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High frequency passive micro-magnetic sensor based on surface acoustic wave transponder and giant magnetoimpedance sensitive element

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ABSTRACT

This paper presents a high frequency micro-magnetic field sensor composed of a surface acoustic wave (SAW) transponder and a giant magnetoimpedance (GMI) sensitive element. The coupling-of-mode(COM) method is used to design and optimize the structure of the SAW transponder. An amorphous wire as the GMI element is used to conjunct with the SAW transponder. The experiment result shows the magnetic sensitivity of the sensor of 1.13 dB/Oe changes when the magnetic sensitivity does not exceed 2.0 Oe. For the two-dimension intensity measurement of the magnetic field, a two-dimension SAW-GMI sensor is developed and tested.

1. Introduction

Passive micro-magnetic sensors which are able to measure magnetic fields remotely without any on-chip power supply and wireless interrogation are an ideal solution for many applications that require power management and wireless connection. Various types of new micro-magnetic sensors have been reported in the literature using different materials, structures, and operating principles [1–5]. SAW device could be motivated by antenna RF signal to become passive. It has a great advantage to use SAW device to develop magnetic sensors for passive applications like the human body electromagnetic positioning, spacecraft navigation, biosignal detection and so on. In recent years, there are some researchers who focus on SAW magnetic sensors. For instance, Al Rowais H developed micro-magnetic sensors with thin-film magnetoimpedance element and surface acoustic wave transponder of 80 MHz in 2011 [6] and Bodong Li develop optimized magnetic sensors to 525 MHz a few years later [7]. However, their SAW magnetic sensors are still too big to apply in the human body electromagnetic positioning which has strict requirements in the size of the sensor. It is necessary to develop a small and passive SAW magnetic sensor for some specified applications.

In the paper, we present a micro-magnetic sensor device composed of a SAW transponder and a GMI sensitive element and with approximate size of 6.5*4.5 mm. Magnitude responses of the S11 parameter are measured for magnetic intensity ranging from 0 to 2 Oe by using a vector network analyzer(VNA). Parameters of the amorphous wire are optimized. Compared with other researchers' works, a high frequency micro-magnetic field sensor with the magnetic sensitivity of 1.13 dB/Oe at frequency of around 1 GHz is developed. As the extension of the one-dimension SAW-GMI sensor, a two-dimension SAW-GMI sensor is developed and tested.

The paper is organized as follows: In part II, the structure of a SAW transponder composed of one single finger IDT and two double finger IDTs is presented, and corresponding simulation of the SAW transponder is given for ensuring the matching of the designed SAW transponder and its antenna. The selection of the amorphous wire, experimental verification of its impedance value and the resonance match of the amorphous wire and SAW transponder are discussed in Part III. In part IV, two kinds of SAW-GMI sensors are implemented for the one-dimension magnetic intensity and two- dimension magnetic intensity measurement. Corresponding experimental tests are performed in order to assess these SAW-GMI sensors. Conclusions are summarized in part V.

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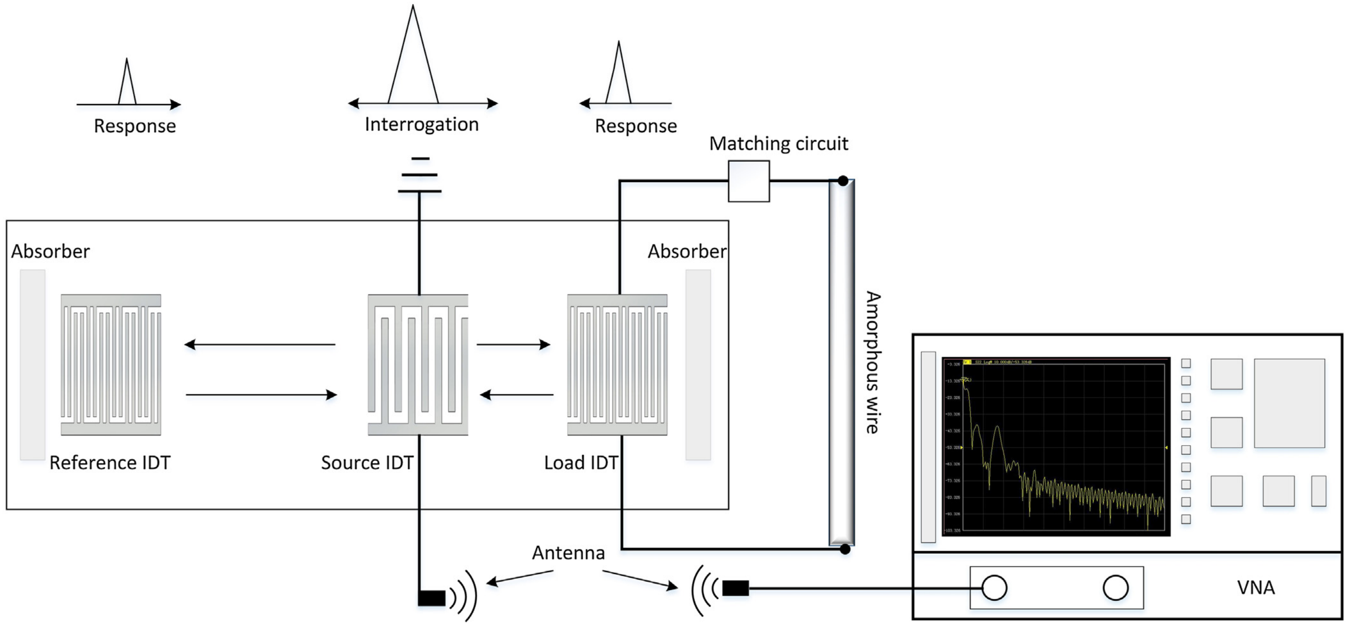

Fig. 1. Schematic of the SAW-GMI sensor.

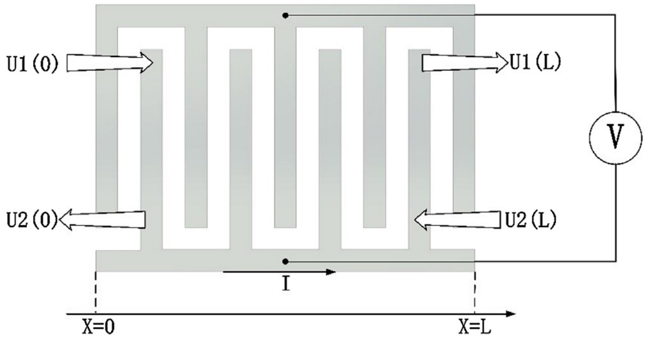

Fig. 2. P-matrix model of IDT.

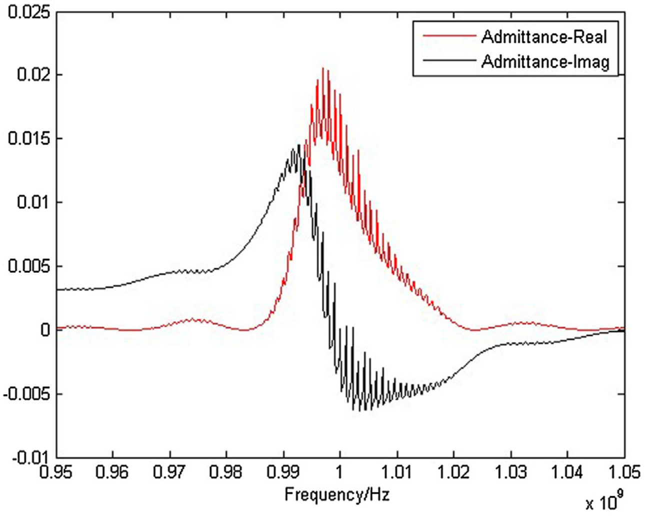

Fig. 3. Simulated admittance of SAW transponder.

Table 1
Definition of P-parameters [11].

P_{11}, P_{22}	Acoustic port reflection coefficient
P_{12}, P_{21}	Acoustic port transmission coefficient
P_{13}, P_{23}	Voltage to SAW transfer elements
P_{33}	Transducer admittance
χ	$\chi = 2$ for RMS I, V, and U; $\chi = 4$ for peak I, V, and RMS U

2. SAW transponder

2.1. SAW transponder

The SAW transponder plays a key role in converting the impedance change of GMI materials caused by the change of the magnetic field into the change of SAW signal. For the impedance-loaded SAW sensor, the relationship between interdigital transducer (IDT) and load is [8]:

$$P_{11_r}(Z) = P_{11_{sc}} + \frac{2 \cdot P_{13}^2}{P_{33} + \frac{1}{Z}} \tag{1}$$

Where P_{11_r} is the acoustic reflectivity, P_{11_sc} is the short acoustic reflection coefficient, P_{13} is the electromechanical coupling coefficient, P_{33} is the input admittance and Z is the load impedance.

In order to increase P_{11_r}, a double-electrode design is employed to minimize P_{11_sc}. The electrode period p = λ/2 = 2 μm is required when the velocity of SAW in 128° Y-X $LiNbO_3$ is approximately equal to 3992 m/s and the desired frequency is designed up to 998 MHz. So the electrode width of single finger IDT is equal to 1 μm and electrode width of double finger IDT is equal to 0.5 μm. Both single finger IDT and double finger IDT consist of 50 pairs of electrodes. The apertures size has to be set to 80λ because the apertures size has to be greater than $2\sqrt{L\lambda}$, where L is the distance between source IDT with load IDT [9]. The distance between closer IDT with source IDT is designed to 850 μm and distance between closer IDT with source IDT is set to 2000 μm to avoid interference of reflected SAW signal.

Fig. 1 is schematic of a SAW-GMI sensor. The SAW-GMI sensor is composed of a SAW transponder and a GMI element. The SAW transponder is composed of the source IDT which is a single finger IDT, and two double finger IDTs. The two double finger IDTs, one of them plays the role of reference IDT and another plays the role of load IDT, are shown in Fig. 1. The difference between closer IDT and further IDT is the distance from the source IDT. The GMI element is composed of one amorphous wire and the matching circuit. The closer IDT plays the role of load IDT and is connected with the matching circuit and amorphous wire in Fig. 1.