Linear Position Encoder based on Piezoelectric materials and Surface Acoustic Waves (Rev. 3)

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The following provides an overview for two ideas in using Piezo material and its inherent characteristics for producing acoustical waves on its surface at radio frequency.

Surface Acoustic Wave (SAW) technology is commonly used for RF filtering using components known as SAW resonators.

Some work for its use as passive (no active electronics) remote sensors is outlined in this paper from Oak Ridge National Laboratory.

The potential for using this technology in linear position measurements is presented below.
There are two approaches suggested.

Figure 1 (encoder wired to SDR):

- A linear encoder connected to the Software Defined Radio (SDR) platform. Here a continuous RF excitation signal is used using one TX channel directly wired to the two RX connections on the SDR
- The form in which measurement is determined is by the interference effects (similar to a two frequency laser interferometer) of two opposing SAW's, one on the stationary element and one on the movable element.
- TX1 and TX2 interfaces of the moveable member of the encoder to measure both displacement and direction of motion and return this information to RX1 and RX2 channels on the SDR. Displacement is determined by the increment counting of an interference cycle and an analysis of the standing wave amplitudes of the return signal (which is a combination of the signals sent from the two TX interfaces on the stationary member of the encoder).
- Even though the wavelenght is only 1 uM, the RX A/D's can determine slight shifts within an a cycle (similar to an analog multiplier on a traditional encoder).

Figure 2 (wireless encoder):

- A simpler variation of this idea using a Bragg reflector on the moveable member.
- This approach is similar to that described in ORNL above except the Bragg is contained on a seperate and movable piezo substrate.

- Measurement is based on time. The RX interface sees a short pulse sent by the SDR. The returned reflection is a decaying RF signal (in this case 1 uM) to the same interface now acting as a TX interface. The SDR determines the difference in time between the pulse sent and the returned reflection.
- Literature indicates that for a typical piezo material, the transverse speed of the wave is 4000 Meter/Sec. This is 0.000004 M/nSec. Current day SDR's (using high performance FPGA's) should be able to work with this constraint. However, the measurement accuracy of this approach would be typically less than the first example.

For both approaches described above and illustrated below, there is one unknown..
The electromagnetic properties of the piezo which produce the wave are formed by a vibrating dipole within the piezo substrate.

There is question of how much (if any) of electromagnetic fields produce by the waves are *seen* in the air gap between the two piezo interfaces. The type of piezo material may play a role here (see *Aluminum nitride surface acoustic wave resonaters* link above).

The acoustic *coupling* in the air gap between the interfaces may make up for this potential inadequacy if the gap is very small. At this point, this effect is unknown.

Revision:

1. Figure 1 in error. Interface between stationary piezo substrate and movable piezo substrate must detect standing wave generated by SDR TX connections at opposite ends of stationary piezo substrate.

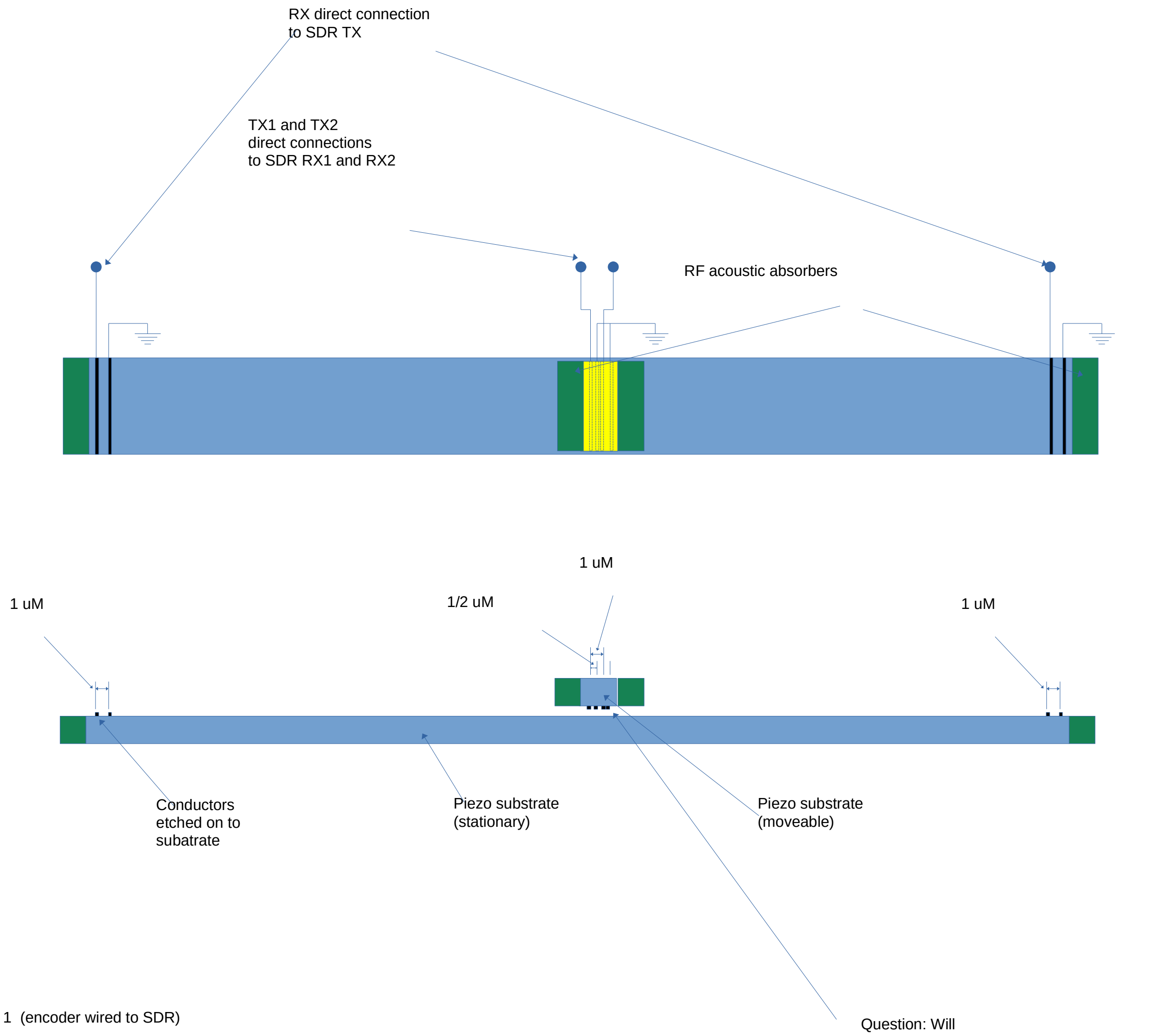

Figure 1 (encoder wired to SDR)

Question: Will these two receiving conductors *see* a common mode field generated by the surface waves on both substrates?

A continuous surface wave of 1 mM wave length is induced by RX signal on both substrates. Speed of the traveling wave for this example is not important here because we are looking for the *standing wave* effect of the two waves at the TX1 and TX2 interfaces.

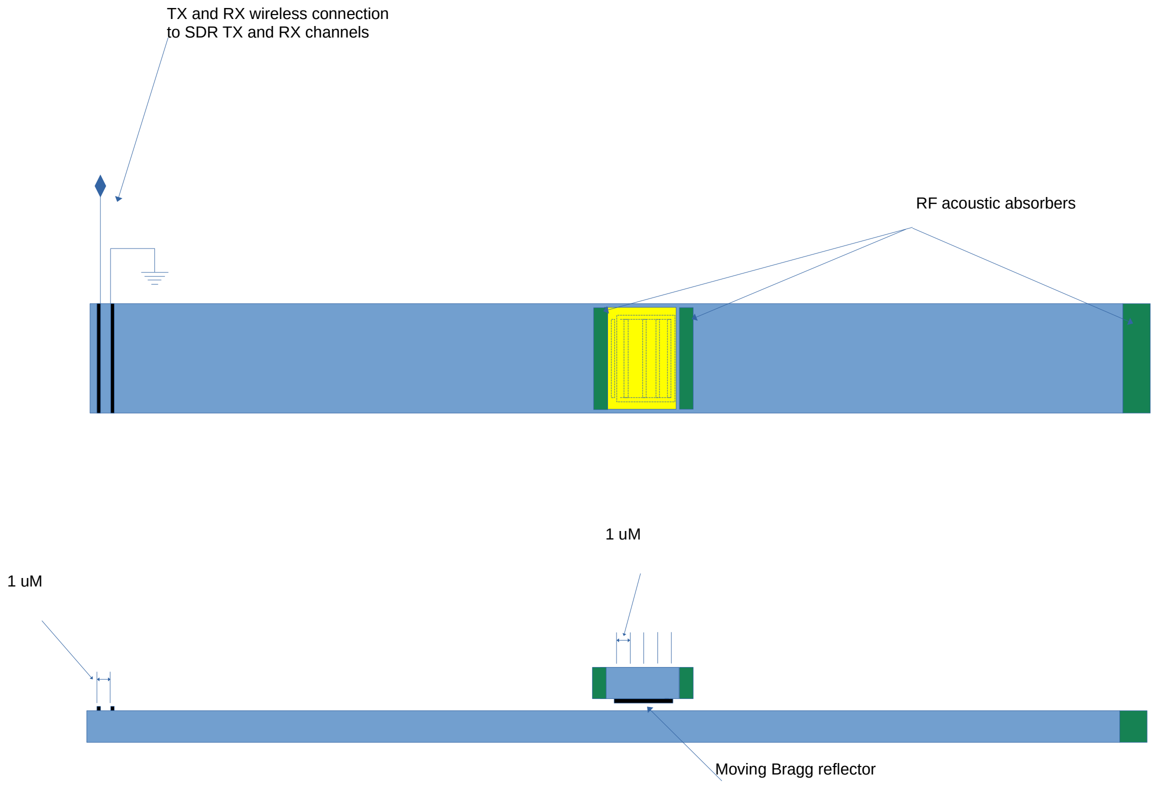

Figure 2 (wireless encoder)

A pulse sent by the SDR TX interface is received by antenna interface above. The Bragg reflector returns the signal to the antenna some time later as a decaying sinusoidal wave with a 1 uM wave length. This is different then the first example above because send and return time to the SDR is used to measure the distance of the refector from the antenna. Documentation states the typical speed of the wave is 4000 M/Sec. This method does not produce a very accurate measurement of the displacement of distance compared to the first example above which works similar to a two frequency laser interferometer.

A 2-D Finite Differences Time Domain (FDTD) simulation was made for the stationary Piezo substrate shown in Figure 1 above.

The code for this simulation is shown in document saw_fdtd_simulation.c[1].

The 2-D FDTD map created by this simulation is shown in Figure 3 below

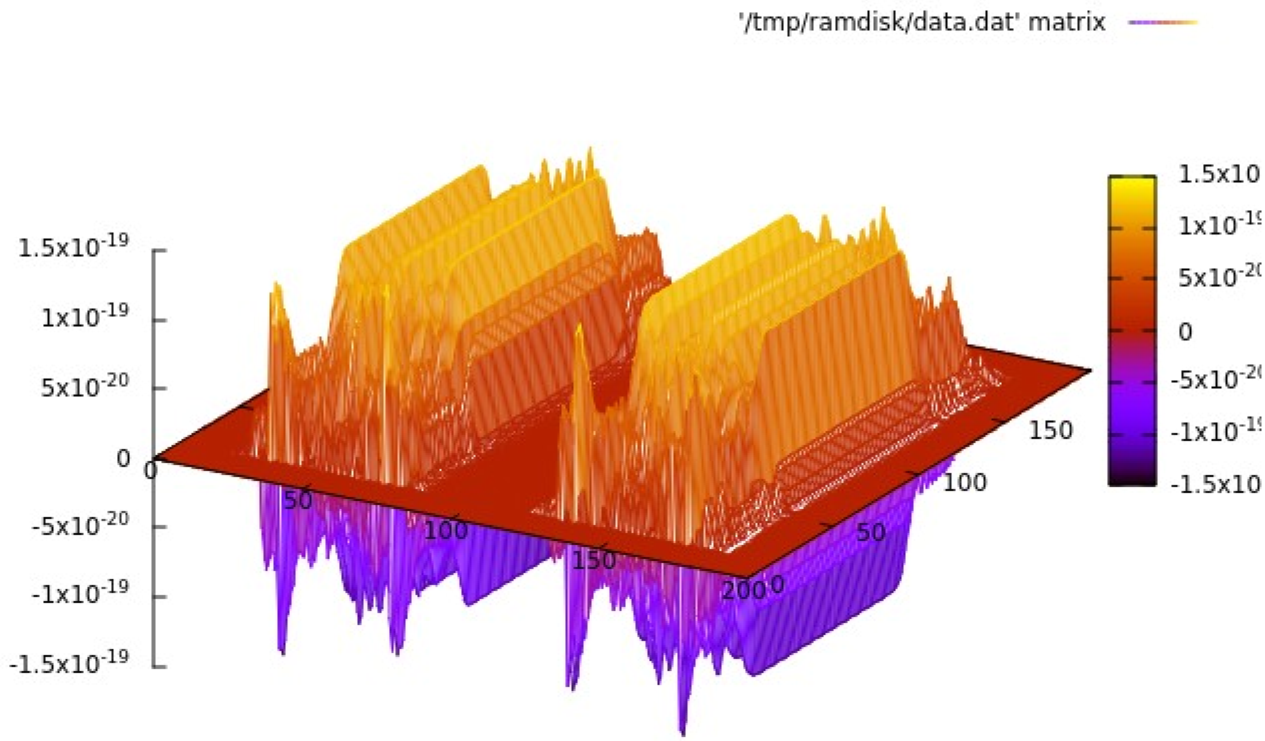

Figure 3   2-D FDTD simulation map of stationary stationary Piezo substrate at time iteration 1000 with Delta_t = .159e-10.

This simulation is derived from three papers cited at the top of saw_fdtd_simulation.c. The model is arbitray in selection of parameters and is ment to be informative only.

1 See: **References for FDTD (Finite Differences Time Domain) method applied to SAW analysis**

A slice view of this simulation is shown in document Simulation snapshots for saw_fdtd_simulation starting at time interation 1000. A progression of time interations is shown showing two travaling surface waves converging towards the center to form the beginning of a standing wave.

FDTD simulation is inherently unstable so only formation of the first few *lobes* can be shown before error takes over and degrades the simulation.

References for FDTD (Finite Differences Time Domain) method applied to SAW analysis

Contribution to Finite-Difference Time-Domain procedures for simulation of Surface Acoustic Wave

Analysis of SAW Filters using Finite-Differences Time-Domain Method

Fintie-Difference Time-Domain Simulation of Dispersive Layered SAW Filters including Electrode Massloading

Analysis of the Surface Acoustic Wave Modes Using Finite-Difference Time-Domain Method

A general background on SAW analysis

Fundamentals of Piezoelectricity

Bulk and Surface Acoustic Waves in Piezoelectric Media

Surface Acoustic Waves on Piezoelectric Media Applications to Acoustic Charge Transport