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Developing the 150%-FBW Ku-Band Linear Equalizer

Sungtek Kahng

Abstract

This article reports the development of a linear amplitude equalizer for the linearity of the slope of the amplitude over 150% fractional bandwidth in Ku-band. The circuit model is featured by the resistor placed between each pair of a transmission-line and a stub. The design includes finding the values of resistors and stubs to have the optimal linear slope and return loss performances. The measured data show the acceptable performances of the slope variation and return loss over 2~18 GHz.

1. Introduction

The Radar Warning Receiver(RWR) for a helicopter tends to end up with the increasing overall insertion loss that is attributed to the cascaded placement of dissipative components such as Switch, Filter, Power-divider, Coupler and the like in the wide-banded RF channel. In order to reach for the target of quality performance, it is necessary to compensate for the insertion loss with flattening in the gain amplitude over the frequency band of interest. This is what is all about the gain(amplitude) equalization techniques which quite often entails the slope linearization.

To date, even though the domestic technical groups have presented that they are mature in implementing the gain equalization for commercial products operating in the relatively narrow frequency bands, they do not seem to meet the challenge of the equalization in broader bands for military applications.

As an attempt to meet the rising demands and boost the competitiveness of our technology, we have developed the linear gain equalizer working in the band as wide as over 10 GHz for the RWRs.

With a look into the current techniques of the gain equalization, it is found they can be classified to the followings : Linear and non-linear gain equalization methodologies[1-5]. The non-linear scheme is exploited to the narrow-banded sub-bands of one given broad-band, This is relatively easy to build up in the design, but it requires multitude of different stages corresponding to the sub-bands, which leads to cumbersome extra insertion losses, when the stages are electrically combined for its physical implementation. On the contrary, the linear equalizer necessitates one module, though its design seems tougher than the non-linear case. Besides, the linear equalization is advantageous in that it aims at the operation in one broad-band.

Making a noteworthy progress from what has been done previously as in [1-5], we present

the linear gain equalizer working over 2 GH ~ 18 GHz by transmission lines with coupling elements.

2. Theoretical Side of Design

The gain equalizer plays a role of flattening the amplitude of the resultant insertion loss of the equalizer following the former component over the specified band[1-4].
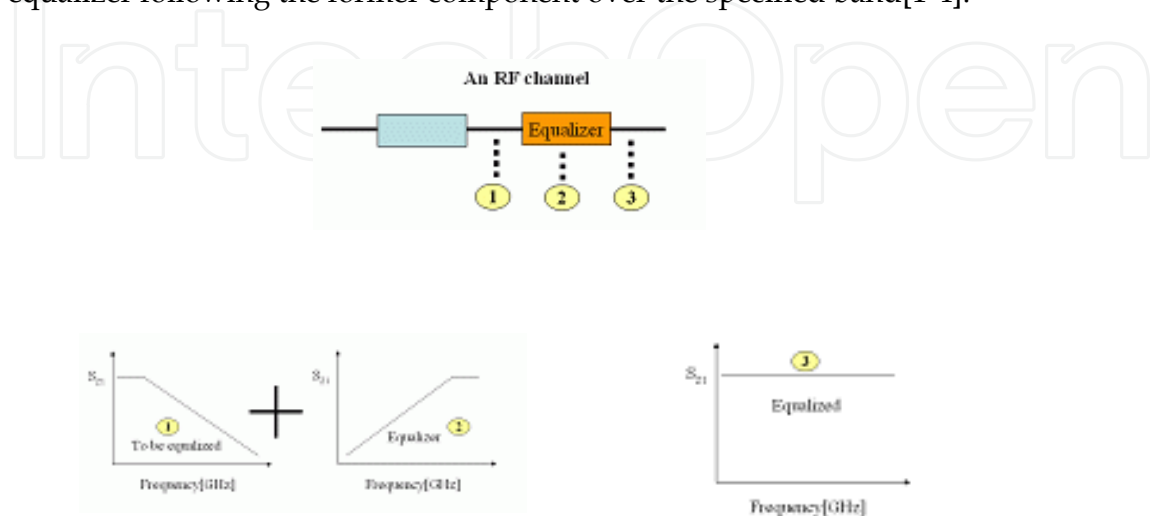

Fig. 1. Function of the linear gain equalizer

As shown in the result marked number 3, the balance is made by the ascending amplitude(marked number 1) added to the descending one(number 2). Particularly with Fig. 1, the equalizer shows the minimum loss at the high end of the band. Depending on cases, the slope of the equalizer's amplitude should be negative with the maximum loss at the upper end of the band. As a matter of course, the minimum loss of the equalizer is designed the lowest possible.

To begin, a low-ordered bandpass filter(BPF) is considered. In detail, the center frequency of the BPF is set at the end of the band(18GHz or 20GHz here), which is called the cut-off frequency in the gain equalizer design, with the ripple level of 0.1dB and the fractional bandwidth of 1. That is to say the Chebyshev filter of 1st order. Using this, it is effective to get the idea of how we get started, but falls short of satisfactory levels on return loss and linear slope. So it is inevitable to expand to a higher order circuit.

Regarding the fundamentals of the operation, the transmission line with the serial resistor is let go open at the cut-off frequency that is equivalent to the resonance frequency of series inductor and capacitor. At this point, the insertion loss becomes ideally zero. The rest of the band is designed to undergo the attenuation due to the T-network of three resistors, which determines the slope.
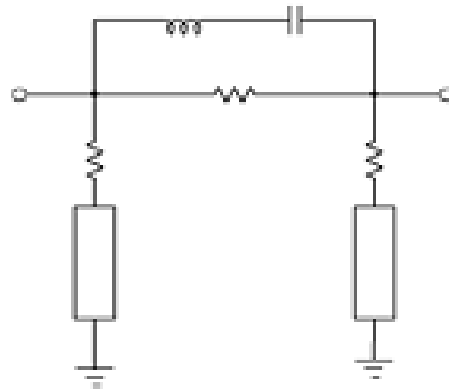
Fig. 2. Basic circuit of the linear equalizer

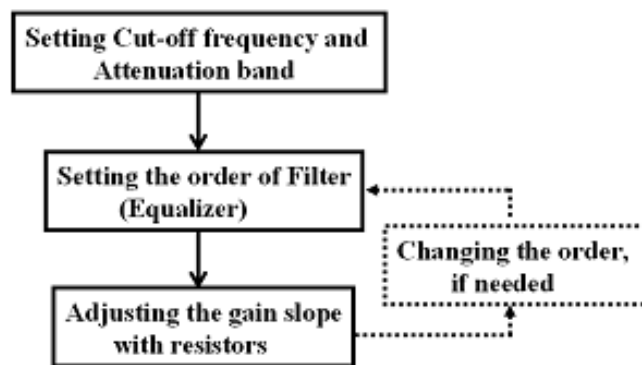The design flow can be simply described as

Fig. 3. Flowchart of the design

In the first place, we set the cut-off frequency of the gain equalizer at the center frequency of the nominal filter. Simultaneously, the attenuation band is defined. In the second place, the order of the filter is decided to have the slope of the amplitude as close as possible to the wanted value. And then, varying the resistors, the slope is adjusted to meet the spec. over the entire frequency band. If it is not satisfactory, return to the step where the order of the filter is determined and change to the immediate higher order.

3. Results of Design

Here comes the summary of the design specifications.

Item	Specs
fo, FBW	10GHz, 150%
Slope	10dB over the BW
Insertion loss	< 3dB at 18GHz
VSWR	< 2.0:1

Among the items, the slope is set the top priority. Maintaining the slope, the return and insertion losses are considered.

Firstly, let us start the design by changing the order of the basic circuit from 1 to 2.

(a)   (b)
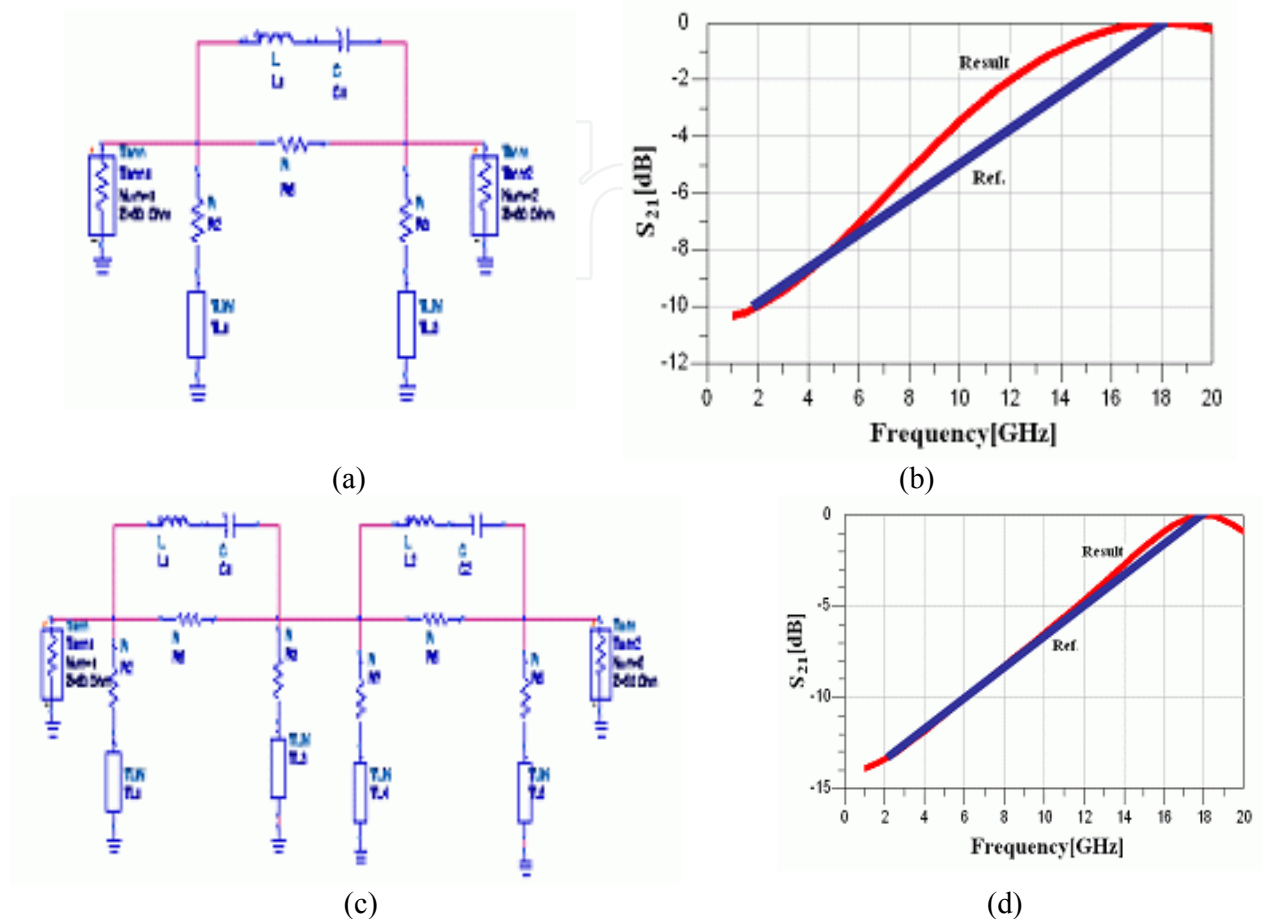

(c)   (d)

Fig. 4. The 1st and 2nd order linear equalizers (a) 1st order circuit   (b) Performance(1st order) (c) 2nd order circuit   (d) Performance(2nd order)

The reactive elements are found by having their resonance at the cut-off frequency given in the specs. The resistors are computed, assumed that the T-networks are symmetric, to secure the gradient of the amplitude curve parallel to the given slope. Increasing the order of the equalizer, the slope performance has improved from Fig. 4(b) to Fig. 4(d). Taking into account the fabrication based upon the microstrip line, the reactive elements are replaced by the lossy transmission line(better for considering dispersion). The order of the entire circuit should be increased and the final design lends the performance in the insertion and return loss as follows.

Going through the tuning and trimming on the fabricated equalizer, the measured return and insertion losses amount to less than -10 dB and roughly 9 dB throughout the band(2GHz ~ 18GHz), respectively. Actually, the slightly non-linear behavior happens in the vicinity of 18GHz and it is believed to stem from the design ignorant of the capacitance parasitic to the resistors and transmission lines.
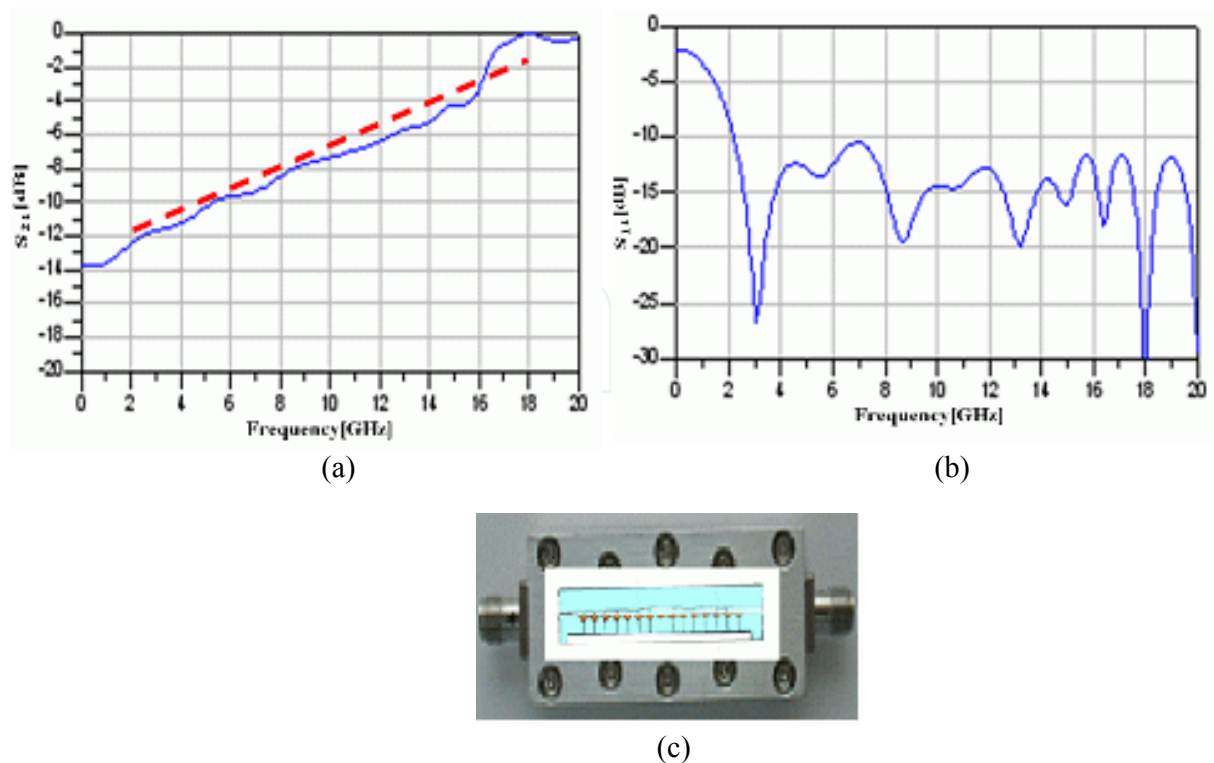
(a)   (b)

(c)

Fig. 5. The 14th order linear equalizers (a) Insertion loss (b) Return loss (c) Photo of the fabricated circuit

4. Conclusion

In this article, the design of a gain equalizer has been conceptualized to achieve the linear slope over the very wide band 2GH ~ 18GHz and good return loss performance. Besides, it has been implemented by fabrication with the microstrip transmission lines and SMT resistors. The measured data prove the realized equalizer outputs the acceptable linearity in the slope and return and insertion losses.

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