

DESIGNING A MICROWAVE FILTER BY STUDYING AND SIMULATING THE DISCONTINUITY IN THE WAVEGUIDE

Ibrahim Ghafir, Václav Přenosil

Faculty of Informatics, Masaryk University
Botanická 68a, 602 00 Brno, Czech Republic
ghafir@mail.muni.cz, prenosil@fi.muni.cz

Abstract: *This research aims to design a microwave filter by studying and simulating the discontinuity in the waveguide. We suggest a filter consists of three waveguides connected to each other and different dimensions. Changing the dimensions of the waveguide will change the conditions of propagation of microwaves and in our suggested filter we have two discontinuity regions affecting on the modes of frequencies propagated through the waveguide. We apply Galerkin method for studying the discontinuity region in the waveguide. We have modelled all the calculations and results by Matlab program so we could simulate the filter and study and the effect of changing the dimensions on the propagated modes, calculate $[Z]$ matrix and scattering matrix $[S]$ for the designed filter and find the relation between transmission coefficient (T), reflection coefficient (R) and the frequency (f) to determine the properties of the designed filter.*

Keywords: microwaves; microwave filters; waveguide; Galerkin method.

INTRODUCTION

Microwaves are radio waves with wavelengths ranging from as long as one meter to as short as one millimeter, or equivalently, with frequencies between 300 MHz (0.3 GHz) and 300 GHz.

We have many uses of microwaves (heating, communication, medicine and astronomy) and when we use microwaves we often need to use microwave filters. To design these filters we have two cases: the first case is when the frequency is less than 10 GHz, in this case we can easily design microwave filters by using traditional circuits consist of common elements such as resistances, coils and capacitors, but in the second case when the frequency is more than 10 GHz, in this case and because the frequency is very high the wavelength will be small and close to the real dimensions of those elements (resistances, coils and capacitors), therefore we can't use them in designing microwave filters and this is a problem.

That problem was solved by waveguide technology and in our research we suggest a filter consists of three waveguides connected to each other and different in dimensions and the aim of our research is to determine the type of this filter whether it is low pass filter, high pass filter, band pass filter or band stop filter.

1. PREVIOUS STUDIES

The discontinuity region of the waveguide is the region where the dimensions of the waveguide are changed as it is shown in figure 1.

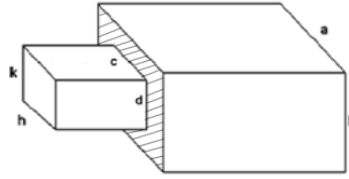


Fig. 1. The discontinuity region in the waveguide

When the dimensions of the waveguide are changed the conditions of propagation of frequencies will be changed, that means frequencies after the discontinuity region will not be the same of frequencies before it and there are some researches have been made to determine the effect of the discontinuity region on the propagated frequencies and they applied different methods such as Green method [1], Integration method [2], and Determined Differences method [3], all of these methods study the effect of the discontinuity region and determine which frequencies will be attenuated and which will be passed.

In our research we have applied a new method (which is Galerkin method) on the discontinuity region as it will be explained later.

2. STEPS OF RESEARCH

In our research we suggest a filter consists of three waveguides connected to each other and different in dimensions as it is shown in figure 2.

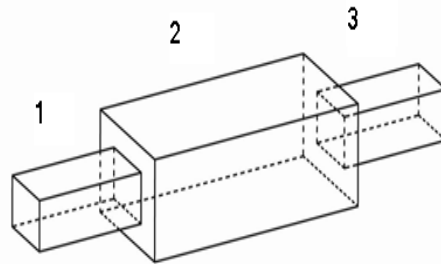


Fig. 2. Suggested filter consists of three waveguides

When we apply a band of frequencies into the input of the first waveguide each frequency will propagate according to many modes through this waveguide and when frequencies reach to the discontinuity region and because of changing the dimensions the conditions of propagation will be changed, that means some of these frequencies will be attenuated and the others will be passed to the second waveguide and when they reach to the second discontinuity region the same behavior will be repeated, as a result the frequencies at the output of the third waveguide will be different from frequencies at the input of the first waveguide. Figure 3 shows longitudinal section of the filter.

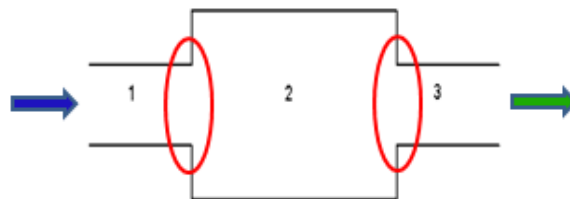


Fig. 3. Longitudinal section of the filter

That means this form will behave as a filter and the aim of our research is to determine the type of this filter weather it is low pass filter, high pass filter, band pass filter or band stop filter and to do that we have followed two basic steps:

- Studying the effect of the discontinuity region on the propagation of frequencies and for that we have applied Galerkin method.
- Calculating the scattering matrix of the filter.

2.1 Galerkin Method

This method depends on the equivalent electric circuit of the discontinuity region and using of Kershof laws [4]. Figure 4 shows the equivalent electric circuit of the discontinuity region.

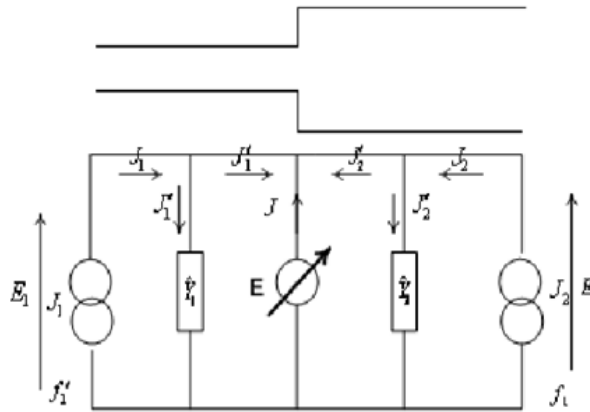


Fig. 4. The equivalent electric circuit of the discontinuity region

From the equivalent electric circuit we can see that:

$$E = E_1 = E_2$$

$$J + J_1' + J_2' = 0$$

From the last two equations (Kershof laws) we can derive the impedance Z of the discontinuity region to the propagated frequencies.

$$[Z] = \begin{bmatrix} [A] \\ [B] \end{bmatrix} [D]^{-1} [[A]^t [B]^t]$$

$[A]$ is a matrix related to the frequencies propagated in the first waveguide.

$[B]$ is a matrix related to the frequencies propagated in the second waveguide.

$[D]$ is a matrix related to the frequencies propagated in the first and second waveguides.

So by applying Galerkin method we can calculate the impedance of the discontinuity region to the propagated frequencies, thereby we can determine which frequencies will be attenuated (when the impedance is high) and which will be passed (when the impedance is low or zero).

2.2 Calculating Scattering Matrix

We have calculated the scattering matrix $[S]$ of the filter depending on the impedance matrix $[Z]$ of the filter. Figure 5 shows the impedances of the filter.

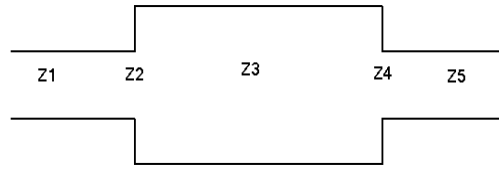


Fig. 5. Impedances of the filter

We can see in figure 5 that we have five impedances of the filter:

Z1, Z3, Z5 are the impedances of three waveguides.

Z2, Z4 are the impedances of two discontinuity regions.

For Z1, Z3, Z5 we can easily calculate these impedances by using common laws [5] and for Z2, Z4 we can calculate them by applying Galerkin method mentioned above in (2.1).

After we calculate those five impedances we can find the equivalent impedance matrix $[Z]$ of the filter, then we convert it to the scattering matrix $[S]$ of the filter by using common laws [6] and in the next paragraph we will know why we calculate the scattering matrix.

$$[S] = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

3. RESULTS

We have modeled all the calculations and results of our research by using Matlab program, so we can apply real parameters for the dimensions of the filter and simulate it.

We have considered these parameters to the dimensions of the filter:

- Dimensions of small waveguide: $L1=75$ mm , $d=40$ mm , $c=60$ mm
- Dimensions of big waveguide: $L2=150$ mm , $b=110$ mm , $a=130$ mm
- Input frequency band: (1-5)GHz .

Figure 6 shows S11 and S12 according to frequency.

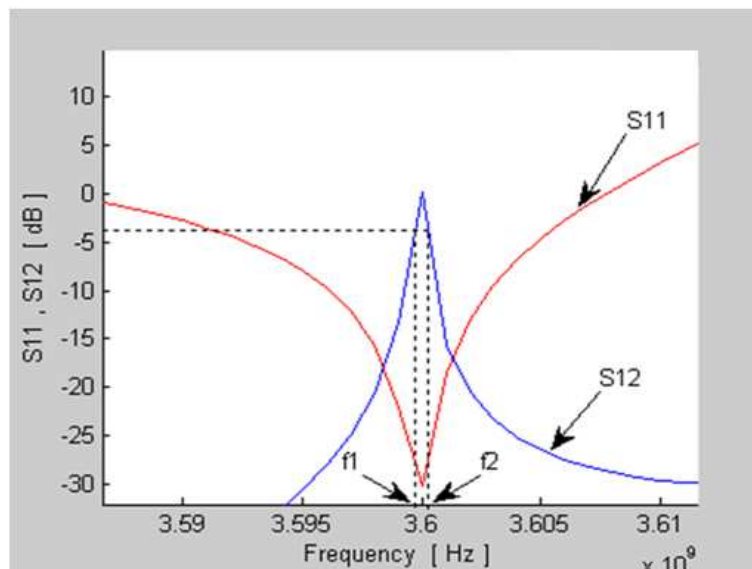


Fig. 6. S11 and S12 according to frequency

We have calculated the scattering matrix [S] because this matrix has a property that when S11 (reflection coefficient R) has a maximum attenuation at one frequency and S12 (transmission coefficient T) has a minimum attenuation at the same frequency, that means this filter will be a band pass filter and that frequency (3.6 GHz as it is shown in figure 6) will be the center frequency (f0) of that band.

To determine the passed band of this filter we can find in figure 6 that when the attenuation is (-3 dB) f1 = 3.59975 GHz, f2 = 3.6002 GHz and the passed frequency band will be (f2 - f1 = 450 KHz). This result matches with the common law:

$$f_0 = \sqrt{f_1 * f_2} = 3.6 \text{ GHz}$$

which prove that our result is correct.

We know the type of the filter (band pass filter) and we have our software (by Matlab program), so we can easily study the relation between the dimensions of the filter and the center frequency. Figure 7 shows the studied dimensions of the filter.

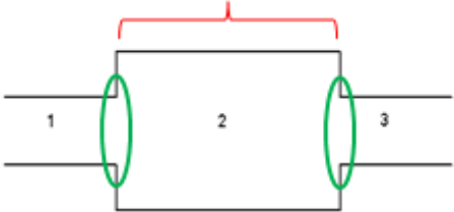


Fig. 7. The studied dimensions of the filter

We have studied the relation between the center frequency and the length of the second waveguide and got the results shown in figure 8.

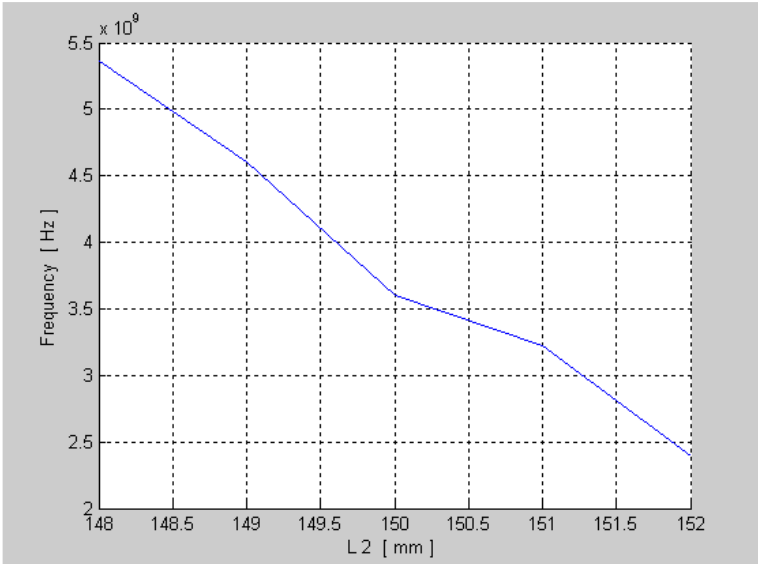


Fig. 8. The relation between the center frequency and the length of the second waveguide

We have also studied the relation between the center frequency and the dimensions of the discontinuity region and we got the results shown in table 1 and figure 9.

c [mm]	d [mm]	57	38	58.5	39	60	40	61.5	41	63	42
f0 [GHz]		3.745		3.681		3.6		3.544		3.487	

Table 1. The relation between the center frequency and the dimensions of the discontinuity region

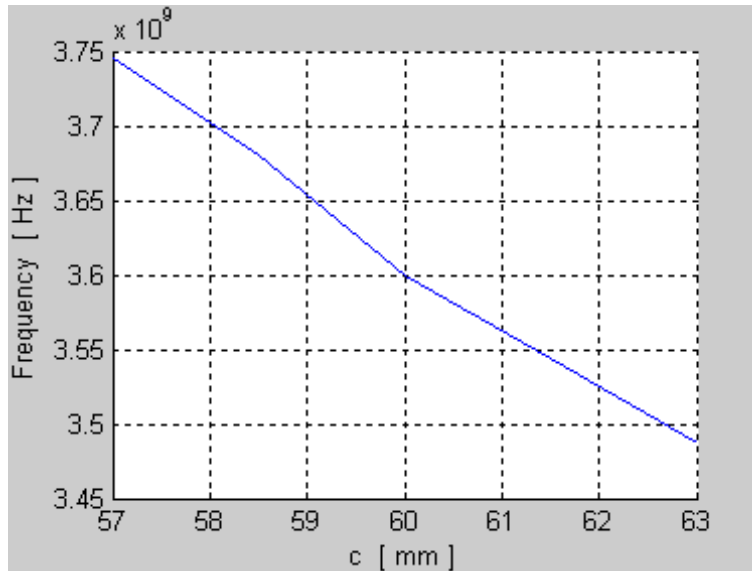


Fig. 9. The relation between the center frequency and the dimensions of the discontinuity region

CONCLUSION

We have suggested a filter consists of three waveguides connected to each other and different in dimensions and studied the effect of the discontinuity region on the propagated frequencies by applying a new method (Galerkin method). We have modeled all the calculations and results by Matlab program so we could simulate the filter, determine its type (band pass filter) and study the relations between the center frequency and the dimensions of the filter. The most important thing is that by using our software and using those relations we can easily determine the dimensions of the filter according to the desired center frequency. In other words, we can design this filter.

LITERATURE

- [1] IRSADI,S;CHUANG,L. On Slot-Coupled Microstrip Antennas and their Applications . IEEE Trasn, Antennas and propagation,1990
- [2] ARUNK,B .Long Rectangular Patch Antenna with a Single Feed. IEEE Trasn, Antennas and propagation, 1995.
- [3] BABNIS ,A. Antenna Theory, Analyses and design . seconde edition, New York,Harper& Row, 1997.
- [4] BAUDRAND H., 2001- Introduction Au Calcul de Circuits Microondes. Toulouse University, Toulouse.
- [5] ZAID A., 2009- Microwaves. Aleppo University Publications, Aleppo.
- [6] POZAR D.M., 2008- Microwave Engineering, 4 nd Ed. Jone Willy and Sons, New York.