Dispersion Analysis of Finite Dielectric Coplanar Waveguide (FCPW) on Alumina and FR4 Substrate

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Abstract: This paper presents dispersion analysis of coplanar waveguide transmission line. The Characteristic Impedance, effective permittivity, transmission and reflection coefficient of CPW are plotted for alumina and FR4 dielectric materials for various height of substrate and characteristic impedance. Simulations are carried out on SONNET software; it is based upon Method of Moments principle and gives excellent simulations which are consistent with actual fabrications. This paper will help to optimize the design of CPW for various applications.

Key words: CPW, Dispersion, Transmission line, Method of Moments, SONNET.

I. INTRODUCTION

Transmission lines are the most basic microwave circuit element in RF and wireless communication systems. They are basically required for interconnecting electrical elements together that comprise a Monolithic Microwave Integrated Circuit (MMIC), and also with other microwave components such as antennas, filters to construct RF systems. In addition, filters, couplers, power dividers, tuning stubs, matching networks, and other critical RF system components are all constructed by connecting together transmission lines with different propagation characteristics [1]-[3]. While no single transmission line can be used for this wide variety of tasks, coplanar waveguide (CPW) has been widely used for many of these applications.

Fig. 1. Shows cross sectional view of FCPW and electric and magnetic field distribution in CPW. CPW transmission line currently enjoying renewed interest in the RF and microwave field for their different applications in the microwave and millimeter-wave integrated circuits. Coplanar waveguide (CPW) structures are also used in high-speed circuits and interconnect [4].

CPW is also suitable because of its unique structural advantages such as: signal line and the ground planes are on the same plane of the substrate so there is no via hole process is needed and the fabrication of the CPW is simpler than that of the microstrip line. Secondly, the CPW provides greater design flexibility because the widths of the slots and signal line of the CPW can be easily adjusted for the determination of the characteristic impedance as compared with the microstrip line [1], [5], [10].

II. MATERIAL & METHOD

Alumina: Alumina is the ceramic form of sapphire. It has balanced properties of insulation, thermal conductivity and breaking strength. It is usually available in white color having dielectric constant varying from 9.5 to 10 with loss tangent tanδ = 0.0002. Its unique property is surface roughness and excellent adhesion with a thin film and thick film metallization due to fine particles. Various advantages of Alumina are: physical and chemical properties are stable even at very high temperatures, high mechanical strength, good in insulation properties, less porous with good smoothness. Gold metallization is frequently used with alumina. Usually a very thin adhesion layer is used between alumina and gold.

FR4: FR4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing). FR4 glass epoxy is a popular and versatile high pressure thermostet plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR4 is most commonly used as an electrical insulator possessing considerable mechanical strength. This is a rank designation assigned to glass reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). The dielectric constant for FR4 is equal to 4.4 and loss tangent i.e. tanδ = 0.02, Copper metallization is frequently used with FR4.

Method of Moments (MoM): Among all methods available for estimating true value of parameter of interest Method of Moment is most efficient and economical method. The basic idea behind MoM is to reduce a functional equation (operator equation) to a matrix equation and then use computer to solve the matrix equation using numerical techniques available. This method is very general and can be applied to non-electromagnetic problems also. The principle objective behind MoM is to calculate primary electromagnetic parameters i.e. fields, currents that are solution to Maxwell’s equation [5], [6].
Design and Geometry: For practical applications it is impossible to take dielectric substrate and ground planes to be infinite so CPW with finite dielectric substrate and finite width ground planes are required for many practical applications. The CPW analyzed in this paper is Finite substrate thickness CPW. The CPW studied in this paper is shown in Fig.1. It consists of a center strip conductor with two ground planes on either side mounted on dielectric substrates. Alumina and FR4 were used as the substrate, the dielectric constant for alumina is 9.8 and for FR4 is 4.4. Simulation is done using SONNET software commercial software available for simulation of high electromagnetic analysis with different tools available. The simulation makes use of a modified method of moments based on Maxwell’s equations to perform a three dimensional full-wave analysis of predominantly planar structures [6]-[8]. CPW is designed for characteristic impedance of 50 ohms. Fig.2. & 3 Shows two and three dimensional view of coplanar waveguide.

III. RESULT AND DISCUSSION

Simulation is done for FCPW on alumina and FR4 substrate with help of SONNET Software by varying the height of substrate and also the characteristic impedance [9]. Effect of varying frequency on effective permittivity, characteristic impedance, scattering parameters is plotted on graphs shown below. For alumina simulation is done upto frequency 20 GHz while for FR4 frequency selected is upto 3 GHz, and it is seen that both substrates shows same behaviors in this frequency range. Effect of dispersion is analyzed by this study.

Fig.4 & 5 Shows variation in effective permittivity with frequency of CPW for different heights of alumina and FR4 substrates respectively. From Fig.4 & 5 it is clear that as frequency increases effective permittivity also increases but as height of dielectric substrate increases effective permittivity decreases for both substrates. Graph is almost same for both substrates.

Fig. 4. Variation in effective permittivity of CPW for various heights of alumina substrate

Fig.5. Variation in effective permittivity of CPW for various heights of FR4 substrate

Fig. 6 & 7 shows variation ineffective permittivity of FCPW for different impedance of alumina and FR$ substrates. From fig. 6 & 7 it is clear that as frequency increases effective permittivity also increases slowly and for higher characteristic impedance effective permittivity decreases with increasing frequency.
Fig. 6. Variation in effective permittivity of CPW for different impedance on alumina substrate.

Fig. 7. Variation in effective permittivity of CPW for different impedance on FR4 substrate.

Fig. 8 & 9 Shows variation in transmission coefficient of FCPW for different heights of alumina and FR4 substrates respectively. From fig.8 & 9 it is clear that as frequency increases transmission coefficient increases for both substrates but for alumina the increase is abrupt than for FR4. It is also seen that as height of substrate increases transmission coefficient for alumina increases but for FR4 transmission coefficient decreases.

Fig. 10. Variation in Reflection Coefficient of CPW for various heights of alumina substrate.

Fig. 11. Variation in Reflection Coefficient of CPW for various heights of FR4 substrate.

Fig. 10 & 11 shows variation in reflection coefficient of FCPW for various heights of Alumina and FR4 substrates respectively. From fig. 10 & 11 it is clear that as frequency increases reflection coefficient decrease and for alumina this decrease in reflection coefficient is abrupt while for FR4 it decreases slowly. It is also seen that as height of substrate increases reflection coefficient for alumina decrease while for FR4 it increase.
Fig. 12 & 13 shows variation in transmission coefficient of FCPW for different impedance on alumina and FR4 substrates respectively. From fig. 12 & 13, it is seen that transmission coefficient for both substrates increases for increasing frequency and for increasing impedance transmission coefficient decreases. Fig. 14 & 15 shows variation in reflection coefficient of FCPW for different impedance on alumina and FR4 substrates respectively. From fig. 14 & 15, it is seen that reflection coefficient for both substrates decreases for increasing frequency and for increasing impedance reflection coefficient increases.

Fig. 16 & 17 shows variation in characteristic impedance of FCPW for various heights of alumina and FR4 substrates respectively. From fig. 16 & 17 it is clear that as frequency characteristic impedance remains constant and for increasing height of substrate characteristic impedance increases for both the substrates.

IV. CONCLUSION

We presented simulated dispersion characteristics of FCPWs on alumina and FR4 substrate with finite width ground planes. According to simulated results it is concluded that, in the process of the CPW’s fabrication, special attention needs to be paid to the accuracy of the thickness of the dielectric used. Furthermore, dispersion can be reduced by reducing the
lateral line dimension of the CPW. It would be better if the widths of the center conductor and the gap between every two electrodes, together with the thickness of the electrodes should also be known accurately for particular characteristic impedance. These characteristics can be helpful in integrated circuits to design different antenna models, filters, couplers.

REFERENCES


