COVER story

Broadband YIGs Yield Fundamental Tones To 20 GHz

To switch or not to switch? These lines of YIG-tuned sources offer low-phase-noise coverage of 2 to 20 GHz continuously and by switching between two frequency bands.

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Microwave frequency generation relies on many exotic structures, including Gunn diodes, dielectric resonators, and carefully cut pieces of quartz crystal. But perhaps no oscillator approach is quite as detailed as sources based on yttrrium-iron-garnet (YIG) spheres placed within a cavity and subjected to an electromagnetic (EM) field. Fortunately, the engineers at Micro Lambda Wireless (Fremont, CA) have devoted many engineering years to taming this technology, and leading to the development of the firm's highest-performance YIG oscillators to date: the MLXB Extreme Wide Band Series oscillators with continuous fundamental-frequency coverage of 2 to 18 GHz and 2 to 20 GHz, and the MLXS-T Series of broadband oscillators with switched-band fundamental-frequency coverage of 2 to 18 GHz and 2 to 20 GHz.

Broadband YIG oscillators find homes in many applications, including as local oscillators (LOs) in receivers and spectrum analyzers, as microwave sources in frequency synthesizers, and for signal generation in threat simulators, and in wideband electronic-warfare (EW) systems.

Assembling a YIG oscillator requires skill and time, but the benefits in terms of low-noise performance are worth the effort. A YIG oscillator is formed with a tiny YIG sphere precisely positioned within the air gap of an electromagnet. In a well-designed YIG oscillator, the field strength of the electromagnetic is a linear function of the applied current as is, hopefully, the tuning behavior of the final YIG oscillator. A wire loop couples energy from the electromagnet to the sphere; similarly, a coupling loop extracts resonant energy from the sphere to produce the YIG oscillator's output frequencies. The tank circuit that produces resonance with the YIG sphere is designed according to the requirements of the electromagnet's coil and the sphere itself. The circuit is designed for high unloaded quality factor (Q) in order to generate high-quality output signals.

In order to produce output levels meeting the requirements of the many applications mentioned above, YIG oscillators incorporate transistors to boost the signal level of the final output signals. Bipolar transistors were once the active devices of choice for this function, but the development of higher-frequency YIG sources reaching beyond 20 GHz has prompted the use of GaAs field-effect transistors and, more recently, silicon-germanium (SiGe) transistors to take advantage of the excellent low-noise perfor-

1. The Extreme Wide Band Series of YIG-tuned oscillators includes models in cube and cylindrical package types with fundamental frequency ranges of 2 to 18 GHz and 2 to 20 GHz and outstanding phase-noise performance.

mance of these devices. In some cases, monolithic-microwave-integrated-circuit (MMIC) amplifiers are used in place of discrete-device circuits for this output-stage boost.

The main coil in a YIG oscillator accounts for frequency tuning, but a second coil is also needed for generating frequency modulation (FM) or for stabilizing the output frequency to an external reference source, as in a phase-locked-loop (PLL) oscillator or synthesizer. As with the main coil, the FM coil is tuned by current. The FM loop should be able to produce wideband modulation deviations and tune with enough sensitivity that is practical for use with modern PLL integrated circuits (ICs).

Historically, broadband YIG oscillators have been available but not with fundamental-frequency outputs. Designs from several manufacturers have featured the use of lower-frequency fundamental-tone YIG oscillators integrated in standard cylindrical YIG packages with frequency multipliers and wideband output amplifiers to achieve output frequencies to 18 or 20 GHz. But both the MLXB Extreme Wide Band Series YIG oscillators ***(Fig. 1)*** and the MLXS-T Series of switched-band YIG oscillators ***(Fig. 2)*** provide fundamental-frequency outputs without multiplication.

The MLXB Extreme Wide Band Series YIG oscillators currently features four different models, with two each covering 2 to 18 GHz and 2 to 20 GHz ***(Table 1)***. The lower-frequency models provide output power levels to +13 dBm across the frequency range while the two 20-GHz models provide at least +12 dBm output power across the frequency range; all of the oscillators maintain worst-case output-power flatness of ±3 dB across the full tuning bandwidth. All four YIG oscillators are designed to run on maximum current of 100 mA from a +15-VDC supply and 20 mA current from a +5-VDC supply, with an additional +24-VDC (±4 V, maximum of 250 mA on surge and 25 mA at steady state) supply to power each YIG source's internal heater circuitry.

Table 1: The MLXB Series YIG oscillators at a glance

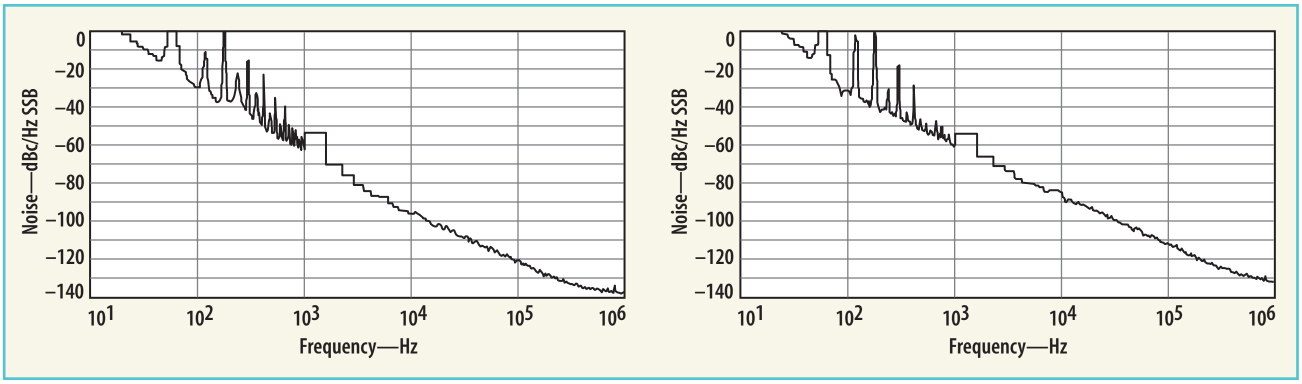
	MLXB-0218	MLXS-0218	MLXB-0220	MLXS-0220
Frequency range (GHz)	2 to 18	2 to 18	2 to 20	2 to 20
Output power (dBm)	+13	+13	+12	+12
Frequency drift with temperature (MHz)	20	20	25	25
Phase noise (dBc/Hz) @ 100 kHz offset	–112	–112	–112	112
From 2-12 GHz	–120	–120	–120	–120
From 12-18 GHz	–112	–112	–112	–112
From 18-20 GHz	–	–	–107	–107
Spurious (dBc)	–70	–70	–70	–70
Second harmonics (dBc)	–12	–12	–12	–12
Third harmonics (dBc)	–15	–15	–15	–15
Main coil sensitivity (MHz/mA)	18	20	18	20
FM coil sensitivity (kHz/mA)	410	410	410	410
Case style	1.25 x 1.25 x 100 in. cube	1.75-in diameter cylinder	1.25 x 1.25 x 100 in. cube	1.75-in. diameter cylinder

That heater circuitry is included to minimize frequency variations as a function of changing temperature. Maximum frequency drift with temperature, which is specified over a temperature range of 0 to +65°C, is only 20 MHz through 18 GHz and 25 MHz through 20 GHz. In addition to low drift, these YIG oscillators are also relatively immune to the influence of load mismatches, with a typical frequency pulling figure of 1 MHz for a load return loss of 12 dB. The effects of power-supply variations are also minimal, with a frequency pushing figure of typically 0.1 MHz/V for the +15-VDC supply and typically 1 MHz/V for the –5-VDC supply.

When comparing the published specifications for a 2-to-20-GHz model MLXB-0220 YIG oscillator with actual measured data from an automated test system at Micro Lambda Wireless, the specifications for temperature stability and output power were found to be quite conservative. For this unit, output power is specified for a minimum of +12 dBm (although output power is specified as a function of frequency and not temperature). The measured output power across the 2-to-20-GHz range hit a minimum of +12.4 dBm at 20 GHz and more than +17 dBm at the lower end of the frequency range. Frequency drift over temperature is specified for maximum of 25 MHz, although measurements showed errors of 1 MHz at 9 GHz, 0 MHz at 10 GHz, and a worst case of 20 MHz at 16.4 GHz.

The broadband oscillators feature the outstanding spectral purity associated with YIG technology. Spurious levels are –70 dBc or better for all four models, while second harmonics are –12 dBc or better and third harmonics are –15 dBc or better. The single-sideband phase noise ***(Fig. 3)*** offset 100 kHz from 2 to 12 GHz is –120 dBc/Hz. The phase noise measured at the same offset for carriers from 12 to 18 GHz is –112 dBc, rising to –107 dBc/Hz measured at the same offset frequency for carriers from 18 to 20 GHz. The spectrally narrow out-

2. The MLXS-T Series of low-noise YIG-tuned oscillators covers a broad frequency range in two bands, switching between the lower- and higher-frequency bands by means of TTL control.



3. These plots of measured phase noise show the characteristics of a 2-to-20-GHz YIG oscillator in the Extreme Wide Band Series in a 1.25-in.-cube package. The plot on the left is for a carrier frequency of 7.9 GHz while on the right for a carrier of 17.9 GHz.

put signals occupy a 3-dB bandwidth of a mere 5 kHz, tuned by merit of 18-MHz/mA main-coil sensitivity. The main-coil tuning linearity is typically ±0.1 percent at all frequencies, with typically hysteresis of 16 MHz or less. The FM coil, for modulation or for the purposes of stabilizing output frequencies by means of a PLL, controls a 3-dB modulation bandwidth of 1 MHz with typical sensitivity of 410 kHz/mA. For all models, the FM coil commands deviations as wide as 40 MHz.

The MLXB and MLXS Extreme Wide Band Series YIG oscillators are supplied in two package styles: a "cube" package measuring 1.25 × 1.25 × 1.00 in. and a cylindrical package measuring 1.75 in. in diameter and 1.40 in. high, excluding the extension of the SMA RF output connector. They can also be specified for an operating temperature range of –40 to +85°C for military applications.

In contrast to the continuous broadband tuning range provided by the Extreme Wide Band Series oscillators, the two sources in the MLXS-T Series ***(Table 2)*** of broadband YIG oscillators incorporate an internal switch to select between bands. Each oscillator switches between two frequency bands. In the MLXS-0218T, the bands are 2 to 8 GHz and 8 to 18 GHz; in the MLXS-0220T, the bands are 2 to 8 GHz and 8 to 20 GHz. There is a 200-MHz overlap at 8 GHz for each oscillator. The bands are switched by a TTL control, with an internal driver used to turn off the unused band to eliminate signal leakage and conserve power. The worst-case accuracy of this band-switching arrangement is 8 MHz for the 2-to-18-GHz model MLXS-0218T and 10 MHz for the 2-to-20-GHz model MLXS-0220T.

The band-switching architecture allows slightly higher output power in the MLXS-T Series compared to the Extreme Wide Band Series oscillators, with at least +14 dBm output power through 18 GHz and at least +13 dBm output power through 20 GHz. The worst-case output-power variation with frequency is ±3 dB. Frequency drift with temperature is 20 MHz or less in the MLXS-0218T and 25 MHz or less in the MLXS-0220T. The frequency pulling for both models into a 12-dB return-loss load is typically 1 MHz while the frequency pushing is typically 0.1 MHz/V for the +15-VDC supply and 1 MHz/V for the –5-VDC supply.

As with the Extreme Wide Band Series oscillators, the MLXS-T Series sources achieve excellent low-noise performance, with minimum second harmonic levels of –12 dBc and minimum third-harmonic levels of –15 dBc. Spurious content is –70 dBc or better.

For both models, the minimum phase noise is –103 dBc/Hz offset 10 kHz from the carrier, typically –108 dBc/Hz offset 10 kHz from the carrier, and typically –128 dBc/Hz offset 100 kHz from the carrier. **Micro Lambda Wireless, Inc., 46515 Landing Parkway, Fremont, CA 94538; (510) 770-9221, FAX: (510) 770-9213, Internet: www.microlambdawireless.com.**

Table 2: The MLXS-T Series YIG oscillators at a glance

	MLXS-0218T	MLXS-0220T
Frequency range (GHz)	2 to 18	2 to 20
Output power (dBm)	+14	+13
Frequency drift with temperature (MHz)	20	25
Pulling (MHz)		
Pushing (MHz)	1	1
For +15-VDC supply (MHz/V)	0.1	0.1
For –5-VDC supply (MHz/V)	1	1
Phase noise (dBc/Hz)		
@ 100 kHz offset	–123	–123
Spurious (dBc)	–70	–70
Second harmonics (dBc)	–12	–12
Third harmonics (dBc)	–15	–15
Main coil sensitivity (MHz/mA)	20	20
FM coil sensitivity (kHz/mA)	310	310
Band switching		
TTL = 0	8 to 18 GHz	8 to 20 GHz
TTL = 1	2 to 8 GHz	2 to 8 GHz
Band-switching accuracy	8 MHz	10 MHz
Case style	2.00-in. diameter cylinder	2.00-in. diameter cylinder