ELECTRONICALLY TUNABLE BAND-STOP FILTER

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SUMMARY

The design procedures for an electronically tuned band-stop filter are presented. A novel technique for realizing tunable band-stop filter with coupled lines is described.

The physical design and electrical performance of a five sections band-stop filter tunable from 6.5 GHz to 10 GHz, with a constant bandwith, is given. The circuit required to drive the band-stop filter and the calibration procedures are described.

INTRODUCTION

The modern electromagnetic environment consists of threat, potential threat, or friendly emitters, which can choke a wide open electronic-warfare receiver. This scenario is common and has generated the requirement for tunable band-stop filter to cancel high power signals. To be efficient the settling time of the filter has to be much smaller than the one of an YIG tuned filter. This condition is easily realized with tuning diodes. The advantages of the circuit are : very good performance, small dimensions of the hybrid microstrip technology realization and a very low cost.

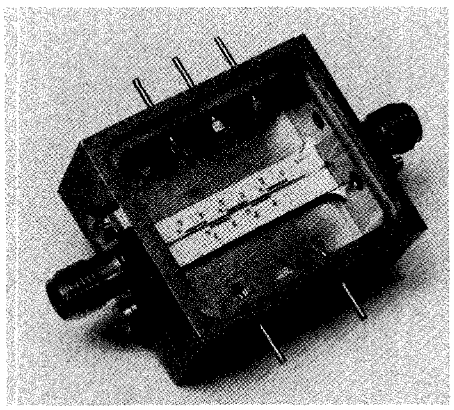

FIG. 1 - Tunable band stop filter

Principle of operation

To determine the influence, of the tuning diode, on the frequency response of the filter we first analyse the equivalent circuit of a directional coupler with unequal terminations (1).

The complete transformation shown in fig. 2 can be achieved and the elements value found as functions of the coupling coefficient (k) and of the characteristic impedance (Zo).

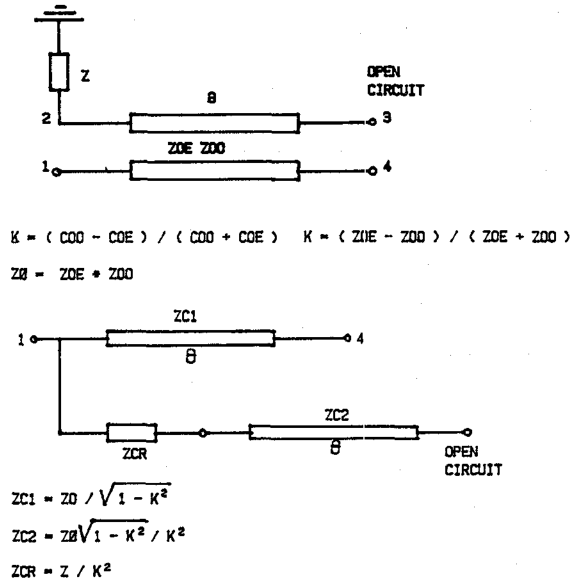

FIG. 2 : Directional coupler equivalent circuit

As we can see in fig. 2 the resonant frequency of the circuit is a function of ZCR, ZC2 and Θ. To realize a tunable band-stop filter the impedance ZCR in fig. 2 has to be a **serie resonant circuit** made of a tuning diode and an inductor.

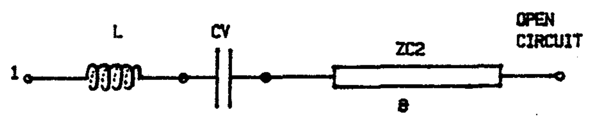

FIG. 3 : Parallel branch of the band-stop filter

The center frequency of the band-stop filter response is determined when the input impedance of the network in fig. 3 is a short circuit. The equation to calculate the center frequency is :

$$tg\Theta \left[LC_V W^2 - 1 \right] - ZC_2 \, C_V W = 0$$

To solve this equation the best way is to find a numerical solution. The curve shown in fig. 4 gives the tuning frequency of the network in fig. 3 for a particular value of the parameters.

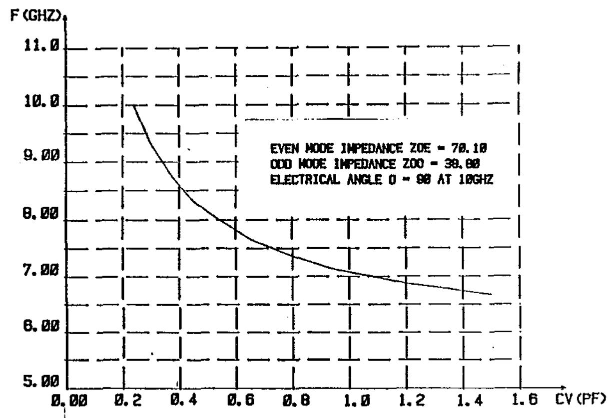

FIG. 4 : Resonant frequency of the coupled lines as a function of the tuning diode capacitance

We can notice that the exact design of band-stop filter will give different coupled lines characteristics and this fact induces a resonant frequency slighty differents for each parallel coupled lines.

Circuit configuration

The exact design of a 5 coupled resonators band-stop filter has been achieved (2) and the computed performance of the same filter in which the short circuit has been replaced by a serie resonant circuit is shown in fig. 5.

Theoretical performances of the filter, for different values of the tuning diode capacitance and for a 50 Q factor at 10 GHz, are presented in fig. 6.

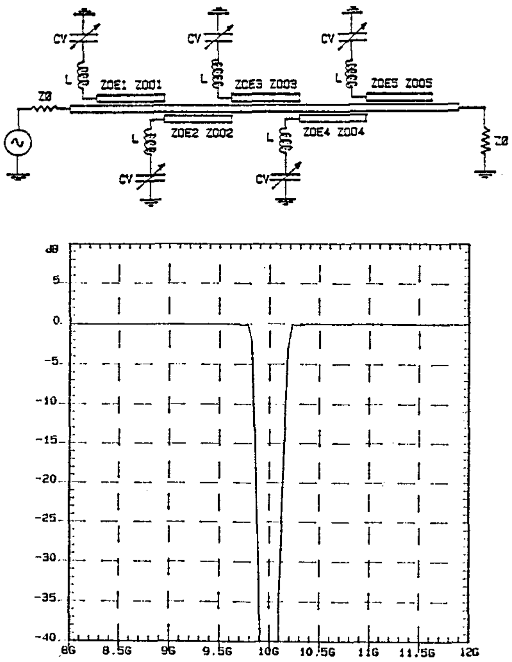

FIG. 5 : Computed response of the band-stop filter

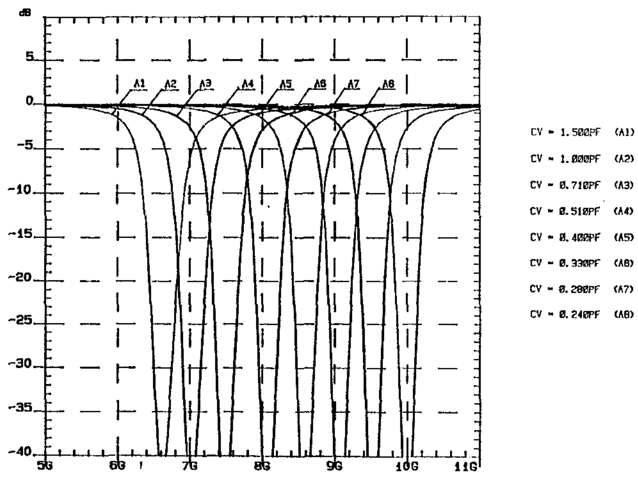

FIG. 6 A : Computed responses for differents values of CV

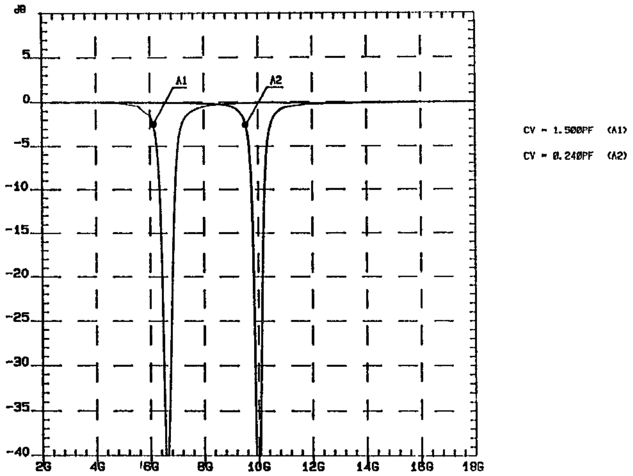

FIG. 6 B - Computed responses at both ends of the tunable frequency range

Device fabrication

The circuit has been realized in hybrid microstrip technology with via-holes. The tuning diodes are connected to the resonators with a .8 millimeter bonding length to realize the inductor. The biasing circuit is made of a low pass filter which is connected in parallel with the tuning diode. A via-hole is set at each end of the resonators to allow the calibration that gives the resonant frequency of the coupled lines as a function of the voltage applied to the tuning diodes.

CALIBRATION

At first to be able to drive the filter with a computer we have to know the resonant frequency of each resonator as a function of the voltage applied to the tuning diode. Since a resonator, short circuited at both ends, is an all pass filter, we can measure the resonant frequency of each section, as a function of the biasing voltage, by connecting the other resonators to the ground through via-holes.
With an automatic measurement program we get a file, that gives us the resonant frequency as a function of the biasing voltage, for each section.

DRIVER CIRCUIT

The network shown in fig. 7 has been designed to drive the filter with the frequency data and the files already filled with calibration. Since the outputs voltages of the driver change at the same time we can also measure the settling time of the tunable band-stop filter.

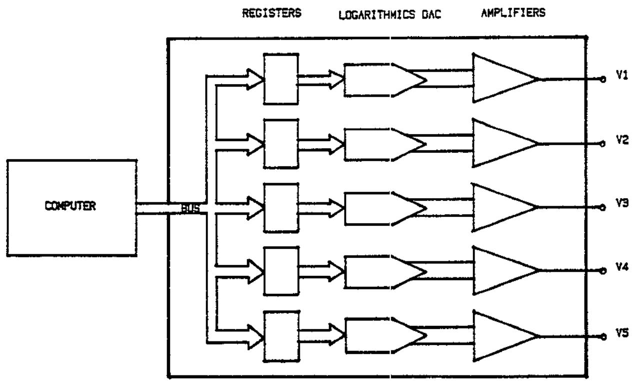

FIG. 7 : Driver circuit of the filter

RESULTS

The essential characteristics of the device are presented in fig. 8 : the filter can be tuned from 6.5 GHz to 10 GHz with a constant bandwidth of 250 MHz at 25 dB and with an attenuation greater than 40 dB. The filter can be used over the 2 - 18 GHz frequency band with insertion losses smaller than 1 dB.

. The measured settling time is about 1 µs.

. As the filter is tuned with active components we have measured the second harmonic level as a function of the input power. The results of this measure, presented in fig. 9, show that the second harmonic level allows a 50 dB dynamic range if the input power is less than 0 dBm.

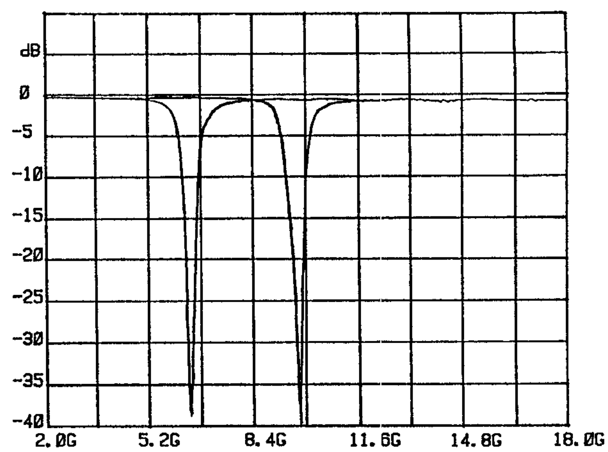

FIG. 8 A - Attenuation characteristics at both ends of the tunable frequency range

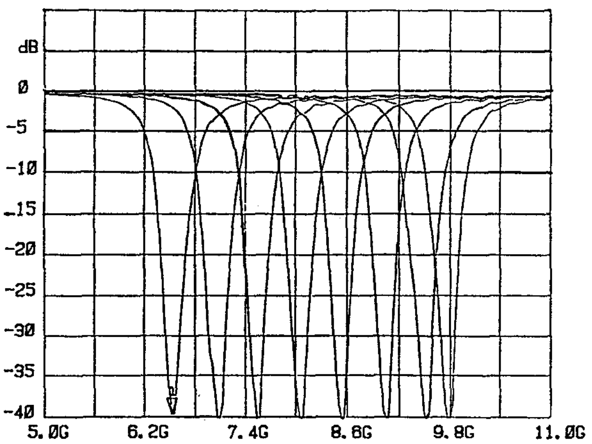

FIG. 8 B - Attenuation characteristics for several states of the tunable filter

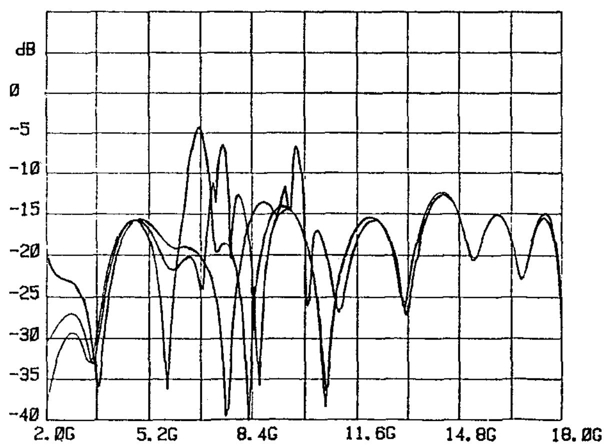

FIG. 8 C - Return loss for 3 states of the tunable filter

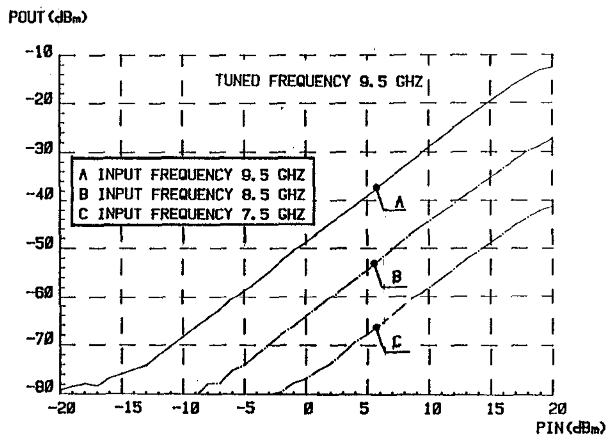

FIG. 9 A - Second harmonic level relative to the input power (tuned freq. 9.5 GHz)

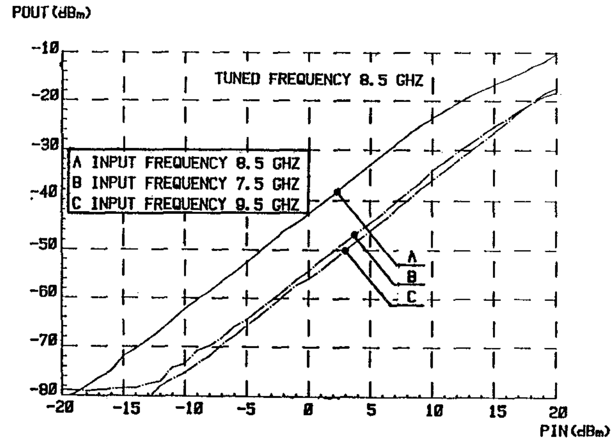

FIG. 9 B - Second harmonic level relative to the input power (tuned freq. 8.5 GHz)

CONCLUSION

The circuit described illustrates the good performance of filters realized in hybrid microstrip technology. A novel technique for designing tunable band-stop filter with coupled lines and serie resonant circuits has been developped. The filter exhibited tuning from 6.5 GHz to 10 GHz and performed according to theoretical expectations. Computer analysis showing the effect of tuning diodes capacitance and serie resistor on filter response was presented. The block diagram of the driver has been described and the calibration method developped.

The result will encourage further effort in this area to produce tunable filter that could be also switchable. By cascading several different devices of that type, we could get a tunable filter that operates over a very large frequency band. Since the driver and the filter can be made in hybrid microstrip technology the device should be easily integrated in electronic-warfare equipments.

REFERENCES

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