

Effect of feeders in 3D modeling of low impedance multilayer CPW transmission line

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Abstract. Improved characteristics with low dissipation loss MMICs are highly desirable for wireless communications. However, the current industrial MMIC design is mainly based on microstrip concept which suffered from parasitic and unwanted phenomenon especially at higher frequency (>20 GHz). On the other hand, for future wireless technology, higher frequency operation is required and on-wafer microwave characterizations as well as precise modeling of 3D Multilayer CPW components are vital. This project concerns with understanding of the microwave characteristics behavior of Multilayer CPW components in MMIC applications. Feeder effect as unwanted parts in the characteristics has been investigated to determine its relation with the half wavelength resonance of the Multilayer CPW Low Impedance Transmission Line.

1. Introduction

Considerations to embed probe pads and launch transitions (feeders) in MMICs are due to requirement to have an interface between the probes and Device under Test (DUT) for testing purpose. Probing onto via-hole in multilayer structure would give more accurate results but with some consequences. The probe tip contacts may puncture and damage the gold pads on top of the via-holes [1-3]. This leads to damage the probe tips or destroy the MMICs. In addition, layers of metal in the probe pads are implemented for several reasons such as fabrication flexibility, better grip of the metal contacts on polyimide dielectric layers and maintaining 50 Ω of characteristic impedance for measurement matching purpose [1-3].

In some fabricated multilayer transmission line structures [4], most of feeders are designed with matched taper and only few have been designed with straight launcher. Furthermore, if the 50 Ω characteristic impedance is not maintained throughout the transitions even though the launcher is very short, significant parasitic capacitance or inductance can occur [2,5,6]. In order to obtain the targeted overall performance of MMICs, components make up the circuit must be accurately characterized including their probe pads and launchers.

In transmission lines, mainly there are three main characteristics i.e. characteristic impedance, effective dielectric constant and dissipation loss that required analyses in order to obtain the targeted specifications. The MMIC multilayer CPW transmission lines with a wide range of characteristic impedances have been fabricated [4]. However, the reported analysis only for frequency up to 20 GHz, while some phenomena characteristics occurs above 20 GHz have not been reported yet. Therefore, this paper will provide some analyses on the effect of feeders for characteristics of multilayer CPW transmission lines up to 50 GHz. Feeder effect as unwanted parts in the characteristics has also been investigated to determine its relation with half wavelength resonance.

2. Conventional Planar MMIC Transmission Lines

In order to obtain the overall accurate performance of MMICs, fabricated components and circuits must be accurately characterised. It is essential, for example, to check that components are within the target specifications and to observe any variations of the characteristics arising from the fabrication process. Some researches [7-10] have suggested that probe pads (bonding pads and feeders) which provide



space to accommodate probes in on-wafer measurements may exert a significant parasitic effect. To address this concern, one can observe the effect of probe pads from the compared on-wafer measurements of fabricated non-multilayer conventional planar transmission lines as shown in figures 1 and 2. The probe pads utilised in this research are designed to provide 50 ohms impedance. This is to minimise reflection arising from any mismatch with the measurement system impedance. Dimension of the fabricated CPW transmission lines both with and without probe pads are shown in table 1. Measured characteristic impedance and effective dielectric constant are shown in figures 3 and 4 respectively.

As can be observed in figures 3 and 4, the parasitic effect of the probe pads on the characteristics of the intrinsic transmission lines is not significant. This is clearly demonstrated by the compared characteristic impedance and effective dielectric constant of both structures. However, the fabricated transmission lines experience $\lambda/2$ resonance effects at different frequencies due to their different lengths. Results in figures 3 and 4 indicate that the bonding pads and feeders increase the influence of $\lambda/2$ resonance to the characteristics of the line. This is also demonstrated in their dissipation loss characteristics, as shown in figure 5. The transmission line with probe pads experiences slightly higher losses at $\lambda/2$ resonance. As mentioned earlier, in order to obtain the desired performance of MMIC, components making up the circuit must be accurately simulated and modelled. An accurate layout simulation technique for passive MMIC components is therefore very much needed and this is provided in the following discussion.

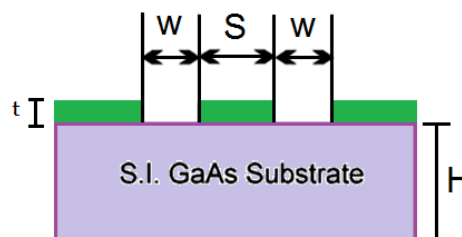


Figure 1. Cross-sectional view of a non-multilayer planar CPW transmission line.

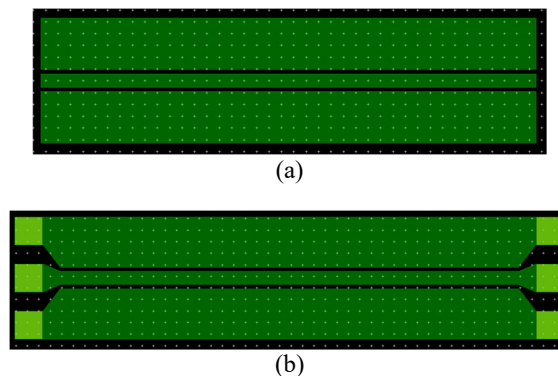


Figure 2. Top views of the non-multilayer planar CPW transmission lines (a) without probe pads and (b) with probe pads.

Table 1. Dimension of the fabricated non-multilayer planar CPW transmission line.

Parameters	Dimension (μm)	Remarks
S	60	signal conductor width
W	15	gap
L	2000 (no pads) 2398 (with pads)	length of the line
H	600	substrate thickness
T	0.8	Ti/Au conductor thickness

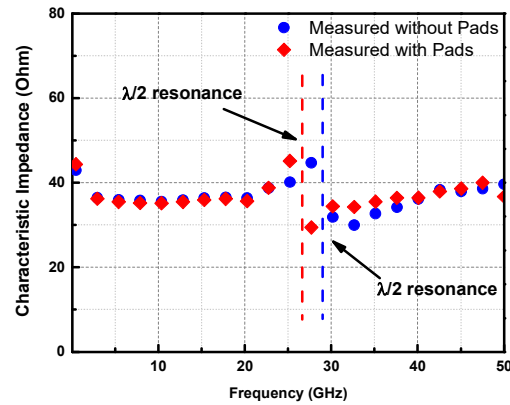


Figure 3. Comparison of measured characteristic impedance of the fabricated non-multilayer planar CPW transmission lines with and without probe pads.

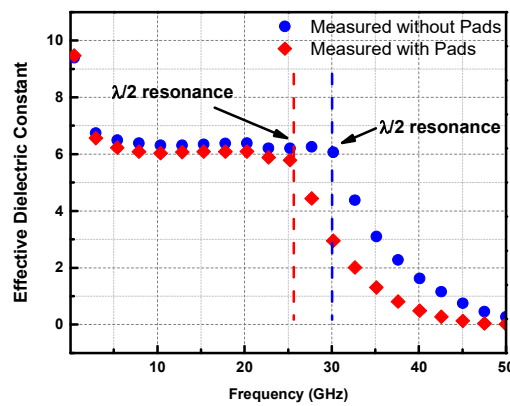


Figure 4. Comparison of measured effective dielectric constant of the fabricated non-multilayer planar CPW transmission lines with and without probe pads.

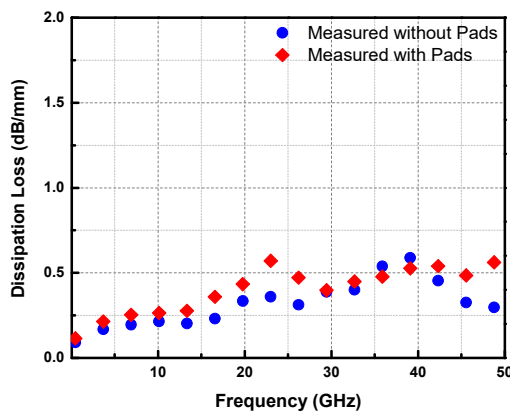


Figure 5. Comparison of measured dissipation loss of the fabricated non-multilayer planar CPW transmission lines with and without probe pads.

3. Multilayer MMIC Transmission Lines

After implementing particular size of feeders i.e. $200\mu\text{m}$ for the purpose of measurement, it is important to observe the deviation (if any) that may occur due to impedance mismatch of this feeder at the input and output port. It is also important to analyze other effects at higher frequency such as the resonance effect. By investigating this problem, one can assure that the characterization results presented in this report are accurate. As shown in figures 6 and 7, multilayer transmission lines with feeders experiences higher resonance effect.

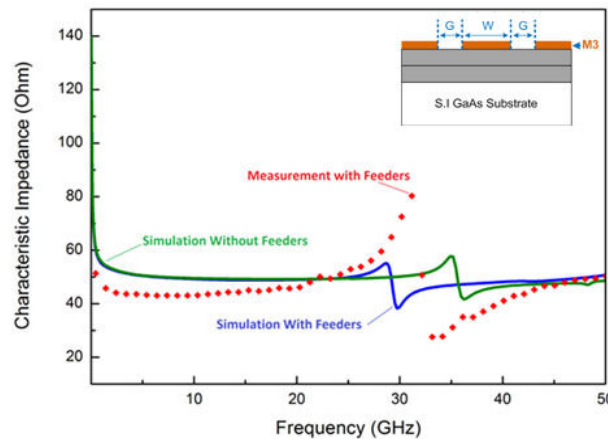


Figure 6. Comparison of Characteristic Impedance of Multilayer Planar CPW transmission line with and without feeders

In the results as shown in figure 6, structure with feeder with length of $2398\mu\text{m}$ suffers earlier resonance effect compare to the simulation with feeder with length of $2000\mu\text{m}$. This is due to resonance effect depends very much on the length of the structure ($\lambda/2$). In term of magnitude, both simulations have almost similar resonance effect. But in the measured data, the resonance magnitude is larger with those in the simulation. This means the feeders contributes in increasing the resonance effect. This is due to tapered shape of the feeders.

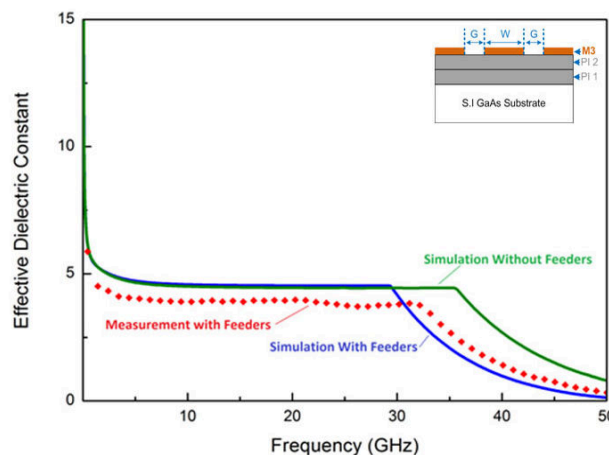


Figure 7. Comparison of Effective Dielectric Constant of Multilayer Planar CPW transmission line with and without feeders

In order to provide additional accurate arguments for the effect of feeders in the multilayer transmission line, one needs to investigate the characteristics of more complex structure such as the

multilayer overlapped transmission line. The results are shown in figures 8 and 9. Once again, the feeders show significant effect in the characteristics deviation values at lower frequency and it also affects the half wavelength resonance of the transmission line. This can be verified by comparing the simulation with and without feeders in figure 8. In this figure, feeders disrupt the characteristic impedance of the line by enlarging the resonance effect. At frequency of 25 GHz for simulation without feeders, one can observe that $Z_0 = 32\Omega$. But for simulation with feeders and verified by the measured data too, $Z_0 = 10\Omega$. One can conclude that below frequency of resonance, structure with feeders do not have significant different characteristics values compare with structure without feeders. But to avoid inaccuracy characterization, especially for the overlapped structure with length of $2398\mu\text{m}$, the accurate reading of characteristics values should not beyond frequency of 15 GHz. This means that feeders limit the operating frequency of the line.

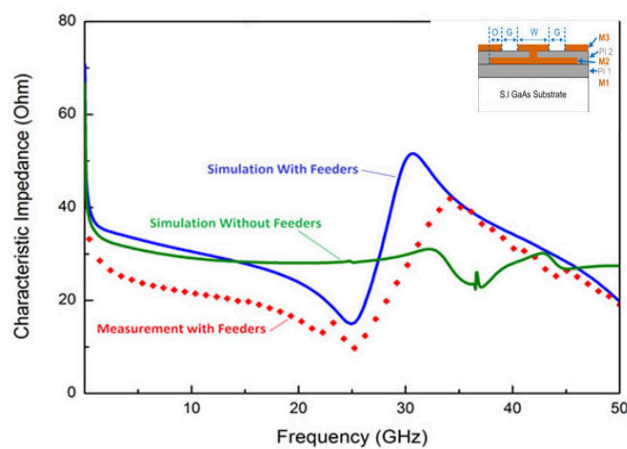


Figure 8. Comparison of Characteristic Impedance of Multilayer Overlapped CPW transmission line with and without feeders

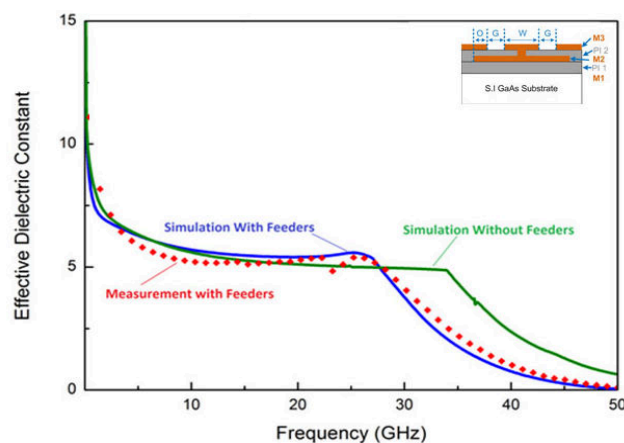


Figure 9. Comparison of Effective Dielectric Constant of Multilayer Overlapped CPW transmission line with and without feeders

Other knowledge that one can gain from this characterization is by observing the trend of effective dielectric constant as shown in figure 9. One can observe that the effective dielectric constant decreases as frequency increases. This happens at the frequency where resonance effect occurs as shown in the characteristic impedance. One can conclude that transmission line will have electrical behavioral change after the resonance effect ($\lambda/2$).

4. Conclusion

In the multilayer transmission line with feeders, the resonance frequency increases due to the effect of multilayer feeders. Furthermore, as the structure become more capacitive (overlapped metals structure), the resonance effect even significantly increases due to the presence of feeders. This means feeders contribute to the resonance effect especially for more capacitive structure. This proves that one need to treat the effect of feeders in the structure more carefully.

5. References

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