SAW AND INTERDIGITAL TRANSDUCERS

Sapna Tyagi[1] and Varde G. Mahesh[2]

Abstract- A review of the surface acoustic waves, SAW devices and their uses along with the applications of SAW devices is given in this paper. Here is a review of transducers which serve the main function in SAW devices. SAW transducer helps in generating the signals constructively and destructively both. The bus bars used in transducers help in performing this function. These bus bars are also called as finger pairs. With the help of the finger pairs we are able to calculate the transfer function of the devices and related parameters also. Also we will study the apodization term which takes place in SAW transducer used in the communication systems and see how this helps in generating a signal into a sinusoidal signal and then how it gives its impulse response. Then, we see some SAW devices along with their applications. Currently, there is some fabrication work is going on in the field of diamonds so that diamond film can be fabricated on the substrate as diamond has different properties in comparison to the piezoelectric materials.

Index Terms- SAW, IDT (Inter Digital Transducer), Apodization.

1. INTRODUCTION

A surface acoustic wave is a wave which travels along the material surface which exhibits elasticity and amplitude of material decays with the depth into the substrate. The motion of these waves arises the possibility for accessing the wave within its propagation path and helps in increasing the versatility of the devices. The main key point in these devices is the invention of InterDigital Transducer (IDT) in 1965. IDT helps the SAW devices to generate acoustic waves on the surface of the piezoelectric crystal that includes quartz or lithium niobate on which a thin metallic film is deposited. These waves travel along an acoustic path to either of the reflector or second transducer where these two are formed of two sections that Operate at mutually different frequencies. IDT converts an electrical signal into a Rayleigh wave or vice versa as IDT is has the reversible property which operates as both emitter as well as receiver. In case of solid materials, wave involves some changes in the positions of the atoms and is termed as strains. Also we can specify these position changes in terms of displacement from their equilibrium state. The material generates some internal forces in the presence of strains which intend the material to return to its equilibrium state. Here the internal forces are called as stresses and SAW involves both stress and strain as it is a propagating phenomenon. Waves propagating inside the solid material freely are called as bulk waves. Where in an isotropic solids, all the variables are constant over a plane and known as wave front and the direction of propagation is normal to the wave front. Basically, acoustic waves are of two types: longitudinal waves and transverse waves. The waves in which displacement is parallel to the direction of propagation is longitudinal wave and if we have the displacement in any of the direction parallel to the wave front is transverse wave. Transverse waves are also called as shear waves. The propagation velocity of longitudinal wave is 6000m/s and that of transverse wave is 3000m/s.

Now in the coming sections, in section II, we study about SAW transducers that how inter digital

- *Sapna Tyagi pursuing masters degree program in department of electronics and communication engineering in Amity School of engineering and Technology,Noida,Uttar Pradesh, India,E-mail: sapna_tyagi@ymail.com*
- *Varde G. Mahesh pursuing masters degree program in department of electronics and communication engineering in Amity School of engineering and Technology,Noida,Uttar Pradesh, India, E-mail: vardemahesh@yahoo.co.in*

transducers help in generating signals with the help of the electrodes. In this section, we also see the structure of transducers. In section III, we see apodization, in which we see how we obtained the impulse response of the sinusoidal signal. Section IV, will give some information about SAW devices that includes SAW delay lines and resonators where in section V, we see some of the applications and lastly, in section VI, along with the conclusion the work which is going on is also given. Let's take each section one by one.

2. SAW TRANSDUCERS

The interdigital transducer is the key point in the surface acoustic waves. The transducer is a source which is used for generation and reception of waves. It is made of sequence of metal electrodes which consists mainly of aluminum and they are connected to two bus bars.

The given figure clearly shows us the SAW device in which we are using two IDTs where one IDT is used for generation of waves and other one is used for reception of waves. Here device uses a substrate, a piezoelectric material showing that electric and mechanical fields are coupled within the material [4]. Quartz and lithium niobate are the materials which we used as a piezoelectric material. We can use lithium tantalite material also.

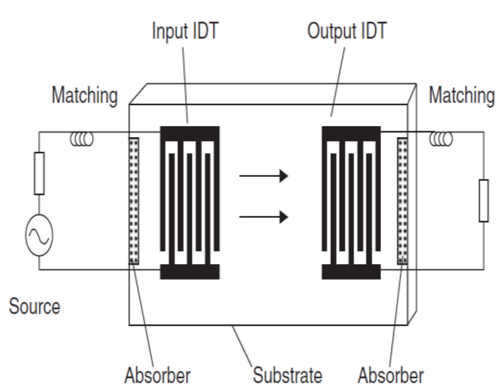

Figure 1. SAW device showing two IDTs

In the above figure, when a voltage is applied at the first IDT, it generates an electric field and at the receiver side we received the generated wave which converts the electrical input signal into an electrical output signal. A transducer may have up to 1000 electrodes and these electrodes are also called as bus bars. The time varying electric fields between the adjacent electrodes at the input of IDT helps in converting the electric fields into the mechanical acoustic waves and converse of this takes place at the output of that IDT.

Basically, IDT is a three port device which has 1 electric port and two acoustic ports. Whenever we take an electrical signal as input signal, SAW is generated from both the acoustic ports and if we provide the input at one acoustic port, wave is generated from the other port and electric signal also takes place across the bus bars due the voltage which is present across the IDT electrodes. The nature of this 3 port device results in regeneration with the help of which 3db bidirectional loss can be controlled.

2.1 Structure of IDT:

We have different structures of IDT according to the different characteristics they have. These characteristic may be differ according to the geometry, fabrication properties, frequency varying factor, etc. Here we see the two IDT structures which differ from each other on the basis of their geometry, phase angle and wavelength. These two termed as 'single-electrode' and 'double-electrode'. Let us take them separately.

2.2 Single Electrode IDT:

In this type, there is a uniform spacing between the bus bars and here the acoustic wavelength, $\lambda 0$ equals to twice of the pitch of the electrode,2p i.e.,$\lambda 0 = 2p$. There is a phenomenon called as internal reflection takes place in single electrode IDTs and that is why they are also called as reflective transducers.

Figure 2 is showing the reflective phenomena in single electrode IDT. In the figure, there is a weak reflection but if we add them in phase these reflections become powerful. But to solve this issue we use double electrodes IDT.

2.1.2 Double Electrode IDT:

In this we have electrode connected to two bus bars in pairs and reflections in the adjacent electrodes have phase angle differing by 180 degree. The electrode pitch p equals to $\lambda 0/4$. We can also call it as non-reflective transducers.

Figure 2 is showing the non-reflective phenomena in double electrode IDT. Among the two, we choose double electrode IDT because the distortion of frequency response caused by single electrodes is difficult to deal with. The decrement in pitch of the electrode from λ0/2 to λ0/4 limits the operating frequency.

Below is figure showing single and double electrode IDTs and reflective phenomena is taking place in both the electrodes.

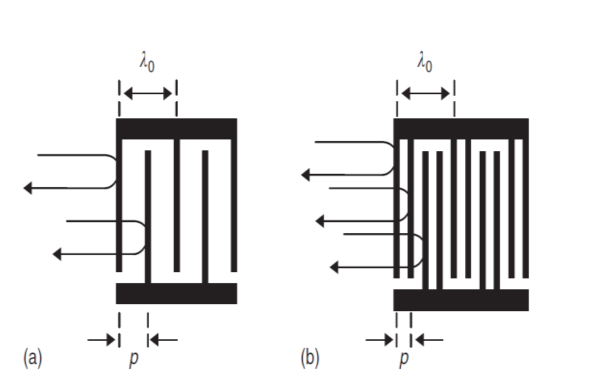

Figure2 (a) Single-electrode transducer (b) Double-electrode transducer.

3. APODIZATION

Apodization is the term which we use in transducer for obtaining the impulse response of the signal generated in it, in which the overlapping of the bus bars varies according to the length of the transducers. Mainly, here we get the impulse response of the signal. For generating a wave pulse, we provide a short pulse travelling along the surface to the input and at the output we get the electrical signal appearing at the bus bars. The overlapping of the electrodes is equal to the strength of the signal and we obtain the impulse response which is a function of frequency where electrical signal is the function of time [1].

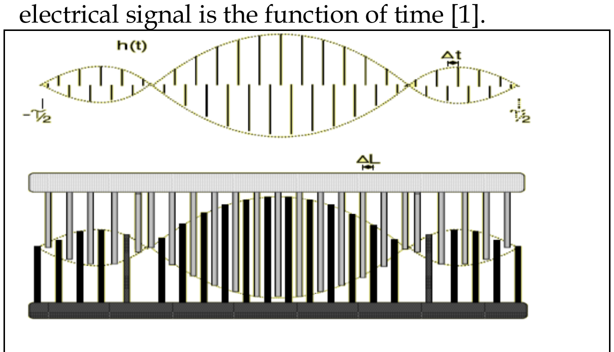

Figure 3. Schematic representation of an impulse responseoverlapping into an apodized IDT

With the help of this apodization, we can easily obtain any kind of impulse response from the frequency response of any signal.

4. SAW DEVICES

We can use SAW devices with wired or wireless connections both. With the advancements in the wireless communications these devices become complex and critical for electronic manufacturers. Today SAW devices are provided to a wide range of filters and resonators. SAW resonators may be one port or two ports and their frequency ranges from (200MHz-600MHz) approx. Whereas SAW filters can be of RF SAW filter whose frequency ranges from (0.1GHz to 2GHz) approx. or IF SAW filter whose range varies from (10MHz-500MHz) approx. As SAW devices are manufactured using photolithography only, the cost of the components remain low for high quantities. Below we are taking two SAW devices:

(i) SAW Delay Line, (ii) SAW Resonator [9]

4.1 SAW Delay Lines:

In SAW devices, an electrical delay is received by an acoustic propagation length, selection of frequency according to the geometry and period of the IDT electrodes. Since the propagation of SAW is slower than an electromagnetic wave (EMW), it delays an electrical signal up to several tens of µs, which corresponds to a few km EMW propagation. Actually here the widening of impulse due to the convolution of burst response and bursts and unwanted effects due to triple transit signal are neglected. SAW delay lines uses the propagation delay T= L/vsaw between IDTs, the ratio of length and velocity.

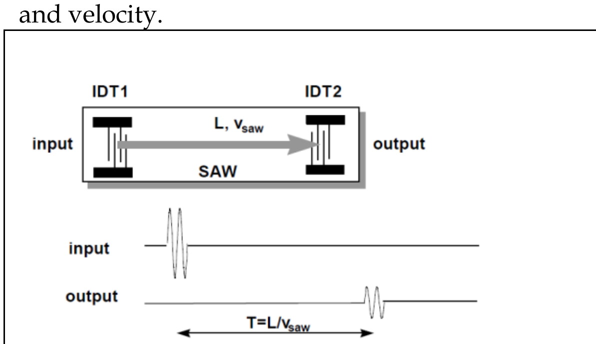

Figure 4. SAW Delay Line

4.2 SAW Resonator

The resonance frequency is determined by the reflector period d=□saw/2 geometrically. The resonance frequency is shifted due to the changes that take place in velocity and wavelength of SAW. Also, the reflectivity of the reflectors having fixed geometric period d leads to the changes in the above said parameters. The Q, Quality factor of the resonator is 1/ (ωrCmr), where the resistance r stands for losses. The resonator can also be used as a controlling element for a high-stability oscillator.

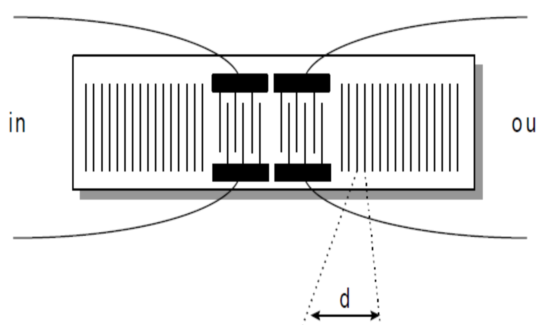

Figure 5. SAW Resonator

5. SAW APPLICATIONS

Presently, these components are getting implemented in mobile phones, wireless LAN systems, RF remote control systems, etc. The market for these devices is still growing for the manufacturers. SAW devices mainly helps in the field of sensor technology and can operate in the harsh environments. The use of wireless, battery free, low maintenance SAW sensors has been successfully demonstrated in applications including high temperature turbine engines and inflatable aerospace structures. With the help of wireless passive SAW sensors many parameters can be found out. SAW also helps in monitoring various health monitoring vehicles which ensures the safety of the vehicle. Another application of these devices is in measuring both temperature and pressure of in the combustion chamber of thermal engines.

6. CONCLUSIONS

Lastly, the conclusion after whole study is that SAW tags and sensors are very much useful in wireless and multiple access system. In passive wireless SAW device systems, insertion loss is the main designing parameter, and by minimizing it more power is returned from the device which increases the read out distance of the device as required in practical applications.[6]

The current research uses a bi-directional transducer. For eliminating some transducer loss and unwanted delay signals between reflector and input transducer a unidirectional transducers can be used .If a UDT is used properly reflections coming from the acoustic port can be eliminated and all energy from incident surface wave can be coupled to the electrical port.[8]

Presently, work is going on that how we can use diamond in SAW devices because diamond is not a piezoelectric material so it cannot be used in SAW devices by itself. But on the other hand, diamond has some hard properties also, so fabrication work is going on in this field for depositing the diamond film on the substrate as it looks very appealing but there are some difficulties in this. So this work is going on in progress for overcoming these difficulties by choosing the best way of fabrication and right substrate for the diamond on which it can be fabricated. [5]

REFERENCES

[1] Evolution of the SAW Transducer for Communication Systems Donald C. Malocha, ECE Dept., University of Central Florida, Orlando, Fl. 32816-2450.

[2] Applications of Surface Acoustic and Shallow Bulk Acoustic Wave Devices COLIN K. CAMPBELL, IEEE.

[3] Campbell, Colin K., (1998), “Surface Acoustic Devices for Mobile and Wireless Communications” Academic-press, Inc.

[4] D. Morgan, Surface Acoustic Wave Filters, 2nd ed. Elsevier, 2007.

[5] Joana C. MENDES1, Margarida FERNANDES2, Debarati MUKHERJEE1, Dinis M. SANTOS2 Centre for Mechanical Technology and Automation, University of Aveiro, Portugal (1) Telecommunications Institute, Aveiro, Portugal (2)Simulation of acoustic wave devices using Mat lab.

[6] Hribsek M., Tosic D., Radosavljevic M., Surface acoustic wave sensors in mechanical engineering, FME Transact., 38 (2010) 11-18.

[7] Gallagher M.W., Santos B.C., Malocha D.C., Wireless wideband SAW sensor - antenna design, IEEE Int. Frequency Control Symposium (2010) 291-296.

[8] J.-M. Friedt, T. R´etornaz, S. Alzuaga, T. Baron, G. Martin, T. Laroche, S. Ballandras, M. Griselin, and J.-P. Simonnet, “Surface acoustic wave devices as passive buried sensors,” Journal of Applied Physics, vol. 109, no. 3, p. 034905, 2011.

[9] C.-J. Lin, C.-W. Hung and H.-P. Lin, “A study of wireless torque sensing based on saw sensors,” in Computer Communication Control and Automation (3CA), 2010 International Symposium on, vol. 2, may 2010, pp. 211 – 214.