FREQUENCY HOPPING EVANESCENT MODE FILTER

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ABSTRACT

This paper describes a novel high speed varactor tuned evanescent (EV) mode hopping filter operating at C-Band. The 6 μsec tuning speed is compatible with military frequency-hopping applications. Loss compensation is provided by variable gain MMIC amplifiers between 3-pole filter sections.

INTRODUCTION

A major component required for the generation and reception of narrow band Frequency Hopping Spread Spectrum (FHSS) is the RF tunable bandpass filter. A coded RF signal has its origin at baseband where M-ary frequency shift keying (MFSK) modulation is applied to the data which is subsequently frequency-hopped with a pseudo-random (PN) code at RF frequencies. The advantage of the spread spectrum approach is that many users may occupy the same RF bandwidth simultaneously. It is desirable to use a tunable preselector filter to eliminate adjacent RF signal interference from simultaneous spectrum users.

This paper describes a new varactor tuned C-Band voltage tunable preselect filter. Traditionally, magnetically tuned YIG [1] (Yttrium Iron Garnet) filters have been used, but they have several disadvantages. YIG filters rely upon a very uniform DC magnetic field making them sensitive to stray interference. The size and weight of a YIG filter is constrained by the electromagnets. YIG filters have hysteresis problems contributing to relatively slow tuning speed of several hundred μsec. In fast tuning applications, YIG tuning speed is improved by the addition of multiple YIGs in a switched configuration. Temperature compensation in a YIG filter comes from a heat strip leading to increased power requirements and additional warm-up time. The varactor tuned EV filter provides a solution to these disadvantages.

DESIGN

The EV hopping filter was developed from the pioneering fixed frequency filter work of George Craven [2]. The principle is based upon using sections of waveguide below the cut-off frequency to form inductive elements. This new filter uses varactor diodes to provide voltage controlled variable capacitance to resonate with the inductive sections. It consists of multiple sections of varactor tuned 3-pole EV filters separated by variable gain amplifiers for loss compensation. A block diagram is shown Figure 1. Digital to analog converters provide the high speed tuning voltage to the varactors and gain control to the MMIC variable gain amplifiers.

The 3-pole filter section is constructed with increased height WR42 waveguide (shown in Figure 4). The waveguide provides an inductive discontinuity [3,4] that is ideal for bandpass filter performance when used with multiple capacitive discontinuities. Electronic tuning capability is added through the use of varactor diodes. Varactor diodes are not usually used at microwave frequencies in hopping filters because of the low Q [5] causing filter loss and degraded selectivity. A typical abrupt junction GaAs varactor diode has a Q of 750 at 1 GHz which degrades rapidly as frequency increases. It also degrades as voltage is decreased. The low Q is compensated here via gain stages placed between the lossy filter sections. An MDT 2102-22 abrupt junction diode was used in this design. The diodes are attached to a cylindrical post to form the resonator. Reverse bias voltage is applied through a low pass decoupling network consisting of a shunt capacitor followed by a series inductor and shunt capacitor. RF is coupled into the filter by coaxial launches and two additional air gap resonators. A single 3-pole EV section has a measured return loss of better than 15 dB across the band.

The variable gain amplifier (VGA) is a MMIC design consisting of three active devices. It was developed using the Triquint 0.5 um HA MESFET process (see Figure 2). The first amplifier stage uses series inductive feedback for simultaneous noise and input match. The second stage consists of two devices connected in cascode. Feedback is used to provide flat amplitude frequency response with variable attenuation. The second stage is matched for power to provide a maximum of +10 dBm output power. The gain of the amplifier is 18 dB with 25 dB of voltage controlled attenuation range. The attenuation is electronically adjusted by voltage control on the common gate MESFET at the output.
The 3-pole filter and variable gain amplifier have complementary loss and gain which result in flat response across the frequency band. Together the amp and filter form a modular unit that can be cascaded for additional selectivity. In this application the EV filter has a total of 12 poles and uses 4 amp/filter units to obtain the same selectivity as a 7 pole YIG filter.

RESULTS

The EV filter is used in a military frequency hopping FSK application. It was developed to replace an existing YIG filter assembly which consists of two YIGs and two switches in a Ping-Pong configuration. Ping-Pong is a technique used to increase the hopping speed of the YIG filters. While one YIG is active the other YIG is tuned to the next frequency.

The overall loss of the EV filter (shown in Figure 1) is -10 dB +/- 0.5 dB. The measured data is shown in Figure 3. This plot is overlaid with 13 traces each showing the selectivity of the filter every 50 MHz. The bandwidth varies from 20 to 25 MHz. The tuning range of this filter covers a 600 MHz bandwidth (approx. 15%).

Other measured comparisons of the EV and YIG are shown in Table 1. Data includes contribution from the control circuit. Table 1 provides information on a single YIG filter and does not include Ping-Pong circuitry overhead.

	EV (12-pole)	YIG (7-pole)
Tuning Speed	6 μsec	300 μsec
DC Power	4.8 W	17.25 W
Warm-up Time	N/A	5 min.
Volume	12 in^3	28 in^3

Table 1: EV and YIG Measured Technology Comparison

CONCLUSION

The varactor tuned EV filter provides smaller size, less weight, high tuning speed, and simple voltage control with no warm-up time. This makes the EV hopping filter a viable alternative to existing YIG filter designs.

REFERENCES

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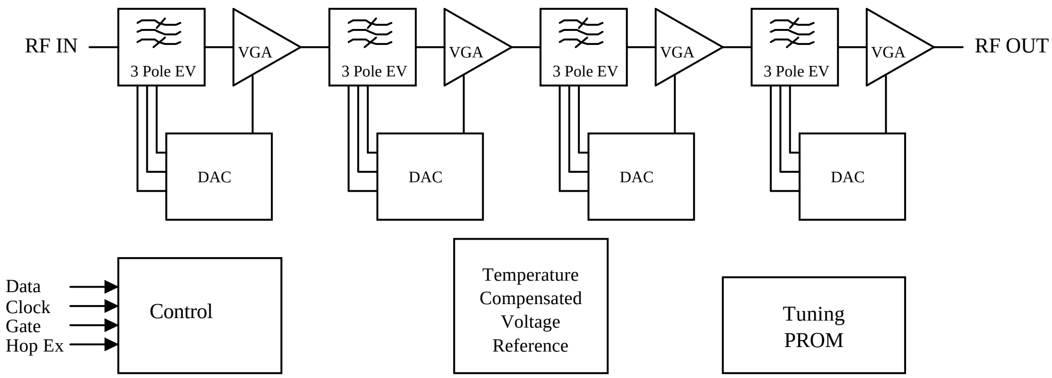

Figure 1: Evanescent Mode Hopping Filter Block Diagram

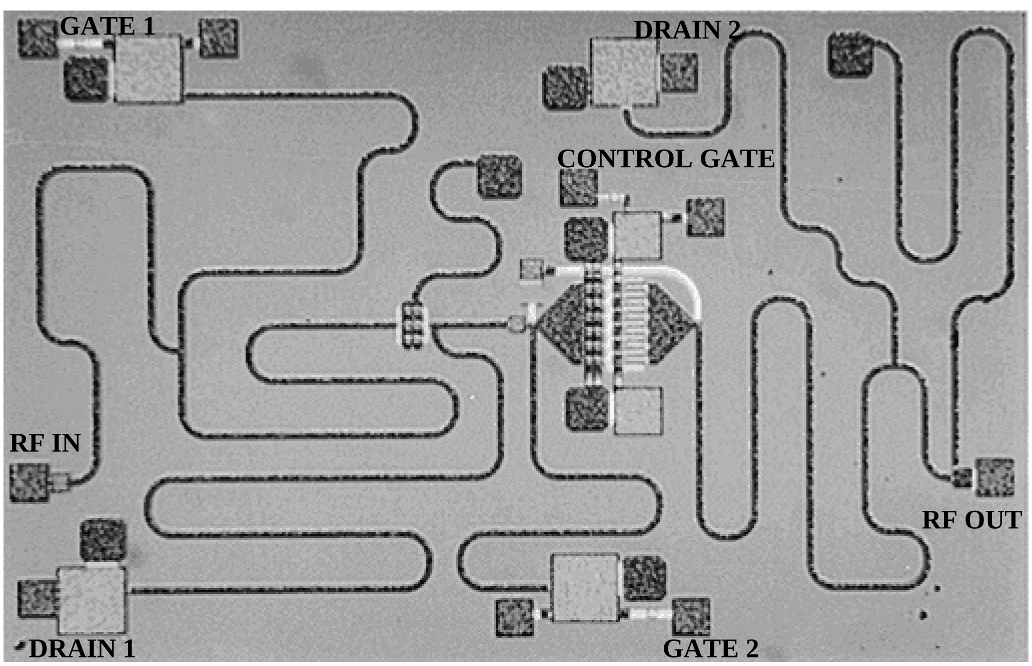

Figure 2: C-Band Variable Gain MMIC Amplifier (VGA)

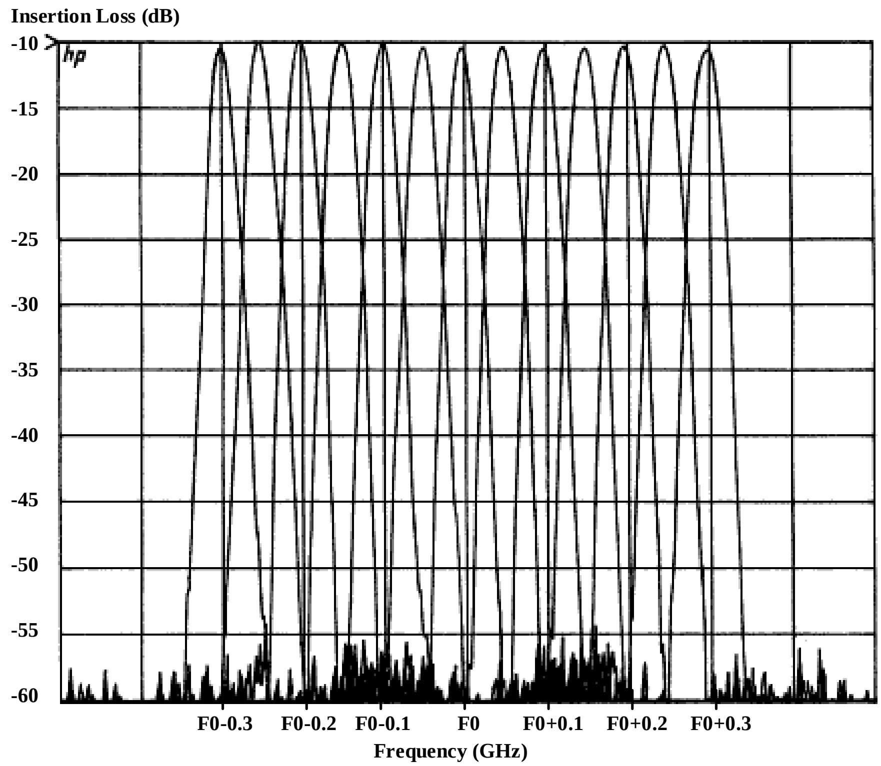

Figure 3: Measured Insertion Loss vs. Frequency

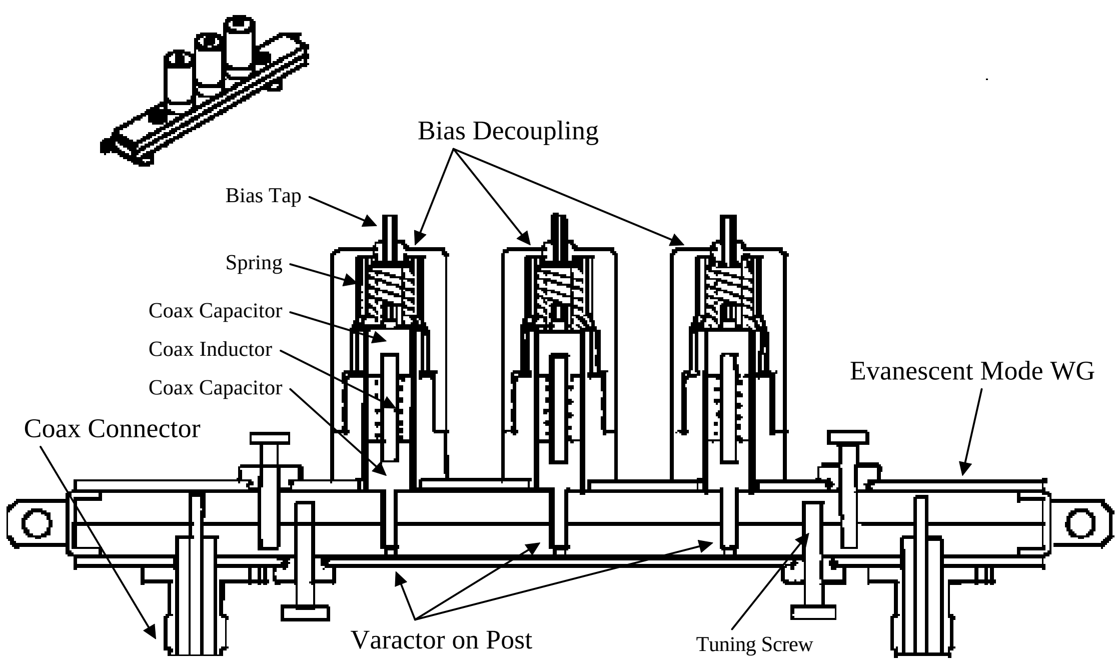

Figure 4: Evanescent Mode (EV) Hopping Filter Cross Section