ANALOG FINAL PROJECT

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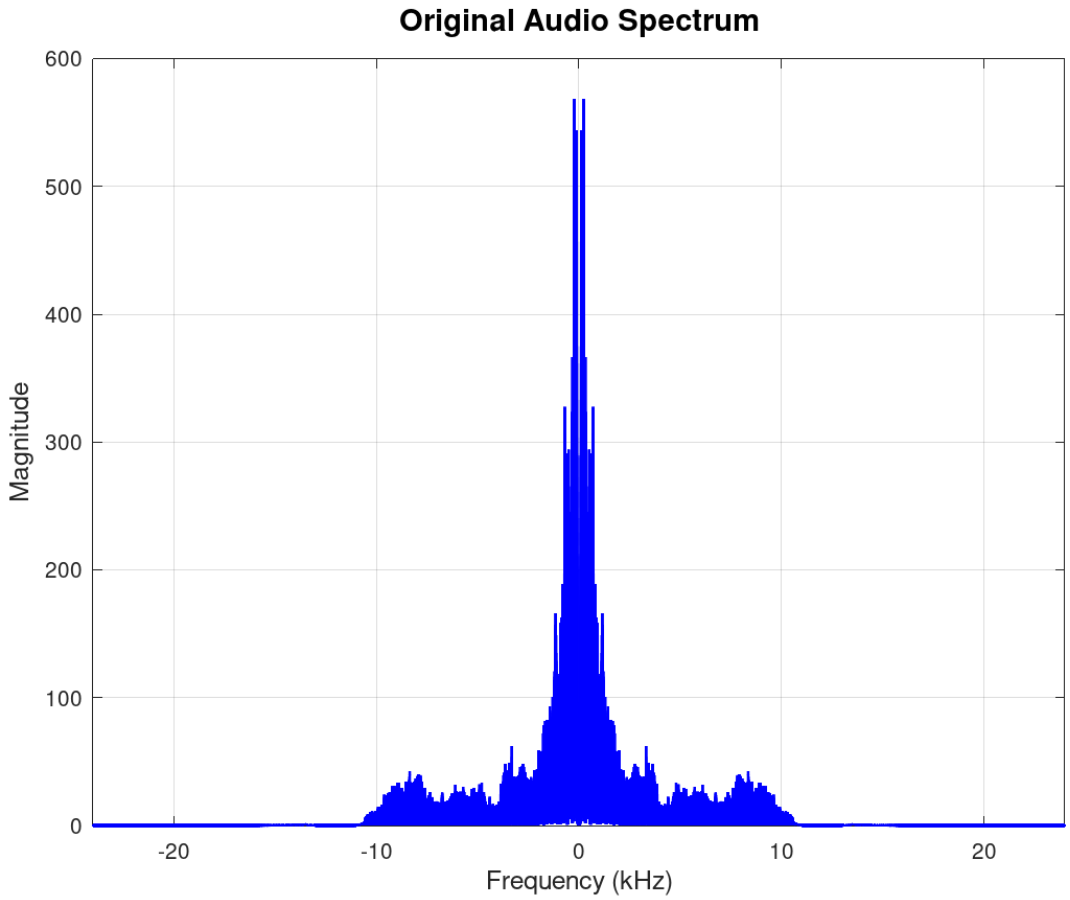
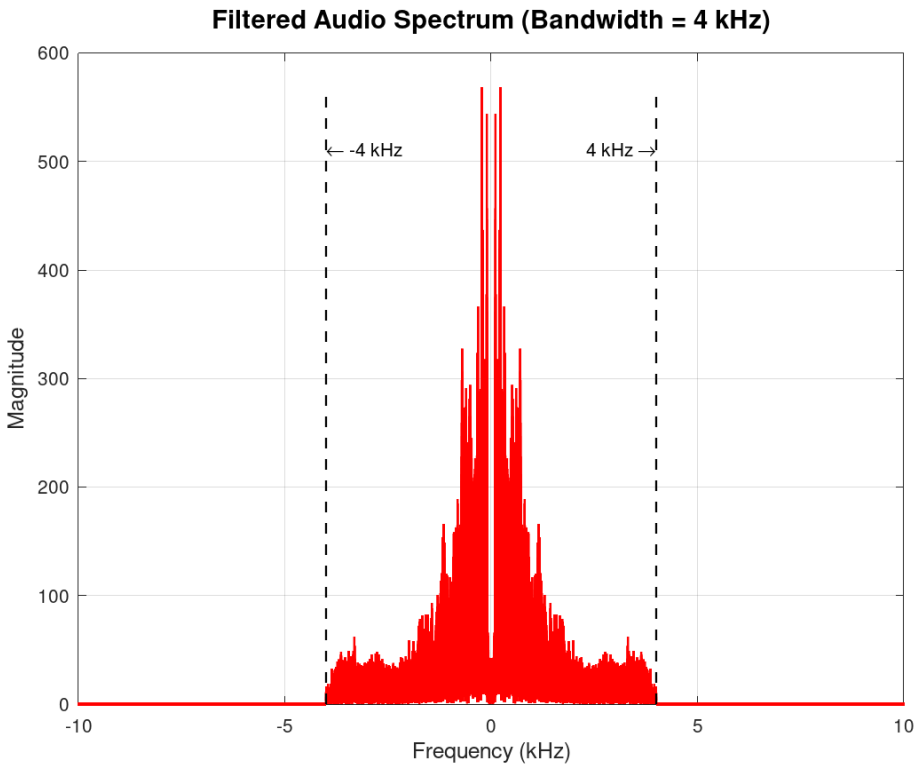
EXPERIMENT 1

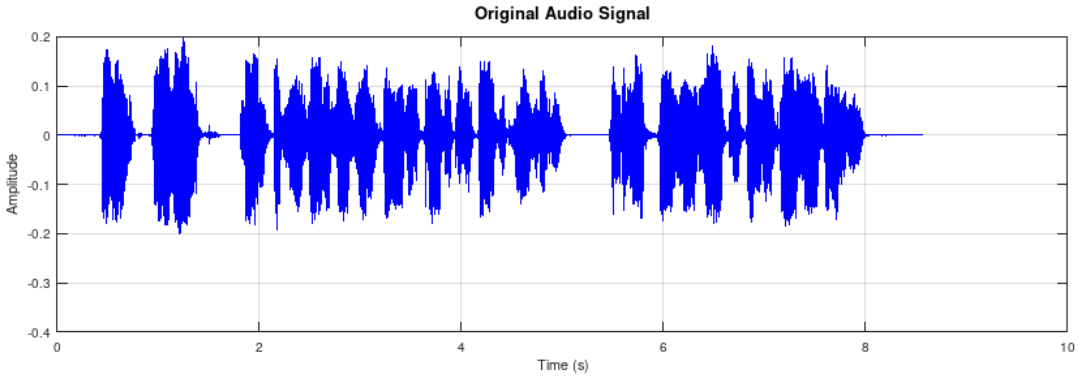
- **Original Spectrum**

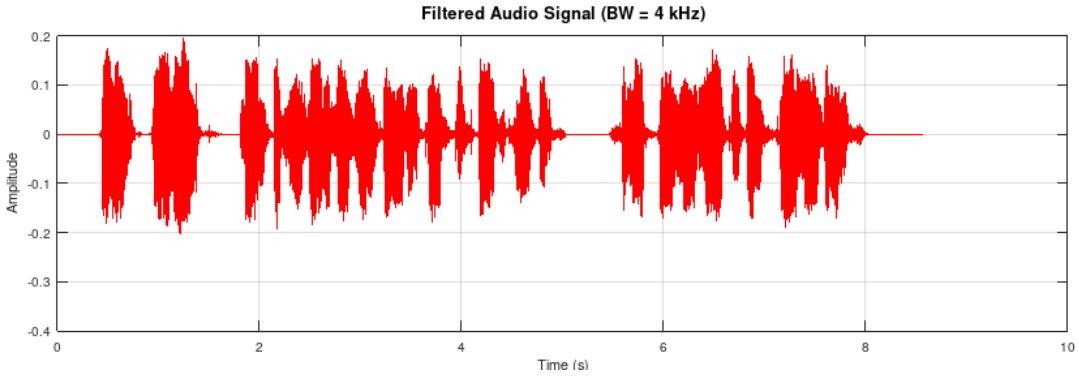


- **FIltered spectrum after low pass filter**



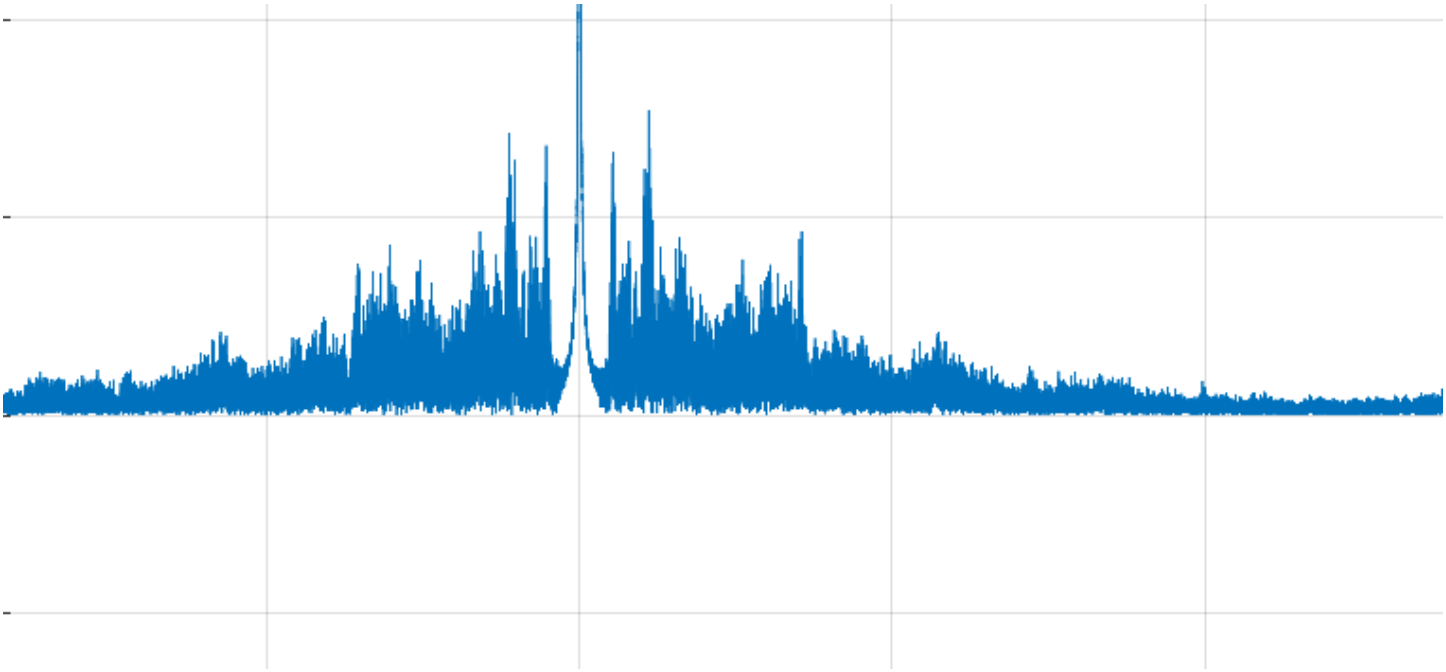
- **Time comparison**



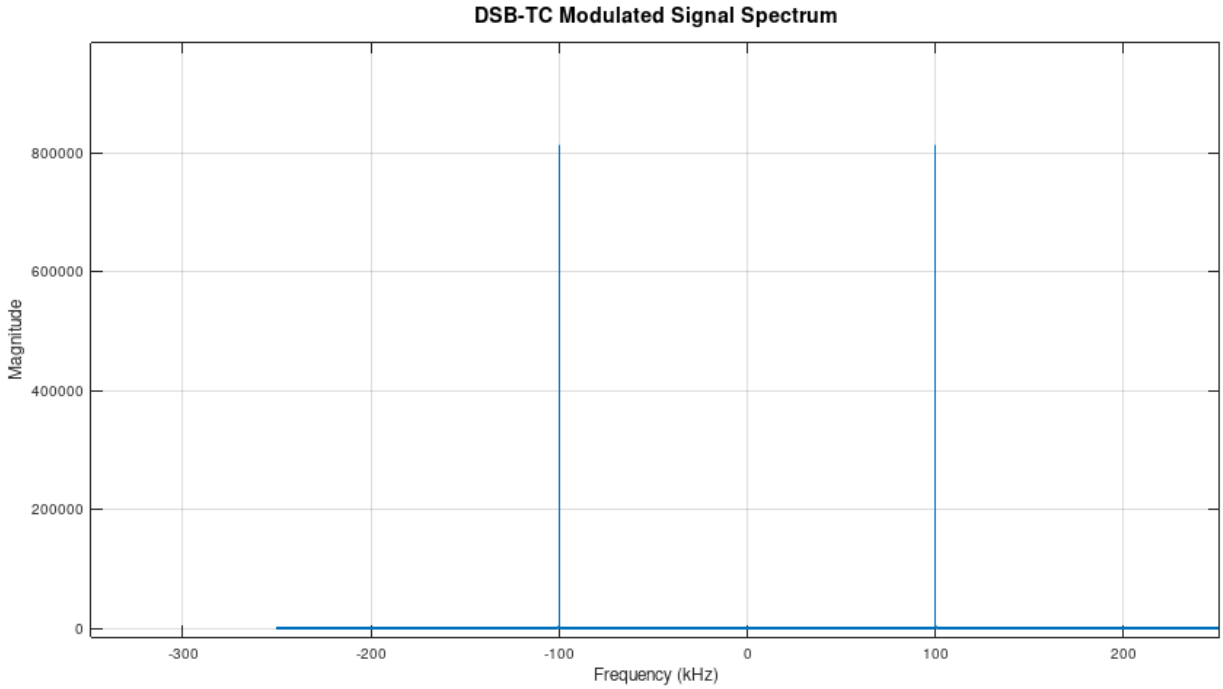


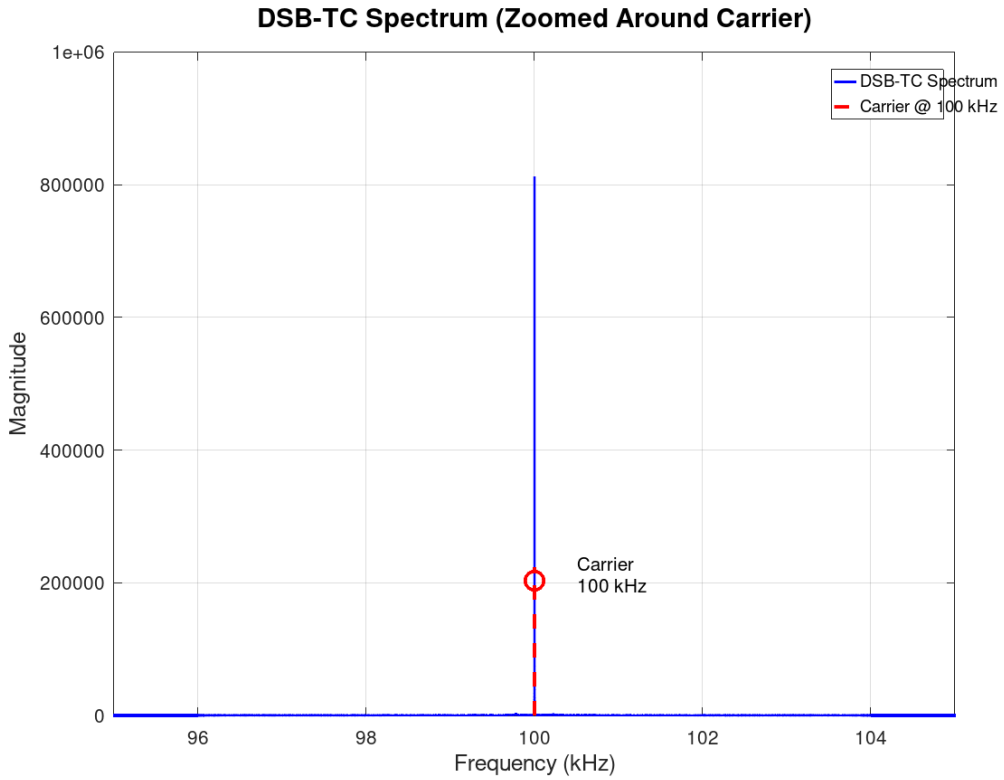
- **DSB-TC spectrum frequency domain**

Zoomed in

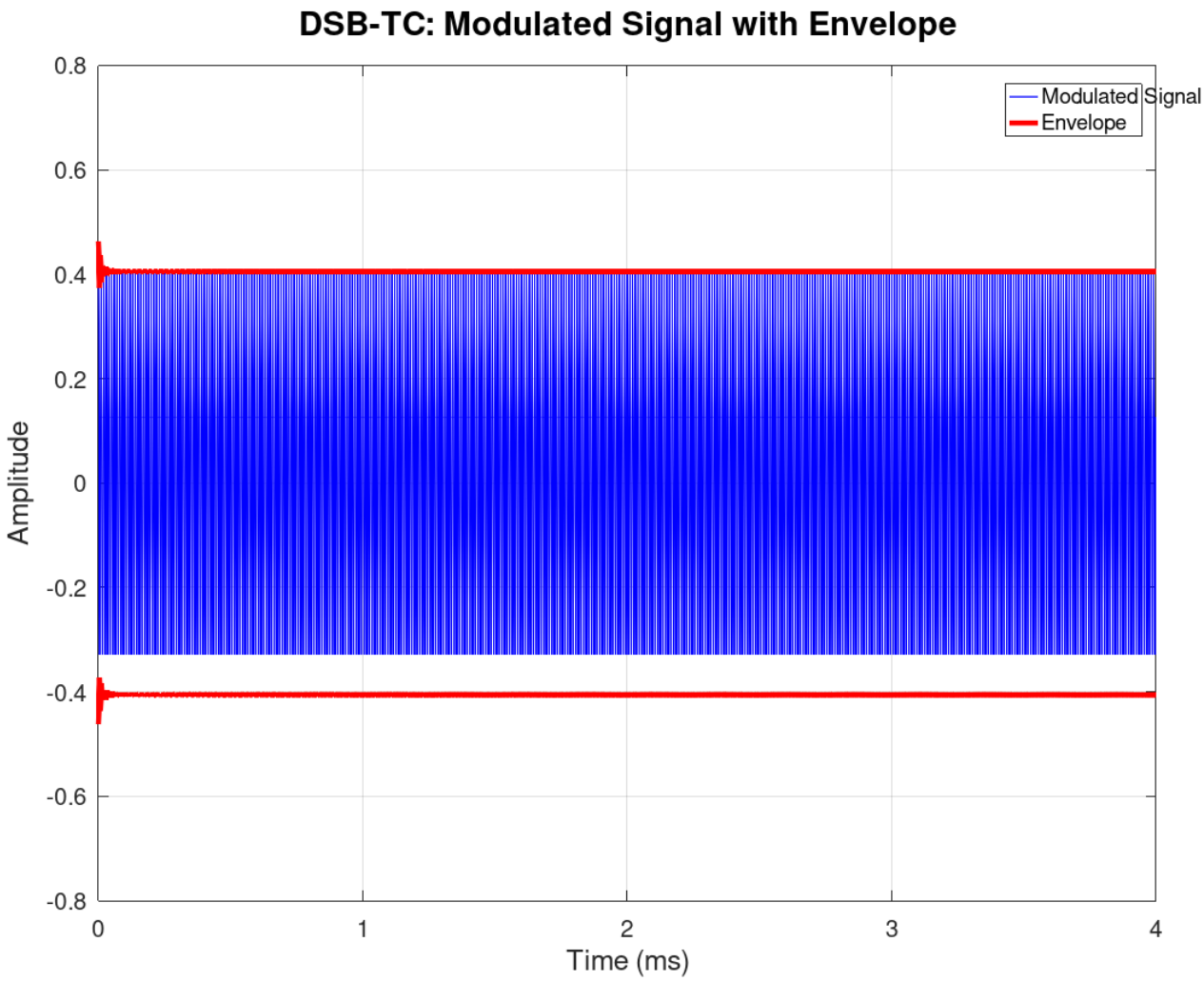


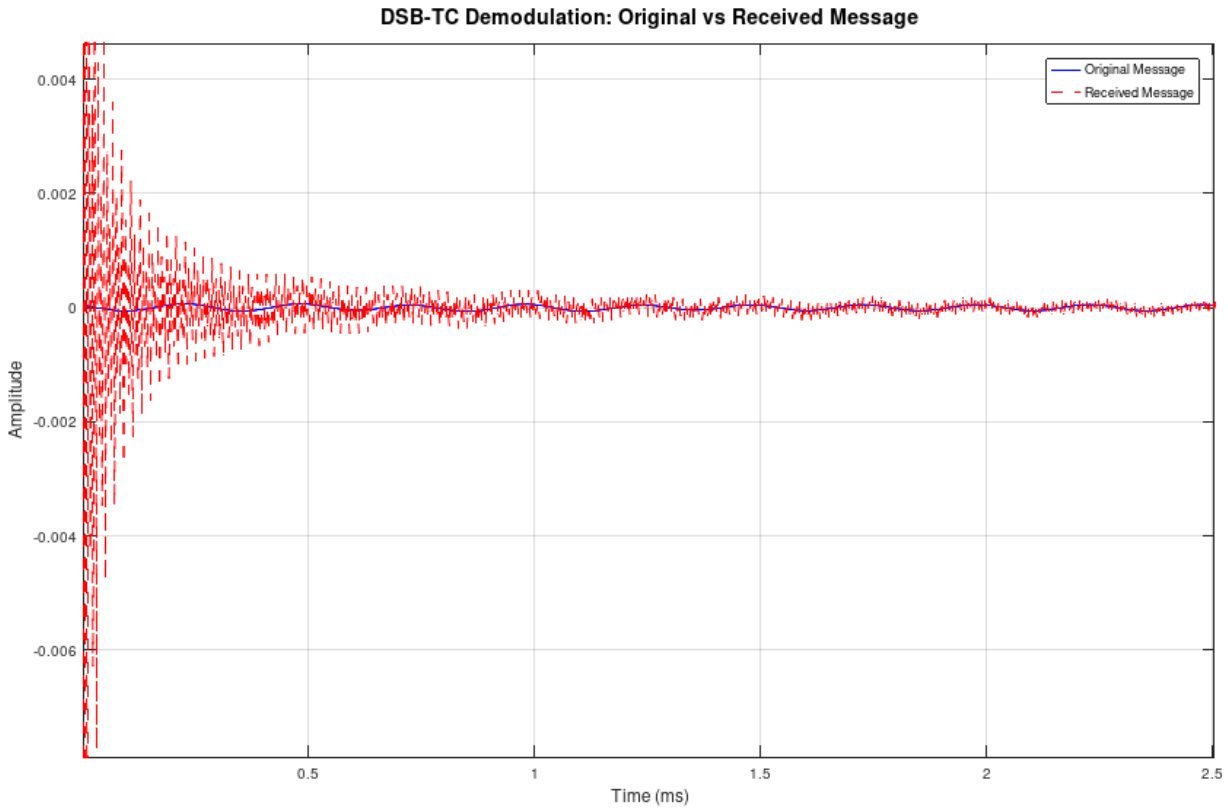
Zoomed out


DSB-TC Modulated Signal Spectrum
Magnitude
800000
600000
400000
200000
0
-300
-200
-100
0
100
200
Frequency (kHz)


DSB-TC Spectrum (Zoomed Around Carrier)
1e+06
800000
600000
400000
200000
0
Magnitude
DSB-TC Spectrum
Carrier @ 100 kHz
Carrier
100 kHz
96
98
100
102
104
Frequency (kHz)

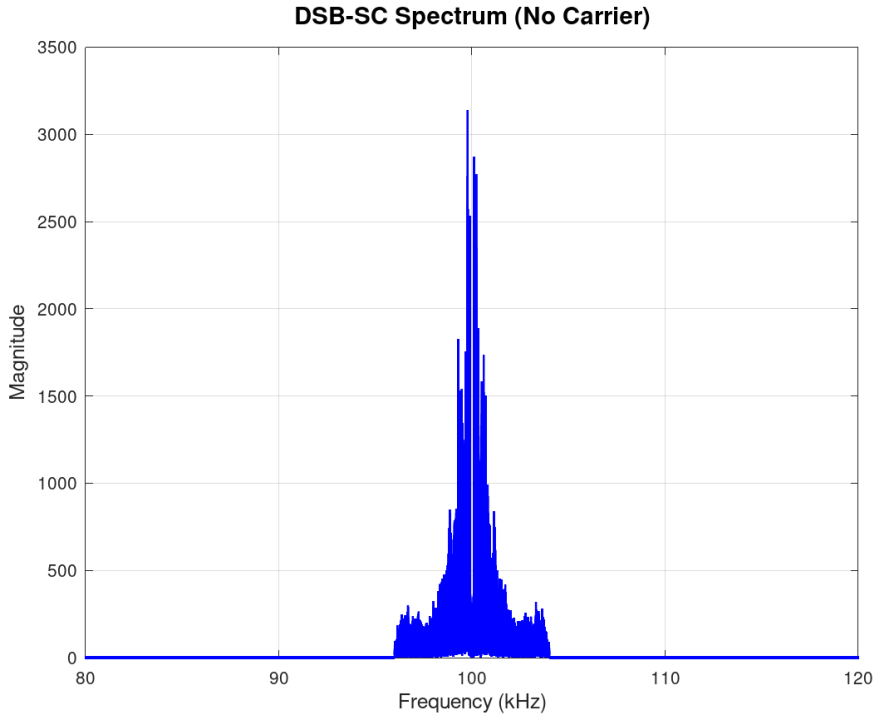
DSB-TC with detector

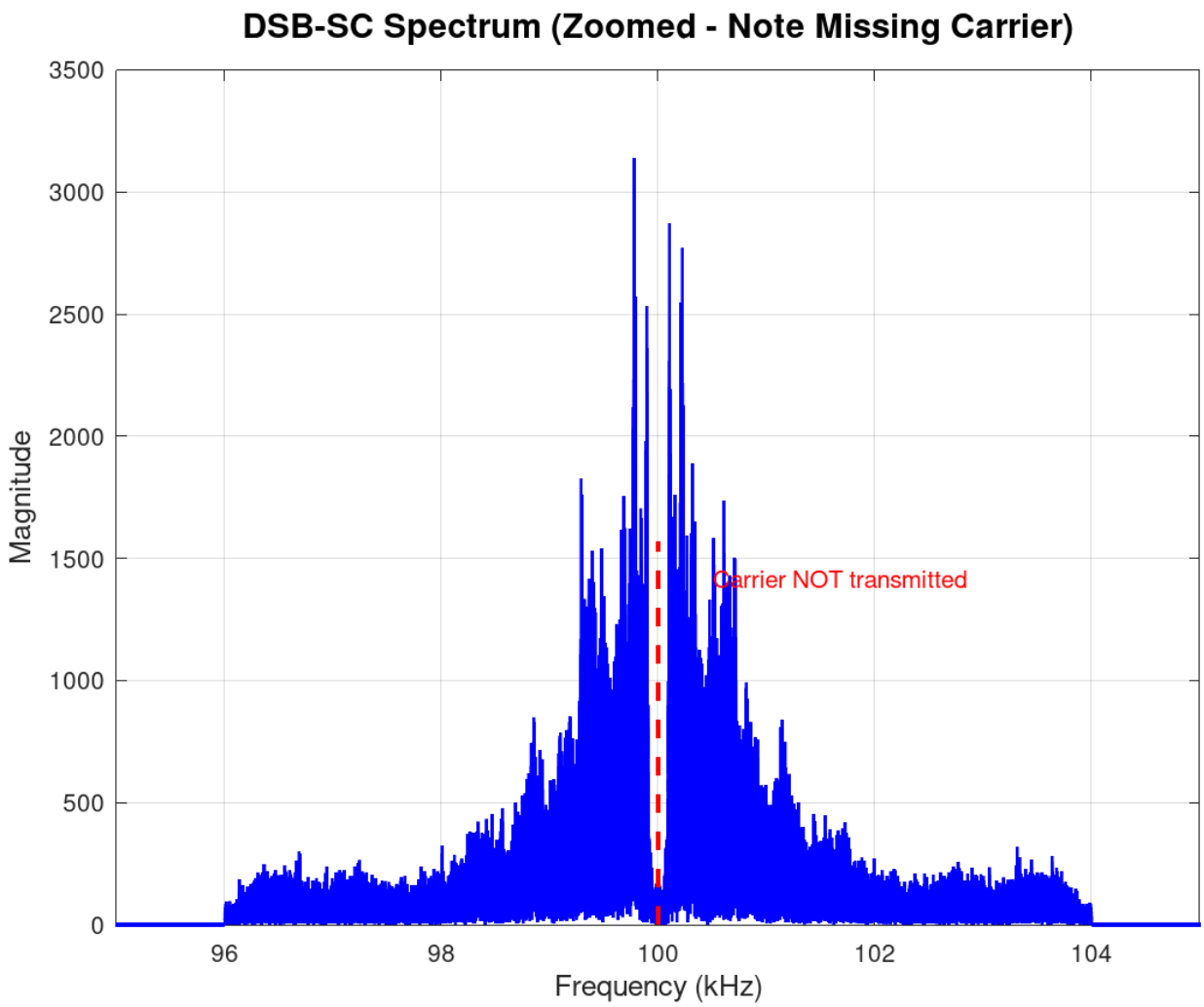



DSB-TC Demodulation: Original vs Received Message
Original Message
Received Message
0.004
0.002
0
-0.002
-0.004
-0.006
Amplitude
0.5
1
1.5
2
2.5
Time (ms)

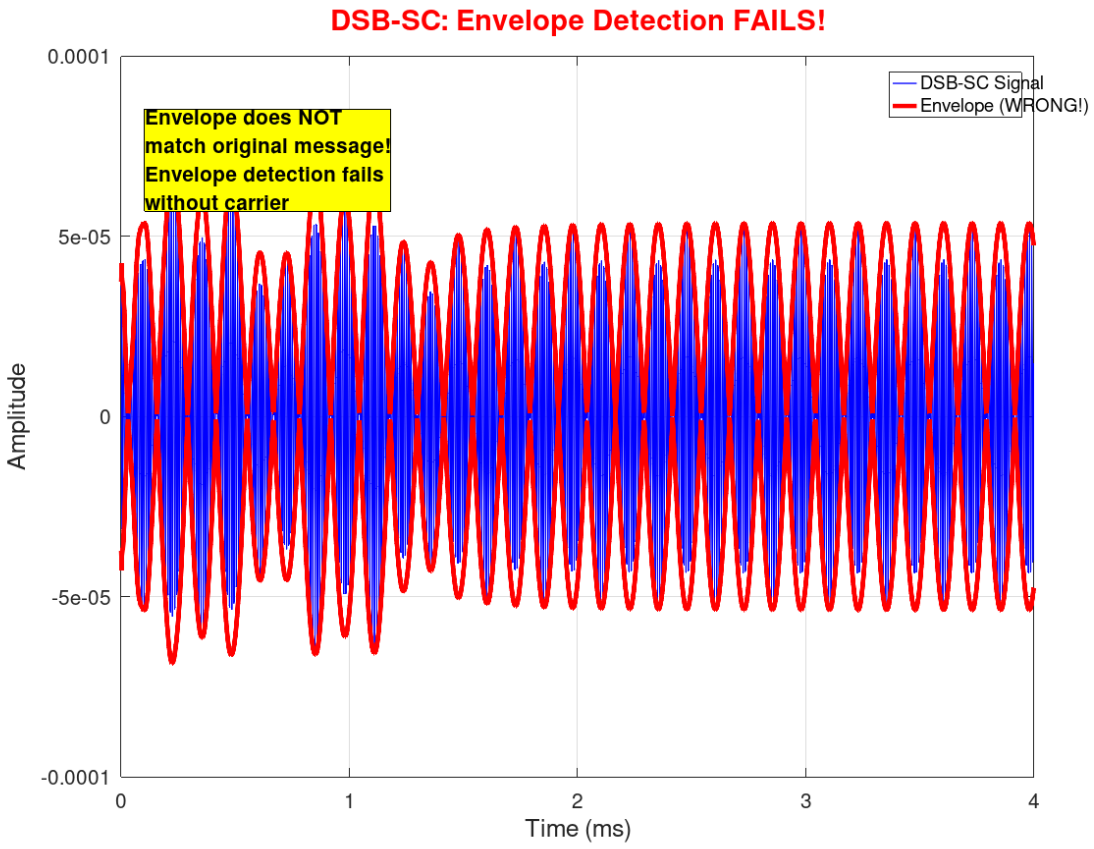
DSB-SC

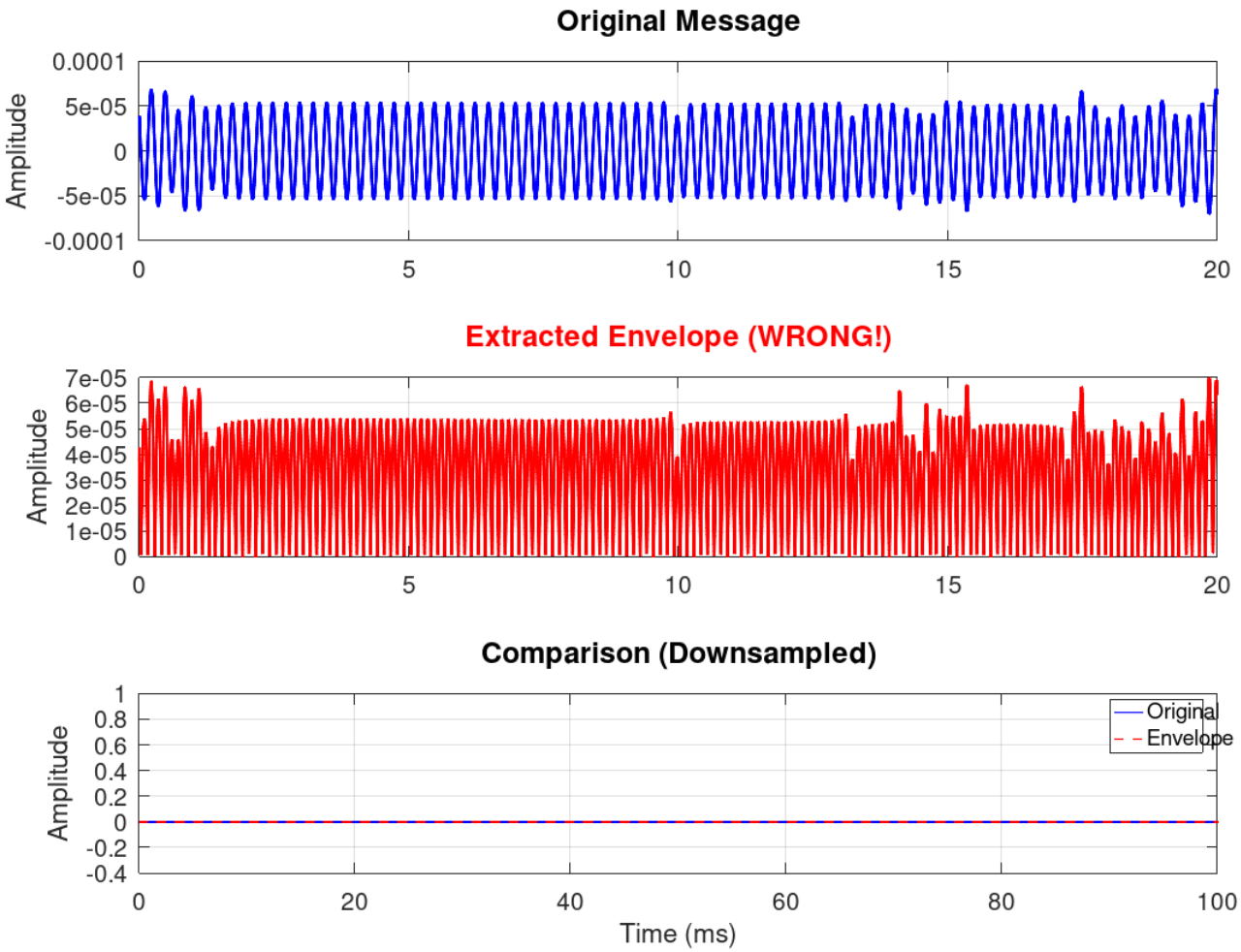
Frequency domain




DSB-SC Spectrum (Zoomed - Note Missing Carrier)
Magnitude
Frequency (kHz)
Carrier NOT transmitted
3500
3000
2500
2000
1500
1000
500
0
96
98
100
102
104

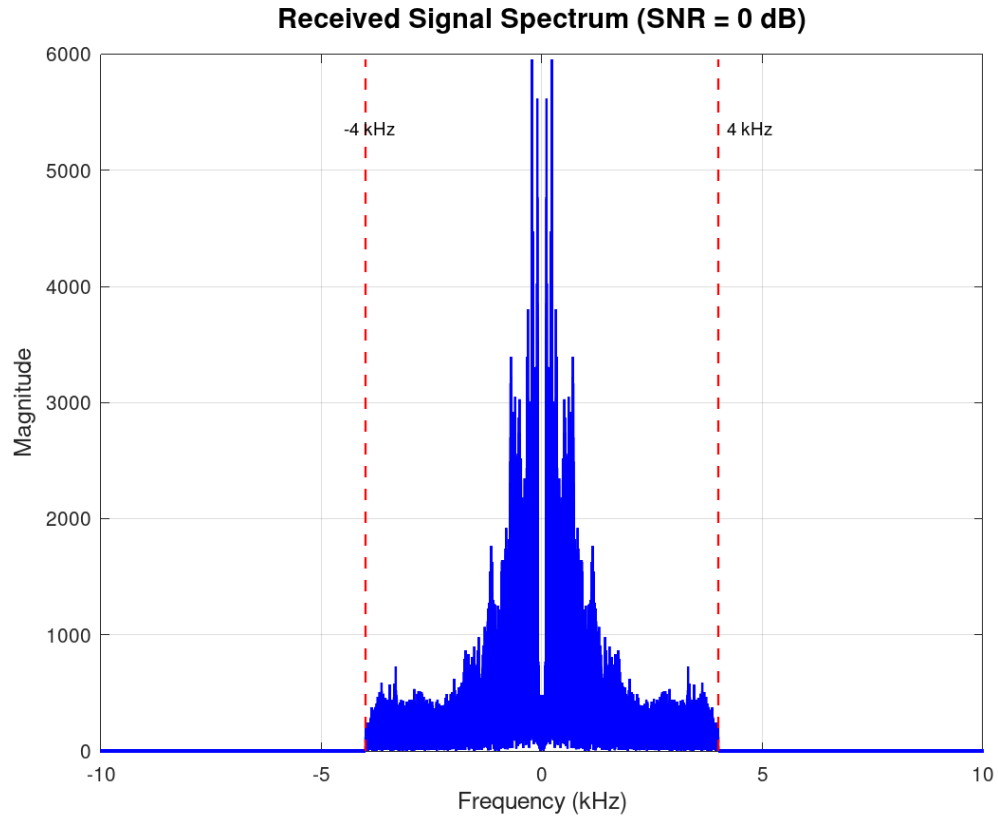
DSB-SC Envelope

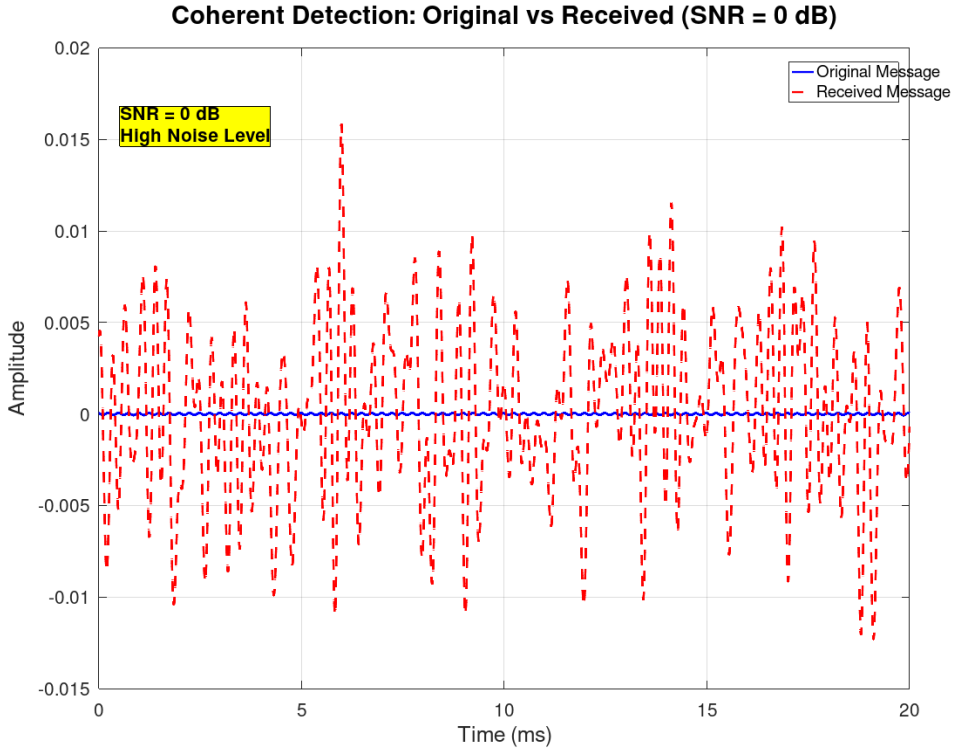




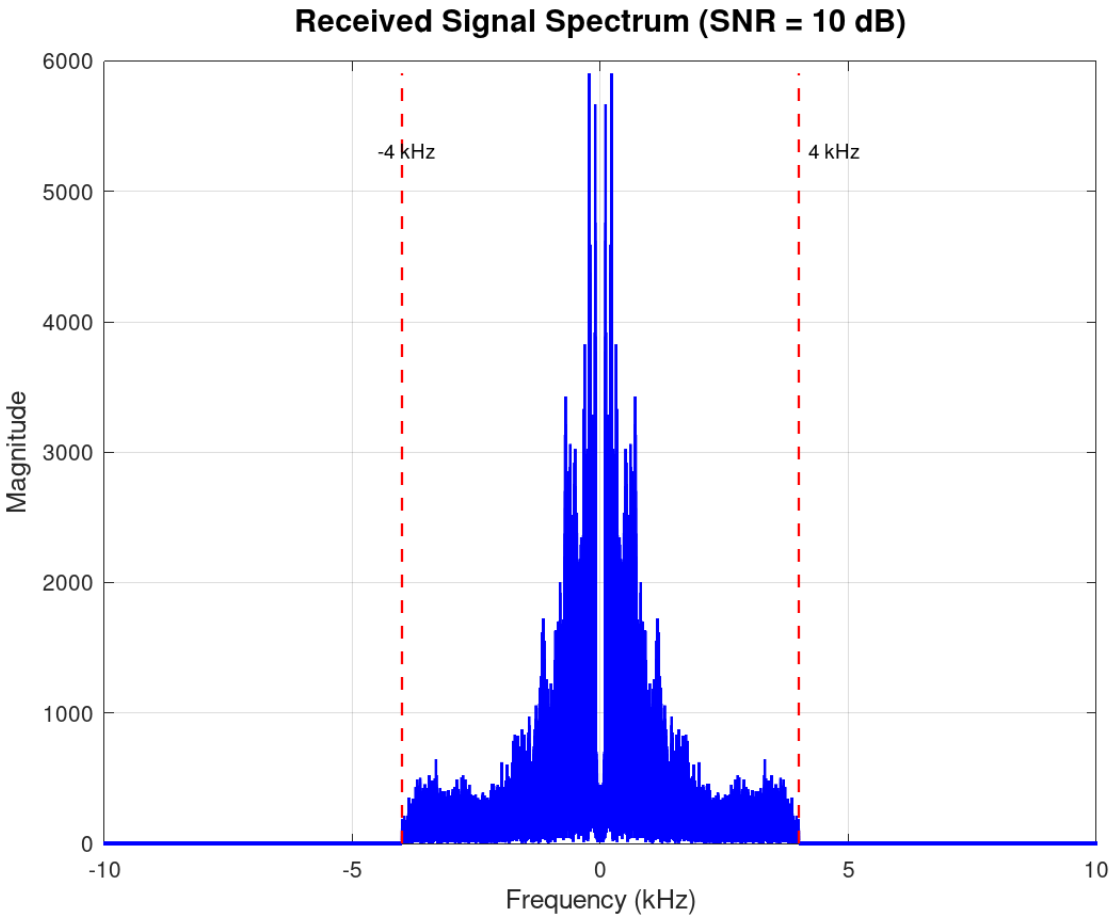
- For DSB TC: The demodulated signal is slightly attenuated or/and distorted
- While for DSB – SC: the demodulated signal is distorted and unintelligible

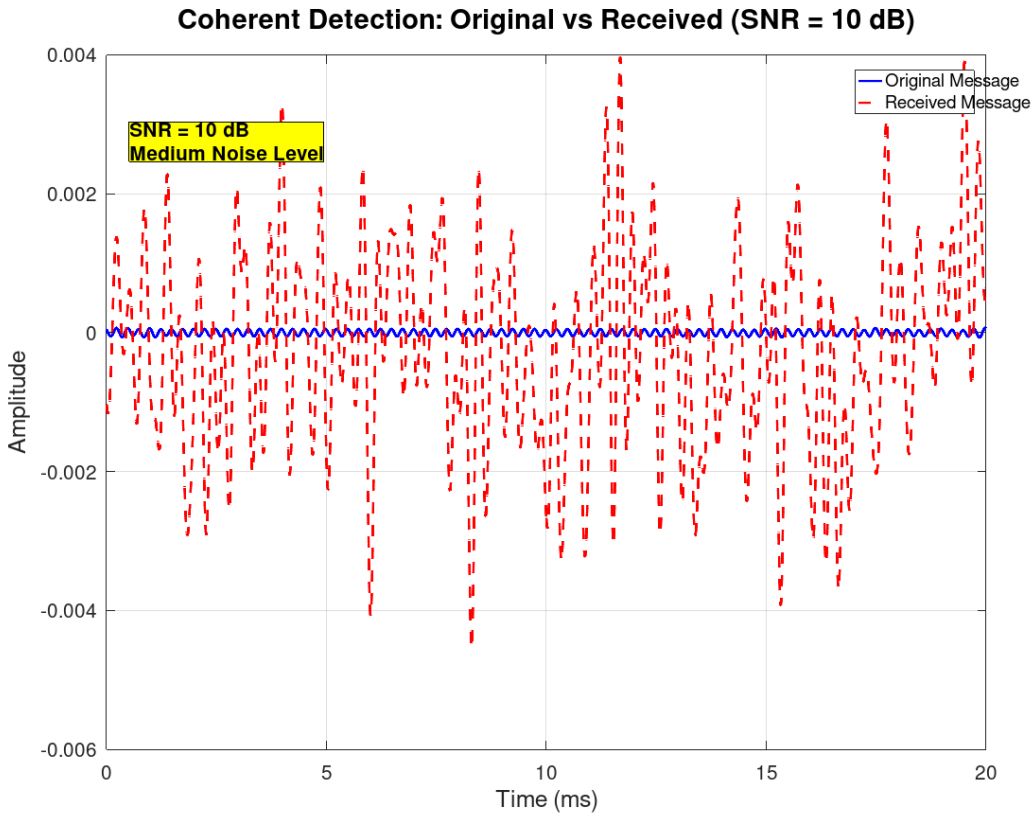
Coherent detection
SNR = 0


Received Signal Spectrum (SNR = 0 dB)
-4 kHz
4 kHz
Magnitude
Frequency (kHz)
6000
5000
4000
3000
2000
1000
0
-10
-5
0
5
10

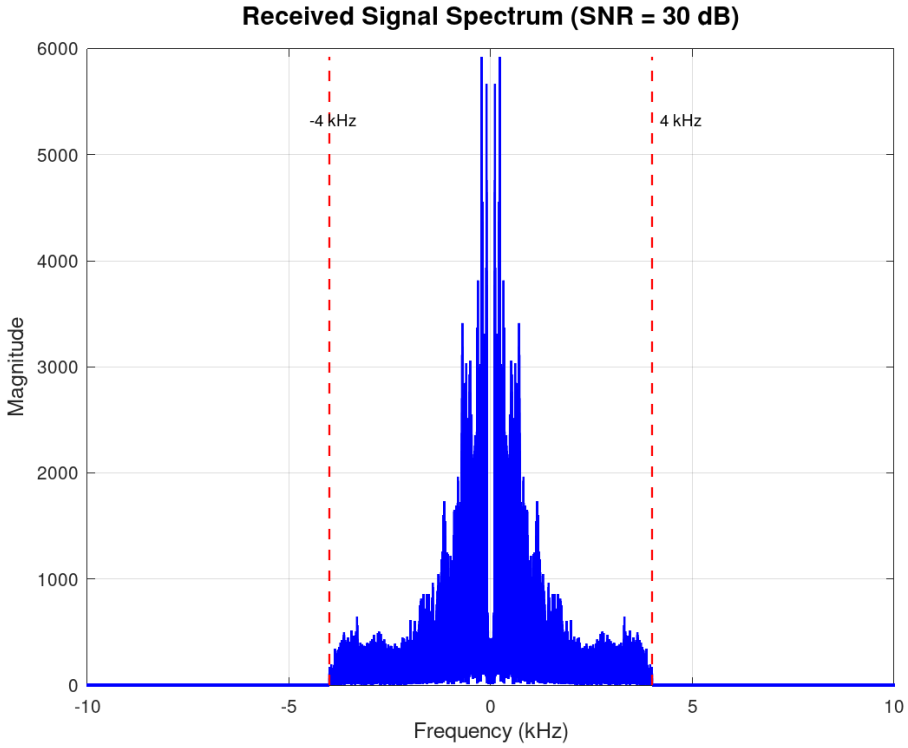

Coherent Detection: Original vs Received (SNR = 0 dB)
SNR = 0 dB
High Noise Level
Original Message
Received Message
Amplitude
Time (ms)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
5
10
15
20

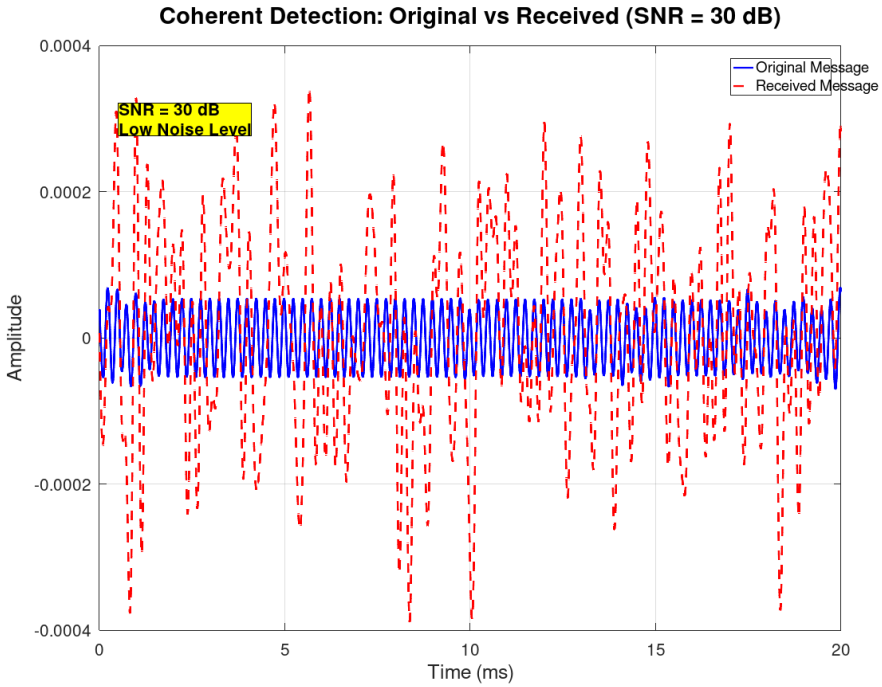
SNR = 10


Received Signal Spectrum (SNR = 10 dB)
Magnitude
Frequency (kHz)
-4 kHz
4 kHz
6000
5000
4000
3000
2000
1000
0
-10
-5
0
5
10


Coherent Detection: Original vs Received (SNR = 10 dB)
SNR = 10 dB
Medium Noise Level
Original Message
Received Message
Amplitude
Time (ms)
0.004
0.002
0
-0.002
-0.004
-0.006
0
5
10
15
20

SNR = 30


Received Signal Spectrum (SNR = 30 dB)
-4 kHz
4 kHz
Magnitude
Frequency (kHz)
6000
5000
4000
3000
2000
1000
0
-10
-5
0
5
10



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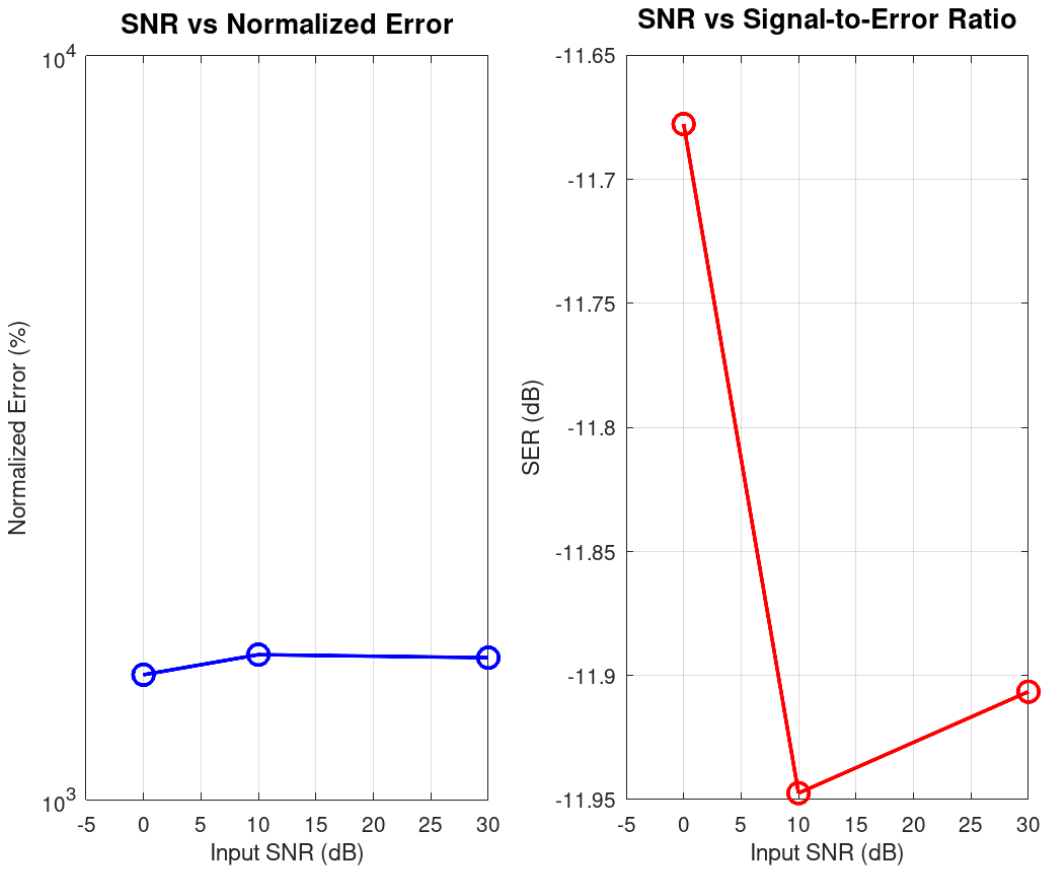
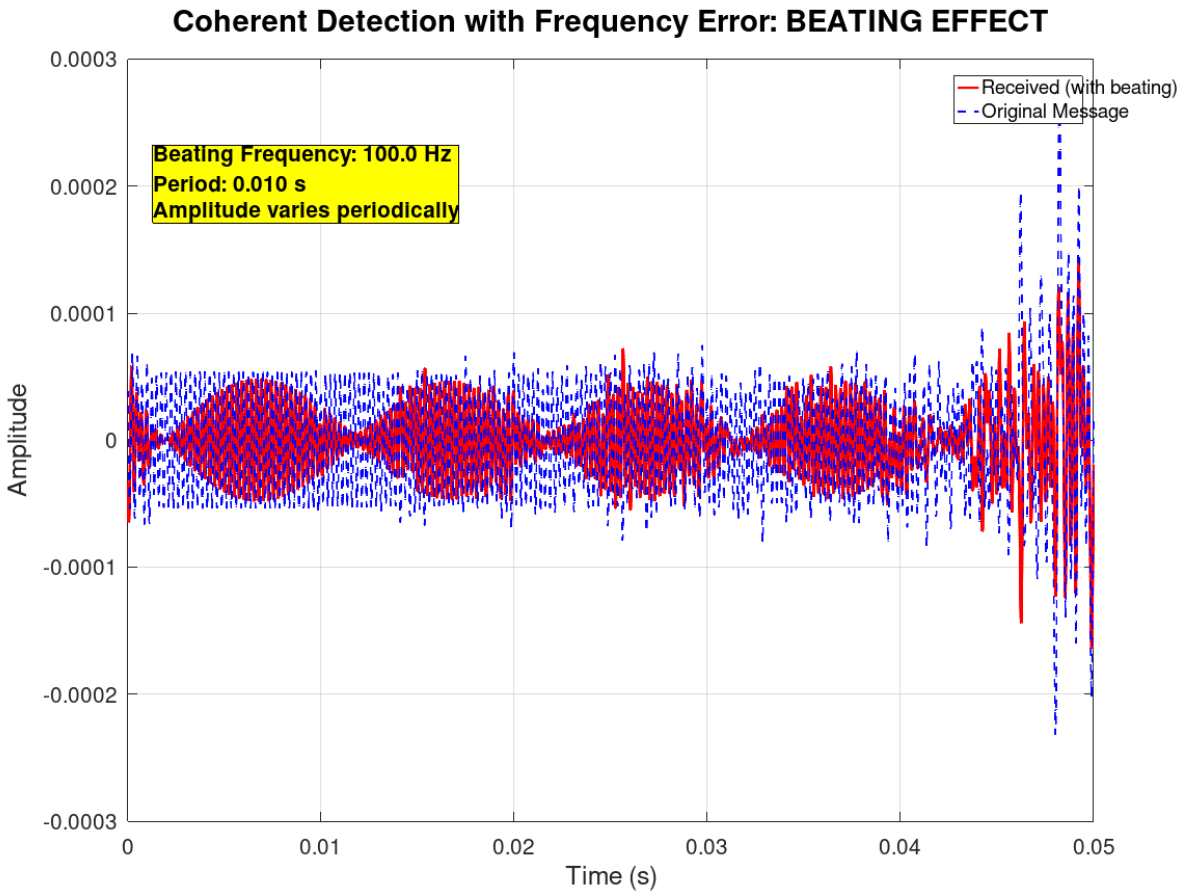
Coherent Detection Performance Summary

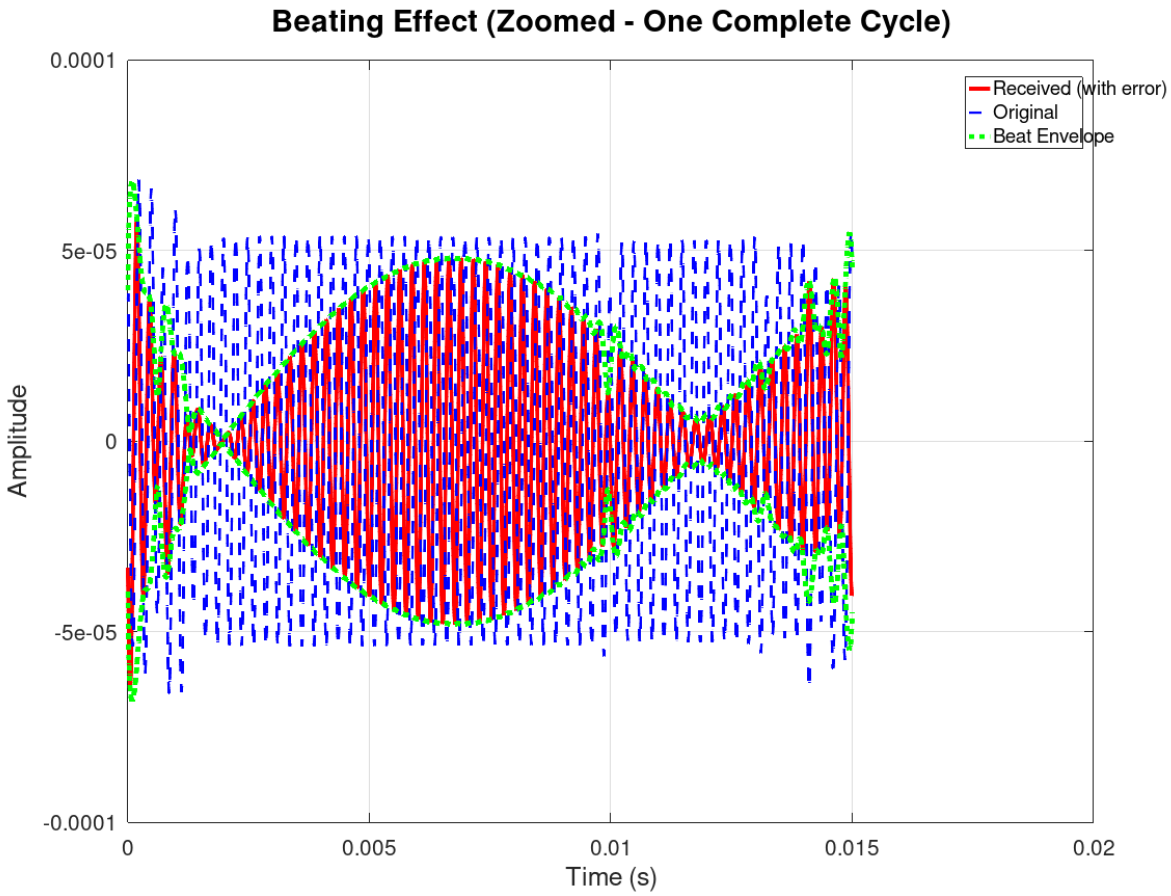
SNR (dB)	Actual SNR	MSE	Norm. Erro	SER (dB	Quality
0	-0.00	0.019244	1471.5227	-11.68	Noisy but usable
10	9.99	0.020477	1565.8122	-11.95	Good quality
30	30.00	0.020285	1551.1380	-11.91	Excellent

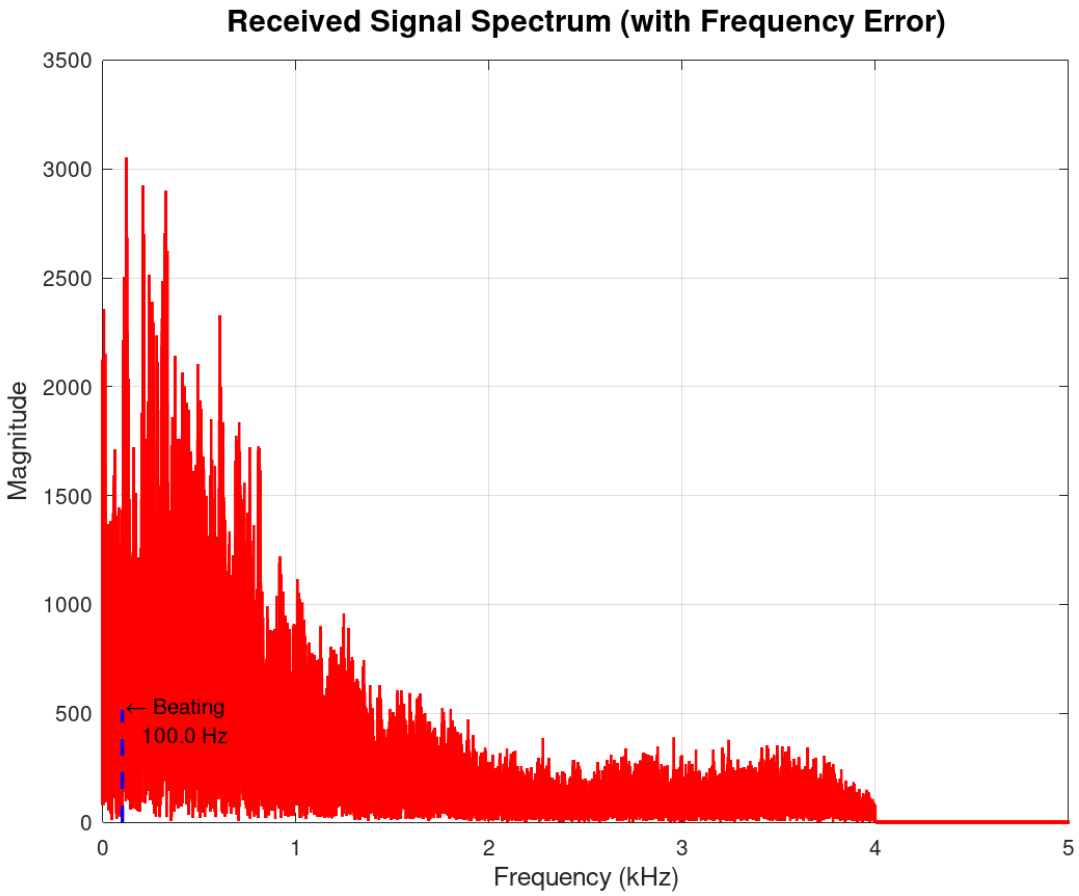


Frequency Error

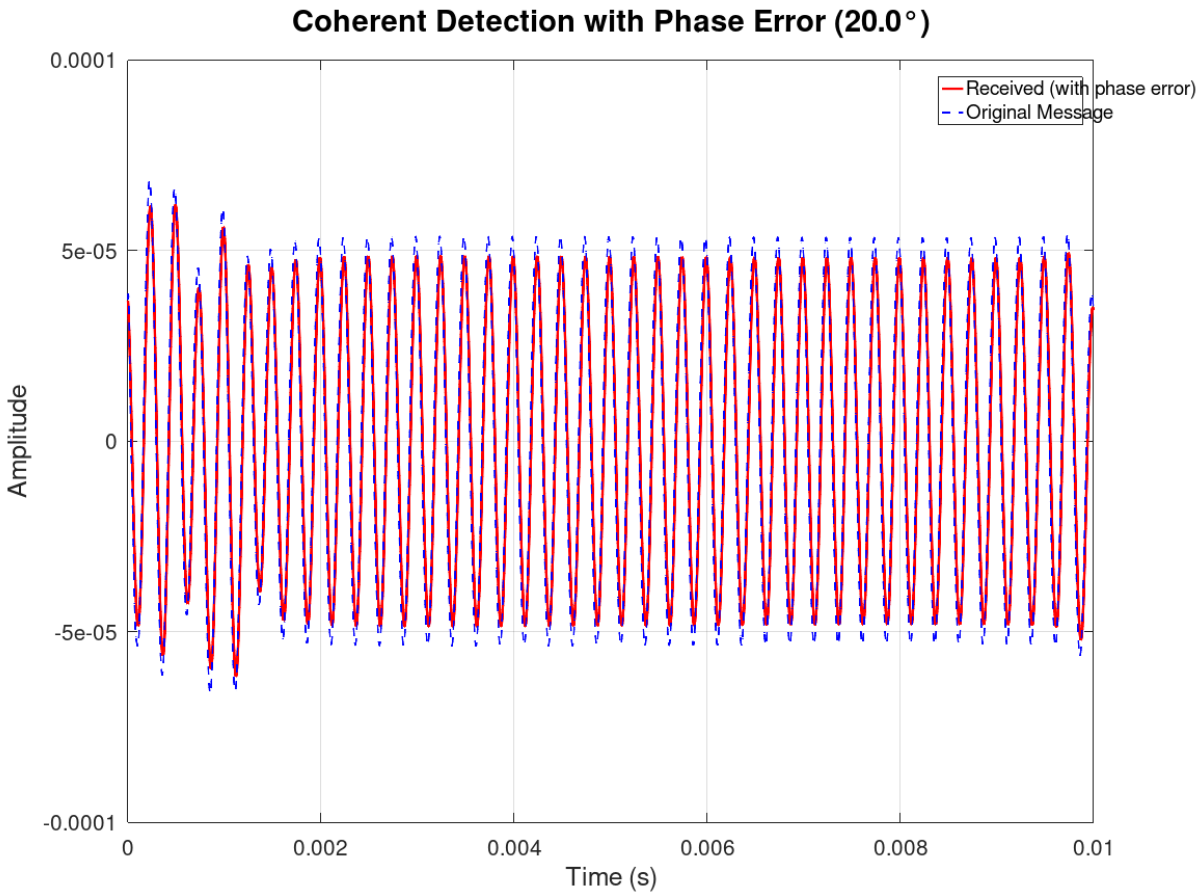
Frequency error causes a beating effect with a beating frequency of 100 hz, beating effect is when a signal amplitude oscillates periodically


Coherent Detection with Frequency Error: BEATING EFFECT
Received (with beating)
Original Message
Beating Frequency: 100.0 Hz
Period: 0.010 s
Amplitude varies periodically
Amplitude
Time (s)
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
-0.0003
0
0.01
0.02
0.03
0.04
0.05


Beating Effect (Zoomed - One Complete Cycle)
Received (with error)
Original
Beat Envelope
0.0001
5e-05
0
-5e-05
-0.0001
Amplitude
0
0.005
0.01
0.015
0.02
Time (s)

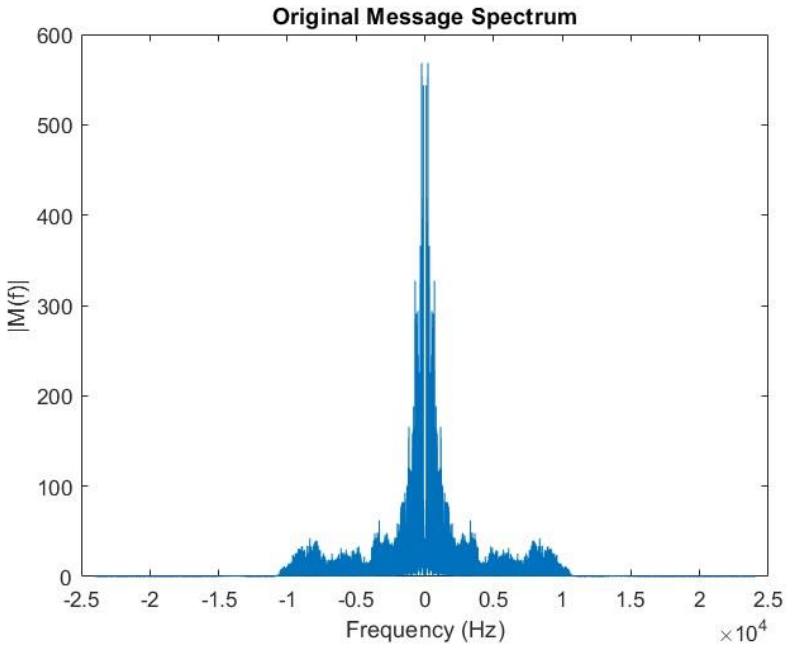

Received Signal Spectrum (with Frequency Error)
Magnitude
Frequency (kHz)
← Beating
100.0 Hz
0
500
1000
1500
2000
2500
3000
3500
0
1
2
3
4
5

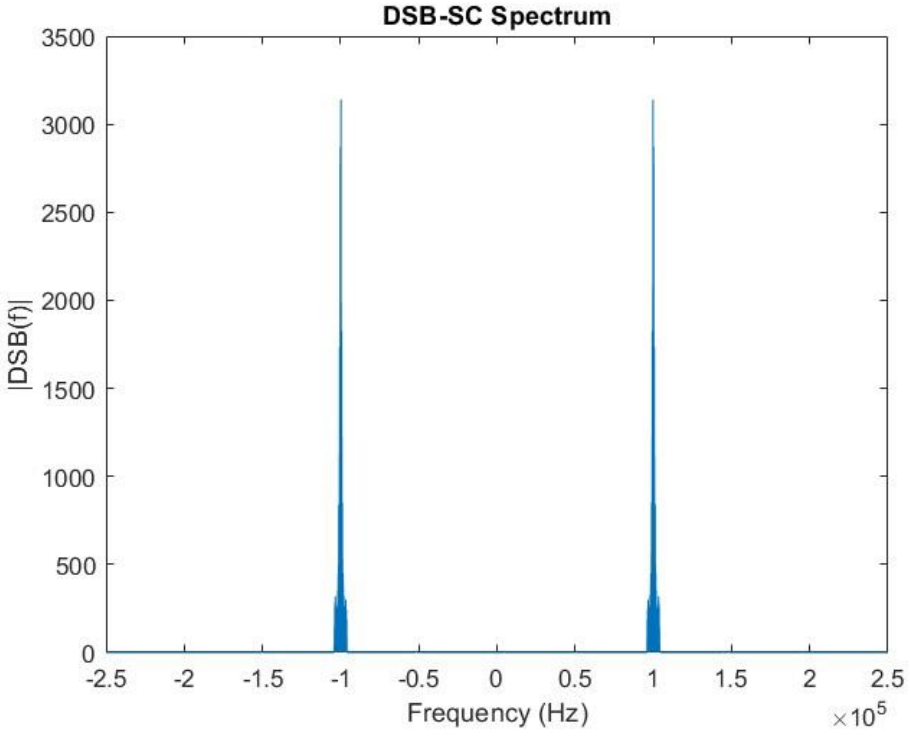
Phase Error

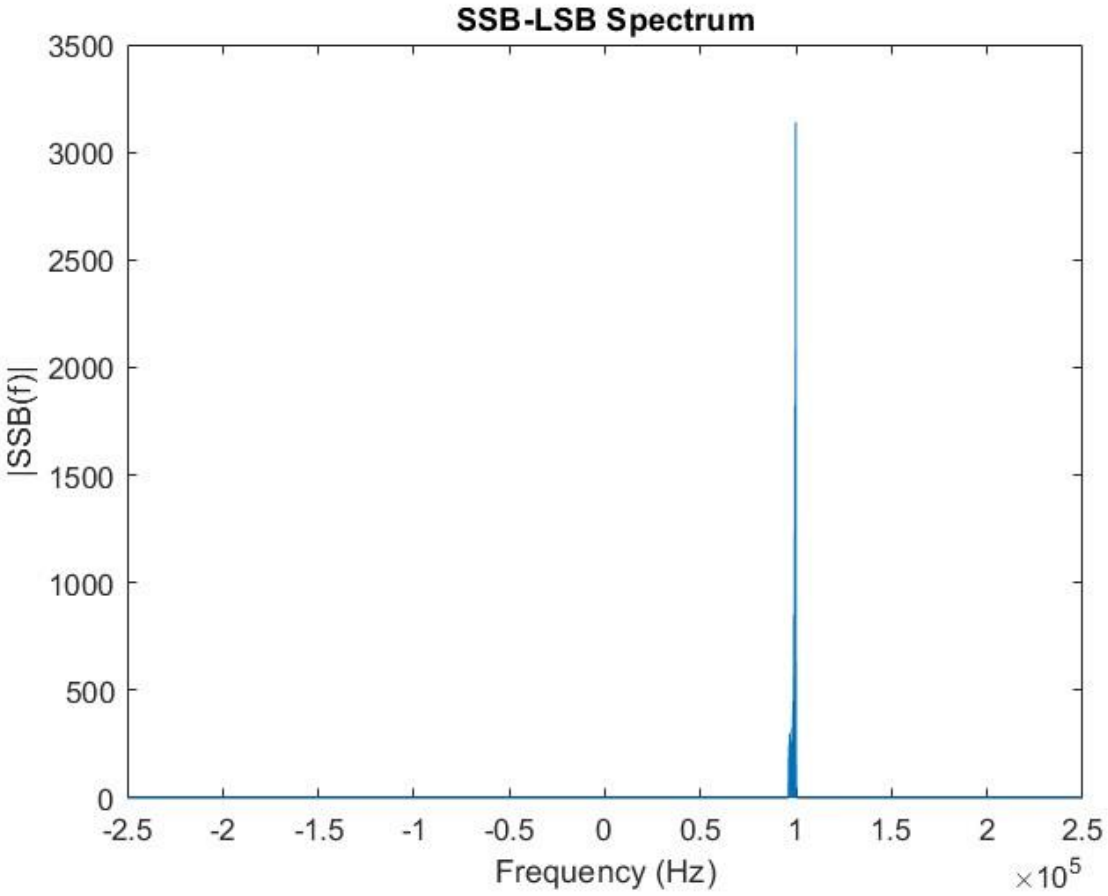


Phase error causes reduction in amplitude, but the audio is still clear

EXPERIMENT 2


Original Message Spectrum
|M(f)|
Frequency (Hz)
×10^4
600
500
400
300
200
100
0
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

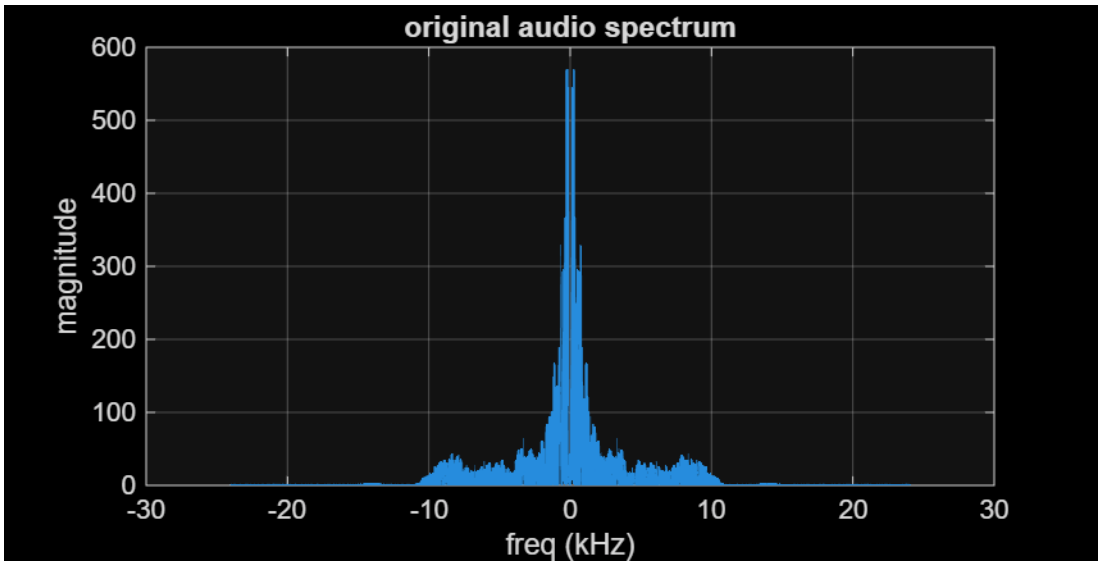

DSB-SC Spectrum
|DSB(f)|
Frequency (Hz)
×10^5
3500
3000
2500
2000
1500
1000
500
0
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

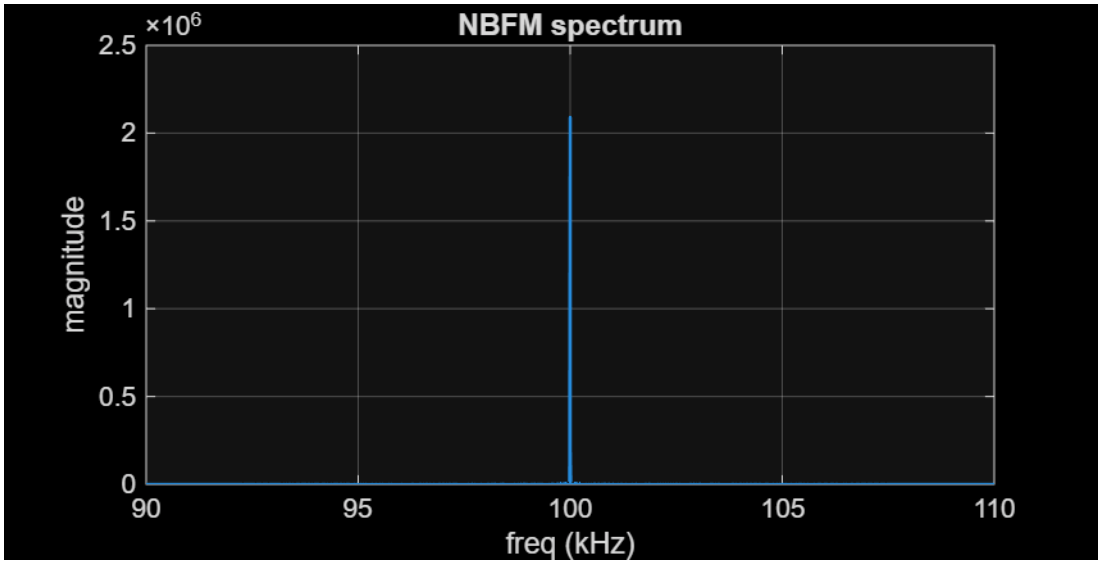


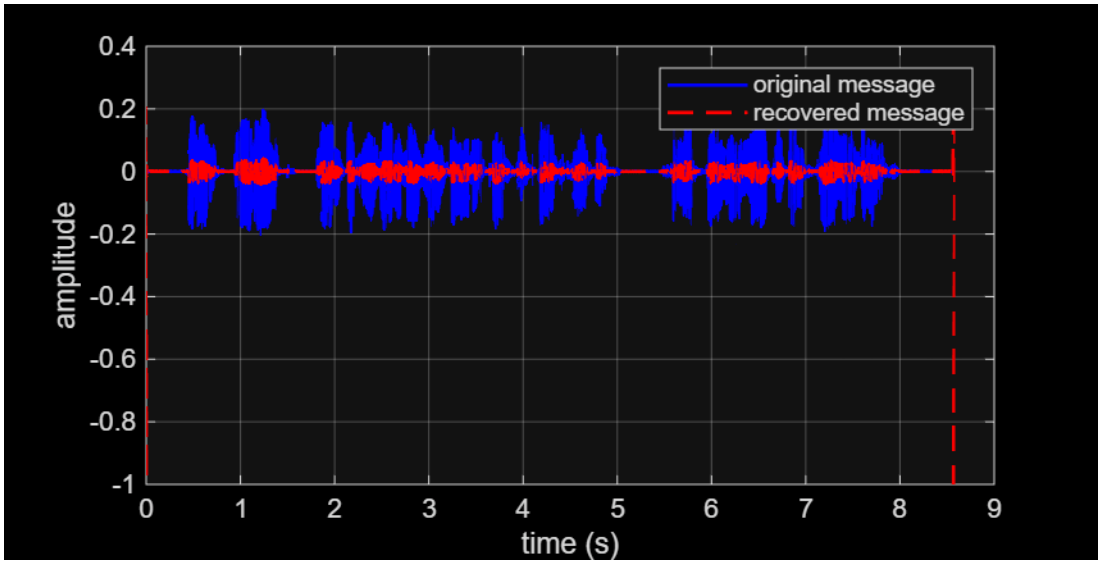
Disadvantages of SSB:

- Generating SSB requires sharp filtering (to remove exactly one sideband without hurting the other) or complex phase-shifting networks.
- SSB-SC requires precise Coherent Detection (synchronization of frequency and phase). A slight frequency error results in the "Donald Duck" effect (pitch shift), unlike DSB where it might just result in fading.
- Practical SSB filters struggle to separate sidebands if the message has significant low-frequency content near DC, as the gap between the LSB and USB vanishes at f_c.

EXPERIMENT 3







Observation:

- The envelope of the recovered signal matches the timing and shape of the original message.
- The recovered signal has a significantly lower amplitude than the original signal. Since this is Narrowband FM, the modulation index β and frequency deviation are intentionally kept small, so the resulting amplitude variations after differentiation are also very small. To match the original signal, the recovered message would need to be amplified.

Similarities and Differences AM vs. NBFM:

- Similarities:
  - They both occupy the same bandwidth (2×BW).
  - Both signals consist of a discrete carrier component and two sidebands (Lower Sideband and Upper Sideband) located at fc±fm.
- Differences:
  - AM has variable amplitude while NBFM has variable frequency.
  - In AM, total power fluctuates with the message. In FM, the total transmitted power is constant regardless of modulation