East West University

Department of EEE

Project Report

Analysis of the frequency domain response of a superheterodyne receiver

Course Code: EEE303 Course Title: Signals and Linear Systems

Section-1 Summer 2025

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Objective:

Superheterodyne receivers are widely used in almost all modern radio receivers. The objective of this project is to exercise the knowledge of Fourier Transform to understand the frequency conversions of the received signal in a superheterodyne receiver.

Theory:

A super-heterodyne receiver is used to convert the received radio signal with RF frequency into a signal with standard frequency for further processing.

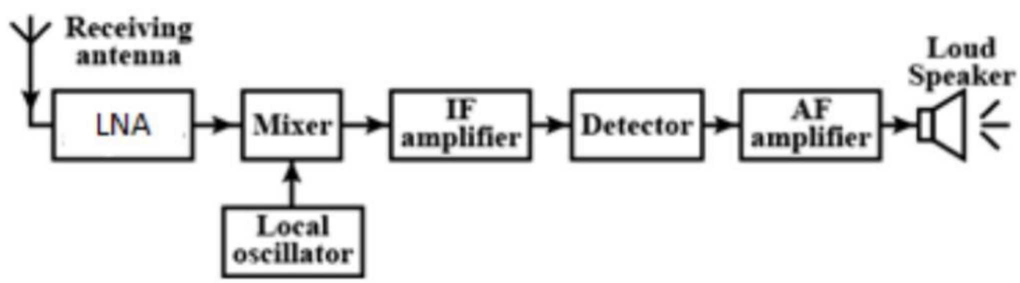

Figure- 1: Functional block diagram of a superheterodyne receiver [1, 2]

Figure 1 shows the functional block diagram of a superheterodyne receiver. The radio-frequency (RF) waves from the broadcasting station are received by the receiving antenna. The Low Noise amplifier (LNA) reduces the noise content in the received signal by amplifying the signal components in the desired frequency band and suppressing the signal components out of the desired band. The mixer multiplies the received signal with the signal generated by the local oscillator (LO). The product of this multiplication has two frequency components – one component has the frequency equal to the summation of the RF and LO frequencies, and the other component has the frequency equal to the difference between the RF and LO frequencies. The IF amplifier works at the intermediate frequency by amplifying the signal components having frequencies equal to the difference between the RF and LO frequencies and suppressing the signal components at other frequencies.

The detector is used to extract the signal of interest from the IF signal, for example – here an audio signal is extracted. A mixer can be used as the detector or demodulator, where the output from a local oscillator (LO2) is multiplied with the IF amplifier output, resulting in a product which has two frequency components – one component has the frequency equal to the summation of the IF and LO2 frequencies, and the other component has the frequency equal to the difference between the RF and LO2 frequencies. Finally, the Audio Frequency (AF) amplifier extracts the signal of interest by amplifying the signal components having frequencies equal to the difference between the IF and LO2 frequencies and suppressing the signal components at other frequencies.

Deliverables-1

Super-heterodyne Receivers:

A high-frequency radio signal is converted to a lower, intermediate frequency (IF) via a superheterodyne receiver so that processing is simpler. The incoming signal and the local oscillator (LO) signal are combined using a mixer to produce sum and difference frequencies. The receiver may filter and amplify the signal with great sensitivity and selectivity by choosing the difference frequency (IF). In communication systems like radio, TV, and mobile networks, superheterodyne receivers are crucial because of their improved capacity to separate the required signal from noise and interference.

Major operations

There are some major operations of “Super-heterodyne receivers”

Broadcasting Television:

These receivers allow audio and video data to be reused in boxes. By switching to an intermediate frequency, the signal's clarity and stability are enhanced, producing highquality audio and visuals.

Mobile Communication:

The differences Super-heterodyne receivers manage Bluetooth, Wi-Fi, and cellular signals in smartphones and tablets. This technique offers high-quality signal events in colorful bias and harmonic connectivity.

Radio Broadcasting on AM and FM:

Marketable radio receivers utilize super-heterodyne receivers to improve signal quality by converting incoming radio frequency to a lower intermediate frequency (IF), which results in better audio knowledge and improved filtering.

Radar System:

Radar systems implement super-heterodyne receivers to detect and locate objects by processing high-frequency radar signals and converting them to intermediate frequency. This method improves signal processing and target identification.

Navigation and Communication in Aerospace:

A consistent and clear signal event is provided by these receivers, which are used in airplanes for navigation and communication. This is an essential component of efficient air business control and safe flying.

Satellite Dispatches:

Ground stations and satellite transponders handle satellite signals with super-heterodyne receivers. This function is necessary for stable and efficient communication in satellite TV, the internet, and navigation systems.

Military Communication system:

Military activities use super-heterodyne receivers to provide secure and dependable communication. Like radios and navigation systems, they are essential for dependable performance under demanding circumstances in a range of military gear.

Deliverables-2

Calculating the values from My student ID

Student Id: 2022-2-80-018.

Last three digit of student ID: 018 .So, A=0, B=1, C=8.

Frequency	Value in (kHz)
ω_m	18
ω_1	11
ω_{LO}	20

Deliverables-3

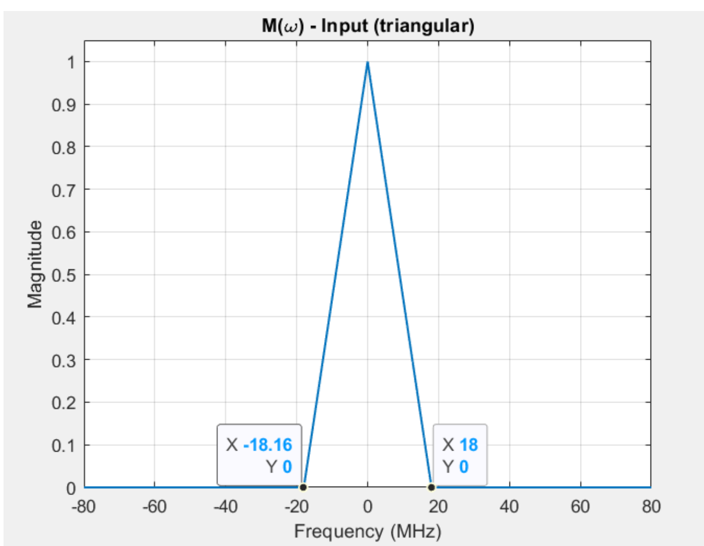

Figure-1: Spectrum of M(ω)

3(a)

P(ω)= m(ω) * H1(ω)   [from convolution properties]

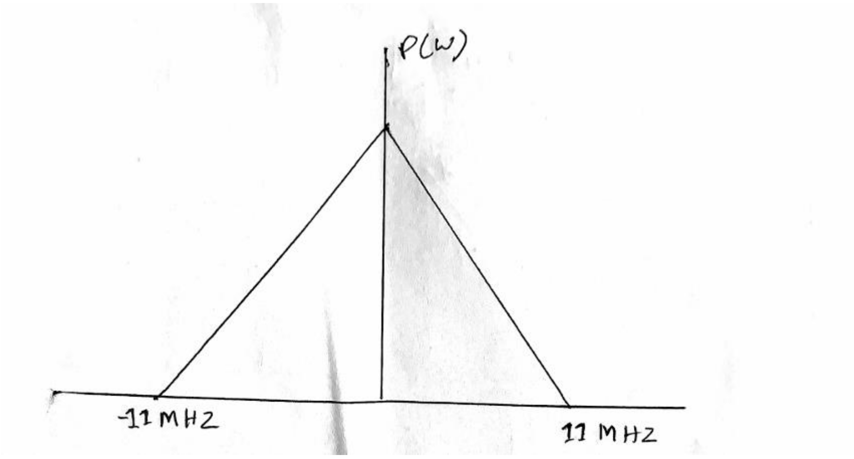

Figure-2: Spectrum of P(ω)

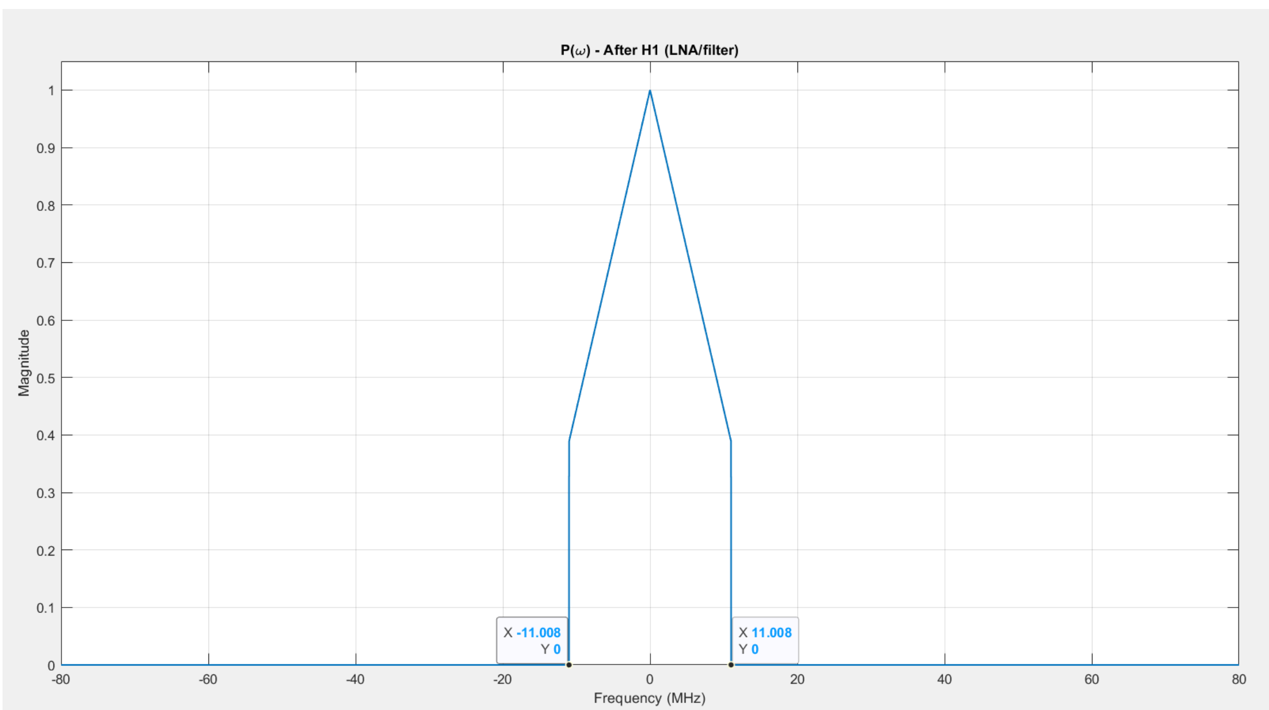

Figure-3: Spectrum of plot P(ω), Using Matlab.

3(b)

$Q(\omega) = P(\omega) \, . \, \cos(\omega_{LO} t)$

$Q(\omega) = \frac{1}{2}[P(\omega - \omega_{LO}) + P(\omega + \omega_{LO})]$ [from calculation]

$= \frac{1}{2}[P(\omega - 20) + P(\omega + 20)]$

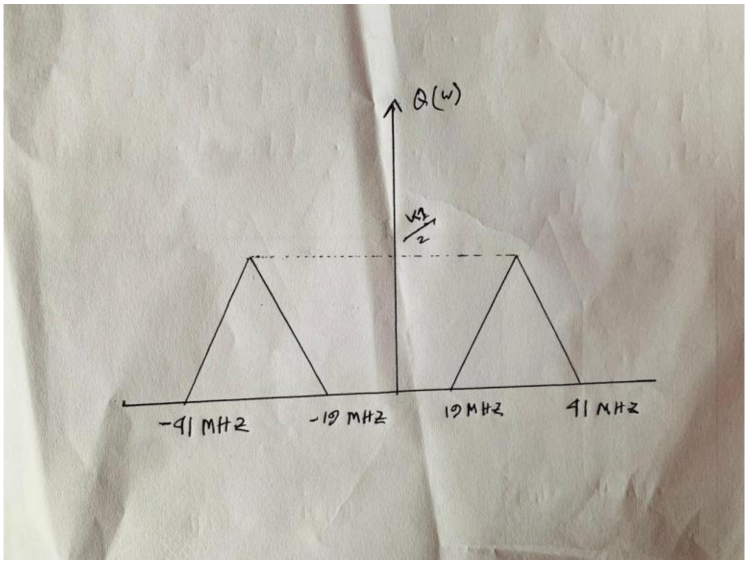

Figure-4: Spectrum of Q(ω)

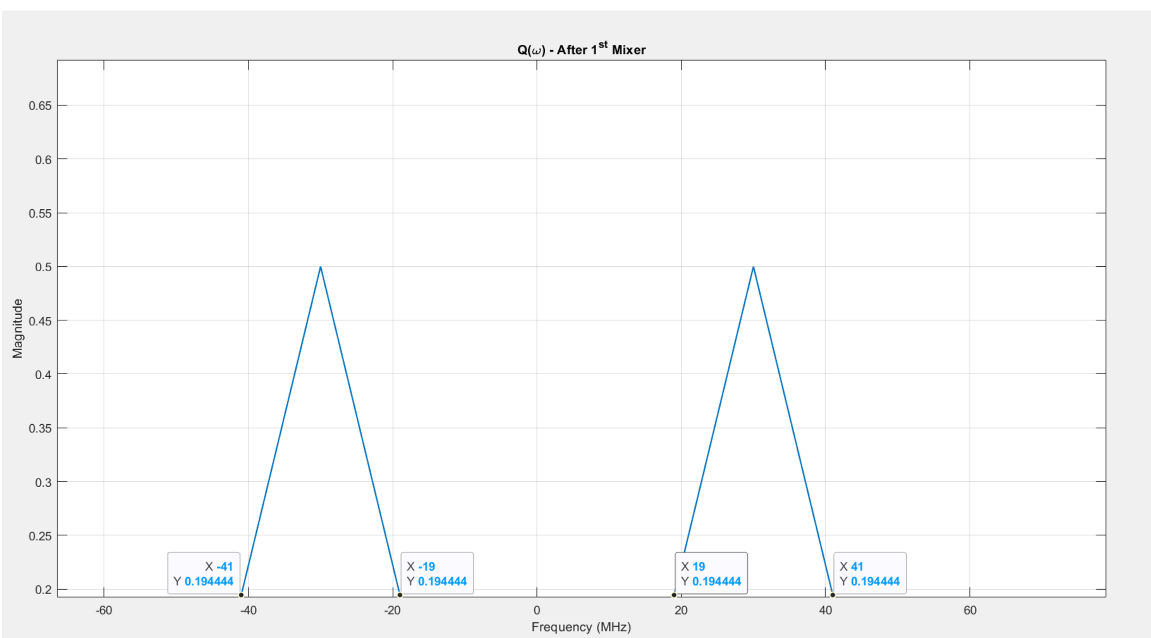

Figure-5: Spectrum of plot Q(ω), Using Matlab.

3(c)

Thus Spectrum,

$R(\omega) = Q(\omega) \cdot H_2(\omega)$ [from convolution properties]

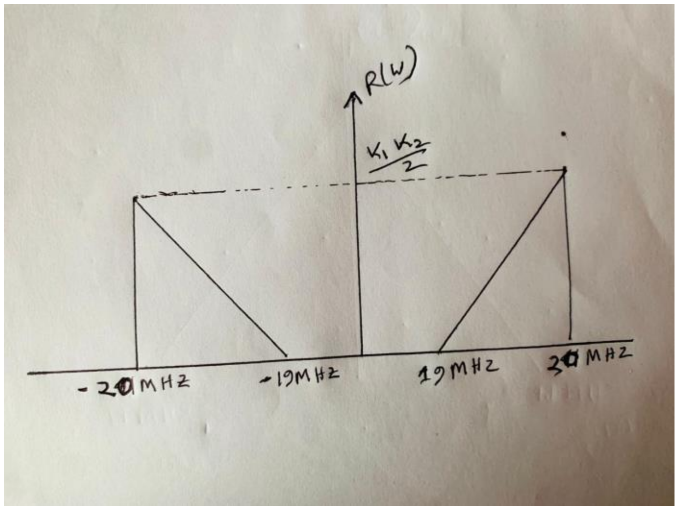

Figure-6: Spectrum of $R(\omega)$

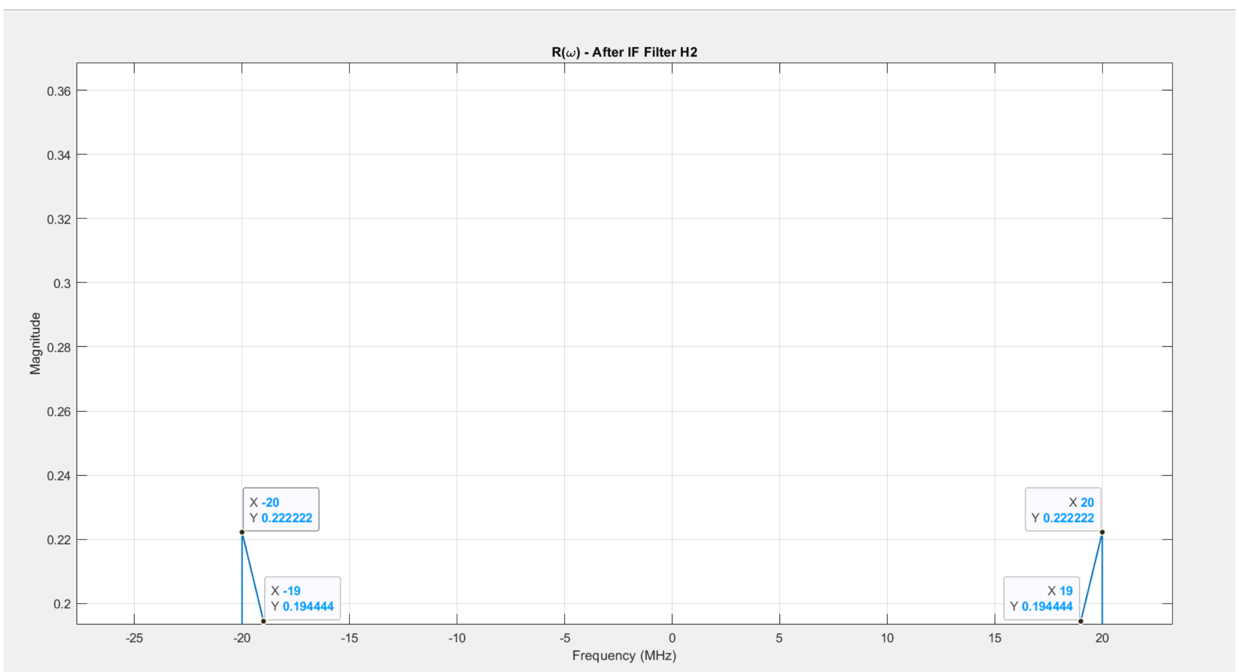

Figure-7: Spectrum of plot $R(\omega)$, Using Matlab.

3(d)

$$S(\omega) = \frac{1}{2}\Big[R(\omega - 30) + R(\omega + 30)\Big]$$

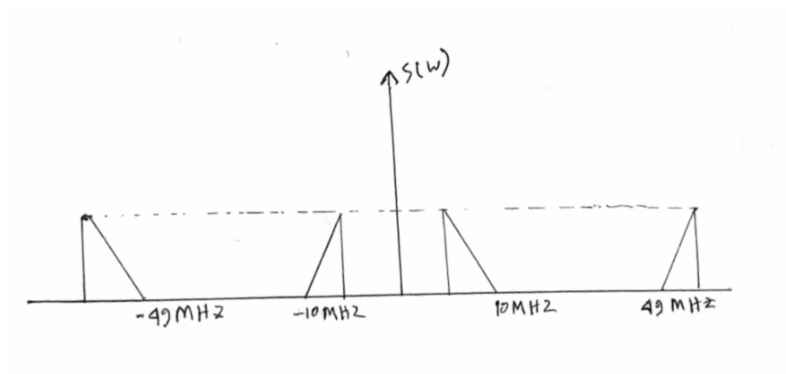

Figure-8: Spectrum of S(ω)

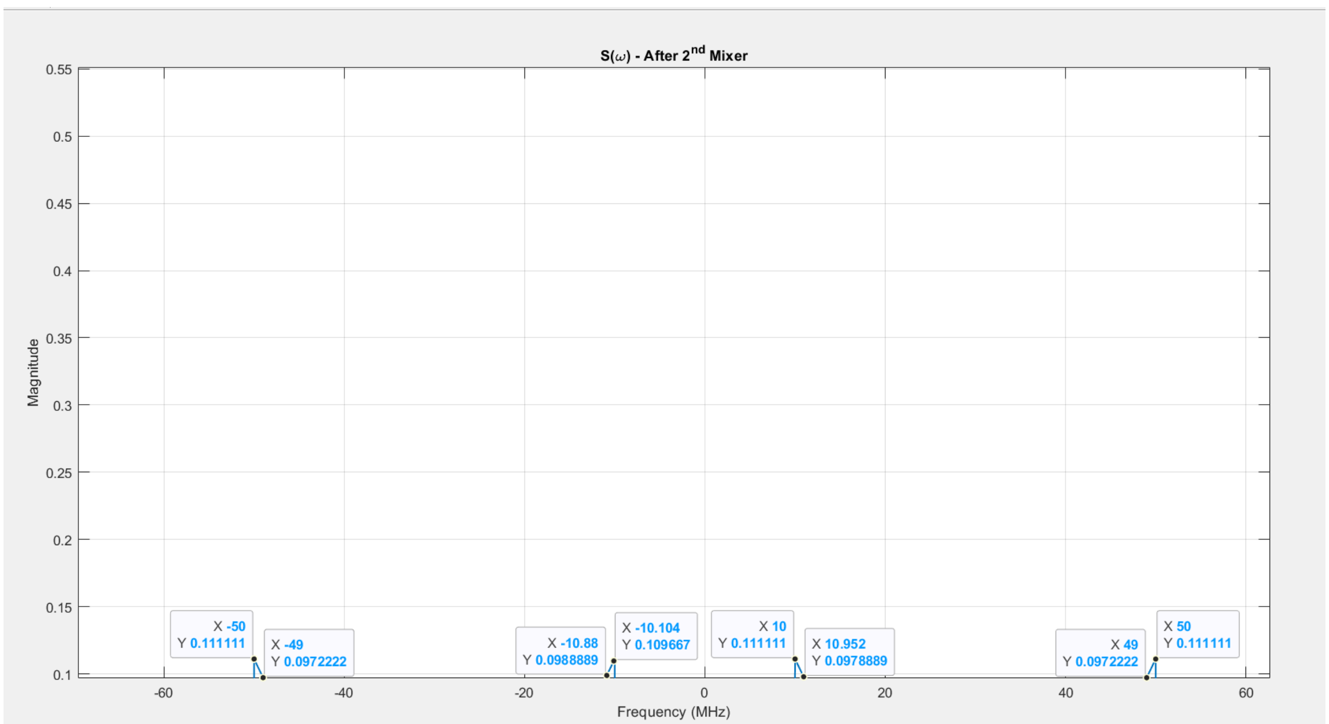

Figure-9: Spectrum of plot R(ω), Using Matlab.

Conclusion:

A superheterodyne receiver's frequency domain response entails transforming the incoming signal to an intermediate frequency, which makes filtering and amplification easier. By effectively separating the required signal and rejecting undesired frequencies, this method helps the receiver achieve greater selectivity and sensitivity. Because it can handle complicated signals and produce dependable, unambiguous output in a variety of communication systems, its architecture is frequently employed.