



### **Wideband Single-Crystal Transducer for Bone Characterization**

**These transducers have uses in medical ultrasound imaging and room-temperature ultrasonic flow meters.**

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The microgravity conditions of space travel result in unique physiological demands on the human body. In particular, the absence of the continual mechanical stresses on the skeletal system that are present on Earth cause the bones to decalcify. Trabecular structure decreases in thickness and increases in spacing, resulting in decreased bone strength and increased risk of injury. Thus, monitoring bone health is a high priority for long-term space travel. A single probe covering all frequency bands of interest would be ideal for such measurements, and this would also minimize storage space and eliminate the complexity of integrating multiple probes.

This invention is an ultrasound transducer for the structural characterization of bone. Such characterization measures features of reflected and transmitted ultrasound signals, and correlates these signals with bone structure metrics such as bone mineral density, trabecular spacing, and thickness, etc. The techniques used to determine these various metrics require measurements over a broad range of ultrasound frequencies, and therefore, complete characterization requires the use of several narrowband transducers.

This is a single transducer capable of making these measurements in all the

required frequency bands. The device achieves this capability through a unique combination of a broadband piezoelectric material; a design incorporating multiple resonator sizes with distinct, overlapping frequency spectra; and a micromachining process for producing the multiple-resonator pattern with common electrode surfaces between the resonators.

This device consists of a pattern of resonator bars with common electrodes that is wrapped around a central mandrel such that the radiating faces of the resonators are coplanar and can be simultaneously applied to the sample to be measured. The device operates as both a source and receiver of acoustic energy. It is operated by connection to an electronic system capable of both providing an excitation signal to the transducer and amplifying the signal received from the transducer. The excitation signal may be either a wide-bandwidth signal to excite the transducer across its entire operational spectrum, or a narrow-bandwidth signal optimized for a particular measurement technique. The transducer face is applied to the skin covering the bone to be characterized, and may be operated in through-transmission mode using two transducers, or in pulse-echo mode.

The transducer is a unique combination of material, design, and fabrication technique. It is based on single-crystal lead magnesium niobate lead titanate (PMN-PT) piezoelectric material. As compared to the commonly used piezoceramics, this piezocrystal has superior piezoelectric and elastic properties, which results in devices with superior bandwidth, source level, and power requirements. This design necessitates a single resonant frequency. However, by operating in a transverse length-extensional mode, with the electric field applied orthogonally to the extensional direction, resonators of different sizes can share common electrodes, resulting in a multiply-resonant structure. With carefully sized resonators, and the superior bandwidth of piezocrystal, the resonances can be made to overlap to form a smooth, wide-bandwidth characteristic.

*This work was done by Yu Liang and Kevin Snook of TRS Technologies, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18842-1.*