

# **Double-Sideband Suppressed-Carrier (DSB-SC) Communication System Design**

DGE-203 Final Project Report

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17 October AD 2021

# DSB-SC System design report summary

A double-sideband suppressed-carrier communication system design. The design in this report are presented in three major parts, which are modulation, distortion and demodulation of the signal. Which the transmitting message frequency is based on the last three, non-zero digits of student ID numbers.

The DSB-SC system composed of: Modulation of a signal, which modulates the amplitude of the incoming signal, Distortion of a signal when it passes through a communication channel, Demodulation of a signal, which utilize the low-pass-filter. In which the final signal will form a scaled and distorted version of the original message signal.

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# Contents

1. Introduction to DSB-SC and design overview	1
2. Modulated signal analysis	3
3. Distortions in communication channel	5
4. Demodulated signal analysis	7
5. Conclusions	10
Appendices	11

Note: The main content of this report, which is from page 1 to page 10, is within the range of 10 pages, following the guideline stated in the report instruction.

# 1. Introduction to DSB-SC and design overview

## 1.1 Double-sideband suppressed-carrier (DSB-SC) transmission

Double Sideband Suppressed Carrier transmission is the transmission of a modulated wave, which **only sidebands** are transmitted through the communication system, while the **carrier wave** is being **suppressed**.

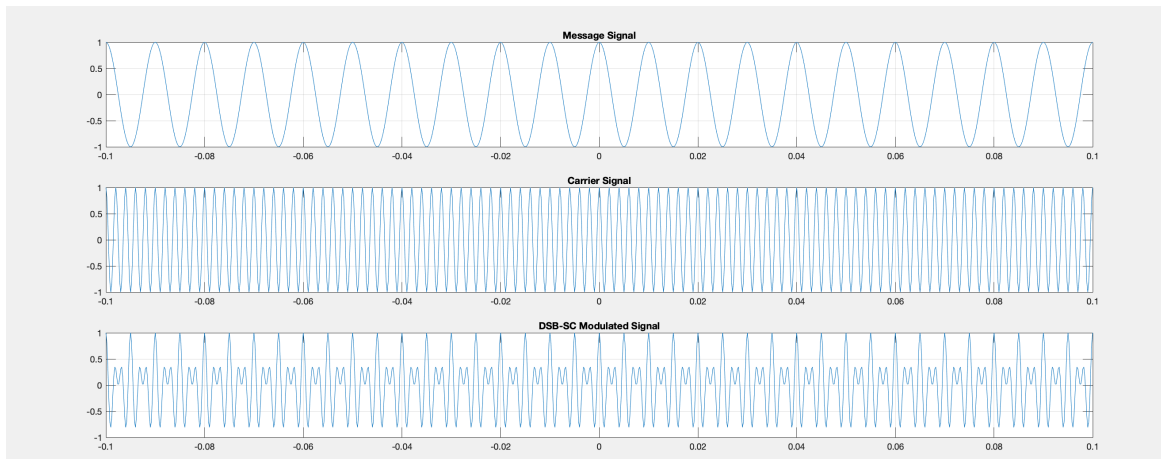


Fig 1.1 Example simulation of DSB-SC transmission in time domain

In example above, figure 1.1, the frequency of message and carrier wave is 100Hz and 500Hz respectively and the amplitude of both is 1.

## 1.2 DSB-SC communication system design problem statement

### 1.2.1 Design a DSB-SC communication system following the diagram below

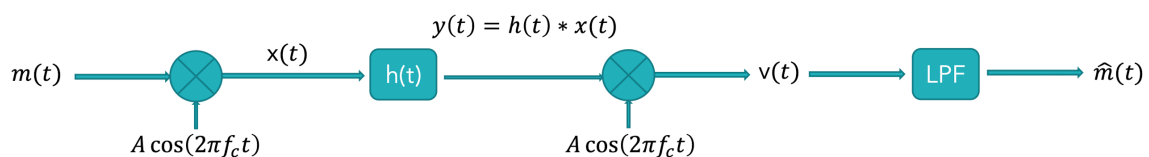


Fig. 2.1 DSB-SC communication system diagram

Given channel characteristic  $H(f) = e^{-2j\pi 30t} + e^{-2j\pi 5t}$  (1.2.1)

### 1.2.2 Baseband signal for my DSB-SC system

Baseband message signal  $m(t)$  is composed with three frequencies, based on my last 3 digits of my student ID, which is 2021610064

$$m(t) = \cos(2\pi 100t) - \frac{1}{3}\cos(2\pi 60t) + \frac{1}{5}\cos(2\pi 4t) \quad (1.2.2)$$

### 1.3 Overview of the system design

Introduction to the approach to the design of each part of the system, which each steps will be expand further in the next respective sections.

#### 1.3.1 Message signal modulation

Generation of modulated message signal,  $m(t)$ , with the carrier signal, resulting in a DSB-SC modulated waveform.

$$x(t) = m(t) \times c(t) \quad (1.3.1)$$

Where  $x(t)$  is the output modulated signal,  $m(t)$  is the message signal, and the multiplying term,  $c(t)$ , is the carrier signal.

#### 1.3.2 Channel distortion

Once the modulated signal pass through the Linear Time-Invariant communication channel, distortion will have effect on the passing signal, by the channel characteristic.

#### 1.3.3 Demodulation of signal

Demodulated signal is the product of  $y(t)$  and the carrier signal.

$$v(t) = y(t) \times c(t) \quad (1.3.3)$$

Where  $v(t)$  is the demodulated signal,  $y(t)$  is the modulated signal after being distorted through the communication channel.

#### 1.3.4 Entering Low-Pass-Filter

Passes original message signals, with a frequency lower than the cutoff frequency and reduce the amplitude of carrier signals with frequencies higher than the cutoff frequency.

#### 1.3.5 Resulting output signal

The resulting signal after the demodulation and the application of the Low pass filter, will be a scaled and distorted version of the message signal.

#### 1.3.6 Note on graphical plots

The range of the time that use to scale the figures in time domain is from -0.1 to 0.1, with incrementation of  $1/f_s$ , where  $f_s$  is the sampling frequency.

## 2. Modulated signal analysis

### 2.1 Baseband signal observation

Baseband signals are signals that occupied the range of frequencies, which has not been through the process of modulation.

#### 2.1.1 Message and Carrier signals

The message signal, eq.(1.2.2) and the carrier signal,  $c(t) = A_c \cos(2\pi f_c t)$  with carrier signal amplitude of 1 and frequency of 1kHz is plotted and shown in figure 2.1.1 below.

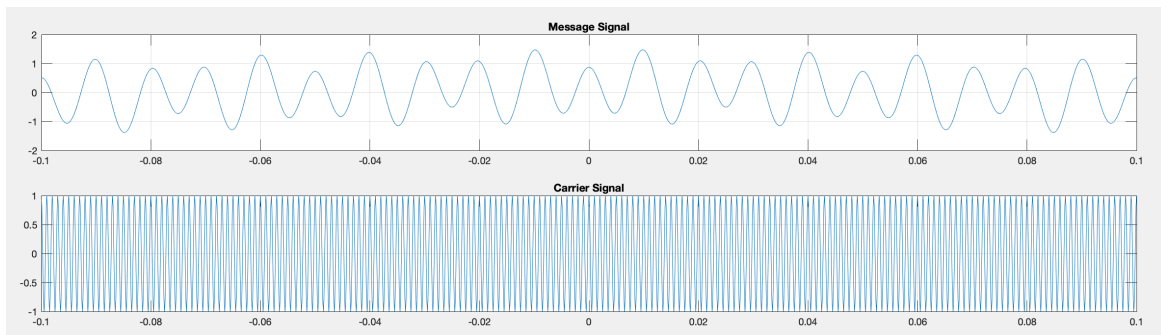


Fig 2.1.1 Message signal & Carrier signal in time domain

#### 2.1.2 Fourier transform of Message signal

We can observe the frequency range of the message signal clearer in the frequency domain. As shown in figure 2.1.2, the frequencies are around at 4Hz, 60Hz and 100Hz, which represent the frequencies of equation (1.2.2).

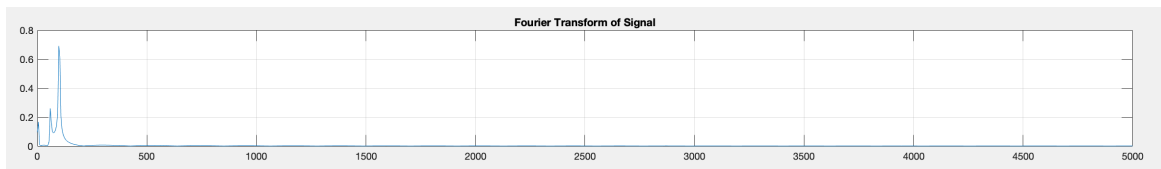


Fig 2.1.2 Fourier transform of message signal in frequency domain

### 2.2 Message signal modulation

From equation (1.3.1), we can get the modulated signal from the product of the message signal and the carrier signal. The plot of the signal after DSB-SC modulation is shown in figure 2.2.1 below.

From (1.3.1);  $x(t) = m(t) \times c(t)$

$$x(t) = (\cos(2\pi 100t) - \frac{1}{3}\cos(2\pi 60t) + \frac{1}{5}\cos(2\pi 4t)) \times (\cos(2\pi 1000t))$$

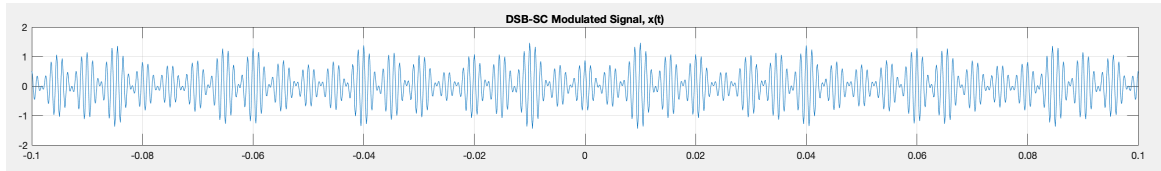


Fig 2.2.1 DSB-SC modulation in time domain

## 2.3 Fourier transform of modulated signal

If we take the Fourier transform of the modulated signal, it is apparent that the carrier signal component is being suppressed, as it isn't visible in the output signal in frequency domain.

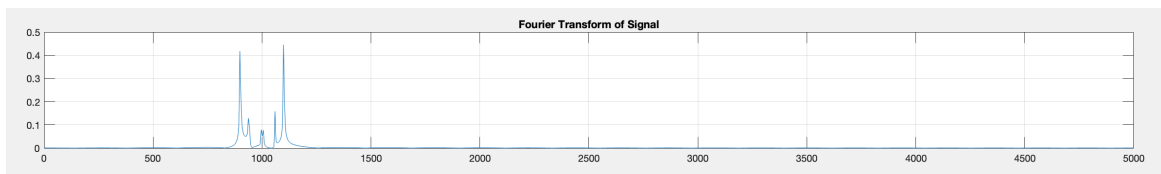


Fig 2.3.1 Fourier transform of modulated signal in frequency domain

When the spectrum of the output signal is viewed. In figure 2.3.1 we see six peaks, the three peaks below 1kHz are the lower sideband and the three peaks above 1kHz are the upper sideband, but there is no peak at the 1kHz point, which denotes the frequency of the carrier, which has been suppressed.

### 3. Distortions in communication channel

#### 3.1 Channel distortion in frequency domain

To get the signal  $y(t)$ , with given channel characteristic  $H(f)$ , we can convert  $x(t)$  to  $X(f)$ , and use the converted signal to find  $Y(f)$  in frequency domain. Which lastly the signal can be convert back to time domain as  $y(t)$ .

##### 3.1.1 Convert $x(t)$ to $X(f)$ in frequency domain

We can take the Fourier transform of the signal  $x(t)$  to get  $X(f)$ .

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-2\pi j t} dt$$

$$X(f) = \int_{-\infty}^{\infty} (\cos(2\pi 100t) - \frac{1}{3}\cos(2\pi 60t) + \frac{1}{5}\cos(2\pi 4t)) \times (\cos(2\pi 1000t)) \cdot e^{-2\pi j t} dt$$

$$X(f) = \frac{1}{2}[\pi\delta(f - 1800\pi) + \delta(f + 1800\pi)] - \frac{1}{6}[(\pi\delta(f - 1880\pi) + \delta(f + 1880\pi))] + \frac{1}{10}[(\pi\delta(f - 1992\pi) + \delta(f + 1992\pi))] + \frac{1}{10}[(\pi\delta(f - 2008\pi) + \delta(f + 2008\pi))] - \frac{1}{6}[(\pi\delta(f - 2120\pi) + \delta(f + 2120\pi))] + \frac{1}{2}[(\pi\delta(f - 2200\pi) + \delta(f + 2200\pi))]$$

The figure 3.1.1 shows signal  $X(f)$  in frequency domain.

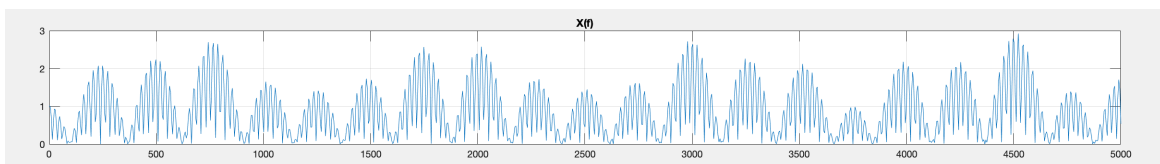


Fig 3.1.1 Modulated signal in frequency domain

##### 3.1.2 Apply channel distortion

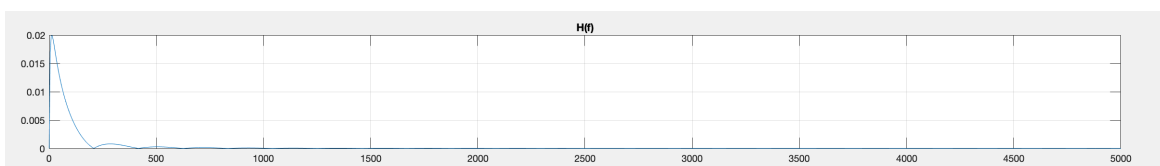


Fig 3.1.2 i. Channel characteristic in frequency domain



Now that both of the channels characteristic and the modulated signal are in the frequency domain, the input-output relationship in frequency domain is given by  $Y(f) = H(f)X(f)$ .

$$Y(f) = X(f)H(f)$$

$$Y(f) = \pi(\delta(f - 1800\pi) + \delta(f + 1800\pi))(1 + 1.1392e^{-14j}) - \pi(\delta(f - 1880\pi) + \delta(f + 1880\pi))(\frac{1}{3} + 3.7972e^{-15j}) + \pi(\delta(f - 1992\pi) + \delta(f + 1992\pi))(\frac{1}{5} + 2.2783e^{-15j}) + \pi(\delta(f - 2008\pi) + \delta(f + 2008\pi))(\frac{1}{5} + 2.2783e^{-15j}) - \pi(\delta(f - 2120\pi) + \delta(f + 2120\pi))(\frac{1}{3} + 3.7972e^{-15j}) + \pi(\delta(f - 2200\pi) + \delta(f + 2200\pi))(1 + 1.1392e^{-14j})$$

By multiply  $H(f)$ , which is given by the equation (1.2.1) and shown in figure 3.1.2 i. with  $X(f)$ , the resulting signal will be  $Y(f)$  in the frequency domain, which is shown in figure 3.1.2 ii.

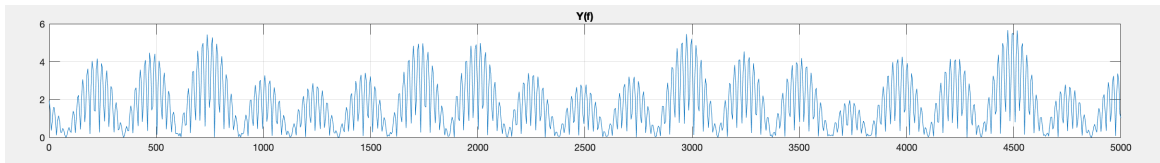


Fig 3.1.2 ii. Distorted signal in frequency domain

## 3.2 Conversion to time domain

### 3.2.1. Convert $Y(f)$ back to $y(t)$

We can take the inverse Fourier transform to the signal  $Y(f)$  to get  $y(t)$ , which is in the time domain again. Converted signal is shown in figure 3.2.1.

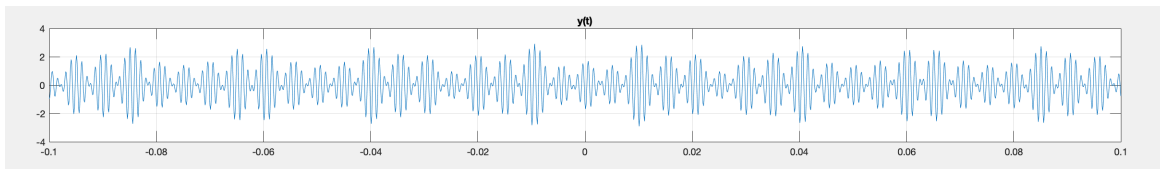


Fig 3.2.1 Distorted signal in time domain

$$y(t) = \frac{1}{2\pi} \left[ \pi(e^{-\pi t 1800j} + e^{\pi t 1800j})(1 + 1.1392e^{-14j}) - \pi(e^{-\pi t 1880j} + e^{\pi t 1880j})(\frac{1}{3} + 3.7972e^{-15j}) + \pi(e^{-\pi t 1992j} + e^{\pi t 1992j})(\frac{1}{5} + 2.2783e^{-15j}) + \pi(e^{-\pi t 2008j} + e^{\pi t 2008j})(\frac{1}{5} + 2.2783e^{-15j}) - \pi(e^{-\pi t 2120j} + e^{\pi t 2120j})(\frac{1}{3} + 3.7972e^{-15j}) + \pi(e^{-\pi t 2200j} + e^{\pi t 2200j})(1 + 1.1392e^{-14j}) \right]$$

## 4. Demodulated signal analysis

### 4.1 Signal Demodulation

#### 4.1.1 Demodulated signal

The first step of DSB-SC demodulation is done by multiplying the DSB-SC modulated signal with the carrier signal, as denoted in eq.(1.3.3).

From (1.3.3);  $v(t) = y(t) \times c(t)$

$$v(t) = \frac{1}{2\pi} \left[ \pi(e^{-\pi t 1800j} + e^{\pi t 1800j})(1 + 1.1392e^{-14j}) - \right. \\ \pi(e^{-\pi t 1880j} + e^{\pi t 1880j})\left(\frac{1}{3} + 3.7972e^{-15j}\right) + \\ \pi(e^{-\pi t 1992j} + e^{\pi t 1992j})\left(\frac{1}{5} + 2.2783e^{-15j}\right) + \\ \pi(e^{-\pi t 2008j} + e^{\pi t 2008j})\left(\frac{1}{5} + 2.2783e^{-15j}\right) - \\ \pi(e^{-\pi t 2120j} + e^{\pi t 2120j})\left(\frac{1}{3} + 3.7972e^{-15j}\right) + \\ \left. \pi(e^{-\pi t 2200j} + e^{\pi t 2200j})(1 + 1.1392e^{-14j}) \right] \cos(2\pi 1000t)$$

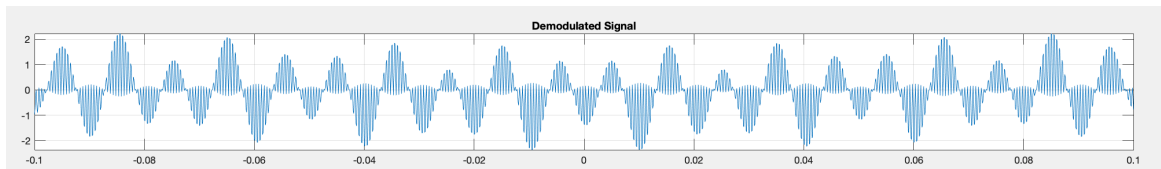


Fig 4.1.1 Demodulated signal in time domain

#### 4.1.2 Fourier transform of demodulated signal

It is apparent in figure 4.1.2 below, that there is 2 batches of frequencies along the frequency spectrum, which the lower frequency batch is the original message, while the higher are the DSB-SC modulated signal's.

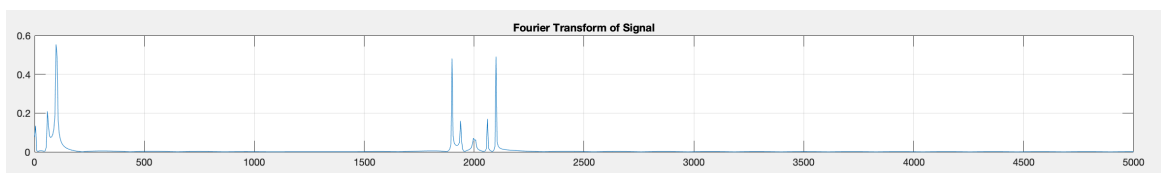


Fig 4.1.2 Fourier transform of demodulated signal in frequency domain

## 4.2 Low Pass Filter (LPF)

### 4.2.1 Application of Low pass filter

This demodulated signal is passed through a low pass filter to form a scaled version of the original message signal and for the signal to pass only the message signal.

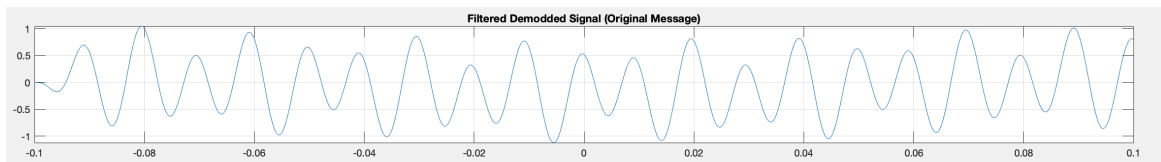


Fig 4.2.1 Filtered demodulated signal in time domain

### 4.2.2 Characteristic of signal after application of LPF

A low-pass filter or LPF passes signals with a frequency lower than the cutoff frequency and decrease the signal with frequencies higher than the cutoff frequency. Which means once the demodulated signal passes through the low pass filter, the higher frequency component, or the carrier's frequency is removed, leaving just the original message.

### 4.2.3 Fourier transform of signal after application of LPF

From the plot of figure 4.2.3, the remaining batch of frequencies on the frequency spectrum is from only the message signal, hence, the demodulation of the signal.

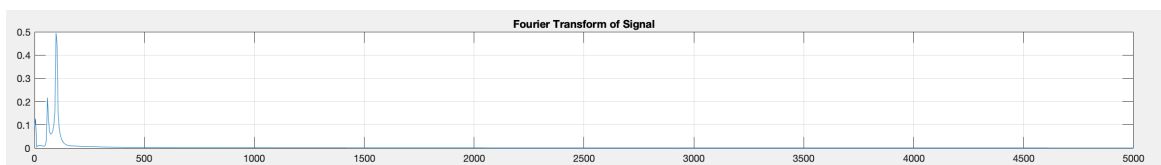


Fig 4.2.3 Fourier transform of filtered signal in frequency domain

## 4.3 Resulting output signal

The resulting figure 4.2.1 is the message signal that has been modulated, distorted through communication channel, demodulated and applied low pass filter. Which the signal presented in the said figure is the signal that the receiver will receive.

### 4.3.1 Original message comparison in time domain

By comparing the final resulting signal and the original message signal in the time domain in figure 4.3.1. The following observations can be made:

- The final resulting signal after modulation, distortion, demodulation and filtration is a scaled and distorted version of the original message signal.
- The amplitude of the demodulated (final) signal appears to be slightly lower than the amplitude of the original message signal.

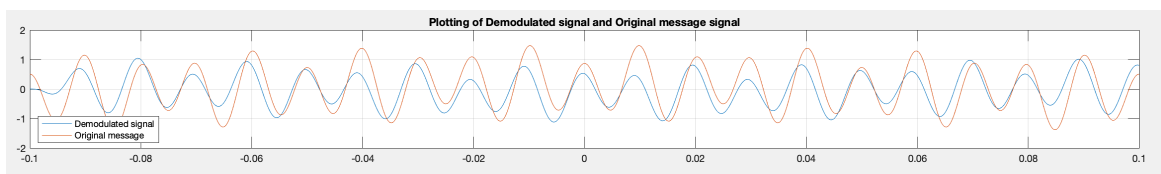


Fig 4.3.1 Demodulated signal and original message signal in time domain

### 4.3.2 Original message comparison in frequency domain

And by comparing the final resulting signal and the original message signal in the frequency domain in figure 4.3.2. We can observe that:

- The amplitude of the demodulated signal has been attenuated and scaled down from the original message signal.
- However, the distribution of frequencies of the demodulated signal remains the same as the original message, which are around 4, 60 and 100 Hz on the frequency spectrum.

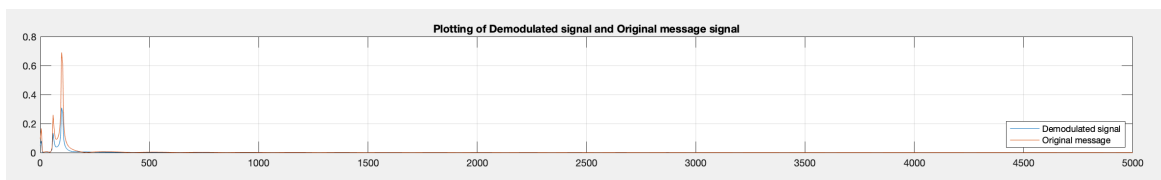


Fig 4.3.2 Demodulated signal and original message signal in frequency domain

## 5. Conclusions

Given a baseband signal, with no prior modulation, with frequency respecting to student's ID number. We can design a DSB-SC communication system. In order of modulation, channel distortion, demodulation and low pass filter.

A message signal can be modify by multiplying with a carrier signal. This type of amplitude modulation is called "Double-sideband suppressed-carrier" or DSB-SC modulation. The signal that has been modulated, are affected with channel distortions, which are distinguish by the channel characteristics, and are differs from channels to channels.

The demodulation of a signal can be obtain by the product of the modulated signal and the carrier signal. After getting the product, the signal is now demodulated, but with the carrier signal's frequency included. In order to attenuate the carrier frequency, we can apply low pass filter to the signal. The original message will be the only thing that's left in the output signal, while the carrier signal component is suppressed.

The final signal will output a scaled and distorted version of the original message signal.

# Appendices

## Figures

### MATLAB Simulated figures

The table below denotes the purpose of each file and their respective figures.

File name (↓ a-z)	Purpose	Produced figures
example.m	Example modulation	Fig 1.1
main.m	Call all required functions once.	-
plotFourier.m	Plotting result of a Fourier transform	Fig 2.1.2, Fig 4.1.2, Fig 4.2.3
signalDemod.m	Signal demodulation and LPF	Fig 4.1.1, Fig 4.2.1
signalDistort.m	Simulate channel distortion	Fig 3.1.1, Fig 3.1.2 (i, ii), Fig 3.2.1
signalMod.m	Signal modulation	Fig 2.1.1, Fig 2.2.1, Fig 2.3.1
summary.m	Compare resulting signal	Fig 4.3.1, Fig 4.3.2

Source codes as .m files are attached in the **assignment on Google classroom**, and are also viewable on **GitHub**: <https://github.com/alfyn78/dsbsc-report-simulation>

### Other figures

**Fig. 2.1 “DSB-SC communication system diagram”** is from page 21 from the slides of week 10, “ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING”, page titled “Final Project” along with project report instructions.