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Permanent Magnet Biased YIG-tuned Oscillators

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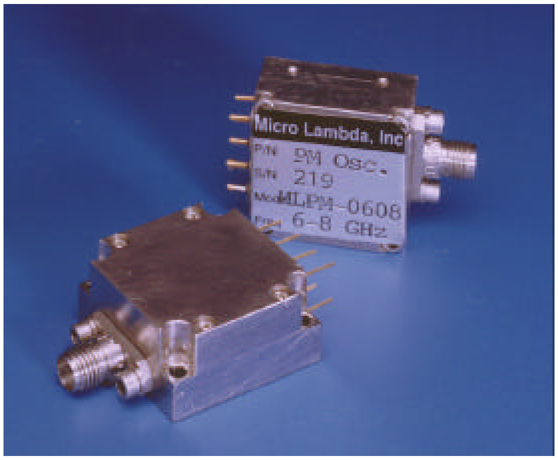

Introduction

YIG-tuned permanent magnet oscillators (PMO) are coming of age. The productization of this previously developed technology is driving oscillator sizes down to one-half the volume of what was available just a few years ago. PMOs are fast becoming good alternatives to dielectric resonator oscillators (DRO). The MLPM series YIG-tuned PMOs operate over the 2 to 18 GHz frequency range. Table 1 lists key specifications.

Current circuit designs utilize negative feedback topology, yielding low noise, narrowband sources. This approach differs from typical wideband YIG sources, where achieving the n X 2 radian phase shift necessary for wide tuning ranges is inherently obtained. Low frequency designs to 8 GHz utilize bipolar transistors in the oscillator circuit, followed by a single buffer amplifier stage for power and load change immunity. These designs do not require a –5 V bias supply. Higher frequency designs (8 to 18 GHz) incorporate GaAs FETs in the oscillator circuit, followed by a single buffer amplifier stage at the output. The oscillator circuits are all thin-film designs for repeatability. Figure 1 shows the feedback topology used in these configurations.

Performance

Standard product power levels available for these designs are +16 dBm to 8 GHz and +13 dBm to 18 GHz. Careful device selection for both the oscillator and buffer amplifier can yield up to +20 dBm to 8 GHz and +16 dBm to 18 GHz in the standard configured package. A single input voltage of +12 V is used with protection for the active devices provided by an internal voltage regulator. A C-band unit has been produced that provides +20 dBm over the 4 to 6 GHz frequency range. The power flatness obtained is ±0.5 dB across a 2000 MHz tuning range, including the operating temperature range of -20° to +70°C.

The phase noise of a 6 GHz PMO measures -103 dBc/Hz at 10 kHz offset and -128 dBc/Hz at 100 kHz offset. A 15 GHz oscillator measures –88 dBc/Hz and –112 dBc/Hz at 10 kHz and 100 kHz, respectively. Noise performance of a 12.8 GHz unit tested using a standard commercial 9 V battery is shown in Figure 2. Performance of this unit was maintained over a six-hour time period before battery degradation took place.

Tuning Capabilities

The 2000 MHz tuning range of these devices can be provided using two methods. The first method is to set the free-running frequency to a desired center frequency and tune the low power coil current in a negative and positive direction to achieve ±1000 MHz tuning. The second method is to set the free-running frequency to a desired low end frequency and tune the low power tuning coil current in a positive direction to achieve +2000 MHz tuning range. Given either of these conditions, the low power coil requirement to achieve —>>

TABLE 1
PERMANENT MAGNET OSCILLATOR SPECIFICATIONS

MLPM-Series Model No.	Frequency (GHz)	Power Output (dBm)	Phase Noise @ 100 kHz (dBc/Hz)	Frequency Drift (MHz)
-0204	2 to 4	16	-120	+/-2.5
-0406	4 to 6	16	-120	+/-4.5
-0608	6 to 8	16	-120	+/-6.0
-0812	8 to 10	13	-120	+/-8.0
-1012	10 to 12	13	-110	+/-10
-1214	12 to 14	13	-110	+/-10
-1416	14 to 16	13	-110	+/-12.5
-1618	16 to 18	13	-105	+/-15.0

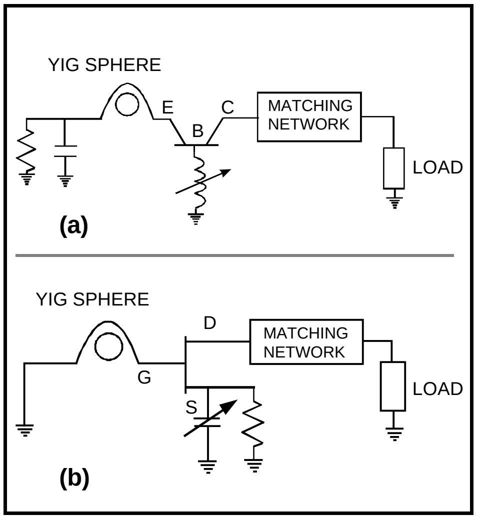

Fig. 1: The Feedback topology or the (a) common-base bipolar and (b) common-source FET configurations.

2000 MHz of tuning range is only ±100 mA or +200 mA. This specification provides a considerable advantage over traditional YIG sources, which would require 300 mA of coil current (in the case of 6 GHz) to achieve the equivalent frequency. As the frequency increases the benefits become more advantageous. At 18 GHz, a permanent magnet source still only requires either ±100 mA or +200 mA to achieve the tuning band, as compared to the typical YIG source, which would require 900 mA to provide 18 GHz.

Standard permanent magnet units offer a frequency modulation (FM) coil to further set the frequency, or for phase locking. The frequency deviation is ±50 MHz, which is a wider frequency window than the combined linearity and frequency drift error. This characteristic is required to ensure that the units will remain phase locked under all conditions. Sensitivity of the FM coil has been set at 150 kHz/mA with a modulation bandwidth (BW) of 400 kHz (min). The sensitivities and modulation BW up to 1 MHz can be tailored to specific customer requirements.

A significant advantage in PMO designs is the low prime power required to operate them. Traditional YIG sources have required many watts of power, especially at 18 GHz. If chosen, operation of a fixed-tuned PMO at 18 GHz is achievable without any main coil current. A YIG-based oscillator set at the free-running frequency can be obtained with the single +12 V input. Using a MHz/mA, worst-case current required to tune the 2000 MHz band is +200 mA.

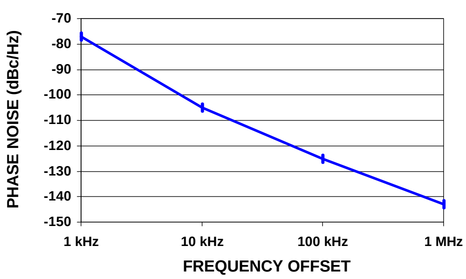

Fig. 2: Phase noise of a 12.8 GHz PMO.

The equivalent voltage necessary to drive the mail coil is less than 7 V, which is obtainable in current driver technology. Under these conditions, the worst-case power consumption to drive the main coil is .57 W.

Current units require a heater operating from a +15 V input. The surge current is 250 mA with a steady state current of 25 mA. The elimination of the heater is currently under evaluation and can already be realized with sacrifices in temperature stability. The objective is to eliminate the heater without sacrificing the stability.

Frequency Drift

The frequency drift of free-running PMOs varies from ±2.5 MHz at 2 GHz to ±15 MHz at 18 GHz. Units can be manufactured and compensated to obtain better drift performance per customer requirements. Compensation of the YIG resonator and careful selection of the magnet are key to enhanced performance.

The long term drift of permanent magnets had been a concern for a few years. With the current availability of stable magnets, YIG sources using stable magnets have shown good frequency error over extended periods of time. A 6 GHz permanent magnet YIG-tuned oscillator is currently on life test, yielding less than 5 MHz of drift over 1000 hours.

Mechanical Design

The current PMOs have been designed in a 1.0” x 1.0” x 0.5” high package with field-replaceable SMA RF connectors. The mechanical configuration is shown in Figure 3. Mounting configurations of through holes for mounting through the top, threaded holes for mounting up through the bottom or PCB mount for plug-in boards are currently available. An advantage in these configurations over DROs is that the size does not change as the frequency changes. The DRO’s size changes depending upon the dielectric resonator size required to obtain a particular frequency. The mechanical design also includes provisions for input line filtering, frequency settability, a ruggedized settability, a ruggedized package for environmental usage, manufacturability and the most critical of all, lower unit cost.

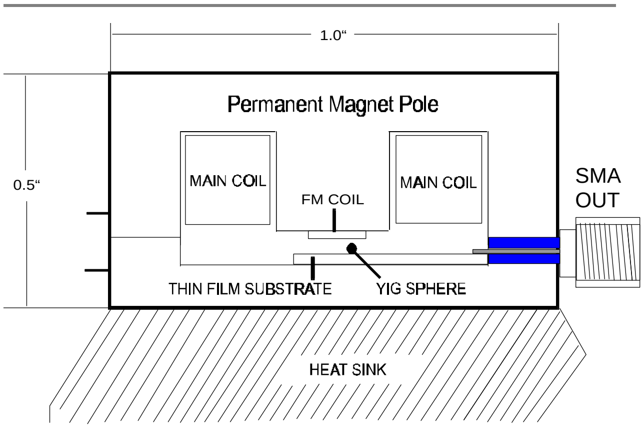

Fig. 3: YIG-tuned PMO cross section.

Input filtering of all the input lines is provided with glass-to-metal capacitive feedthroughs. Frequency settability (to within ±1 MHz) is obtained by critical part tolerances and magnetic gap setting. Similar products, such as DROs, have a mechanical tuner to set the required frequency. Incorporating mechanical tuners can add microphonic problems, which have been eliminated in these new PMO designs.

Ruggedization design techniques commonly used to pass military environments have been incorporated to improve the vibration and shock sensitivity of these units. However, special assembly and test processes had to be developed to further improve the microphonic and phase hit performance criteria. Studies of actual performance under hammer tests, steel ball tests for microphonics and phase hit tests in digital radios are currently underway with results available in the next few months.

Applications

PMOs are currently finding their way into various commercial markets. Communications, V-SAT, digital radios, synthesizers and phase-locked sources are areas where this technology is finding a home. The PMOs make good DRO replacements in fixed-tuned, main coil tuned or FM coil tuned versions. The low prime power/ current required to tune over 2000 MHz requiring less than 10 V now can be easily handled. The wide tuning range available makes it possible to replace four to six DRO units currently required for a specific commercial frequency band.

Conclusion

Permanent magnet oscillator technology will continue to evolve over the next few years. Production versions covering 2 to 18 GHz with various mounting configurations are currently available. The PMOs will find a place in commercial markets once evaluation and testing are completed, and will rival DROs for key production sockets. Further development to add additional functions and to increase power levels will aid in extending their product life cycle. The technology will be pushed higher in frequency in the years ahead, with cost being the driving factor. The development of 1.0” x 1.0” x 0.5” PMOs has been leveraged into a complete line of 2 to 8 GHz miniature oscillators already in production. This progress will help in the standardization of packages while reducing the unit cost.