Broadband Amplifier Gain Slope Equalization Filter

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Abstract— Since the achievable gain of transistors typically falls off as the frequency increases, an equalization filter with positive gain slope is necessary to compensate for the gain roll-off of broadband amplifiers. This paper proposed an novel equalizer structure and design a equalization filter by applying this novel structure and a modified SIW-PBG (Substrate Intergrated Waveguide-Photon BandGap) filter. The numerical simulated results show that the proposed design of Gain Slope Equalization Filter has a positive gain slope from 8.5 GHz to 18.5 GHz with good impedance matching,low excess loss,and good selectivity.

1. INTRODUCTION

With the new and increasing demand of the internet and multimedia on the commercial side, RF and microwave amplifiers are being used in many broadband applications in the 2 GHz to 20 GHz [6]. However, Modern microwave and millimeter-wave receivers have long struggle with the excessive pass-band negative ripple and gain slopes [4]. Therefore,the equalization filter with a sloped pass-band performance are needed to provide compensation for the gain roll-off of the active devices.

The ideal passive slope equalizer should be no excess slope(that is, the minimum loss should be 0 dB), and the good matching should present to both source and load. Many types of equalizer circuits are provided in G. Vendelin's work [2]. However, according to momentum-simulated results, simple-form equalizer circuits based on lumped capacitors or inductors usually have a large excess loss and a poor input matching characteristics. One of most direct causes is the parasitic effect of lumped elements at the very high frequencies. These problems are well solved in Matt.Morgan and Travis Newton's work [4] by using non-reflective transmission lines.

However, different from their designs, in this paper we proposed another improved equalizer circuit in which the series resonant circuit in traditional models is substituted by series microstrip gap and high-resistance microstrip lines. In addition, we also apply the SIW-PBG technology and design a filter which provide a high-selectivity stop-band for the equalizer. The numerical simulated results of each parts and the entire performance would be presented in the 3rd section. By applying and synthesizing the two parts, we also design an example which could yield a positive gain compensation of 10 dB between 8.5 GHz–18.5 GHz. It has the characteristics of well-matching, low excess loss, low non-linear distortion and high selectivity.

2. THE DESIGN OF GAIN SLOPE EQUALIZATION FILTER

To meet the both requirements of compensating and filtering, we propose an entire network model as shown in Figure 1. The design of equalizer would be discussed in Section 2.1, and the PBG filter in Section 2.2.

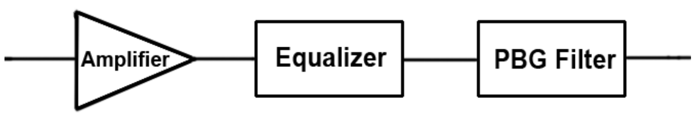


Figure 1: The entire network model.

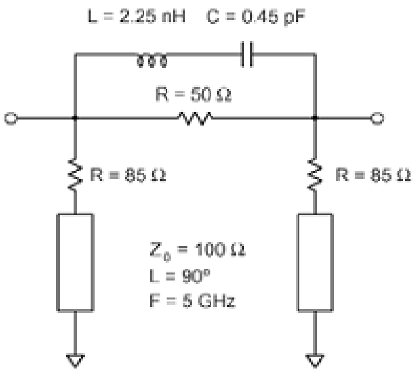


Figure 2: The traditional equalizer circuit.

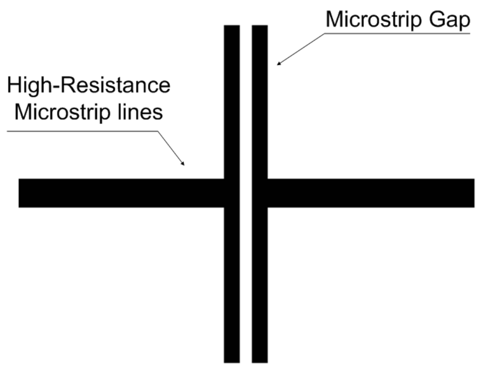


Figure 3: The LC structure after improved.

2.1. Improved Equalizer Structure

Among various equalizer circuits provided by Mellor [3], the circuit shown in Figure 2 presents the best characteristics in good linear slope, good matching and low excess loss. The operating frequency of both the series resonant circuit and the one-quarter-wavelength transmission lines is 5 GHz, which is also the high end frequency of the positive gain slope.

However, for the parasitic effect, the performance of this circuit get worse a lot when we implement this circuit with chip elements. We find the situation would become much better if we apply boradband adaptive lumped elements, but the cost is also increased at the same time.

To seek less drift effect, the LC series resonant circuit in traditional equalizer model is substituted by microstrip gap and high-resistance microstrip lines as shown in Figure 3. After synthesis and optimization steps, the frequency response of this structure presents approximately the same with the LC series resonant circuit. The entire structure and the parameter definition could be seen in Figure 4.

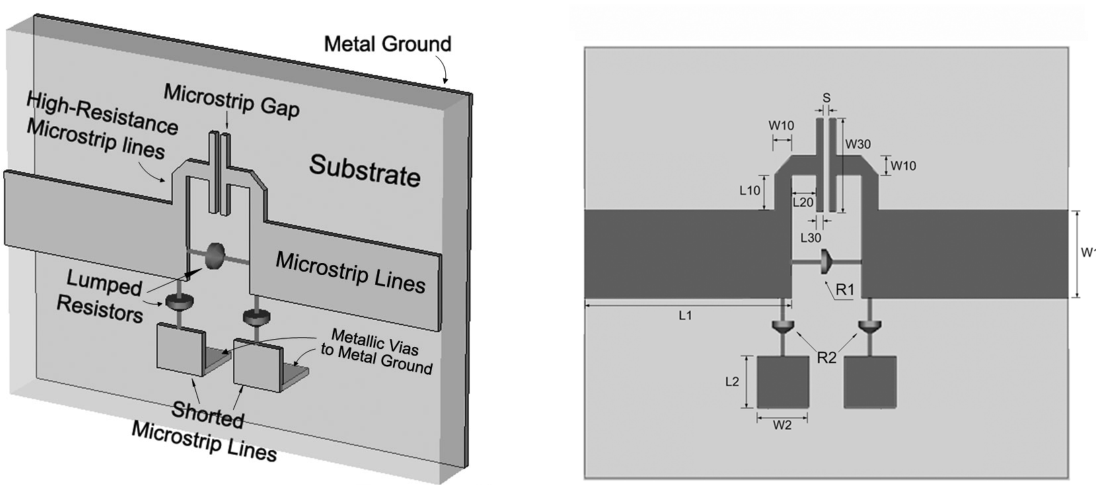
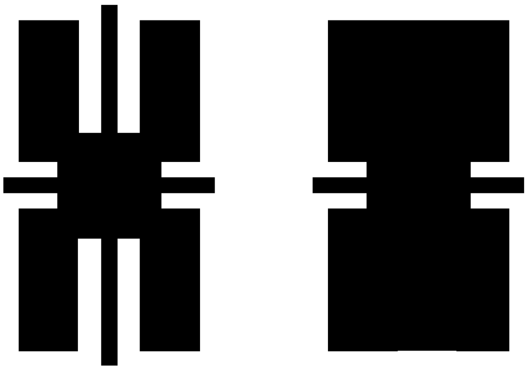


Figure 4: Improved equalizer structure with parameter denition.

2.2. Compact Super-wide Bandpass SIW-PBG Filters

The improved structure described in Section 2.1 could provided a positive gain slope from DC to 18 GHz. To filter out the out-of-band frequencies, we design and apply the SIW-PBG filter for its characteristics of low insertion loss, low band ripples and high selectivity.

On the basis of PBG equivalent circuits and the SIW-DGS (Defect Ground Structure) developed by Zhang-Cheng Hao and Wei Hong [2], we modify the PBG cell structure to meet the requirement of our work as shown in Figure 5. The main purpose of this modification is to reduce the equivalent capacitance and inductance, then increase the cut-off frequency.



(a) (b)

Figure 5: Modification of PBG cell, (a) The classical cell structure, (b) Modified PBG cell structure.

TABLE I
GEOMETRIC PARAMETERS OF THE EUQALIZER

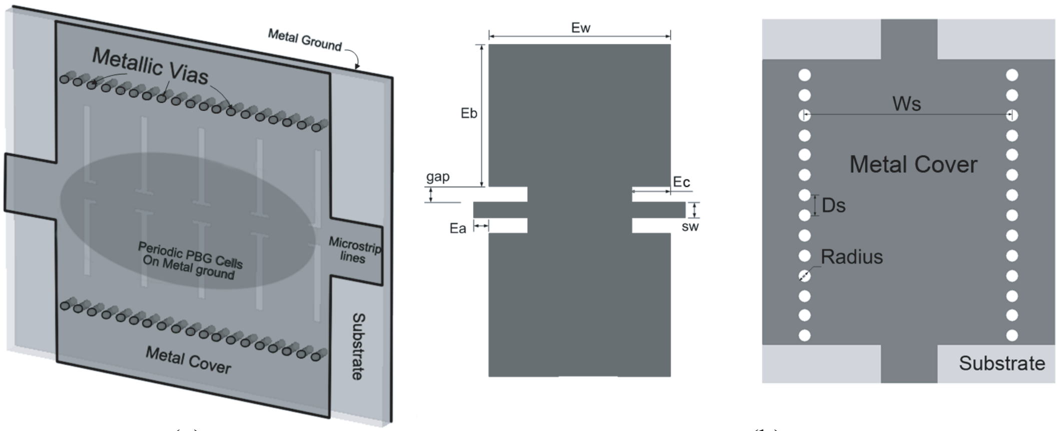
S (mm)	0.05	W10 (mm)	0.1
W30 (mm)	0.85	L10 (mm)	0.3
L20 (mm)	0.3	L30 (mm)	0.1
W1 (mm)	0.85	W2 (mm)	1
L1 (mm)	4.3	L2 (mm)	0.75
R1 (Ω)	70	R2 (Ω)	35

TABLE II
GEOMETRIC PARAMETERS OF THE SIW-PBG FILTER

Eb (mm)	3.5	Ew (mm)	2
gap (mm)	0.2	Ec (mm)	0.25
Ea (mm)	0.1	sw (mm)	1
Ws (mm)	10.5	Ds (mm)	0.7
Radius (mm)	0.4		

Figure 6: The value of parameters.

The substrate intergrated waveguide provide a excellent high-pass effect, and the photon bandgap yield a periodic stop-band. The entire modified structure and the definition of parameters are presented in Figure 7.



(a) (b)

Figure 7: The proposed PBG structure and the parameter definition, (a) Modified PBG structure, (b) Congurations for PBG cell and the SIW with their geometric parameters.

3. NUMERICAL SIMULATION

To demonstrate performances of positive gain slope equalizer and the wide-band filters, we have investigated these parts with the aid of two software-ADS (Advanced Design System 2003A) and CST (CST Microwave Studio 5.1.3). The dielectric substrate in the simulation model has a thickness of 0.8 mm, a relative permittivity of 4.3, the thickness of metal is 0.03 mm.

3.1. Simulation Results of Gain Slop Equalizer

Simulated by ADS, Figure 8, Figure 9 show the simulation results of schematic models of the improved equalizer structure discussed in Section 2.1. It can be found that the improved equalizer structure proposed provide a linear gain slope between 8.5 GHz–18.5 GHz from −10 dB to 0 dB. The loss at the 18.5 GHz is 0.08 dB. The return loss is better than −15 dB.

With the geometric parameters listed in Table I, the Momentum simulation results of the same structure made by CST could be seen in Figure 10. in the plot of S_{21}, The excess loss is 0.88 dB, and the average value of S_{11} parameter approximates −15 dB.

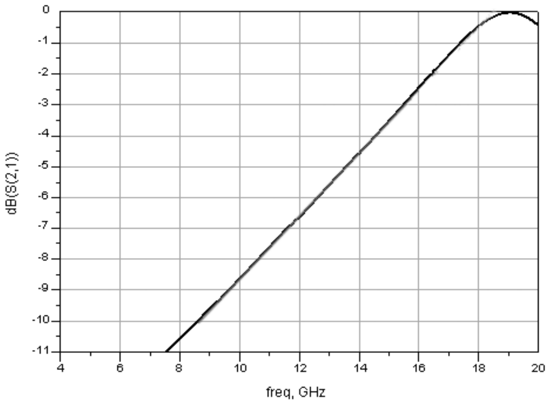


Figure 8: S_{21} plot achieved by ADS.

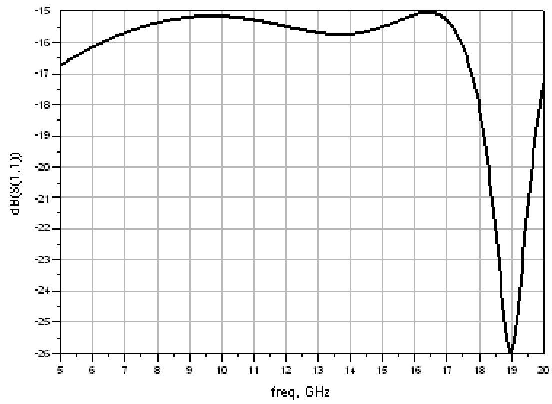


Figure 9: S_{11} plot achieved by ADS.

From the results yielded by CST, we can find that the parasitics of the lumped elements have been greatly reduced. Although worse than schematic results, the performance of this proposed structure show the characteristics of slope, matching and excess loss, which are well enough to meet the requirement of the entire system.

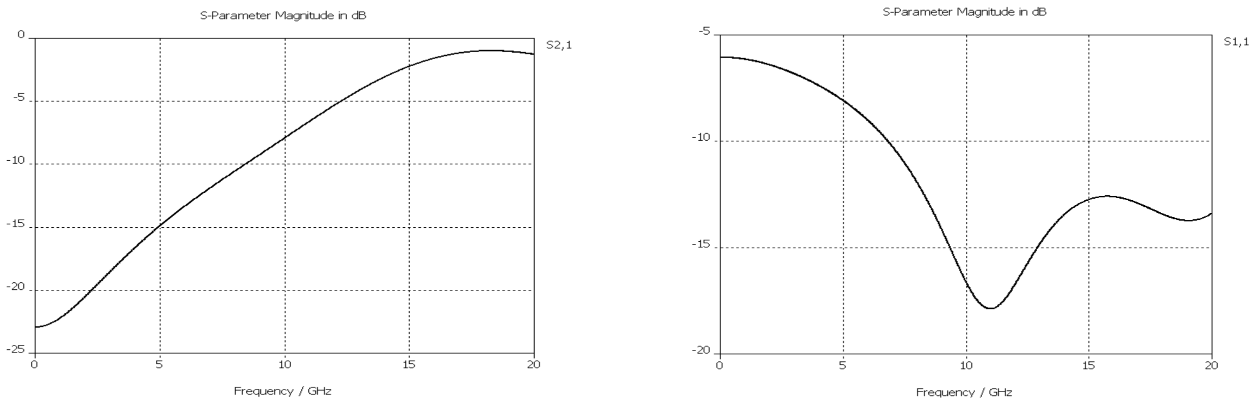


Figure 10: S-parameter plot achieved by CST momentum simulation.

3.2. Simulation Results of SIW-PBG Filter

Obtaining the improved structure equalizer, we design a super-band filter with the passband from 8.5 GHz to 18.5 GHz by applying the new PBG structure discussed in Section 2.2. To enhance the performance, we add the number of PBG cells to 11, and with the parameters listed in Table II, the S-parameters simulated results by CST are shown in Figure 11. According to the results, the

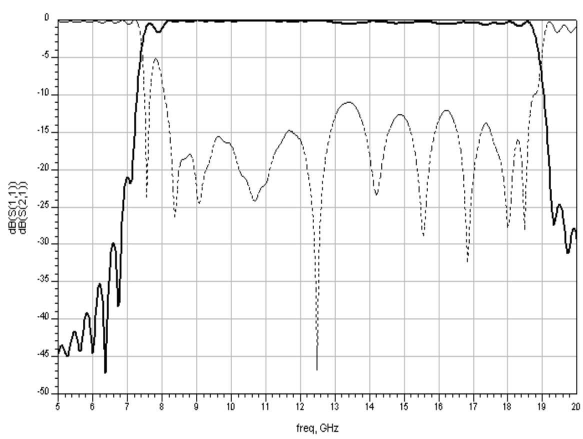


Figure 11: Simulation results of modified SIW-PBG structure achieved by CST.

average insertion loss of this filter is lower than 0.32 dB, and the return loss is better than −10 dB.

3.3. Simulation of Gain Slope Equalization Filter

To combine the filter and the equalizer proposed in former sections into a series system, we pack and export the data of SIW-PBG filter we designed from CST and import it into ADS. For the two parts have the same input resistance and output resistance (both of their input resistance and output resistance are 30 Ω), we connect the data package of SIW-PBG filter and the improved equalizer structure in ADS without impedance transformation. The performance of the entire system — Gain Slope Equalization Filter in ADS would be described in Figure 12.

From the Figure 12, we can see that with the excess loss of −0.79 dB, the passband is from 8.5 GHz to 18.5 GHz, and the return loss is better than −10 dB, showing good characteristics of filter selectivity, low insertion loss, linear slope and the impedance matching. In addition, to described the linear performance of this work, we add a ideal reference slope (the lighter line) between 8.5 GHz to 18.5 GHz from −10 dB to 0 dB as shown in Figure 13. The variance and the largest offset between the reference slope and the simulated one are respective 0.164(0.66 dB) and 0.093(0.34 dB).

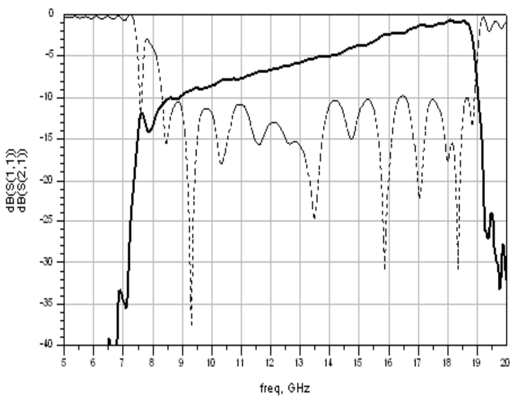


Figure 12: S-parameter plot of the GSEF by ADS.

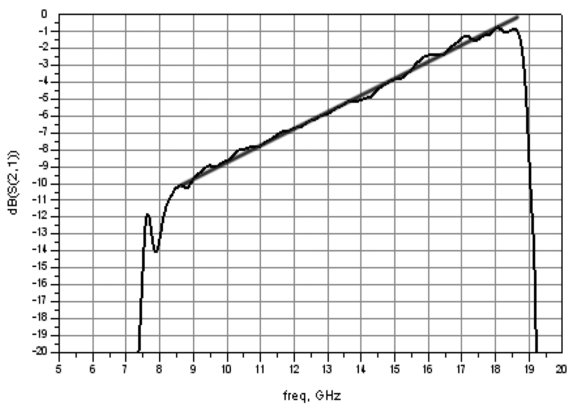


Figure 13: S_{21} plot of the GSEF with reference line.

4. CONCLUSION

Improved equalizer circuit and modified SIW-PBG structure has been proposed. By applying these designs, the GSEF developed in this paper could provide a 10 dB compensation from 8.5 GHz to 18.5 GHz with the excellent characteristics of selectivity, matching, low insertion loss, wide band and low nonlinear distortion.

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