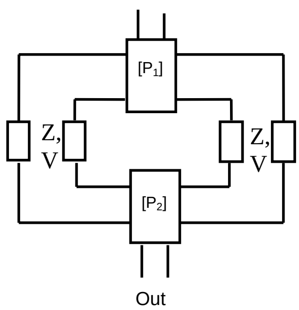

Fig. 2. Equivalent circuit of the balanced SAW ring filter

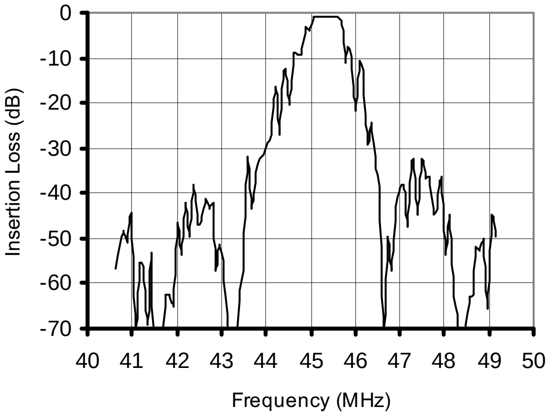

Fig. 3. Simulated frequency response of the ring filter

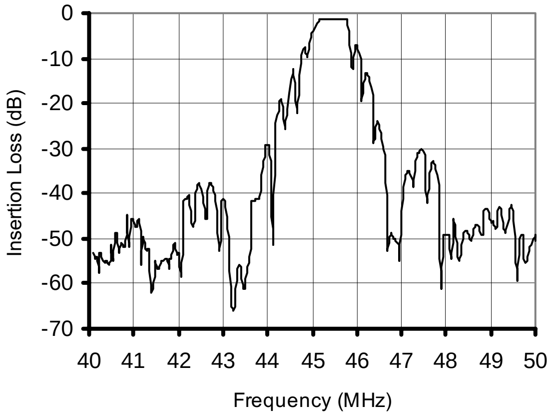

Fig. 4. Measured frequency response of the ring filter

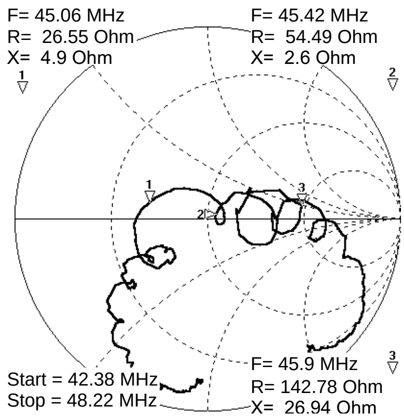

Fig. 5. Measured input impedance characteristic of the ring filter

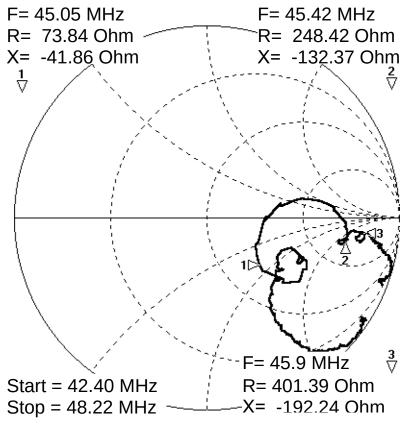

Fig. 6. Measured output impedance characteristic of the ring filter

A measured input impedance characteristic of the filter is shown in Fig. 5. As will be seen from Fig. 5 at the center frequency of 45.42 MHz the input impedance of the filter is close to real value of 50Ω. A measured output impedance characteristic of the filter is shown in Fig. 6. As will be seen from Fig. 6 at the center frequency of 45.42 MHz the output impedance of the filter is close to real value of 250Ω. Thus the impedance conversion from 50Ω to 250Ω was obtained experimentally in the low-loss SAW ring filter with the output sectional IDT (Fig. 1). To increase the stopband attenuation we can use phase weighting [6] in the input IDT of the balanced filter or cascading two filters The frequency response of the balanced filter with phase weighted input IDT is presented in Fig. 7. The stopband attenuation increased up to 50 dB and the insertion loss increased up to 2 dB. Fig. 8 shows the frequency response of the cascade of two balanced filters. The first filter is built with phase weighted input/output IDTs but without the impedance conversion. The second filter is built with the impedance conversion but without phase weighting input/output IDTs. In a 75-Ω–250-Ω symmetrical system the cascade structure has shown an insertion loss of less than 3 dB and the record attenuation around of 100 dB!

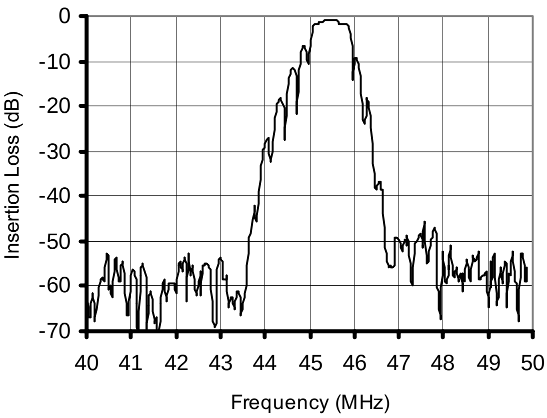

Fig. 7. Measured frequency response of the weighted balanced ring filter

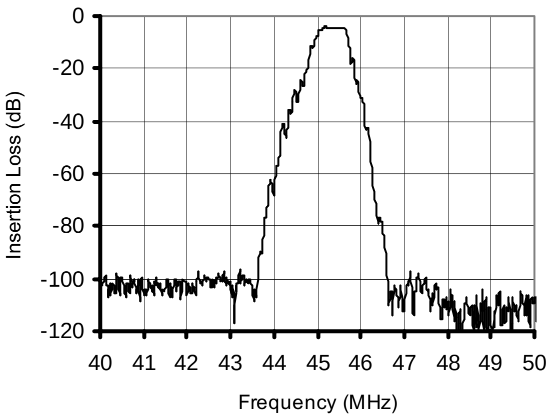

Fig. 8. Measured frequency response of the cascade balanced ring filter

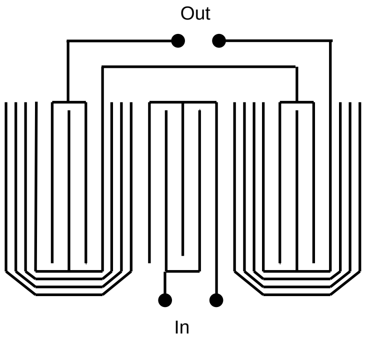

Fig. 9. Balanced three-transducer SAW filter on U-shaped MSCs with impedance conversion

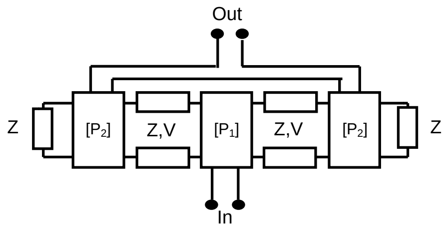

Fig. 10. Equivalent circuit of the balanced three-transducer SAW filter with U-shaped MSCs

4. BALANCED LOW-LOSS THREE-TRANSDUCER SAW FILTERS WITH IMPEDANCE CONVRESION

For a fractional bandwidth of 3–7% we used previously developed wideband low-loss three-transducer SAW filters with unidirectional IDTs on U-shaped MSCs on 128°YX, 64°YX, 41°YX $LiNbO_3$ [3] (Fig. 9). As will be seen from Fig. 9 in the three-transducer filter the input and output IDTs connected in series/parallel have not a common grounded busbar. So the symmetrical connection of the input and two output IDTs to the loads is possible. Consequently, the three-transducer filter can be both the balanced/unbalanced structure similar to the ring filter (Fig. 1). This construction allow to increase the output impedance in sufficiently large limits by a series connection of the outer unidirectional IDTs with U-shaped MSCs (Fig. 9). In this case as a simulation shows in three-transducer filter the impedance conversion as 1:4 is achievable. The optimization of the balanced three-transducer filters with impedance conversion was provided with the computer simulation using the equivalent circuit model [3]. The equivalent circuit of the balanced three-transducer filter using unidirectional IDTs on U-shaped MSCs is shown in Fig. 10. Here $[P_1]$ is a mixed matrix of IDT, $[P_2]$ — a mixed matrix of IDT with U-shaped MSC, Z — characteristic impedance of the medium between IDTs, V — SAW velocity. Fig. 11 shows a simulated frequency response of the filter on 128°YX in a symmetrical 50Ω–200Ω system. The filter has shown a 3-dB fractional bandwidth of 3.5% with minimal insertion loss and ripple, stopband attenuation of around 10 dB at ±4% offset from the center frequency. It can be shown that filters on 41°YX, 64°YX provide the similar frequency responses with 10% and 5% fractional bandwidth respectively and the impedance conversion from 75Ω to 250–300Ω. The measured frequency response of the filter on 128°YX is shown in Fig. 12. The filter has been symmetrically connected to 50Ω input load and to 150Ω output load. At the 70 MHz the filter has shown an insertion loss of less than 2 dB, 3-dB fractional bandwidth of 3.5% with a very low ripple of 0.1 dB and stopband attenuation around 12–15 dB at ±4% offset from the center frequency. Measurements of this filter were carried out similarly to the measurements of the ring filter. Fig. 11 and Fig. 12 show good agreement between the simulated and experimental responses. A measured input impedance characteristic of the filter is presented in Fig. 13. As will be seen from Fig. 13 at the center frequency of 70 MHz the input impedance of the filter is close to real value of 50Ω. A measured output impedance characteristic of the filter is shown in Fig. 14. As will be seen from Fig. 14 at the center frequency of 70 MHz the output impedance of the filter is close to real value of 150Ω. Thus the impedance conversion from 50Ω to 150Ω was obtained experimentally in the low-loss SAW three-transducer filter with series connection of the output unidirectional IDTs with U-shaped MSCs. To increase the stopband attenuation we can use the phase weighting in the input

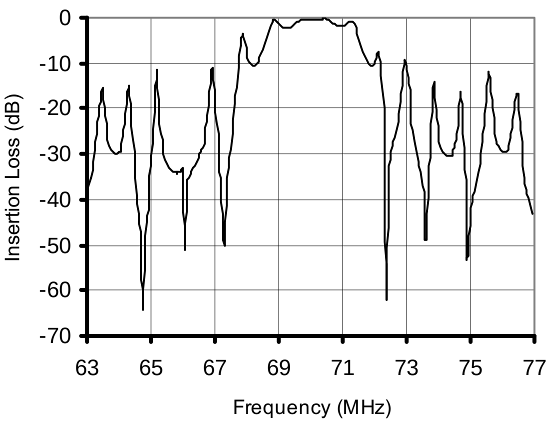

Fig. 11. Simulated frequency response of filter with U-shaped MSCs on 128° YX $LiNbO_3$

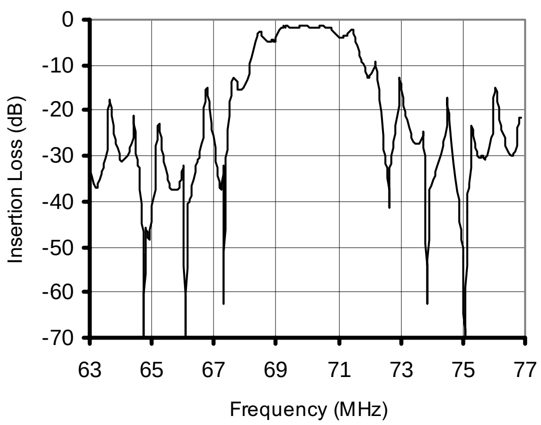

Fig. 12. Measured frequency response of filter with U-shaped MSCs on 128° YX $LiNbO_3$

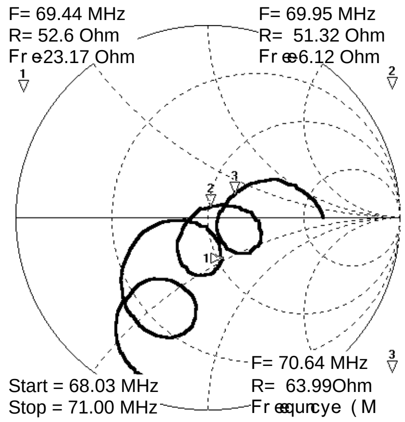

Fig. 13. Measured input impedance characteristic of the filter with U-shaped MSCs on 128° YX $LiNbO_3$

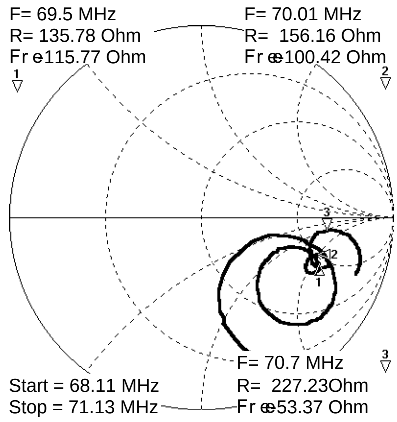

Fig. 14. Measured output impedance characteristic of the filter with U-shaped MSCs on 128° YX $LiNbO_3$

IDT balanced three-transducer filter or cascading two filters. Fig. 15 shows the frequency response of the 52 MHz balanced filter on 64°YX with the phase weighted central IDT. The filter was provided an insertion loss of around 2 dB, 3-dB fractional bandwidth of 4.9%, stopband attenuation of 35–40 dB in a symmetrical 50-Ω–200-Ω system. The frequency response of the 44 MHz balanced cascade filter on 41°YX is presented in Fig. 16. The first filter is built with phase weighted central IDT and parallel connection of outer unidirectional IDTs with U-shaped MSCs. The second filter is built with phase weighted central IDT and series connection of outer unidirectional IDTs with U-shaped MSCs. The intercascaded connection is realized via the phase weighted IDTs. The cascade filter has shown an insertion loss of around 3 dB, 3-dB fractional bandwidth of 7%, stopband attenuation over 60 dB in a symmetrical 75Ω – 250Ω system.

5. CONCLUSION

Developed SAW ring and three-transducer filter with a low insertion loss of 2-3 dB have demonstrated the balanced operation and impedance conversion in a wide fractional bandwidth of 1.5-7%. These filters have the wider functionalities than their much used prototypes and they are very promising for the front-end stages of the handheld VHF transceivers. In these HF stages the developed SAW filters will good match a low impedance antenna with modern high impedance double balanced mixer and provide the high suppression of the local oscillator frequency and image frequency.

6. REFERENCES

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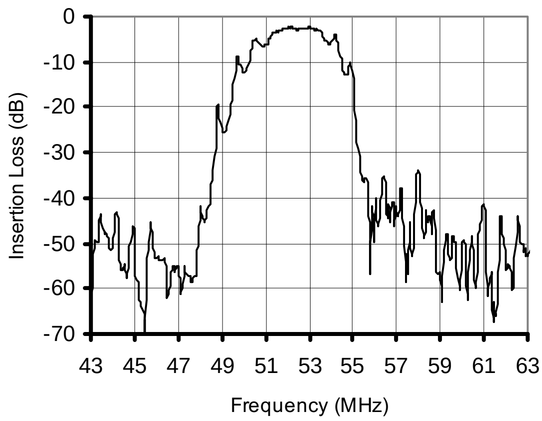

Fig. 15. Measured frequency response of the weighted SAW filter on 64° YX $LiNbO_3$

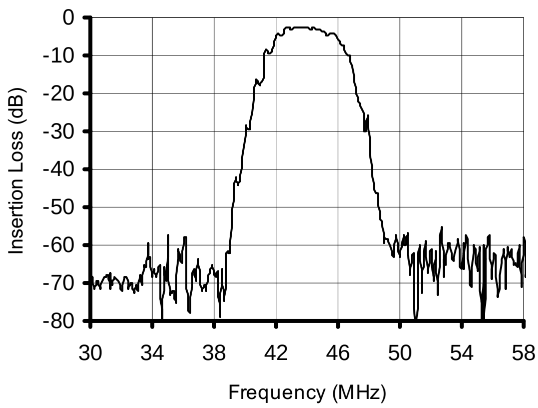

Fig. 16. Measured frequency response of the cascade filter on 41° YX $LiNbO_3$