Design and Performance of a Multistrip Coupler

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Abstract

In this paper, an algorithm suitable for the computer aided design (CAD) has been developed, to give us a table of calculated data which can be used as a design tool for optimum multistrip-coupler. Design criteria for multistrip components are discussed in terms of substrate and bandwidth requirements. In other words, the effects of substrate types and center frequency on the performance of multi-strip coupler in the presence of material, limitations are demonstrated. The obtained results show that, different substrates will enable us to use relatively small size strips which leads to miniaturization the design as well as extends the usefulness of the strip lines to higher frequency.

Key Words: *BAW, MSC, SAW*

1- Introduction

The multistrip coupler, (MSC) [1] is a directional coupler for use with surface acoustic waves (SAW) [2]. It performs the function of propagating SAW on a piezoelectric substrate. It is described as a parallel metallic strips isolated from each other, spaced with a constant distance *d* and fabricated on piezoelectric substrate (Figure 1). Multistrip couplers eliminates the bulk wave problem which appears at higher frequency end of the filter passband, due to higher velocity of bulk wave than surface waves. In other words we can say that the major purpose of using MSC is to transfer laterally the surface power of the acoustic wave incident to one of its ports [3]. SAW device based multistrip coupler is a better scheme for various research and applications of SAW device [4]. It is noticed that the output acoustic wave occupies an adjacent track with respect to the incident input wave. So, in SAW filters, the multistrip couplers may be used between two interdigital transducers (IDTs). When the surface acoustic wave generated from one of the transducers into track A, an induced voltage generated between metallic strips due to piezoelectric substrate. So, the coupling action occurs. Because the metal strips considered perfect conductors, so the same voltages are launched in the second track generating a secondary output surface wave.

The frequency response of SAW device with Multistrip coupler can be obtained by the product of the transfer function of two apodized interdigital transducers. MSC may fully transfer SAW without effecting Bulk acoustic wave (BAW) continuing to propagate in the primitive acoustic track

[5]. The bulk acoustic wave may be suppressed by Multistrip coupler [6]. Another important criteria in studying MSC is the inversely proportional relation between the number of the metallic strips in MSC depends and the piezoelectric coupling of the piezoelectric substrate material such as GaAS Z, LiTaO3 YZ, Quartz ST, YX Quartz, and YZ LiNbO3.

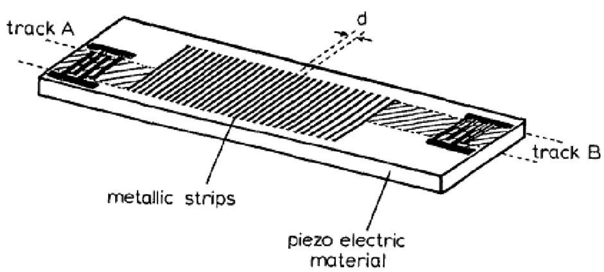

Figure 1: the basic multistrip directional coupler [8].

The multistrip coupler (MSC) can be used as a directional coupler to transfer SAW energy from one acoustic path like (track A) to another acoustic path (track B) with low possible loss. The multistrip coupler also mainly used for energy transfer in wide frequency bands. There are many applications based on using multistrip coupler like operating as a former of frequency modulated signals or as a high selectivity bandpass filter [7], also in unidirectional transducers, surface wave mirrors with very low reflection loss, reduction of bulk wave responses, magic TS, and many other applications. In case of using SAW multistrip coupler as SAW filters it is known that while one of the interdigital transducers, either the input or output IDTs, is apodized, then the other IDT have to be unapodized. This restriction because the wave front of an apodized transducer is not uniform in amplitude. A multistrip coupler placed between the two IDTs to average the wave front from the input IDT causing a uniform wave front on the second one, and allows both input and output transducers to be apodized [8].

2- Approach to Design of MSC.

The multistrip coupler is designed to minimize the effect of Fresnel ripples exist in the amplitude of the acoustic signal generated in the output acoustic track versus frequency characteristics of the device [9].

The basic multistrip directional coupler structure is consists of a series of parallel metallic strips fabricated on a piezoelectric substrate lying in and perpendicular to the path of an acoustic beam which is of smaller aperture than the complete width of the coupler. The wave launched in track B propagates only in the direction of the wave in track A, and the launching efficiency is only weakly dependent upon frequency [10]. There are no interconnections between the strips, so the broad bandwidth arises. An optimum multistrip coupler design obtained if each pair of strips is regarded as a single-finger-pair transducer in track A, coupled directly to a similar transducer in track B. At the stopband ($\lambda = 2d$, d is the distance between strips), strong reflections can occur, and the simple coupler action breaks down.

An important parameter of the MSC is the number of strips necessary to transfer a given fraction of power from one track to another.

$$N_T = \frac{\pi}{FK^2} \cdot \frac{\theta/2}{\{Sin(\theta/2)\}^2} \qquad (1)$$

Where

$$\theta = \frac{2\pi f \alpha d}{\upsilon} \qquad (2)$$

Here θ is the phase shift in a periodic section, FK^2 is effective coupling constant, f is the SAW frequency, d is the repeat distance of periodic MSC, υ is SAW velocity, and α is activity factor. The frequency scale is normalized to the stopband frequency, it uses the assumption that MSC behavior scales with repeat distance.

Thus,

$$f_n = f/f_o = \theta/\pi\alpha \qquad (3)$$

The expression for a perfectly anisotropic film may be obtained as

$$N_T = \frac{2}{K^2}\left(\frac{f}{f_o}\right)^{-1} \qquad (4)$$

$\boldsymbol{N_T}$ is the number of strips for 100% transfer of energy between tracks. The minimum value of $\boldsymbol{N_T}$ is obtained when the strips are approximately as wide as gaps between them. In figure 3 number of strips N_T is plotted against normalized frequency (figure 3). This figure obtained using equations [1], [2], and [3].

There are some specific features may be obtained from the curve such as a minimum value of N_T, a characteristic shape of the stopband, the frequency f_o at which a stopband occurs. These features are controlled by separate parameters. The value of the minimum for N_T is determined by the effective coupling constant FK^2, The stopband frequency controlled by the repeat distance, $f_o = \upsilon/2d$, The frequency of the minimum N_T is controlled by the length of the active element of the line αd.

Finally, it is clear that Multistrip coupler simple structures offer some features like high bandwidth, no external connections are required for their operation. Their main disadvantage is that the use of a high K^2 material is necessary for many of the structures to avoid them becoming unacceptable owing to the path length they occupy.

3- Analysis of MSC.

In our designed Multistrip coupler, both acoustic tracks are identical and have equal aperture. The width of the acoustic tracks is much larger than the MSC period. The number of the MSC strips is sufficiently large. Coupling to bulk waves can be neglected. Diffraction of the acoustic waves can be neglected. Surface waves propagate perpendicular to the strips. Metal strips are infinitely thin and deposited on a strongly piezoelectric substrate like lithium niobate.

4 - Results and discussions

An algorithm established using computer aided design (CAD) to design the multistrip coupler, the estimated program based on calculating the number of strips, and the width of strip or gap width for different values of center frequency, and for a selected substrate from five different substrates (YZ LiNbO3, YX Quartz, LiTaO3 YZ, GaAs Z, and Quartz ST). We have selected the Normal mode representation of a Multistrip coupler in our design consideration. Figure 2 show our algorithm sequence in form of flowchart. Our algorithm idea described briefly within the following example of a selected substrate like Quartz ST, we selected the

$K^2 = 1.1*10^{-3}$ (5)

$C_s = 0.55 * 10^{12}$ pf/cm (6)

$V_s = 3.158*10^5$ cm/s (7)

Then we used the following equation in our algorithm for each substrate, $f_o = 10^6 * f_o$, λ= Vs/fo, R=0.6, γ=0.375, L= λ /(R*K^2), b= γ * λ, Number of strips= L/b, and Strip length = b/2.Then we repeat the previous equations for the four other substrates but for other values of K^2, C_s, and V_s. The results have been calculated according to our established different values of center frequencies and different substrates, shown in (table 1). The obtained results compared with experimental published results [11]. Also, it is noticed that for higher center frequency, the width of strip or gap strip decreased. While number of strips change according to type of substrate. On a plot of N_T against normalized frequency, this gives a rectangular hyperbola.

Table 1: calculated parameters of multistrip coupler.

Center frequency (MHz)	Width of strips in (micron) for Selected substrates				
	GaAs Z	LiTaO3 YZ	Quartz ST	YX Quartz	YZ LiNbO3
25	20.7225	24.6925	23.685	23.6925	26.16
50	10.3613	12.1125	11.8425	11.8463	13.08
75	6.9075	8.075	7.895	7.8975	8.72
100	5.1806	6.0562	5.9212	5.9231	6.54
125	4.1445	4.845	4.737	4.7385	5.232
150	3.4538	4.0375	3.9475	3.9487	4.36
175	2.9604	3.4607	3.3836	3.3846	3.7371
200	2.5903	3.0281	2.9606	2.9616	3.27
225	2.3025	2.6917	2.6317	2.6325	2.9067
250	2.0722	2.4225	2.3685	2.3692	2.616

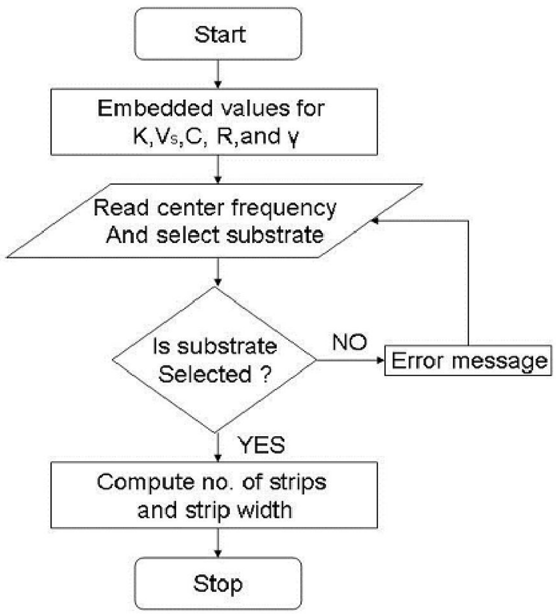

Figure 2: algorithm flowchart of the program.

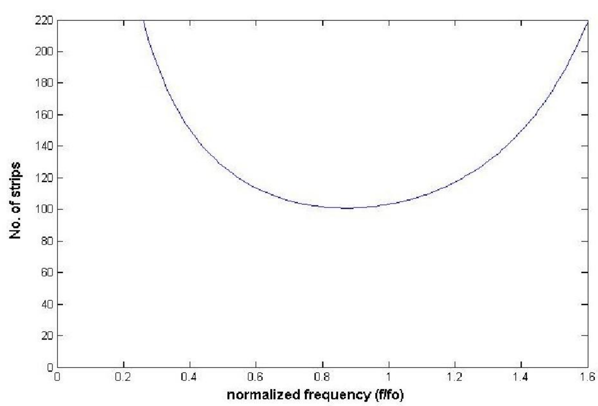

Figure 3: the number of strips for transfer plotted against frequency normalized to the first stopband frequency using our constructed algorithm.

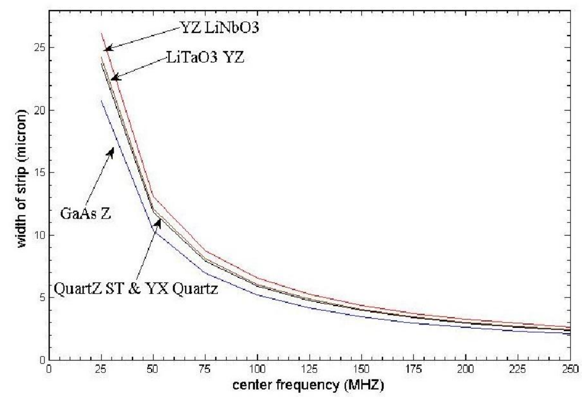

Figure 4: the relation between center frequency and gap width of strip for different substrates.

5 – Conclusion

In this paper our objective has been to develop a method of analyzing the behavior of the multistrip coupler which leads to useful design criteria. A simple computer algorithm has been constructed as a tool to achieve this design. The ability to produce high performance multistrip coupler with small dimensions achieved with our simulation program. Number of strips N_T and width of strip are two main important parameters included in our algorithm which depends on type of substrate, and center frequency, respectively. It is noticed that for higher center frequency, the strip width decreased. Also the minimum value of N_T is obtained when the strips are approximately as wide as gaps between them. This constructed program simulates quickly, but does not include sufficient information detail for MSC design. Finally, this model relies on simplistic approximations although it is incapable of considering some other parameters.

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