Master's Thesis

RF Test Points

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Abstract

In most mobile phones available on the market today the RF interface for conducted RF measurement is a RF coaxial connector. To access the connector a RF coaxial probe is used. This Master Thesis investigates, from a production point of view, the possibility to replace the RF coaxial connector with Test Points for RF testing. Emphasis has been on finding a selection of probes that meet Sony Ericsson general requirements, both business and technical requirements, and then evaluating the probes behavior and performance in a production test environment.

Acknowledgement

In the process of working on my thesis many people have helped me, both directly and indirectly. Their ideas, suggestions, and queries were the source of my inspiration. This thesis could not have been completed without their assistance. First of all I would like to thank to Mr. Anders Eriksson, Mr. Andreas Breggen and Mr. Joakim Johansson for giving me this wonderful opportunity. I appreciate this wonderful opportunity to do my thesis at Sony Ericsson, Lund.

My heartily thank goes to my supervisor at Sony Ericsson Mr. Joakim Johansson. His knowledge and wisdom have guided me in my research; his continuous support and encouragement have helped me through many challenging situations.

I would like to thank to my supervisor & examiner at university, Mr. Anders J Johansson, for his timely advice and suggestions during this thesis work.

I would like to thank to Ms. Jessica Meggerle and Ms. Maria Schier for giving me an opportunity to test the solution in platform build. I would like to thank to fixture group members for helping me in some areas. Also I would like to thank to Mr. Krister Nilsson for helping me with CAD design.

Several persons have contributed with ideas, technical solutions and practical help when I needed it the most. Finally I would like to thank all the people in the RF Section at SEMC for their welcoming attitude and great company.

Thank You!

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Summary

In this thesis project an effort is made to investigate the possibility to use RF test point for RF testing instead of RF connector. In order to access the RF test point the RF probe is needed. During this investigation three different kind of RF probes have been selected for evaluating the new solution, which are ECT, Ingun and IDI. For evaluating the performance of new probe solution Return Loss was measured. Along with the Return Loss measurement repeatability of the results are also analyzed.

From the measurement it can be noticed that ECT probe has good Return Loss values for low frequencies.

The Ingun probe has some issues but if the issue has been solved then it is also possible to use the ingun probe in production. The Ingun probe gives good result when it is connected properly.

The IDI probe has not been evaluated because of hardware unavailability. The reason is that the IDI probe has continuous ground, which is not compatible with our design pattern on printed circuit board (PCB).

Removing the need for RF connectors would mean a huge cost benefits.

1. Introduction

1.1 Motivation

Walking and talking, working on the train or on a way, always connected to the world, never out of touch—Mobile phones have significantly changed the way we live and work. No one knows exactly how many little plastic handsets there are in the world, but the best guess is that the total is approaching one billion. That's almost one for every six people on the planet! In developing countries, where large-scale landline networks (ordinary telephones wired to the wall) are few and far between, over 90 percent of the phones in use are Mobile phones [1].

Mobile phones are changing the way the world connects & communicate. In the early 1990s, only 1% of the world's population owned a mobile phone; but today nearly a quarter of people make their phone calls this way. In developing countries, the usage of Mobile phones is increasing day by day. Mobile phones are also used in different ways around the globe.Some uses, mobiles still mostly for voice conversations on the other hand some uses for sending "texts" (text messages, also known as SMS) and also with the availability of the high-speed "third-generation" (3G) mobile networks and cutting-edge phones many people surf the Web and send emails from mobile phones than in any other way; over a quarter of world population now use the Internet like this i.e. via mobile phones. They are opening many channels for human being to become more social via face book & many other online communities.

The world, as we now know it, is altering at a terrific rate due to technology advances. Mobile phone Industry is one such area in which we hear every day about the innovation & emergence of new application and services. Technological advances for Mobile phones are increasing at a very fast pace. In last few decades mobile phones have influenced not only the professional life but also the routine life of human being. By using mobile phone one can do most of his routine work like paying bills, watching online TV, download music, weather reports, etc. Their importance in human life is escalating very much as they are capable of many technologies like, WLAN, GPS, NFC, IrDA, Bluetooth, etc.

Today Mobile Industry is very big communication industry. It has many technologies that fulfill the needs of people in their day today work. They have made human life easy and help more to increase the social contacts across the world. There value in the corporate world is remarkable, as they have increased the working efficiency and made simple for them to communicate across the global boundaries. Below is the brief introduction of generations of wireless telecom technology:

1G, 2G, 3G & 4G ("G" stands for "Generation") are the generations of wireless telecom connectivity.

1G (First Generation) is the name given to the first generation of mobile telephone networks. These systems during this generation use analogue circuit-switched technology, with TDMA (Time Division Multiple Access) & FDMA (Frequency Division Multiple Access), and worked mainly in the 800-900 MHz frequency bands.The networks had some limitations like low traffic, capacity, unreliable handover, poor voice quality, and poor security [2].It's out-dated now. The analog “brick sized phones” & “bag sized phones” are under 1G technology. Mobile phones era began with 1G.

The next epoch, 2G has taken the place of 1G. This is the generation where generation Mobile phones have received their first major upgrade. The transition from 1G to 2G was remarkable for the growth of mobile phones. This leap effectively took mobile phones from analog to digital [2]. 2G and 2.5G were versions of the GSM and CDMA connections. And GSM is still the most popular technology, but with no internet. Fortunately, later for accessing internet with GSM technology an additional feature is added with it i.e. known as GPRS. As GPRS has been developed from that EGPRS was created. It's more secure and faster than GPRS.

Then the current generation 3G came, which includes the new Wireless CDMA technology. 3G is the first wireless telecom technology that provides broadband-speed internet connection on mobile phones. It has been especially made for the demand of internet on smart phones. Further expansion led to the creation of 3.5G, which provides blazing fast internet connection on phones, up to the speed of 7.2 Mbps. A smart phone can be connected to a PC to share its internet connection and 3G & 3.5G are ideal for this. But, as this WCDMA technology is not available in all regions, it’s not as popular as GSM yet. Before taking the major dive from 2G to 3G wireless networks, the lesser-known 2.5G was an interim standard that bridged the gap. Following 2.5G, 3G & 3.5G technologies which have transformed in faster data-transmission speeds, so one can use the cell phone in more data-demanding ways. This has meant streaming video (i.e. movie trailers and television), audio and much more. Cell phone companies & operators today are spending a lot of money to brand to you the importance of their 3G network [2].

4G, which is also known as “beyond 3G” or “fourth-generation” cell phone technology, refers to the entirely new evolution. Developers are now going for 4G (OFDMA), which will provide internet up to the speed of 1 GBPS! It is said to be able to overcome the problems of weak network strength and should provide a much wider network, making sure that the users get high-speed connectivity anytime anywhere. No doubt, 4G will open new doors of revolutionary internet technologies, but for now, 3G and 3.5G are the best. 4G promises voice, data and high-quality multimedia in real-time form all the time and anywhere.

There are many different techniques or ways to test the different functionalities within mobile phones. The foremost focus of this thesis is RF testing. RF testing needs a lot of instrumentation & special testing conditions. Today at SEMC we use coaxial RF Connector with Probe for testing of RF Antenna and RF circuitry. This method of testing using RF connector with probe gives very good performance and perfect 50Ω matching, but the idea is to replace this solution with other innovative & intuitive solution, in order to overcome the cost of RF Connector. The cost of RF Connector is not too much but if we took high volume (HVM) production into consideration then the cost sums up to the large amount.

Due to thought of Cost cutting we come up with the possibilities to do an investigation and find an appropriate replacement or removal of the current Coaxial RF connector and to find an alternative solution, which will be cheap as well as good in performance.

1.2 Purpose

The purpose of this thesis project is to investigate if a suitable solution for replacement of the RF connectors/switches by test points (TP) can be found. This could give a significant cost save compared to today’s solution.

- Finding a solution where we still can use a simple calibration method.
- Be able to have 3 – 4 test probes in same fixture.
- Decrease design space constraints when using TP instead of RF connectors/switches. [3]

1.3 Outline

The remainder of this work is organized according to the following chapters.

1. Introduction - In this chapter the basic information about the thesis and its motivation and Purpose of thesis are mentioned.

2. Background & Current SEMC Testing Approach - This chapter includes information about today's RF testing solution at SEMC and basic information and background on what a connector with switch is? It also includes the information about today's RF probe and connector.

3. Test & Fixture Requirements - The Fixture requirements and RF probe requirements that needs been taken into consideration during selection of a new probe solution are presented in this chapter.

4. New solution - This chapter contains all the information about the new Probe solution and the RF probes that have been selected. It also provides information about the PCB trace.

5. Business case –

6. LAB Measurements - Here detailed information on measurements taken to evaluate the new probe solution is presented. Along with the measurement results it also highlights the comparisons between the measurement results taken with old and new Probe solution.

7. Conclusion - This chapter shows the outcomes of this thesis project, whether it is better to use the new solution or not. This chapter also presents the business case for both solutions.

2. Background & Current SEMC Test Approach

2.1 Background

Today SEMC use RF connector with RF Coaxial Probe for RF testing and calibration purposes. This solution, using the connector with probe, is efficient and gives us a switching functionality. The RF connector is placed between RF antenna and transceiver circuitry. As this solution gives the switching functionality, when the probe connects to the connector, it breaks up the connection with the antenna matching circuit and gives us perfect 50 ohms matching at transceiver side. This method is very good & proficient in performance.The RF connector decides which type (types) of RF probe should be matched in the test fixture and usually both of them come from the same vendor as a complete solution. This solution i.e. connector with probe is really good one but a bit expensive if we consider high volume production.

Looking at phones available on the market 2009-2011 from other vendors, it's clear that RF connector is the solution used by the industry. Only one phone that used test points as RF interface was found.

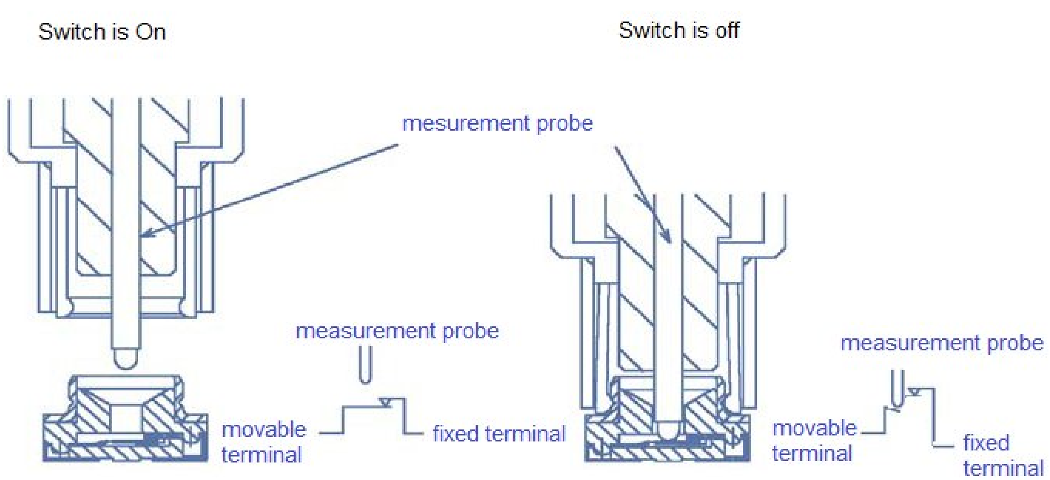

Figure 1:- Switch and Connector

Above figure shows the function of a connector with switch.

In the normal state, two internal terminals show the function of a connector with a switch.

In the normal state, two internal terminals, which are the movable and the fixed terminals, are put in the conduction mode (On mode). When the dedicated measurement probe is inserted from the top of the connector, the movable terminal with the flat spring structure is displaced. As a result, the contact between the movable terminal and the fixed terminal is disconnected (Off mode). Connection between the movable terminal and the measurement probe can be achieved. This signal path switching function is provided in the connector with switch.

Normally, the connector with switch is mounted between a radio circuit and an antenna in a most of cases. Due to its switching property it breaks the connection from antenna and stops any reception from antenna and then used for measuring the radio output. Measurement is enabled even after a printed circuit board (PCB) is assembled in the equipment housing [4]

2.1.1RF Connector and RF Probe

Today SEMC uses RF connector & Probes from mainly two suppliers - Hirose and SMK.

2.1.1.1SMK

SEMC use the SMK supplier with TS-7 RF switch series number. And the RF switch part number is CRC 5001-3001F.

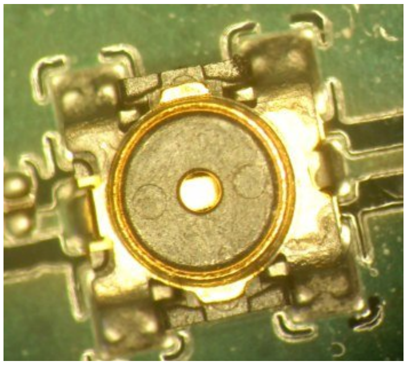

Figure 2:- SMK cnnector

The size of this connector is 2.9 X 2.9 X1.5mm [4]. This connector has been used in many SEMC products.

The matched RF probe is TS-7 series with RF probe number CRC 9001-4001F.

Figure 3 - SMK TS-7 series probe

The data sheet of this RF coaxial connector with switch can be found under reference [5].

2.1.1.2Hirose

SEMC uses Hirose connector and probes with RF switch no. MS-156A and MS-156C.

MS-156A:

The size of MS-156A is 2.7 X2.7 X1.6 mm. This type of switch has been used in number of SEMC products.

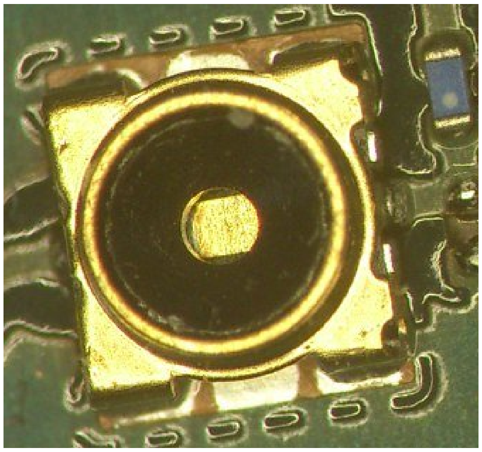

Figure 4 - Hirose connector

The matched Probes for this connector are MS-156-HRMJ-3, MS-156-HRMJ-12 and MS-156-HRMJ-29.

The main features of MS-156-HRMJ-3 are Press down, with flange. This probe has been used in number of SEMC products.

Figure 5 - Hirose MS-156-HRMJ-3 probe

The data sheet for this probe and for MS-156-HRMJ-12 probe can be found under reference [6].

The main feature of MS-156-HRMJ-12 probe is floating (self pressing).

Figure 6 - Hirose MS-156-HRMJ-12 probe

And the MS-156-HRMJ-29 probe is upgraded based on type of HRMJ-12.

MS-156C:

The size of MS-156C is 2.3 X2.3 X1.4 mm.

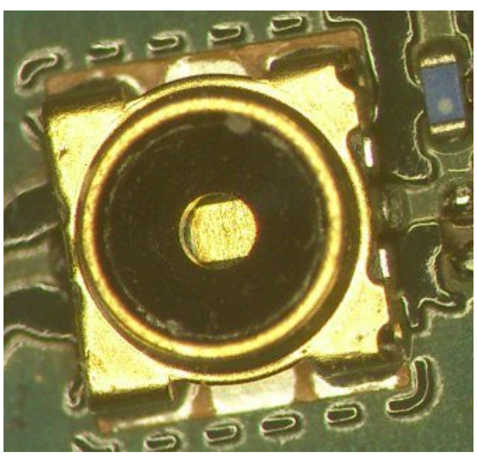

Figure 7 - Hirose MS-156C connector

This RF connector is small in size as compare to the MS-156A. But the matched probes are same as MS-156A.

3.Requirements

Today a coaxial RF connector is used as an interface on the phone PCB for RF calibration and testing purpose in volume production.

The goal of this Thesis work is to find an alternative probe solution which can be used with test point instead of RF connector. During the selection of probe for evaluation I need to take all the requirements into consideration such as test fixture point of view, PCB point of view, and all the requirements related to the Probe.

During this thesis work, I have created a time plan and according to time plan the first step is to collect all the requirements which I need to consider while selecting a new solution and performing the evaluation.

3.1 Fixture Requirements

The board test fixture is used to perform tests like voltage and current level measurements, resistor load couplings, and conducted RF tests, and calibrations.

3.1.1General Test Fixture Requirements

All the fixtures shall be designed with the focus of

- Low cost, especially the application part.
- Simple maintenance.
- Easy to swap applications [7].

3.1.2Fixture Maintenance & Durability

- Daily maintenance and cleaning the fixture.
- Maintenance shall not need to be performed more than after approximately 5000 repetitions.

- Repair of the fixture shall not need to be performed more than after approximately 100,000 repetitions.

- Fixture end of life shall not occur until after approximately 1000,000 repetitions.

- All the RF cables used in fixture should hold for ≥200,000 cycles.

- RF cables that break before 500,000 cycles should be easy to change without need of tools [8].

3.1.3Mechanical Requirements

The following are the mechanical requirements for the board test fixtures:

3. Test fixture shall be able to connect to a system connector placed at any side of the PCB and to a PCB with double sided placement of test points. For some projects the system connector is replaced by test points on the PCB, in this case the system connector signals are to be equalized with test points.

4. The flexible board test fixture shall be able to handle multiple amounts of RF probes (e.g. GSM/UMTS, Bluetooth/ WLAN, CDMA, ISDB-T, etc)

5. The flexible board test fixture shall be able to connect to all test points on the PCB.

6. Test related yield loss for one product should be < 1% [8].

3.2Requirements on connection and guiding of the PCB

3.2.1Size of Test Points

The fixture shall be able to probe test point with a diameter of at least 1.0 mm (40 MIL), with tolerances of guide holes.

3.2.2 Test Point Requirements

- One test point needle act with a force of F_{max} = 0.84 N.
    - The product must be able to manage such force from the needles.
    - The board needs to have the support areas needed to manage the force.
    - (This requirement is needed to ensure that the surface where the test points are located can withstand the force generated by test needle and test fixture.)
- Maximum tolerance on test point/RF switch shall be +/- 0.1 mm.
- Test point durability: - Test point matrix located on the DUT PBA shall be able to handle at least 50 connection cycles from a test needle [9].

3.2.3 Spacing between test point and adjacent object

The fixture shall be able to connect to the test point if the following is fulfilled.

If the centre-centre distance is min 2.5 mm (100MIL) the fixture shall be able to probe with a 1.7 mm diameter needles. If the centre-centre distance is 2.5-1.8 mm (100MIL) the fixture shall be able to probe with 1.4 mm diameter needles.

If the centre of the test point and the outer edge of the adjacent component are at least 1.3 mm. Misplaced components could otherwise bend the test pin and cause disturbances in the production.

If a test point is placed near a tall component, height >3.5 mm (140 MIL), the fixture shall be able to probe the test point if the distance between the centre of the test point and the outer edge of the adjacent component are 1.7 mm [9].

If the distance between the centre of a test point and the adjacent edge of the copper foil are at least 1.5 mm the fixture shall be able to probe the point without risk for the receptacle of the probe pin to hit the board.

If the distance between the outer edge of a test point and the outer edge of a location hole are at least 2.0 mm the fixture shall be able to probe the point [8].

3.3RF Probe Requirements

There are different parameters, both technical and business, on which we need to give attention to, when selecting new probe, such as impedance of probe (mostly 50 Ω), VSWR (voltage standing wave ratio), insertion loss, return loss, durability or life cycle of probe, size of probes, spacing between needles, cost, vendor track record, availability of probes, lead time etc.

3.3.1VSWR (Voltage Standing Wave Ratio)

VSWR stands for voltage standing wave ratio. When a cable or transmission line is terminated with impedance that does not match with characteristic impedance (means mismatch of antenna) of transmission line, not all of the power is absorbed by the termination. A mismatches antenna reflects some of incident power back towards the transmission line. The incident power combines with reflected power to cause a standing wave pattern in the transmission line. Then the ratio of maximum to minimum voltage is called voltage standing wave ratio (VSWR) [10].

Mathematically

$$\mathrm{VSWR} = |V(\max)| / |V(\min)|$$

Where V (max) is the maximum voltage of the signal along the line, and V (min) is the minimum voltage along the line.

VSWR should be always ≥ 1.

If we consider in a real world situation, a VSWR of 1.2:1 is considered acceptable in most of the situation.

3.3.2Insertion Loss

Insertion Loss of transmission line is defined as the ratio of Power received at the end of transmission line to the power transmitted into the line.

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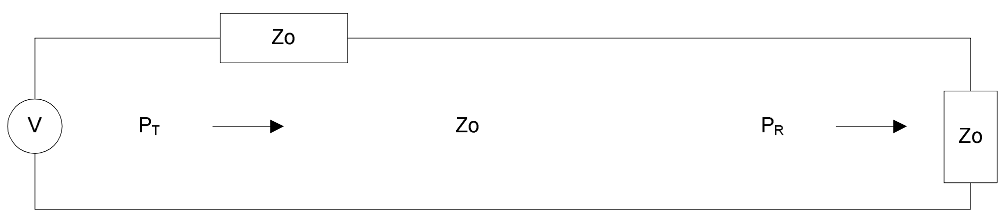

Figure 8 -Insertion loss for transmission line

If the power transmitted by the source is PT and the power received by the load is PR then the Insertion Loss can be written as:-

I.L. = PR/PT

For maximum power transfer the above ratio should be closer to 1 as possible. In decibel the Insertion loss should be closer to 0 dB as possible.

3.3.3Return Loss

Return Loss is caused due to mismatch of impedance between two or more circuits. The Return Loss of a line is the ratio of power reflected back from the line to the power transmitted into the line. It is expressed in decibel (dB).

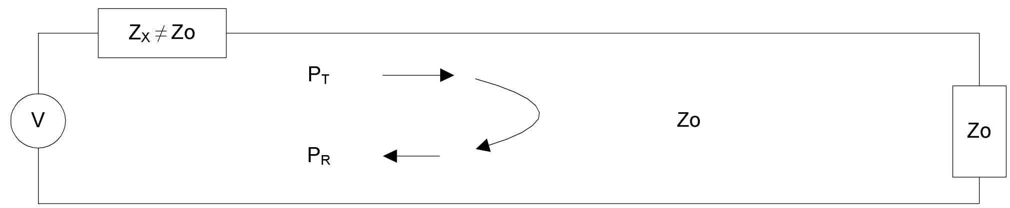

Figure 9 - Return loss for transmission line

If the power transmitted by the source is P_T and the power reflected back is P_R, then the return loss is given by P_R divided by P_T [11].

At microwave frequencies, the material properties as well as the dimensions of the cable or connector plays important role in determining the impedance match or mismatch. A high value of return-loss denotes better quality of the system under test (or device under test) [12]. The Return Loss should be at least 20 dB for good performance.

Below formula represents the relationship between VSWR and return loss:

$$VSWR = \left[\frac{10^{\frac{RL}{20}} + 1}{10^{\frac{RL}{20}} - 1} \right]$$

3.3.4Durability or Life cycle of Probe

Durability of probe means that how long we can use the same RF probe in production or in other words how many cycles can we use the same RF probe. After one life cycle we need to change the RF probe.

But some of the RF probes have replaceable needles so that we don’t need to change whole RF probe assembly; which may be quite expensive; we need to change only the needles after one life cycle.

Some of the probes have the durability of 10,000 cycles while for the other probes this may be larger than 10,000 cycles.

4.New solution

The current solution, connector with probe, is good. However, we want to investigate if there is a solution that is cheaper but still equally good when it comes to performance and reliability.

The idea is to remove the RF connectors on the board in order to save the component cost. The RF connectors are not used by the end customer anyway so in that way they don’t contribute to the user experience. If there are two RF coax connectors on each produced board this will save a lot of money. When removing the RF coax connectors the idea is to use a pattern on PCB with signal and ground for RF test and measurements. To access this pattern on the PCB we aim to use a RF coax probe with needles. This solution provides a way of connecting to the PCB without a connector.

For evaluating this new solution we need to find suitable RF coax probes, modify the fixture parts to handle the new probes and we need to update the PCB CAD design with a suitable pattern on PCB.

4.1Selection of RF Probe

Below flow chart shows the flow of RF probe type selection process. [13]

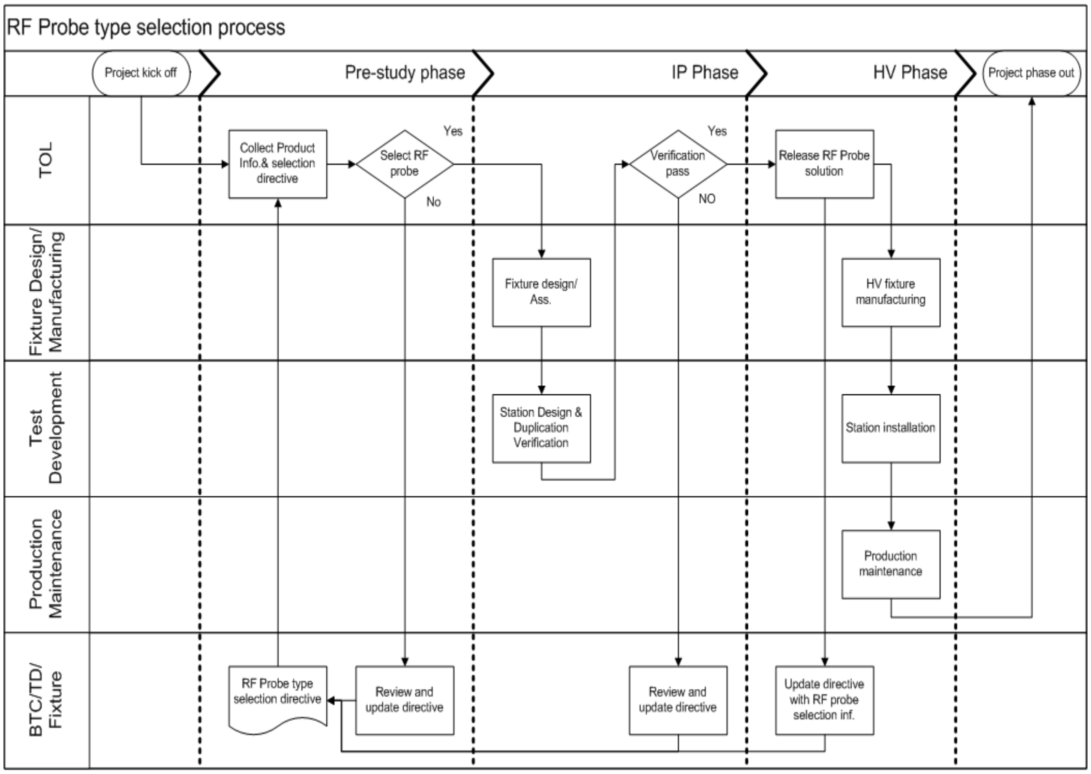

Figure 10 - Process of selection of RF probe

There are many different types of probes and suppliers available on market. As mentioned before all technical and business requirements need to be considered. After collecting the requirements we need to scan the market for probes that can be of interest and that fulfill our requirements. A selection of probes which best matched the requirements were selected for the evaluation. The probes selected are from ECT, INGUN, and IDI.

Table below shows the specification of some key parameters for the selected probes.

Supplier	Probe No	Size of probe(mm)		Performance(dB)		Tip Diameter of probe(mm)	Spacing between tip of probe(mm)
		Length	Diameter	VSWR	Insersion loss		
ECT	K-50L-QL	37.09	7.89	1.15 @ 1GHz	0.06 @1GHz	1.19	3.05
IDI	100559 (SMB Conn)	28.40	3.81	1.2:1 at 3GHz	0.38 @ 5GHz	0.53	1.18
Ingun	HFS810/HFS840	43.0	4.5	1.15dB @ 2GHz	0.12 @ 2GHz	0.51	1.05

Table 1 – Probe specification, main parameters.

4.1.1ECT

The RF Coaxial Probe with Part Number K-50L-QG is from ECT.

ECT, Everett Charles Technologies, products includes signature pogo plus® Contacts, loaded and bare board probes, battery interconnects, High Current/High Frequency Probes and semiconductor test products etc. [14]Below the ECT RF Coaxial Probe: K 50L-QG [15] can be seen.

Figure 11 - ECT probe

This RF probe has one signal pin and four ground pins and the probe is mated with SMA connector. The probe has crown shape needles, and the durability of the probe with crown shape needle (SPL-01L-039) is 10,000 cycles.

For high volume production applications, pogo-1 probes may be used with minimal impact on performance.

The pogo-1B probes were selected instead of crown shape needle. The durability with Pogo-1B probe is 1000000 cycles. The tip diameter is very small as compare to SPL-01L-039. [16]

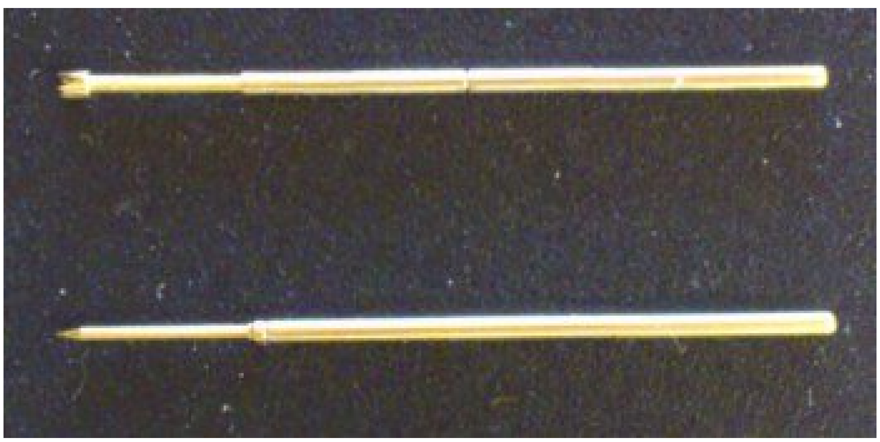

Figure 12 - POGO -1 pin

Overall performance of this probe is good but the cost of this probe is quite high. However, the needles are replaceable which means that then there is no need to replace the whole probe for maintenance. The needles can be replaced at a low cost. The number of ground needles is configurable so it is not necessary to configure the probe with all four ground pins.

4.1.2Ingun

Ingun is a German company that makes testing equipment for manufacturing and offers a wide choice of test probes and test fixtures.

The Ingun RF test probes with series HFS-810 and HFS-840 with integrated MCX-connectors are used in application upto 4GHz and seems to be interesting probes for our needs. [17]

We selected HFS-840 201 051 A 53 06 P coaxial probe.

Below the Ingun probe can be seen.

Figure 13 - INGUN probe

This RF probe has one signal pin and two half ground rings. The length and diameter of this probe is good and has good performance. The cost of Ingun probe is not too high but more expensive as compare to today's probe. [17]

4.1.3IDI

IDI, Interconnect Devices Inc, provides many different types of RF probes, such as spring loaded probe, high current probe, double ended probe and many more. [18]

IDI probe with series IDI 100559-B-N seems to best match our needs. The B and N is the type of signal plunger and shielding plunger respectively.

Below figure shows the probe IDI 100559. There are also some different options available for signal pin and shielding plunger. [19]

Figure 14 - IDI probe

The IDI 100559B-N RF coaxial probe has one signal pin and a continuous ground ring and the probe is mated with SMB connector.

This probe is not expensive and the performance is good. This probe is small in length as compare to the other two probes.

After selecting the above mentioned probes then as per the plan I have to design the trace on PCB according to all RF probes that I have chosen already.

4.2Design of the pattern on PCB

In order to be able to evaluate the selected probes we need to design a pattern on PCB to which the probes can connect. In our case the PCB pattern was designed in such way that it was able to handle the all different dimensions of the selected probes.

PCB trace must contain signal and ground. All three probes have different diameter and different signal and ground pin configurations.

In the PCB pattern design the signal test point was selected to have 1mm diameter. This is suitable for all three probes. There is a general rule of thumb stating that the distance between signal line and ground shall be two times the signal line width i.e. in our case the spacing between outer edge of signal point and inner edge of ground ring was selected to be 0.5 mm(following the dimensions of signal line (0.250 mm wide) going to and from the signal test point).

Below a principle sketch of the PCB pattern is showed together with a picture of resulting PCB design.

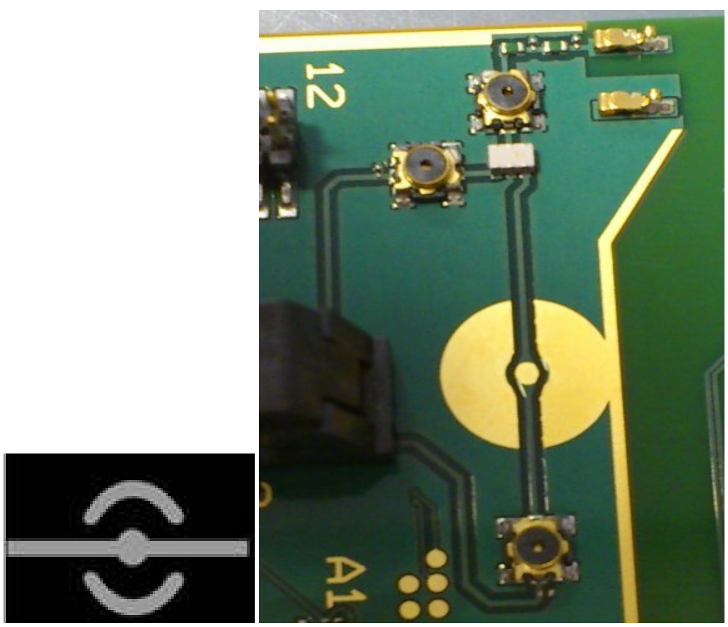

Figure 15 - PCB trace design, principle drawing and real life implementation

The diameter of signal test point is 1mm, strip line is 0.25mm wide, and the distance between centers of signal point to inner edge of ground is 1mm. The distance between centers of signal point to outer edge of ground ring is 3.8mm and the length of open area in the ground ring is 1.25mm. The keep out area is 14mm in diameter. The keep out area means all the components on PCB are at least 7mm away from the centers of signal point. This will prevent components on the PCB being damaged by the probe and vice versa.

4.3PBA Modification

The PBA signal path is matched to 50 Ohm. In the old solution, using the RF connector, the signal path to the antenna output is disconnected when the probe is inserted and 50 Ohm matching is maintained. In the new solution, when connecting the 50 Ohm probe to the PCB pattern, the probe impedance will be put in parallel to the signal path 50 Ohm impedance resulting in 25 Ohm impedance. The return loss performance will be poor.

It is necessary to modify the PBA. The modifications made to the PBA was to isolate the PCB pattern from the connecting signal paths by removing the components in both ends of the strip line going to and from the RF test point. Then two 100 Ohms resistors were mounted in parallel between the RF test point strip line and ground according to Figure 16 below. The opposite side of the strip line was then cut; the length to the RF test point was shortened, till best matching was obtained, close to 50 Ohm.

Below the modifications of the PBA are illustrated.

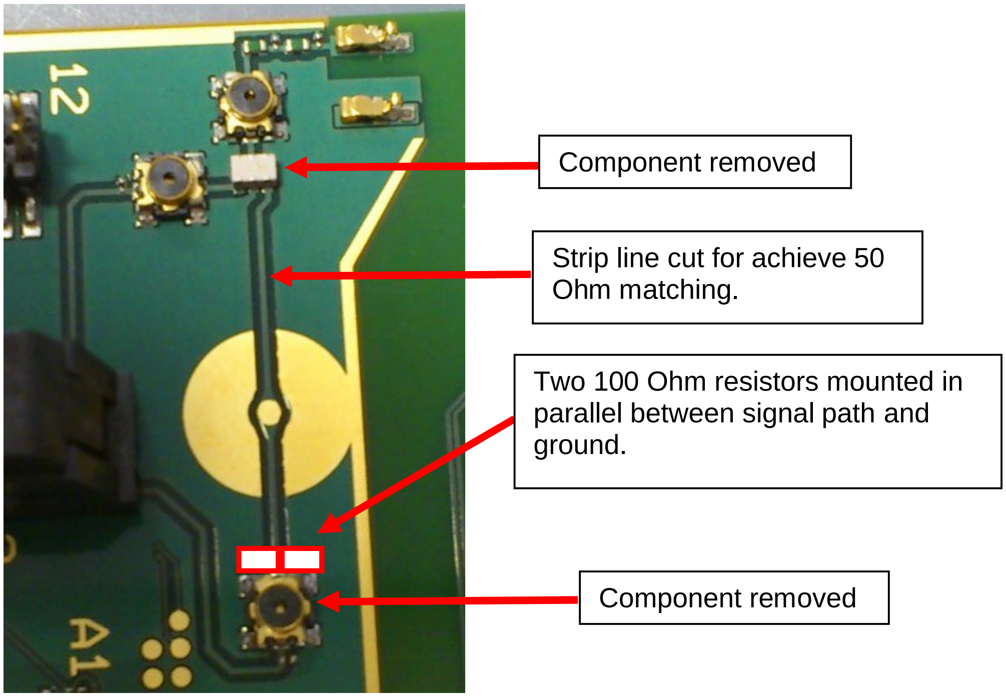

Figure 16 – Modifications made to PBA

Below figure shows the smith chart for ECT probe, when connected to the modified PBA.

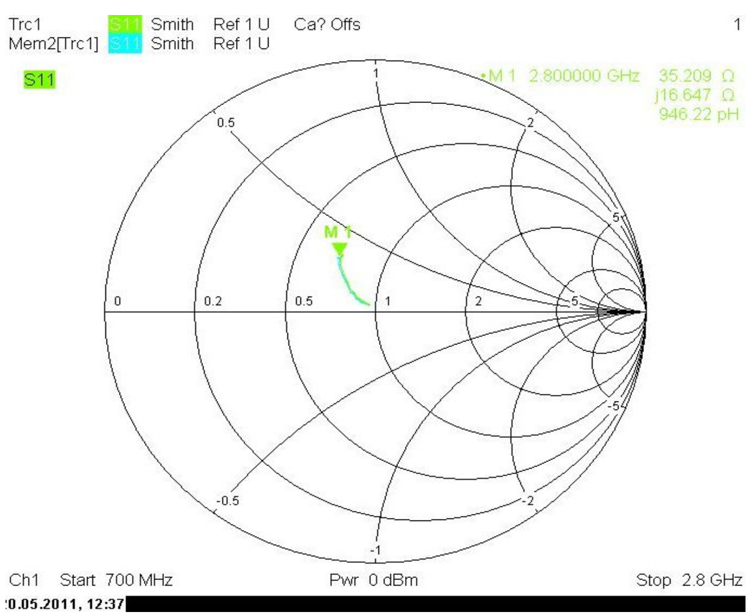

Figure17 - Smith chart for ECT probe

Below is the smith chart for Ingun probe, when connected to the modified PBA.

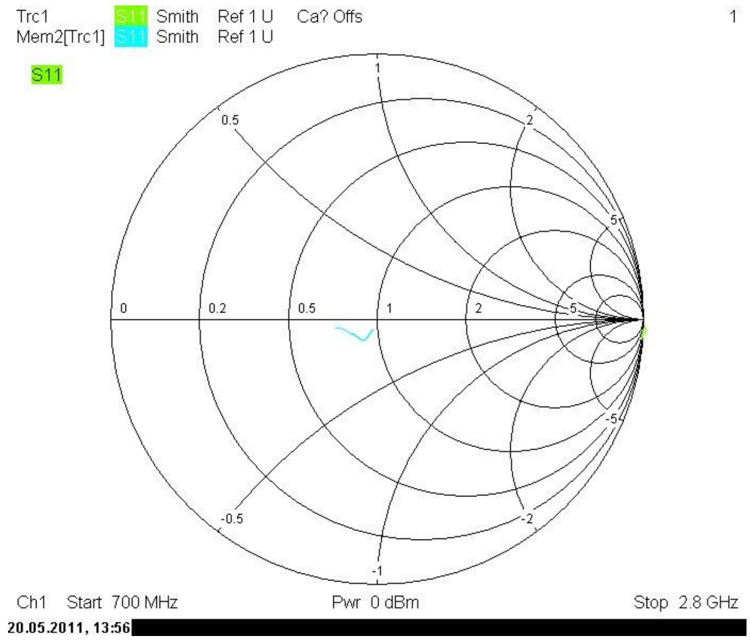

Figure 18 - Smith chart for Ingun probe for RL measurement

If this test point solution will be used later in production in that case good matching is essential, to achieve that one alternative is to place the test point exactly on antenna pad. By doing this it is possible to accomplish good matching. Also there could be some more possible alternatives, so an investigation is needed from R&D before implementing this solution in production.

5. Business case

Removing the need for RF connectors would mean a huge cost benefit. The cost reduction will be the component cost of the RF connectors.

Currently most of the phone product uses two RF connectors but day by day the number of technologies is increasing in mobile phone which arises the need for more RF connector in each phone. As the number of RF connectors increases, the cost per phone will increases as well.

If the test point solution will be used in production, then the cost of new RF probes is a-bit high as compare to today's probe, however this cost is nothing compared to the total cost of RF connectors used in complete phone project. That's why this test point solution can give huge cost benefits.

6. LAB Measurements

After collecting all requirements, preparing the PCB trace and selection of probe now it's time for lab measurements, in order to evaluate the performance of the selected probe. For evaluating the performance of new probe solution return loss was measured. Not only is the performance of return loss interesting but also the repeatability of the result. In a good solution the return loss shall remain the same independent of connection cycle otherwise the measurement accuracy of the test system is worsen.

The following items were used in measurement setup.

- Vector Network Analyzer (VNA): For measuring the return loss.
- SEMC Global Indus test station and Solid fixture: For controlling the measurement on PCB board.
- Lab View program: A Lab View script for controlling the VNA and collecting the return loss measurement data.

6.1Measurement Setup

To initiate the measurements all the equipment must be setup in correct way so unnecessary errors can be avoided. Here is the pictorial description and instructions are provided to do the measurement setup. Below the measurement setup is illustrated.

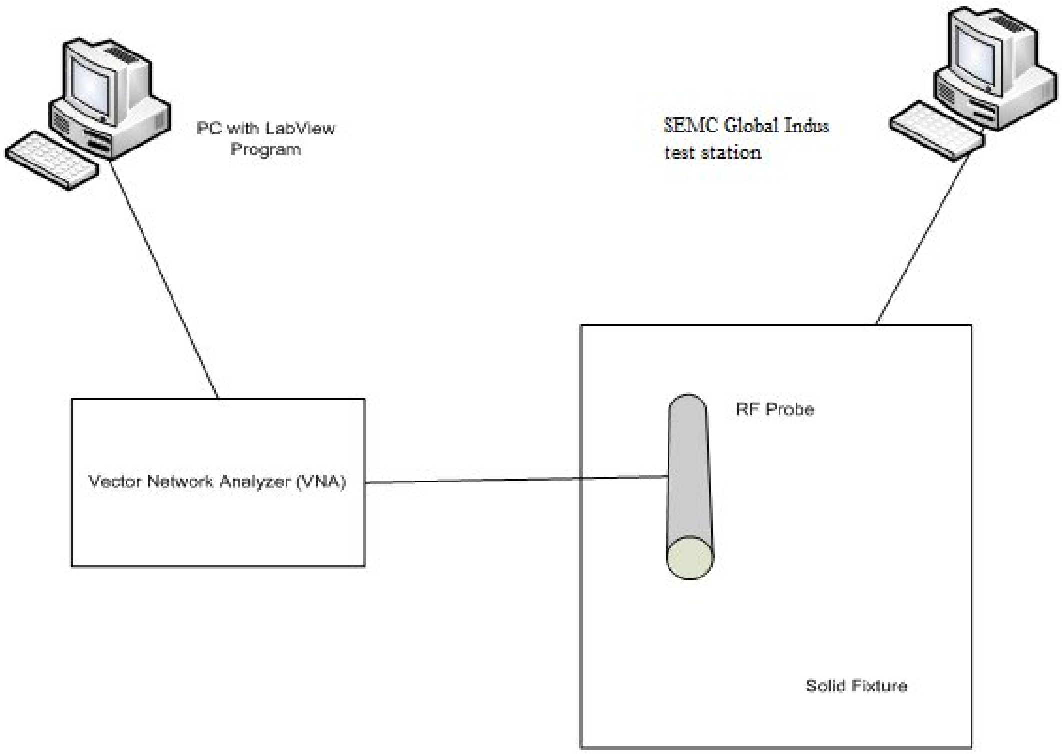

Figure 19 - Lab measurement setup

From the above figure we can see that the RF port of Rode & Schwartz VNA is connected to RF probe in solid fixture, to measure the return loss value from the PBA board and GPIB port is connected to the PC with Lab view program, from which the VNA is controlled and return loss measurement results are recorded. The fixture is connected to the SEMC Global Indus test station, to control the PBA and solid fixture.

Before performing any measurements it is very important to calibrate the test setup to get correct and accurate measurement results. After the calibration is done than it is ok to begin with the measurements.

6.2RF Probe holder

Figure 20 - RF Probe holder

6.3LABVIEW Program

LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench which is a platform and development environment for a visual programming language from National Instruments. It is easy to get started making small and simple program with no or small prior knowledge about the Lab View. In this thesis work, lab view was used to create a program to control the VNA and to collect the RL measurement results. Lab view program contains the front panel and block diagram.Below figure shows the front panel of program.

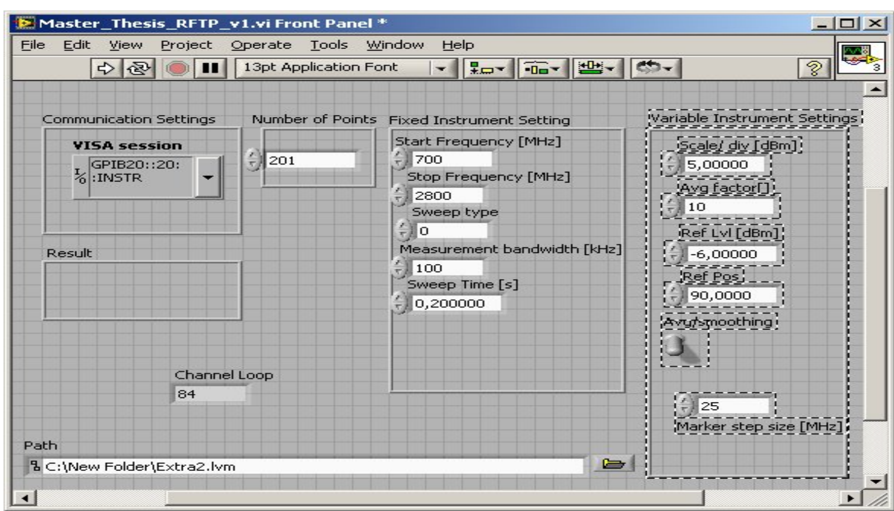

Figure 21 -labview front panel

Below is the basic flow chart of Labview program for controlling the VNA and collecting the RL measurement result record.

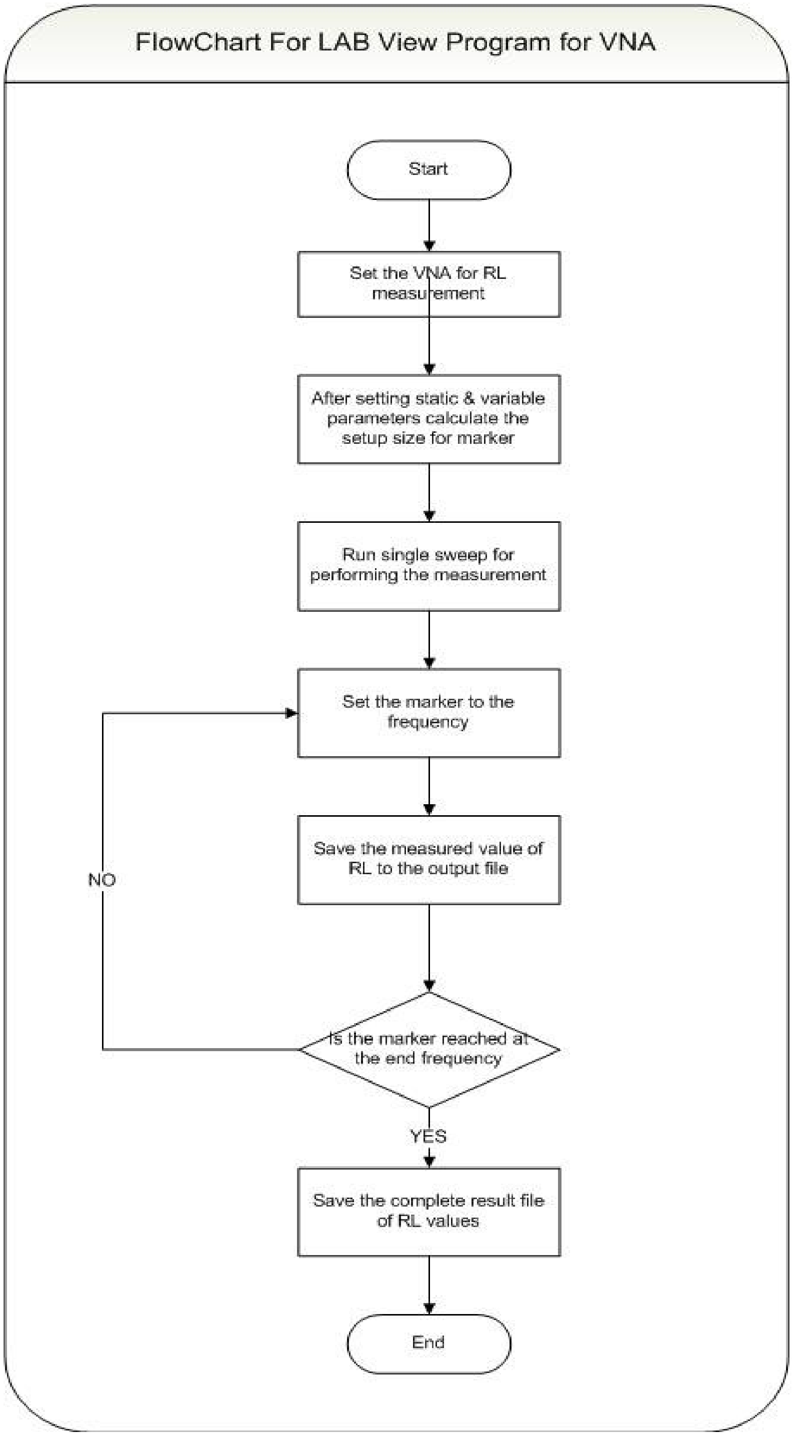

Figure 22 - Flow chart for labview program for VNA

6.4 Measurement Procedure

After the measurement setup and writing down the LabView program script now we are ready to do the measurements. The selected RF probe which we will use for measurements is mounted in the application part of solid fixture. As mentioned above that please calibrate the measurement setup, this is applicable to VNA as well. And then test board having test point is put into the fixture. When the fixture is closed, the RF probe is connected to test point, and then we can see the RL measured value on VNA, after that labview program has to be run for recording the measured RL values at different frequencies.

To check the measurement accuracy the test is repeated 30 times, and each test result is recorded by labview program.

6.5 Measurements Results

The ECT and Ingun probes have been evaluated while the IDI probe could not be evaluated due to the incompatibility of its ground plunger shape with the PCB pattern ground shape.

6.5.1 ECT Probe

The RL measurement has been repeated for 30 connection cycles. From the results we can get a picture of the repeatability of the connection. The result can be seen in the plot below.

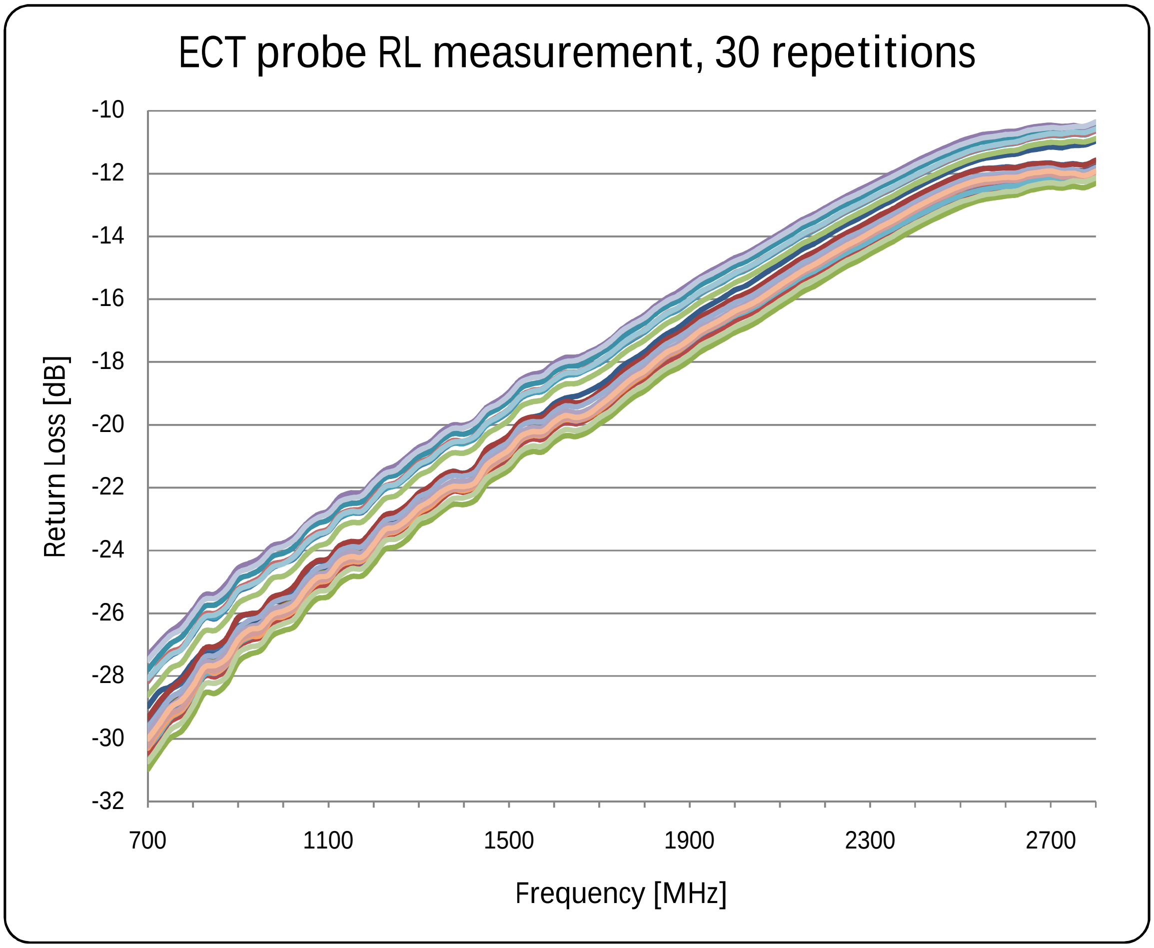

Figure 23 - Plot for ECT probe RL measurement for 30repetitions

From the measurements we can observe that-

- The probe has good performance at lower frequencies.
- There is small deviation between each repetition and linearity in values.
- Not so good at higher frequencies.

6.5.2Ingun Probe

This probe has some issues. It seems like the signal pin spring is too strong compared to the ground plunger spring (probe suspension) causing the ground plunger not connecting to the PCB some times. Also, the way that probe's suspension work makes the cable move when the PBA is connected or released, which increase stress on the cable. It is also sensitive for tilting since "ground crown" is in one piece, which could be difficult to adjust in production later. If it had been two independently moving pieces it would have been better for tilting issue.

The hit pattern can be seen in below figure. The signal pin is not exactly in center and there is only one side ground connection, the other side ground is not connected. This is the main problems with Ingun probe connection.

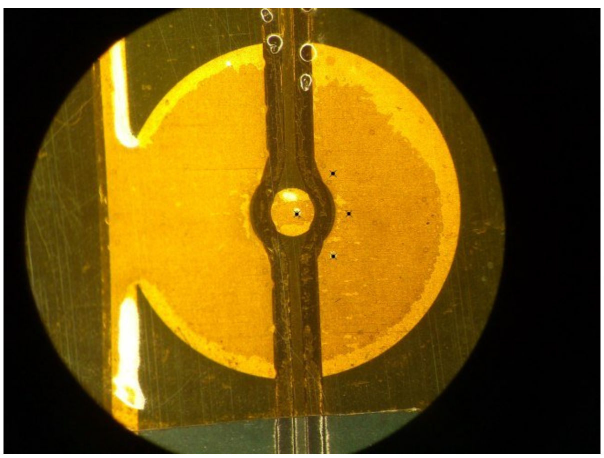

Figure 24 – Hit pattern for Ingun probe

Below is the plot for RL measurements for Ingun probe with 8 repetitions.

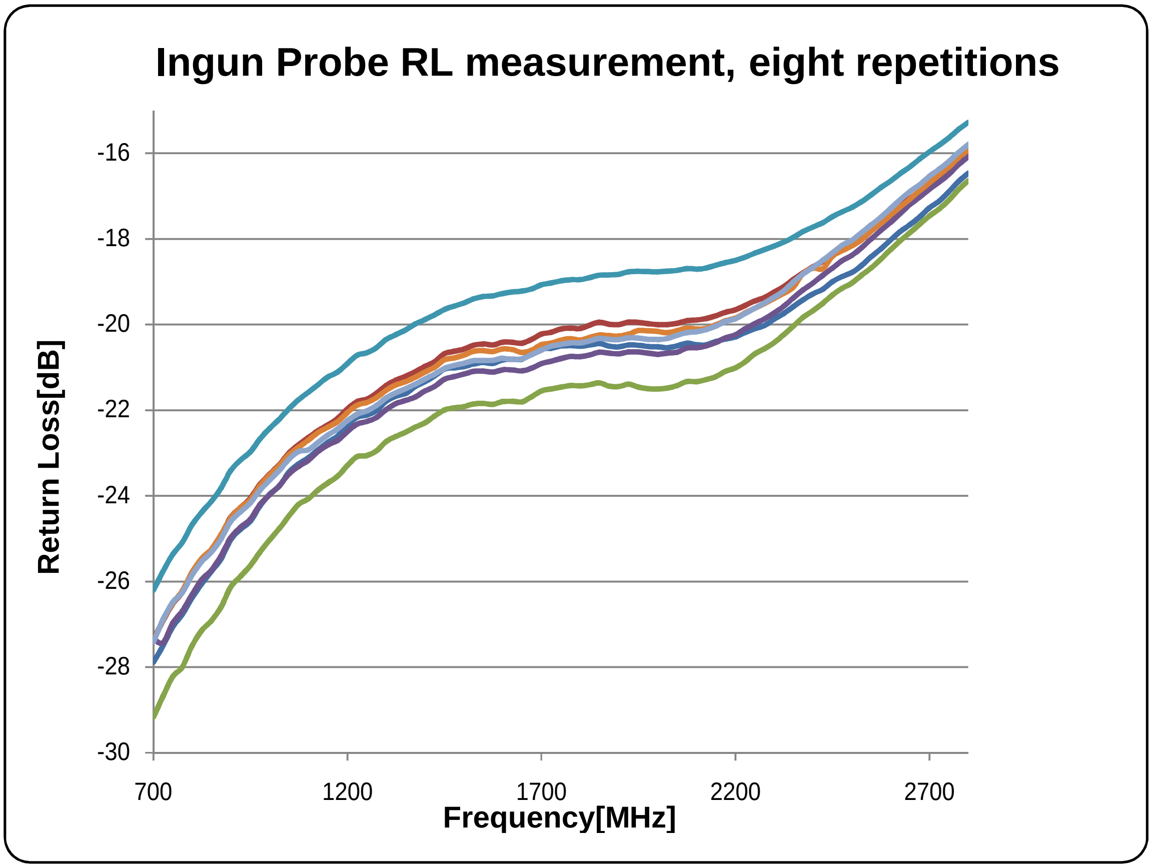

Figure 25 - Repetition plot for RL measurements with Ingun probe

7. Conclusion

At present SEMC is using RF connector with RF probes for RF testing. Nowadays as the number of RF technologies is increasing in mobile phones which leads to an increase in number of RF connector on each phone. Currently SEMC is using two RF connectors in most of the products but now when diversity and ISDB-T appeared in the scope of new products then it arises the need for one more RF connector. As the number of RF connectors increases, the cost per phone increases as well. So from the following investigation it can be mentioned that if today's solution (RF connector with probe) is replaced by this new solution (RF probe with test point), then surely it will reduce huge cost.

The new solution has been tested with ECT and Ingun probe. ECT probe shows the good RL value at low frequencies. And the advantage of ECT probe is that the needles are replaceable. So we don't have to change the complete probe only changing the needle will serve the purpose. By this we can save a lot of money. Whereas the Ingun probe has some connection issues which needs to be investigated in future. There is some connection problem with Ingun probe, for this reason one part of ground is not connected to PCB. But some time (approx. 50%) it is connected properly and shows really good results.

This new solution has good performance at low frequencies and also cheaper as compare to the today's solution. This new solution is cost saving solution.

The disadvantage of these probe is that the size of the probe is quite large as compare to the HIROSE and SMK (today's) probe.

This solution has been tested for lower frequencies. And for lower frequencies it gives good performance.

8. Future Work

In this thesis work there is some work left for future. As mentioned earlier that Ingun probe has some connection issue, it does not connects properly sometimes during measurement this needs to be solved.

ECT probe has been evaluated with two ground needles, but further study of how different grade of compression of the needles affects the performance could be interesting.

Also due to the lack of time and unavailability of hardware IDI probe is not analyzed, so its performance needs to be evaluated in future.

A study needs to be done in future for achieving good matching on the PCB for RF testing with the test point.

Only the performances at low frequencies were analyzed so possibly in future an investigation can be done for higher frequencies as well. By doing so, one can see the performances of these RF probes at complete RF frequency band.

9. Glossary

RF	-	Radio Frequency
TP	-	Test Points
RL	-	Return Loss
IL	-	Insertion Loss
VSWR	-	Voltage Standing Wave Ratio
VNA	-	Vector Network Analyzer
ECT	-	Everett Charles Technologies
IDI	-	Interconnect Devices Inc
USD	-	United State Dollar
PCB	-	Printed Circuit Board
SEMC	-	Sony Ericsson Mobile Communication

10. References

1. http://www.explainthatstuff.com/cellphones.html
2. http://ieeemacau.eee.umac.mo/ieee_student/history%20of%20mobile%20phone.htm
3. 56/12261-LXE10880sonyericsson internal document
4. http://www.murata.com/articles/ta0791.pdf
5. http://www.smk.co.jp/p_file/TS7e_20080919.pdf
6. http://www.hirose.co.jp/cataloge_hp/e35802384.pdf
7. 12/1056-LXE10880sonyericsson internal document
8. 8/1056-LXE10880sonyericsson internal document
9. 1/1056-LXE108724sonyericsson internal document
10. http://emc.toprudder.com/vswr.pdf
11. http://www.trendcomms.com/multimedia/training/broadband%20networks/web/main/Copper/theme/Chapter2/Return%20Loss.html
12. http://www.tutorialsweb.com/rf-measurements/co-axial-cable-measurements.htm
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14. http://www.ectinfo.com/cpg/category/default.cfm?exec=home&deptid=1
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