FOUR-PORT YIG FILTER

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Abstract

The four-port YIG filter represents a new class of multifunction YIG components. This device, by proper coupling techniques, yields a reciprocal and tunable YIG filter with balanced outputs and two inputs. One input is coupled through the YIG resonator and is delivered as two equal amplitudes, 180 degrees out-of-phase signals at the balanced outputs. This signal, as it is coupled through the YIG, has a bandpass characteristic. The second input does not couple to the YIG but is split in-phase between the balanced outputs. The transmission of this signal does not involve the YIG resonance. The component thus combines the function of a tunable bandpass filter and a 180 degree hybrid junction, and so may be accordingly used.

Experimental devices were built and evaluated as a combined preselector and balanced mixer, in particular, in regard to subharmonic mixing for multioctave performance. Also, the same device was evaluated as a tunable phase discriminator showing the versatility of this new component.

Subharmonic mixing was evaluated using the four-port filter from 2.0 to 8.0 GHz while the discriminator, as breadboarded, was found to tune from 1.0 to 5.0 GHz with decade performance clearly feasible.

NOTES

Introduction

The four-port YIG filter is a class of tunable YIG devices that provides additional circuit functions besides that of a bandpass filter. This device combines a four-port hybrid function with that of the tunable filter. The balance and isolation of the hybrid is dependent on the symmetry and orthogonality of the coupling structure and is not frequency dependent to the first approximation. Multioctave performance is thus easily obtainable. Applications of the device include its use as tunable filter-mixer and a phase discriminator.

Electrical Characteristics

The electrical characteristics of the four-port filter can be determined by the equivalent circuit of Figure 1. The input signal A is coupled through the YIG resonator to a balanced output. The two outputs thus differ by 180^{o}. In terms of the input there is also the nonreciprocal 90^{o} phase shift typical of a YIG filter. The fourth port, B, is introduced at the plane of symmetry of the output coupling structure. This signal splits with equal phase to the two outputs and does not couple to the resonator.

The frequency characteristics of the transmission of signals from port A to the outputs are determined by the bandpass of the YIG resonator, while the transmission characteristics of the signal introduced at port B are inherently frequency independent from dc through the operating band of the filter. Isolation exists between ports A and B inside or outside the passband of the filter because the symmetry of current flow from port B to ports C and D effectively reduces any coupling.

Applications, Filter-Mixer

The phasing of the combined signals leaving ports C and D of Figure 1 are proper for operation as a balanced mixer with these ports terminated by appropriate mixer diodes. Figure 2 shows the proper connection for this application. It is to be noted that the device would serve as a combined preselector and mixer, and even as a harmonic mixer.

One advantage of harmonic mixing is that it allows the use of a YIG tuned solid-state LO. As a harmonic mixer, the LO is injected as a subharmonic of the desired LO frequency. Consider for an example, the RF signal could be in C-band at 5 GHz, while the LO in L-band was 1647 MHz, thereby giving an IF of 60 MHz. The above would allow generation of the LO by solid-state means such by a YIG tuned transistor oscillator. The inherent pre-selection of the device suppresses responses at other input frequencies that would yield spurious IF frequencies.

In systems where small size or simplicity is important, this additional compensation loss of 8 to 20 dB resulting from harmonic mixing may not be excessive. The sensitivity would be considerably better than that achievable by video detection. The filter-mixer using a subharmonic LO would provide a favorable solid-state replacement for the TWT and YIG filter TRF system. The sensitivity would be better and additional selectivity could be provided in the IF amplifier if desired.

Another advantage of harmonic mixing with the filter-mixer is that of using a low frequency LO to allow the installation of the filter-mixer at a remote antenna location. For instance, an L-band LO could be used to feed the filter-mixer. The returning IF signal would contain the phase and amplitude information of the received signal.

Measured performance shown in Figure 3 of an experimental four-port filter yielded an insertion loss of 1 to 1.5 dB beyond 3 dB power split from port A to the output ports C and D. This measurement was from 1 to 4 GHz. The filter exhibited low level limiting below 1.5 GHz. Isolation between LO and signal ports (A and B) was greater than 20 dB on-resonance and 28 dB off-resonance over the same frequency range. Off-resonance isolation of the filter (A to C and D) was a minimum of 31 dB. This was for a single resonator structure; greater isolations could be obtained by using more stages, as is done in normal filter practice.

Figure 3 also shows the measured conversion loss of the four-port filter used as a harmonic mixer. This data should be considered as proof of feasibility and not best performance, as the mixer diodes were not optimized for the application and no bias was used. The loss in sensitivity resulting from subharmonic mixing using non-optimized diodes ran 8 to 20 dB higher with the 1/2 and 1/3 harmonic compared to that with the fundamental LO frequency.

Phase Discriminator

Similar to the mixer application, the balanced outputs of the four-port filter make it useful as a tunable phase discriminator. The filter is arranged as shown in Figure 4. In this case, the signal is split into two channels. One channel is coupled through the YIG resonator and the second serves as a phase reference channel and is connected to what is the LO input for the mixer application. The YIG resonator provides a frequency sensitivity in phase shift that causes a selective reinforcing or cancellation with the reference signal at the output ports. For one output this reinforcing occurs above the tunable YIG resonance and for the other output, it occurs below.

A discriminator circuit was breadboarded and was found to tune from 1 to 5 GHz with one fixed setting of a line stretcher. A decade tuning range is felt to be possible with care in the selection of the reference couplers and line stretcher.

Figure 5 is an oscilloscope photograph of a typical "S" curve, discriminator response measure with the four-port filter used as a phase discriminator. Figure 6 is the response for frequencies swept from 1 to 2 GHz showing the wide capture range of this type discriminator. As mentioned previously this discriminator tuned from 1 to 5 GHz and was actually usable to 8 GHz.

Antenna Coupler

The four-port filter has applications in antenna feeds where transitions from balanced to unbalanced transmission lines are required. Such a circuit is shown in Figure 7. In this case, the balanced signals would be coupled by the YIG resonator to the receiver port. The unbalanced or in-phase signals would be coupled to port B which is shown terminated. This port could be used in certain diplexer applications with a microwave log-periodic antenna also excited in phase at VHF for dual use or for a communications antenna.

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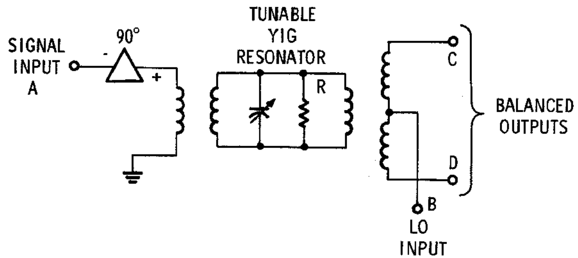

FIGURE 1 - EQUIVALENT CIRCUIT

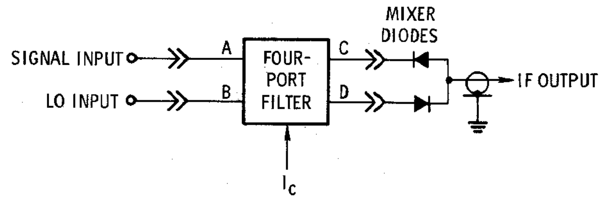

FIGURE 2 - PRESELECTOR MIXER-FILTER

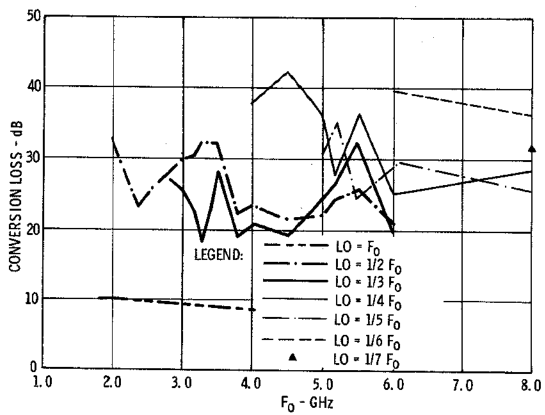

FIGURE 3 - CONVERSION LOSS HARMONIC MIXING

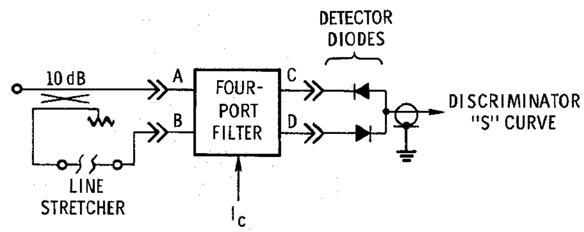

FIGURE 4 - PHASE DISCRIMINATOR

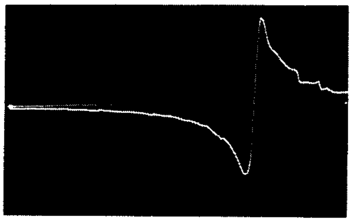

FIGURE 5 - DISCRIMINATOR L-BAND RESPONSE

1.60 to 1.85 GHz
Sweep 25 MHz/cm
I_c = 98.33 mA

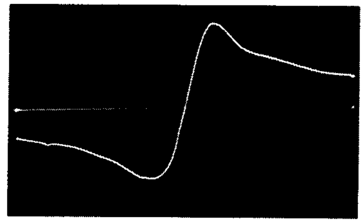

FIGURE 6 - DISCRIMINATOR L-BAND RESPONSE

1 - 2 GHz octave
Same I_c (tuning current)
100 MHz/cm

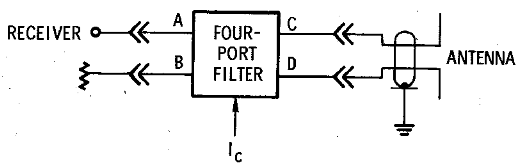

FIGURE 7 - PRESELECTOR AND ANTENNA COUPLER