VARACTOR TUNED MICROWAVE FILTERS

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Abstract

The design and realization techniques of varactor tuned microwave filters are presented. Novel filter circuits are used and these are realized using Suspended Substrate Stipline. Experimental devices exhibit broad tuning bandwidths and low dissipation loss. Both bandpass and band-stop filters are described.

Introduction

The phenomenon of the variation in depletion layer capacitance of varactor diodes as a function of externally applied bias voltage has been usefully employed for many years in the control of the centre frequency of electrical filters. Varactor tuned filters generally require broad tuning bandwidths and in the case of band-pass filters narrow instantaneous bandwidths and low passband insertion loss are desirable. Unfortunately, due to the low Q factor of varactor diodes at microwave frequencies, the above requirements have until recently not been possible for filters with centre frequencies much above 1 GHz. However, with the advent of Gallium Arsenide technology, varactor Q factors have been steadily increasing. This paper describes recent developments in the design and realization of tunable filters and experimental devices employing GaAs varactors and operating in the 4 GHz region are discussed.

Varactor Tuned Microwave Bandpass Filters

The development of a varactor tuned bandpass filter can be divided into two areas. These being firstly the choice of a suitable circuit and secondly the realization of the circuit.

Initial investigations involving the tuning of microwave bandpass filters indicated that unless the filters were correctly designed serious problems could occur when they were tuned. Specifically, due to the frequency dependent coupling between microwave resonators, as the centre frequency of the filters is changed, the filter can become undercoupled or over-coupled (ref. 1). The change in coupling between the resonator can occure over even narrow tuning bandwidths and results in a deterioration of the passband return loss and an increase in the passband insertion loss of the filter. To overcome this problem, a novel form of the combline filter has been employed. The combline filter (fig. 1) is composed of a commensurate N wire line with coupling constrained to be between adjacent lines only.

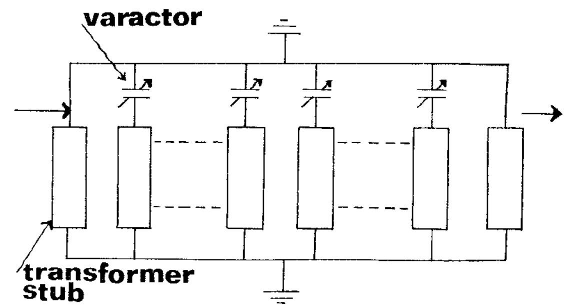

Fig. 1 Tunable Combline Filter

The lines are each grounded at the same end whilst opposite ends are terminated in lumped capacitors. The filter possesses the important properties of a very broad stop-band and also the capability to be tuned over an octave with only a 6:1 variation in the lumped capacitors. By correct design of the input and output transformer elements the frequency dependence of the coupling between the resonators can be approximately cancelled over greater than octave bandwidths. In addition, the filter will retain approximately constant instantaneous passband bandwidth over broad tuning bandwidths. The details of the electrical design of this filter are presented in ref. 2.

The varactor tuned filters were realized in M.I.C. form because of ease of integration of the varactor diodes and also so that the bias filters could be printed. Suspended Substate Stripline was chosen as the M.I.C. medium because of its low loss and absence of surface wave effects which occur when using microstrip.

An experimental two cavity varactor tuned combline filter has been designed. GaAs varactor diodes with a zero bias junction capacitance of 0.9 pF and a package capacitance of 0.18 pF were used. The use of packaged varators limited the capacitance variation of the diodes (7:1 in chip form) to 3.5:1. The filter was designed with all the complexity confined to one side of the circuit board. A picture of the filter with the cover plate removed is shown in Fig. 2.

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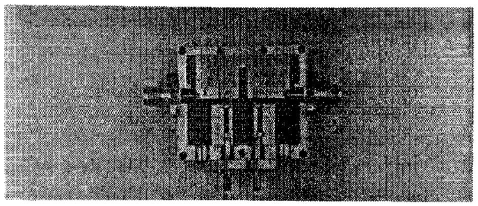

Fig. 2 Interior of varactor tuned combline filter

The experimental filter achieved the following performance:

Centre Frequency = 4 GHz ± 850 MHz	
Passband Bandwidth	210 MHz Maximum 186 MHz Minimum
Passband Insertion Loss	5.4 dB Maximum 3.1 dB Minimum
Passband Return Loss	8.1 dB Minimum 11 dB Maximum
Stopband Insertion Loss	
Centre Frequency ± 400 MHz=24 dB	
Centre Frequency ± 1 GHz=38 dB	
Intercept Point. Second order=+7 dBm	Minimum

In summary the filter achieved tuning from 3.15 GHz to 4.85 GHz. The passband bandwidth of the filter exhibited a variation from 186 MHz at the extremes of the tuning bandwidth to 210 MHz at 4 GHz. The passband insertion loss was primarily caused by the epilayer resistance of the varactor diodes, and was a maximum of 5.4 dB at zero varactor bias. The filter exhibited on equiripple passband with the worst case return loss at the extremes of the tuning band. A stopband insertion loss of a minimum of 38 dB 1GHz from the instantaneous passband centre frequency was observed up to 7.7 GHz, at which point higher ordered modes propogated through the filter cavity. The filter produced second harmonic distortion due to the nonlinearity of the varactor diodes. This was worst at zero varactor bias when the varactor capacitance is most sensitive to voltage variations.

Varactor Tuned Microwave Bandstop Filters

As with the bandpass filters these filters were to be realized in suspended Substrate Stripline. The choice of filter was that shown in Fig. 3.

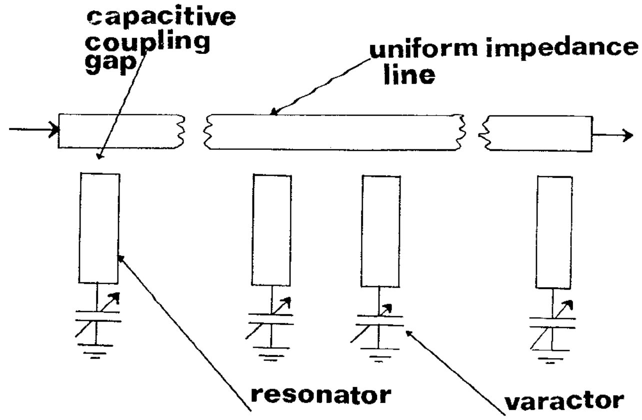

Fig. 3
Suspended substrate tunable bandstop filter

The filter consists of a uniform impedance main line with capacitively coupled resonators located at intervals along it. Varactor diodes terminate the ends of the resonators. The resonant frequency of this filter is determined by the lengths of the resonators and the value of the varactor cacitance, whilst the stopband bandwidth is determined by the value of the capacitance between the resonators and the main line.

It has been shown that with this type of filter, the correct phase shift between the resonators at the stopband centre frequency is somewhat less than the expected value of 90°. This is a consequence of the pole zero pattern of the resonators which produces an asymmetric or skewed frequency response from a single resonator. The phase shift between the resonators must be correctly designed in order to produce a symmetrical frequency response. The design theory for this filter is presented in ref. 3.

An experimental three cavity varactor tuned bandstop filter has been realized in suspended Substrate Stripline (fig. 4) and it achieved the following performance.

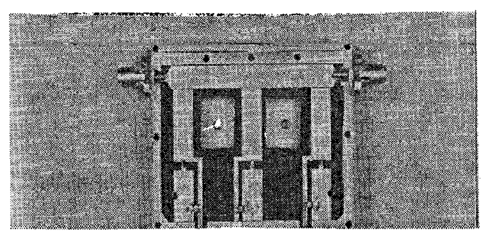

Fig.4 Interior of varactor tuned bandstop filter

Centre Frequency	3.6 GHz ±600 MHz
1dB Bandwidth	430 MHz Maximum 417 MHz Minimum
3dB Bandwidth	380 MHz Maximim 207 MHz Mimimum
20dB Bandwidth	62 MHz Maximum 48 MHz Minimum

Passband Return Loss >15dB to 7.2 GHz

Intercept Point Second Order +13dBm Minimum

In summary this filter tuned from 3 GHz to 4.2 GHz. Note that the stopband of this filter increased fairly rapidly with increased centre frequency. This is caused by the increase in capacitive coupling admittance between the resonators and the main line with increased frequency. The frequency response of the filter was symmetrical at 3.6 GHz but it was skewed as the filter was tuned away from this frequency. At 3 GHz centre frequency the filter was approximately 50% more selective on the low side of the stopband than on the high side, vice-versa at 4.2 GHz. The filter exhibited a good passband return loss due to the use of a uniform impedance main line.

Conclusions

The design and experimental performances of varactor tuned microwave filters are presented. Two experimental devices are described. These were a two cavity varactor tuned combline filter tunable from 3.15 GHZ to 4.85 GHz and a three cavity varactor tuned bandstop filter tunable from 3 GHz to 4.2 GHz. Both filters were realized in Suspended Substrate Stripline.

Acknowledgement

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