Modeling of Multilayer MMIC Coplanar Waveguide Low Pass Filter for Cellular Application

Cakra D. Sedayu, Emerson P. Sinulingga*, and Syafruddin Hasan
Department of Electrical Engineering, Universitas Sumatera Utara, Medan, Indonesia

*Email : emerson.sinulingga@usu.ac.id

Abstract. In the early development of Monolithic Microwave Integrated Circuit (MMIC) technology, most of the components use Microstrip structure. In order to connect the active components to the ground in the Microstrip design is limited by the thickness of the substrate to avoid circuit performance degradation due to vertical coupling. Thus it can be said that the Microstrip is not the primary choice of design in operating components at microwave and millimeter wave frequencies. The Coplanar Waveguide (CPW) design technique was proposed as an alternative to the Microstrip structure for MMIC components. With CPW design technique, it generates components and circuits which are cost-effective and allow miniaturization of components in MMIC environment. In this paper, CPW Low Pass Filter (LPF) electromagnetic modeling has been demonstrated based on multilayer MMIC technology for the 2,100 MHz mobile application. The LPF CPW specification has been modeled with the substrate of GaAs ($\varepsilon_r=12.9$) and Polymide ($\varepsilon_r=3.7$). The thickness of GaAs substrate and Polymide dielectric is 600 micron and 2.5 micron respectively for each layer.

1. Introduction
The Monolithic Microwave Integrated Circuit (MMIC) technology is widely used in modern telecommunications devices because the advantages it possessed, namely having small dimensions, can be reproduced on a large scale and work at frequencies of 300 MHz to 300 GHz. One component in the RF front-end diagram of the cellular telecommunications system of 2,100 MHz is the Low Pass Filter. This component serves to negate frequencies above 2.1 GHz [1 - 3]. One type of design technique for LPF is an elliptical filter or Cauer filter. This filter has a faster gain transition between the pass band and stop band so that it gets faster cut-off frequency. Research on LPF components in MMIC technology has been carried out to obtain optimal performance and increase reliability. However it was not done using elliptic filter design techniques [4] - [8]. This study discusses elliptical low pass filter modeling using MMW CPW multilayer technology.

2. Multilayer CPW MMIC Low Pass Filter
Low pass filter is a filter that only passes signals with a frequency lower than the cut-off frequency and weakens the signal with a frequency higher than the cut-off frequency. Cut-off frequency ($F_c$) is the frequency at which the response filter leaves a band error (or $-3$ dB points from the peak) [9]. In addition to the response from insertion loss that determines the cut-off frequency of a filter, it is necessary to look at the return loss response that determines the working frequency of a filter. A device can work well when it has Voltage Standing Wave Ratio (VSWR) below 2. Therefore the
return loss of a device must have a minimum response of -10 dB at the desired work frequency [10]. In this research, the component that has been designed has specifications as shown in Table 1. These specifications are based on standardization from previous studies [10].

| Table 1. Design Specification | Specification |
|------------------------------|---------------|
| Operating Frequency          | 2.1 GHz with VSWR < 2 |
| Cut-off Frequency            | ≥ 2.2 GHz |
| Number of Layers             | 3 Layers |
| Substrate and Layers’ Material | GaAS and Polymide |
| Dielectric Constants         | GaAs ($\varepsilon_r = 12.9$) and Polymide ($\varepsilon_r = 3.7$) |
| Substrate and Layer Thickness | GaAS (600 microns), Polymide (2.5 microns) |
| Conductor Thickness          | 0.8 microns |
| Return Loss ($S_{21}$)       | < -10 dB |

2.1. Schematic of Elliptic Planar Low Filter
Designing schematic elliptical LPF is done using ADS software in the Design Guide Filter menu. In the Design Guide Filter menu the 2.4 GHz cut-off frequency is selected with the 6 GHz stop frequency, and the attenuation of 30 dB. This application only has a cut-off frequency setting, but not an operating frequency. Therefore tuning was required so that the LPF can work at a 2.1 GHz frequency. Figure 1 shows the results of the schematic elliptic LPF after the tuning.

![Figure 1. Schematic Circuit of Elliptic Low Pass Filter](image)

2.2. Coplanar Waveguide MMIC Low Pass Filter
Based on the schematic design, there are four main components in an elliptic Coplanar Waveguide (CPW) LPF, namely three capacitors and one inductor. All components are transformed accordingly into MMIC LPF component as shown in Figure 2 and tuning is carried out so that the elliptic LPF component can work well at a frequency of 2.1 GHz and has a cut-off frequency above 2.2 GHz.
Figure 2 shows a layout design of elliptic CPW MMIC LPF. This component has a size of 1188x1029 μm².

![Figure 2. Layout Design of elliptic CPW MMIC LPF](image)

2.3. Elliptic Multilayer CPW MMIC LPF

By using the same circuit pattern in the momentum component of the planar MMIC LPF, the transformation of each component in the multilayer CPW form is carried out. Tuning is also performed so that elliptical components of multilayer LPF can work well at a frequency of 2.1 GHz with a cut-off frequency above 2.2 GHz. Figure 3 shows a layout design of elliptic multilayer MMIC LPF with size of 973x721 μm².

![Figure 3. Layout Design of elliptic multilayer CPW MMIC LPF](image)

The simulation process is carried out using stages of optimization based on 3D momentum references [11]. In this work steps are taken so that the simulation results have a better response and can approach the results of the measurements.

3. Results

Figure 4 shows a comparison of return loss and insertion loss of elliptical components of multilayer and planar MMIC LPFs respectively.
Elliptic planar MMIC LPF with optimal settings has a size of 1188x853µm² and elliptic MMIC multilayer LPF has a size of 973x695µm². It can be seen in Figure 4 that the return loss responses of planar and multilayer produces almost the same trend. Both graphs show frequency response that can work well at 2.1 GHz because it has a return loss value below -20 dB. This shows that with multilayer techniques can produce the same response with smaller component dimensions. The dimension size decreases by 49.85%. In addition, it can be seen also in Figure 4 that the return loss value decreased by 3.57% from -48.95 dB on planar LPF and -50.70 dB in multilayer LPF. In addition there was also a decline in the stop band by 43.02% from -21.589dB to -30.877dB. This proves that using multilayer techniques can produce a better response.

4. Conclusions
The use of multilayer techniques in LPFs results in smaller components with size reduction of 49.85% compared to planar LPF. This technique also produces a better return loss value of 3.57%, with a return loss of -48.95 dB on planar LPF and -50.70 dB in multilayer LPF. The simulation results of LPF components using multilayer techniques have been demonstrated with operating frequency of 2.1 GHz frequency and can be applied to cellular applications.

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