Design and Simulation of Down Conversion Mixer for Front-end Portion of Satellite Receiver

Hnin Yu Wai[#1], Zaw Min Naing[*2], Kyaw Soe Lwin[#3]

[#]*Mandalay Technological University, Mandalay, Myanmar*

[*]*Technological University (Maubin), Myanmar*

[1]power lay@gmail.com, [3]kyawsoelwin007@gmail.com

[2]zawminnaing@pmail.ntu.edu.sg

***Abstract*— In this paper, design and simulation of receiver analogue front-end portion (downconversion mixer) of satellite ground station is presented. The receiver chain is designed to down convert and band pass filtering required for the front-end portion. In this design, the Radio Frequency (RF) and Local Oscillator (LO) frequencies are filtered at 20GHz and 19.5GHz which offers an Intermediate Frequency (IF) of 500MHz. The output IF value can meet the requirements of ultra-wide band receiver analogue front-end portion. The conversion gain for the proposed mixer design is evaluated. The simulation results show input signals and output signal of the mixer.**

***Keywords*— front-end, downconversion mixer, IF, Ka-band**

I. Introduction

The rapid growth of wireless communication such as cordless and cellular phones, wireless local area networks, global positioning satellite (GPS) requires higher performance which has increased the demand for low-cost RF front-end receivers. New technologies are improved to increase higher data rates and capacity. There are a number of different ways that satellite receivers can be designed. But, this paper concentrates on superheterodyne architecture only.

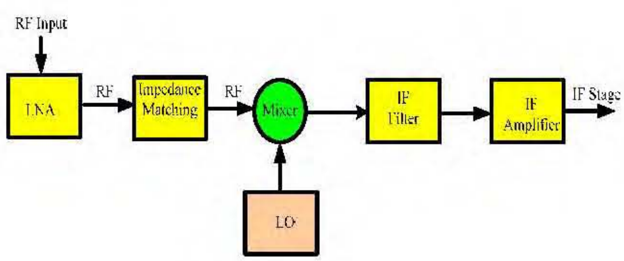

Fig. 1 RF front-end

Fig. 1 shows the block diagram of a typical RF receiver front-end portion. A superheterodyne architecture is used to translate an RF signal down to intermediate frequency(IF), where filtering of adjacent interferer signals as well as amplification and gain control of the target signal is more practical. In the superheterodyne radio, low noise amplifier (LNA) raises the very weak radio frequency (RF) signals to a more convenient level for future processing. Then, the received RF signal enters one input of the mixer. A locally generated signal (local oscillator signal) is fed into the other. The result is that new signals are generated. These are applied to a fixed intermediate frequency (IF) amplifier and filter. Any signals that are converted down and then fall within the passband of the IF amplifier will be amplified and passed on to the next stages. The signals that fall outside the passband of the IF filter are rejected.

Channel selection and amplification occurs at IF. The target signal is selected from among the other signals via one or more passive filters. The IF amplifier is responsible for providing most of the gain in the receiver, as well as the narrowest band pass filtering. It is a high gain, usually multi-staged, single frequency tuned radio frequency amplifier [1].

This paper is divided into five parts. Section II discusses about the front-end portion of satellite receiver. Section III describes downconversion mixer design. The aim is to optimize the performance of down conversion mixer to make it useful for applications around an RF frequency equal to 20GHz. The conversion gain has to be tuned to acquire an acceptable value and make the linearity as high as possible for compensation. Then, Section IV gives the simulation results of downconversion mixer. Finally, Section V presents the conclusion.

II. Front-end Portion of Satellite Receiver

The front-end of a modern superheterodyne radio receiver is the circuitry between the antenna input terminal and the output of the first mixer stage. So, the front-end section consists of Low Noise Amplifier (LNA), Mixer and IF Filter / Amplifier.

A. Low Noise Amplifier

The low noise amplifier (LNA) is the first amplifier in the system. It raises the very weak radio frequency (RF) signals to a more convenient level for future processing. The LNA must have a low noise figure (NF) in order to prevent an excessive degeneration of the signal to noise (S/N) ratio as well as the completely loss of the weak input radio signal. The amplified signal then enters one port of the mixer.

An LNA design presents a considerable challenge because of its simultaneous requirement for high gain, low noise figure, good input and output matching and unconditional stability at the lowest possible current draw from the amplifier. Although Gain, Noise Figure, Stability, Linearity and input and output matching conditions are all equally important, they are interdependent and do not always work in each other's favour.

B. Mixer

The mixer is a very important circuit in satellite receiver as its performance affects the system performance and the performance requirements of its adjacent circuit such as low noise amplifier and the IF amplifier. Mixers are used to translate a signal spectrum from one frequency to another by using nonlinear devices, such as diodes, transistors or field-effect-transistor (FET) mixer in time-varying circuits. The output of the mixer contains the sum and different frequencies of the LO signal and an incoming information signal, the RF signal.

Mixers can be divided into three types according to their topologies. They are single-ended, single-balanced, and double-balanced. This paper concentrates on singled-ended mixer only. In addition, it can be categorized into passive and active mixers in terms of conversion gain. Passive mixers, such as diode mixers and passive field-effect transistor (FET) mixers, have no conversion gain. On the other hand, active mixers have conversion gain which acts to reduce the noise contribution from the IF stages. Downconversion mixer should provide sufficient power gain to compensate for the IF filter loss, and to reduce the noise contribution from the IF stages. Because the receiver gain can be supported by the LNA, high conversion gain for the Mixer is not often needed [2].

C. IF Filter / Amplifier

The output of the frequency translator or downconversion mixer is called the intermediate frequency (IF). The main attribute of the superheterodyne receiver is that it converts the radio signal's RF frequency to a lower standard IF frequency for further processing. The reason is that higher frequencies were more difficult to process than lower frequencies.

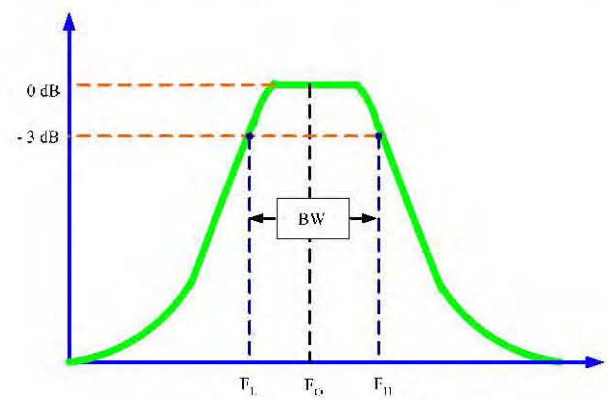

Fig. 2 IF bandwidth response

The two frequencies that are generated at the output of the mixer are then fed into a fixed frequency intermediate frequency (IF) amplifier and filter. Since the mixer's IF port is terminated with a conventional IF filter, such as bandpass or lowpass type, the sum frequency re-enter the mixer and generate intermodulation distortion. Any signals that are converted down and then fall within the passband of the IF amplifier will be amplified and passed on to the next stages. Those that fall outside the passband of the IF filter are rejected.

Most of the selectivity of the receiver is provided by the filtering in the IF amplifier section. The filtering might be L-C filters, a ceramic resonator, a crystal filter or a mechanical filter. The intermediate frequency (IF) bandwidth is measured from the points on the IF frequency response curve where gain drops off -3dB from the mid-band value. Figure 2 illustrates this. The intermediate frequency (IF) bandwidth must be matched to the bandwidth of the received signal for best performance. If the wider signal bandwidth is selected, the signal to noise ratio (SNR) will deteriorate and then the received signal may be noise. If the bandwidth is too narrow, then it may be experienced the difficulties for recovering all of the information that was transmitted [1].

III. DOWNCONVERSION MIXER DESIGN

DownConversion mixers perform frequency conversion by using nonlinear elements in time-varying circuits. The basis of mixing relies on the multiplication of two signals: an ideal square wave, the local oscillator signal and an incoming information signal, the RF signal.

When two signals are multiplied together the output is the product of the instantaneous level of the signal at one input and the instantaneous level of the signal at the other input. It is found that the output contains signals at frequencies other than the two input frequencies [3]. If the two input signals are referred to as V_1 and V_2 in Eqs. (1) and (2),

$$V_1 = A_1 \sin(\omega_1 t) \quad (1)$$

$$V_2 = A_2 \sin(\omega_2 t) \quad (2)$$

The output is according to the (1) and (2) as following:

$$V_o = V_1 V_2$$

$$= A_1 A_2 [\cos(\omega_1 - \omega_2)t - \cos(\omega_1 + \omega_2)t]/2 \quad (3)$$

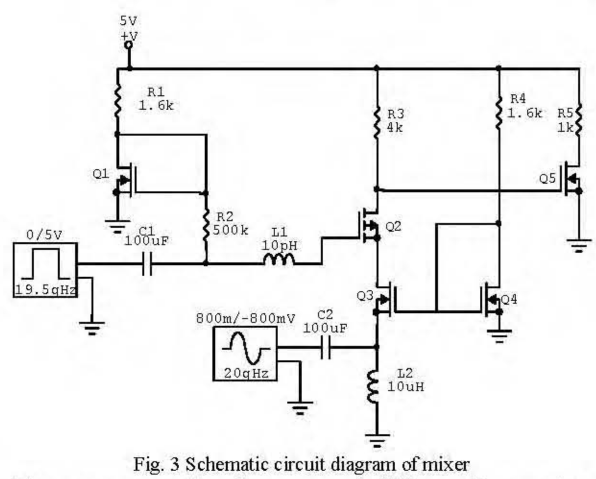

Fig. 3 Schematic circuit diagram of mixer

The output contains the sum and different frequencies of the two input signals. For downconversion purpose, the sum