Simulation Of A Surface Acoustic Wave RFID Tag With Reduction Of Size And Data Capacity Consistency

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ABSTRACT

Surface Acoustic Wave (SAW) RFID tags use Short Metal reflectors for coding the incoming signals. In this paper the simulation of a SAW RFID tag using peizo plane strain of COMSOL Multiphysics is presented which is designed by the FEM method. The simulations are performed in order to show the response of this device. To better design, it is essential to model two dimensional SAW tag and analyze the wave propagation characteristics in piezoelectric SAW devices. In this study the time Position Encoding method is used which uses time delays for coding the input signals. By this method data capacity of the SAW RFID tag is found to be increased. This study presents a SAW RFID tag with a SPUDT consist of two electrodes and two aluminum reflectors which placed on a YZ $LiNbo_3$ piezoelectric substrate. The Center frequency of the SAW RFID tag is found to be 2.45 GHz. Here a two dimensional Simulation of a SAW wave propagation is presented which leads to a proper response for the devices obtained by several simulations. The development of the two Dimensional Finite Element Mode provides a proper insight for the understanding of the SAW RFID tags mechanism without having to perform the actual fabrication.

Keywords: SAW, RFID Tag, Reflector, Time positioning, Piezoelectric.

1. INTRODUCTION

A Radio Frequency Identification system is structured by readers and tags. A typical system includes a few readers, either stationary or mobile and many tags which are attached to the objects. The communication between a reader and the tag takes place within its wireless range. In this way it collects information regarding the same. Tags are classified into three categories, depending on their operating basis: passive, semi-passive, and active. The least complex and thus the cheapest is the passive tag which uses the electromagnetic field, transmitted by a reader to power its internal circuit since it has no internal power source. It relies on backscattering in order to transmit to the reader. Other tags include the semi-passive tag which has its own power source but no transmitter and also uses backscattering and the active tag which has both internal power supply and an on-tag transmitter. Surface acoustic wave (SAW) radio-frequency identification (RFID) tags are passive tags. The use of reflected radio energy dates back to the basic radar technology.

Tags that may be carried by people, animals, objects or vehicles use Radio frequency identification , a wireless technology, to be identified [1]. The first use of RFID devices dates back to World War II. They were used by the United Kingdom in order to identify English airplanes and avoid confusing them with inbound German ones. Many believe that the first known device may have been invented by Leon in 1945. The Radar was only able to indentify the presence of a plane, not the kind of plane it was [2].

Surface acoustic waves propagate on the surface of the elastic medium with most of the energy concentrated near the surface.They are based upon the piezoelectric effect and on the surface-related dispersion of elastic waves at low speed. If a crystal is elastically deformed in a certain direction, surface charges occur, giving rise to electric voltages in the crystal. Conversely, the application of a surface charge to a crystal leads to an elastic deformation in the crystal grid. Surface acoustic wave devices are operated at microwave frequencies, normally in the ISM range of the 2.45GHz.

In the type of RFID tag that we proposed in this paper, the surface acoustic wave tag, is similar to RF SAW filters in many aspects, which we are widely used in mobile phones. SAW tags and SAW filters use the same technology. The main goals of designing the SAW tag in this paper are a reduction of device losses, a reduction of device size, and an enhancement of data capacity.

2. PRINCIPLE OF OPERATION

A vital component of a SAW RFID tag is an interdigital transducer (IDT) which is a metallic comblike structure fabricated over a piezoelectric substrate. On a nano-scale SAW chip, it converts a radio wave pulse into a surface acoustic wave. Surface acoustic wave devices are micro-electromechanical systems (MEMS) that make use of the surface wave propagation in a piezoelectric substrate such as Lithium Niobate. Depending on the application they can be made of different kind of metals such as copper and aluminum.In this paper we use aluminum for reflectors and IDT's electrodes. Electroacoustic transducers and reflectors can be created using planar electrode structures on piezoelectric substrates. The normal substrate used for this application is Lithium Niobate or Lithium tantalate. In this paper we use Lithium Niobate as a substrate. The electrode structure usually is created by a photolithographic procedure, similar to the procedure used in microelectronics for the manufacture of integrated circuits. Fig. 1 illustrates the basic layout of a surface wave transponder. A fingershaped electrode structure which used in the interdigital transducer is positioned at the end of a long piezoelectric substrate and a suitable dipole antenna for the operating frequency is attached to its bus bar. Individual electrodes are positioned along the remaining length of the surface wave transponder. The edges of the electrodes form a reflective strip which reflect a small proportion of the incoming surface waves. Reflector strips are normally made of aluminum; however some reflector strips are also in the form of etched grooves. A high frequency scanning pulse is supplied from the dipole antenna of the transponder into the interdigital transducer. In a SAW RFID system, a reader releases electromagnetic pulses. A high frequency scanning pulse is supplied from the dipole antenna of the transponder into the interdigital transducer. An alternating electrical signal is applied to an interdigital transducer that is placed on top of a piezoelectric substrate; a mechanical wave will be generated in the substrate within a confined distance of one wavelength from the surface of the substrate which is converted into nano-scale acoustic wave pulses by an IDT. These pulses travel away from the transducer on the surface of the SAW chip. The SAW pulse is partially reflected and partially transmitted by each of the code reflectors, placed at precisely determined positions on the chip. These reflectors usually consist of one or a few narrow aluminum strips. These set of wave reflectors on the chip produce a unique sequence of reflected acoustic wave pulses. These pulses travel in the opposite direction, towards the IDT, and are converted back to radio pulses and transmitted back through the tag's antenna. The reader receives the radio pulses and identifies the ID of the SAW tag, based upon the time gaps in the pulse sequence received. The response signal is then detected and decoded by the reader. Fig. 2 illustrates the operation and shows a typical time response of a SAW tag.

The substrate material properties, The crystal cut, and the structure of the electrodes define the propagation of the acoustic waves in piezoelectric media. The distance between successive electrodes as shown in Fig. 3 decides the elastic wavelength λ and they are related by

$$\lambda = 2p \qquad (1)$$

The associated frequency f of the waves propagating with velocity v is given by

$$f = {}^{v}/_{\lambda} \qquad (2)$$

The reflecting electrodes in a Surface acoustic wave radio-frequency identification (RFID) tag must amount to 20-50, particularly in the beginning of the code reflector array which implies the presence of only a few electrodes in order to achieve a reasonably high data capacity [3]–[5]. Evidently the knowledge of reflection, transmission, and scattering parameters is crucial in tag design.

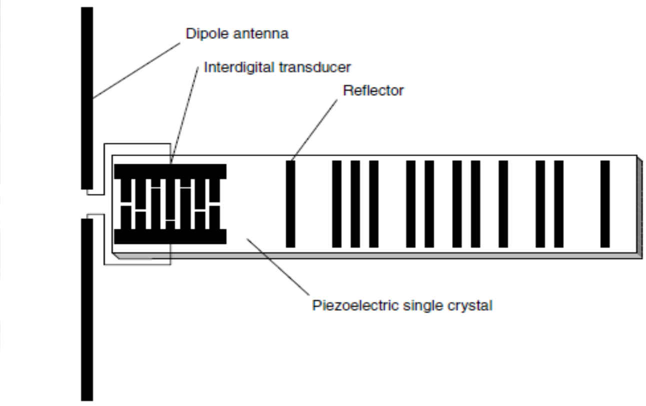

Fig. 1 Basic layout of an SAW transponder. Interdigital tansducers and reflectors are positioned on the piezoelectric crystal [13]

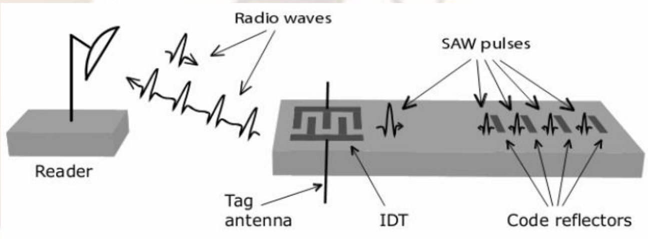

Fig.2 Operation of a SAW tag [11]

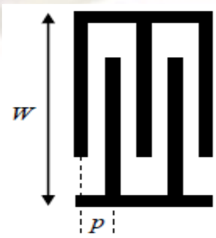

Fig.3 Interdigital transducer (IDT) [12]

3. TIME POSITION ENCODING

As illustrated by the mask image in Fig. 4, ten of the reflectors are used for encoding itself; the first and the last reflector are used for calibration and are typically designed to have stronger responses than the others; while the two reflectors preceding the very last one are used for error control, for creating a checksum. The reflector array is designed to produce uniform amplitudes for code reflections, in order to help achieve a maximal read range. Amplitudes of response signals are adjusted by gradually increasing the reflectivity of code reflectors, by adding electrodes to reflectors and by increasing their width [6], [7]. The number of different codes is determined by the BT product where B is the used frequency band and T is the coding time. SAW RFID tags can be encoded in several ways. Currently existing SAW tag products use the time position encoding, which represents the most straightforward way of data encoding in SAW tags. This is the only method currently used in commercial SAW tags. In this encoding scheme, the total time delay is divided into slots of certain duration. In a time based position encoding SAW RFID, each code reflector occupies a slot corresponding to certain duration of time as illustrated schematically in Fig. 5. These slots form groups of, for example, five slots. When such grouping is used, one of the first four slots of each group is occupied by a reflector; the fifth one, the guard slot, is always left empty. The width of a single slot is Δt = 1/B where B is the used frequency band. Thus, for a SAW tag operating at 2.45GHz and using a 40MHz band, the slots are 25ns wide. Typically, about 20 code reflectors are required for a fairly great number of codes. An initial delay for environmental echoes of about 1µs, corresponding to 2mm of chip space on lithium Niobate, is also essential.

For time position encoding as shown in Fig. 5, window is divided into five 25ns slots, one of the first 4 of which is occupied by a reflector. In other words, each reflector has 4 possible positions, corresponding to 2 bits of data. The total data capacity of our time-delay-based tags, having 10 code reflectors each, is thus 20 bits. All reflector positions for the time-position-encoded tags lie at multiples of λ from each other, as illustrated in Fig. 6. For this paper, as all the code reflectors must now be placed on the same side of the IDT, we replace the bidirectional IDT by a unidirectional transducer (SPUDT) this halves the space required by the initial delay [8]. In comparison to the bidirectional transducer a unidirectional IDT (UDT) type of transducer generates wave propagation predominantly in one direction, which reduces losses.

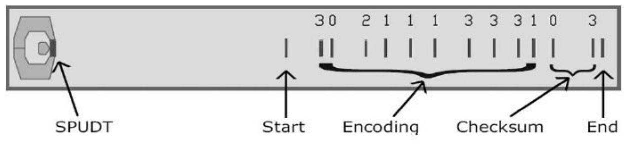

Fig. 4 Mask image of a reflector-based SAW RFID tag[10]

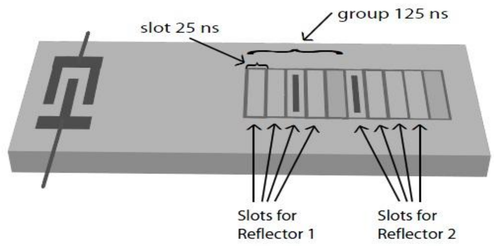

Fig. 5 Principle of time position encoding. Schematic drawing [10]

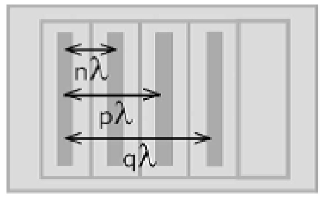

Fig. 6 Possible reflector positions for time position encoding [10]

4. SIMULATION RESULT

The SAW RFID Tag's responses were obtained by utilizing a structure which contains the YZ $LiNbO_3$ as a piezoelectric substrate, two Aluminum electrodes for SPUDT and two reflectors. The first reflector is distanced by 79.6μm from the SPUDT. For the simulation of the SAW RFID Tag in this paper, the FEM method of the COMSOL Multiphysics is used. In the first step a SPUDT with two electrodes is simulated and the displacement of the SAW wave on the surface of the SPUDT is shown. Subsequently by placing the SPUDT electrodes and the reflectors in a suitable position an optimized tag response is acquired. In the design of SAW RFID Tags, the position of the SPUDT electrodes and reflectors is of vast importance; displacement of reflectors by even 1μm will cause an improper response. In these conditions the output signal is not recognizable nor extractable. The SPUDT has one pair of fingers with a width of 0.4μm and the spacing of 0.4μm . The Dimensions of the piezoelectric substrate are 400µm in the X axis and 8µm in the Y axis.The bottom layer of the piezoelectric substrate is grounded.

For grounding the bottom layer of the substrate, in the boundary condition section the term "fixed" must be selected. For the remaining boundaries the term "free" is selected. SPUDT also contains floating electrodes, therefore, in the boundary section, the term "free" is selected.For the other electrodes in the boundary condition section the term“free” has been chosen. Input voltage is applied to SPUDT Thus electrical signal is converted to SAW Wave by the Transducer and is reflected by the reflectors. Output signals are received and detected with certain time delays. The center frequency of the device is found to be 2.45GHz. In the solver parameter section, transient analysis is selected. Fig.7 shows the design of the proposed SAW RFID tag. The obtained tag response is shown in Fig. 8. The first signal is the input signal and the remaining two signals are the two reflectors' responses. As expected these two signals have been weakened by 50 percent compared to input signal and are detectable at last.

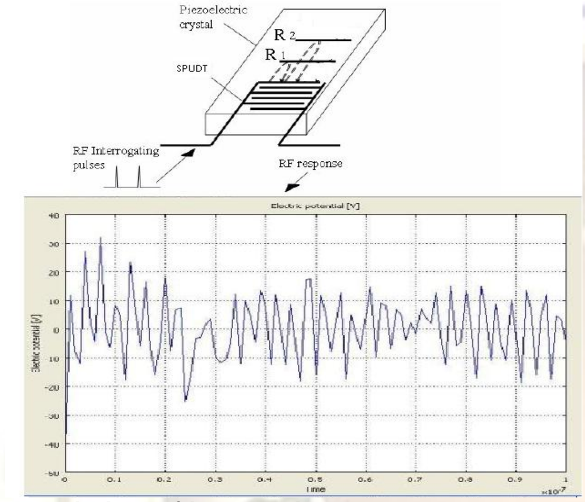

Fig. 7 The design of the proposed SAW RFID tag

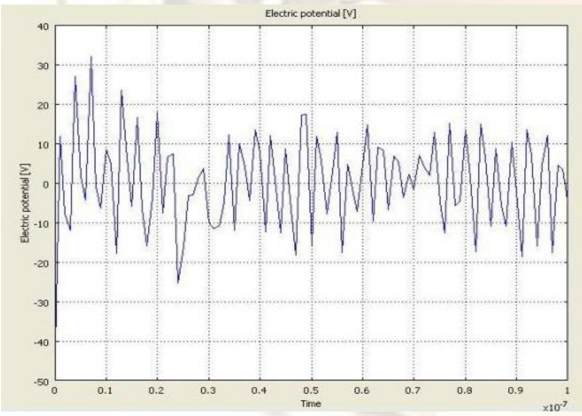

Fig.8 Theresponse of the proposed SAW RFID tag

5. Conclusion

A two dimensional SAW RFID tag with YZ LiNbo3 as substrate, a SPUDT with two aluminum electrodes and two reflectors, is modeled and simulated. As a result of the simulations, total displacement of the SAW wave is obtained. Placing the first and the second reflector in the right distance from the last electrode of SPUDT, results in optimized tag response. The first reflector's response, compared to the initial signal, has been attenuated 50 percent. The second reflector's response compared to the first one's response is slightly weakened.

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