TRANSITIONS AND INTERCONNECTS USING COPLANAR WAVEGUIDE AND OTHER THREE CONDUCTOR TRANSMISSION LINES

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Abstract

Multilayer substrates allow high density packaging of microwave components. Because of this, microwave products are being developed using technologies such as cofired AlN, LTCC, polyimide, soft substrates and various multilayer thin film methods. These multilayer boards often require the use of vertical interconnects and transitions to and from various transmission line types. By using three conductor lines such as CPW, it is possible to develop a packaging technique which permits operation up to 20 GHz. A packaging approach tailored for airborne radar is described along with the interconnects and transitions used in the module. This includes the use of 3-wire line. Transitions to/from CBCPW, stripline, 3-wire line, and microstrip are described along with modeling and test data. In addition, test data is presented on solderless interconnects using button connectors.

1.0 Introduction

As part of a T/R module development program, a high density microwave module was developed. It features the use of MMIC flip chips, multilayer aluminum nitride substrates, solderless interconnects, and vertical transitions. As part of the development of that module, several interconnects and transitions were developed. This document is a summary of the results.

2.0 Transition and Interconnect Data

The transitions and interconnects were modeled and tested. The modeling was conducted using Maxwell, a three dimensional finite element field solver. Some data was taken using Cascade Microtech CPW probes and a HP 8510 network analyzer, while the other data was taken within a fixture with SMA coaxial connectors. Indication is given as to the method used.

2.1 Transmission Lines Used

<u>3-wire Line:</u> This transmission line uses three parallel cylindrical conductors imbedded in a

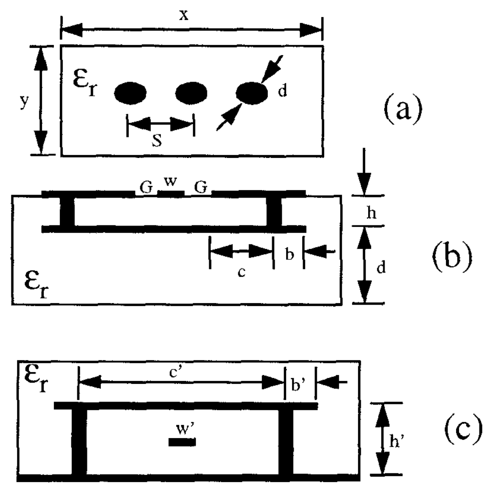


Figure 1. Transmission Lines Used.

dielectric header as shown in Figure 1a. Various analysis techniques have been used

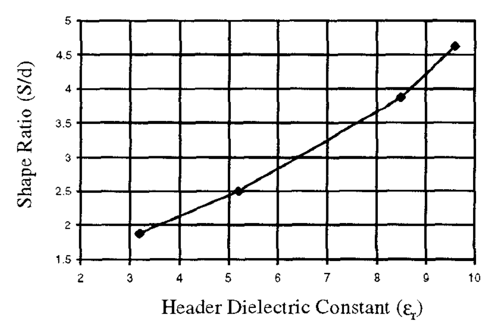


Figure 2. Finite element modeling of the required shape ratio to obtain a 50 ohm 3-wire line for various header dielectric constants.

to determine the characteristic impedance [1,2]. Finite element simulations were conducted to determine the line impedance for various geometries. Figure 2 shows the required shape ratio (S/d) to achieve a 50 ohm line for various header dielectric constants. 3-wire line has been used as a vertical transmission line within multilayer substrates using via techniques and as matched impedance solderless connectors. The incorporation of button connectors within the header material has resulted in matched impedance 3-wire line connectors.

Conductor backed coplanar waveguide: CBCPW transmission line was used on the surface of the substrates. Figure 1b shows a cross-sectional view with vias connecting the topside grounds with the buried ground. These vias are used to reduce the unwanted modes such as the microstrip-like (MSL) and the patch resonator modes [3] as well as radiation in the transverse direction [4]. In some practical multilayer applications there is additional dielectric under the buried ground. This additional dielectric with attached ground can support unwanted parallel plate type modes. Therefore, additional vias (not shown in Figure 1b) can be added between the buried ground and the backside of the substrate to suppress this effect.

Stripline: This transmission line is used to route the signal within the substrate. Vias are used to connect the top and bottom ground plans. The spacing between vias (dimension c in Figure 1c) was chosen as the minimum before a change in line impedance would occur. A quasi-static variational technique was used in the analysis. The pitch between vias in the direction perpendicular the page (see Figure 1c) was chosen to be 1/10 of a wavelength at the highest operating frequency.

2.2 CBCPW Via Location Tests

A series of tests were conducted to determine the effect of via location on the performance of CBCPW [5]. Twenty four different cases were prepared and tested using the Cascade CPW probes. In this test, the conductor backing formed the back of the substrate. That is, there was no additional substrate material under the CBCPW buried ground. The substrates were processed using thick film processing. The vias were filled with

Part Name	Pitch = 20	Pitch = 40	Pitch = 60	Pitch = 80	Pitch = 100	Pitch = 150
c=7	1A	1B	1C	1D	1E	1F
c=14	2A	2B	2C	2D	2E	2F
c=20	3A	3B	3C	3D	3E	3F
c=27	4A	4B	4C	4D	4E	4F

Table 1. Listing of the dimensions of each case tested in the via location test for CBCPW. Dimensions are in mil (1mil = 0.001"). w=13 mil, G=7.0 mil, via diameter= 6.0 mil, substrate thickness (h) =25 mil. Line length = 1.800"

Electro-Science Laboratories ESL-8835 gold and the surface was printed with ESL-8836 gold. X-ray florescence tests show the metal thickness to be approximately 12 μm thick. Table 1 lists the dimensions of the various cases tested.

In addition to providing information on resonances and higher order modes, the results, shown in Figure 3, indicate the insertion loss is lower as the via pitch is decreased. This is apparently due to reduced transverse radiation.

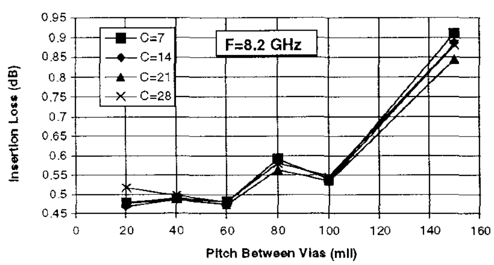


Figure 3. Insertion loss as a function of via pitch and distance from the inside edge of the topside grounds.

2.3 CBCPW to 3-wire Line

The CBCPW to 3-wire line transition allows for the microwave signal to be sent vertically into the substrate for routing in buried layers.

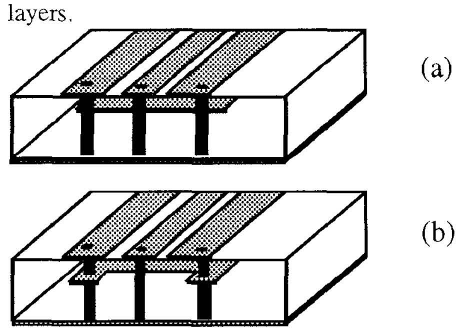


Figure 4. Two approaches for CBCPW to 3-wire line transition.

Two approaches were examined for the attachment of the CBCPW buried ground to the two ground lines on the 3-wire line. In the first approach, illustrated in Figure 4a, the buried ground is not connect. This approach can result in an unwanted mode in the buried ground [6]. The second approach is shown in Figure 4b. Notice that the buried ground is connected to the two ground vias of the 3-wire line and the buried ground is recessed to allow the signal line on the 3-wire line to pass through. Figure 5 shows test data for the case of Figure 4b where a matched load was placed at the end of the 3-wire line. Data was taken using the coax launch fixture.

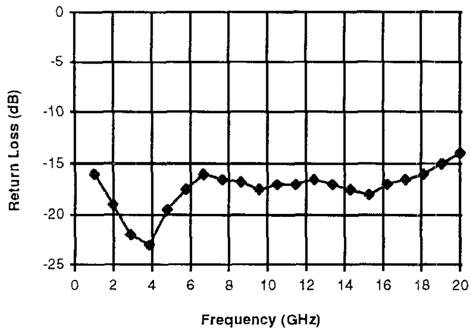
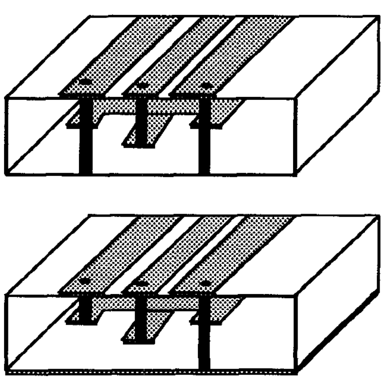


Figure 5. Measured performance of the CBCPW to 3-wire line transition.

2.4 CBCPW to 3-wire to Stripline

One of the purposes of 3-wire line is to allow for a smooth connection of topside transmission line to buried transmission line. This matched impedance connection allows for optimum performance at high frequencies.



(a)

(b)

Figure 6. Two possible interconnect techniques for the CBCPW to 3-wire line to stripline transition.

In this approach, the 3-wire line connects CBCPW to buried stripline. The connection between CBCPW and 3-wire line is the same as for Figure 4b. However, there are two possible connection approaches for the 3-wire line to stripline transition. The first is a direct connection as shown in Figure 6a. This is straight forward and performs well. An improved connection technique is shown in Figure 6b. In this approach, the two outer ground lines on the 3-wire line are non-symetrically attached to the stripline grounds. This provides a smooth transition of the fields. Initial data suggests a performance improvement over the direct connection technique.

2.5 CBCPW to 3-wire to Button Connector

Solderless interconnects can provide a means to interconnect stacked 3D microwave modules. These connectors can provide very reliable connection and allow for the module to be ‘unstacked’ for trouble shooting. Connectors such as elastomeric [7] and button have been investigated. The button connector is fabricated by randomly woaded wire approximately 1 mil diameter that is inserted into a cylindrical hole. In this instance, three buttons are used for each connection to form a 3-wire line connector.

Figure 7 shows the measured performance, in a coax launch fixture, of two back-to-back CBCPW to 3-wire to button interconnects. The configuration of CBCPW to 3-wire is the same as is shown in Figure 4b. The interconnect to the button is provided by pads on the backside of the substrate.

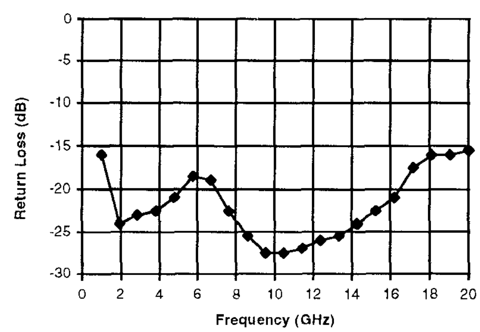


Figure 7. Measured performance of the CBCPW to 3-wire line to button connector.

2.6 CBCPW to Microstrip

Although CBCPW was used as the surface transmission line, it was expected that microstrip may also be needed. Therefore, a transition from microstrip to CBCPW was developed. By providing a smooth 50 ohm taper to the topside grounds of the CBCPW as shown in Figure 8, a wide band transition was developed. It is expected that the bandwidth is a function of the length of the taper. The measured performance, in a coax launch fixture, is shown in Figure 9.

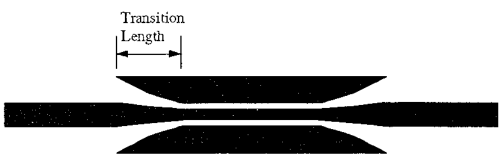


Figure 8. Illustration of the microstrip to CBCPW transition.

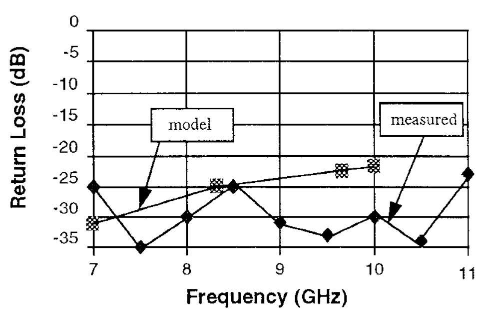


Figure 9. Measured and modeled performance of the CBCPW to microstrip transition. Transition length = 150 mil.

3.0 Conclusions

The development of new high density module technology usually requires the design and optimization of transitions and interconnects. In this instance, several transitions from one transmission line type to another have been developed. In addition, solderless connectors, which have traditionally been used in low frequency or digital circuits, were adapted for use at microwave frequencies. In the future, rapid development of high density modules will require advanced analysis tools and data bases containing test data on transitions and materials which will provide the required information for trade studies, system level design, and detailed design.

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