H-8

INVESTIGATION AND EVALUATION OF LOW LOSS INTERCONNECTS ON SOFT SUBSTRATES CLAD TO ALUMINUM

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ABSTRACT

The purpose of this study is to provide a comparative evaluation of the quality of RF grounds used with microstrip circuitry on aluminum clad soft substrates. The data obtained by the study is documented and analyzed in the report with appropriate conclusions and recommendations provided.

INTRODUCTION

Results are presented of a study comparing and evaluating the quality of RF grounds used with resonant microstrip circuits on high–K soft substrates clad to aluminum. The grounds investigated were obtained by two methods: roll pin insertion and plated-through holes. Resonant frequencies were measured initially and after each of several environmental tests.

Until the introduction of soft substrate materials having high dielectric constant, usually between 10 and 11, most microwave amplifier microstrip circuitry was fabricated on alumina. Ground interconnects are primarily achieved on alumina by edge plating or manual hole plating.

For the high-dielectric soft substrate clad to aluminum, the techniques used to obtain low-loss RF grounds are quite different and require evaluation. A reliable connection must be made from the copper through the dielectric and into the aluminum. Hole plating cannot be obtained by simply hand-painting conductor material as with thick films.

INTERCONNECTION TECHNIQUES

The techniques for obtaining the grounds in metal-clad soft substrates are (a) the accepted roll-pin method and (b) plated-through holes. For this investigation, roll pins were inserted by two different semiautomatic pin inserters and plated-through holes were produced by two vendors. All boards had 0.050-inch-thick dielectric.

Roll Pins

Figure 1 shows a cross section of a roll pin in the metal-clad soft substrate. The roll pin, which is a tin-plated carbon steel spring pin, is pressed into the substrate. The spring tension of the inserted pin creates a reliable electrical connection to the bare aluminum. Connection from the copper to the aluminum is completed by a solder fillet from the copper conductor to the roll pin.

Manual insertion of roll pins was used in the early days of fabricating circuits with metal-clad soft substrates. However, since this method is slow and too costly, we progressed to using a press and then to semiautomatic machines.

Shown in figure 2 is one of the semiautomatic ground-pin insertion machines used for this study. Pins are fed from the vibrating bowl feeder through a tube to a pneumatic controlled chuck. A pin below the chuck is used to locate the hole where the roll pin is to be inserted. At least seven roll pins can be inserted per minute with this system. A board that has 66 pins can be completed in less than 10 minutes. A computer-controlled X-Y table on this machine would drastically reduce the time of inserting the 66 pins from 10 minutes to 3 minutes per board. With this machine, proper alignment of the roll pin into the substrate can be attained at all times. This machine without the X-Y

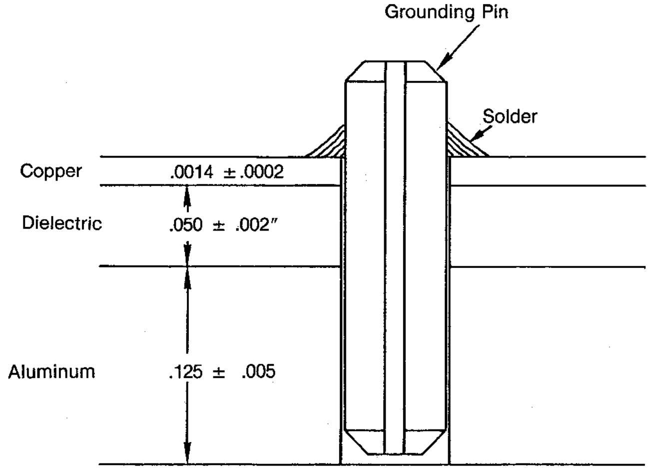

Figure 1. Cross-Sectional View of a Roll Pin in the Metal Clad Soft Substrate

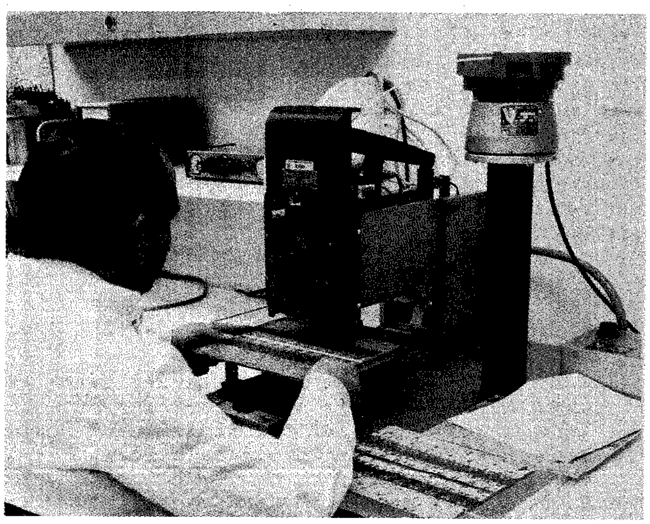

Figure 2. Semiautomatic Ground Pin Insertion Machine

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table is presently being used to insert pins for production and development boards at Westinghouse, with an X-Y table addition planned for the future.

Shown in figure 3 is a cross section of a properly aligned roll pin assembly at 30X magnification. Note the good solder fillet from the copper circuit to the pin.

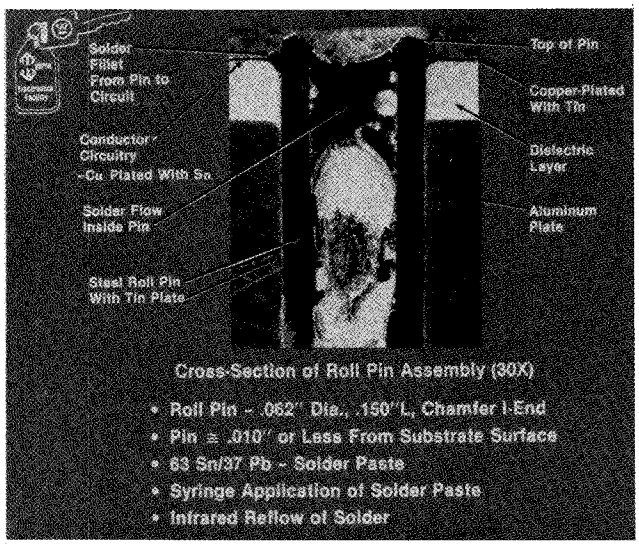

Figure 3. A Properly Aligned Roll-Pin Assembly

Plated-Through Holes

Plated-through holes for low-loss grounds could reduce the cost of a microwave assembly. The first vendor attempt at making circuits with plated-through holes was not good. Examples of some poorly plated-through holes can be seen in figure 4.

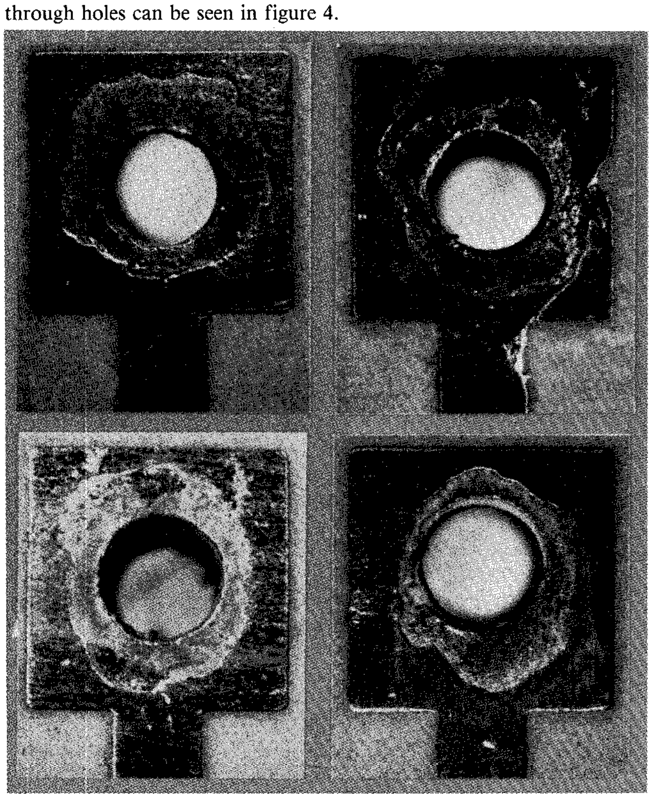

Figure 4. Examples of Poorly Plated-Through Holes

Our second attempt at obtaining good vendor plated-through holes was successful. Shown in figure 5 is an example of a plated-through hole that we considered good. The dc resistance from the copper circuitry to the aluminum ground plane was about 5 milliohms, which was comparable to that of roll-pin grounds.

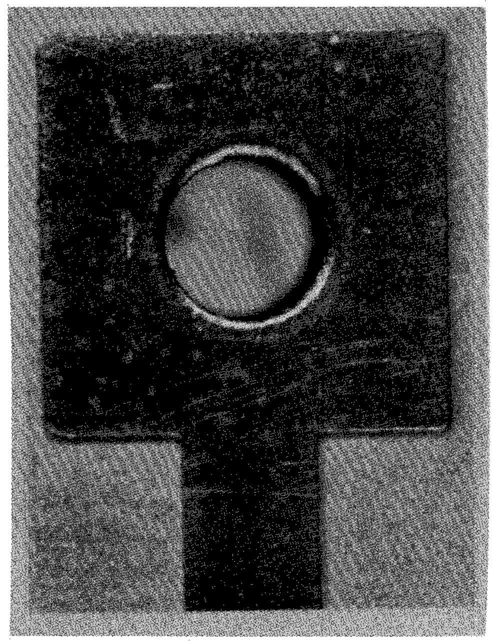

Figure 5. Example of a Good Plated-Through Hole

TEST PLAN AND BOARD PREPARATION

Since microwave circuitry is involved, it was essential to evaluate the grounds from an RF standpoint. Therefore, two types of resonant half-wavelength circuits were designed for microstrip. The first is a 50-ohm shunt that branches off a 50-ohm transmission line and is terminated in a ground (reflective type). The second is a 50-ohm resonant line with grounds at either end. It is loosely coupled to and terminates a 50-ohm line (absorbtive type). Both circuits are shown in figure 6.

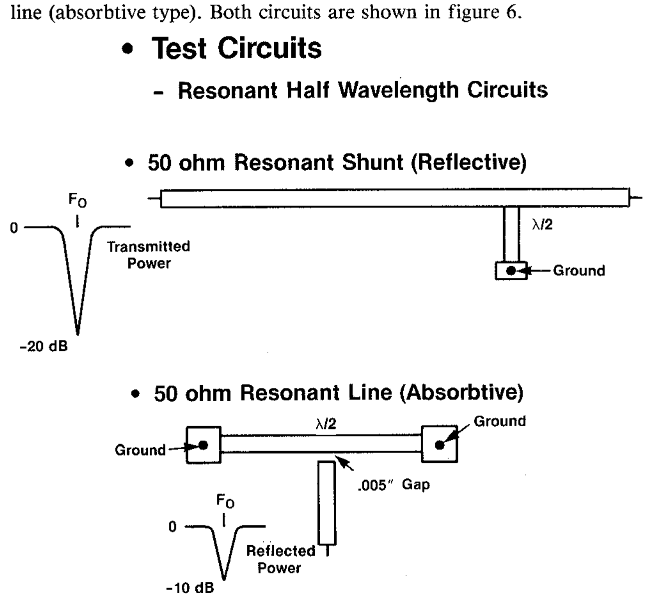

Figure 6. The Two Types of Resonant Test Circuits Used in This Study

Circuits were etched on nine boards. Each board is 9 inches by 9 inches, and each has 12 resonant lines, six of the reflective type and six of the absorbtive type.

The 12 circuits were designed to resonate at different frequencies ranging between 1500 and 8500 MHz. The artwork used on all boards was identical. All boards for pin insertion were etched and plated at the Westinghouse Hybrid Electronics Facility.

Shown in figure 7 is the board in which the circuits were etched, plated, and inserted manually with ground pins at Westinghouse. This board served as a standard.

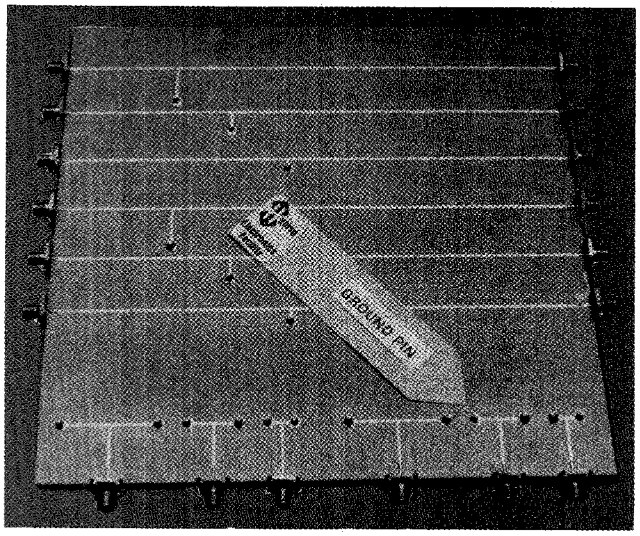

Figure 7. Westinghouse Board With Ground Pins Inserted

Two different semiautomatic machines were used to insert the pins in three other boards because at that time we were also evaluating the type of machine to procure for our development and production line.

As previously discussed, two vendors were selected for producing plated-through holes. All boards having plated-through holes were etched and plated by the respective vendors.

The resonant frequencies of all circuits were measured as follows:

1. Initially at room temperature.
2. At room temperature after temperature shock per Mil-Std-810 (USAF), Method 503
3. At 80°C
4. At room temperature
5. At room temperature after humidity cycling per Mil-Std-810 (USAF), Method 507

RESULTS AND CONCLUSIONS

The measured data for all circuits was documented in tables similar to the one shown in figure 8. Resonant frequency measurements were made at L-, S-, and C-band on all boards. No measurements were taken at X-band to simplify the testing by avoiding the use of an additional frequency source. This eliminated two resonant circuits, both of the reflective type. Therefore 10 resonant circuits were measured on each board, which was considered sufficient.

After thermal shock, the vast majority of resonant frequencies dropped. After humidity cycling, the vast majority of resonant frequencies continued to drop. This is an indication that water may have been absorbed by the material. Since the relative dielectric constant E(r) of water at 3 GHz is 76.7, the absorption of water raises the dielectric constant and therefore increases the electrical length of the resonant lines and lowers their resonant frequencies.

Shown in figure 9 is the average change in resonant frequency from initial resonance for each of the boards tested. As can be seen, the circuits of all boards having plated-through holes consistently have a greater average change in resonant frequency than those having pins.

Frequency Measurements in MHz

Band	Resonant Circuit Number	Initial	After Thermal Shock	At 80°C	After Cool Down	After Humidity Cycling
L	8	1454	1452	1473	1453	1454
	5	1463	1462	1482	1463	1462
S	6	2790	2787	2830	2790	2787
	9	2838	2834	2875	2836	2834
	3	3202	3200	3242	3202	3198
	1	3290	3289	3332	3289	3284
C	7	5213	5209	5287	5223	5208
	10	5325	5314	5385	5318	5315
	4	6101	6096	6185	6102	6092
	3	6360	6358	6448	6363	6352
Average Change From Initial (%)			0.094%	1.3%	0.056%	0.12%
Maximum Change From Iniial (%)			0.21%	1.4%	0.19%	0.2%

Figure 8. Example of a Test Data Table. This Is the Data for the Westinghouse Standard Board. Such a Table Was Completed for Each Board.

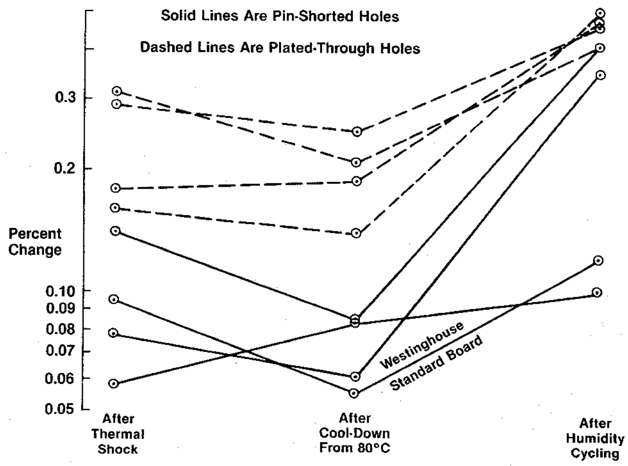

Figure 9. Average Change in Frequency From Initial Resonance

Figure 10 shows the maximum change in resonant frequency from initial resonance for each of the eight boards tested. Again the circuits of all boards having plated-through holes consistently exhibit a greater maximum change in resonant frequency than those having pins.

The high-K material has a maximum water absorption specification of 0.25 percent. The resulting change in E(r) would account for 0.7 percent change in resonant frequency. The worst change in resonant frequency for a pin-grounded circuit (0.66 percent) therefore can be attributed purely to water absorption, and not to a change in the quality of the ground. This is acceptable.

Unacceptable, however, is the maximum resonant frequency change up to 2.5 percent for plated-through holes. The change is well over the 0.7 percent change that can be attributed to water absorption. Also, the Westinghouse-specified acceptable difference in dielectric constant is ± 0.3 about the nominal 10.5. This calculates to be a maximum possible

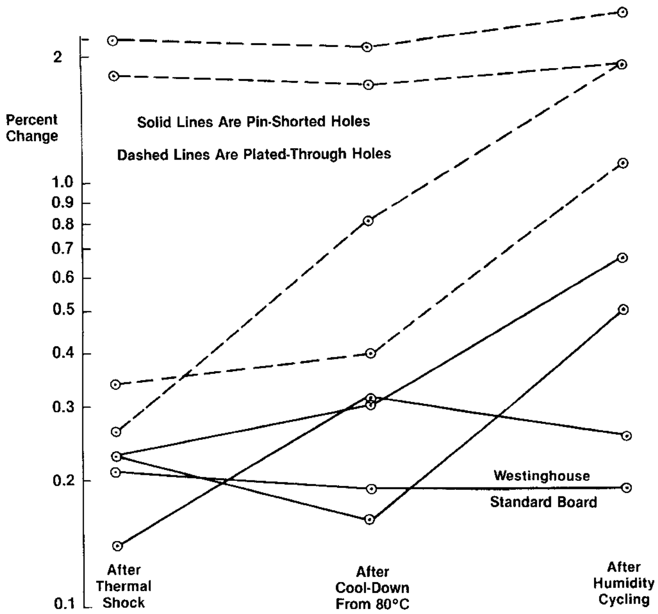

Figure 10. Maximum Change in Frequency From Initial Resonance

change of 2.5 percent in the frequency of a resonant circuit. Since the plated-through circuits already cause the resonant frequency to change by up to 2.5 percent, the maximum change could be as high as 5 percent. Also, both the average change and the worst change in resonance of the plated-through circuits are large compared with those on the Westinghouse standard board using pin-shorted grounds. Therefore, based on this data, it is not recommended that plated-through holes be used for RF grounds on high-K soft substrate Westinghouse products. It is also possible that such large changes could be a precursor of a complete failure of one or more of the plated-through grounded holes.

The worst change in resonant frequency of 0.66 percent for a pin-grounded resonant element is well within the allowable changes discussed above. Therefore, roll-pin insertion is considered an acceptable procedure for obtaining a good ground on high-K aluminum-clad soft substrate.

ACKNOWLEDGMENTS

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