

What is YIG?

Yttrium Iron Garnet (YIG) is a crystal that has very high Q characteristics. This high Q provides very low phase noise in oscillators and multi-octave frequency tuning for both oscillators and filters.

YIG crystals are “grown”, similar to silicon crystals. The pulled crystal is “sliced and diced”, resulting in small YIG cubes. (Unfortunately, the cube shape is non-uniform, and as a result has non-uniform coupling in a resonator circuit.) These small YIG cubes are then put into a “tumbler” that slowly shape the YIG cube into a YIG sphere (very similar to smoothing a stone for jewelry). The size of the YIG spheres range from 10-30 mils.

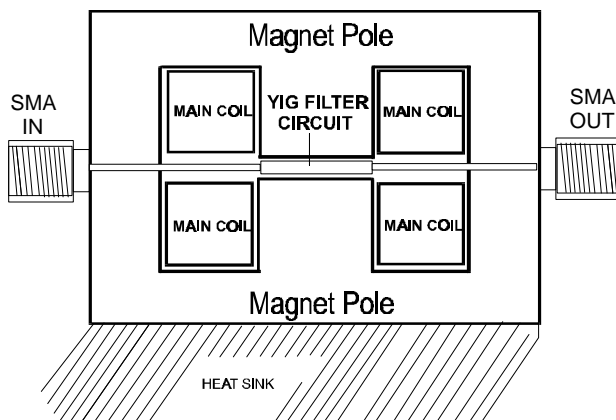
The YIG sphere is typically mounted on the end of a thermally conductive rod (normally beryllium). This is done for two reasons: 1) the rod acts as a “tuning stick” for orienting the YIG sphere in the resonant circuit, and 2) YIG has best performance when it’s temperature is kept constant; the rod is a thermal conductor to/from a proportional heater and the YIG sphere. (YIG oscillators and filters have been designed without the rod and heater for low cost. However, the impact on performance limits applications.)

How Does YIG Work?

YIG is a ferrite material that resonates at microwave frequencies when immersed in a DC magnetic field. This resonance is directly proportional to the strength of the applied magnetic field and has very linear “tuning” over multi-octave microwave frequencies.

The DC magnetic field is generated using an electromagnet, a permanent magnet, or a combination of both. The magnetic field of an electromagnet can be “tuned” using a variable current. Figure 1 illustrates a typical YIG filter magnet.

Figure. 1: Typical YIG-tuned filter cross section.

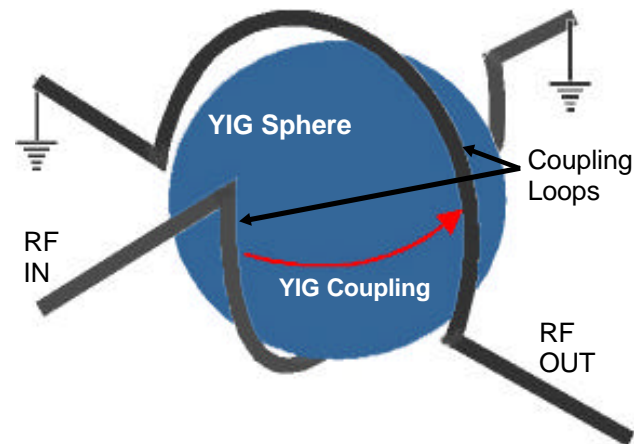


YIG crystal resonance is the alignment of external electron paths at the molecular level (precession), creating a “combined” magnetic dipole: a magnetic field resonating at microwave frequencies around the YIG sphere.

How Do We Use YIG?

Current generates magnetic fields, and magnet fields can generate current when coupled to a conductive “loop”. Using small conductive “loops” allows coupling **to & from** the YIG spheres resonant magnetic field (see figure 2).

Figure 2: Coupling structure of single stage bandpass filter.



There are three basic methods in which this coupling is applied:

- Signal Transfer - Bandpass Filters
- Signal Reflection - Band Reject Filters
- Oscillation-Feedback (see oscillators)

Bandpass Filters

Figure 2 illustrates typical coupling of YIG resonators in a single stage (sphere) bandpass filter. The coupling loops are aligned at a 90° angle to prevent direct RF coupling. One end of each loop is grounded. This prevents the filtered signal from being reflected.

The RF input signal of the coupling loop modulates the magnetic field around the YIG sphere, this modulation is coupled to the magnetic field resonating around the YIG sphere, which then couples to the second/output loop. The RF signal passing through the filter must be the same frequency as the RF magnetic field resonating around the YIG sphere.

The frequency bandwidth/spectrum that is coupled through the YIG resonator is dependent on the spacing between the YIG resonator and the coupling loop. The closer the loop, the wider the bandwidth. Bandwidth can also be expanded by increasing the number of YIG resonators and carefully “tuning” the RF coupling loops. Filter insertion loss increases with expanded bandwidth.

A YIG bandpass filter's 3 dB bandwidth expands as the filter is tuned to higher operating frequencies at a rate of approximately 20% per octave (e.g. 30 MHz @ 2 GHz, 50 MHz @ 18 GHz).

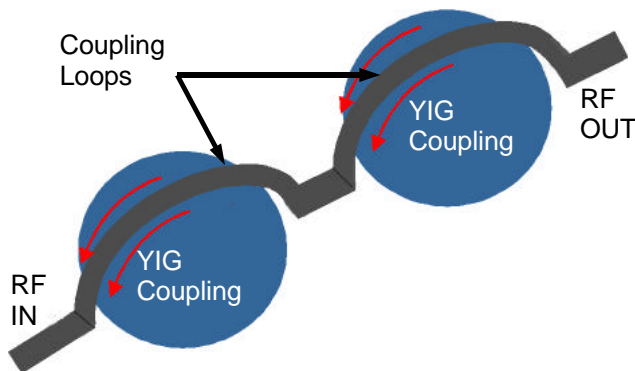
Micro Lambda's standard YIG bandpass filter's 3 dB bandwidth is 15 MHz to 40 MHz (@ 2 GHz); 20 MHz to 50 MHz (@ 18 GHz). Filters with 3 dB bandwidths greater than 500 MHz are available above 6 GHz operating frequency.

There is a limit (i.e. Limiting) on the total amount of RF energy that a YIG resonator/sphere can couple/transfer (e.g. 0 dBm to +10 dBm).

Band Reject Filters – Signal Rejection

Figure 3 illustrates typical coupling of YIG resonators in a two stage (sphere) band reject filter. There is only one coupling loop (ribbon) per YIG sphere. The coupling loops are aligned along a straight line and are interconnected between the YIG resonators.

Figure 3: Coupling structure of two stage band reject filter.



The coupling loops are essentially RF transmission lines that pass all RF energy. However, when these transmission lines are located close to the surface of the YIG sphere, the loop couples to the magnetic field resonating (@ microwave frequencies) around the YIG sphere.

This coupling essentially reflects/rejects in coming frequencies that are at the same RF frequency as the RF magnetic field resonating around the YIG sphere.

Rejection bandwidth is widened by increasing the number of YIG resonators and carefully "tuning" the RF coupling loops.

Micro Lambda's standard band reject filter's 40 dB rejection bandwidth is 15 MHz to 70 MHz.

YIG Filter Specifications

There are four basic specification categories for YIG filters: RF, magnet, power consumption and environmental conditions. They are all somewhat interdependent and define unit performance and cost.

**RF Specifications:
3 dB BANDWIDTH**

The frequency span (in MHz) between the points on the selectivity curve at which the insertion loss is 3 dB greater than the minimum insertion loss. Also called 3 dB passband. See item A, Figure 4.

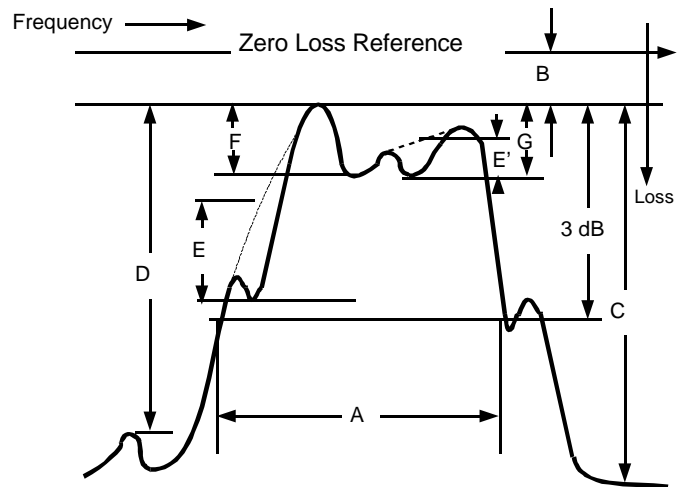


Figure 4: Bandpass Filter Skirt

FREQUENCY RANGE (BAND CENTER)

The range of frequencies (in GHz) over which the YIG Filter must meet all specifications.

INSERTION LOSS (BAND PASS)

The transmission loss measured in dB at that point in the passband which exhibits the minimum value. See item B, Figure 4. (Band Reject: Item B, Figure 5)

LIMITING LEVEL

The input power level at which the input/output characteristics exhibit 1 dB compression, i.e., the transfer function becomes non-linear in that the output increases less than 1 dB for a 1 dB increase in the input.

LOSS BANDWIDTH

The frequency span (in MHz) at a given insertion loss referenced to the passband minimum insertion loss.

NON-OPERATING SIGNAL REJECTION

The amount of signal rejection (in dB) referenced to the insertion loss, measured at any point across the frequency range with zero current through the tuning coil.

OFF RESONANCE ISOLATION

The amount of signal rejection (in dB) referenced to the passband minimum insertion loss measured at a point outside the YIG filter passband skirts. See item C, Figure 4.

OFF RESONANCE SPURIOUS

The amount of suppression (in dB), referenced to the passband minimum insertion loss, of spurious responses outside the YIG filter passband skirts. See item D, Figure 4.

PASSBAND RIPPLE

The peak to peak value (in dB) of ripple occurring within the 3 dB passband referenced to the minimum insertion loss. See item F, Figure 4.

PASSBAND SPURIOUS (BAND PASS)

The additional transmission loss (in dB) within the 3 dB passband attributable to the presence of spurious resonance (absorption) modes. Spurious modes within the minimum loss (ripple) region are referenced to the normalized filter response curve (See item E, Figure 4).

RIPPLE AND SPURIOUS - COMBINED

The worst case transmission loss (in dB) within the YIG filter 3 dB passband due to the presence of passband ripple (See item F, Figure 4) and/or passband spurious (See item E, Figure 4) responses. See item G, Figure 4.

PASSBAND SPURIOUS (BAND REJECT)

The additional transmission loss (in dB) attributable to the presence of spurious resonance (absorption) modes. See item C, Figure 5.

TEMPERATURE DRIFT

The change in resonant frequency (at a fixed coil current) associated with the change in operating temperature.

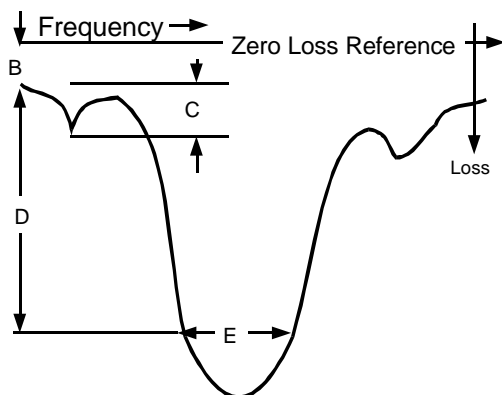


Figure 5: Band Reject Filter Skirt

PASSBAND VSWR

The best VSWR as measured at any point within the 3 dB passband.

REJECTION (BAND REJECT)

The amount of attenuation (in dB), referenced to the insertion loss. See item D, Figure 5.

REJECTION BANDWIDTH (BAND REJECT)

The frequency span (in MHz) of the rejection notch at the specified degree of rejection. See item E, Figure 5.

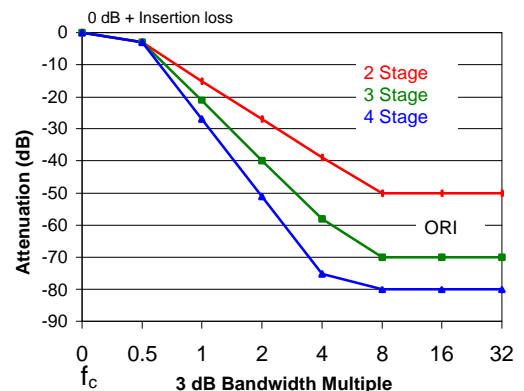
RESONANT FREQUENCY OR PASSBAND CENTER FREQUENCY

The arithmetic mean of the low and high normalized 3 dB frequencies.

SELECTIVITY

The nominal YIG filter passband skirt roll-off as measured in dB per passband octave, typically -6 dB per octave (stage). See figure 6.

Figure 6: Filter skirt selectivity and off-resonance isolation (ORI)


Magnet Specifications:

The magnet generates a DC magnetic field using an electromagnet, a permanent magnet, or a combination of both. The magnetic field of an electromagnet can be "tuned" using a variable current.

The electromagnet offers very linear, multi-octave tuning (e.g. 2-18 GHz). A typical 2-18 GHz YIG filter has a main tuning coil sensitivity of 20 MHz/mA; therefore the required tuning current at 2 GHz is: $2 \text{ GHz} / (20 \text{ MHz/mA}) = 100 \text{ mA}$, at 18 GHz it is 900 mA.

COIL INDUCTANCE

The tuning coil inductance as measured on an impedance bridge at a specified test frequency.

COIL RESISTANCE

The tuning coil resistance as measured on an ohm meter.



HYSTERESIS

The maximum differential (in MHz) of the center frequency (at a fixed coil current) seen when the YIG filter is tuned in both directions through the operating frequency range.

LINEARITY

Maximum deviation (in MHz) of the measured resonant frequency vs coil current curve from the ideal linear tuning line over the YIG filters operating frequency range.

SENSITIVITY

The normalized change in YIG filter center frequency resulting from a change in tuning coil current, specified in MHz/mA.

TUNING RESPONSE TIME

The time required for the filter response to come within a specified value of the desired frequency for a specified frequency sweep.

Tuning Input Impedance

The small signal impedance seen at the tuning input port at a specified modulation frequency of frequencies.

Power Consumption Specifications:

There are three basic power consumption areas: circuit biasing, YIG sphere heater and tuning current. Tuning current is addressed in the "Magnet Specifications" of this data sheet, and is in addition power to those described below.

Heater Current

Proportional heaters are normally used in YIG devices to keep the temperature of the YIG sphere constant (~+85° C). This improves RF performance, particularly spurious outputs.

Heater Current, Steady State

Heater current requirements during normal operations after reaching steady state conditions.

Heater Current, Surge

The peak current the heaters will draw upon initial power up.

Environmental Specifications

Environmental specifications define the operating and non-operating extremes that the YIG filter must operate, or withstand without damage.

Altitude-Operating

The altitudes (measured in feet or meters) that the YIG filter operate while meeting all specifications.

Humidity-Operational

The relative humidity (compared to 100% saturation) measured in %, at a specific temperature.

Shock-Non-Operational

Is the magnitude of a short term impact (measured in Gs/mSec) that the non-operational YIG filter can survive without damage.

Temperature Range-Operating

The range of temperature as measured near the filter mounting surface over which the operating filter must meet all specifications, unless otherwise noted.

Temperature Range-Storage

The range of temperature that the YIG filter can be exposed to, non-operational, without damage.

Vibration-Operational

Is the frequency modulated (random or sinusoidal) G force that the filter can meet the specifications.

Vibration-Non-Operational

Is the frequency modulated (random or sinusoidal) G force that the non-operating YIG filter can withstand without damage.

Warm-Up Time

The minimum time required for the unit to meet all specifications.