1.0 RESEARCH PROJECT DESCRIPTION

The purpose of this research project is to develop and demonstrate the viability of wirelessly extracting measurand data from a network of surface acoustic wave (SAW) sensor devices using an Advanced Wireless SAW System (AWSS) being developed by Mnemonics Inc. This sensing technique has several advantages over existing sensors. These include:

1. Wireless – no wired connections are needed to extract the data,
2. Passive – the sensors are passive and require no power,
3. Robust – the SAW sensors can withstand temperatures from 4 degrees Kelvin up to 1000 C and they can operate in the vacuum of space,
4. Inexpensive – SAW sensor devices can be mass produced at a reasonable cost.

1.1 System Overview

The AWSS is a complete sensor and data processing system shown in **Error! Reference source not found.**. It is composed of three (3) primary elements:

1. SAW Sensor network
2. Interrogator
3. Data Processing

The SAW Sensor network is a collection of SAW sensors (packaged SAW device with an integrated antenna) located within range of the Interrogator unit. When interrogated, each sensor responds with a return signal that contains the unique sensor ID and information about a specific item that tag is measuring, e.g. temperature, strain, pressure, etc.

The Interrogator transmits the interrogation signal, then receives and digitizes the return signals from the sensors. The digitized return signals are then passed to the Data Processing element where the sensor IDs and measurands are extracted and displayed. Data Processing can be integrated with or remotely located from the Interrogator.

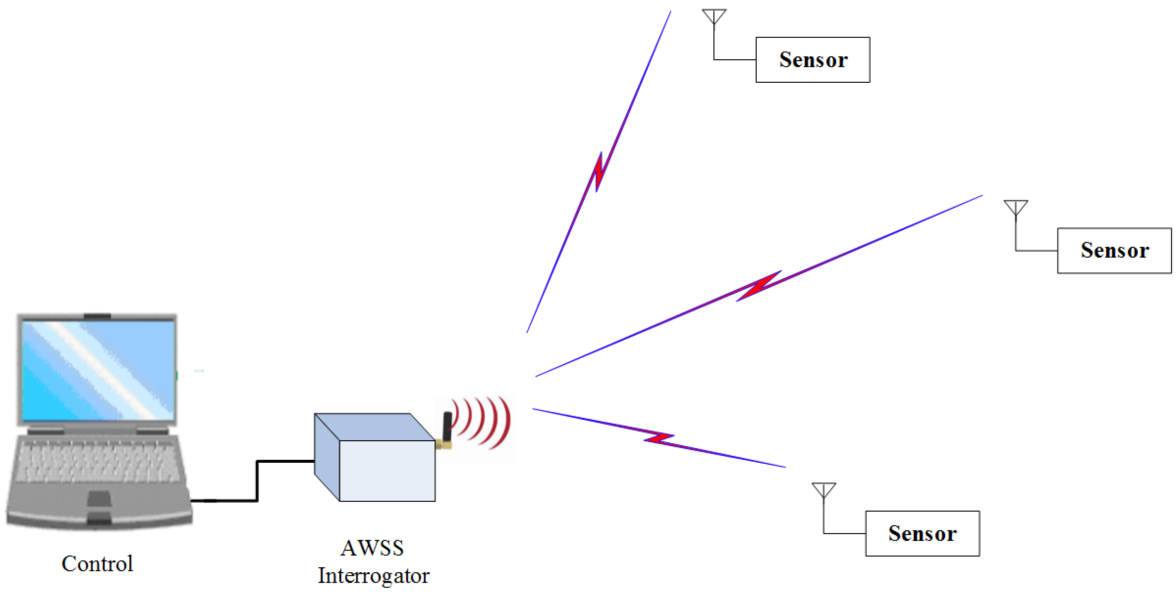

Figure 1. Prototype AWSS System Diagram

1.2 SAW Sensor Background

As mentioned above, the Interrogator transmits a signal to the network of SAW sensors. This signal is a stepped-chirp radio frequency (RF) pulse (time domain) as shown in Figure 2. The spectrum of the interrogation signal is depicted in Figure 3.

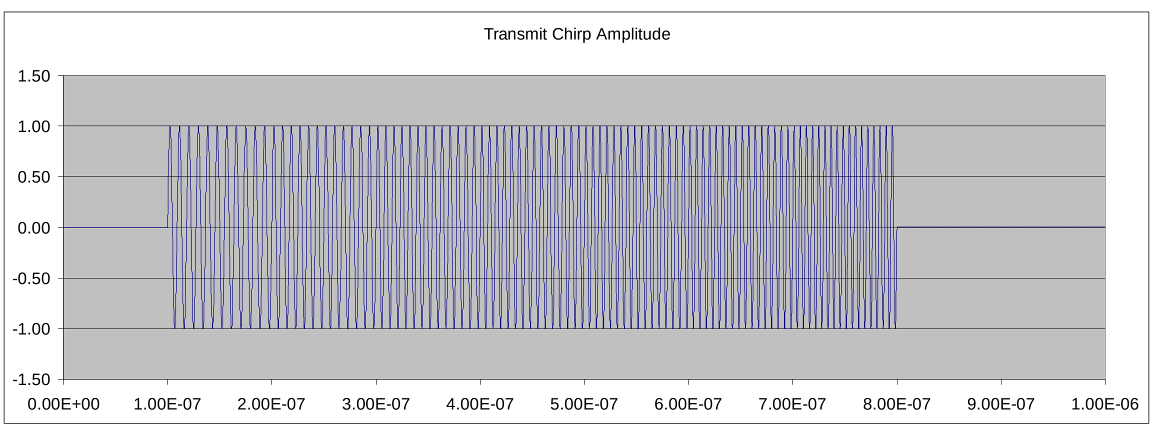

Figure 2. Up-chirp Signal

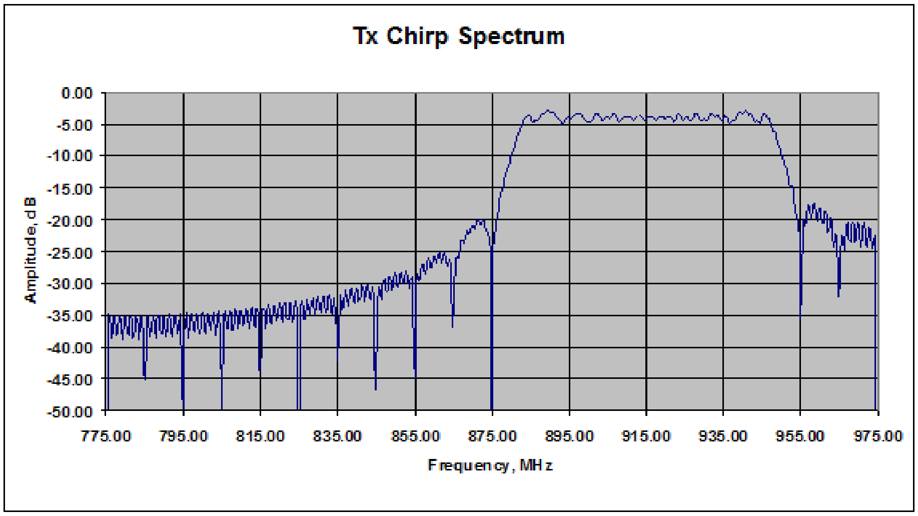

Figure 3. Spectrum of Interrogating RF Signal

The interrogation pulse is received by an antenna connected to the input inter-Digitated Transducer (IDT) of each SAW sensor as seen Figure 4. The input IDT generates a SAW wave on top of the crystal to the left and to the right of the IDT. The SAW wave traveling to the left is ignored but the SAW wave traveling to the right is reflector is used to excite the reflector bank.

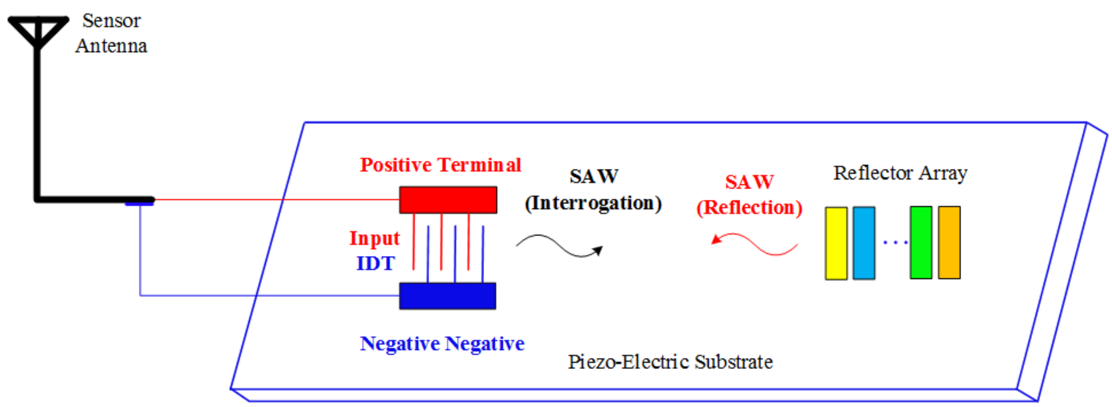

Figure 4 Wireless, Passive SAW Sensor

The reflector banks are composed of individual reflectors, each made up of electrodes shorted to the positive and negative bus bars. Part of the energy is reflected from each reflector and part is transmitted to the next reflector. The reflections from each sensor are delayed in time from each other and are sent back to the IDT where they are converted back to RF energy by the device transduction mechanism. These RF signals are then transmitted back to the Interrogator.

The reflector bank made up of equally spaced reflectors are characterized by its impulse response. The impulse response of a typical SAW device is shown in Figure 5. It is clear that the reflected signal from the first reflector is stronger that the reflection from the second etc.

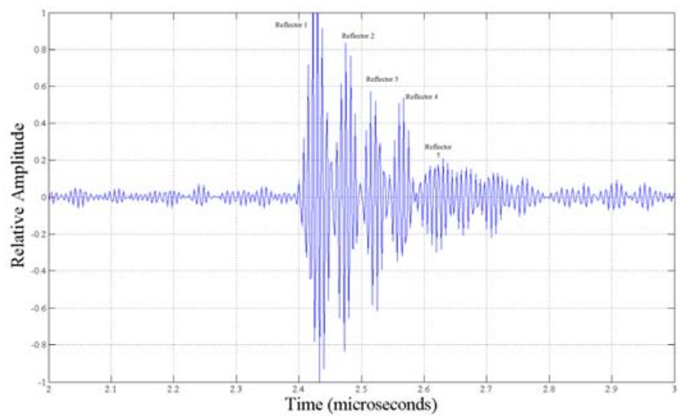

Figure 5 SAW Device Impulse Response

When the piezoelectric, SAW substrate is put under stress by temperature, pressure, etc. the SAW velocity of propagation changes and so does the time delay between the two return pulses. By measuring the change in time separation from the design value, the temperature, pressure, or whatever is stressing the substrate can be determined. The sensor RF signal response is the convolution of the received interrogation signal similar to the signal in Figure 2 and the device

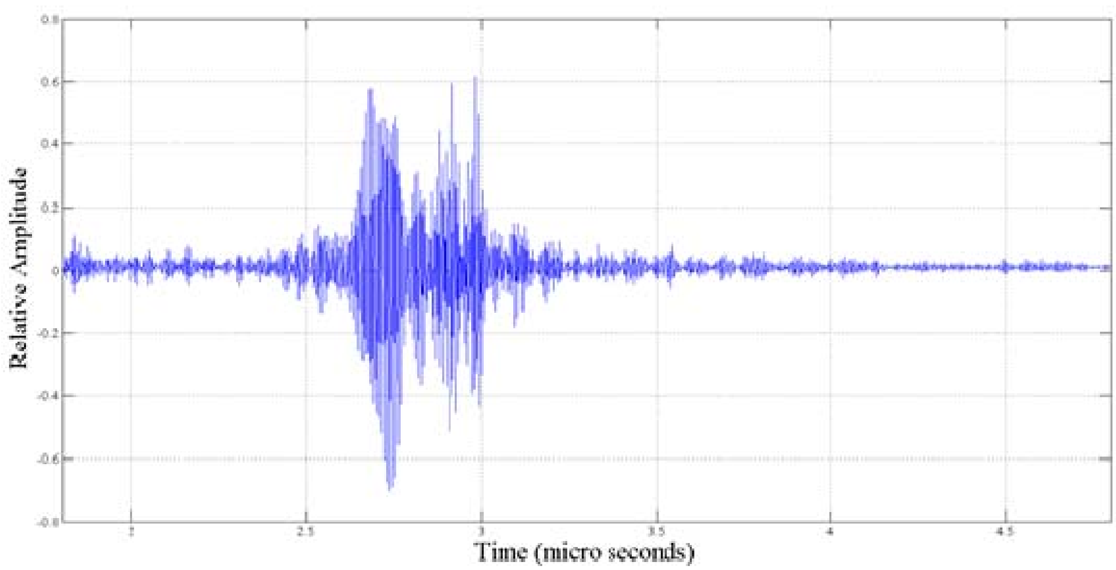

Figure 6. Sensor Response

impulse response shown in Figure 5. This resulting convolution is the RF signal that each sensor sends back to the interrogator as a response to the query. The RF power level that the passive sensor transmits back in response to the interrogation is less very small with an EIRP in micro-Watts. An example of the sensor response is shown in Figure 6.

In addition, this type of sensor can be used for gas, and possibly, chemical sensing. For example, if a thin film of palladium is applied to the surface of the SAW device between the input IDT and the reflector bank, then a hydrogen gas sensor can be built. The palladium responds to the presence of the hydrogen, which changes the propagation characteristics of the SAW wave.

2.0 NECESSARY COMMUNICATIONS FACILITIES

Transmission of the chirp signal is necessary for demonstration of the technology in a network of sensors. These sensors uses SAW devices with wideband reflectors in order to achieve reading resolution that compete with non-SAW technology. The synchronization between the transmit and receive mode requires a special interrogator to be designed and prototyped as no COTS interrogator with the desired capability exit.

3.0 EXISTING COMMUNICATIONS FACILITIES

There are currently no known communications facilities that can be utilized for the transmission of the chirp signal and the reception and processing of the return pulses.