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Research Article

Acoustic Electric Generation for Morlet Wavelet Transform of Surface Acoustic Wave Device

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Abstract: Surface Acoustic Wave (SAW) device is present in application ranging from professional radar and communication systems for its excellent properties, namely, passive, small size, low cost, excellent temperature stability, high reliability and high reproducibility. But the waveform can be influenced by the error of acoustic electricity regeneration. In the study, acoustic electric generation of SAW device is decreased by using different materials and changing spread speed of SAW materials and selecting variable electrode structures for tilt and double of Interdigital Transducer (IDT). In addition, parameters about IDT of Morlet wavelet transform and the waveform point coordinates are calculated. The L-edit software is used to drawing tilt or double electrode variable fork and the painting size is also done precisely.

Keywords: Acoustic electric generation, Interdigital Transducer (IDT), L-edit, Morlet wavelet transform, Surface Acoustic Wave (SAW) device

INTRODUCTION

Wavelet transform has found application in a variety of fields, such as communication, radar, water-sound, mechanical vibration and chemical industry. The Acoustic wave has been used in electronics for many years. Rayleigh found the SAW firstly in 1885 (Rayleigh, 1885). The first application of SAW dates from 1965 with the invention of the piezoelectric transducer, in the form of an interdigital comb, by an American scientist (White *et al*., 1965). These devices have exceptional versatility because the propagation path is accessible to components for generating, receiving or modifying the waves. The advantages of SAW are its ability to electro-acoustically access and tap the wave at the crystal surface and its wave velocity is approximately 100,000 times slower than an electromagnetic wave (Brocato, 2004).

And now, except more stability and best properties, the researches pay more attention on error of SAW device including second-order error which is the most important one, process technology and signal source resistance (Subramanian and Bhethanabotla, 2008). The second-order errors also include acoustic electric generation, triple-transition reflection, waveform distortion and body wave problem and finger reflection.

The study researches on errors of acoustic electricity regeneration. In this study, the working principle of IDT and ultimate principle of SAW were recorded, Simulation of Morlet waveform for envelope structure of IDT were handled by MATLAB, the characteristics of different materials and the method of selecting materials were also introduced, the electrode structures for tilt and double of IDT were constructed clearly (Lu and Zhu, 2010; Wen and Zhu, 2006).

Finally, the painting size of tilt and double electrode variable fork was measured and calculated precisely by using L-edit software. It can be concluded that using different materials and changing spread speed of SAW materials and selecting variable electrode structures for tilt and double of IDT can decrease acoustic electric generation of SAW.

WORKING PRINCIPLE OF IDT

The IDT is metal cross-shaped patterns like fingers, which precipitate on the piezoelectric substrate surface. The role of IDT is to achieve acoustic-electricity conversion. Because of its low loss, flexibility in design and easy manufacture, IDT obtains a widespread application and it becomes the important part of each kind of SAW, the structure of IDT is shown in Fig. 1.

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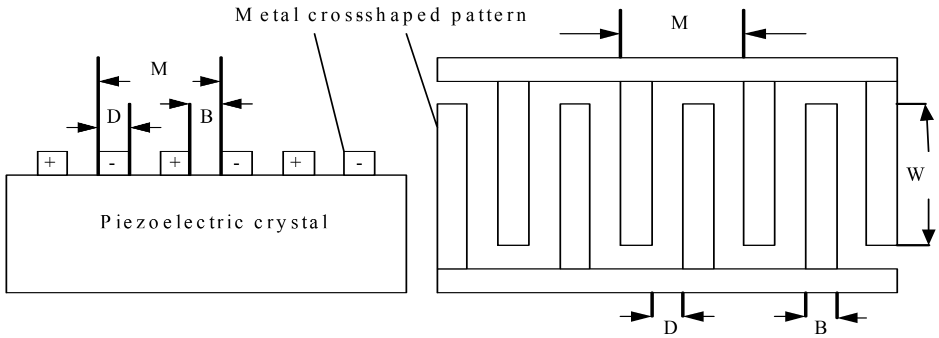


Fig. 1: The structure of IDT

The technique parameters are as follows, M is wavelength of SAW, W is cross diameter, D is width of IDT, B is interval of IDT.

The speed of SAW is V_s, the cycle of SAW is T and the center frequency is f_0 and M is defined as in:

$$M = V_s T = \frac{V_s}{f_0}$$

The following result can be deduced from above equation:

M = 2D+2B
Let D = B, then
M = 4D

According this equation, the formula can be deduced:

$$D = B = \frac{V_s}{4f_0}$$

If we select the substrate of fork piezoelectric transducer, then V_s is a definite value, while from equation the D and B can be determined, so last equation is the basic theory to design IDT.

ULTIMATE PRINCIPLE OF SAW

The SAW has the basic structure and it manufacture 2 acoustic electric transducers on the piezoelectric characteristic substrate material polishing surface, named Input and Output of IDT. The structure of SAW is shown in Fig. 2.

One of the unique advantages of SAW transducer is the internal weighting and then to obtain the desired time or frequency domain response. Typically, the surface acoustic wave system can be expressed in the form of Fig. 3.

The frequency response of system can be expressed as:

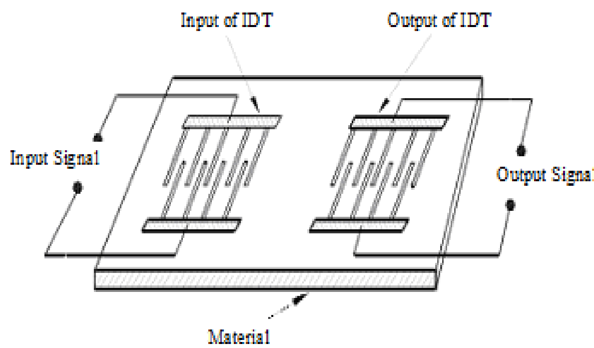


Fig. 2: Structure of SAWF

$$H(\omega) = \frac{U_0}{U_i} = H_1(\omega) e^{-j\frac{\omega L}{V_s}} H_2(\omega)$$

where,

$H_1(\omega)$ = The frequency response of the transmission interdigital transducer
$H_2(\omega)$ = The frequency response of the receiving interdigital transducer
$e^{-j\frac{\omega L}{V_s}}$ = The SAW delay network
L = The distance between 2 interdigital transducers

THREE METHODS TO SOLVING ACOUSTIC ELECTRIC GENERATION ERROR OF SAW DEVICE

Selecting different materials: Acoustic electric generation is decided by the electro-mechanical coupling factor of IDT that is K^2. When K^2 is higher, the acoustic electric generation is stronger, the interaction between IDT and acoustic wave is powerful. Different materials has different performance, such as single crystal material of SAW need low loss, high reliability and good repeatability, but higher electro-mechanical coupling factor and lower temperature coefficient are in opposition to each other.

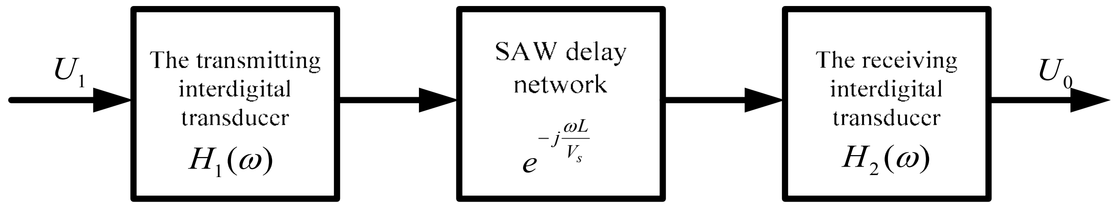


Fig. 3: The principle diagram of SAW

Table 1: Characteristics of different materials

Material	Speed of SAW (m/s)	Electro-mechanical coupling factor k2/%	Film thickness/wavelength	Temperature coefficient
ZnO	5000	9.5	0.13	30
ALN	5500	4.2	0.24	-
CdS	1700	11.8	-	-
ZnS	3900	-	0.40	-
$KNbO_3$	-	2.1	0.24	-
$LiNbO_3$	9000	1.2	-	0
$LiT\alpha O_3$	3295	6.4	-	0

Above all, the most important problem is to select K^2 of different materials because K^2 has significant effect on materials.

From Table 1 we know some characteristics of different materials. Therefore, the piezoelectric single crystal material is usually used to solving acoustic electric generation of SAW. Because K^2 for $LiTaO_3$ have lower value in piezoelectric single crystal than other materials, $LiTaO_3$ are more adaptive to deal with acoustic electric generation of SAW.

RECONSTRUCTING THE STRUCTURE OF IDT

Tilt structure of IDT: The interaction field between acoustic wave and interdigital electrode can be decreased by tilt structure of IDT. The acoustic electric regeneration and the edge reflection of interdigital electrode also can be reduced. The wavelet function is:

$$\psi_s(t) = \frac{1}{\sqrt{s}}\psi(\frac{t}{s}),$$

where,
S : The scale of wavelet function

The wavelet transform of signal f(t) is given:

$$WT_s(\tau) = f(t)\psi_s(t) = \int_R f(t)\frac{1}{\sqrt{s}}\psi(\frac{\tau - t}{s})\mathrm{d}t$$
$$= \frac{1}{\sqrt{s}}\int_R f(t)\psi(\frac{\tau - t}{s})\mathrm{d}t.$$

When ψ_s (t) is a Morlet wavelet function, formula can be converted into:

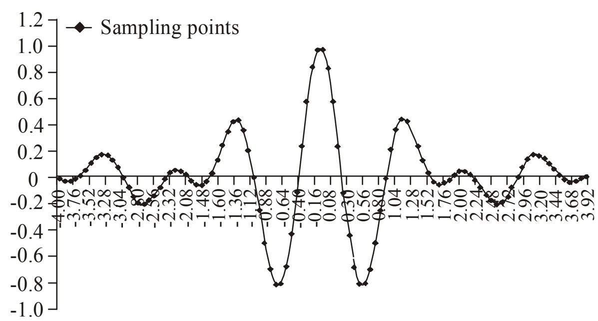


Fig. 4: Input transducer design of Morlet waveform

$$\psi_s(t) = \frac{1}{\sqrt{s}}\mathrm{e}^{-\frac{1}{2}(\frac{t}{s})^2}\mathrm{e}^{j2\pi\frac{f_0}{s}t}$$
$$= P_s(t)\mathrm{e}^{j2\pi\frac{f_0}{s}t},$$

Where P_s (t) is the wavelet-envelop function.

$P_s(t) = \frac{1}{\sqrt{s}}\mathrm{e}^{-\frac{1}{2}(\frac{t}{s})^2}$, $\frac{f_0}{s}$ is the center frequency [12-13]. The simulation of Morlet waveform by using MATLAB is in Fig. 4.

In the study, 100 pairs of interdigital electrodes are used to design IDT, the material of $LiTaO_3$ is selected for its lower electro-mechanical coupling factor which is 0.64. The speed of surface acoustic wave on $LiTaO_3$ is 3295 m/s and the equation of width of IDT is as follows:

$$a = \frac{v_s}{4f_0}$$

In the above equation v_s = 3295 m/s, f_0 = 27.375 MHz and α = 30 µm.

The interval of IDT is equal to the width of IDT, then α = b = 30 µm.

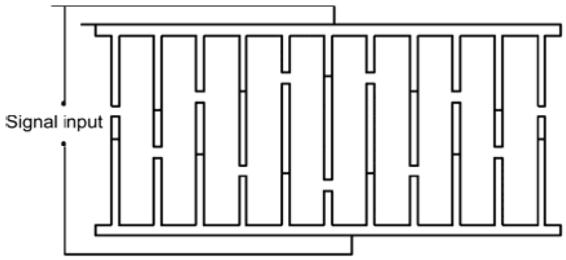


Fig. 5: Input transducer design of Morlet waveform

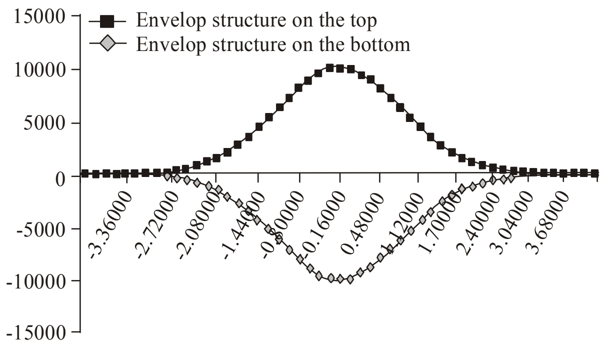
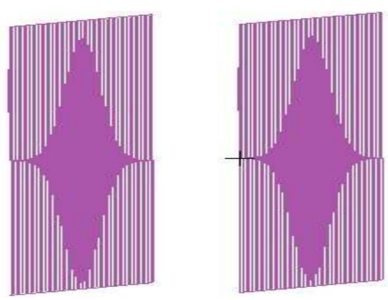


Fig. 6: Simulation of Morlet waveform for envelope structure of IDT



(a) (b)

Fig. 7: Tilt structure of IDT (a) input of IDT, (b) output of IDT

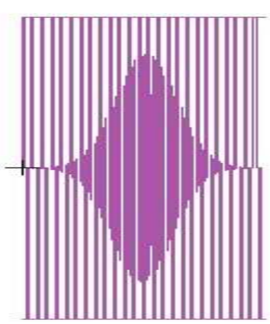


Fig. 8: Double structure of IDT

Figure 5 is the input transducer design of Morlet waveform and the simulation of Tilt structure of IDT is shown in Fig. 6 by using MATLAB.

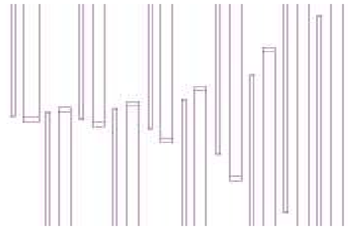


Fig. 9: Detail structure of IDT

The point of each interdigital electrode can be calculated first, then the finger is drowning by using L-Edit software and the unit is μm. The inclination of IDT is 15°. Input and output of tilt IDT are same to each other, the structure is shown in Fig. 7 and its width is 6 mm.

Double structure of IDT: If the width of IDT for double electrode are λ/16 and 3/16 λ and the interval of IDT is 2λ/16, a phase relation between edge reflection of IDT and acoustic electric regeneration can be cancel out each other. Construction process is as same as tilt structure of IDT. The equation can be expressed as:

$$\lambda = \frac{v_s}{f_0}$$

where,
v_s = 3295 m/s
f_0 = 30 MHz

then λ = 109.83 μm, the widths of IDT of double electrode are λ/16 and 3/16λ, so the real widths are 6.86 and 20.59 μm.

The point of each interdigital electrode can be calculated in the same way, then the finger is drown by L-Edit software like Fig. 8 and its detail structure is expressed in Fig. 9.

CONCLUSION

The method of decreasing acoustic electric generation for Morlet wavelet transform processor with an SAW device is proposed in the study. Three different methods are given to resolve the error, selecting different materials and changing spread speed of SAW materials and using tilt and double of IDT construction. The theory and the simulation results confirm that the SAW device can implement the Morlet wavelet transform processor, so we draw the conclusion that when 3 kinds of method are used, the acoustic electric generation can be decreased.

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