A Compact 5.6GHz BAW Filter Design Using Meandered Path

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***Abstract*—In this study, we investigate the design of a 5.6GHz BAW filter, demonstrating how modifying the die layout can achieve a 45% reduction in size while maintaining nearly identical performance. A comparison of simulation results and measurement data reveals that the new die layout introduces only a slight increase in insertion loss (less than 0.12 dB) within the band, while exhibiting similar performance in terms of out-of-band characteristics, rejection levels, steepness, and return losses. These findings highlight the trade-off between size reduction and minimal performance loss, making the modified die layout a promising option for compact 5.6GHz filter designs.**

***Index Terms*—BAW, die layout, filter, compact design**

I. Introduction

The rapid evolution of wireless communication systems has created an increasing demand for compact, high-performance RF filters capable of operating across wider frequency bands and handling higher power levels. Bulk Acoustic Wave (BAW) technology has become indispensable due to its low insertion loss, sharp frequency selectivity and excellent out-of-band rejection [1]–[3]. While BAW filters are already more compact compared to other RF filters, further miniaturization is essential to address the needs of next-generation microwave circuits and devices. The compacting of the die layout offers significant advantages in line with current market trends, where the demand for smaller and more efficient electronic modules continues to grow. As devices shrink in size, achieving a compact design is crucial for meeting industry requirements and maintaining a competitive edge. Additionally, reducing the die size directly impacts manufacturing efficiency by enabling more filters per wafer, which lowers production costs and increases yield.

Among the various miniaturization methods [4]–[7], one particularly simple and effective approach is the use of meander lines instead of straight transmission lines, significantly reducing the device footprint. The equivalent meandered-straight line concept has been explored in [8], [9], and this method has been widely applied to minimize the size of different microwave devices such as waveguides [10], antennas [11], [12], couplers [13] , and filters [14], [15].

In this study, a compact 5.6GHz BAW filter is designed and analyzed using the meandered line method. Section II presents the filter design, including the die layout for both straight and meandered lines. Sections III details the simulation results. Finally, Section IV- validates the simulations through measurement results.

II. Design Environment

This section presents the design of a 5.6GHz BAW filter. The filter adopts a ladder topology comprising five series and five shunt resonators, starting with a series element. The design operates across three distinct frequencies: one for the shunt resonators and two for the series resonators. The key resonator parameters are summarized in Table I.

TABLE I
Resonator parameters

resonator	***Cap. (pF)***	***Area (μm2)***	***Freq. (MHz)***
Ser1	1.78	5244	5675
Ser2	1.05	3094	5675
Ser3	1.72	5193	5617
Ser4	1.55	4680	5617
Ser5	1.20	3521	5675
Shu1	1.36	4459	5386
Shu2	0.86	2811	5386
Shu3	0.82	2684	5386
Shu4	0.94	3090	5386
Shu5	0.96	3150	5386

Figure 1 illustrates two distinct die layouts of the filter. Figure 1(a) depicts the conventional layout, which employs a straight path from input to output. In contrast, Figure 1(b) features a meandered path designed to minimize the die size and maximize wafer area usage. This study aims to evaluate and compare the performance of the filter using these two layout configurations.

III. Simulation

To ensure a fair comparison, both designs are implemented on the same die, as illustrated in Figure 2. All parameters are kept as consistent as possible, except for the series path. The series path from input to output is highlighted with red arrows, and all other bumps are connected to ground.

Figure 3 presents the simulation results for insertion loss, Gmax, passband, wideband, and return losses at both input and output. The results for the straight and meandered designs are represented by black and blue traces, respectively. Both designs have port impedances of 80+j30 ohm . The straight design exhibits approximately 0.04 dB better performance at both the lower and upper bands. However, both designs

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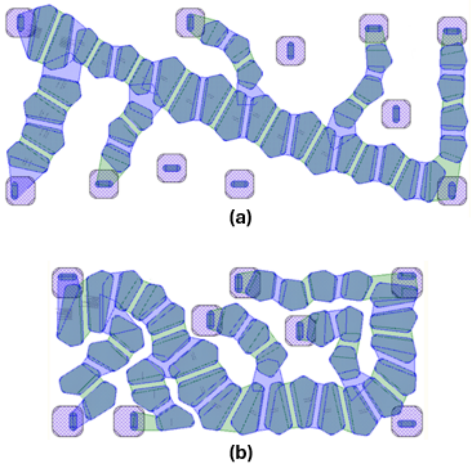

Fig. 1. Die layout of the filter: (a) Straight design, (b) Meandered design

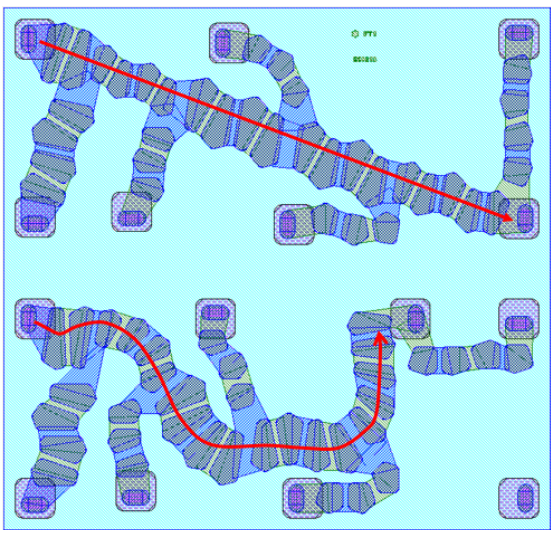

Fig. 2. Straight path design and meandered path design on the same die

demonstrate comparable steepness, rejection levels, and out-of-band performance. Additionally, the input and output return loss patterns are nearly identical within the frequency band for both designs.

IV. Measurement

To verify the accuracy of the simulation results, small-signal measurements were conducted for both designs. The die layouts are incorporated into a module footprint to assess their performance in a practical implementation. Figure 4 shows the laminate layouts, where black and blue colors represent the straight and meandered designs, respectively. The input and output ports of each design are connected through Metal 3 layers, ensuring proper integration within the module. Other metal layers are not shown here. The measurement is done using GSG probes as shown in Figure 5. These measurements provide an experimental validation of the simulation data and allow for a more comprehensive performance comparison. As

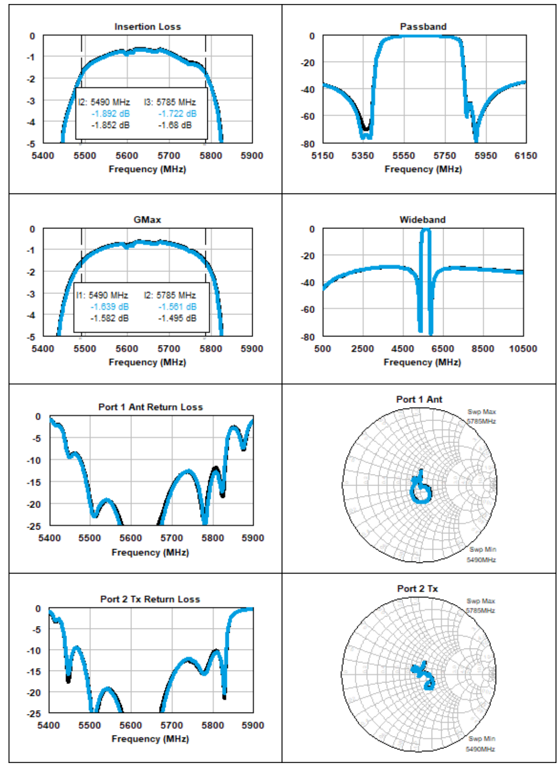

Fig. 3. Simulation results for both straight (black) and meandered (blue) designs: insertion loss, Gmax, pass-band, wide-band and input/output return losses

illustrated in Figure 6, the measured results align closely with the simulation data, confirming the validity of the simulation approach.

The measured insertion loss indicates that the straight design outperforms the meandered design by approximately 0.09 dB and 0.12 dB at the lower and upper band edges, respectively. This difference highlights the slight performance advantage of the straight design in terms of band-edge efficiency.Both designs exhibit similar out-of-band performance, including comparable rejection levels and steepness. However, the meandered design achieves this with a die size 45% of the straight design.

V. Conclusion

In conclusion, this study analyzed a 5.6GHz BAW filter design to compare the performance and practicality of straight and meandered die layouts. While the straight design demonstrated slightly better performance with lower insertion loss at the band edges, the meandered design offers a significant advantage in die size, achieving nearly half the area of the straight design. Despite the compact size, the meandered design maintains comparable out-of-band performance, rejection levels, and steepness, making it a highly efficient solution for wireless applications.

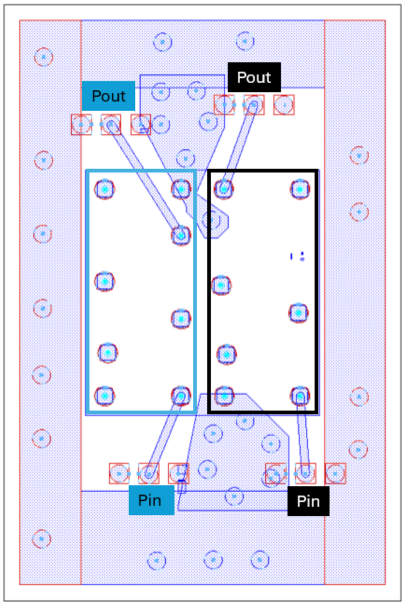

Fig. 4. Laminate design on 3mm×2mm module footprint

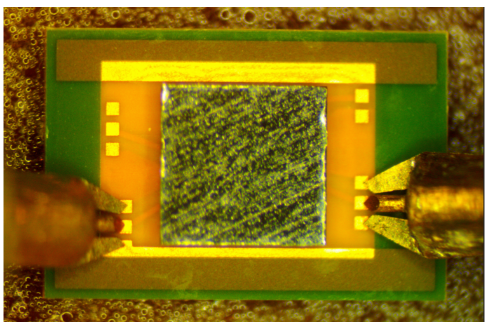

Fig. 5. Die under test using GSG probes

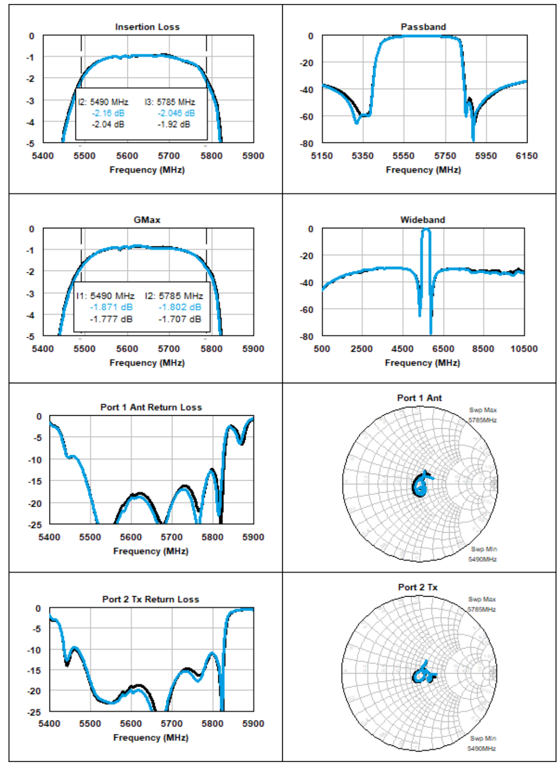

Fig. 6. Measurement results for both straight (black) and meandered (blue) designs: insertion loss, Gmax, pass-band, wide-band and input/output return losses

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