行政院國家科學委員會專題研究計畫　成果報告

單晶片電視調諧器之經濟有效測試方法

計畫類別：個別型計畫
計畫編號：NSC92-2622-E-002-040-CC3
執行期間：92 年 12 月 01 日至 93 年 11 月 30 日
執行單位：國立臺灣大學電子工程學研究所

計畫主持人：李建模

報告類型：精簡報告

處理方式：本計畫為提升產業技術及人才培育研究計畫，不提供公開查詢

中　華　民　國 94 年 5 月 17 日

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※※

※　單晶片電視調諧器之經濟有效測試方法　※

※※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：■個別型計畫(小產學)　　□整合型計畫

計畫編號：NSC92－2622－E－002－040-CC3

執行期間：　92 年　12 月　1 日 至 93 年　11 月　30 日

計畫主持人：李建模　博士

計畫參與人員：林柏州

執行單位：台灣大學電子工程研究所

中　華　民　國　　94　年　5 月　17

中、英文摘要

本研究計畫發展一套經濟有效的單晶片電視調諧器測試方法。為達此目標，我們將運用三種技術：1.統計電路模擬 2.測試流程化簡 3.測試後資料分析。統計電路模擬可以預測電視調諧器電路在不同製程變化下的測試結果。

This report develops an economic and effective test methodology for single chip TV tuners. Three techniques will be applied to achieve this goal: 1. Statistic circuit simulation, 2. Test flow simplification, and 3. Post test data analysis. The statistic circuit simulation predicts the test results of TV tuners under process parameters variation.

關鍵詞： 電視調諧器測試，射頻測試方法

報告內容：

前言

隨著手機與無線網路的大眾化，射頻(RF)系統已進入人們的日常生活中，國內轉進 RF 領域的設計公司亦呈現穩定成長的趨勢，而無線產品輕薄短小的需求，促使 IC 設計工程師致力於發展高度整合的射頻系統晶片(RF-SOC)。單晶片電視調諧器(Single-Chip TV Tuner)即為 RF 領域中重要的產品之一。

應用在各種裝置或設備上的調諧器, 其基本的功能為在輸入的頻帶之內接收所有可以使用的頻道(Channels)，進而從中選取我們想要的頻道並排斥其他不需要的頻道，而後將所選取的頻道轉譯成標準的中頻(Intermediate Frequency，IF)以供應用。傳統的調諧器操作的頻率範圍在 54MHz 至 862MHz 之間，而此頻帶正被廣播電視及有線電視所使用。

世界各地區之電視系統規格差異極大，我國電視系統採用與美國相同的 NTSC 系統，其中一個典型的電視信號，其頻寬都在 4MHz 以上。本產品是單一晶片的電視調諧器積體電路，它可以相容於 NTSC，DOCSIS，DVB，ATSC 等標準的電視系統，且能夠接收頻率範圍在 48MHz 到 1000MHz 的輸入訊號並將訊號轉變至 30MHz 到 60MHz 的頻率範圍(IF)供視訊上的應用。此調諧器在多媒體方面應用廣泛，不論是接收有線電視(Cable TV)、或接收類比及數位式地面廣播電視台(Terrestrial TV)的訊號階合適，亦可應用於視訊轉換盒(Set-Top Box), 及個人電腦與電視間的切換介面卡上。從以下所述的產品規格中，將會發現此電視調諧器優於一般同類型的產品並俱備更高的可靠度。

此電視調諧器預定的規格如下：

Absolute Maximum Specifications				
Parameter	**Min**	**Typ**	**Max**	**Units**
Power Supply Voltage	3.0	3.3	3.6	V
Junction Temperature			130	^{o}C
Relative Humidity			95	%
Storage Temperature	-40		+85	^{o}C

Electrical Characteristics						
Parameters	**Symbol**	**Min**	**Typ**	**Max**	**Units**	**Notes**
Power Supply Voltage	Vdd	3.0	3.3	3.6	V	
Input Frequency	rfin	48		1000	MHz	
Noise Figure(SSB) at max. gain setting	NF		7		dB	48-1000MHz
Input Return Loss	S_{11}	6			dB	48-1000MHz
Composite LO Phase Noise			-85		dBc/Hz	At 10kHz offset
			-105		dBc/Hz	At 100kHz offset
Composite Triple Beat	CTB			-55	dBc	
Composite Second Order	CSO			-55	dBc	
Composite Cross Modulation	CXM			-50	dBc	
Image Rejection	IM_{rej}	60			dB	48-1000MHz
VGLNA Dynamic Range	DR		30		dB	
RF Gain(VGLNA + Down Conversion Mixing Block)			25		dB	Maximum gain
Gain Flatness				3	dB	48-1000MHz
Power Dissipation			1000		mW	

此高度整合的晶片由 VGLNA(Variable Gain Low Noise Amplifier)，Mixers，PLLs(Phase Locked Loops)，Local Oscillator 等必要成份所組成，如此可以減少外部元件且不需手動調整。RF VGLNA 提供高線性度，寬廣的動態範圍(dynamic range)，以及低雜訊的放大。Mixer 被用來做向下轉換(down conversion)，提供良好的 image rejection 與 channel selectivity。頻率合成器(Frequency Synthesizer)掌控 Local Oscillator 的頻率及準確性。以上主要的電路區塊均可經由設定電源管理電阻而被數位上的關閉，節省功率的消耗。

全球每年生產超過 3 億個操作在電視頻帶中的調諧器，這些調諧器被整合至多種消費性電子產品中，從普通的家用電視與卡式錄放影機，到較新、較複雜的設備如纜線數據機(Cable Modem)、纜線電話系統(Cable Telephony System)、網路電視台(WebTVs)及數位電視中，均有調諧器的應用。通訊系統的設計越小、越

快、越複雜，就更需要下一個世代的調諧器來提供更高的可靠度以及符合新興的標準。當調諧器發展的更專業化，它們便能擴展其原有的功能至豐富的多媒體應用上，如此即更顯示出調諧器的重要性[Norsworthy 01]。

研究目的

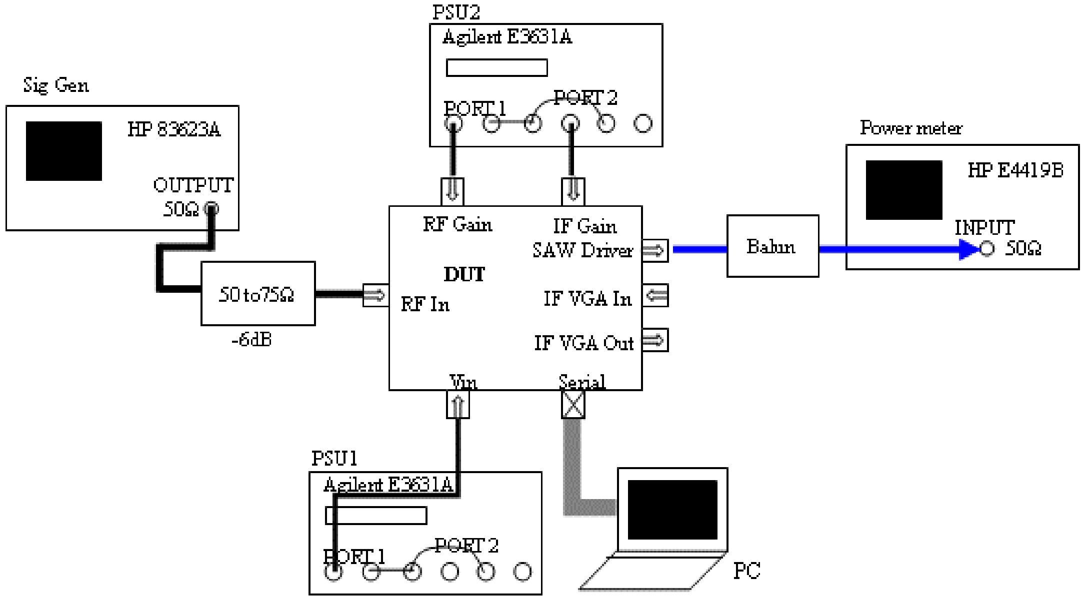
雖然電視調諧器的製造成本可以隨著單晶化而降低，然而測試成本卻一直十分昂貴，因為詳盡地量測每一個電視調諧器參數需時甚久。由於高頻、RF 測試技術及人才不足、測試機台價格昂貴，許多 RF IC 往往在測試，耗費相當多的時間和資金成本。為滿足系統晶片在消費性應用上低成本的需求，在增加設計與測試複雜度的同時，還必須尋求一些方法以有效的縮短測試時間，降低 RF IC 測試的成本。

The available channels of this tuner IC is from channel 14 to channel 69, and every point in the curves of following figures corresponds to a channel.

結果與討論

1. Power Gain

Instrument set up:



Measurement Procedure:

Once the above conditions are complete, the measurement can be made directly from reading the output power on power meter display.

Calculations:

The power gain can then be calculated via the following formula:

$$\text{Gain} = P_{\text{out}} - P_{\text{in}} + P_{\text{loss at input}} + P_{\text{loss at output}}$$

P_{out} = Power read from power meter.

P_{in} = Power read from Sig Gen.

$P_{\text{loss at input}}$ = Power loss due to input impedance transfer and cable loss.

$P_{\text{loss at output}}$ = Power loss due to 1K to 50Ohm single to differential transformer and cable loss.

Measurement Result:

The power gain is typically about 19dB, and its value with respect to all channels is shown below (Figure 1). This figure display the distribution of power gain on all channels, and the trend of the distribution is similar through several measurements.

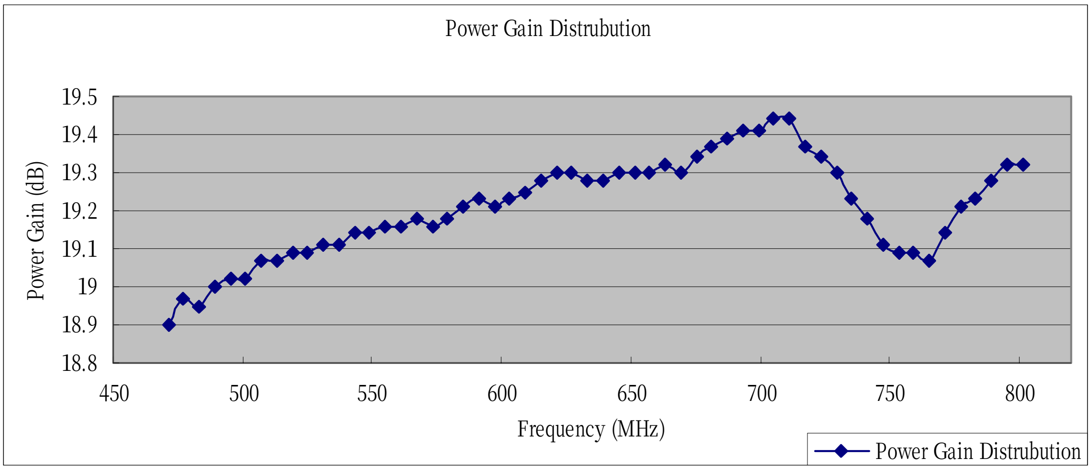


Figure 1

Another measurement method for gain gives the different result. It measures the noise figure at first, and then calculates the gain by the formulation. This method is called Y-factor technique and is predicted to be more accurate for a well matched DUT. Its result compared with the previous one is shown in figure 2.

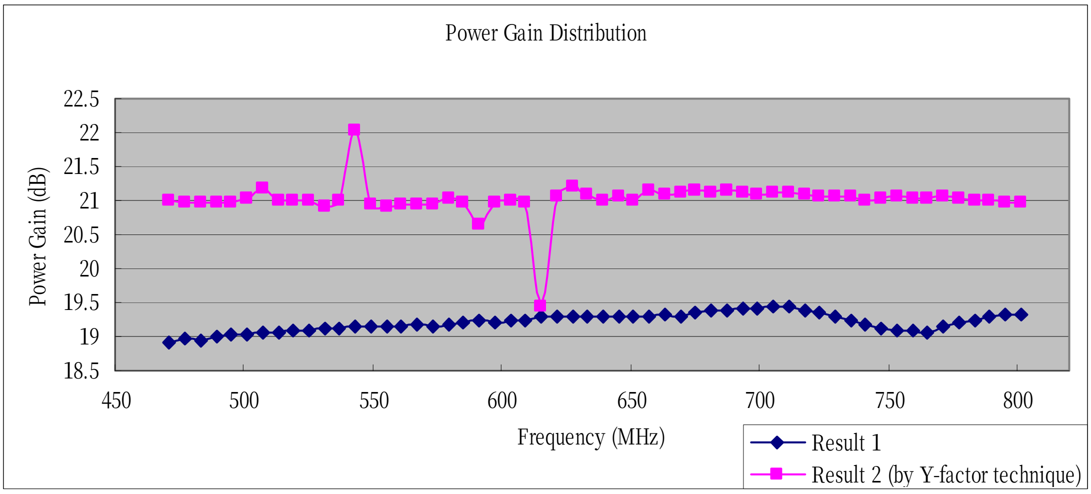
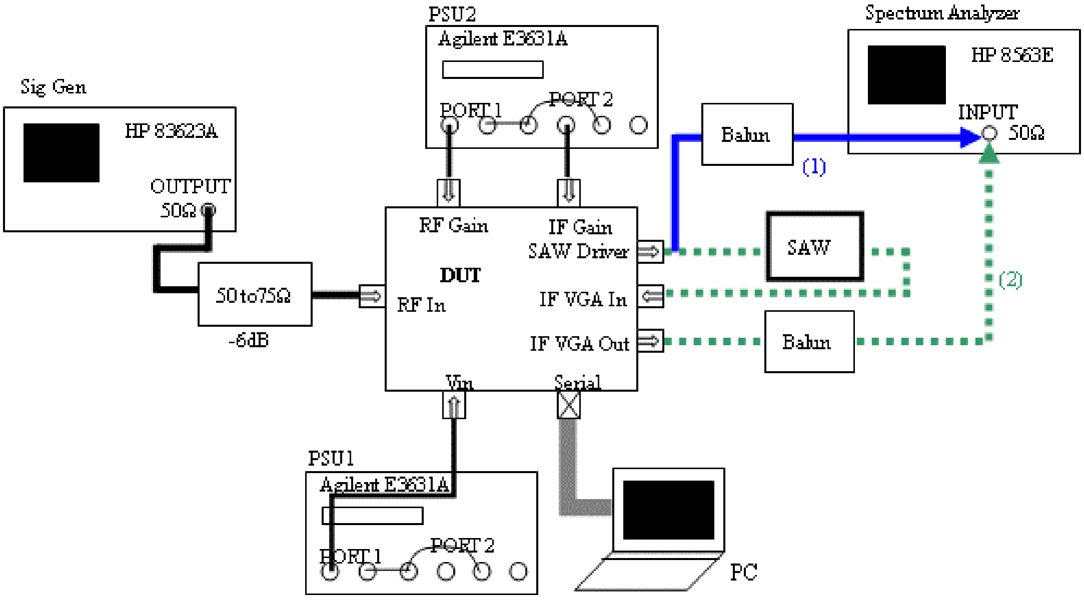


Figure 2

2. Channel Tilt

Instrument set up:



Measurement Procedure:

a) Ensure there is a peak on the SA at about 44MHz,-15dBm.

b) Set the center of the SA to the peak.

c) Set up the display on the SA for peak hold.

d) Sweep the Sig Gen frequency manually from 505MHz to 497MHz.

e) If the SA display looks grainy then reduce the step size on the Sig Gen.

f) Set a delta marker between the lowest and highest level on the display in the 6MHz bandwidth centered around the carrier.

g) Plot the result.

Measurement Result:

Channel tilt is gain variation through the receiver across the channel bandwidth (6MHz). The gain difference is the difference between maximum gain value and minimum gain value in the channel bandwidth, and figure 3 shows its distribution with respect to all channels.

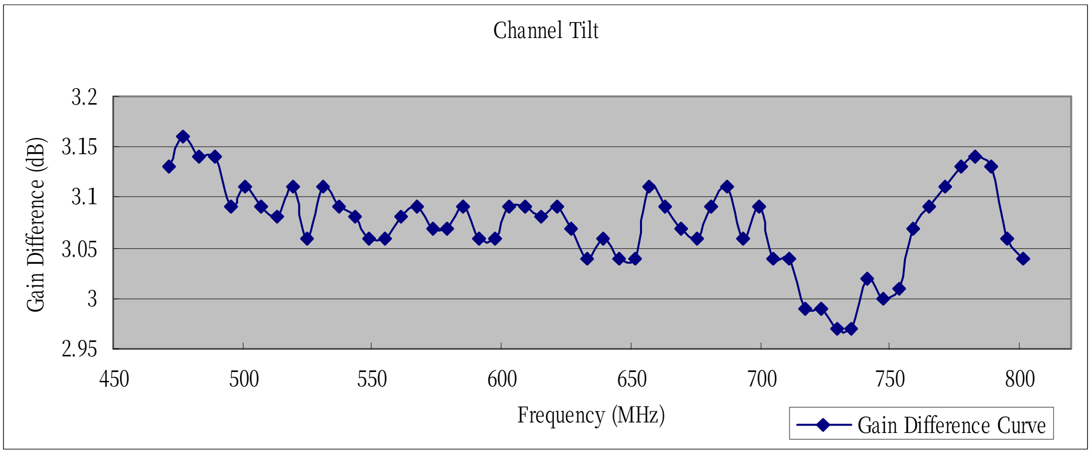


Figure 3

3. Image Rejection

Definition:

Any heterodyne receiver will, via the mixing process, mix two frequencies to the IF. One is wanted and the other which is unwanted is called the image. There is an image frequency for every IF in the receiver, which is always at $F_{lo} \pm F_{if}$. Where the sign used for the image is the opposite of that for the wanted signal. Using IF filtering or using a Single Sideband (SSB) architecture reduces the susceptibility of the receiver to image power. The image rejection is the ratio in (dB) at the IF of a signal at the wanted frequency to one at the image frequency. It can be measured as the difference in input power of the two signals to create the same power signal at the IF.

There are 3 IF, 1^{st} image is out of band, only the 2^{nd} and 3^{rd} image rejection needs to be measured.

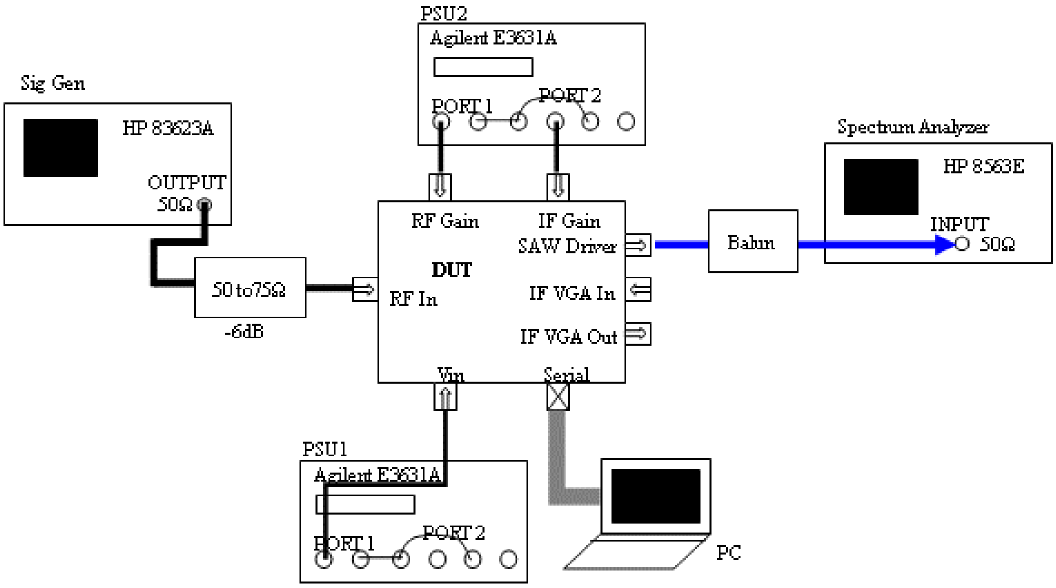
The 2^{nd} image lies at: $F_{2nd\text{-}image}=F_{in} + 2 \times 2^{nd}IF$

Where the nominal 2^{nd}IF is 300MHz

The 3^{rd} image lies at: $F_{3rd\text{-}image}=F_{in} + 2 \times 3^{rd}IF$

Where the nominal 3^{rd}IF is 44MHz

Instrument set up:



Measurement Procedure:

a) Ensure the DUT is initialized and the synthesizer is programmed for channel 59.

b) Set the Sig Gen for the wanted signal frequency (399MHz) for channel 59. Ensure the peak seen on the spectrum Analyzer is at least 10dB above the noise floor. Record the Sig Gen power output (Pin1).

c) Measure & record (Pout1) the power reading for the peak close to 44MHz on the Spectrum Analyzer, using the marker.

d) Set the Sig Gen for the 2nd image frequency of 999MHz.

e) Increase the power of the Sig Gen until the Spectrum Analyzer marker reads the same as Pout1, for the peak close to 44MHz. The exact frequency may be different in (d) and (b), due to crystal frequency offset.

f) Record the Sig Gen power output (Pin2).

Repeat (c) through (e) but for a Sig Gen frequency of 487MHz. Record Sig Gen power as Pin3.

Calculations:

2nd Image rejection = Pin2 – Pin1.

3rd Image rejection = Pin3 – Pin1.

Measurement Result:

Through the mixing process, two frequencies will be mixed to the same IF. One is the wanted and the other that we don’t want is called the image. Applying two different signal with the same amplitude, wanted and its image respectively, and then measure the IF output. The difference of these two output signals is the image rejection (Figure 4).

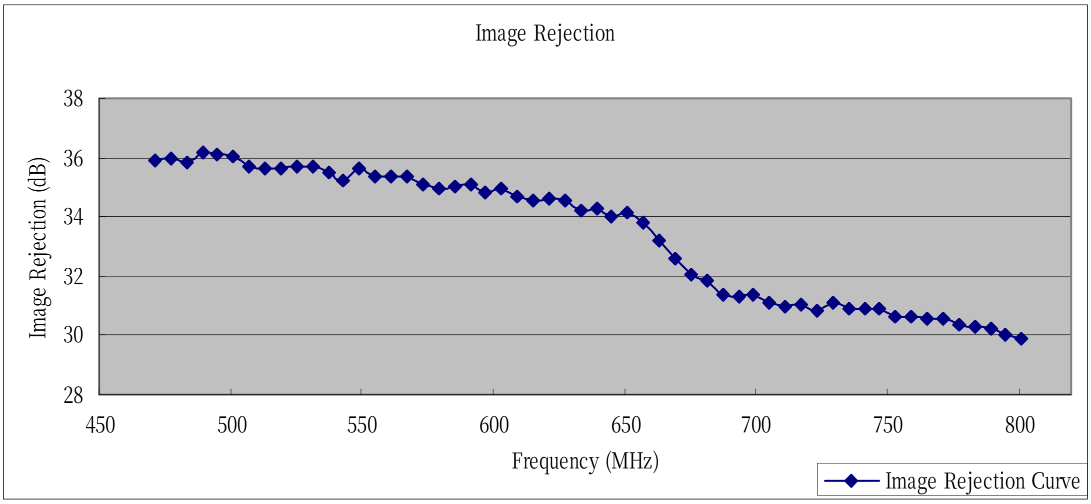
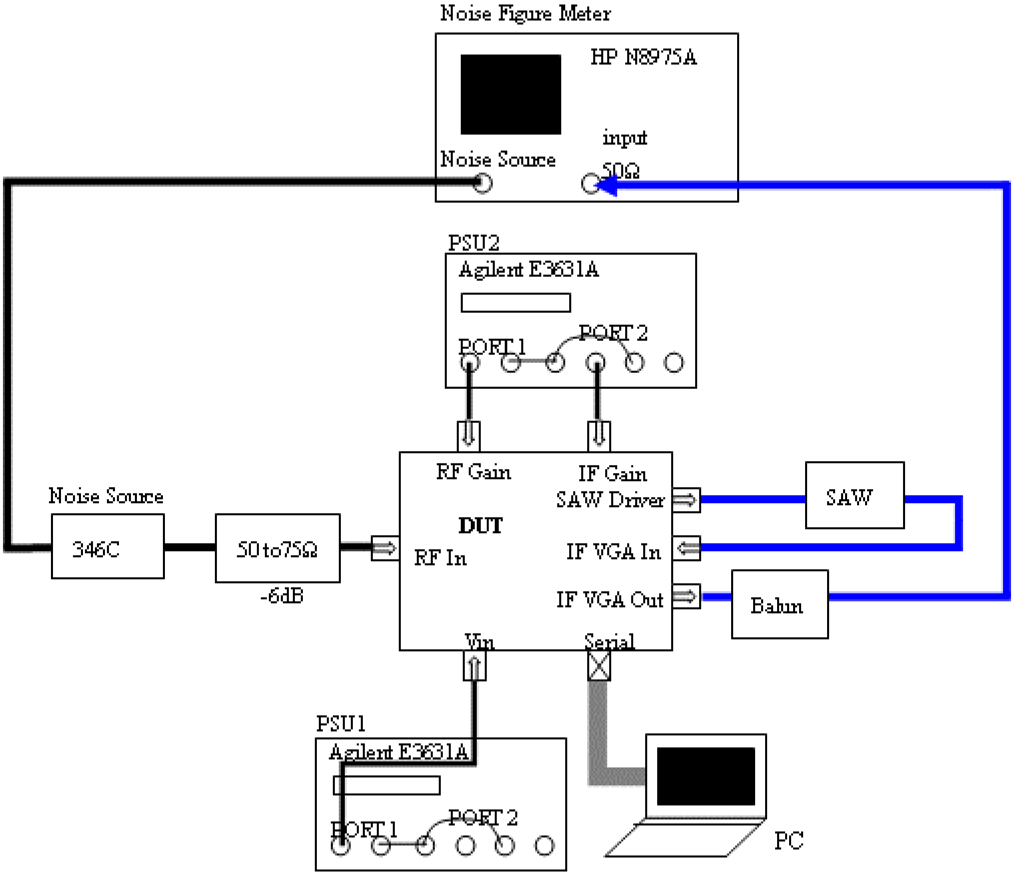


Figure 4

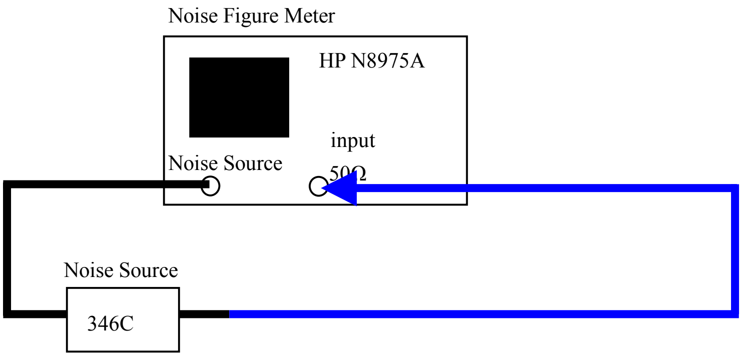
4. Noise Figure and Power Gain

Instrument set up:



Measurement Procedure:

Select heterodyne down-converter mode for the Noise Figure Meter. Ensure the noise source file (346C) is installed in the Noise Figure meter (Agilent N8975A). Set the RF (501MHz) and IF(44MHz) frequency. The Calibration setup is shown below:



After calibration, the gain and noise figure shown on the Noise Figure Meter should be 0dB. Connect the noise source to the RF input of the DUT via the impedance transformation and connect the input of Noise Figure Meter to the VGA output via Balun transformer as shown in the initial setup. The Noise Figure Meter will show $Gain_{total}$ and NF_{total} directly. The authentic NF_{dut} will be calculated in the next subsection.

Calculations:

NF_{total} is the noise figure for the entire system. The losses associated with the input are subtracted from the noise figure.

$$NF_{dut} \cong NF_{total} - P_{loss\text{-}at\text{-}input}$$

Note: The losses associated with the output are ignored for noise figure calculation.

Measurement Result:

Noise figure is the amount of noise source (in dB) that is added to the signal path. The NF can be simply measured by Noise Figure Meter, and the Noise Figure Meter will show $Gain_{total}$ and NF_{total} directly. The result of NF_{total} measured has shown in figure 5. The result of $Gain_{total}$ measured from this method has shown in figure 2.

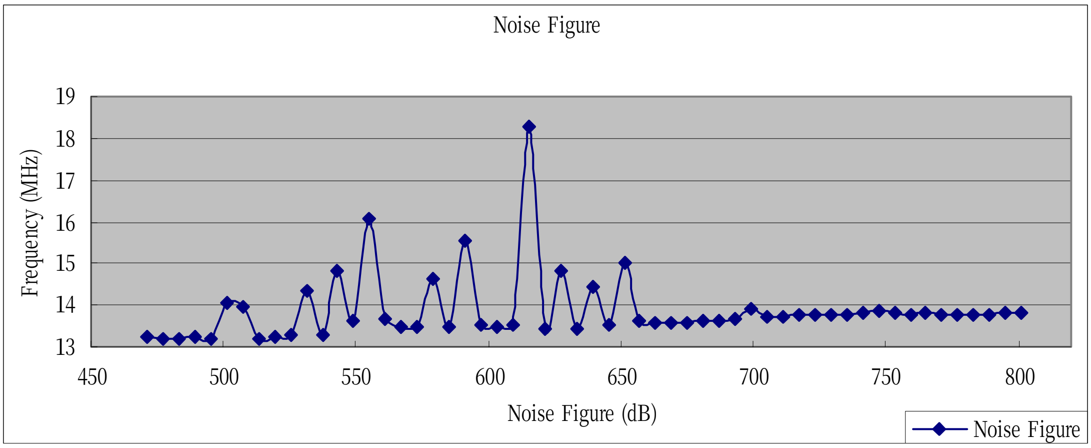
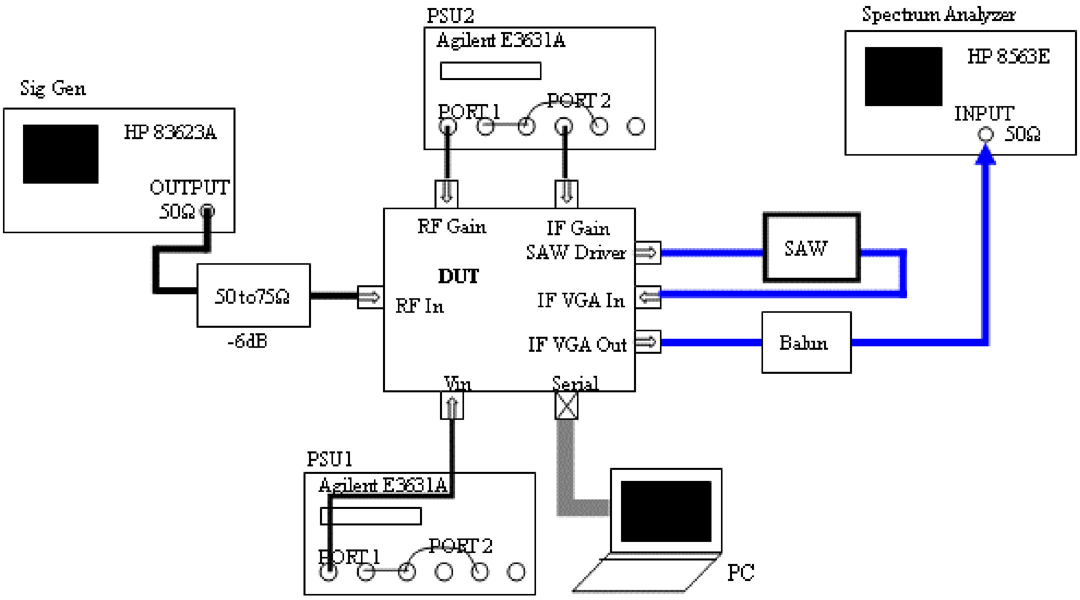


Figure 5

5. Phase Noise

Instrument set up:



Measurement Procedure:

a) Ensure the carrier is present on the Spectrum Analyzer display, near 44MHz and is above 0dBm.

b) Set the marker on the carrier and hit delta marker. Move the delta marker to f_m which is one of the following three offsets frequencies

   a. 10KHz
   b. 100KHz
   c. 1MHz

Calculation:

The Phase Noise at f_m (dBc)=

power difference between carrier and $f_m - 10\log_{10}$(resolution bandwidth of SA)

Measurement Result:

Phase noise is defined as the single sideband power due to phase fluctuations referenced to the carrier frequency power. That is in a 1 Hz bandwidth and at a frequency, f_m Hz, from the carrier. This divided by the signal's total power and expressed in dBc/Hz.

The Phase Noise at f_m =

Power difference between carrier and $f_m - 10\log_{10}$(resolution bandwidth of SA)

(1) Phase Noise at an offset of 10000Hz

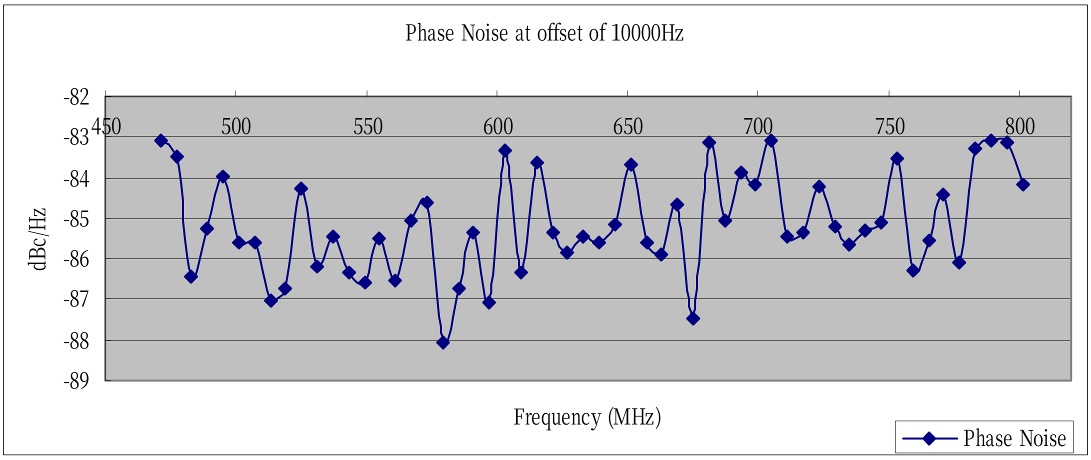


Figure 6

(2) Phase Noise at an offset of 100000Hz

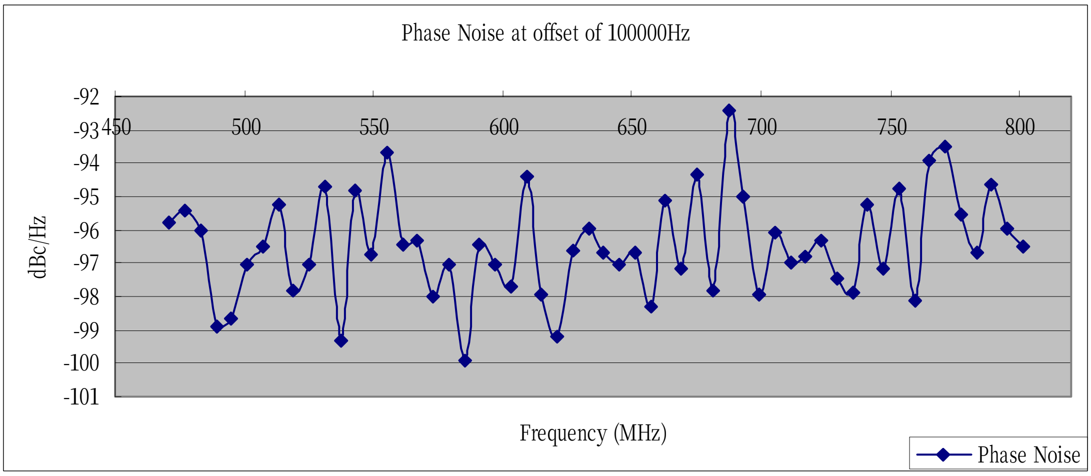
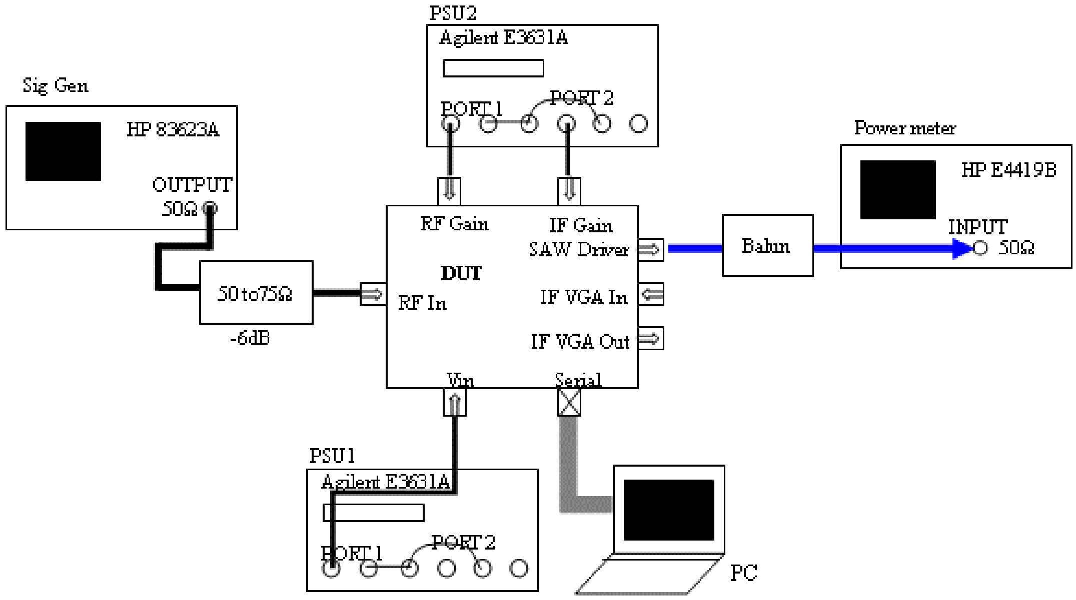


Figure 6

6. 1dB Compression Point

Instrument set up:



Measurement Procedure:

For this measurement the gain of the DUT is measured at a point well below the expected 1dB compression point. The input and output power at this point are noted as reference power levels. The input power is then increased and the output power measured. When the delta in output power(between the new value and the reference)is 1dB less than the delta in input power, then the input power is noted. Note that the real input 1dB point is that input power minus any losses in the system between the IC and the Sig Gen.

a) Set the Sig Gen. power level much below the expected input 1dB point and note it as P_{inref}. Read out the output power and record it as P_{outref}.

b) Increase the power level at the Sig Gen until

$(P_{in}-P_{inref})-(P_{out}-P_{outref})=1dB$.

Record P_{in} at this point as P_{1db}'.

Calculations:

The losses have to be incorporated to get the true 1dB point of the IC.

$1dB = P_{1db}' — P_{loss-between-IC-and-SigGen}$

Measurement Result:

The input 1dB compression point is the power level applied to the input of the DUT where the output power has reduced by 1dB from its linear gain. The measurement result is shown in figure 7.

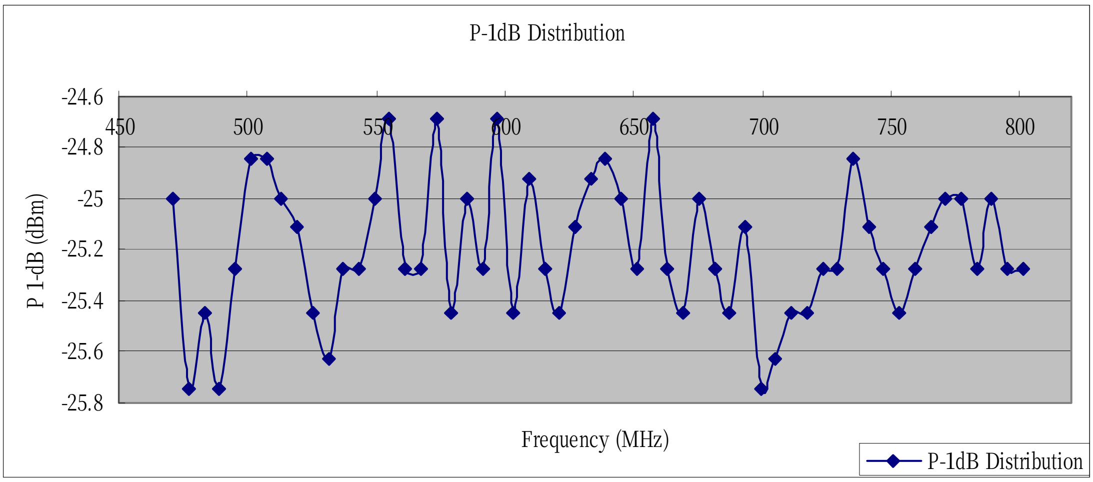


Figure 7

TV Tuner Design：

[Norsworthy 01] John Norsworthy “ Broadband tuner for modern systems ” *RF Design Magazine*, August 2001.

[Super Scanner] “ Super Scanner 45-860MHz with 0.01Hz stepsize ” web page, *http://hem.passagen.se/communication/supertuner.html*

[UV916] “ 45-860MHz Radio receiver based on UV916-tuner ” web page, *http://hem.passagen.se/communication/uv916rec.html*

[VCRTV] “ VCR and TV-tuners web page, *http://hem.passagen.se/communication/tuner.html*

TV Tuner Testing：

[GIE 00] “ GIE 463 Noise/Final Test Extender ELW ” Internet URL www.gie-rf.de GIE mbH, Mannheim 2000.

[Mini 03] Mini Circuits Inc., “ Characterizing Phase Noise ” RF Design Magazine, January 2003.

RF Design 基本原理：

[ETEK 01]育英科技有限公司,*射頻電路設計實習,* 滄海書局,2001.

[Haykin 01] Haykin,Simon, *Communication System* 4th edition, John Wiley&Sons, Inc. 2001

[Razavi 98] Razavi, Behzad, *RF Microelectronics*, Prentice-Hall PTR, 1998.

Analog/Mixed-Signal and RF Testing:

[Asami 02] Koji Asami, Yasuo Furukawa “ WCDMA Testing with a Baseband/IF Range AWG ” *Proc. IEEE International Conference*，2002.

[Barnett 01] Barnett, Thomas S.; Singh, Adit D.; Nelson, Victor P., “Estimating burn-in fall-out for redundant memory,” *Proc. IEEE Int’l Test Conf.*, pp. 340-347, 2001.

[Burns 01] Burns, M. and G.W. Roberts, An Introduction to Mixed-Signal IC Teset and Measurement, Oxford, 2001.

[Bushnell 00] Bushnell, Michael L, *Essentials of Electronic Testing, for digital, memory &mixed-signal VLSI circuits.* SCI-TECH Publishing Co., Ltd 2000.

[MacKay 02] Kevin M MacKay “ Testing Wireless Local Area Network Transceiver Ics at 5GHz ” *Proc. IEEE International Conference,2002.*

[Ferrario 02] John Ferrario, Randy Wolf, Steve Moss “ Architecting Millisecond Test Solutions for Wireless Phone RFIC’s ” *Proc. IEEE International Conference,*2002.

[Daasch 01] Daasch, W. R. and Cota, Kevin; McNames, James; Madge, Robert, “Neighbor selection for variance reduction in I_{DDQ} and other parametric data,” *Proc. IEEE Int’l Test Conf.*, pp. 92-100, 2001.

[Ferrario 01] John Ferrario, Randy Wolf, Hanyi Ding “ Moving from Mixed Signal to RF Test Hardware Development”*Proc. IEEE International Conference,*2001.

[Ozev 01] Ozev,S. Gaard,C. Orailoglu,A.“Testability implications in low-cost integrated radio transceivers：a bluetooth case study”*Proc. IEEE International Conference,*2001.

[Nam 01] Hui S. Nam, Bernard Cuddy, and Dieter Luecking “ A Phase Noise Spectrum Test Solution For High Volume Mixed Signal/Wireless Automatic Test Equipments ” *Proc. International Test Conference,*2001

[Sign 97] Singh, A. D. ,” Comprehensive Wafer Oriented Test Evaluation (WOTE) scheme for the IDDQ testing of deep sub-micron technologies,” IEEE International Workshop on IDDQ Testing, pp. 40-43, 1997.

手冊

[GAME 99] *General Analysis of Mismatch Effects, user’s manual*，1999.

Others：

[3GPP]“3GPP-Third Generation Partnership Project”web page, http://www.3gpp.org/ *3GPP Technical Specification 25141,*Base station conformance testing.

[Juran 99] Juran, J. M. (editor), A. B. Godfrey, Juran’s Quality Handbook, 5th edition, McGraw Hill, NY, January 1999.