imity to the conductive surface, the inductance is fixed. As long as the inductance is fixed, all variations of the magnetic field response are due to capacitance changes. Numerous variations of inductor mounting can be utilized, such as providing a housing that provides separation from the conductive material as well as protection from impact damage. The sensor can be on the same flexible substrate with a narrow throat portion of the sensor between the inductor and the capacitor, Figure 1. The throat is of sufficient length to allow the capacitor to be appropriately placed within the container and the inductor placed outside the container. The throat is fed through the orifice in the container wall (e.g., fuel tank opening) and connects to the inductor and capacitor via electrical leads to form a closed circuit, Figure 2. Another embodiment is to have the inductor and capacitor fabricated as separate units. In this embodiment, the inductor is mounted external to the container, and the capacitor is mounted internal to the container, Figure 1. Electrical leads are fed through the orifice to connect the inductor and capacitor, Figure 2.

When a container holding multiple sensors is made of a conductive material, an antenna can be placed internal to the container. An internal antenna allows all components of the sensors to reside inside the container. The antenna must be separated from the container wall's conductive surface. Additionally, the inductors must be maintained in a fixed position relative to and separated from the container wall. Antenna leads are fed through an orifice in the container wall.

This work was done by Stanley E. Woodard of Langley Research Center and Bryant D. Taylor of ATK Space Division. Further information is contained in a TSP (see page 1). LAR-16571-1

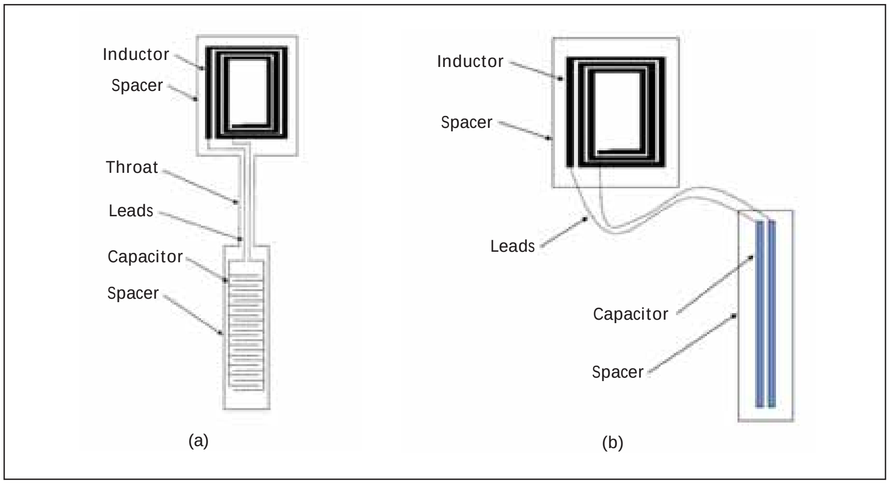

Figure 1. **Magnetic Field Response Sensors** for measurements in conductive containers: (a) Inductor and capacitor on same substrate, (b) Inductor and capacitor on separate substrates.

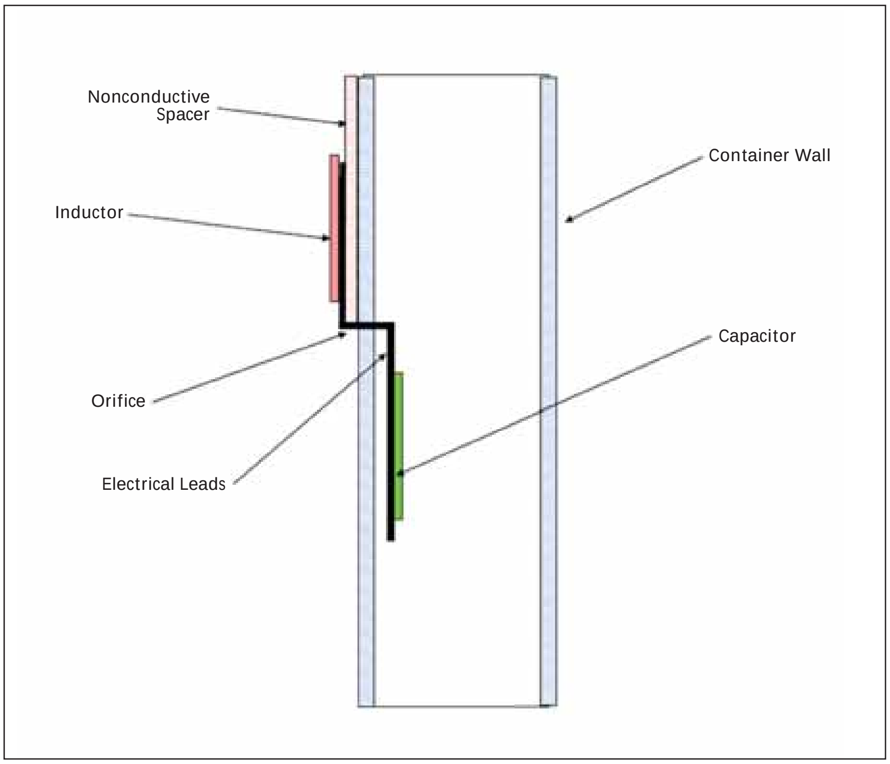

Figure 2. **Cross-Section View**: Magnetic field response sensor for closed electrically conductive container mounted with capacitor within container and inductor external to the container.

Differential Resonant Ring YIG Tuned Oscillator

This oscillator can be used in cognitive radios and for satellite communications.

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A differential SiGe oscillator circuit uses a resonant ring-oscillator topology in order to electronically tune the oscillator over multi-octave bandwidths. The oscillator's tuning is extremely linear, because the oscillator's frequency depends on the magnetic tuning of a YIG sphere, whose resonant frequency is equal to a fundamental constant times the DC magnetic field. This extremely simple circuit topology uses two coupling loops connecting a differential pair of SiGe bipolar transistors into a feedback configuration using a YIG tuned filter creating a closed-loop ring oscillator. SiGe device technology is used for this oscillator in order to keep the transistor's 1/f noise to an absolute minimum in order to achieve minimum RF phase noise.

The single-end resonant ring oscillator currently has an advantage in fewer parts, but when the oscillation frequency is greater than 16 GHz, the package's parasitic behavior couples energy to the sphere and causes holes and poor phase noise performance. This is because the coupling to the YIG is extremely low, so that the oscillator operates at near the unloaded *Q*. With the differential resonant ring oscillator, the oscillation currents are just in the YIG coupling mechanisms. The phase noise is even better, and the physical size can be reduced to permit monolithic microwave integrated circuit oscillators.

This invention is a YIG tuned oscillator circuit making use of a differential topology to simultaneously achieve an extremely broadband electronic tuning range and ultra-low phase noise. As a natural result of its differential circuit topology, all reactive elements, such as tuning stubs, which limit tuning bandwidth by contributing excessive open-loop phase shift, have been eliminated. The differential oscillator's open-loop phase shift is associated with completely non-dispersive circuit elements such as the physical angle of the coupling loops, a differential loop crossover, and the high-frequency phase shift of the n-p-n transistors. At the input of the oscillator's feedback loop is a pair of differentially connected n-p-n SiGe transistors that provides extremely high gain, and because they are bulk-effect devices, extremely low 1/f noise (leading to ultra-low RF phase noise). The 1/f corner frequency for n-p-n SiGe transistors is approximately 500 Hz. The RF energy from the transistor's collector output is connected directly to the top-coupling loop (the excitation loop) of a single-sphere YIG tuned filter. A uniform magnetic field to bias the YIG must be at a right angle to any vector associated with an RF current in a coupling loop in order for the precession to interact with the RF currents.

In this example, a second bottom coupling loop (the feedback loop) transfers RF energy out of the YIG filter and connects it, in a fully differential configuration, to the input of the differential pair of transistors. The conditions for start oscillation for a ring oscillator require that its open-loop phase shift be equal to N(360°), where N is an integer equal to 0, 1, 2, 3 ... , and its open-loop gain must be greater than 1.0 (or 0 dBs). The electrical phase shift associated with the relative coupling loop to coupling loop physical angle is simply equal to the relative angle between the loops, which is usually –90°. The choice of 90° is important because it places the RF magnetic fields of the two loops in quadrature, which prevents any RF energy coupling between the two loops unless it is coupled through the mechanism of the YIG sphere's resonance, which is a chief source of spurious oscillations. The direction of the magnetic field is important because the sign of the phase shift depends on the direction of the magnetic field.

In one magnetic bias field direction, the oscillator will oscillate, and in the other direction, the oscillator will not oscillate over the designed frequency range. The differential output from the transistor pair is a perfect configuration match for the naturally differential coupling loops of this YIG tuned filter. The YIG filter has a *Q* of greater than 1,000, significantly contributing to the excellent overall phase noise of the oscillator. Therefore, the differential oscillator's electronic tuning can achieve multiple octaves of tuning, perhaps approaching a full decade. Oscillations will naturally occur at all frequencies for which the YIG sphere is tuned, magnetically biased to resonance by the DC magnetic bias field, without the need to make adjustments of any kind to a frequency selective reactive network, such as a tuning stub. By eliminating the need for making alignment adjustments, the differential oscillator is expected to have low-cost manufacturing. Output from this oscillator can be taken from the collectors in a differential manner, assuring that a balance is maintained to keep both transistor collectors at the same impedance, or from a third separate coupling loop which has the advantage of being a tracking filter on the output RF.

Since SiGe technology has a Ft in excess of 100 GHz, this oscillator circuit can be made to operate at frequencies in excess of 50 GHz.

This work was done by Ronald A. Parrott of VIDA Products, 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-18512-1.