How to match CDMA PA

Written by Harry Lee on 25th January 2005

Introduction

This Application Note provides a method how to match between Skyworks Solutions' CDMA Power Amplifier Modules(PAM) and standard duplexer on the mobile phone.

Definition

The Characteristic Impedances of Telecommunication systems, e.g. Mobile Phone, is generally 50Ωs, and all components develop to 50Ωs. But, Power Amplifier Module amplifies RF signals and it is very difficult to make 50Ωs. Match means that Impedances match between PAM & Duplexer to 50Ωs. But, Nowadays Engineers tune to specific impedances using Loadpull data provided by PAM makers on purpose (Improve efficiency or linearity).

Impedance Matching Network

Block Diagram of Power Amplifier is shown in Figure 1. Power Amplifier is in a dotted square. As I mentioned, this simple system is also 50Ωs system. Z_S is the source impedance and Z_L is the load impedance of Power Amplifier. As shown, this system terminated by 50Ωs and Input Matching Network/Output Matching Network is designed to transform the generator impedance to Z_S and transforms the 50Ωs termination to Z_L.

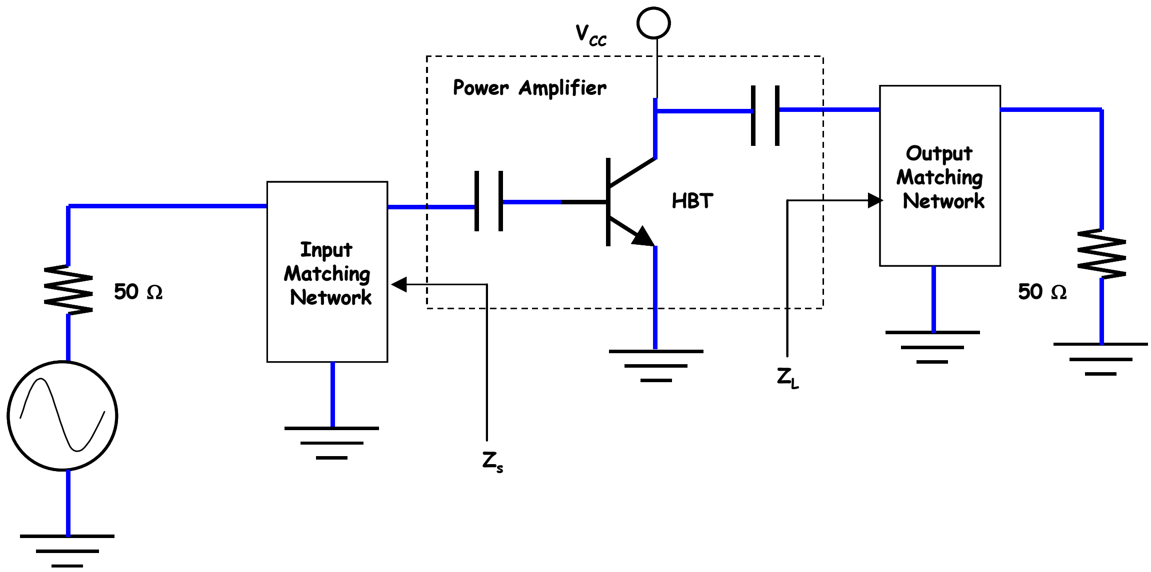


Figure1. Block Diagram of Power Amplifer

To match impedance between termination and Z_S/ Z_L , you have to prepare Loadpull data provided by Skyworks Solutions. Figure 2. is Loadpull data of SKY77162. Normally we just give load impedance, Z_L to customers. We don't provide Source pull data to you. Because input match between saw filter and PA is related to the performances that are gain flatness, noise power, and so on(output match is dominant to efficiency and Linearity of PA). Usually engineers don't match it at all or just use resistor pad. Sometimes, Saw filter makers prepare matching circuitry. Anyhow, Input matching is not important than output matching.

When You see loadpull data in Figure 2., you can see the conditions of loadpull data. It means that this loadpull data gets these conditions using loadpull machine. So, if you measure loadpull data with different condition, you get a different results. PA is a non-linear component so we can't expect constant performance.
Loadpull data is devised to help to design system. You can see blue and red contours lines in Figure 2.. Blue is efficiency contours and red is ACPR1(Adjacent Channel Power Ratio 1) contours.

Mode IS95, Freq=836.5MHz Pout=28dBm Vcc=3.4V Vref=2.85V Vcont=2.0V Temp=25°C

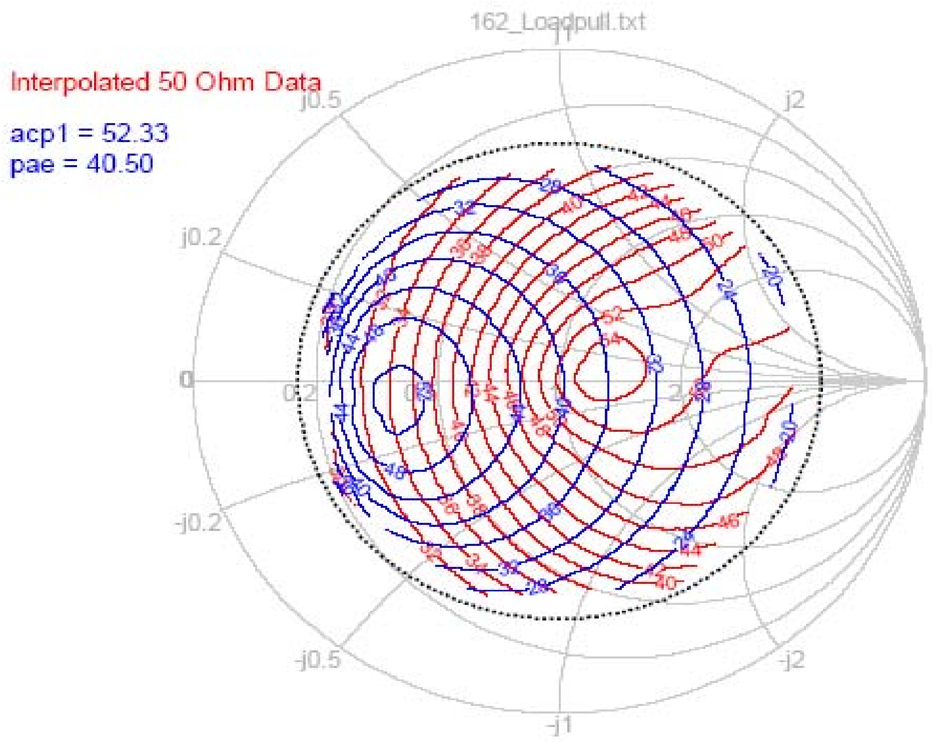


Figure 2. Loadpull data of SKY77162 @ 836.5MHz

The most efficiency impedances is around 25Ωs and you get 52% but, the most linear impedances is around 75Ωs(-54dBc). At 50Ωs, the performance of PA is shown 40.5%, -52.33dBc. @ IS95, Freq.=836.5MHz, Pout=28dBm,Vcc=3.4V, Vref=2.85V, Vcont=2.0V, Temp=25°C.

Now, I come back to real transceiver Chain of Mobile phone to explain matching procedure step by step.

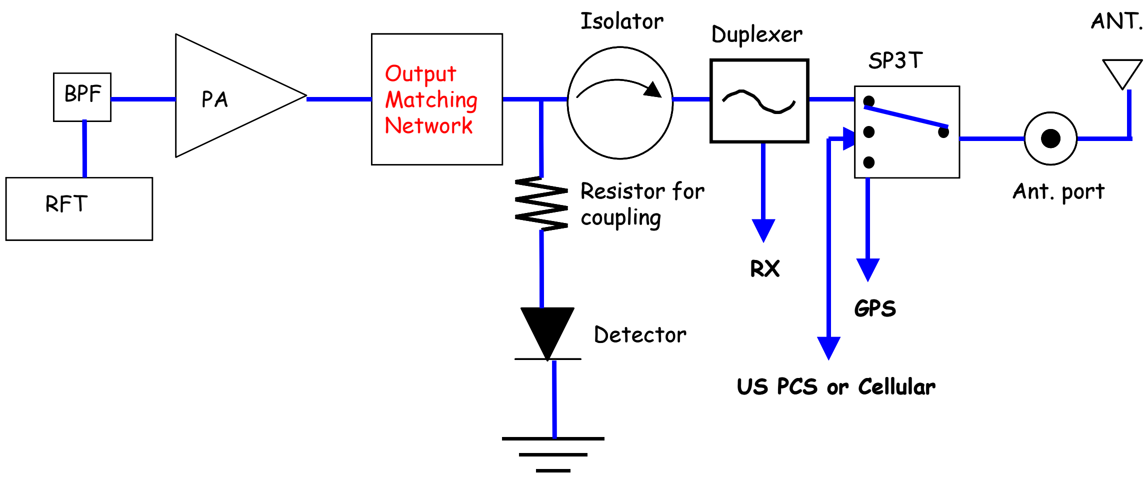


Figure 3. Typical Transceiver Chain

Figure 3. is shown a typical dual band transceiver chain. RFT makes RF signal and it applies PA via Band Pass Filter that makes useful signal pass but cuts down spur signal. PA amplifies RF signal though matching circuits. After than some signal is coupled via resistor(or directional coupler) and goes to detector. This detector converts RF to DC to control Tx path. Simultaneously major signal flows to Duplexer via Isolator. Some engineers don't use isolator at all. It depends on their mind. Anyhow, Duplexer passes RF signal of its own frequency range. Passed signal propagates through Ant. Via SP3T and Ant. port.

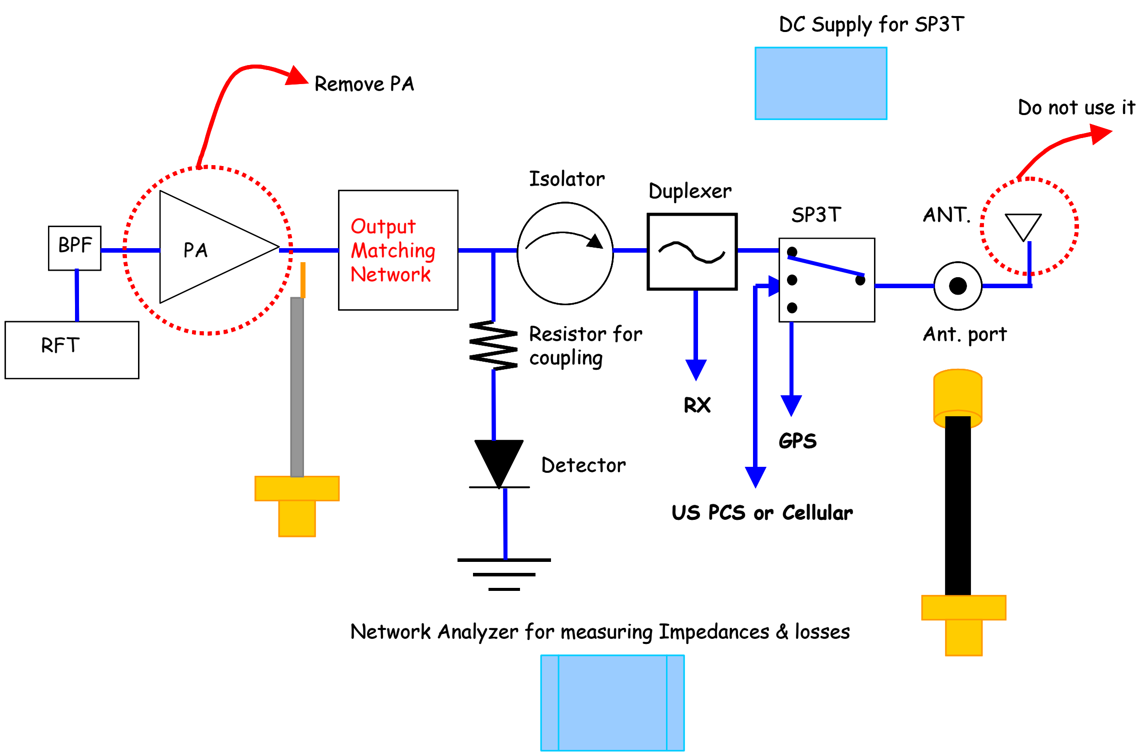


Figure 4. Matching procedure 1.

Preparation of Matching

When you match between PA and Duplexer(I consider engineer do not use isolator to reduce losses of Tx chain), you'd better use all circuitry of post PA, like Figure 4.. Because when you tune impedances with this conditions, you can get the expected performance of real field status. The following is procedure.

First, you calibrate Vector Network Analyzer with 'Full 2 port Cal.' Or you calibrate 'signal S11 Cal.' After you remove Antenna port and terminated 50Ωs. But, I would like to recommend full 2 port calibration because 'Full 2 port Cal.' can check losses(S21) of post PA. When you match PA & Duplexer, loss information of Tx Chain is important. In instance, Even though you get good contours of PA, if duplexer losses at that impedance is not good enough, you can't get expected results, You'd better consider Z_L impedance and losses of duplexer.
Second, You prepare a semirigid connecter, a coaxial cable and DC supply for feeding SP3T.
Third, do measure electrical delay of semirigid connecter to compensate impedances of connecter. And, check losses of connect and cable to make up for losses of post PA.
Fourth, Remove PA by heating gun and attach semirigid connecter to output port of PA and connect coaxial cable to Ant. port.

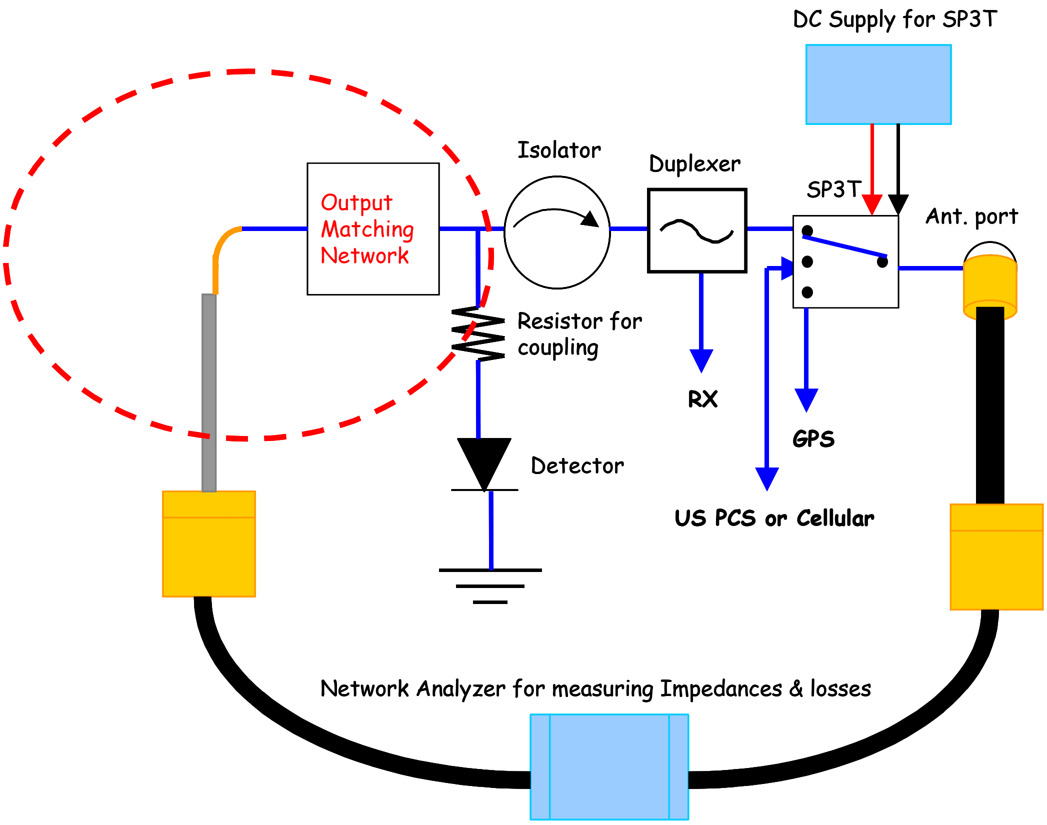
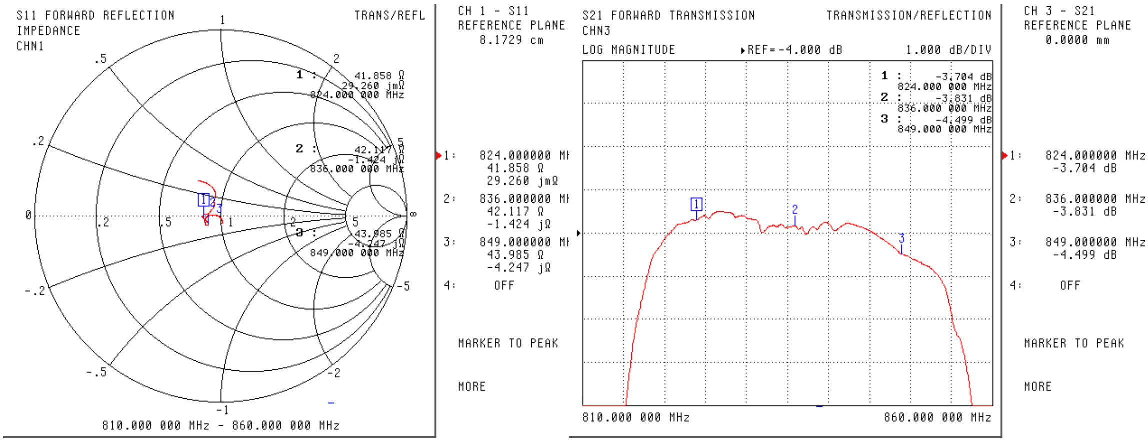


Figure 5. Block Diagram of Test setup

Fifth, connect DC cable to SP3T for supplying bias circuits .
Now, You finish preparations to test impedances and Figure 5. is one of block diagram of test setup.

Let set test bench like Figure 5. Input and output of Vector Network Analyzer connects to input of output matching network and Ant. port same as Figure 5. And supply 2.85Volts typically to SP3T using DC supply. Then, you can see impedances of Z_L and Losses. I show an example of impedances and losses. Look at Figure 6.



A. Impedances of Z_L **B. Losses of Post PA**

Figure 6. An example of impedances Z_L and Losses of Post PA

It measures in cellular Band(824~849MHz). I get impedances contours cross freq. Range. Because this example uses isolator, contours is located almost 50Ωs and it is not spread out but losses are a litter bit higher compare to Tx chain that does not use isolator.
Graph B of Figure 6 is said that losses are about 3.78 to 4.49dB cross freq. range. And when I compensate semirigid cable(-0.15) and connecter(-0.5), compensated losses of post PA are 3.13 to 3.84dB cross freq. range.

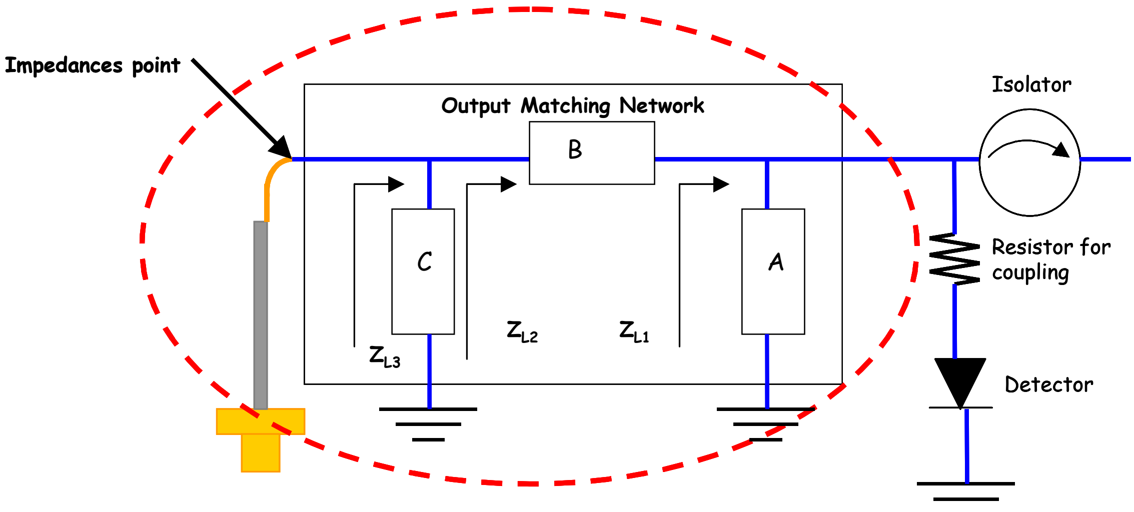


Figure 7. Output matching Network

Matching Topology

Now, you get all information to start match between PA and Duplexer(or Isolator). You get load impedances information and Loadpull data. Let's start match!!!

To help to understand matching topology, I magnify output matching network of Figure 5. It is Figure 7. An example shows the impedances at impedances point of Figure 7. And I use 100pF series capacitor at 'B' of output matching network. It is the impedances without matching.

I try to transform the impedances using 3 pi type components that is A, B and C. I have to meet target impedances using loadpull data (Figure 2.) at impedance point.

First, Define target performance.

Typically, You'll test 24dBm at Ant. port and You decide on target linearity and efficiency at that power.

Second, Define target impedances at loadpull data.

Loadpull data shows performance contour at Maximum power that is typically 28dBm. and You know losses of post PA, in instance , 3.13~3.84dB. You get extra power to design mobile phone.

So, You can choose more efficient point.

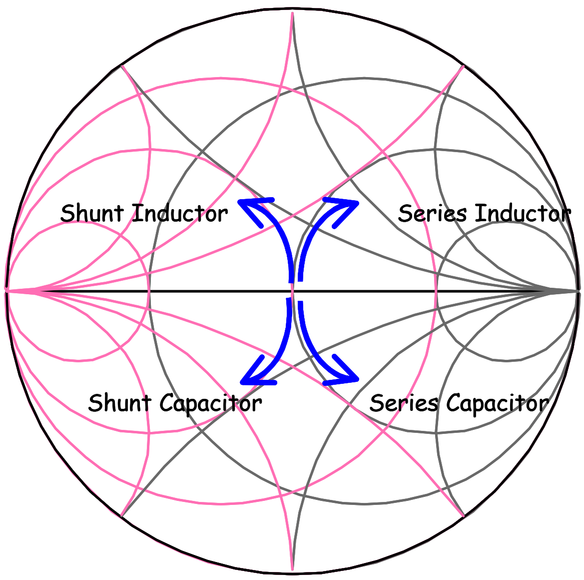


Figure 8. Direction of component in Smith Chart

In matching network, there are many different types of matching network, like loss pass filter type, high pass filter type. Whatever there are several types of network, the important thing is choosing component that you would like to move toward.

To match impedances, you use smith chart to tune easily. Smith Chart is very powerful tool to match impedances.

Back to the output matching networks, I change impedance Z_{L1} using shunt A component. If I move forward to inductance plane, I may use inductor, if I transform to capacitance plane, I use capacitor. Figure 8. explains it easily. It also explains series component follows impedance circles and shunt element follows admittance circles.
I already said I would like to transform more efficient point that is area around 25Ωs, you choose shunt capacitor first(Z_{L1}). And then you use series inductor to move up at smith chart(Z_{L2}). And you don't use component C(Z_{L3} = Z_{L2}). Alternatively, to begin with shunt inductor(Z_{L1}) and then I use series capacitor(Z_{L2} = Z_{L3}). As the results,

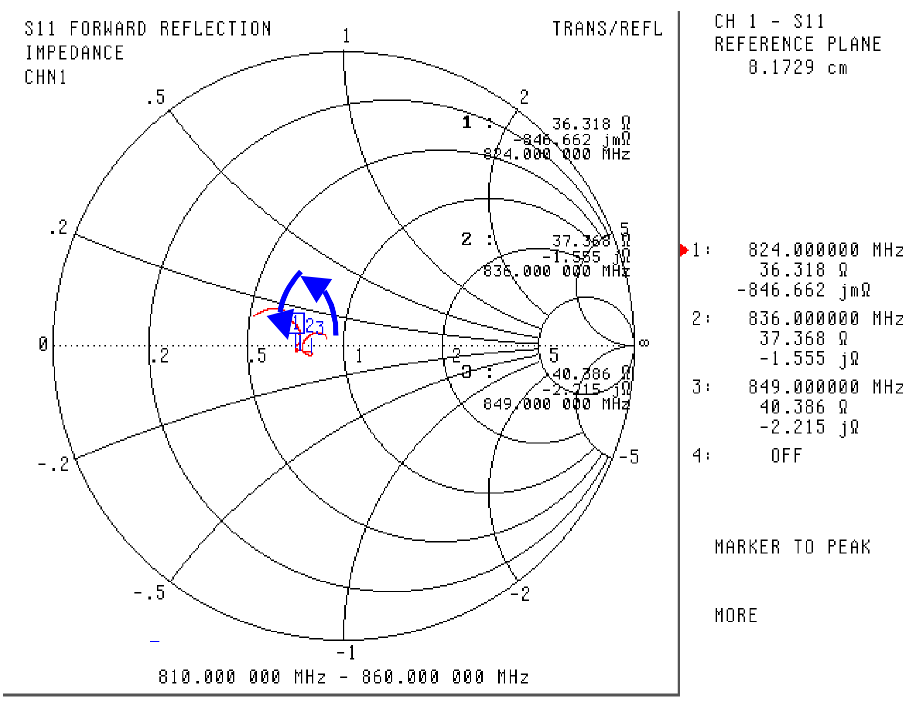


Figure 9. Matching results

I get the impedances, like Figure 9. I attached shunt 22nH and then series 10pF. After getting target impedances, I check linearity and efficiency of Tx Chain. It is shown at Figure 10.

	Max. currents	Gain Variation	worst -885KHz	worst - 1.98MHz
After match	**385mA**	**0.96dB**	**-51.79dBc**	**-59.61dBc**
Before match	420mA	0.92dB	-51.35dBc	-62.48dBc

Figure 10. Brief performance data after matching

This results is gotten at 24dBm Ant. port, Vcc=4.0V, Vref=2.85V, Vcont=2.0V. As you know, after matching between PA and Isolator(Duplexer), you have to check the performance data of mobile phone, Because, sometimes you can not get good results after tuning. So you need do trial and error to get reasonable results. You may get good results how many hours you spend to match.

Conclusion

Up to now, I explain how to match between PA and Isolator(or Duplexer) step by step. As you can see the result, you get optimum performance using same PA. So, Match is very important and basic skill to design mobile phone.

Revision History

Revision	Level	Date	Description
A		January 25, 2005	

Reference

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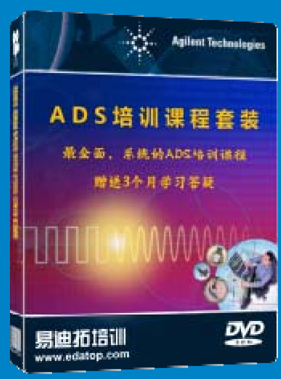

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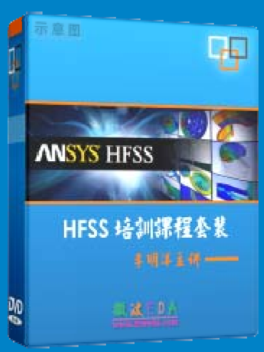

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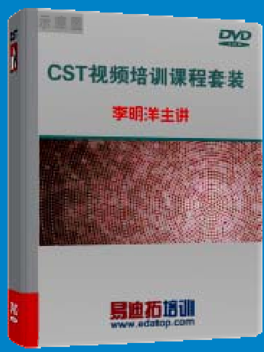

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