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A Design of Doubly Corrugated Filter for The Continues Belt Microwave Drying System

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Abstract

This paper presents a design of doubly corrugated filter. It used to reduce a microwave energy radiation from the open entry of a microwave continuous belt process. The purpose of this work is a major concern of microwave leakage energy on human that must less than 10 mW/cm^2. The design conditions are a range of stop band between 2,300 – 2,600 MHz, the operating frequency at 2,450 MHz, and the attenuation parameter must greater than 60 dB. All parameters of doubly corrugated filter will be optimized for this purpose and it will be installed to a combined unsymmetrical multi feed microwave heater and continues belt system at R.C.M.E..

Keywords: microwave filter, microwave choke, waffle-iron filter, radiation energy

1. Introduction

Microwave filter are used to separate or combine different frequencies, as in frequency converters or multipliers, or in multiplex communications. The electromagnetic spectrum is limited and has to be shared; filters are used to confine the radiation energy from high power transmitters with in assigned spectral limits; conversely, other filters are used to protect receivers from interference outside their operating bands. They may be classified by function (band-pass, band-stop, etc.), by mode of operation (reflecting, absorbing, etc.) by physical structure (coaxial line, rectangular waveguide, etc.), by application (tunable or fixed-tuned), by loading (singly terminated, doubly terminated, etc.), by energy manifestation (electromagnetic, spin-wave, acoustic, etc.). Most of these types are shown in [1]. By loading function, a doubly corrugated filter or another name is waffle-iron filter that used in this paper because the aims of this filter are wide-band, start-band and stop-band, which can designed. Some publications describe the design and measured of the microwave filter from open waveguide such as in [2], it demonstrates the design and measured of an L-band model of a high power wide band filter and in [3] the design and experimental of a singly and a doubly corrugated filter are shown. The main purpose of microwave filter that used in the microwave heating or drying continues processing, the safety issues must be considered because this process has open entries for the passage of workload through the cavities. By this reason microwave can propagate to the environment. It makes a bad effect to the electronic parts, communication and human who operated around the area. Many countries use this standard for the whole body exposure level limit is 100 W/m^2 (10mW/cm^2) at 2,450 MHz [4]. Attempted to reduce or stop this effect into permissible levels many techniques are shown in these text books [4] and [5] such as the first techniques is the partially filled choke tunnels (part filled height and part filled width) in this method the high lossy material will be used as the absorption of residual microwave leakage. The next is the reactive (reflective) choking or the corrugated filter. It has traditionally been performed by an approximate method based on monomode equivalent circuits [6] but in this paper, a multimode analysis method based on the generalized admittance matrix (GAM) representation in [7].

At R.C.M.E., we have a combined unsymmetrical multi feed microwave heater and continues belt system. It is two open entries. They have geometry that show in figure 3. The first for input the workload and the second for workload pass through the cavity. For concerning with a safety issues, the doubly corrugated filters are designed. The advantage for choosing the doubly corrugated filter is a periodic structure that can design a pass band and stop band depend on your design and this paper show an optimum technique to find the residual radiation energy, which must have the attenuation greater than 60 dB. After that we will implement them to the open entries of the system. But in this paper we will show the concept design of the doubly corrugated filters only.

2. Theory

Normally, the microwave continues processing has a rectangular open entry look like figure 1 and the doubly corrugated filter will be installed to the open entry. It consists of a series of equal length stubs which periodically load the output open entries and exhibit pass and stop bands characteristic of similar periodic structure.

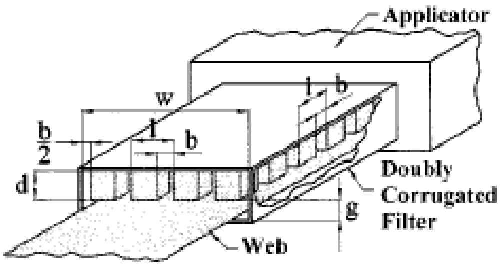


Figure 1. Open entry of the microwave continues process and the doubly corrugated filter under consideration.

The traditional design method is based on a monomode equivalent representation of all the elements integrating the structure. So, the E-plane T-junction of the structure is modeled by the monomode equivalent circuit proposed in [8]. The rectangular waveguides (open entry port) interconnecting such T-junction is represented by a simple transmission line related to the fundamental mode. The periodicity of the monomode equivalent circuit of the filter can show in figure 2.

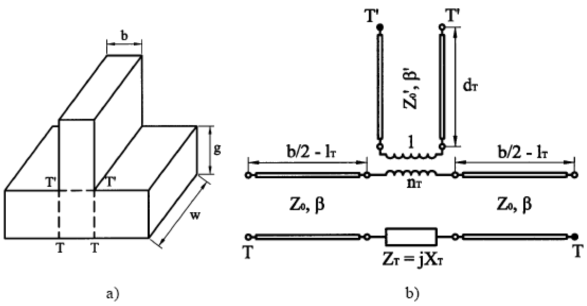


Figure 2. a) General view and b) Equivalent circuit of E-plane T-junction.

The attenuation α in the stop-band is shown in equation 1 and 2 [7].

$$A = \cosh^{-1}\left(\left| \cos(\beta l') - \left(\overline{X}_T + m^2{}_T \frac{b}{g} \tan(\beta d') \right) \cdot \frac{\sin(\beta l')}{2} \right| \right) \qquad (1)$$

$$\alpha(dB) = 8.686 \cdot n \cdot A \qquad (2)$$

Where A represents the attenuation constant in Np/m, n represents the number of sections of E-plane T-junction of filter, β is the propagation constant of fundamental mode ($\beta = \frac{2\pi}{\lambda}$), b and g are physical parameters of the filter shown in figure 1 and $l', \overline{X}_T, m^2{}_T$ and d' are electrical parameters derived from the equivalent circuit of a filter section [8] in figure 2 (b).

3. Design

The geometry of the open entries is $a \times b$ that show in figure 3.

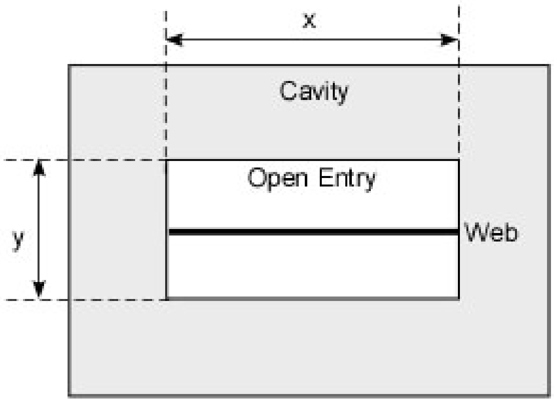


Figure 3. Geometry of open entry.

Where x is 695 mm, y is 200 mm and the material of web is polypropylene. The electrical requirements for filters is a high attenuation level (greater than 60 dB) and a wide stop band response ± 150 MHz (2.30 - 2.60 GHz) the centered frequency at 2.45 GHz. Step by step to design a doubly corrugated filter is the first, by the conditions at above we know w equal to x and g is 135 mm. The w and g parameters are fixed by the material dimensions. Then select n is 13, it represents the number of sections of E-plane T-Junction of filter and l is the number of rectangular post per section. It should be chosen as close as possible to 60 mm, Next select the stub height (d) near 30 mm, corresponding to a quarter of wavelength [6]. The last designing parameter b, the stub width of the equivalent T-junction is the only value that has to be careful selected. When, b parameter is change from 19, 21 and 23 mm and l is change from 53.38, 53.54 and 53.69 mm. By using the computer program to optimize attenuation parameter, the result is shown in figure 5, 6 and 7.

4. Result and Discussion

All geometry parameters of doubly corrugated filter in reference [3] (w = 172.72 mm, g = 13.97 mm, d = 29.21 mm, l = 17.27 mm b = 6.29 mm and material inside the waveguide is air, so dielectric constant = 1) are enter to the program for confirm the correction and accuracy of this program. The design cutoff frequency and infinite attenuation of the operating frequency 2.45 GHz. It has been designed to reject the energy related to the TE10 mode propagating through the access ports in the band 2.30 – 2.60 GHz. All results shown in figure4 that it has the same trend like a graph of figure 5 in reference [3].

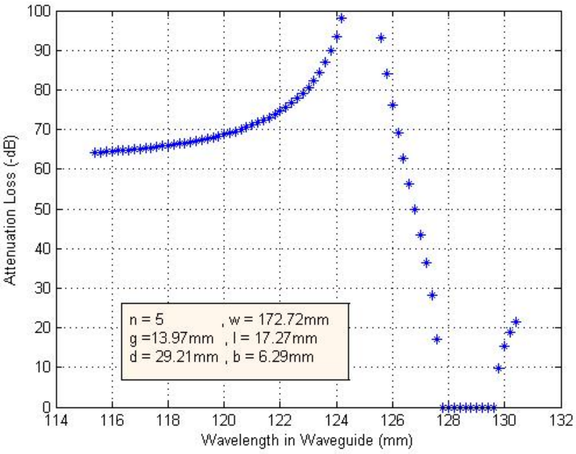


Figure 4. The attenuation loss of the doubly corrugated filter when use all geometry parameters in reference [3]

The different of this work and the reference [3] are the dimension of open entry and material inside it. So, in this work the material inside the open entry is not air, it is the belt (web) that make by polypropylene that has a dielectric constant equal to 3.3. Then input all parameters of equation (1) and vary some condition to the computer program, It shows the result of these actions at below.

The figure 5 shows the result when parameters b and l are changed but w, n, d and g parameters are fixed.

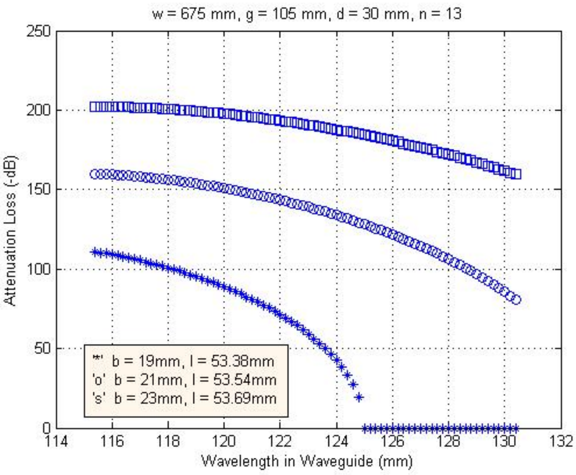


Figure 5. The attenuation loss of the doubly corrugated filter when b and l parameters are changed.

When b parameter equal to 19 mm and l equal to 53.38 mm, the line that represent them ('*') show a pass band of wavelength from 125 mm to 130 mm (2.40-2.31 GHz). Then b is increased, the attenuation is increased too. Because of in equation (1), the increase attenuation comes from parameter $\tan(\beta d')$ term (which can increase to infinite). A higher value of b increase this term and provides a higher attenuation. So the attenuation will increase with b but there is an upper limit for b (since the equivalent circuit in figure 2b). It will not be valid if higher order mode appears, and equation (1) will not represent the real structure). If the number of sections (n) are increased from 10, 13 and 15, but other parameters are fixed, the attenuation loss parameter will be increased. The result show in figure 6 and the effect of the open port height (g) and the stub height (d) show in figure 7. The influence of these values can appreciate that the central frequency of the filter is shifted with the penetration of the stubs, since d is also modified, and the attenuation and bandwidth of the filter are altered as well.

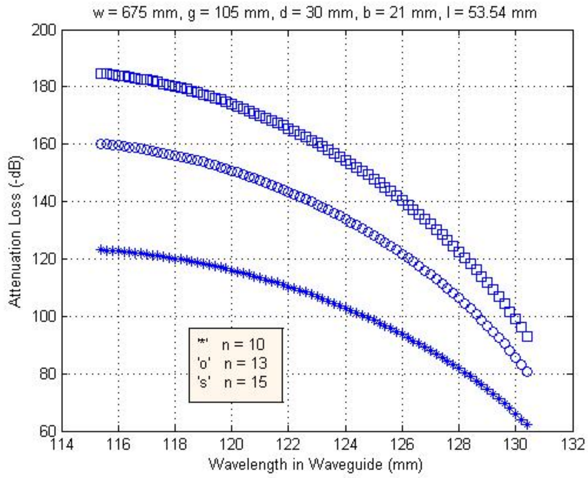


Figure 6. The attenuation loss of the doubly corrugated filter when n parameter is changed.

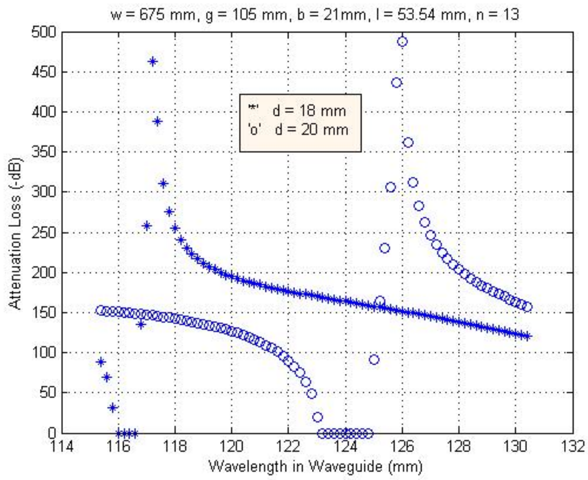
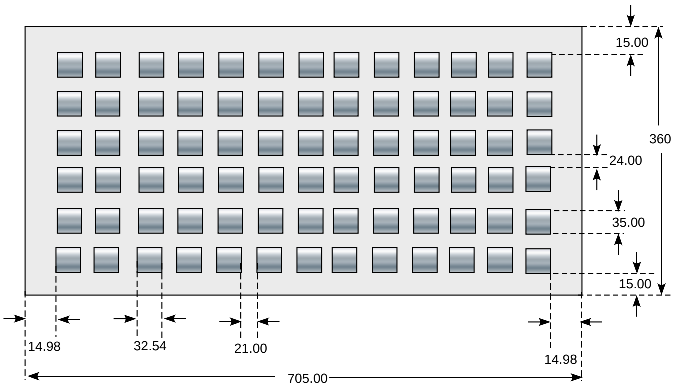
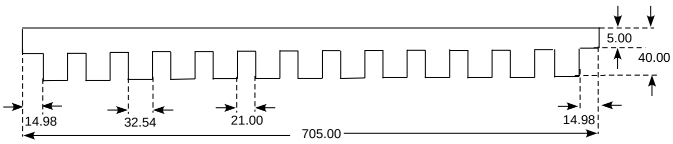


Figure 7. The attenuation loss of the doubly corrugated filter when g and d parameters are changed.

By the way, w = 675 mm, g = 105 mm, d = 30 mm, n = 13 mm, b = 21 mm and l = 53.54 mm all parameters of the doubly corrugated filters will build by these dimension that shown in figure 8 and the doubly corrugated filters are going to install to the open entry of the combined unsymmetrical multi feed microwave heater and continues belt system at R.C.M.E. soon. After implement them to the system, microwave leakage measurement will be done.



a)



b)

Figure 8. A general view diagram of the whole structure of doubly corrugated filter a) Bottom view b) Side view

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