Current quartz oscillator technology is limited by quartz mechanical Q. With a possible improvement of more than ×10 Q with sapphire acoustic modes, the stability limit of current quartz oscillators may be improved tenfold, to 10^{-14} at 1 second. The electromagnetic modes of sapphire that were previously developed at JPL require cryogenic temperatures to achieve the high Q levels needed to achieve this stability level. However sapphire's acoustic modes, which have not been used before in a high-stability oscillator, indicate the required Q values (as high as Q = 10^8) may be achieved at room temperature in the kHz range. Even though sapphire is not piezoelectric, such a high Q should allow electrostatic excitation of the acoustic modes with a combination of DC and AC voltages across a small sapphire disk (≈ 1 mm thick). The first evaluations under this task will test predictions of an estimated input impedance of 10 kilohms at Q = 10^8, and explore the Q values that can be realized in a smaller resonator, which has not been previously tested for acoustic modes.

This initial Q measurement and excitation demonstration can be viewed similar to a transducer converting electrical energy to mechanical energy and back. Such an electrostatic tweeter type excitation of a mechanical resonator will be tested at 5 MHz. Finite element calculation will be applied to resonator design for the desired resonator frequency and optimum configuration. The experiment consists of the sapphire resonator sandwiched between parallel electrodes. A DC+AC voltage can be applied to generate a force to act on a sapphire resonator. With the frequency of the AC voltage tuned to the sapphire resonator frequency, a resonant condition occurs and the sapphire Q can be measured with a high-frequency impedance analyzer.

To achieve high Q values, many experimental factors such as vacuum seal, gas damping effects, charge buildup on the sapphire surface, heat dissipation, sapphire anchoring, and the sapphire mounting configuration will need attention. The effects of these parameters will be calculated and folded into the resonator design. It is envisioned that the initial test configuration would allow for movable electrodes to check gap spacing dependency and verify the input impedance prediction.

Quartz oscillators are key components in nearly all ground- and space-based communication, tracking, and radio science applications. They play a key role as local oscillators for atomic frequency standards and serve as flywheel oscillators or to improve phase noise in high-performance frequency and timing distribution systems. With ultra-stable performance from one to three seconds, an Earth-orbit or moon-based MSAR can enhance available performance options for spacecraft due to elimination of atmospheric path degradation.

This work was done by Rabi T. Wang and Robert L. Tjoelker of Caltech for NASA's Jet Propulsion Laboratory For more information, contact iaoffice@jpl.nasa.gov. NPO-47343

Process-Hardened, Multi-Analyte Sensor for Characterizing Rocket Plume Constituents

Stennis Space Center, Mississippi

A multi-analyte sensor was developed that enables simultaneous detection of rocket engine combustion-product molecules in a launch-vehicle ground test stand. The sensor was developed using a pin-printing method by incorporating multiple sensor elements on a single chip. It demonstrated accurate and sensitive detection of analytes such as carbon dioxide, carbon monoxide, kerosene, isopropanol, and ethylene from a single measurement.

The use of pin-printing technology enables high-volume fabrication of the sensor chip, which will ultimately eliminate the need for individual sensor calibration since many identical sensors are made in one batch. Tests were performed using a single-sensor chip attached to a fiber-optic bundle. The use of a fiber bundle allows placement of the opto-electronic readout device at a place remote from the test stand. The sensors are rugged for operation in harsh environments.

This work was done by Kisholoy Goswami for Stennis Space Center. For more information, contact: Kisholoy Goswami, InnoSense, LLC; (310) 530-2011. SSC-00348

SAD5 Stereo Correlation Line-Striping in an FPGA

NASA's Jet Propulsion Laboratory, Pasadena, California

High precision SAD5 stereo computations can be performed in an FPGA (field-programmable gate array) at much higher speeds than possible in a conventional CPU (central processing unit), but this uses large amounts of FPGA resources that scale with image size. Of the two key resources in an FPGA, Slices and BRAM (block RAM), Slices scale linearly in the new algorithm with image size, and BRAM scales quadratically with image size. An approach was developed to trade latency for BRAM by sub-windowing the image vertically into overlapping strips and stitching the outputs together to create a single continuous disparity output.

In stereo, the general rule of thumb is that the disparity search range must be 1/10 the image size. In the new algorithm, BRAM usage scales linearly with disparity search range and scales again linearly with line width. So a doubling of image size, say from 640 to 1,280, would in the previous design be an effective 4× of BRAM usage: 2× for line width, 2× again for disparity search range.

The minimum strip size is twice the search range, and will produce an output strip width equal to the disparity search range. So assuming a disparity search range of 1/10 image width, 10 sequential runs of the minimum strip size would produce a full output image.

This approach allowed the innovators to fit 1280×960 wide SAD5 stereo disparity