行政院國家科學委員會專題研究計畫　期中進度報告

射頻電路系統前瞻測試技術開發(1/3)

計畫類別：個別型計畫
計畫編號：NSC92-2218-E-009-012-
執行期間：92 年 08 月 01 日至 93 年 07 月 31 日
執行單位：國立交通大學電機與控制工程學系

計畫主持人：蘇朝琴

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中　華　民　國 93 年 5 月 31 日

行政院國家科學委員會補助專題研究計畫 **□成果報告** **☑期中進度報告**

射頻電路系統前瞻測試技術開發

計畫類別：☑ 個別型計畫　　□ 整合型計畫
計畫編號：NSC － 2218 － E － 009 － 012 －
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計畫主持人：蘇朝琴
共同主持人：無
計畫參與人員：無

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執行單位：國立交通大學電機與控制工程學系

中 華 民 國 93 年 5 月 28 日

射頻電路系統前瞻測試技術開發

計畫編號：NSC 92-2218-E-009-012-
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摘要

推導和實作一種利用產生以及接收中頻信號來測試與偵測混合信號電路中之中頻與射頻電路模組的方法。利用數位信號處理器產生測試訊號，經由數位類比轉換器產生較低頻的中頻測試訊號輸入至待測的發射器之中頻與射頻模組。在接收端，利用類比數位轉換器擷取波形，接著傳送到數位信號處理器作分析。利用這個方法可以大幅節省測試成本，因為所需之各項元件均已內建在原本之電路中。且我們不需要額外的射頻自動化測試設備。

Abstract

To derive and implement a methodology to test and debug IF and RF modules using the IF signal generated and received at the mixed signal modules. Low IF test signal is generated by DAC from DSP module and fed to the IF/RF module at transmitting end. At the receiving end, the response waveform is captured by the ADC and transported to DSP for analysis. By this method, the test cost is minimal because the AD/DA converters and DSP modules are built in already. There is no external RF ATE needed.

1. Introduction

After years of development, wireless communication has become essential for telephony and data communication. In mobile communication, there are many different standards and systems in use simultaneously, such as GSM, DECT, PHS, GPRS, WCDMA, and CDMA2000. In data communication, Bluetooth and 802.11 are competing for market acceptance. Therefore, RF circuit design and applications are wide and extensive. Furthermore, in wired communication, fiber and high speed copper wired serial links are all fall in RF frequency range. Due to its high added value, design houses, foundry, and system houses are focus on this sector of semiconductor industry in order to make high profit margin. However, the testing of RF circuits and systems are not well developed as design and manufacturing.

Traditionally, RF circuit and system test are achieved in two ways. The first one is to use specialized instrument to send and receive high quality RF signals to determine the circuit parameters [3, 4, 5] and go-no-go of the circuits. The disadvantage is the cost overhead. The instrument in RF range is not only expensive but also very difficult to operate and maintain. It seems that it is difficult to meet the requirement of low cost mobile phone handset or wireless local area network. The second type uses the loop back mechanism [1, 2] for the test. The digital data is sent by the transmitter and received and recovered by the receivers. It checks the bit-error rate (BER) of the received data to determine the function of the CUT. It has the properties opposite to the first method. The test equipment cost is low. But, the test time is very long.

2. RF Test Methodology

We would like to propose an RF test methodology which takes the advantage of the RF system architectures nowadays. We utile the built-in analog/digital (AD/DA) converters and digital signal processors (DSP) as the test resources for the test.

2.1 RF Test Architecture

The DSP is responsible for sending digital IF signal to the DAC. Then DAC coverts the discrete signal into analog signal. After that, it is up converted into RF band by the RF transmitter module. The RF receiver module receives the RF signal and down converts it into IF band. The ADC converts it into digital form. Finally, the DSP collects the received digital signal and use DSP techniques to extract the circuit parameters. The DSP techniques will be based on the “intrinsic response extraction”. The simple architecture of wireless system is shown in Figure 1.

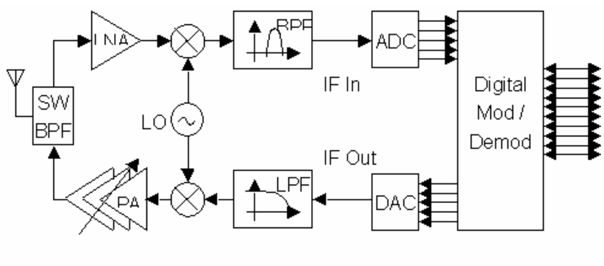


Figure 1. Wireless RF/IF and mixed signal circuit

2.2 RF Test Method

We use convolution technique to develop our method. When convolution in time domain,

$$y(t) = x(t)*h(t)$$

It takes multiplication in frequency domain

$$Y(s) = X(s)\,H(s)$$

$$H(s) = Y(s) / X(s)$$

$$H(s)_{db} = Y(s)_{db} - X(s)_{db} \text{ (log scale)}$$

The RF block in wireless transmission system is shown in Figure 2.

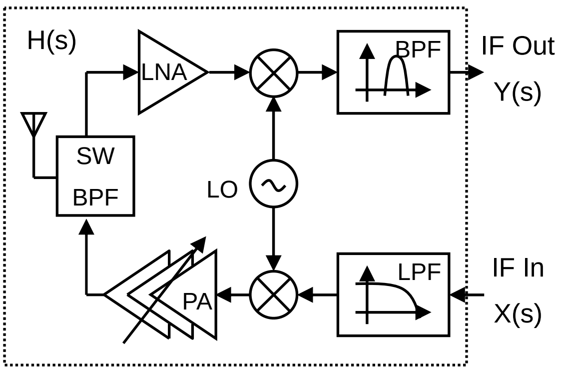


Figure 2. RF block in wireless transmission system

Use build-in DAC in the transmitter to generate x(t), and receive y(t) by ADC in the receiver. Then use FFT to convert time domain signal, x(t) and y(t), to frequency domain, X(s) and Y(s). Finally we can easily find system transfer function H(s) = Y(s) / X(s).

There are many king signals can be used in our testing method. The single tone sinusoidal waveform is easy to test some frequency response. The two tones test can test harmonics and intermodulation distortion. The sinc function is a band limited signal. It has a flat spectrum in some band. However, the power density of sinc waveform is too small, so we can use multitone signal to test our circuits more efficiency.

3. Emulation and Measurement Results

To verify the proposed methodology, use EDA Tools to simulate and measurement by bench equipment like a waveform generator and a spectrum analyzer.

3.1 Filter Simulation and Measurement

We have use discrete components to build a simple 1^{st} order filter environment. The circuit diagram is as the one shown in Figure 3.

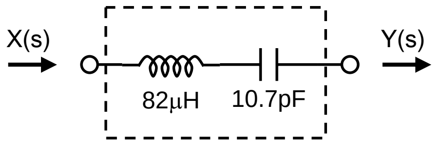


Figure 3.1^{st}-order filter, H(s)

Use EDA-tool to simulate this filter, the simulation result is shown in Figure 4.

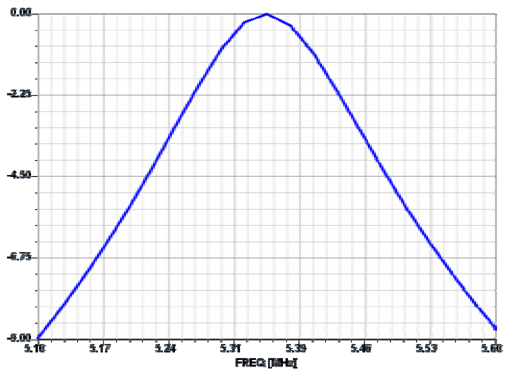


Figure 4. 1^{st}-order filter simulation result

Generate the input signal x(t) by using Agilent 33250A Function / Arbitrary Waveform Generator. The test signal is sinc function which bandwidth is 500 kHz and center frequency is 5.45 MHz. Then feed test signal to the emulation circuit, 1st-order filter. Finally, measure input Signal, X(s), and filter output, Y(s), by signal analyzer. The measurement result is shown in Figure 5.

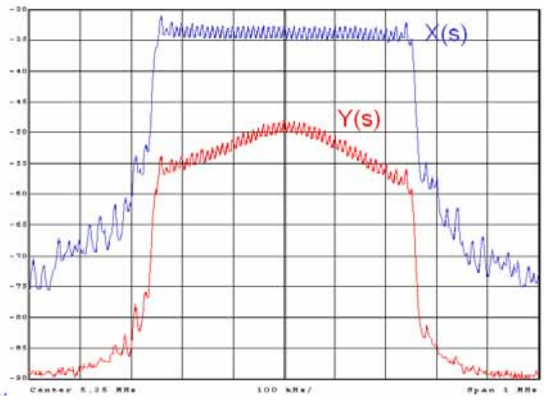


Figure 5. Measurement result

Use Matlab to calculate H(s) = Y(s) – X(s), H(s) is system response shown in Figure 6.

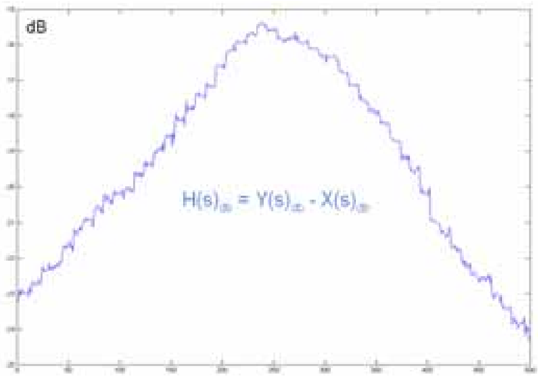


Figure 6. Transfer function of filter

Also take measurement by the HP Network Analyzer. And compare two methods in the frequency domain shown in Figure 7.

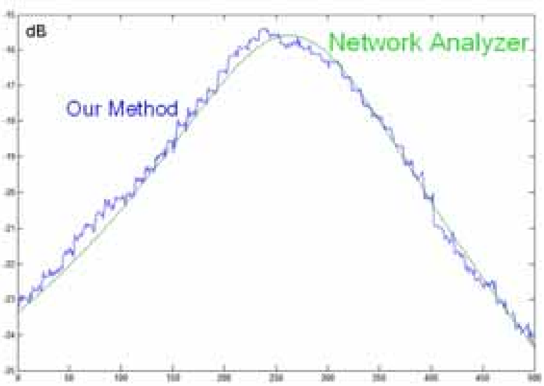


Figure 7. Comparison with a Network Analyzer

The difference between our method and a network analyzer measurement result is small. It is reduce the cost of a network analyzer and extra time for calibrate the instrument.

3.2 RF Front-end Simulation

This section we build whole RF front-end system from the DAC generates IF a signal to the ADC receives IF signals. And use Agilent ADS tool to simulate our circuits. The schematic is shown in Figure 8. The voltage source, V_{in}, generate desire IF signals and through a filter, a up-converter mixer, and a power amplifier to the channel. Then RF signal fed in a low noise amplifier, a down-convert mixer, and a filter to the IF output, V_{out}. The simulation for ideal components is shown in Figure 9. It cans analysis results at each node.

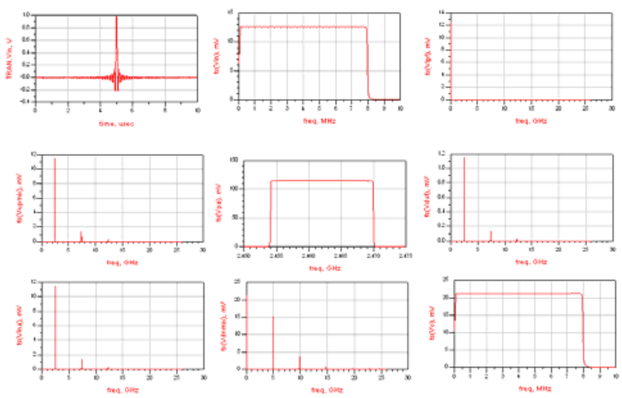
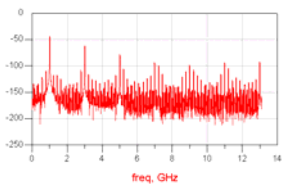


Figure 9. Ideal RF Front-End simulation results

With compare V_{in} and V_{out}, can determinate which component and which specification has errors or degrade. The ideal mixer spectrum is shown in Figure 10 and the mixer with 1 dBm third interception point shown in Figure 11.



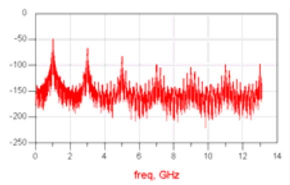


Figure 10. Ideal Mixer Figure 11. IP3=1 dBm

There are two or more amplifiers in the RF front-end. In transmitter end, the power amplifier is key component to amplify signal to antenna. In receiver end, the small signal is amplified by low noise amplifier. The noise figure and gain is the important specifications for amplifier.

Test some specifications of a non-ideal

power amplifier in a wireless LAN transceiver. First, generate the sinc function with 8 MHz bandwidth and up-converter to 2.462 GHz by using an ideal mixer. Second, measure the output of the power amplifier. Finally, calculate the gain of power amplifier by subtracting the output from the input.

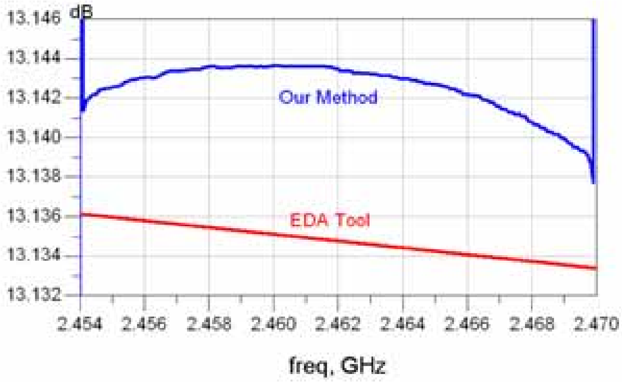


Figure 12. The gain of a power amplifier

Compare with the simulation result of frequency sweep in an EDA Tool shown in Figure 12. The error between two methods is very small which is about 0.06 dB. It is caused by precision of numerical transformation.

4. Conclusions

In this paper, we focus on the IF and RF testing. Low IF test signal is generated by DAC from DSP module and fed to the IF/RF module at transmitting end. At the receiving end, the response waveform is captured by the ADC and transported to DSP for analysis. The DSP is used as the engine for test generation and response analysis digitally.

To derive and implement a methodology to test and debug IF and RF modules using the IF signal generated and received at the mixed signal modules. The sinusoidal single tone or multi-tone signal in conjunction with Fourier transform can be used to test amplifiers, mixers, and oscillators. While, sinc function based test waveforms can be used to test filters effectively.

By this method, the test cost is minimal because the AD/DA converters and DSP modules are built in already. There is no external RF ATE needed.

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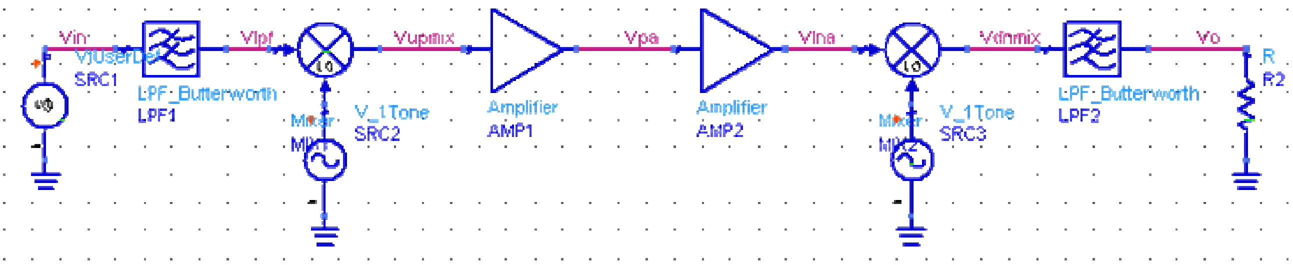

Figure 8. Schematic of RF Front-end