SUBSTRATE INTEGRATED WAVEGUIDE BANDSTOP FILTER

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Abstract

One new type of filter is presented in this paper. The propose filter is a transmission mode bandstop filter utilizing substrate-integrated-waveguide cavity resonators to provide the required resonance. The bandstop operated at X band frequencies with 450 MHz bandwidth. Stop band is from 8.7 GHz to 9.2 GHz. Insertion loss achieved is less than 0.5 dB and return loss of more than 15 dB. 3D simulator was used to model the structure and simulation results showed very good response. To date, this is the first time such bandstop substrate-integrated-waveguide filter has been reported.

Keywords: Component, Substrate Integrated Waveguide, Bandstop Filter, Inverse Chebychev and Lumped Element

I. INTRODUCTION

In 2001, Wu [1] proposed a new technique for high density integration microwave and millimeter wave systems. Using this technique, image guides, non-radiative dielectric waveguides were synthesized inside a dielectric substrate, using rows of dielectric or metal holes. The idea to integrate waveguide inside a dielectric substrate was first proposed in [2]. This was a very useful platform to design high performance microwave circuits such as filters, resonators and antennas. One of the advantages of this type of integration was that it could lead to other planar microwave transmission lines by simple transitions and it preserved the advantages of a waveguide. This paper has introduced new methods to produce a bandstop filter characteristic.

II. DESIGN OF TRANSMISSION MODE SUBSTRATE INTEGRATED WAVEGUIDE BANDSTOP FILTER

Idea of producing a transmission mode substrate-integrated-waveguide bandstop filter originated from [3] and [4]. This paper describes how a series of stub stripline resonators are directly coupled to the main stripline to give a bandstop response. The resonator is separated by a quarter wavelength to avoid inter resonance coupling. The design method adopted for this work is...
based on the inverse Chebychev bandstop characteristics. The principles behind the theory are explained in detail in [3]. The element values for this filter have been obtained from the method by Rhodes, [5].

A three-stage lumped element inverse Chebychev bandstop filter has been designed and the values calculated as shown in Figure 1. Using the reactance slope method, the reactance for each lumped and distributed resonator is equated to give an equivalent length of the resonators. The distance separating the resonators is a quarter of a wavelength long. The resonator length is about half a wavelength. The transmissions zeros that occur at infinity in the original prototype are mapped to odd multiples of the quarter wave frequencies. This explains why there is one transmission zero at the lower side, and one at the higher side of the frequency band. The resonators have been designed using the empirical equations of [6].

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For a lumped resonator

\[ Z(\omega) = \frac{1}{j\omega C_r} + j\omega L_r \]  

(1)

\[ \frac{dZ(\omega)}{d\omega} = \frac{1}{\omega^2 C_r} - L_r \]  

(2)

For a distributed resonator

\[ Z(\omega) = jZ_0 \tan(\frac{\alpha_f l}{v_r}) \]  

(3)

By equating lumped and distributed

\[ \frac{dZ(\omega)}{d\omega} = \frac{1}{\omega^2 C_r} - L_r = \frac{Z_0, \sec(\frac{\alpha_f l}{v_r})}{v_r} \]  

(4)

The solution of these equations will give the length of the resonator

\[ l_1 = 174.4^\circ, \ l_2 = 179^\circ \ \text{and} \ l_3 = 181^\circ \]

The equivalent distributed circuit directly coupled with a uniform quarter wavelength main line is shown in Figure 2.

The frequency response for the distributed element inverse Chebychev filter is shown in Figure 3, centered at 9 GHz, with 8.7 GHz lower cut-off frequency, 9.2 GHz upper cut-off frequency, and a bandwidth of 450 MHz. The distance separating the resonators is a quarter of a wavelength long. The resonator length is about half a wavelength. The transmission zeros that occur at infinity in the original prototype are mapped to odd multiples of the quarter wave frequencies. This explains why there is one transmission zero at the lower side, and one at the higher side of the frequency band. Then,
each substrate-integrated-waveguide resonator is realized to directly couple with the substrate-integrated-waveguide main line.

The length of the substrate-integrated-waveguide resonator is varied to give the same response as that of the distributed and lumped resonators, and the separation between the first and the second, and the second and third resonators are optimized to give correct couplings between adjacent resonators. Size and distance between via holes have been calculated by following the simple design rule in [7], and the transition between the substrate-integrated-waveguide and the microstrip line is realized by simple step impedance. Fig. 2 shows the dimension of the filter.

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Fig. 3 shows the simulated and measured frequency responses for the three stages of the substrate-integrated-waveguide resonator. There is a slight shift in the frequency and this is caused by the variation in the dielectric permittivity of the substrate. However laser trimming would be needed to achieve optimum results.

The separation between each resonator is 3 quarters of a guide wavelength in order to avoid inter resonator coupling. The two transmission zeros that have occurred are the result of the mappings of the odd multiples of the quarter wave frequency from the original prototypes. This filter has been realized by using a standard PCB process. It uses a substrate with 0.5 mm thickness; and the thickness of the metal is 35 μm.

![Figure 5 Manufactured transmission mode substrate-integrated-waveguide bandstop filter.](image)

![Figure 4 Three-stage transmission substrate-integrated-waveguide bandstop filter (a=18.8 mm, b=17.4 mm, c=10.5 mm, d=9.7 mm, e=9.2 mm, f=78.5 mm, diameter of via hole=0.5mm, distance between adjacent via holes=1.0 mm).](image)
to the design of substrate-integrated-waveguide bandstop filter. The design is a transmission mode substrate-integrated-waveguide bandstop filter. This filter has been manufactured and the measured results are in line with the simulated results.

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REFERENCE


III. LOSSES OF BANDSTOP FILTER

The transition loss by the SIW main line is 1.5 dB.

SIW Bandstop losses
= Average Loss – Transition Loss
= 2.75 – 1.5 = 1.25 dB

The SIW bandstop losses may come from a few factors:

a) dielectric losses;
b) losses through via holes;
c) copper losses.

But these losses are still small compared with the transition loss.

IV. CONCLUSION

This paper has presented a new structure