Signal Performance of Multi-Mode Digital IF Receivers in Mobile Communication Environments

by

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Abstract

The aim of this project is to investigate the architecture of conventional and future technologies for communication receivers, and the signal performance of multi-mode digital IF receivers in a mobile environment, by using the MATLAB modelling system. This is an important process in the production of multi-mode receivers. This research will assist engineers in understanding the advantages of multi-mode receivers using digital IF technology. A third generation mobile communication system will be launched shortly. However, the first and second-generation systems will still be used. Because of the co-existence three systems, it is necessary to develop multi-mode receivers, which can support two or three generation systems at the same time.

1 Introduction

In order to understand the architecture of communication receiver, it is essential to have an overview of current and future communication techniques in the design of mobile communication receivers. The modulation methods and the architecture of a simple, the conventional and future receivers are discussed. By comparison of analog and digital signal processing, it is easier to understand the advantages of digitisation. The specifications of three generation communication systems are listed. It brings out the brief idea of what is the difference of three generation communication systems.

2. Industry Implications

Global roaming is expected in the 3rd generation mobile communication system. However, the 3rd generation communication system will not cover the entire world. This is because of the difference in the adaptation of techniques between different countries and also there are a few different standards to deal with. So multi-mode receiver technology is necessary to support different mobile standards to make the 3rd generation communication system seamless.

3. Overview of Currently Techniques

3.1 Modulation

Radio waves have the ability to travel long distances depending on their frequencies and the output power of the transmitters. In order to become the carrier of information, it is necessary to modulate the information signal with a radio wave. There are two common technologies modulation – Amplitude Modulation (AM) and Frequency Modulation (FM). Both have been used extensively in telephony, broadcasting and mobile communication.

(i) AM (Amplitude Modulation)

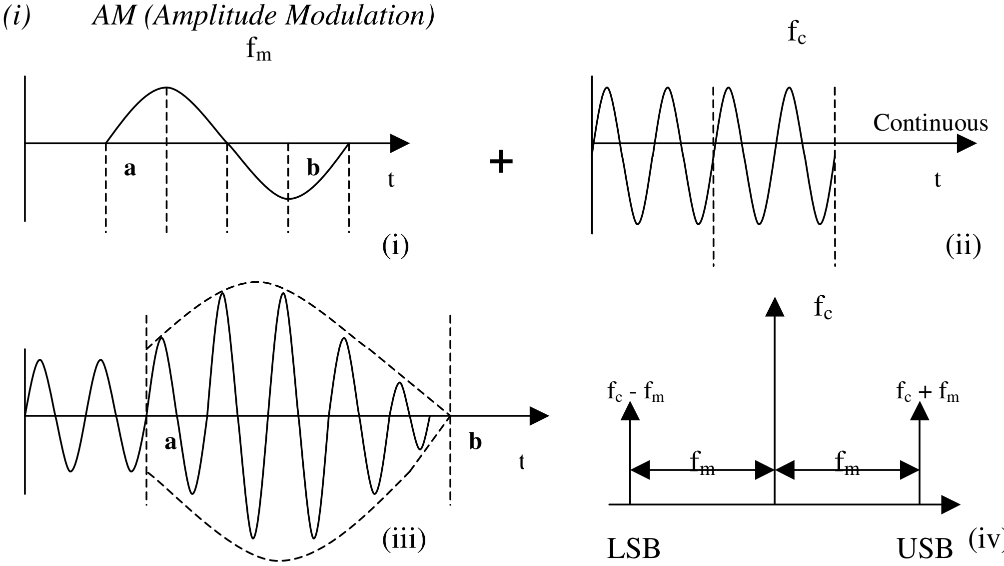

Figure 1 - Amplitude Modulation (i) Modulating signal (f_m) (ii) Carrier frequency (f_c) (iii) amplitude modulated waveform (iv)Spectrum of amplitude modulated double sideband waveform. [Gordon White 1994]

The key factors of AM waveform are varied amplitude and constant frequency.

(ii) FM (Frequency Modulation)

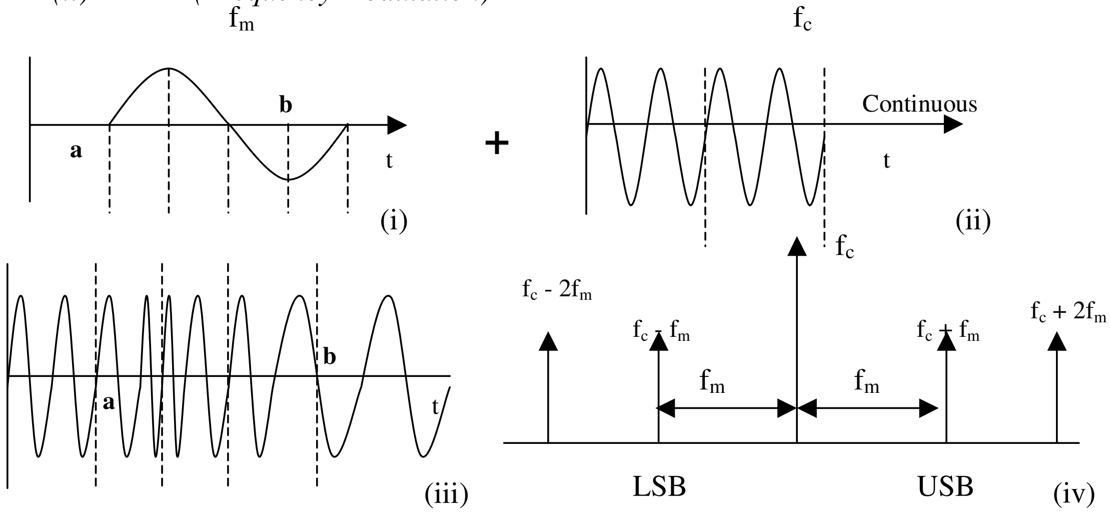

Figure 2 - Frequency Modulation (i) Modulating signal (f_m) (ii) Carrier frequency (f_c) (iii) Modulated FM signal (iv) Spectrum of FM signal [Gordon White 1994]]
The key factors of FM signal are constant amplitude and varied frequency.

3.2 The receiver architecture

(i) Simple receiver

A simple receiver consists of antenna, diode detector, power amplifier and loudspeaker. The circuit is simple by modern technology and it lacks of selectivity and sensitivity.

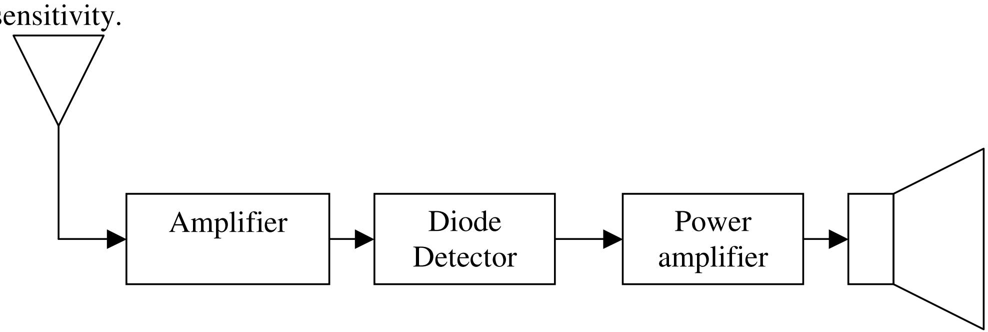

Figure 3 -Simple receiver

(ii) Super heterodyne receiver

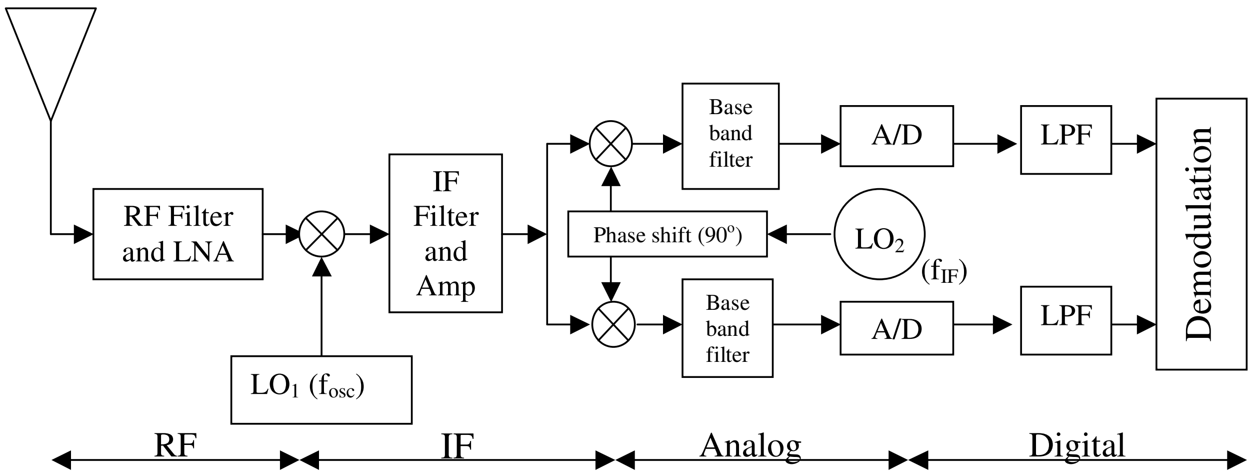

Figure 4 - Superheterodyne receiver [Namgong, W 2001]

The superheterodyne receiver was introduced to improve selectivity and sensitivity. It uses the principle of heterodyning to change all incoming radio signals to the same IF frequency. Good selectivity is achieved by controlled the local frequency because the transmitter frequency is already crystal controlled. The Received signal from the antenna will be filtered by an RF filter and converted to a lower IF signal by mixing with a local-oscillator signal that is crystal controlled to maintain the frequency stability. The resulting IF signal is then amplified before shifting to the baseband and demodulated in DSP environment. At the IF stage, the receiver has most of the gain that is not dependent on the received frequency. The IF frequency remain constant when tuning to different broadcasting stations, the IF stage can then be designed at optimum gain and bandwidth.

(iii) Intermediate Frequency (IF)

Each incoming signal is tuned for reception by varying the frequency of the local oscillator until the intermediate frequency is generated. The frequency of the local oscillator can be either $f_{sig} + f_{IF}$ or $f_{sig} - f_{IF}$. In general, the local oscillator has a higher frequency than the incoming signal. So $f_{osc} = f_{sig} + f_{IF}$. [Gordon White 1994]

3.3 Comparison of Analogue Signal Processing and Digital Signal Processing

Types if Processing	Noise immunity	Programmable	Ease of Filter Implementation	Number of components	Number of Applications
Analog Signal Processing	NO	NO	NO	DIFFICULT	SMALL
Digital Signal Processing	YES	YES	YES	EASY	LARGE

Table1 - Analog and Digital Signal Processing Compared [Nekoogar, F & Moriarty, G 1999]

Analog signal processing is easier to use to provide fast response. It is not efficient in today's signal-processing applications, especially the speed of microprocessor is sufficient fast. Therefore, DSP is ready to replace all the analogue components in receivers. DSP uses software to control signal processing so it is more flexible than analog approach. Filters can be designed digitally, programmed and re-programmed to suit different requirements, which exist in a multi-mode receiver environment. Attenuation and selectivity can also be programmed through the digital means.

4. Research Methodology

MATLAB was selected because the digital signal processing (DSP) Block complemented the powerful algorithm development and signal analysis tool by providing an interactive block diagram environment for system-level simulation and real-time algorithm design. It offers a wide range of built-in DSP techniques, including transforms, buffering, filter design and linear algebra. It is easy to create a sophisticated DSP simulation without low-level programming and adding our own custom algorithms**.** [4]

5 Future technologies

5.1 Digital IF

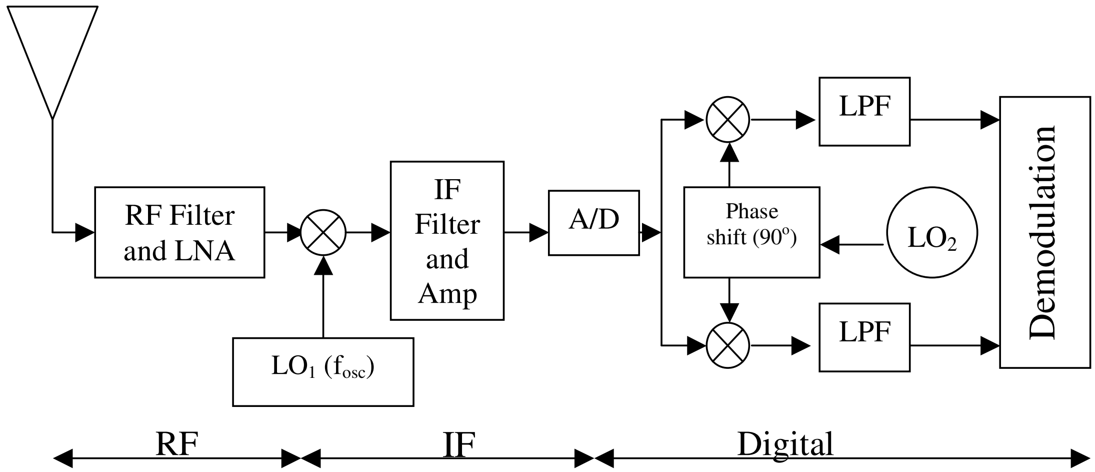

Figure 5 - Digital IF receiver [Mirabbasi, S and Martin, K 2000]

Basically there is only one difference between a superheterodyne receiver (Figure 4) and digital IF receiver (Figure 5). It can be seen that the A/D block is shifted to follow immediately after the IF block. This action will result more analogue components replaced by digital processing. More flexibility and better programmability is the advantages for this receiver. Moreover, those advantages are the key consideration in designing multi-mode receiver.

5.2 Direct Conversion/zero-IF

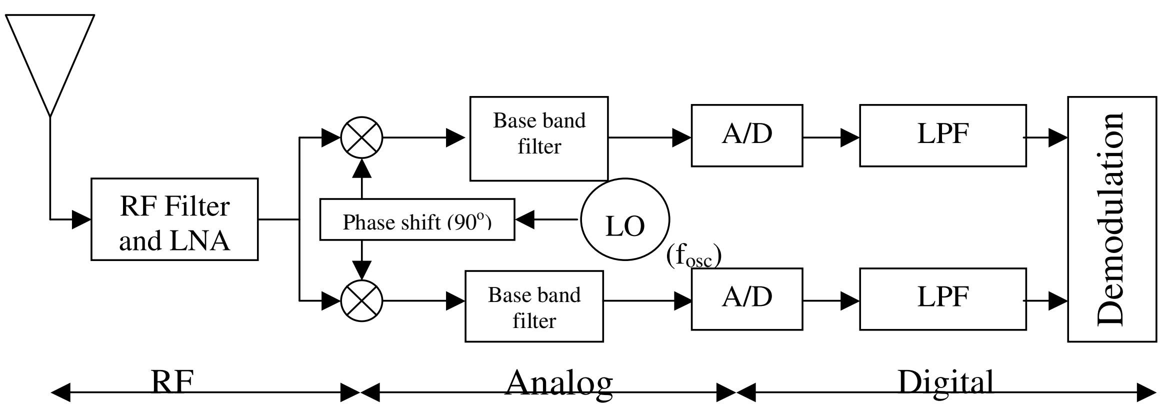

Figure 6: Direct conversion receiver [Namgong, W 2001]

Another approach in obtaining wide bandwidth is to use direct conversion. If the IF is designed to be centered at frequency zero, there is no image signal to be rejected and the analog filtering problem can be easily handled. This process of frequency translation to zero IF is called direct-conversion. With zero IF, the desired signal is translated directly to the baseband. However, it will cause a few critical problems. They are extremely noisy which may result in severe performance degradation. Signal noise is proportional to 1/f, the lower frequency then the higher noise. The other problem is DC offset, dc signal must be stable to overcome the problem

	Modulation	Downlink frequency	Channel spacing	Data rate
AMPS (1st)	FM	869-894MHz	30kHz	N/A
GSM (2nd)	GMSK	935-960MHz	200kHz	207.8 kbps
IS-95 (2nd)	BPSK/QPSK	869-894MHz	1.25MHz	9.6kbps
CDMA2000 (3rd)	BPSK/QPSK	869-894MHz	3.75MHz	~2Mbps
WCDMA (3rd)	BPSK/QPSK	2110-2170MHz	5MHz	>2Mbps

Table 2 - Summary of different generation specification [Sheng, W.J. and Sanchez-Sinencio, E 2000]

6 Conclusion

Multi-mode receivers should have enough flexibility in different mobile environments. Digital receiver will have more advantages than analogue receiver. Better programmability and more flexibility are the key factors in designing multi-mode receivers. Moving the ADC closer to antenna is a trend for creating an ideal receiver that can cope with difficultly in hardware by software programming.

7. Next step

DSP Blockset study in MATLAB, the studying of comprising different generation systems in same IF and the studying of how to simulate different modulation in DSP are to be carried out.

8. References

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