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Analysis, Design and Implementation of a Waveguide Filter and High Power Limiter

Ali Agharasouli, Majid Tayarani

Abstract—In this paper a new method for designing waveguide filters has been introduced. In addition to the filtering function, this filter can be used as a power limiter for protecting the receiver from high power input signals. In order to validate the design procedure, An X-band filter is designed and implemented by a new method and the results have been compared with measurement. Excellent agreement between measured and simulated results was achieved.

Index Terms—Waveguide Filter, Power limiter, Lumped element method, Receiver protector

1 INTRODUCTION

Receiver protectors are widely used in today communication systems in order to protect the sensitive receivers from high power input signals. Interference threats, high power microwave (HPM) pulse attacks, ultra wideband (UWB) pulse attacks, and TX/RX isolation problems are the main causes of compulsory high power limiter usage in radar antenna systems [1-3]. Filtering by using substrate integrated wave guide (SIW) with embedded resonator are investigated in [4-6]. In contrast with other microwave elements, a receiver protector has three operating modes to work properly. To match these kind of elements some matching circuits have been presented [7].These modes include: low power or insertion loss, high power and transition. In low power mode, Receiver protectors pass the signal with the minimum loss. In high power mode, receiver protectors block the high power input signals in order to protect the receiver. .The transition mode is the state when the receiver protectors change their operating mode from low power to high power or vice versa.There are many limiter technologies that provide a variety of protection levels and benefits [8]. Diode limiters are the most common technology and are usually used as the final stage of protection. They can operate over many octaves of bandwidth [9,10] but impose significant insertion loss especially with multiple diode stages to handle high power levels [11].Plasma limiters provide protection up to the highest power levels, and are composed of gas-filled waveguide with discharge gaps located at maximum E-field points [12]. Waveguide ferrite limiters have fast response and recovery, but are expensive, heavy and have high insertion loss [13].In this paper, in order to reject the input high power signals, the flow of electrons causes shorting gap which is embedded in the structure. For high integration, the discrete limiter component is integrated into bandpass filter structure. The combined structure is a novel HPW protection solution for communication systems. A new lumped element model for designing high power bandpass filter is presented in [14-17].

2 DESIGN PROCEDURE

The basic idea of the proposed method in this paper is based on rejecting the input high power signals with discharging electric field in waveguide posts. Therefore, an element is needed to short high power signals. For this purpose, a base element is designed as it is illustrated in Figure.1 (a). In high power mode, when the filter face high power input signal, it can be shorten as shown in Figure.1 (b). So the cut-off frequency of the waveguide would increase. Therefore the input signal cannot passes through the receiver protector. Electrically shorting can be happened like an electrical discharging. The vacuum discharge voltage threshold is 3 kV/mm. In order to decrease this voltage, the inside of the filter can be filled up by Argon or Neon gases. The cut-off frequency of a WR-90 waveguide is:

$$f_{c10} \approx 6.5\ GHz \quad (1)$$

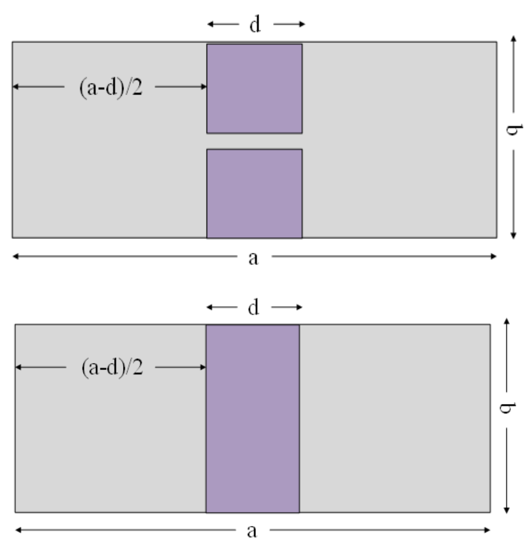

Figure 1. (a) Base structure of the proposed limiter.

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(b) Shortened structure of the limiter.

Now, if the waveguide is shortened by the post, the cut-off frequency of the waveguide can be calculated by:

$$f_{c10} \approx 14.3GHz \quad (2)$$

As it can be inferred, aftershorting the waveguide, the cut-off frequency of the waveguide will increase, so the high power input signals which frequencies below the cut-off frequency, cannot pass the waveguide.

3 ANTENNA DESIGN PROCEDURES

According to this figure, the post is modeled as shown in Fig. 3. The S parameter of the electrical model can be written as follows:

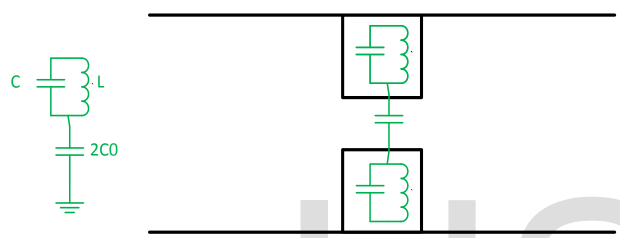

Figure 2. The behaviour of a post in a full wave analysis

L and C can also be written as a function of C_0:

$$L = \frac{A - B}{2C_0} \quad (3)$$

$$C = \frac{2BC_0}{A - B} \quad (4)$$

Where:

$$A = \frac{1}{{\omega_{c,s21}}^2} \approx 10^{-24} \quad (5)$$

$$B = \frac{1}{{\omega_{c,s11}}^2} \approx 10^{-24} \quad (6)$$

The gap between posts is modeled by the capacitor C_0. If the length of the gap is short enough in comparison with the guided wave-length, the electrical field becomes homogenous through the gap. In this condition, the gap can be modeled by a parallel capacitor.

$$C = \varepsilon_0 \frac{A}{d}, C_0 = kC = k\varepsilon_0 \frac{A}{d} \quad (7)$$

In result:

$$L \cong \frac{10}{2C_0}, \; C \cong 2C_0 \quad (8)$$

4RESULTS ANALYSIS

In order to validate the design procedure, an X band filter was designed using the proposed method. According to equation (3)-(8) the capacitance and inductance was calculated. The rectangular posts with cross section of 2×2 square millimeter and height of 1.95 millimeter was chosen. The distance between the adjacent posts was 2 millimeter. The whole structure is simulated with HFSS software,then fabricated and measured. The proposed filter is shown in Figure. 3. Scattering parameters were measured to verify the validity of the design with HP8722D network analyzer. The measured and simulated results are given in Figure. 4. As it is shown inFigure 4, there is an excellent agreement between the measured and the simulation results obtained with HFSS. The frequency ranges, however, cannot be chosen below 1 GHz since the dimensions of the waveguide increase dramatically and above 30 GHz mechanical fabrication tolerances are very challenging.

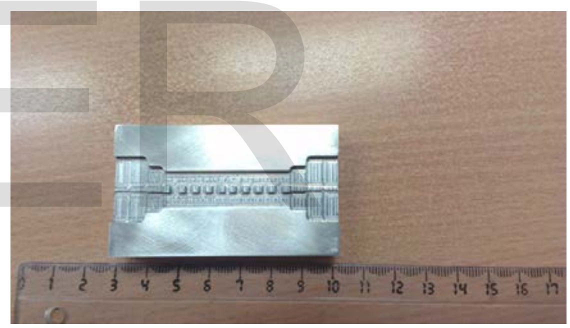

Figure 3. Implemented filter for X-band

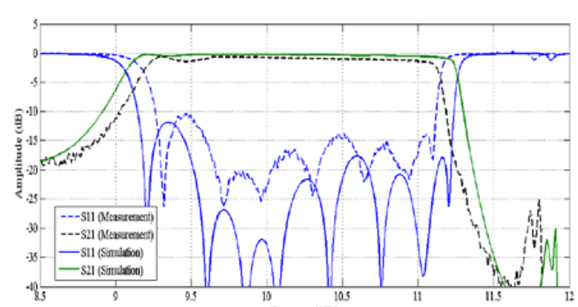

Figure 4. Scattering behaviour of simulation and measurement

5 CONCLUSION

In this paper a new method for designing high power waveguide filter has been proposed. This structure can be filled up by Argon or Neon gases in order to use as power limiter in receivers. In order to validate the design approach, the filter has been fabricated and tested.There is a good agreement between measurement and simulation.

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