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CHARACTERIZATION OFBONDING WIREFOR5 GHZ WLANMMICS APPLICATIONS

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Abstract

In this paper, the bonding-wire interconnection has been considered from the point of view of modeling and fabrication for Conductor-backed coplanar wave guide (CBCPW). The purpose was to get maximum power transfer and minimum reflection. To achieve this goal, we used a software named High Frequency Structure Simulator (HFSS). To get good results, wires of different geometries are analyzed. These were rectangular, circular and half-hexagonal. However, this article describes bonding wire of rectangular geometry with different gaps. The characterization is given in terms of an equivalent conventional lumped equivalent circuit for an incremented length of the CBCPW line on the insulation and semiconductor substrates. This representation is particularly useful in them at ching of the bonding-wire discontinuity. Experimentation was also done which gave convincing results.

Keywords: Bonding wires, MMIC, Interconnects, Millimeter Wave.

1. Introduction and Literature Review

The bonding wire is a wide spread interconnection technology adopted in the fabrication of both microwave in Microwave Integrated Circuits (MICs) and Monolithic Microwave Integrated Circuits (MMICs). Many MMICs and Milimeter wave MMICs are being developed and fabricated worldwide (Boheim and Goebel, 1994). Bond wires are used as the standard method of connecting microwave ICs and interconnect circuitry like connecting solid-state devices to passive circuit elements, as well as multichip modules. Interconnects between mixed transmission lines present transitions (smooth or abrupt) that can severely affect the electrical performance of microwave devices and subsystems if they are improperly designed or, due to a lack of accuracy in the assembly process, deviate from the specified dimensions (Hang, Vahldieck, Jifu, and Russer, 1993).The wire bonding effect, one of the dominant parasitic effects under high-frequency circumstances, must be taken into account from the beginning of the circuit design while wire bonding is in general the last one in the device fabrication procedures (Hai-Young, 1995). In spite of its small length, when mm-wave operations are required, the discontinuity introduced by the bonding wire can significantly affect the performance of the whole circuit. Multiple wire bonding for high frequency devices usually use wedge bonding method since wedge-bonded wires have smaller bonding loop and consequent lower inductance than ball-bonded wires (Sang-Ki , and Hai-Young, 1995).

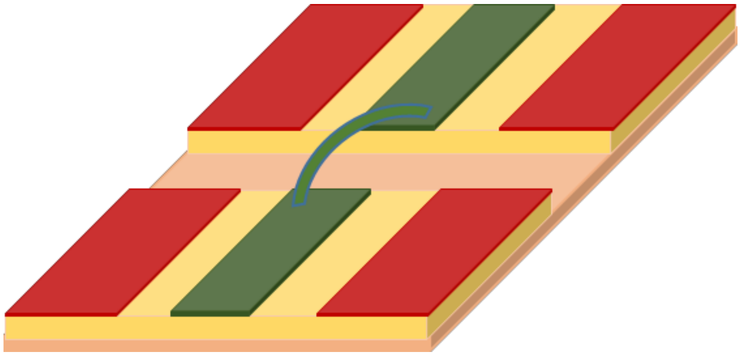


Figure1: A single wedge bound

Fig-1 also describes another particular design (Nicholson D., and Lee. H., 2006). However, this paper describes simulation and experimentation of a single bonding wire design with continuous substrate. The high impedance of the bond wires causes inductive breaks which affects the impedance crepancies and undesirable echoes. Numerous methods have been used to provide lesser discrepancy interconnects between circuits, such as lessening the gap among the circuits to shorten the bond wires, using wider ribbon bonds for lower impedance to connect the circuits, and even going to flip chip ICs to achieve lower inductance interconnects. To alleviate this problem, electromagnetic coupling interconnects have been proposed. However, the bonding wire, remains a very attractive solution since it is robust and inexpensive. Another point to note is that Flip-chip transitions between two CBCPW transmission lines of equal characteristic impedance show significantly better electrical performance than the bond wire/air bridge transition between two microstrip lines of equal impedance. Conductor-backed coplanar wave guide (CBCPW) is a common variant which has a ground plane covering the entire back-face of the substrate. The ground-plane serves as a third return conductor.

Coplanar wave guide was invented in 1969 by Cheng P. Wen, primarily as a means by which nonreciprocal components such as gyrators and isolators could be incorporated in planar transmission line circuits. The electromagnetic wave carried by a coplanar wave guide exists partly in the dielectric substrate, and partly in the air above it. In general, the di electric constant of the substrate will be different (and greater) than that of the air, so that the wave is travel lignin I an inhomogeneous medium. Inconsequence CPW will not support a true TEM wave; at non-zero frequencies, both the E and H fields will have longitude in al components.

The flip chip interconnection technology also opens new possibilities due to higher system integration and performance (Vahldieck, Chen, Jin, and Russer, 1995 and Baumann, Ferling and Richter, 1996).The behavior of bond wire interconnections at millimeter-wave frequencies is determined by the fact that, as frequencies increased, the length of the wires reaches significant fractions of wave length, and the wires exhibit transmission line properties (Krems, Haydl, Massler and Rudiger , 1996). Accurate models of the bonding-wire interconnect are, therefore, necessary for an effective design of ICs operating in the range.

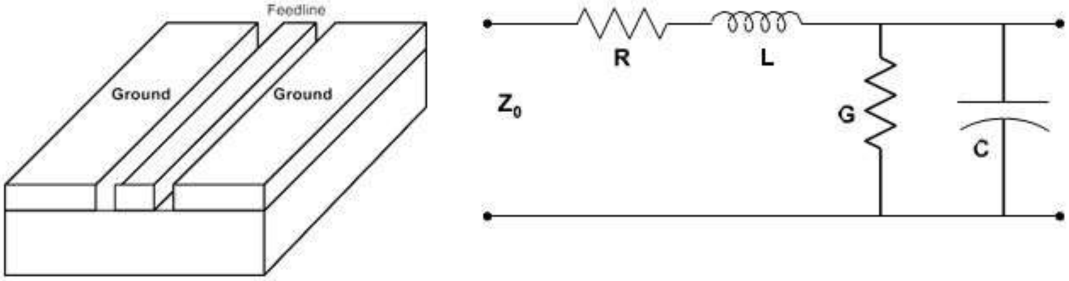
In (Strauss and Menzel, 1994), the MMIC chips are placed on a common carrier substrate which, at the same time, acts as an integral part of a package. The mm wave signals are coupled contact less from the chips to the carrier while DC and IF signals are connected conventionally by bonding across the edge of the chip. A mm wave interconnect from the interior of the package to the outside, once again, can be done by electromagnetic coupling through the carrier substrate. Authors of (Alimenti, Menzel, Mezzanotte, Roselli and Sorrentino , 1996) have analyzed, using FDTD, a complex electromagnetic connection among mm wave MMICs. In (Alimenti , Mezzanotte , Roselli and Sorrentino, 2001) two models are presented with different Derees of accuracy. A rigorous electromagnetic model based on the finite-difference time-domain (FDTD) method uses an appropriate discretization technique to obtain a polygonal approximation of the wire curvature. However, aquasi-staticmodelissuitableforcommercialmicrowavecomputer-aided design (CAD) tools since its parameters can simply be evaluated analytically from the dimensions of the structure.

Wire bonding has many advantages as an interconnection method for integrated system packages, including low cost and easy fabrication. However, due to the self-inductance of the bond wires and shunt capacitance of the bond pads, achieving a good wire-bonding interconnection for mm w applications is a challenge (Chan, Chou and Chuang, 2018). In addition, it has the advantage of being tolerant of chip thermal changes. It is therefore, necessary for an effective design of RFICs operating in this range. In contrary to the low frequency range, bond wire lengths should be kept as short as possible (Goebel, 1994). As mentioned in (Jun, Sung, Pi, and Yeh, 2004), transmission quality of electronic signals in integrated circuits operating at frequencies beyond 1GHz RF circuits, is sensitive to unavoidable parasitic effects of the bonding wires. With dimensions of circuit components and transmission lines in the same order as the wave length, the behavior of the components show and increase in parasitic effects, such as stray fields or the excitation of unwanted modes (Müller, Schäfer, Geenen, Massler, Tessmann, Leutheet al., 2017).The electromagnetic-field behavior within electronic packages used for high-speed digital-circuitor high-frequency analog-circuit applications of ten cannot be accurately modeled by using aquasi-static approximation, and a frequency-dependent analysis is sometimes needed for accurate modeling. The trend towards higher frequencies in antenna and circuit design is increasing the simulation challenges drastically. The interconnection being presented are having different to pologiesor geometries. Maintaining constant optimum wire lengths increase microstrip tolerance to spacing and alignment variations between microstrip lines (Nelson, Youngblood, Pavio, Larson, and Kottman, 1991 and Wang and Lu, 2017).To validate, the model was compared with experimental data obtained which shows a good agreement, especially for 5GHz and for S21. Finally, an extensive analysis was carried out. The characterization is done in terms of an equivalent low-pass network (not presented here). Such representation is very useful in the design of networks capable of compensating for the bonding-wire discontinuity. The capability of adjusting the wires pacing and, thus, the equivalent inductance of double-wire structures, is an additional degree of freedom that can be used to reduce the sensitivity of the interconnection to the mechanical tolerances in the chip positioning.

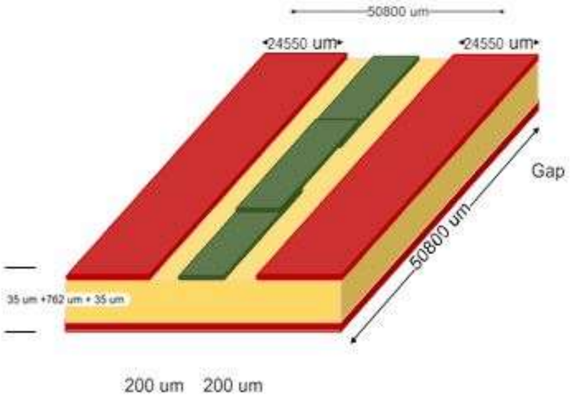
2. Modelling Using HFSS

In this paper, we employ the commercially available software called HFSS, to model the interconnect. The model for the package includes some details, such as bonding wires, bonding pads etc. The frequency responses of the package are tested with HFSS where its main solver is FEM, but it also uses a time domain solver, and a MoM solution. HFSS is based on Finite Element Method (FEM) which is more accurate for designing antennas. A bond wire connecting two microstrips represents a short, high-impedance transmission line embedded in a 50-ohmsystem. Ball bonds with the irrelatively high arch have enough of this high-impedance length to give significant degradation in return loss even at frequencies below 20GHz. There are various ways to minimize this reflective discontinuity either by going to wider inter connects such as ribbon bonds for a lower impedance, or by placing the two circuits extremely close together to minimize the length of the high-impedance section.

As outlined inFig.3, a conventional lumped equivalent circuit is shown for an incremented length of the CBCPW line on the insulation and semiconductor substrates. These ries inductance L represents the total self-inductance of the signal and ground conductors. The shunt capacitance C represents the close-proximity effect of the signal and the ground. These ries resistance R part is related to the conductor losses αC of them etallization caused from the skin effect and radiation losses αR. The shunt conductance G part is related to the substrate leakage losses αL caused by the finite resistance of the substrate and dielectric losses αD of the intrinsic silicon substrate(Hung C. Y. and Weng, M. H., 2012).



Figures2 and 3: Conventional lumped equivalent circuit of a CPW



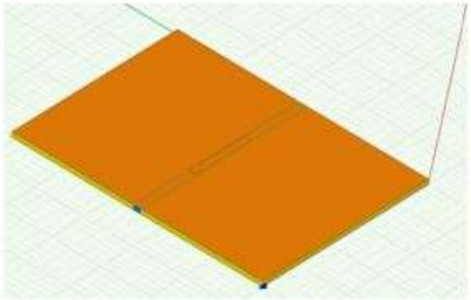


Figure4:CBCPWwithrect.bondingFigure5:HFSS Schematic

For dimensions shown as in Fig.4, theoretical simulations are carried out by HFSS as shown in Fig:5. Different configurations and different geometries were tested, however rectangular bonding wires results and comparison with experimentation are presented in section-III. As shown in above figures, the CBCPW is one of the transmission lines that can schematically be modeled as a lumped element circuit, where R, L, G, and Careper-unit-length quantities. There are four mechanisms that contribute to the attenuation losses of CBCPWs on the silicon substrate and appeared in the resistance R and conductance G. In the well-packaging house, the part of radiation losses αR can be reduced. The resident three mechanisms (conductor losses αC, substrate leakage losses αL, and dielectric losses αD) are responsible for them a in part of the observed losses at microwave and millimeter-wave frequencies (Hung and Weng, 2012 and Riaziat, Majidi-Ahy, Feng et al., 1990).

3. Theoretical and Experimental Results

Figs.6 & 7 represent experimental results of S11 and Figs. 8 & 9 represent experimental results of S21 for different gap lengths.

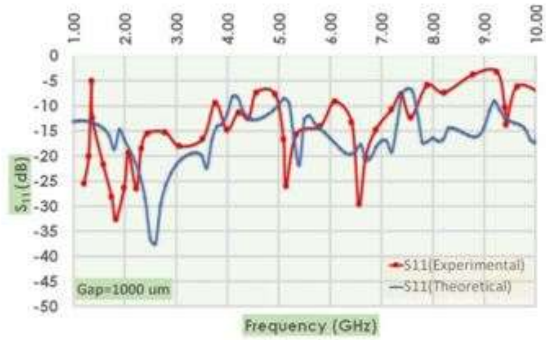


Figure6:S11for Line (Gap=1000 μm)

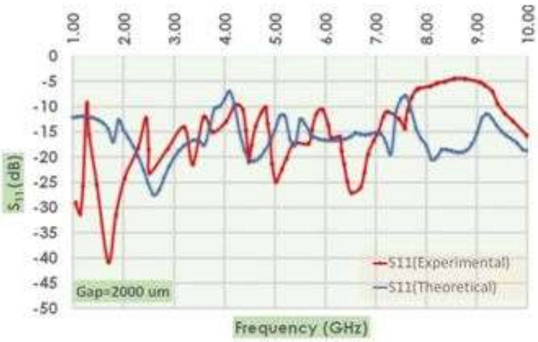


Figure 7: S11 Line(Gap=2000 μm)

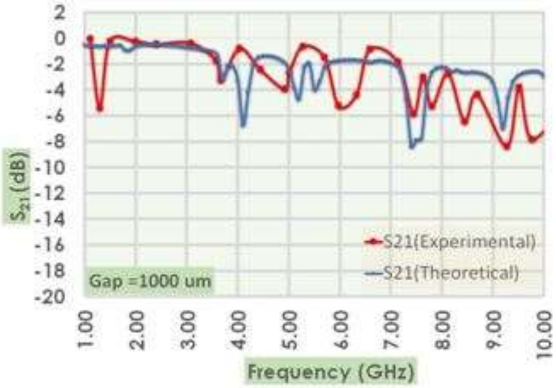


Figure8: S21for Line (Gap=1000 μm)

Figure 9: S21 Line(Gap=2000 μm

Overall for the entire band width, the response of the circuits is realistic. The Scattering parameters gave good agreement between theoretical and experimental values. Further testing and different situations are required to validate further.

Conclusion

This study was mainly carried out to focus on the length of the gap of a rectangular shape bonding-wire interconnects. Initially modeling of one-wire was carried out. Purpose was to get maximum power transfer and minimum loss. Wires of different geometries were analyzed and only one case study is presented in this paper with different lengths of the gap of co-planar transmission lines. The Scattering parameters gave good agreement between theoretical and experimental values. However, when the Gap length increases (i.e. L=3000μm), scattering parameters differ significantly. Further experimentation and different scenarios of geometry of bonding wires are being performed to validate further.

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