Oscillators are Designed for Digital Microwave Communications

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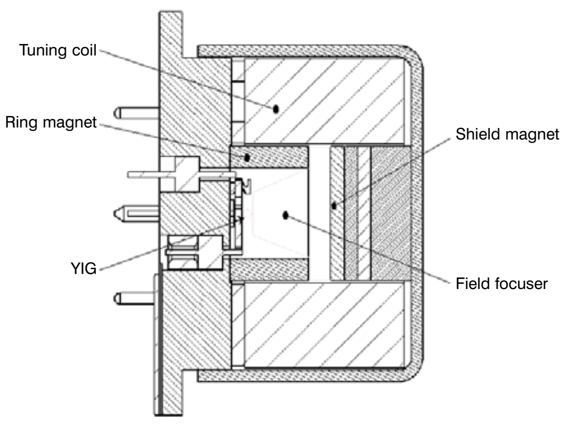
Verticom, Inc.

Verticom, Inc. has developed and is producing a patented line of digital-ready oscillators for Satcom, LMDS and point-to-point communications. The VIDA microwave oscillators are currently in use in the company's MTS1500 synthesizer product line.

This oscillator was designed from the start to satisfy the rigorous requirements of high data bandwidth and digital outdoor links. Verticom's experience in digital satellite communication was systematically applied and defined as the Value Intrinsic Design Axiom (VIDA), simply stated as "reduce parts and improve function." The goals for the intended application were to optimize phase noise to DRO equivalence, tuning and microphonics to VCO equivalence and producibility to disk drive equivalence.



▲ **Figure 1. The VIDA YIG oscillator structure.**

Results

A significant amount of research has been conducted to vibration harden YIG devices for military missile and aircraft applications. An accepted method is to stabilize the air gap by clamping a non-magnetic incompressible structure between the pole pieces. Over temperature, deferential stresses are incurred because of mismatched temperature expansion coefficients, specific heats, thermal conductivity and clamping mechanisms. These problems are greatly magnified in permanent magnet designs, due to magnet non-linear behavior and the brittle nature of permanent magnets. The VIDA solves the vibration problem by defining the air gap with the ring magnet and a re-entrant field focuser, as shown in Figure 1.

A shield magnet is above the field focuser to keep magnetic flux from flowing through the shell. The shell can then be made thinner and lighter. The entire magnetic structure can then be clamped with the shell — the shell deforming within elastic limits. This assures that no air gap develops in the magnetic circuit over temperature and that the magnet clamping force does not exceed the compressive limits of the magnets. Compared to other vibration-resistant YIG devices, nonlinear temperature effects in the VIDA have been minimized by the compliance of the structure, enabling an excellent resistance to phase hits that is not usually associated with YIG oscillators in temperature excursions. Figure 2 illustrates vibration-induced FM as a result of excitation frequency.

Vibration responses are normalized to 2 G peak-to-peak, but responses are linear and tested to 10 G peak-to-peak. The two traces show the differences in a gasket and hard mounting the device to a brass fixture. The hard mount is generally better but the damping factor is lower, resulting in a resonance response at 880 Hz due to the small diameter mounting screws.

The magnetic YIG bias in the VIDA is derived from two types of MMF sources — the permanent magnet material and the electromagnet coils. MMF from two permanent magnets, a ring magnet and a shield magnet, perform the two functions supplying the magnetic flux for the YIG bias and shielding the drive magnet to prevent losing flux through leakage. This method provides improved tuning efficiency for the electromagnet (EM) MMF because the drive flux generated by the ring magnet is not in series with the EM-MMF. However, the shield magnet, in series with (EM) MMF, with an external field scaled to the smaller leakage field, is much shorter. The advantage is apparent since the external field of a magnet is dependent on the intrinsic flux density ($4 \times \pi \times I_d$) and the length of the magnet.

B in the gap (B_g):

$$B_g = ((4\pi\, I_d\,) \times L_m\,) \,/\, (\zeta \cdot (L_g \,/\, L_m) + f \cdot (A_g \,/\, A_m))$$

ξ = reluctance factor
f = leakage factor
L_m = length of magnet
A_g = area of gap
A_m = area of magnet
L_g = length of gap
I_d = induction of the permanent magnet

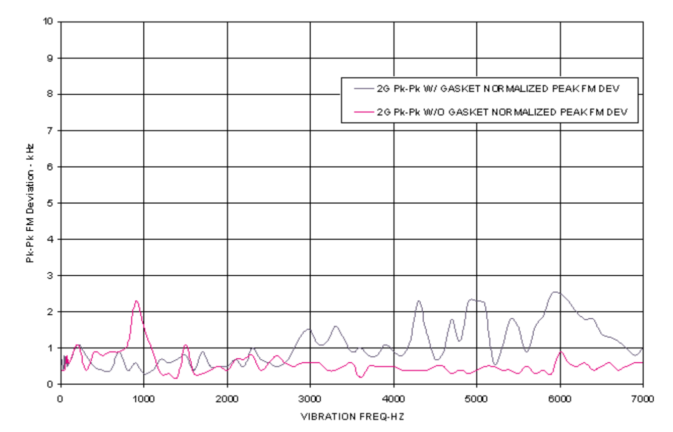
The demonstrated electromagnet air gap of the VIDA oscillator tuned to 12 GHz is 100 mils. If the leakage factor is neglected, then all the flux generated by the electromagnet goes through the gap and the tuning sensitivity is:

$$TS = .0139 \,{*}N$$

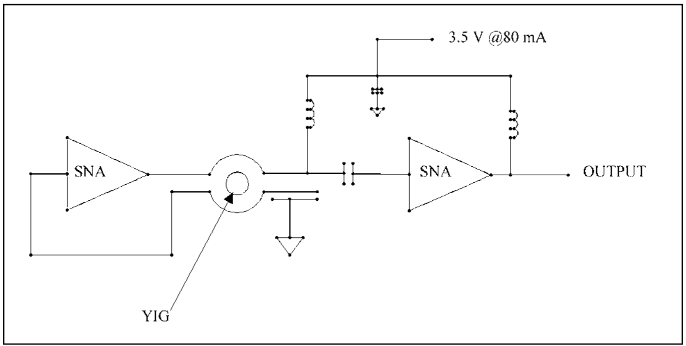
where N is the number of turns.

Balancing voltage with package size, and minimizing the power required, puts the number of turns for the VIDA size coil at 2200, yielding a tuning sensitivity of 30.5 MHz/mA. The resistance of this coil would be 90 ohms and the power required to tune 1 GHz would be less then 100 mW. The voltage for this case is less than 3 volts. Data on production runs demonstrate an average tuning sensitivity of 31.8 MHz with a standard deviation of 1.3.

Oscillator topology uses a three-port YIG resonator with an SNA-100 chip as an amplifier with non-reciprocal positive feedback (NRPF) to produce oscillations up to 1 octave continuous tuning bandwidth and another SNA-100 chip as a buffer amplifier. The circuits in use are optimized for phase noise, and produce good results at up to a 30 percent tuning band. The range of frequencies covered is from 5.8 to 12.1 GHz in ±1 GHz steps, with output power characteristically at 10 dBm due to the saturated output of the SNA-100. Phase noise is typically –100 dBc at 10 kHz offset and 125 dBc at 100 kHz offset. A simplified schematic is shown in Figure 3.



▲ **Figure 2. FM vs. excitation for the VIDA oscillators.**



▲ **Figure 3. IC-based oscillator circuit.**

The use of ICs simplifies bias considerations for wide temperature operation and minimizes circuit elements. Coplanar microcircuit format minimizes performance variation and assures that RF parasitic currents do not couple to the YIG resonator.

Going forward, the use of NRPF will facilitate application of SiGe bipolar devices due to the stability of the grounded emitter amplifier model and the 50 ohm impedance feedback circuit. With the new devices, we expect both the phase noise and frequency coverage to be greatly improved. ■

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