UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

Novel Noise and Radiation Pattern Measurement Technique Using Bit Error Rate (BER) for Active Integrated Antenna (AIA) System

By

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ABSTRACT

A transmit and receive system including up/down conversion system is designed in order to measure the Bit Error Rate (BER) of the system. The transmitter (up-converter) is designed at the radio frequency (RF) 2.4GHz. The front-end superheterodyne receiver (down-converter) is designed to accept the radio frequency from the transmitter and simulated in Advanced Design System (ADS). Harmonic Balance Simulation is performed to the system to obtain the conversion loss of the system, the minimum value of noise figure (NF), and the maximum values of gain. The down-converter is then fabricated on the FR4 type printed circuit board (PCB) for hardware testing and measurement for BER. The signal generator is used as a transmitter to transmit the signal to the receiver. The results of received signal are compare to transmit signal by connected it to the oscilloscope to view the waveforms. The waveforms data are saved for BER calculation at Microsoft Excel. The BER is measured by varies the power of the transmitter and the power of the local oscillator (LO). The minimum power levels that are just above the noise level are investigated.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Overview

In a simple communication system consists of a transmitter and a receiver. The purpose of a communication system is to transmit information signal from the transmitter and get back the original signal from the receiver without distortion. Thus, the performance of a communication system is important and should be investigated.

The performance of a communication system depends on the presence of noise. Noise is a crucial consideration in designing or assessing the performance of virtually any electronic device or system that involves detection or processing of a signal. This includes communications systems, such as cellular phones and home entertainment systems, as well as systems with internal signal detection and processing, such as guidance and tracking systems or electronic test equipment (Jim Randa, 15 July 2005)

The sources of noise may be external to the system such as atmospheric noise, galactic noise, man-made noise, or internal to the system. The noise disturbs the transmission and processing of the signal in communication systems and over which we have incomplete control.

For digital communication, the performance measurement is usually bit-error rate (BER), which quantifies the reliability of the entire radio system from "bits in" to "bits out," including the electronics, antennas and signal path in between (Gary Breed, January 2003).

1.2 Objective

The main purpose of this project is to design a transmit and receive system including up/down conversion system. The single stage down converter is designed and simulated using Advance Design System (ADS) simulation tools and fabricated on printed circuit board (PCB). The performances of transmit and receive system is then measure with Bit Error Rate (BER) measurement in order to estimate the percentage of error of the signal at the receiver compare to the signal at transmitter. The BER is measured by varies the power of the transmitter and the power of the local oscillator (LO). The minimum power levels that are just above the noise level are investigated

1.3 Project Implementation

There are four steps or procedures in order to accomplish the project. Flow chart below shows the implementation of the project.

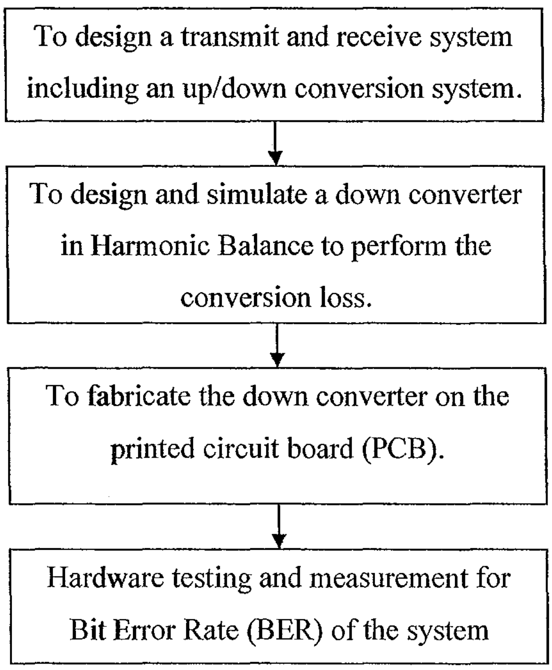


Figure 1.1: Implementation of the project

1.4 Equipments and Components

This project is devided to two part which is software and hardware. For the software part, the main software is Advance Design System (ADS) used for simulation. Another software used is Microsoft Excel for BER calculation. For hardware part, FR4 types printed circuit board (PCB) with the dielectric constant, 5.4 and dielectric thickness, 1.8mm is used. Components to designed a single stage down-converter include chip MGA-85563 low noise amplifier (LNA), chip IAM-91563 down-converter, surface mounted device (SMD) capacitors and inductors, as well as SMA connectors. Other components for BER measurement setup include IF bandpass filter and amplifier, ZFMIQ-70D I/Q demodulator and LM339 voltage comparator.

The equipments used for BER measurement include three signal generators which are Agilent E4433B 250 kHz-4 GHz ESG-D series signal generator, Agilent E4422B 250 kHz-4 GHz ESG-D series signal generator and Agilent 8648A 10 kHz-1000 MHz signal generator, three power supplies, a function generator and LeCroy Wavesurfer 64Xs 600 MHz oscilloscope 2.5Gs/s.

1.5 Organization

The report has been divided into a total of five chapters. Start with Chapter 1 is an introduction with the objective of the project. The implementations of the project on the steps or procedures are discussed. Besides, the equipments and components use for this project are also included.

Chapter 2 discusses the definition, thē standards and the uses Wireless Fidelity (Wi-Fi) technology. Besides, the advantages and disadvantages of Wi-Fi are also included in this chapter.

Chapter 3 provides an in depth look into the transmitter architecture and three common receiver architectures. The detail processes for front end of superheterodyne receiver are also included in the end of the chapter. The receiver performances such as gain and sensitivity, Noise Figure (NF), Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER) are also discussed in this chapter.

Chapter 4 discusses the design of transmitter (up-converter) and receiver (down-converter). The single stage down-converter includes low noise amplifier (LNA), mixer and low pass filter are designed and simulated using Advance Design System (ADS) to estimate the noise figure (NF), conversion gain and conversion loss of the system. The down-converter is then fabricated for bit error rate (BER) measurement in next chapter.

Chapter 5 describes the set up of transmit and receive system for BER measurement. The transmitted power is starting with a high power that is no errors occurred. The transmitted power is then reduced until it starts to produce errors and BER is counted at each input power level. The minimum power level that is just above the noise level is investigated.

Chapter 6 summarizes the whole project and provides a few ideas for future work.

CHAPTER 2: NOVEL NOISE MEASUREMENT TECHNIQUE OF AIA

1. INTRODUCTION

One of the most important characteristics when evaluating a communication system performance is the effect of noise. This is the most important consideration in wireless systems because noise ultimately determines the threshold for the minimum signal level that can be reliably detected by a receiver. Noise is a random process due to several sources such as thermal noise generated by RF components and devices, noise generated by the atmosphere and interstellar radiation and man-made interference [63]. Noise power is introduced in RF and microwave systems from the external environment through the receive antenna and internally by the receiver circuitry.

Only few noise performance techniques for integrated active antennas have been reported [64-66]. Although the noise performance is of great importance in practical application it gets little attention. The major difficulty is probably due to the lack of measurement techniques to characterise the noise performance of such antennas.

An important parameter for describing the noise characteristic is G/T, which is defined as the ratio of the gain of the antenna and the antenna noise temperature towards the cold sky plus the effective noise temperature of the receiver. This is for large aperture antennas for Earth stations in satellite communications [66]. But for mobile communications or applications where the cost and size are prime considerations, the directivity of the antennas is usually low. Therefore, G/T is not a suitable parameter for characterising the noise performance of such antennas. This is because the external noise received by the radiator is much greater than that from the large aperture antennas directed to the cold sky and it strongly dependent on the environment and the orientation of the antenna.

Therefore the objective of this chapter is to present a new technique in characterising noise performance of the AIA IR system. The first part of the chapter describes the relevant noise parameters that can be used to develop the new technique, while section

8.3 explains the development of a technique for characterising the noise performance of the AIA IR system developed and experimental measurements are described.

2. NOISE MEASUREMENT TECHNIQUES

The performance of the conventional receiver is typically characterised by two parameters, the noise figure of the RF-to-IF frequency converter and the bit error rate (BER) of the demodulator. These two parameters are usually specified separately in a procurement specification.

2.1 Noise Figure Measurements

Noise figure is a unique parameter because it is not only suitable for characterizing the entire system but also the individual system components such as pre-amplifier, mixer and IF amplifier that make up the system. The noise figure of the overall system can be determined from the noise figure and gain of the system components. The sensitivity of a receiver can be estimated from system bandwidth once the noise figure is known. A low noise figures provides improved signal/noise ratio for analog receivers and reduces bit error rate in digital receivers. As a parameter in a communications link budget, a lower receiver noise figure allows smaller antennas or lower transmitter power for the same system performance [67]. Noise figure is defined as the ratio of signal/noise power ratio at the input of the DUT, SNR_{in} to the signal/noise ratio at the output of the DUT:

$$F = \frac{(SNR_{in})}{(SNR_{out})} \tag{8.1}$$

Noise figure is also given in terms of noise temperature as described as

$$F = 1 + \frac{T_e}{T_0} \tag{8.2}$$

where T_e is the effective or equivalent input noise temperature of the device and T_0 is the reference temperature which is defined as 290K. T_e is given by

$$T_e = \frac{N_0}{GkB} - T_0 \tag{8.3}$$

where N_0 is the output noise power, $k = 1.38 \times 10^{-23}$ which is the Boltzman constant, B is the bandwidth of the system and G is the receiver gain.

The noise figure for cascaded system, F_{cas} is given as:

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots\cdots \tag{8.4}$$

where F_1 and G_1 are the noise figure and gain of the first stage respectively and F_2 and F_3 are the noise figure of the second and third stage respectively.

2.2 BER Measurements

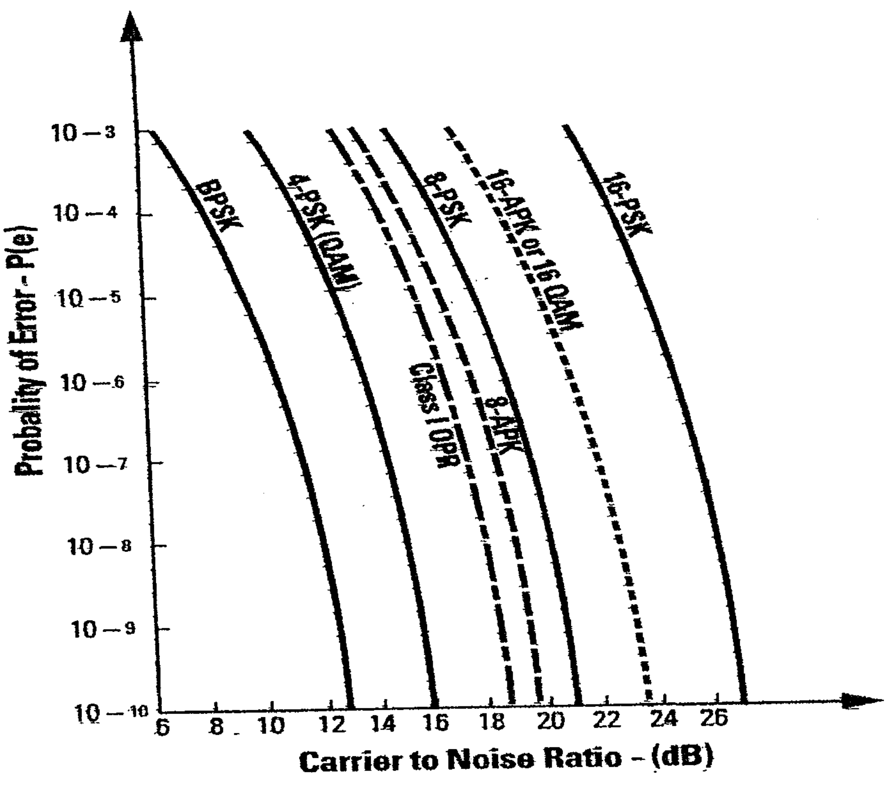


Figure 3 Probability of error, P(e) as a function of carrier-to-noise ratio, C/N (which can be interpreted as signal-to-noise ratio), for various kinds of digital modulation.

From Agilent Technologies, Application Note 57-1 2000 taken from Kamilo Feher, DIGITAL COMMUNICATIONS: Microwave Applications, ©1981, p.71

In this research, BER and noise figure will be the main parameters used in measuring the noise. BER is a quantitative reliability measure for digital communication systems. It is also known as the probability P(e) that any received bit is in error. Noise figure is related to BER in a non-linear way [68]. For example, as S/N ratio decreases gradually, the BER increases suddenly near the noise level where 1s and 0s becomes confused. Noise figure shows the health of the system but BER shows whether the system is dead or alive. BER changes by several orders of magnitudes for only a few dB changes in signal-to-noise ratio. This is indicated from Figure 8.1 below, which shows the probability of errors vs. carrier-to-noise ratio for several types of digital modulation.

BER is the major performance indicator for a receiver that processes a digitally modulated RF waveform. It is the probability P(e) that any received bit is in error. It is usually specified for a particular ratio of the energy-per-information bit, E_b to noise power density, n_o at the input of the demodulator. For BPSK modulation, BER is given by

$$BER = P(e) = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{n_o}}\right) \tag{8.5}$$

where it is related to the complementary error function written as

$$erfc(X) = 1 - erf(X) \tag{8.6}$$

where $erf(X) = \frac{2}{\sqrt{\pi}} \int_0^X \exp(-y^2) dy$. The complementary error functions are given in Appendix 2. Thus BER can be expressed as

$$BER = P(e) = \frac{1}{2}\left[1 - erf\left(\sqrt{\frac{E_b}{n_o}}\right)\right] \tag{8.7}$$

where E_b/n_o is related to the SNR and bit rate, R_b and bandwidth, B of the receiver as follows:

$$\frac{E_b}{n_o} = SNR \times \frac{B}{R_b} \tag{8.8}$$

Equation (8.8) is used for optimal receiver where the received signal goes into an integrator before a discriminator. The integrator should average the demodulated signal over one bit period. Therefore, it generates a signal proportional to the energy per bit and noise that is minimised as much as possible by the averaging process. As the data rate is changed, the integration time needs to be adjusted accordingly to maintain optimum performance. For the proposed technique, signal and noise integrations are both subject to the same filtering process, i.e the input see of the discriminator. Therefore in equation (8.8), $\frac{B}{R_b} = 1$. Thus, The probability of error, P_e for the case of two level bit rate is also given by

$$P_e = BER = \frac{1}{2} erfc(\sqrt{SNR}) \tag{8.9}$$

The noise in this active antenna consists of two parts, the external noise received by the patch-receiving antenna and the internal noise produced by the active and passive circuitry (including that generated by the loss in the antenna itself). A parameter describing the internal noise is very useful because it only depends on the active circuits and is independent of the environment. Since LNAs and image reject mixers are integrated with the passive power divider antenna, thus it is a nonseperable part of the active antenna. Therefore, it is impossible to measure the noise figure directly.

3 NEW NOISE MEASUREMENT TECHNIQUE USING BER

3.1 BER Experimental Setup

This research presents a new measurement technique for determining the noise figure of the attached LNAs and image reject system in a receiving active antenna by using BER to relate to noise figure. If the BER is known, the noise power at the output can be found and thus the system noise figure can be calculated. Similar experimental setup as I/Q demodulation setup is employed, with the addition of a voltage comparator as shown in Figure 4.

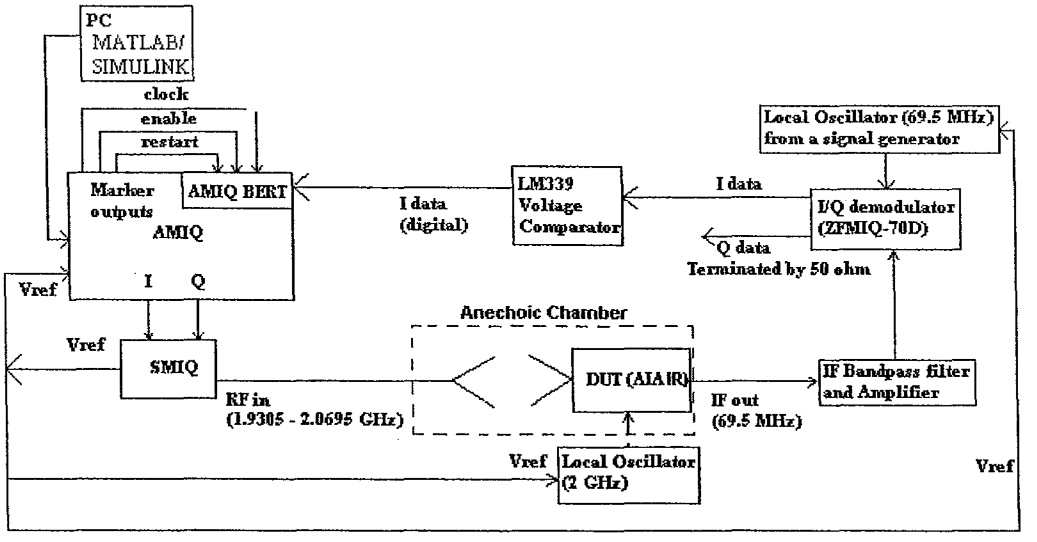
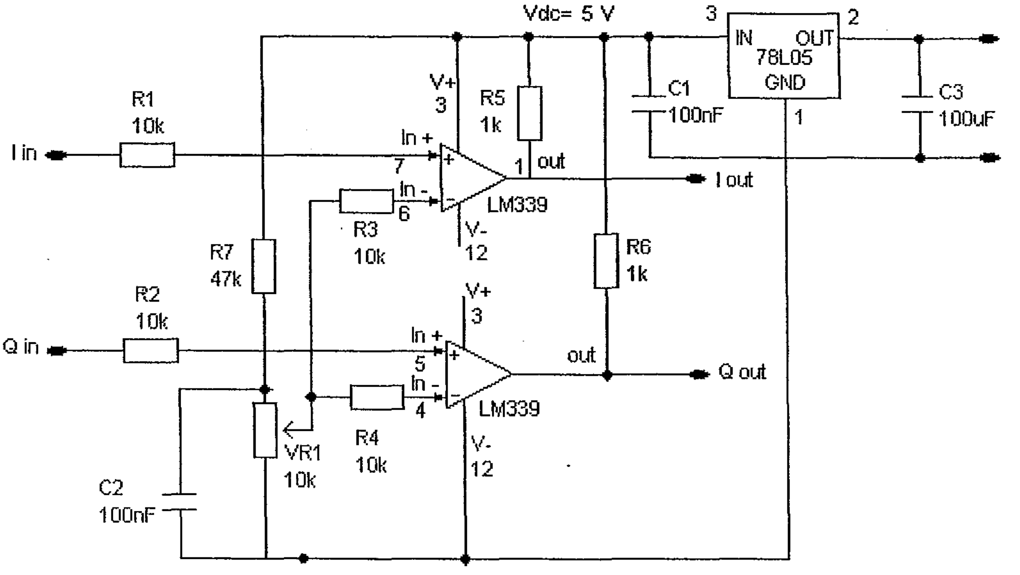
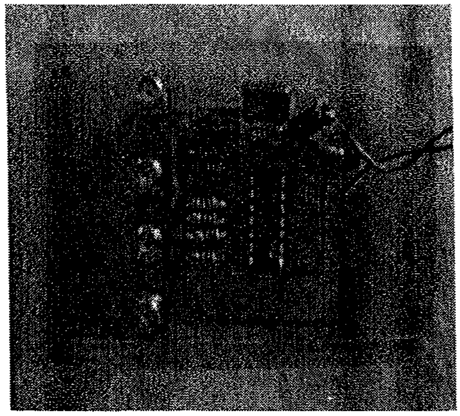


Figure 4 BER Experimental setup block diagram

LM339 is used in designing a voltage comparator as shown in Figure 5. It is biased at 5V and a dual comparator is used for the I and Q received signals. It is used as a peak detector or a signal squarer that turns other cyclical waveforms into square wave (TTL form). Voltage comparator works by taking in two analog signals and provides a binary output that is true if the voltage of one signal is bigger than that of the other and false if not [70].



(a)



(b)

Figure 5 (a) Schematic diagram (b) The fabricated voltage comparator

3.2 BER Measurements Proposed Analysis

3.2.1 BER relationship to Noise Figure

For the AIA IR receiver system, noise figure is determined once the system noise power is found.

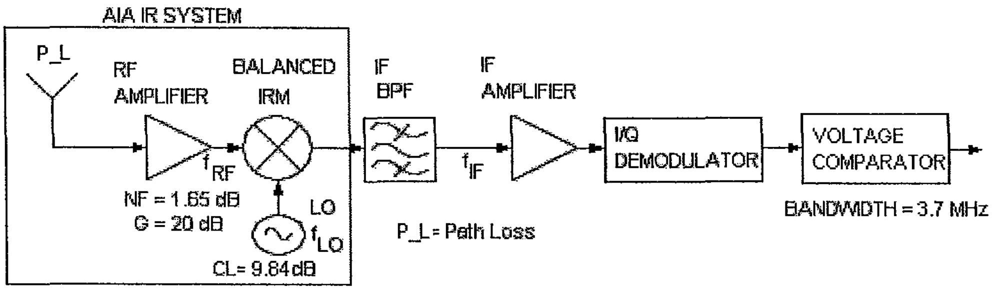


Figure 6 Receiver block diagram

The noise figure of the AIA IR system is given by

$$F_{AIAIR} = P\_L_{antenna}[F_{RFLNA} + \frac{CL_{mixer} - 1}{G_{LNA}}] \tag{8.10}$$

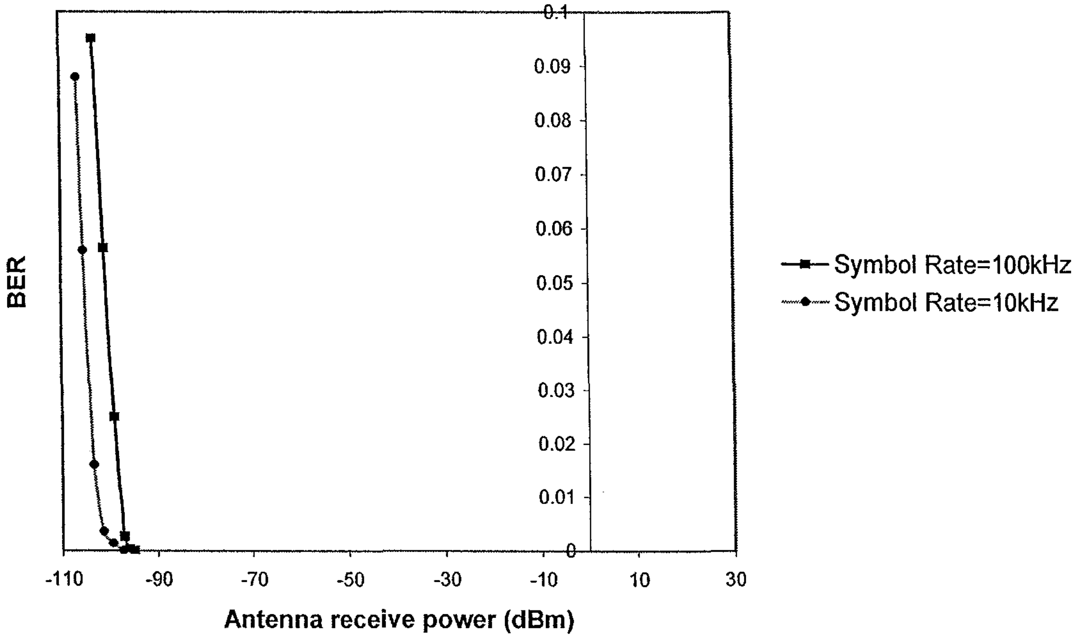
$$F_{AIAIR}(dB) = P\_L_{antenna}(dB) + 10\log_{10}(F_{RFLNA} + \frac{CL_{mixer} - 1}{G_{LNA}}) \tag{8.11}$$

which is contributed mainly by the antenna path loss and the noise figure of the RF LNA which is typically at 1.65 dB. Since, the LNA gains is about 20 dB, the noise figure terms is contributed mainly by the amplifier as shown below.

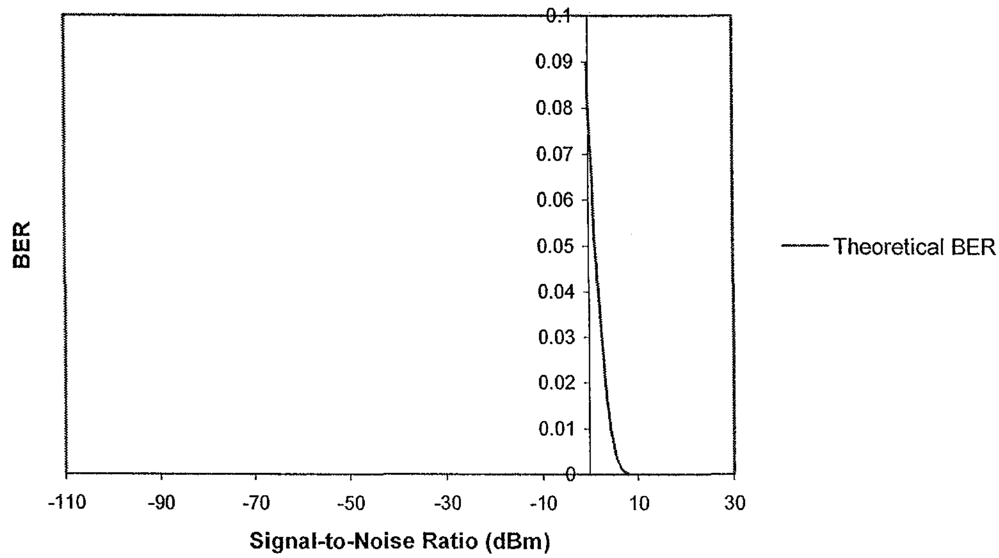
$$F_{RFLNA} + \frac{CL_{mixer} - 1}{G_{LNA}} = 1.46218 + \frac{9.638 - 1}{100} = 1.5486 = 1.90dB$$

The expected measured BER at two different symbol rates are plotted against the antenna received power level as shown in Figure 7. The theoretical probability of bit error in additive white gaussion noise (AWGN) is also plotted against signal to noise ratio, SNR as shown in Figure 7, which is expressed in equation (8.9). Equation (8.9) is used

The minimum antenna received power that is just above the noise level is found to be – 95.161 dBm. This result is measured at a comparator threshold voltage of 0V. It can be seen from Figure 1.5 that the measured BER is almost similar to theoretical BER. The longer the time period i.e. lower symbol rate, the more accurate the BER count which is shown by the measured BER at two different rates.



(a) Expected Measured BER against antenna receive power



(b) Theoretical BER against Signal-to-Noise Ratio

Figure 7 Comparison of the measured BER and theoretical BER

CHAPTER 3

TRANSMIT AND RECEIVE ANTENNA SYSTEM

3.1 Overview

In this chapter, the architectures of transmitter and receiver are discussed. There are three common receiver architectures: superheterodyne, direct conversion and DSP-based digital IF. The differences between these three receivers are discussed. The advantages and detail processes for front-end superheterodyne receiver are also included since it is designed in this project. The performance of the system such as gain and sensitivity, Noise Figure (NF), Signal-to-Noise Ratio (SNR), and Bit Error Rate (BER) are also discussed in this chapter.

3.2 Transmitter Architecture

The input signal is a signal with a frequency, f_m. The input signal is first goes through a low pass filter to remove frequencies beyond the passband of the channel. Then, the local oscillator signal with a frequency, f_{LO} is mixed with the input signal to produce modulated carrier. The mixer is commonly used to multiply signals of different frequencies in an effort to achieve frequency translation (R.Ludwig, P.Bretchko, 2000). The signal obtained after the mixer is a double sideband signal, which contain a lower sideband, f_{LO}-f_m, as well as an upper sideband, f_{LO}+f_m. The process is call up-conversion. The modulated signal with a high frequency is then amplified by the power amplified before transmitted to the antenna. Figure 3.1 shows the architecture of the transmitter (David M. Pozar, 1998).

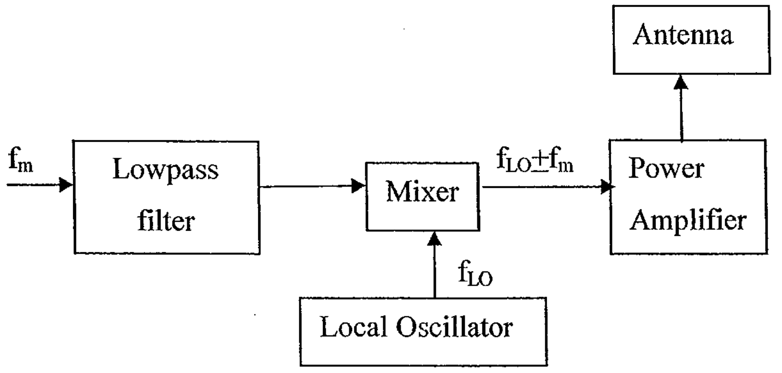


Figure 3.1: Transmitter architecture

3.3 Three Common Receiver Architectures

3.3.1 Superheterodyne Receiver

In this commonly-used architecture, out-of-band signals are reduced by a bandpass filter placed at the antenna input, follow by a low noise amplifier (LNA) and a mixer that converts the signal to Intermediate Frequency (IF). After the mixer, one or more stages of filters and amplifier perform channel filtering. The signal is then amplifier and downconverted to baseband for demodulation (Kal Kalbasi, 7 Oct 2002).

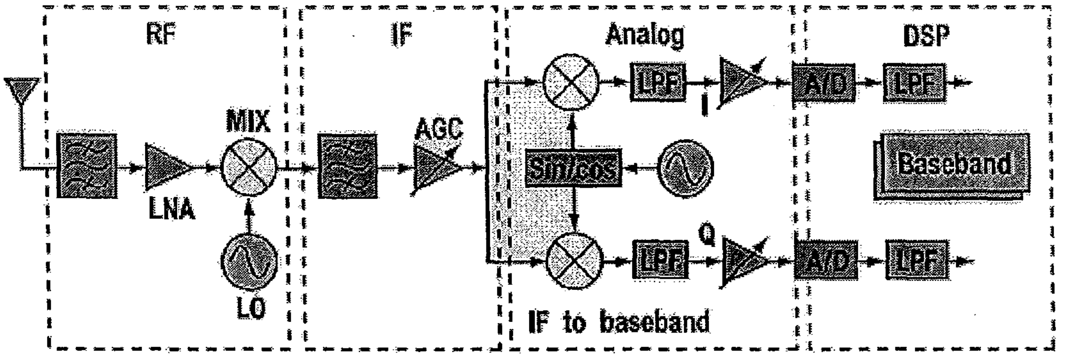


Figure 3.2: Superheterodyne receiver architecture

3.3.2 Direct Conversion Receiver

The direct conversion receiver architecture includes an RF bandpass filter, LNA, and mixer. The mixer, however, converts the signal frequency directly to baseband, which requires an accurate quadrature at the oscillator (LO), which is at the same frequency as the RF input. Other design challenges include dealing with the DC signals generated by the imbalances in the mixer, which can be difficult to filter (Kal Kalbasi, 7 Oct 2002).

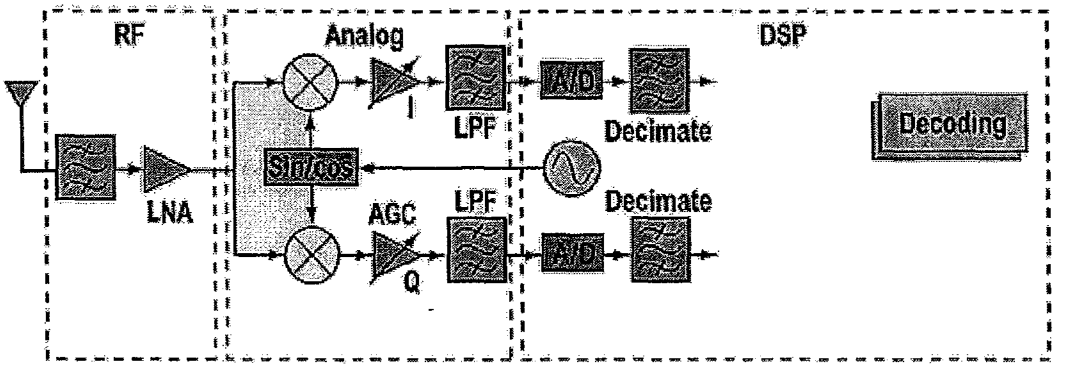


Figure 3.3: Direct Conversion receiver architecture

3.3.3 DSP-Based Digital IF

The advantage of DSP is that channel filtering can be programmable, resulting in a single architecture that will adapt to multiple formats. The full bandwidth of the signal still exists after the first mixer, which must be captures by A/D converter (commonly implemented with a bandpass sigma-delta converter) (Kal Kalbasi, 7 Oct 2002).

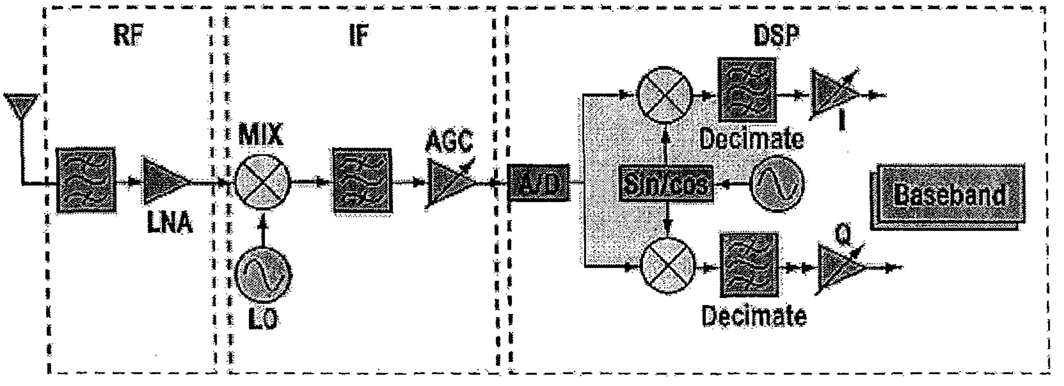


Figure 3.4: DSP-based digital IF receiver architecture

3.4 Advantages of Superheterodyne Receiver

There are three main advantages of superheterodyne receiver, depending on the application used for:

- It reduces the signal from very high frequency sources where ordinary components wouldn't work (like in a radar receiver).
- It allows many components to operate at a fixed frequency (IF section) and therefore they can be optimized or made more inexpensively.
- It can be used to improve signal isolation by arithmetic selectivity

As a conclusion, superheterodyne receivers reduce the signal frequency be mixing in a signal from a local oscillator to produce the intermediate frequency (IF).

Superheterodyne receivers have better performance because the components can be optimized to work a single intermediate frequency, and can take advantage of arithmetic selectivity [12].

3.5 Superheterodyne Receiver

Superheterodyne receiver is a receiver that combines a locally generated frequency with the Radio Frequency (RF) to produce a supersonic signal, Intermediate Frequency (IF) that is demodulated and amplified.

Superheterodyne receivers mix a signal from a local oscillator (within the receiver) with all the incoming signals. In the mixer stage of a receiver, the local oscillator signal multiplies with the incoming signal, producing beat frequencies at both the sum of the two input frequencies and at the difference. The signal at the difference frequency is passed on by tuned circuits, amplified, and then demodulated to recover the original signal.

The diagram below shows the basic elements of a single conversion superheterodyne receiver.

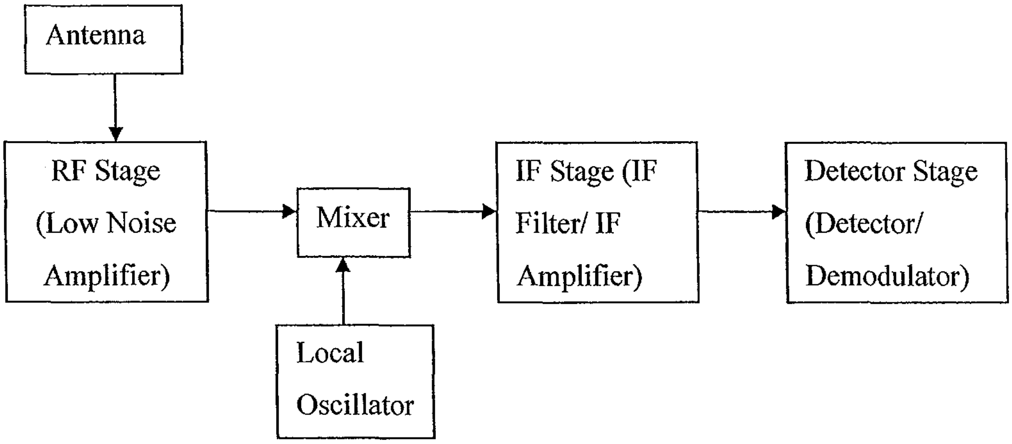


Figure 3.5: Superheterodyne receiver architecture

The received RF signal from the antenna is first amplified by a low-noise amplifier (LNA). The LNA is used to amplify very weak signals captured by an antenna. Using a LNA, the noise of all the subsequent stages is reduced by the gain of the LNA and the noise of the LNA is injected directly into the received signal. Thus, it is necessary for a LNA to boost the desired signal power while adding as little noise and distortion as possible so that the retrieval of this signal is possible in the later stages in the system.

The mixer then down-converts the RF signal to an IF signal, using a local oscillator which the different frequency between RF signal and local oscillator is equal to the IF signal frequency. After the mixer, the IF signal is filtered to eliminated undesired harmonics, and amplified by IF amplifier. The output of IF amplifier is then goes to the detector/ demodulator, from which the baseband signal is recovered.

3.6 Mixer

3.6.1 Overview

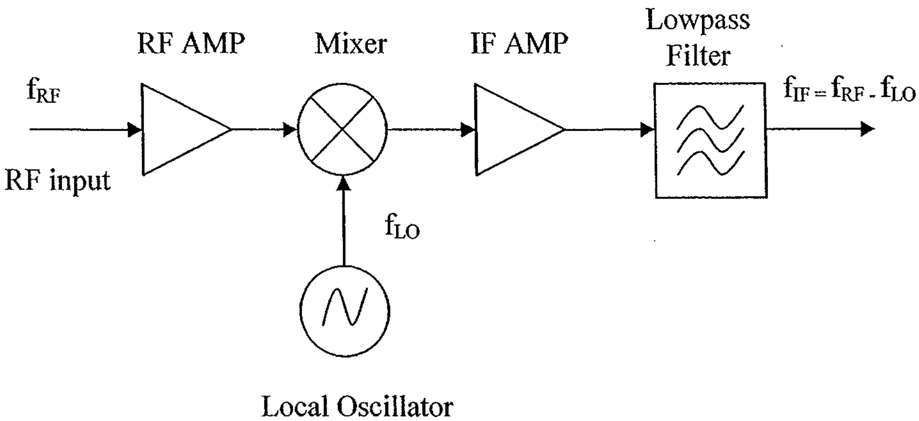


Figure 3.6: Down conversion thoery

Signal at radio frequency (RF) is converted to a lower Intermediate Frequency (IF) or baseband for down conversion and vice versa for up conversion (IF to RF frequency). The down conversion allows improved selectivity (filtering) and easier implementation of low noise and high gain amplification. Down conversion theory states that the frequency for Radio Frequency port and local oscillator port are larger than the Intermediate Frequency port where RF/LO > IF. The analysis for down conversion is realized in the equation below:

LO signal: $V_{LO}(t) = \cos\omega_{LO}t$ (3.3)

RF signal: $V_{RF}(t) = \cos\omega_{RF}t$ (3.4)

The output of the idealized mixer is the product of the LO and RF:

$$V_{IF}(t) = KV_{RF}(t)V_{LO}(t) = K\cos\omega_{RF}t\cos\omega_{LO}t$$

$$= K/2\,[\cos 2\pi(f_{RF} + f_{LO})t + \cos 2\pi(f_{RF} - f_{LO})t] \quad (3.5)$$

K is a constant of voltage conversion loss. The output consists of the sum and differences of the input signal frequencies and the desired IF output can be selected by using a low pass filter.

$$f_{IF} = f_{RF} - f_{LO} \tag{3.6}$$

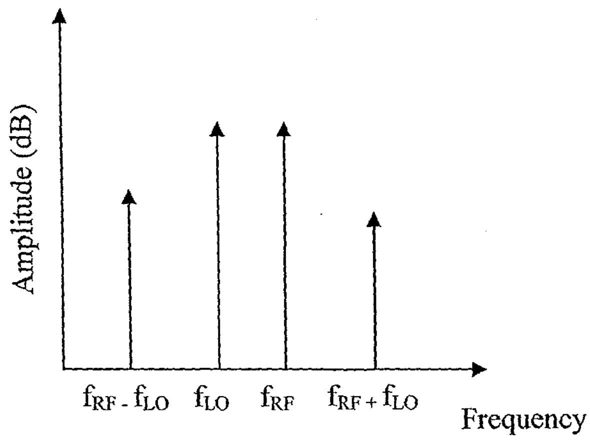


Figure 3.7: Spectrum for a down conversion mixer

3.6.4 Up Conversion Theory

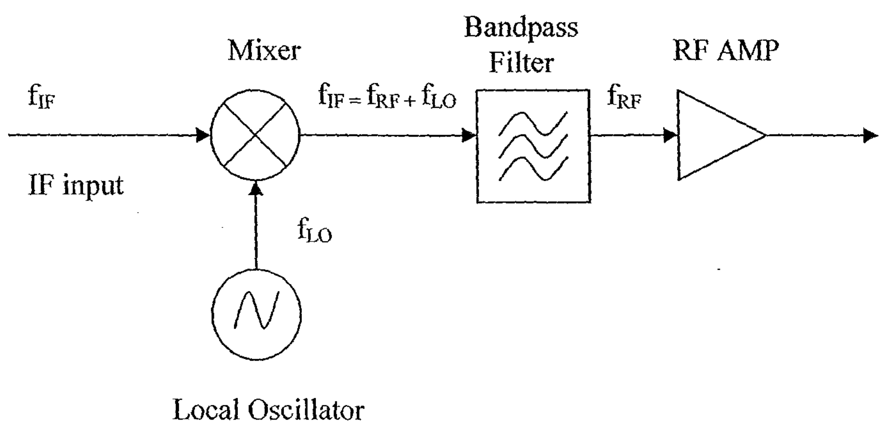


Figure 3.8: Up conversion thoery

Signal at Intermediate Frequency (IF) is converted to a Radio Frequency (RF). The up conversion allows improved selectivity (filtering) and easier implementation of low noise and high gain amplification. The analysis for down conversion is realized in the equation below:

LO signal: $V_{LO}(t) = \cos\omega_{LO}t$ (3.7)

IF signal: $V_{IF}(t) = \cos\omega_{IF}t$ (3.8)

The output of the idealized mixer is the product of the LO and IF:

$$V_{RF}(t) = KV_{IF}(t)V_{LO}(t) = Kos\omega_{IF}t\cos\omega_{LO}t$$

$$= K/2\ [\cos 2\pi(f_{LO} + f_{IF})t + \cos 2\pi(f_{LO} - f_{IF})t] \quad (3.9)$$

K is a constant of voltage conversion loss. The output consists of the sum and differences of the input signal frequencies and the desired RF output can be selected by using a band pass filter.

$f_{RF} = f_{IF} + f_{LO}$ (3.10)

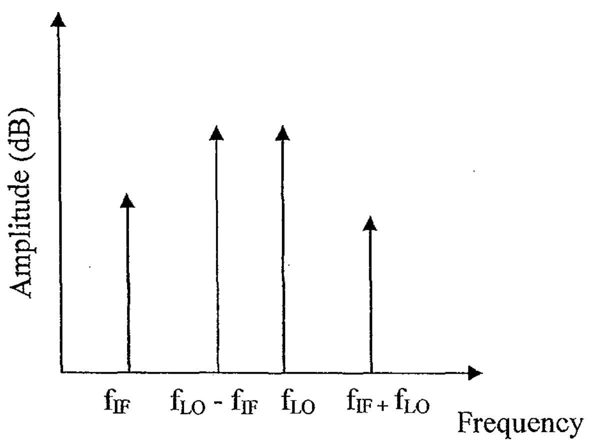


Figure 3.9: Spectrum for an up conversion mixer

3.7 Low Noise Amplifier (LNA)

The low noise amplifier (LNA) is a special type of electronic amplifier or amplifier used in communication systems to amplify very weak signals captured by an antenna. It is often located very close to the antenna. If the LNA is located close to the antenna, then losses in the feedline become less critical. It is a key component, which is placed at the front-end of a radio receiver circuit. As we know from the Friis' formula that the overall noise figure of the receiver front-end is dominated by the first few stages. Using a LNA, the noise of all the subsequent stages is reduced by the gain of the LNA and the noise of the LNA is injected directly into the received signal . Thus, it is necessary for a LNA to boost the desired signal power while adding as little noise and distortion as possible so that the retrieval of this signal is possible in the later stages in the system (Wikipedia). The specifications of LNA are included:

i. Gain (dB)
ii. Noise Figure (NF)
iii. Output power (dBm)
iv. Frequency range

The better performance of LNA is operated with a minimum value of noise figure and a maximum value of gain.

3.8 Filter Types

3.8.1 Lowpass Filter

A low-pass filter is a filter that passes low frequencies but attenuates (or reduces) frequencies higher than the cutoff frequency. The actual amount of attenuation for each frequency varies from filter to filter (Wikipedia). One simple electrical circuit that will serve as a low-pass filter consists of a resistor in series with a load, and a capacitor in parallel with the load. The capacitor exhibits reactance, and blocks low-frequency signals, causing them to go through the load instead. At higher frequencies the reactance drops, and the capacitor effectively functions as a short circuit. At radio frequencies, the LC filter are widely used that resistor is replace by inductor because practical inductors are easily made, even with air cores.

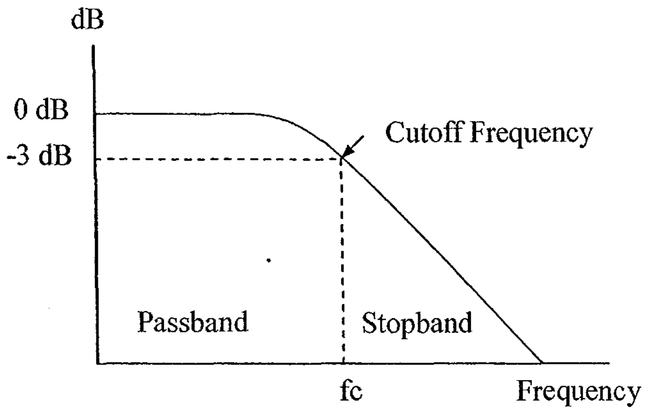


Figure 3.10: The frequency response of a lowpass filter

3.8.2 Bandpass Filter

Bandpass filters are used primarily in wireless transmitters and receivers. The main function of such a filter in a transmitter is to limit the bandwidth of the output signal to the minimum necessary to convey data at the desired speed and in the desired form. In a receiver, a bandpass filter allows signals within a selected range of frequencies to be heard or decoded, while preventing signals at unwanted frequencies from getting through. A bandpass filter also optimizes the signal-to-noise ratio (sensitivity) of a receiver. Between the lower cutoff frequency f_l and the upper cutoff frequency f_2 of a frequency band is the resonant frequency, at which the gain of the filter is at its maximum. The bandwidth of the filter is simply the difference between f_2 and f_1.

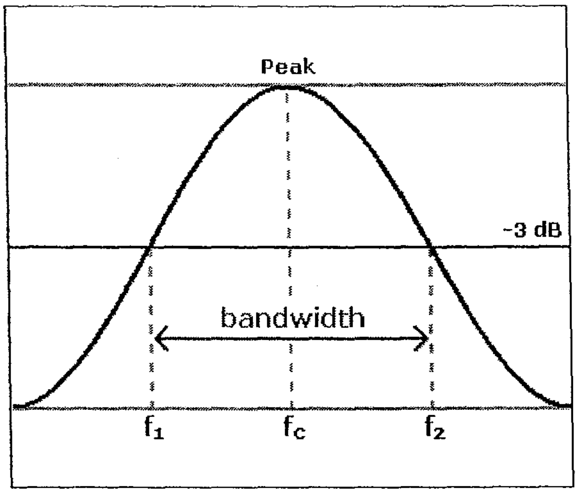


Figure 3.11: The frequency response of a bandpass filter (Wikipedia)

3.8.3 Highpass Filter

A high-pass filter is a filter that passes high frequencies well, but attenuates (or reduces) frequencies lower than the cutoff frequency. The actual amount of attenuation for each frequency varies from filter to filter. A high-pass filter is the opposite of a low-pass filter, and a bandpass filter is a combination of a high-pass and a low-pass. It is useful as a filter to block any unwanted low frequency components of a complex signal while passing the higher frequencies. The simplest electronic high-pass filter consists of a capacitor in series with the signal path in conjunction with a resistor in parallel with the signal path (Wikipedia). At radio frequencies, the LC filter are widely used that resistor is replace by inductor because practical inductors are easily made, even with air cores.

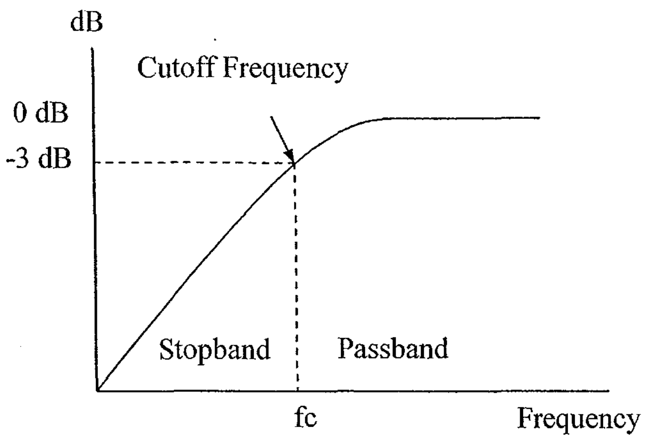


Figure 3.12: The frequency response of a highpass filter

3.9 In phase-Quadrature (I/Q) Modulation and Demodulation

Modulation is a process in which a modulator changes some attribute of a higher frequency carrier signal proportional to a lower frequency message signal. A change in the message signal will produce a corresponding change in the amplitude, frequency, or phase of the carrier. A transmitter can then send this carrier signal through the communication medium more efficiently than the message signal alone. Finally, a receiver will demodulate the signal, recovering the original message.

In digital communication, In phase-Quadrature (I/Q) modulation is used. It is a digital modulation which operates by taking two baseband data sequences (I and Q channels) and varying the amplitude and phase of a sinusiodal carrier signal in response to the instantaneous I and Q channel volatage (Jim Wholey, 1993). The I/Q demodulation is extracts the baseband signal from a modulated signal which has undergone I/Q modulation.

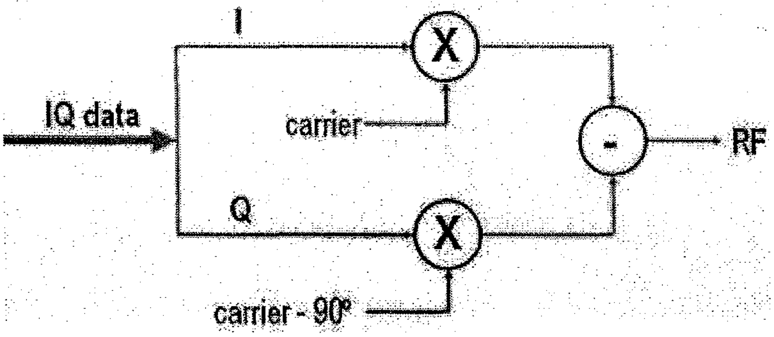


Figure 3.13: Block diagram of an IQ modulation

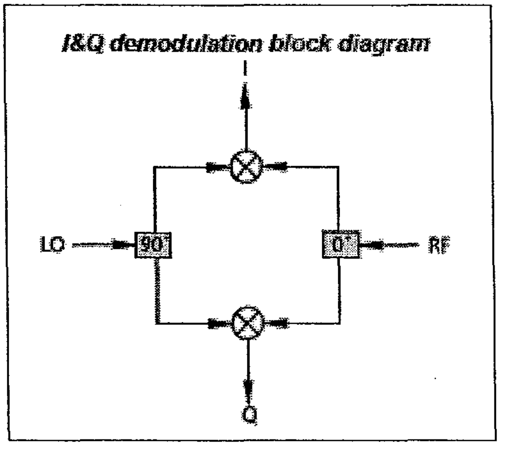


Figure 3.14: Block diagram of an IQ demodulation

3.10 Transmission and Reception Quality

3.10.1 Gain and Sensitivity

One of the quickest and most useful ways to compare microwave system performance is to study system gain values. Gain is usually taken as the mean ratio of the signal output of a system to the signal input of the system.

$$Gain = 10 \times \log\left(\frac{P_2}{P_1}\right) dB \tag{3.11}$$

where P1 and P2 are the input and output powers respectively.

If the ratio is less than unity, the gain, expressed in dB, will be negative, in which case there is a loss between input and output.

When the gain is sufficiently high, the weakest signal power that may be processed satisfactorily is noise-limited. This signal is referred to as the sensitivity. Sensitivity refers to the minimum available signal power at the input terminal of the receiver to give a specific signal-to-noise ratio (SNR) or bit error rate (BER) at the output of the receiver. A receiver's sensitivity is one of its most important characteristics. There is no universal standard for its measurement, although standards have been adopted for specific applications.

3.10.2 Noise Figure (NF)

Sensitivity measures depend upon specific signal characteristics. The noise figure (NF) measures the effects of inherent receiver noise in a different manner. Noise figure is a key performance parameter in many RF systems. A low noise figure provides improved signal/noise ratio for analog receivers, and reduces bit error rate in digital receivers. As a parameter in a communications link budget, a lower receiver noise figure allows smaller antennas or lower transmitter power for the same system performance.

The Noise Figure (NF), or the related Noise Factor (F), defines the noise performance and contributes to the receiver sensitivity. Noise figure (NF) is the ratio of the output noise power of a device to the portion thereof attributable to thermal noise in the input termination at standard noise temperature (usually 290 K). The noise figure is thus the ratio of actual output noise to that which would remain if the device itself did not introduce noise. It is a number by which the performance of a radio receiver can be specified.

Noise figure is given by

$$NF = SNR_{in} - SNR_{out} \tag{3.12}$$

where everything is in dB.

Noise Factor is a straight ratio of SNR ratios. Noise Figure is the deciBel equivalent of Noise Factor.

$$F = \frac{SNR_{in}}{SNR_{out}} \tag{3.13}$$

where everything is a ratio

$$F = 10^{NF/10}, NF = 10\log(F) \tag{3.14}$$

The noise factor of a device is related to its noise temperature via

$$F = 1 + \frac{T_e}{T_0} \tag{3.15}$$

where T_e is the effective or equivalent input noise temperature of the device and T_0 is the reference temperature which is defined as 290K. T_e is given by

$$T_e = \frac{N_0}{GkB} - T_0 \tag{3.16}$$

where N_0 is the output noies power, k=1.38 x 10^{-23} which is the Boltzman constant, B is the bandwidth of the system and G is the receiver gain.

If several devices are cascaded, the total noise factor can be found with Friis' Formula:

$$F = F_1 + \frac{F_2 - 1}{G_a} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots + \frac{F_n - 1}{G_1 G_2 G_3 \ldots G_{n-1}} \tag{3.17}$$

where F_n is the noise factor for the *n*th device and G_n is the gain (numerical, not in dB) of the *n*th device.

3.10.3 Signal-to-Noise Ratio (SNR)

In analog and digital communications, signal-to-noise ratio, often written S/N or SNR, is a measure of signal power to the noise power corrupting the signal. SNR shows how much stronger (or weaker) the desired signal is as compared to the unwanted noise.

$$SNR = \frac{P_{signal}}{P_{noise}} = \left(\frac{A_{signal}}{A_{noise}}\right)^2 \tag{3.18}$$

where P is average power and A is RMS amplitude. Both signal and noise power (or amplitude) must be measured at the same or equivalent points in a system, and within the same system bandwidth. Because many signals have a very wide dynamic range, SNRs are usually expressed in terms of the logarithmic decibel scale (dB).

$$SNR(dB) = 10\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) = 20\log_{10}\left(\frac{A_{signal}}{A_{noise}}\right) \tag{3.19}$$

Ideally, SNR is positive. If SNR is negative, in this type of situation, reliable communication is generally not possible unless steps are taken to increase the signal level and/or decrease the noise level. The greater the SNR shows that the stronger the signal is.

3.10.4 Bit Error Rate (BER)

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10 to the minus 6, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent (Yaochou Yang, Aug 2000).

$$\textit{Bit Bit Error Rate} = \textit{total number of bit errors / total number of bits transmitted} \tag{3.20}$$

BER can also be defined in terms of the probability of error (POE),

$$BER = POE = \frac{1}{2}(1 - erf)E_b / N_0 \tag{3.21}$$

where *erf* is the error function, *Eb* is the energy in one bit and *No* is the noise power spectral density (noise power in a 1 Hz bandwidth).The error function is different for the each of the various modulation methods. What is more important to note is that POE is proportional to *Eb/No*, which is a form of signal-to-noise ratio. The energy per bit, *Eb* can be determined by dividing the carrier power by the bit rate. As an energy measure, *Eb* has the unit of joules. *No* is in power (joules per second) per Hz (seconds), so *Eb/No* is a dimensionless term, or simply, a numerical ratio. Thus, increase the energy per bit by using higher power transmission can reduce the BER (Gary Breed, January 2003).

In digital communication, the BER performs the end –to-end performance measurement, which quantifies the reliability of the entire radio system from "bits in" to "bits out," including the electronics, antennas and signal path in between. In analog communication, the noise figure is suitable for characterizing the individual systems components such as pre-amplifier, mixer and IF amplifier that make up the system. The noise figure of the overall system only can be determined from the noise figure and gain of the system components.

People usually plot the BER curves to describe the functionality of a digital communication system. In optical communication, BER(dB) versus RF Power(dBm) is usually used; while in wireless communication, BER(dB) versus Eb/No(dB) is used.

The scale of Y axis (for BER) is usually in probability scale, so that the curve looks like straight line. Figure 3.15 and Figure 3.16 show the example graph of BER(dB) versus Eb/No(dB) and BER(dB) versus RF Power(dBm) for a receiver.

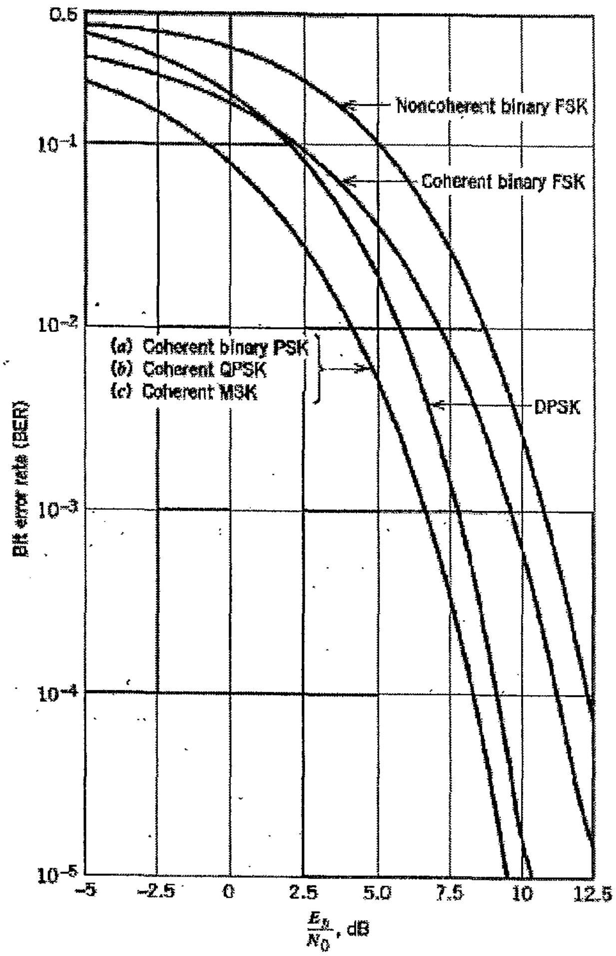


Figure 3.15: Bit Error Rate (BER) versus Eb/No(dB) for vorious kinds of digital modulation (Simon Haykin,2001).

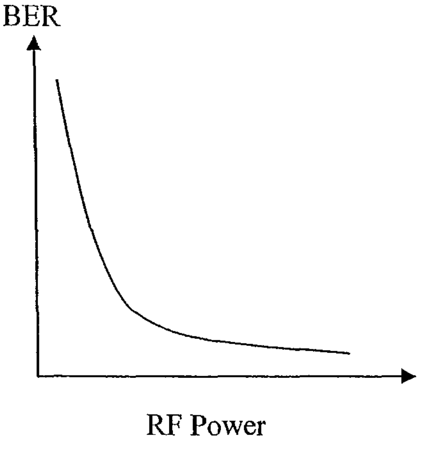


Figure 3.16: Bit Error Rate (BER) versus RF power

CHAPTER 4

LINK SYSTEM DESIGN, SIMULATION AND RESULTS

4.1 Overview

In this chapter, the transmit and receive system including up/ down conversion system are designed. The single stage down-converter includes low noise amplifier (LNA), mixer and low pass filter are designed and simulated using Advance Design System (ADS) to estimate the gain, noise figure (NF), and conversion loss of the system. The down-converter is the fabricated for bit error rate (BER) measurement in next chapter.

4.2 Transmitter Design

The transmitter (up-converter) is designed to transmit I/Q modulated signal at frequency 2.4 GHz. The input signal is a square wave signal I input signal. The frequency of I input signal is set to 10 kHz and the amplitude is set below 1 Vrms. I input signal is up converted by modulated with the frequency 2.4 GHz carrier signal. The design use I/Q modulation technique as up-converter design. After I/Q modulator, the output is a wanted I/Q modulated signal.

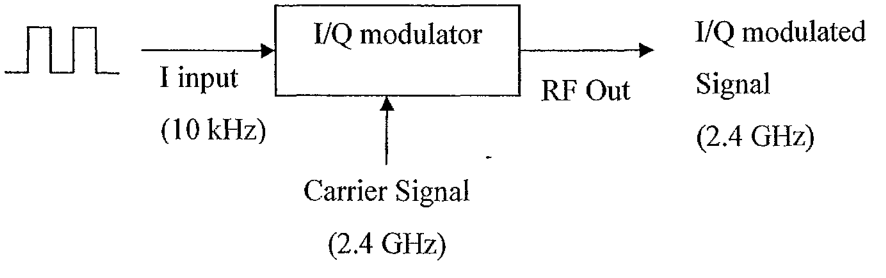


Figure 4.1: The block diagram of transmitter (up-converter) design

4.3 Harmonic Balance Simulation

Harmonic balance is a frequency-domain analysis technique for simulating distortion in nonlinear circuits and systems. It is usually the method of choice for simulating analog RF and microwave problems, since these are most naturally handled in the frequency domain [15]. Circuits that are best analyzed using HB under large signal conditions are:

- power amplifiers
- frequency multipliers
- mixers
- oscillators
- modulators

Harmonic balance simulation makes possible the simulation of circuits with multiple input frequencies. This includes intermodulation frequencies, harmonics, and frequency conversion between harmonics. Harmonic balance simulation calculates the magnitude and phase of voltages or currents in a potentially nonlinear circuit. For the purpose of this project, Harmonic Balance simulation is used to perform nonlinear noise analysis for the down converter. The optimum order is set because using too high of an order is wasteful of memory, file size and simulation time. The "NoiseNode" in the HB Noise Controller are specified to obtain the noise at certain nodes. The generated data is stored in a Dataset, which can be displayed in the Data Display Window.

4.4 S-Parameter Simulation

For filter designs, S-parameter simulator is usually applied. By selecting this simulator, circuit characteristics, such as S-parameters, group delay and linear noise can be obtained. Y- and Z-parameters can also be found by the transformation from the s-

Table 4.1: Components specification for down-converter

Component	Type	Specification
Low Noise Amplifier (LNA)	GaAs MMIC Agilent MGA-85563	RF frequency coverage is from 0.8 GHz-6.0 GHz At RF=2.4GHz Gain=18dB, NF=1.6dB (Refer to data sheet in Appendix C)
Mixer (lower sideband Down-converter)	GaAs MMIC Agilent IAM-91563	RF frequency coverage is from 0.8 GHz-6.0 GHz IF frequency coverage is from 50MHz-700MHz At IF=70MHz Conversion Gain=7.7dB, NF=11dB (Refer to data sheet in Appendix C)
Low pass Filter	LC low pass filter	Cutoff Frequency = 70 MHz

4.5.1.1 Low Noise Amplifier (LNA)

The MGA-85563 Low Noise Amplifier (LNA) is chosen in this design. For most applications, all that is required to operate the MGA-85563 is to apply +3 volts to the RF Output pin, and noise matches the RF Input. To achieve lowest noise figure performance, the input of the MGA-85563 should be matched from the system impedance (typically 50 Ohm) to the optimum source impedance for minimum noise, Γopt. Since the real part of the input of the device impedance is near 50 Ohm and the reactive part is capacitive, a simple series inductor at the input is often all that is needed to provide a suitable noise match for many applications. From the data sheet, the 2.7nH inductor value is chosen for 2.4GHz RF input frequency.

The RF Output port is internally matched to 50 Ohm and will not normally require additional matching. DC bias is applied to the MGA-85563 through the RF Output connection. An inductor between DC supply and RF Output is used to isolate the RF signal from the DC supply. The bias line is capacitively bypassed to keep RF from the DC supply lines and prevent resonant dips or peaks in the response of the amplifier. A DC blocking capacitor at the RF Output is used at the output of the RFIC to isolate the supply voltage from succeeding circuits.

Figure 4.3 shows the schematic for MGA-85563 Low Noise Amplifier in ADS which the RF signal frequency is 2.4GHz. The schematic is simulated in ADS Harmonic Balance simulation to estimate the minimum noise figure (NF) and maximum gain. HB Noise Controller is used to set the "NoiseNode" parameter.

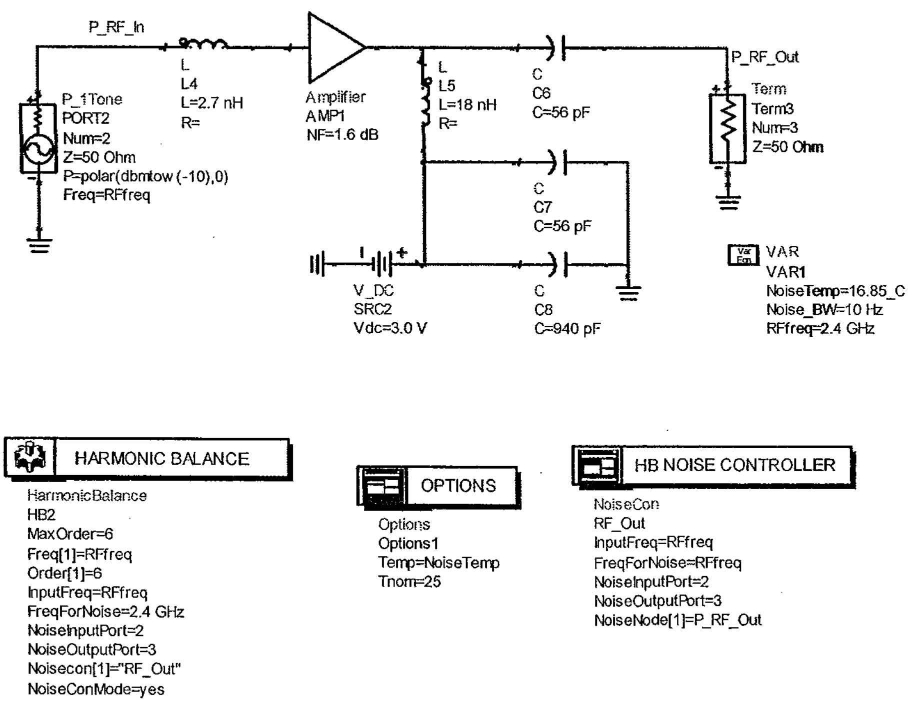


Figure 4.3: The simulation schematic of chip MGA-85563 Low Noise Amplifier

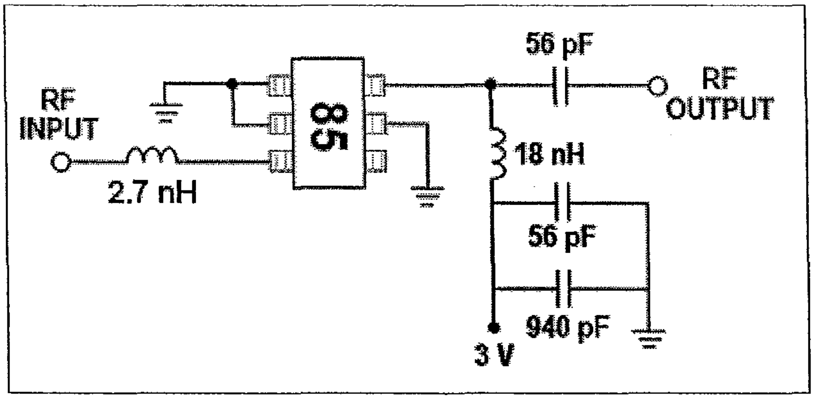
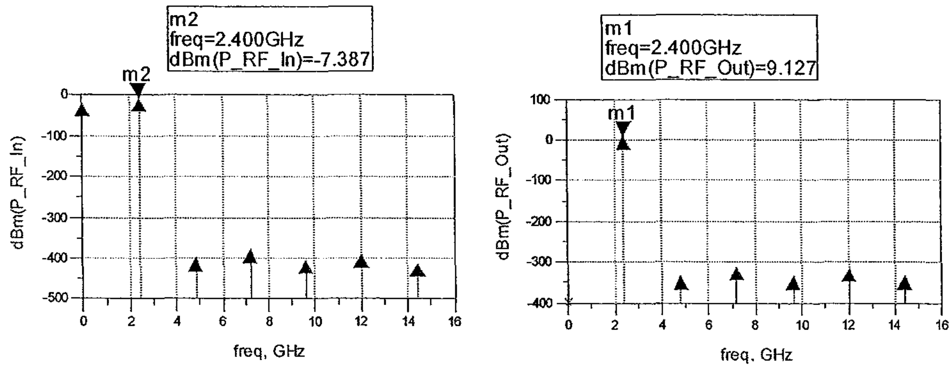


Figure 4.4: The circuit of chip MGA-85563 Low Noise Amplifier



Noise Figure (dB) and Gain (dB)

nf(3)	Gain
1.072	16.514

Figure 4.5: The simulation result of MGA-85563 low noise amplifier

4.5.1.2 Mixer

The IAM-91563 Mixer is chosen in this design. Several design considerations should be taken into account to ensure that maximum performance is obtained from the IAM-91563 down converter. The RF and IF ports must be impedance matched at their

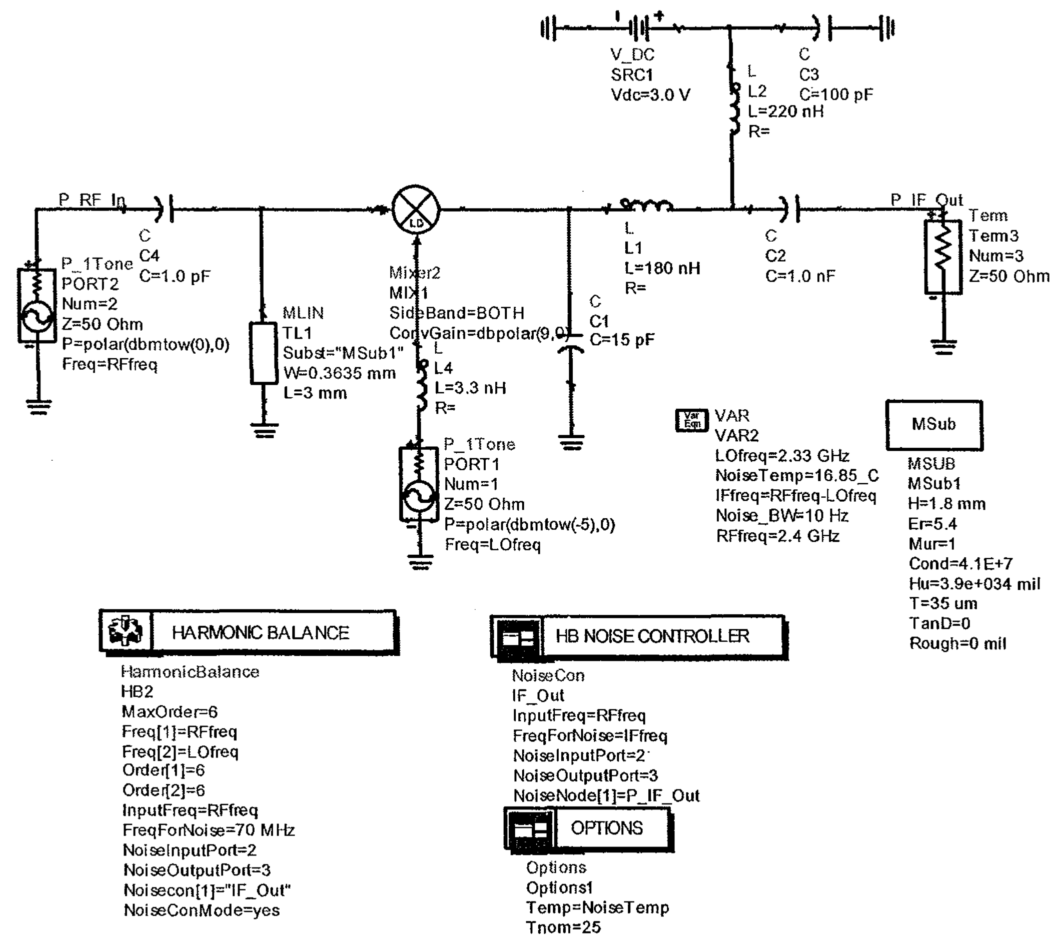


Figure 4.7: The simulation schematic of chip IAM-91563 mixer

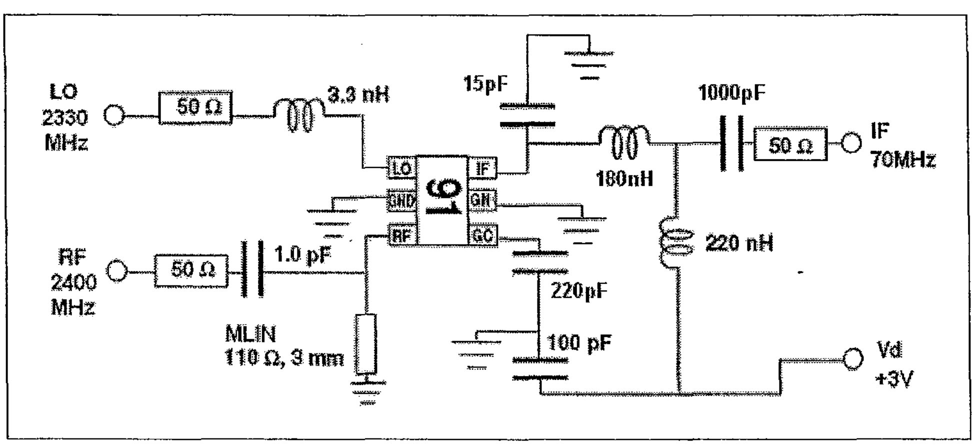


Figure 4.8: The circuit of chip IAM-91563 mixer

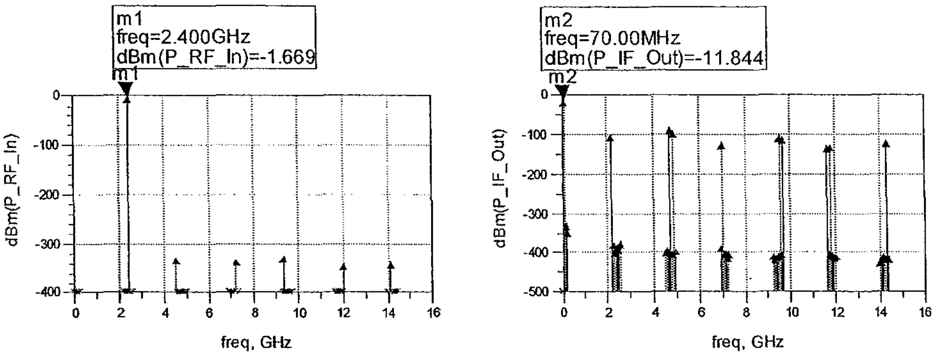


Figure 4.9: The simulation result of IAM-91563 mixer

Conversion loss (CL) = RF input power (dBm) - IF output power (dBm) (4.2)

= -1.669 dBm + 11.844 dBm

= 10.175 dB

4.5.1.3 Lowpass Filter

A low-pass filter is a filter that passes low frequencies well, but attenuates (or reduces) frequencies higher than the cutoff frequency. The simple LC lowpass filter is designed and simulation using ADS S-parameter simulation for the cutoff frequency is equal to 70MHz.

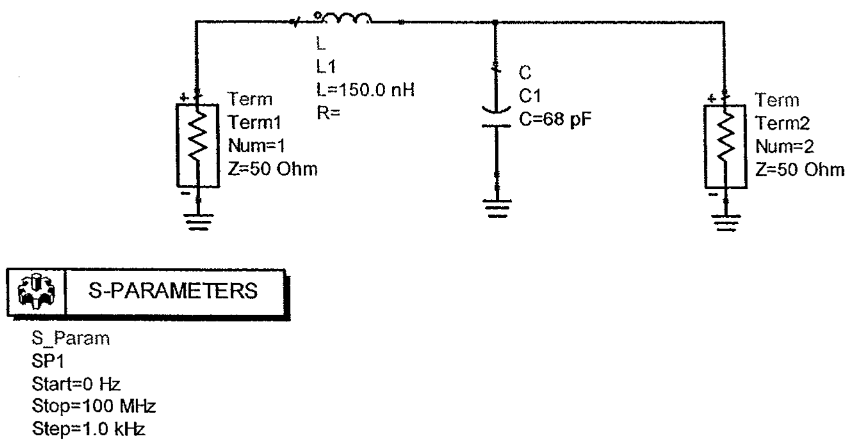


Figure 4.10: The simulation schematic of low pass filter

Input resistance(Term 1)	= 50 Ω
Inductor L1	= 150 nH
Capacitor C1	= 68 pF
Load resistance(Term 2)	= 50 Ω
Cutoff Frequency	= 70 MHz

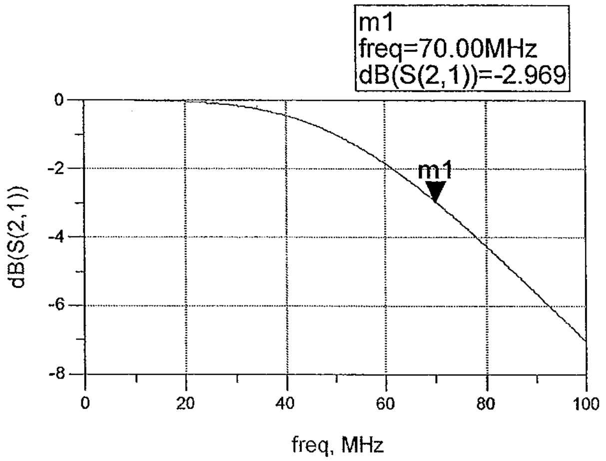


Figure 4.11: The simulation result of low pass filter

The separate simulation schematic of low noise amplifier (LNA), mixer and low pass filter are combined to form a complete single stage down-converter design. The combination schematic is simulated in Harmonic Balance simulation to obtain the conversion loss. The Harmonic Balance simulation includes two input signal: LOfreq and RFfreq with frequency conversion between harmonics. HB Noise Controller is used to set the "NoiseNode" parameter.

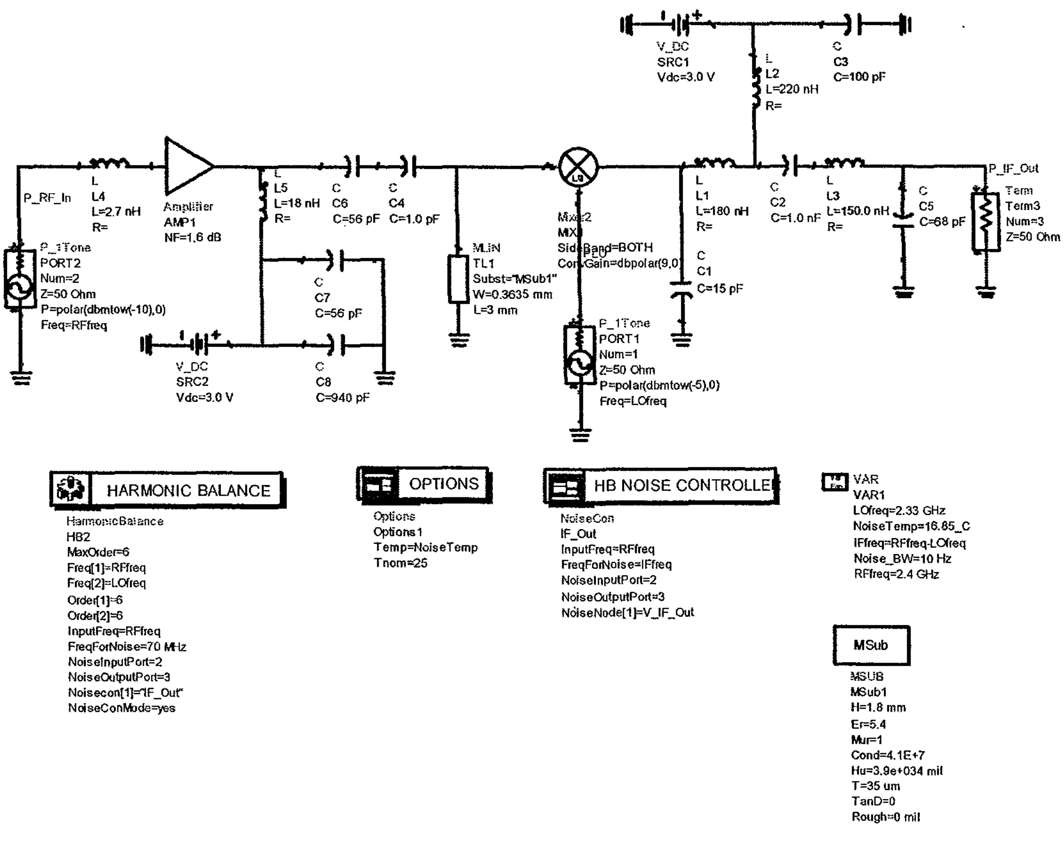


Figure 4.12: The simulation schematic of single stage down-converter design

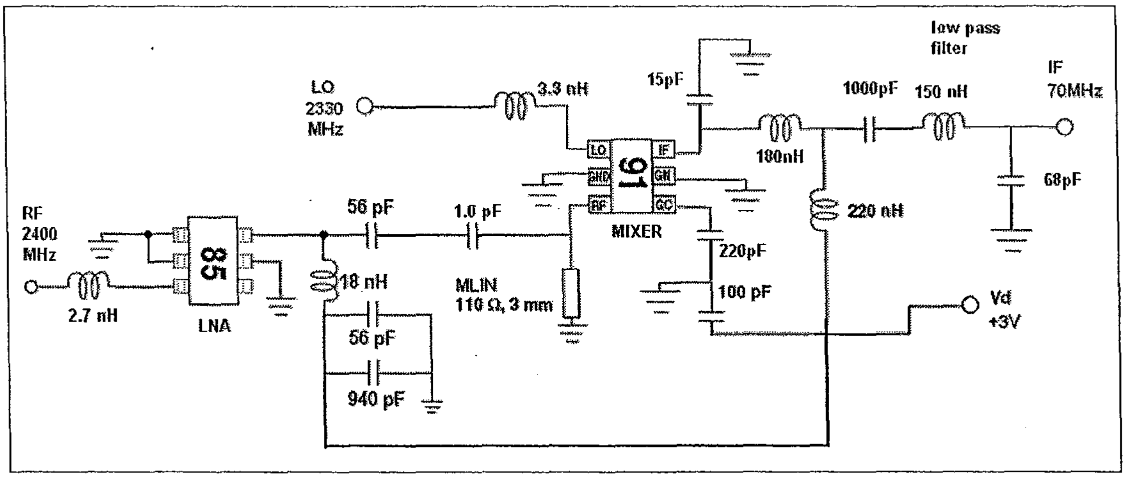


Figure 4.13: The complete circuit of single stage down-converter design

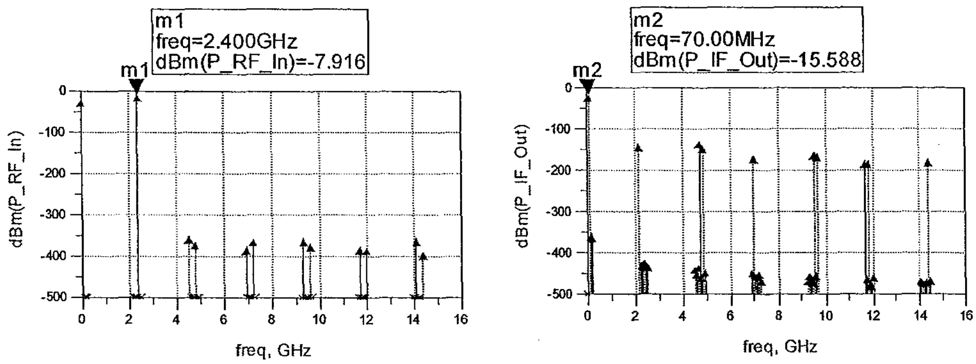


Figure 4.14: The simulation result of single stage down-converter design

Conversion loss (CL) = RF input power (dBm) - IF output power (dBm)

= -7.916 dBm + 15.588 dBm

= 7.672 dB

4.5.1.4 Layout Fabrication of Single Stage Down-Converter

Based on the complete circuit of single stage down-converter design, the layout of the design is draw using ADS tools. The dimensions of each of the component need to be known and the positions of the components need to be set at the suitable place. The layout is just draw manually in ADS tools and cannot be simulate because of the chips are not found in the ADS libraries. The complete of the layout and then will fabricate in the PCB board.

The FR4 type PCB board is chosen for this design. The parameters of FR4 are shown in Table 4.2.

Table 4.2: The parameters of FR4

Dielectric Constant, ε_r	5.4
Conductivity	4.1×10^7
Dielectric Thickness, h	1.8mm
Metal Thickness, t	35μm

4.5.2 IF Band pass Filter and Amplifier

Two IF amplifiers are cascaded in between two bandpass filter to amplifier the IF signals and filter spurious signal because the amplifier has wider bandwidth (500 MHz). Table 4.3 shows the specifications of the IF bandpass filter and IF amplifier.

Table 4.3: Component specifications for IF bandpass filter and IF amplifier

Component	Type	Characteristic		Typical Value
IF Bandpass Filter	Mini-Circuits P_IF-70	Passband Frequency (MHz)		58-82
		Centre Frequency (MHz)		70
		Stop Bands (MHz)	Loss < 10 dB	16 & 280
			Loss > 20 dB	4.4 & 490
		VSRW, 1.3:1		DC-550
IF Amplifier	Mini-Circuits MAN-1	Operating Frequency (MHz)		1.0-500
		Gain (dB)		28 (min)
		Noise Figure (dB)		4.5
		Bias Current (mA)		60
		Bias Voltage (V)		12

4.5.3 I/Q Demodulator

The Mini-Circuits ZFMIQ-70D I/Q demodulator is chosen. Table 4.4 shows the specifications of the I/Q demodulator.

Table 4.4: Component specifications for I/Q demodulator.

Component	Type	Characteristic	Typical Value
I/Q Demodulator	Mini-Circuits ZFMIQ-70D	RF/LO Frequency (MHz)	66-73
		I/Q Frequency (MHz)	DC-2
		Conversion Loss (dB)	7.0 (max)
		Amplitude Unbalance (dB)	0.15
		Phase Unbalance (degree)	0.7

4.5.4 Voltage Comparator

The voltage comparator used the LM339 chip. It is biased at 5V and a dual comparator is used for the I and Q received signals. Voltage comparator is used as a peak detector or a signal squarer that turns other cyclical waveforms into square wave (TTL form). Voltage comparator works by taking in two analog signals and provides a binary output that is true if the voltage of one signal is bigger than that of the other and false if not.

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4.6 Discussion

1. For low noise amplifier (LNA), the values of noise figure and gain from the simulation are approached the values from the data sheet of LNA chip. So, the circuit is contained stable.
2. For mixer, the conversion loss is equals to 10.175 dB from the simulation. The value is still acceptable because it is around 10 dB. For the conversion loss exceeds 10 dB, the mixer is not effective because of the losses during transmission is too high.
3. For lowpass filter to operate well at cutoff frequency 70 MHz, the suitable capacitor is 68 pF and suitable inductor is 150 nH.
4. The combination of the LNA, mixer and lowpass filter become a single stage down converter. From simulation, the conversion loss of down converter is equal to 7.672 dB which is lower than conversion of a mixer. This is because the additional of LNA amplified the weak signal and injected the noise of the signal. Besides, the lowpass filter blocked the signal frequency which is greater than cutoff frequency.

4.7 Summary

The design of transmitter is a simple modulation system that accepts the input message signal and modulated with the carrier signal to produce modulated signal. In this design, the I/Q modulation technique is used.

The design of receiver consists of four parts include single stage down-converter, IF amplifier and bandpass filter, I/Q demodulator and voltage comparator. The design of single stage down-converter consists of three parts which include low noise amplifier, mixer and lowpass filter.

To obtain the better systems performances, it is important to get the minimum value of noise figure, the maximum value of gain and also the minimum value of conversion loss.

CHAPTER 5

BIT ERROR RATE (BER) MEASUREMENT, RESULTS AND DISCUSSION FOR TRANSMIT AND RECEIVE SYSTEM

5.1 Overview

One of the most important characteristics when evaluating a communication system performance is the effect of noise. Bit error rate (BER) is a quantitative reliability measure for digital communication. In this chapter, transmit and receive system is set up for BER measurement. The transmitted power is starting with a high power that is no errors occurred. The transmitted power is then reduced until it starts to introduce errors and BER is counted at each input power level. The minimum power level that is just above the noise level is investigated.

5.2 Measurement Setup

The Agilent E4433B 250 kHz-4 GHz ESG-D series signal generator is used as a transmitter. I input signal with frequency of 10 kHz from function generator is connected to I input port of the signal generator. The signal generator generated the frequency of 2.4 GHz carrier signal internally and modulated with I input signal by actives the I/Q modulation button. The wanted I/Q modulated signal from the RF output port is then transmitted to the low noise amplifier at the receiver part.

A local oscillator with the frequency of 2.33 GHz is needed to down convert the 2.4 GHz RF signal to 70 MHz IF signal. The Agilent E4422B 250 kHz-4 GHz ESG-D series signal generator is used as a local oscillator. The IF signal is then transmitted to a bandpass filter and IF amplifier before being demodulated by I/Q demodulator. Another one local oscillator with the frequency of 70 MHz is used to mix with the IF signal in order to perform the I/Q demodulation producing the I/Q baseband signal. The Agilent 8648A 10 kHz-1000 MHz signal generator is used as a local oscillator at the I/Q demodualtor. Therefore, a total of 3 signal generators are needed, one for transmitter to generate the RF signal, one for mixer and the other one for I/Q demodulator. These 3 signal generators must be locked at the same reference voltage in order to synchronize the signals produced. The transmitter reference voltage, Vref is used to lock the other two signal generators.

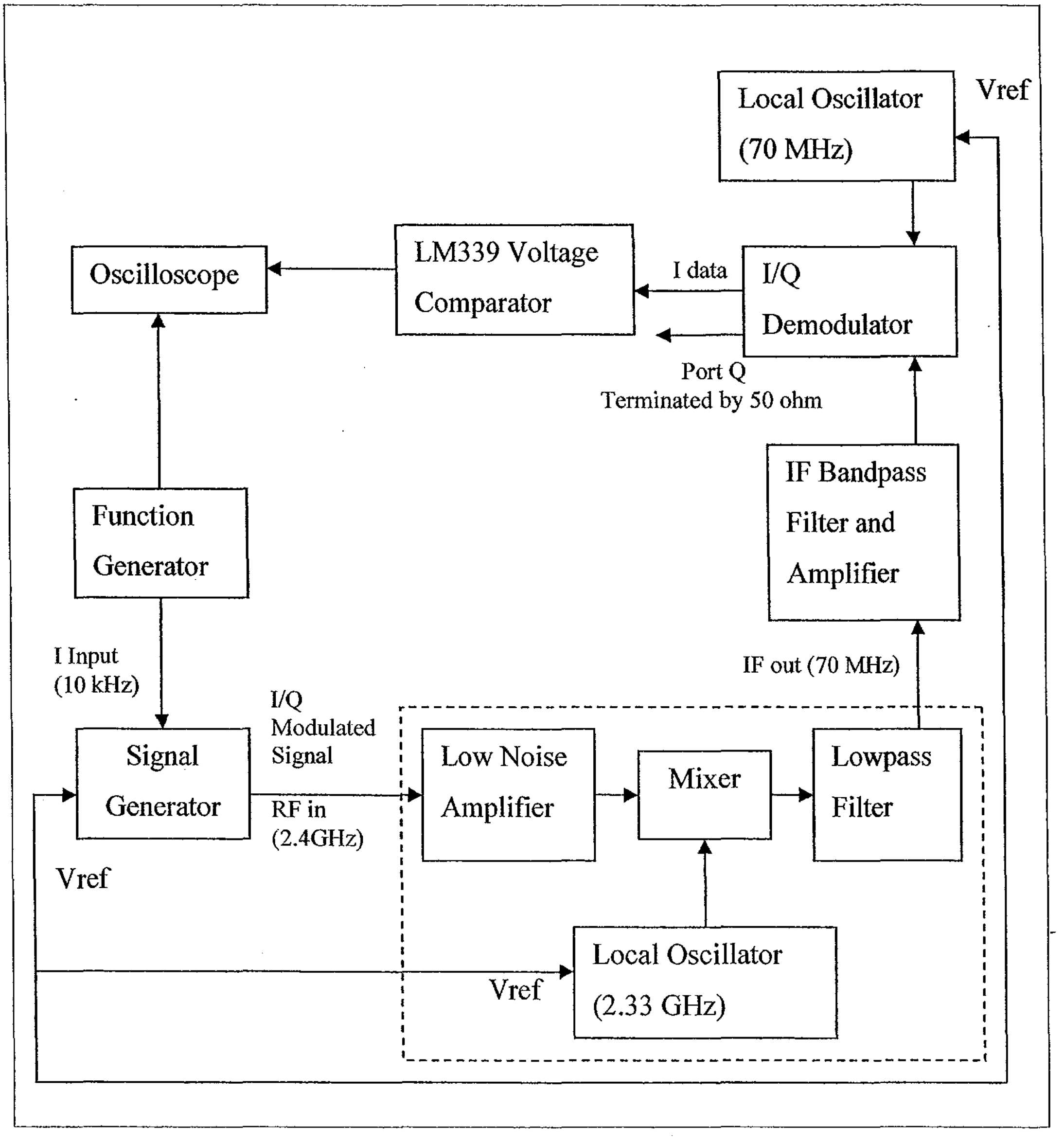

Figure 5.1: The experiment setup for Bit Error Rate (BER) measurement

The I data after demodulation is transmitted to the voltage comparator. The output of the voltage comparator is compare with the I input signal by connect the input and output signal to the oscilloscope. The transmitted signal power is starting with a high power that is no errors occurred. To create a data source containing errors, the power of transmitted signal is reduced until it starts to introduce errors. The bit Error Rate (BER) is counts by taking 10000 samples data for the input signal and output signal from the oscilloscope. The LeCroy Wavesurfer 64Xs 600 MHz oscilloscope 2.5Gs/s is used to save the data for input and output signal. The total errors that 1's are interpreted as 0's or 0's are interpreted as 1's are calculated manually by using Microsoft Excel. The minimum input power level that is just above the noise level is investigated.

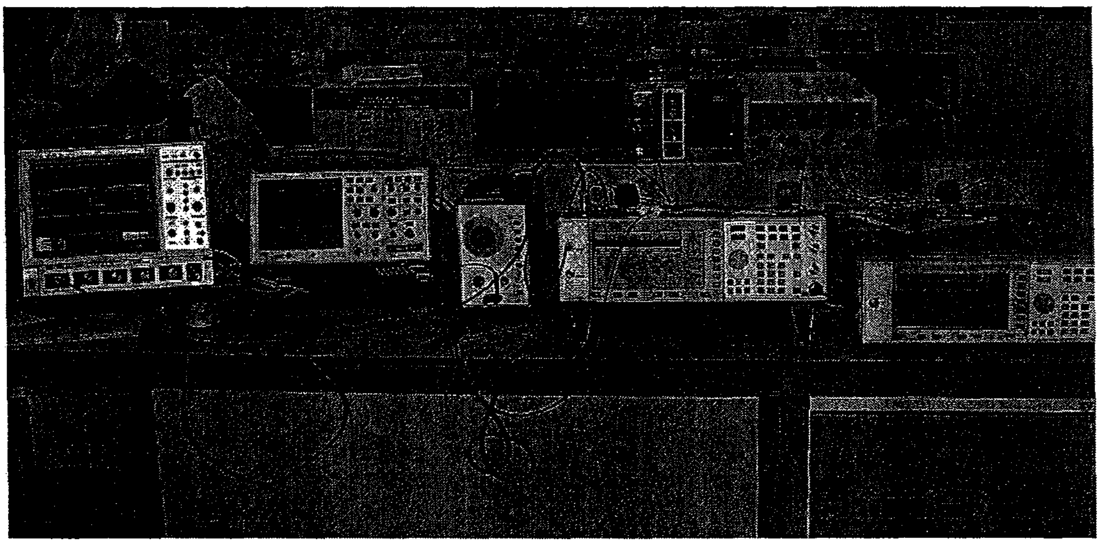

Figure 5.2: Complete BER measurement setup

5.3 Results

1. RF input power is varied

   From the experiment, the minimum RF input power that is just above the noise level is found to be -3 dBm. The output signal will start containing errors below the power of -3 dBm. The graph BER versus RF input power is plot as shown in the Figure 5.3.

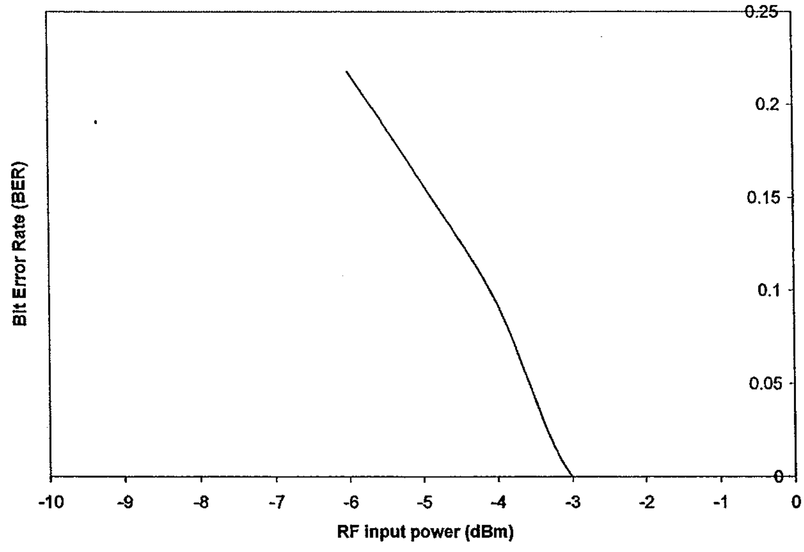

Figure 5.3: BER versus RF power (dBm)

2. Down-converter LO power is varied

   From the experiment, the minimum down-converter LO power that is just above the noise level is found to be -5.6 dBm. The output signal will start containing errors below the power of -5.6 dBm. The graph BER versus RF input power is plot as shown in the Figure 5.4.

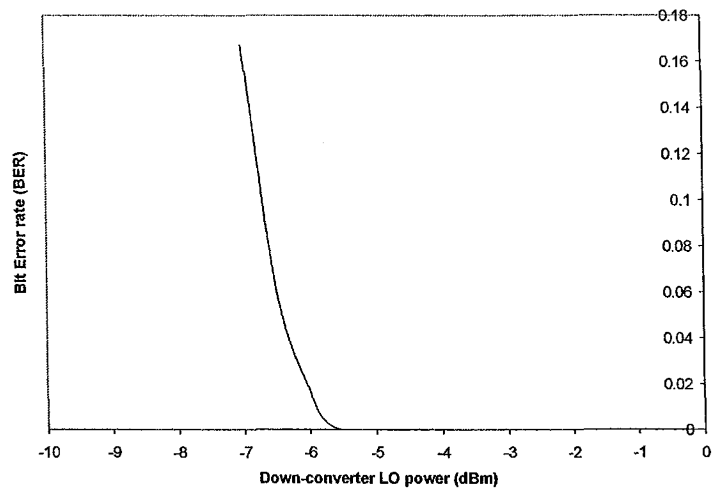

Figure 5.4: BER versus down-converter LO power (dBm)

3. I/Q demodulator LO power is varied

   From the experiment, the minimum I/Q demodulator LO power that is just above the noise level is found to be -12 dBm. The output signal will start containing errors below the power of -12 dBm. The graph BER versus RF input power is plot as shown in the Figure 5.5.

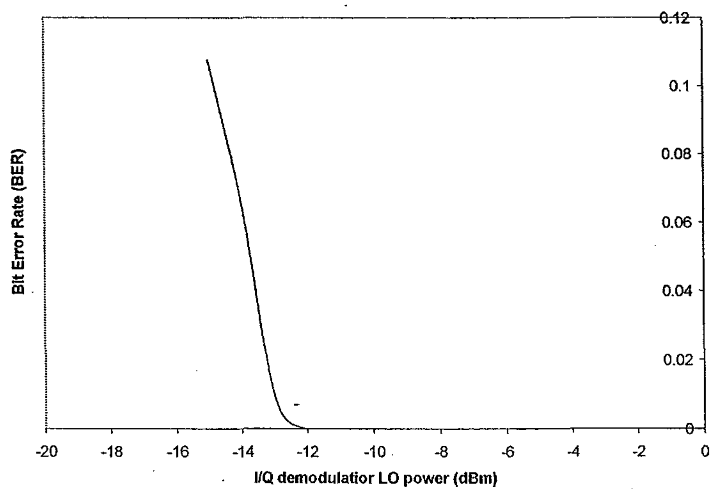

Figure 5.5: BER versus I/Q demodulator LO power (dBm)

Figure 5.6 and Figure 5.7 show the two received signal at different power levels that one of the signal produced no error and one of the signal produced with errors.

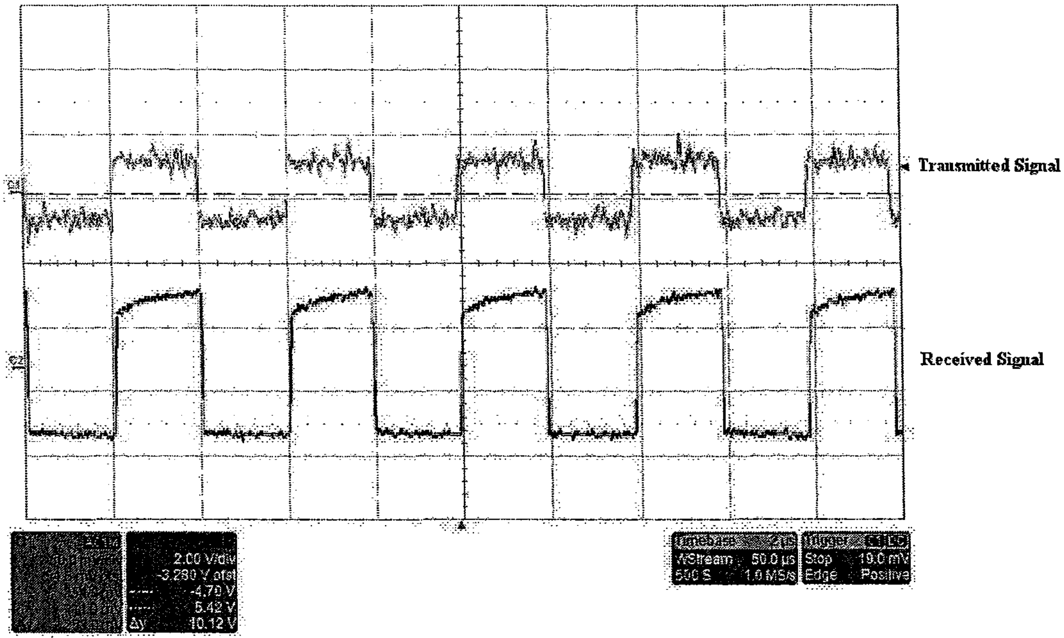

Figure 5.6: Transmitted signal and received signal at RF power of -3dBm showing no error is produced

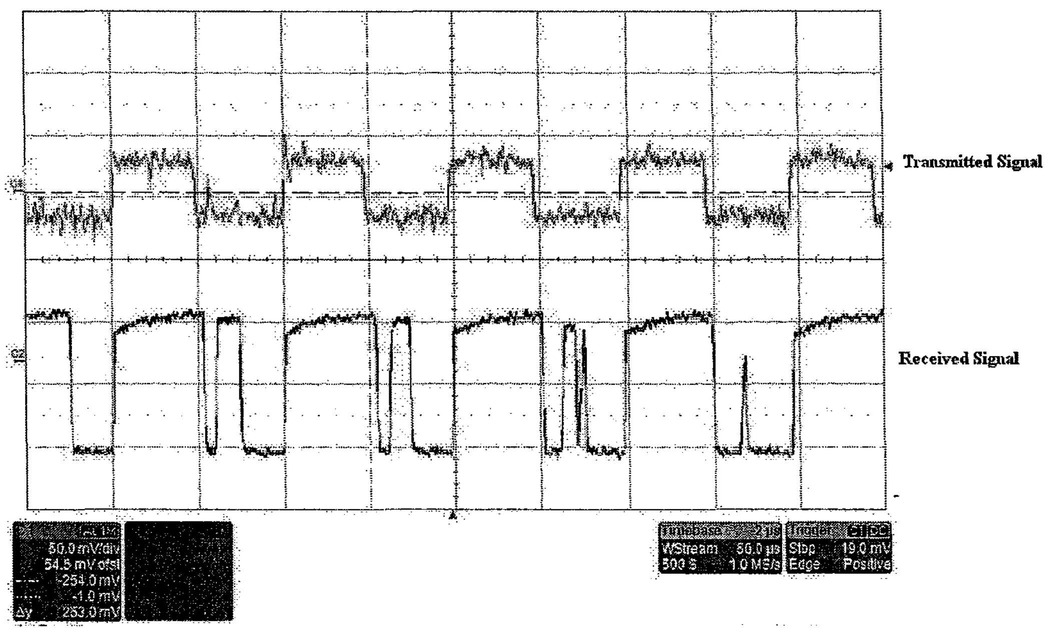

Figure 5.7: Transmitted signal and received signal at RF power of -4dBm showing errors are produced

5.4 Discussion

1. From the BER measurement results, the minimum RF input power that is just above the noise level is found to be -3 dBm. It means that the output signal will start containing errors below the power of -3 dBm. The value of RF power should be as low as possible to make the system operates well at a wide range of RF power. Theoretically, the noise floor is -174 dBm. The RF power cannot be less than the noise floor. The value of RF power around -90 dBm is the usually obtains value in the measurement. The RF power of -3 dBm is contains high compare to the value -90 dBm. This is due to some of the possible causes shown below:
   - The high value of system noise figure results in the losses during the transmission are high and it will causes the errors start contains at a higher RF power.
   - The inaccurate simulation results of single stage down-converter because of the chips of LNA and mixer are not found in the ADS libraries. The simulation is just used the common amplifier and mixer then add on the parameters inside.
   - The layout of single stage down-converter is draw manually and is not directly converts from schematic of simulation. The lengths and widths of microstrip lines connect between two components are not calculated exactly.
   - The voltage comparator threshold voltage is not exactly set to 0V. It affects the BER measurement by increases the value of BER.
   - The fabricated printed circuit board is not well.
   - The soldering problems especially the SMA connector at the input terminal and output terminal will resluts to the losses of signal.

2. The BER measurement results are calculated manually using Microsoft Excel. The input signal data and output signal data are saved from the oscilloscope and campared each of the point. If the value is not same, counted a error is occurred when transmission. The manually calculation is not very accurate to estimate the value of BER.

5.5 Summary

In order to design a good transmit and receive system, it is important to know the performance of the system. The system may have good performance if the BER is small with low noise figure at optimum RF power. It means that the receiver still can performed well at the optimum RF power as well as at low RF power which will gives an optimum BER and low noise figure. The range of RF power for optimum BER should be as high as possible for better performance of the system. So, the relationship between RF power and BER of the system are the keys for RF designer in order to design a good transmit and receive system.

CHAPTER 6

CONCLUSION

6.1 Overview

The main purpose of this project is to design a transmit and receive system including up/down conversion system in order to measure the Bit Error Rate (BER) of the system. The transmitter (up-converter) is designed at the radio frequency (RF) 2.4GHz. The design of transmitter is used the I/Q modulation technique

The front-end superheterodyne receiver is designed to accept the radio frequency from the transmitter. The single stage down converter system include LNA, mixer and lowpass filter is designed and simulated in Advanced Design System (ADS). Harmonic Balance Simulation is performed to the system to obtain the conversion loss of the system, the minimum value of noise figure (NF), and the maximum values of gain. The down-converter is then fabricated on the FR4 type printed circuit board (PCB), with ε_r=5.4.

The receiver system includes single stage down converter, IF amplifier and bandpass filter, I/Q demodulator and voltage comparator. The transmitter and receiver are combined for BER measurement of the system. The BER is calculated manually by using Microsoft Excel. The BER is measured by varied the power of the transmitter and the power of the local oscillator (LO).

From the measurement results, the minimum RF input power that is just above the noise level is found to be -3 dBm. The output signal will start containing errors below the power of -3 dBm. It means that the system will only performed well at the RF power above -3 dBm. This high value of RF power is caused by a lot of losses during transmission from the transmitter to the receiver.

6.2 Suggestion for future work

In this project, the signal from the transmitter is directly sent to the receiver by using a cable as a communication channel. For future work, the antennas can be added at the transmitter and receiver to replace the communication channel which wireless communication system is produced. For this purpose, the noise performance of the wireless communication system can be characterized.

The BER is calculated manually using Microsoft Excel in this project. So, the results are inaccurate. For future work, hardware like BER tester or software that can calculates the accurate BER can add in measuring the BER. By using Advanced Design System (ADS), the ADS simulation signal can downloads to the ESG vector signal generator and input to the transmitter, the Spectrum Analyzer captures the output signal of receiver and then read back into ADS. The BER can be measured by using ADS simulation tools.

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