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Test Platform for RF Systems and Implementation Using Planer Technique

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Abstract: Satellite Communication is performed in various bands of microwave frequency spectrum and such high frequency operation demands a special communication system which provide reliable performance without influenced by frequency band, attenuation factor, environmental loss, modulation scheme etc. which needs complete characterization of card/system behaviour involving testing at ambient, at various environmental conditions including life test at lab environment. Radio frequency cards are highly sensitive and need utmost care while handling to eliminate parasitics and to avoid failures. In order to facilitate and provide appropriate test environment to radio frequency circuit boards, test carrier plates, test jig or test fixtures are evolved.This article details the challenges involved in testing of radio frequency cards, concept of test jigs, implementation strategy etc. further test jig for integrated RF circuit testing is also explained.

Keywords: Test jigs, characterization, interference, impedance, reliability, microstrip

1. Introduction

Test and evaluation of any system is a major milestone in the process of realisation of actual hardware which reviles the defects and provide a provision to put test selectable/ variables, results into a robust, failure proof hardware for delivery. It is always better to have less number of variables to test a system that’s why testing activities are involved from the component level then card/PCB level and finally at system level, which is facilitated by special test fixtures called test platform or test jigs or test carrier plates and are equipped with all kind of interfaces for example power supply, DC measuring equipments, radio frequency equipment etc and safeguard the device under test (DUT) from all intrinsic and extrinsic hazards with excellent repeatability and reproducibility. Radio frequency systems are quite complex to test in any lab/industry environment, hence this article is aim to analyze and discuss the causes of interference and improvement techniques for a reliable test systems.

2. Challenges in RF Testing

Card level testing of RF cards are not similar to low frequency or DC cards because at RF and microwave frequency, length and thickness of wire will be introducing either capacitive or inductive effect and results into impedance mismatch[1-3]. Hence one need to calculate the input and output impedances and accordingly the card can be interfaced for testing. Following are the common challenges for testing a RF card with open wire/ cable

2.1. Interference: Routing of external power supply wires, RF cables or other peripheral devices may create interference with the circuit function.
According to Ampere's law, if a DC current carrying wire is there then there will be a magnetic field exists around it and its direction is given by Flaming's left hand rule[1]. The amount of magnetic field would be

$$B = \frac{\mu_0 I}{2\pi R}, \tag{2.1}$$

where $R =$ distant from the wire, $I =$ Current in the wire

If two current carrying wires are present nearby then there will be some force either attraction or repulsion depending upon the direction of the current flow. If currents in both the wires are in same direction then there will be attracting force or vice versa. The force is represented as under

$$F = \frac{\mu_0 I_1 I_2}{2\pi R}, \tag{2.2}$$

where $R =$ distant between two wires, I_1, $I_2 =$ Currents in the wires
In order to avoid such interferences the routing of supply wires should be isolated from the circuit.

2.2 Impedance mismatch: RF cards used in spacecraft application are populated with microstrip circuits and normally characteristic impedance used is 50 Ohm as standard.

If we use two wire line then its characteristic impedance is given by the formula mentioned below[4]. Characteristic impedance of two wire line,

(2.3) $$Z_0 = \frac{276}{\sqrt{\varepsilon_r}} \log \frac{d}{r}.$$

Here, the gauges of wire may change the impedance of the transmission line. Characteristic impedance of microstrip line,

(2.4) $$Z_0 = \frac{60}{\sqrt{\varepsilon_{\in}}} \ln\left(\frac{8d}{w} + \frac{w}{4d}\right).$$

A microstrip with calculated impedance can be used. If there is transition from two wire line to microstrip and proper impedance matching is not there than maximum power transfer will not happen and some amount of power will be reflected back.

2.3 Repeatability and reproducibility: Repeatability is the variation that occurs when measurements are repeated on same DUT under absolutely identical conditions with same operator on same setup whereas reproducibility is the variation in the average measurement of same operator who measures the different DUT using the same measuring equipment. It very much essential to have repeatability and reproducibility for RF cards of space application as those cards will be tested at bench level as well as in integrated mode and further in spacecraft level.

2.4 Access point: In some cases it not easy to take output from specific orientation of the DUT such as isolator, circulator, filter, MIC etc.

Figure 1. Isolator in the circuit

The above fig shows an example of isolator which has two leads as input and output port. The leads coming out of the device is so delicate to break. Hence a test jig is essential to provide mechanical support and test the same. Similarly the output port locations of DUT may differ and one has to evaluate the DUT with damaging the device mechanically and electrically as well.

3. Features of Test Jig

Following are the main features of the test jigs used for RF/microwave circuit board testing

3.1 DC Supply: DC power supply in radio frequency circuit may vary from zero volt to some ten of volt. If a circuit is completely passive then there no need of any power supply such as directional coupler, microstrip filter, power divider, microwave junctions etc. but the circuits like amplifier, modulator, switch etc. are there then a separate DC power supply to be provided which is free from supply ripple and fluctuations so as to avoid mixing of stray factor and failure at some extent. Hence there is provision of EMI filter at the input of circuit which is commonly called Feed through and it protects the circuit from external disturbances. Feed-through[7] are basically a network with inductor in series and capacitor in shunt as shown in fig. 2.

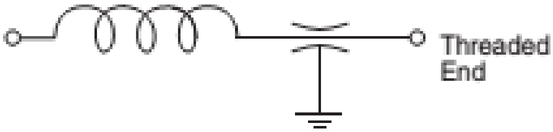


Figure 2. Internal function of feed-through

It works as low pass filter and eliminates ripple in DC power supply and allows smooth DC supply to the DUT.

Figure 3. Feed-through for DC power supply

3.2 Farade's close environment: Handling of RF circuit is more critical in terms of electromagnetic interference. It is desirable to isolate the DUT from the other source of RF signal. Hence the DUT is placed in a closed metallic box and the thickness of the box walls is also specifically chosen in such a way that external EM waves cannot penetrate the wall. The depth of penetration is given by the formula as under

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}, \tag{3.1}$$

where δ is skin depth, ω is angular frequency of the signal i.e. $2\pi f$, μ is permeability of the metal surface, σ is conductivity of metal box

Table 1 Variation of skin depth over frequency

S. No	Frequency (MHz)	Skin depth (mm)
1	0.3	0.1206
2	3	0.0381
3	30	0.0121
4	300	0.0038
5	3000	0.0012

(for Copper, $\mu=4\pi x10^{-7}$H/m, $\sigma= 5.81x10^{7}$ s/m)

The above table shows that as frequency of operation increases, skin depth decreases. Hence for higher operating frequency the wall thickness can be kept less.

3.3 Avoid ice formation in chamber/ condensation: There is requirement to perform climatic tests like cold soak, hot soak etc. on RF cards so it has to undergo various climate changes. As the test platform is a closed box so it is isolated with external environmental effects.

3.4 Input output ports: Transition from microstrip to co-axial line is essential for testing and as both the media support TEM mode so excitation is also easy. The transition is realised by shaping the co-axial connector's structure and soldered to the microstrip for high reliability

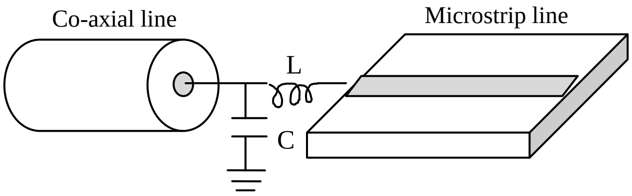
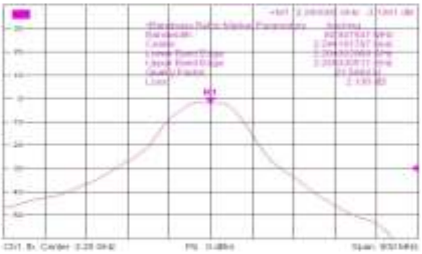


Figure 4. Co-axial to microstrip transition

There should be no gap between co-axial connector's flange and microstrip pattern, any such gap will result into an additional discontinuity reactance [2]. The co-axial to microstriptransition can be represented by a simple equipment circuit as shown in fig. 4, where L_s and C_s are series inductance and shunt capacitance respectively. During design of test jig, either these reactance to be minimized or compensated for making them $\sqrt{(L_s/C_s)} = 50\,\Omega$ for general RF applications.

3.5 Mechanical strength for cables: Co-axial cables used for testing RF cards are very bulky as they are manufactured considering minimal RF leakage. They are most of the time hard and difficult to bend. If the cables are connected with the card using temporarily connector then it may cause of PCB pattern peeling off. Test Jig is a platform or mechanical support for electronic/RF card to be tested with very good repeatability.

(a)



(b)

Figure 5. (a) Filter card mounted on test platform (b) Filter characteristic of microstrip based hairpin type band pass filter

The above fig. 5 shows a typical example of test platform for microstrip based band pass filter[10,11]. Here the filter is mounted on a metallic carrier plate which provides mechanical strength to the card and RF connectors can be mounted at both the ends of the filter with the support of metal plate. Further this metal plate provides support for RF co-axial cables which are generally very bulky and stiff in nature.

3.6 Mechanical stability of card:

3.6.1 Soft substrate: Most of the RF circuits are fabricated on PTFE substrates such as RT/duriod 5870, 5880, 6002, 6006, 6010 etc.[5,6,9] which are mechanically soft and ductile which needs mechanical support while handling and testing the same. The purpose is solved using metallic carrier plates. As shown[12-14] in fig. 5.

3.6.2 Extended transmission line: To make a test platform, there is need of extending the transmission line at both input as well as output ports, here microstrip line is used. There should be proper impedance matching between two microstrips so as to avoid reflections and optimum return and insertion losses.

Here, 50 Ohm microstrip line is optimised at $W_1 = 1.2$ mm and $W_2 = 4.8$ mm width[8] for two different substrates with dielectric constants 10.2 and 2.33 respectively. The simulation is carried out in ADS software.

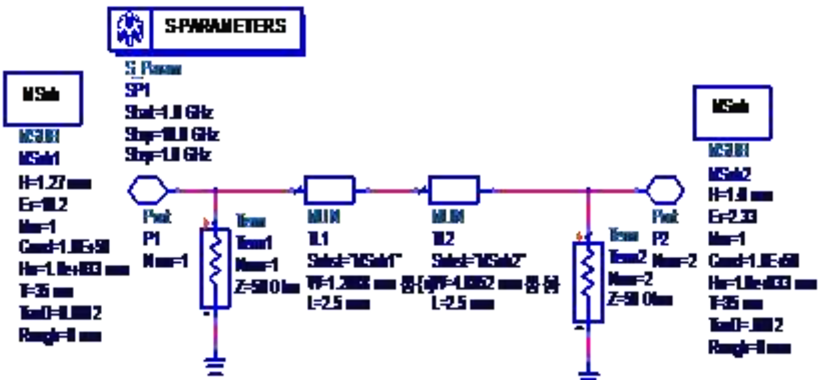


Figure 6. Microstrip line using two different substrates

The simulation results for interfacing of dissimilar microstrip lines (width is different) are shown below in terms of insertion loss and return loss

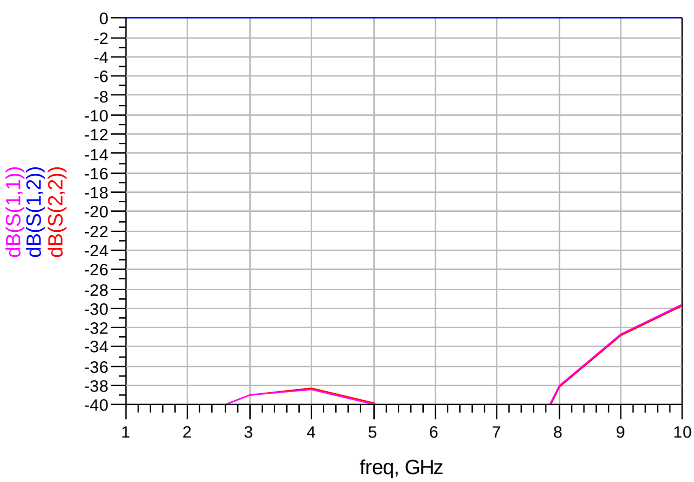


Figure 7. Optimized microstrip junction characteristic

The below fig. 8 shows layout of dissimilar substrate junction which has proper impedance matching scheme.

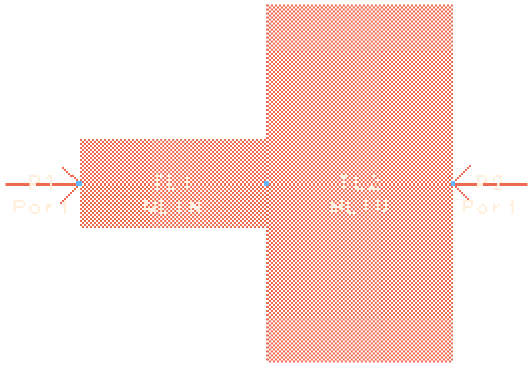


Figure 8. Layout of extended microstrip with matching

If two microstrips are added with same width and different dielectric material then there will not be perfect impedance matching as shown below- (W1=W2= 2mm)

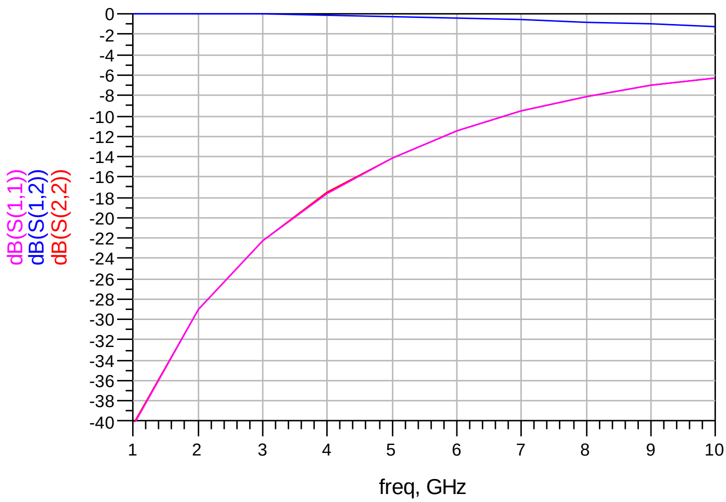


Figure 8. Microstrip with mismatch

The above fig. 8 shows that as the frequency of operation is increasing S11 parameter i.e. return loss is also increasing which result into insufficient feed to the DUT (device under test). Hence the test platform is selected in such as way that test system doesn't affect the DUT performance and can be measured faithfully.

3.7 Test platform design requirement: Following requirements are to be addressed for designing carrier plate or the test platform

(a) Mechanical strength

(b) Clearance/allowance to be given for mechanical expansion

(c) Accessibility to take output

(d) Avoid corrosion of high power devices.

3.8 Test platform for integrated test: A system comprises of various subsystems and it is always necessary to evaluate all the subsystem before realising a system as whole. For example a transmitter chain is to be tested which consists of modulator, frequency multiplier, Band pass filter, isolator and driver amplifier stage. Initially each stage should perform individually for given specifications by mounting on individual test platform then same stages to be integrated and tested. Fig. 9 shows a conventional method to test complete transmitter chain where all cards are mounted on separate carrier plates and connected each other using SMA connectors and extended cables. Here we have flexibility to place the card on test bench comfortably and can be accessed individually. But there is a drawback that interconnection between to cards will play an important role and losses occur on the interconnection will be give fair outcomes in term of sufficient feed to subsequent stage.

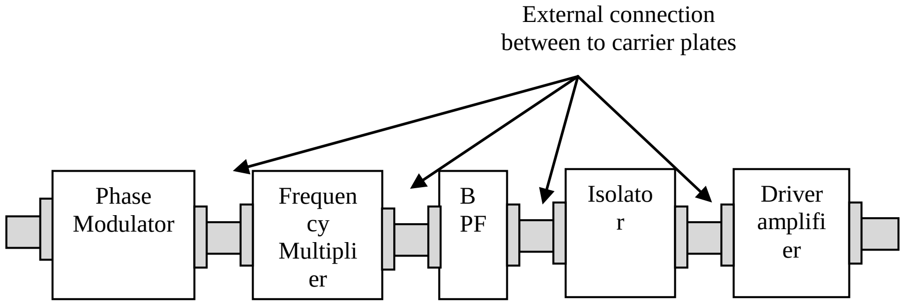


Figure 9. Integrated test test platforms with external interconnections

Alternate way of testing the cards in integrated mode is shown below in fig. 9 where all the cards are mounted on a single carrier plate which provides better mechanical strength and losses between two stages are minimised.

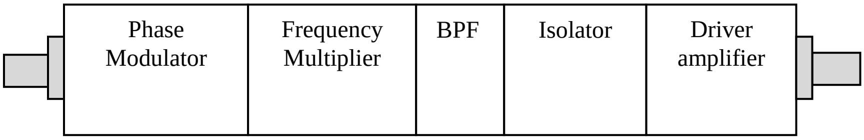


Figure 10. Integrated test platform butt joints

Test setup shown in Fig. 10 will give fair outcomes and measurement will be very close to actual outputs and troubleshooting is also easy as the problem causing elements are eliminated in between the path.

4. Conclusions

Performance of RF circuit is very sensitive to environmental disturbances so testing and integration of RF circuits is very critical. This article details about the challenges for testing the circuits at radio and microwave frequency, the parasitic elements and effect of coupling etc. Designing of test fixers or test jigs are discussed and best practices to carry out testing is explained in this article. Further concept of integrated test method is explained to minimise the losses and external coupling.

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