An Improved Interdigital-based Parallel-Coupled Microstrip BandPass Filter

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***Abstract*—This paper presents a microstrip bandpass filter using an interdigital structure. The filter is designed at a center frequency of 36GHz, while the bandwidth is 4GHz. In the traditional coupled microstrip filter, especially working in the Ka band, the distance between the first coupled microstrip is a little close, so, it can be a little difficult to produce. However, the interdigital structure provides a closer coupling, and thus, it performs better than the first coupled microstrip. This paper based on the traditional coupled microstrip bandpass filter and designed a bandpass filter using interdigital structure optimized by HFSS.**

***Keywords*—Ka band, Interdigital, Microstrip, Bandpass Filter**

I. Introduction

In communication system, filter is of vital important. Its main function is to suppress unnecessary frequency in an arbitrary signal, and to keep frequency which is needed. In high power system, waveguide filter is commonly used, for its high performance such as low return loss, high isolation and high quality factor [1]. However, its volume is so huge thus it cannot be used in minimized condition. Microstrip is wildly used in low power system, especially portable device, because its low cost and much easier to realize.

Many innovated bandpass filters have been designed in unique construction, such as filter with DGS [2], LTCC based filter [3] and etc. Usually, microstrip bandpass filters are designed in a type of coupled microstrip. Truly, this structure is pretty nice in low frequency, as we can read from other theses, most parallel-coupled microstrip filters were designed to work in low frequency, such as X band, S band and Ku band etc. Theoretically, it can be designed in any band, but the higher the frequency is, the closer the distance of the first coupled microstrip will be, and it will be more difficult to produce. So, an interdigital structure is now assumed to solve this problem. We replaced the first coupled microstrip to interdigital microstrip, and fabricated it on a dual-layer Rogers RO5880 substrate, which has the thickness of 0.254mm, and dielectric constant of 2.2.

II. Design

In this paper, a filter which has a center frequency of 36GHz, passband frequency ranges from 34GHz to 38GHz and stopband ranges from 0 to 32GHz, 40GHz and above is required. First, a traditional coupled microstrip filter is designed, and then an interdigital structure is then been added.

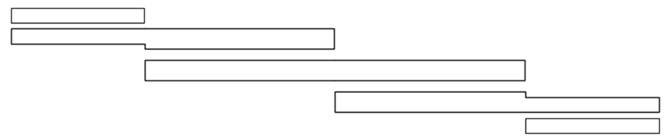

Fig. 1. Structure of paralleled-coupled bandpass filter

A. Parallel-Coupled Filter Design

Parallel coupled-line microstrip bandpass filters are composed of several half-wavelength resonators. and several bandpass coupling lines. The length of each part of microstrip is about $1/4$ the length of wavelength. Parallel-Coupled Filter is the one of the most wildly used type, just as Fig 1 shows. It is a fourth order parallel-coupled bandpass filter, and can be easily designed by Advanced Design System, and CST and etc.

Typically, filter has three types, Chebyshev, Butterworth, and Eclipse. Butterworth filter, also be called as max flat filter, because its passband is the flattest among the three above. Chebyshev filter has a better attenuation feature, but its passband is rippled. For Eclipse filter, it has the best attenuation feature, but most difficult to realize. Thus, Chebyshev filter is mostly used. We can calculate its parameter by the following equations [4] [5] .

$$\beta = ln[coth(\epsilon/(40lg(e)))] \tag{1}$$

$$\gamma = sinh((2k-1)\pi/(2N)) \tag{2}$$

$$a_{\mathrm{k}} = sin((2k-1)\pi/(2N)) \tag{3}$$

$$b_{\mathrm{k}} = \gamma^2 + sin^2(k\pi/N) \tag{4}$$

$$g_1 = 2a_1/\gamma \tag{5}$$

$$g_{\mathrm{k}} = \frac{4a_{\mathrm{k\text{-}1}}a_{\mathrm{k}}}{b_{\mathrm{k\text{-}1}}g_{\mathrm{k\text{-}1}}} \tag{6}$$

In these equations above, we can get primary parameters of the filter, namely g_{k}. Then even and odd mod resistance can be calculated with the following equations.

$$Z_{0\mathrm{e}} = \frac{1}{Y_0}[1 + \frac{J}{Y_0} + (\frac{J}{Y_0})^2] \tag{7}$$

$$Z_{0\mathrm{o}} = \frac{1}{Y_0}[1 - \frac{J}{Y_0} + (\frac{J}{Y_0})^2] \tag{8}$$

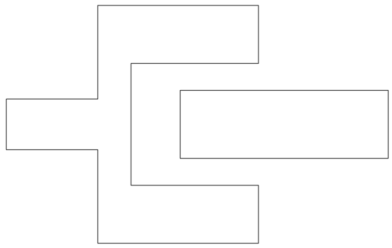

Fig. 2. A type of interdigital structure

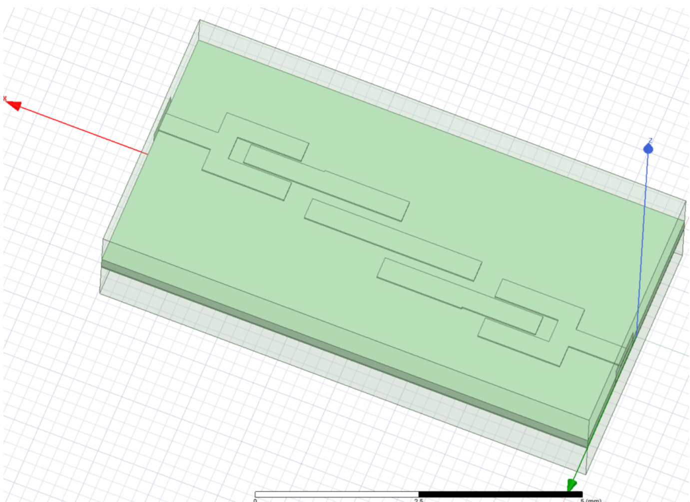

Fig. 3. Layer of the filter

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi\delta}{2g_0}g_1} \tag{9}$$

$$\frac{J_{\mathrm{n,n+1}}}{Y_0} = \sqrt{\frac{\pi\delta}{2g_{\mathrm{n}}}g_{\mathrm{n+1}}} \tag{10}$$

$$\frac{J_{\mathrm{i,i+1}}}{Y_0} = \frac{\pi\Delta}{2}\frac{1}{\sqrt{g_{\mathrm{n}}g_{\mathrm{n+1}}}} \tag{11}$$

In these equations, Δ denotes to relative bandwidth of the filter, denotes characteristic impedance of the microstrip circuit. By these equations, odd and even mod impedance can be calculated. Then the distance, width and length of a coupled microstrip can be calculated by using ADS Linecalc tools.

B. Interdigital

The interdigital structure, shown in Fig 2, is commonly used in filter designing. Its shape can be thought as a hand holding a stick tightly. In fact, interdigital provides higher coupling degree than parallel-coupled. For the structure, each section of line is about $\lambda/4$ in length. This topology is straightforward to implement in planar technologies. The spacing requirement between each lines is not as strict as in the parallel line structure; as a result, higher bandwidths can be achieved, and at the same time, values of quality factor Q, can reach as low as 1.4.

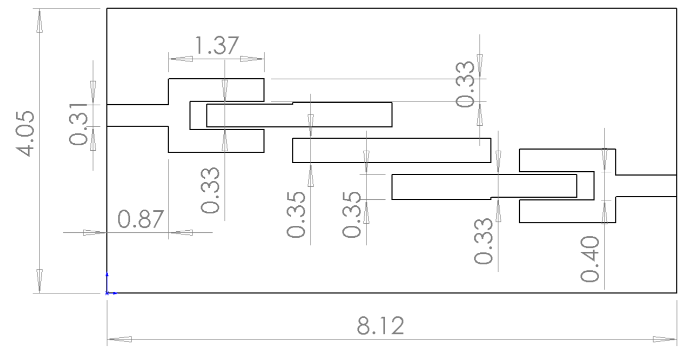

Fig. 4. Layer of the filter

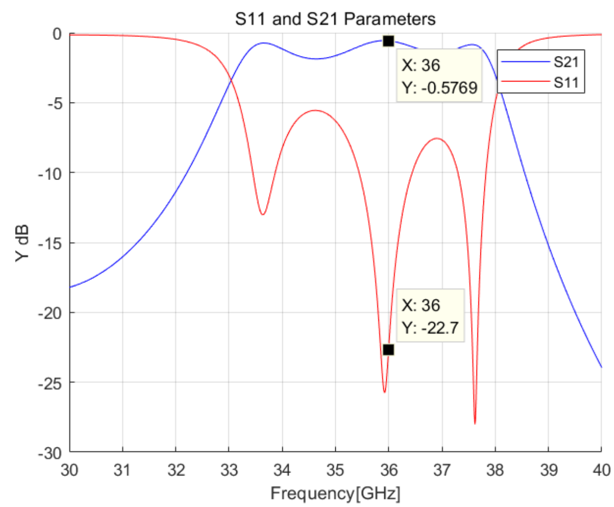

Fig. 5. Simulation result

III. Simulation

Create a model on HFSS, just like Fig 3 does. The structure is symmetrical about its center point. The total size of the model is about $8.12mm \times 4.05mm$. Although the total size is similar to pure parallel coupled microstrip filter, it performs better than that. First, it has wilder passband. Second, it attenuates faster than parallel coupled microstrip filter which has same order. Third, it can be easier to produce, for the sake of its wilder distance between two microstrips. Fig 4 gives the detail size of the filter designed in Fig 3. It is still a little narrow, but, when compared to the first order of traditional parallel-coupled filter, it is wilder than the later one. Thus, it can be easier to manufacture.

As shown in Fig 5, the HFSS simulation result of the designed filter is corresponding to our design purples. The intersection lose at 36GHz is less than 1dB, while the passband ranges from 33.1GHz to 38GHz. And the ripple of the passband is about 1.3dB. Although the passband has a little ripple, it has little effect on the final use. The reflection factor is -22.67dB at the frequency of 36GHz. Therefore, according to the simulation result, this filter designed can meet the requirements.

IV. Conclusion

A interdigital based coupled microstrip filter has been proposed and simulated in this paper. The filter is designed and simulated in HFSS. The result of this design has shown that interdigital structure is also a kind of choice when designing a Ka band bandpass filter. This improved filter can be wildly used in communications system and radar which works in millimeter wave range. Besides, designing process has greatly been simplified by computer assistance software. With the help of the computer software, we can design more and more difficult circuit.

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