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Uğur Demirörs 2231819

EE-430 PROJECT PART I

We firstly demonstrate our outputs. Then, we made comment on some specific window types which are Kaiser, Gaussian, Hamming and Rectangular. The parameters of windows except length has been chosen as default. We compared the window types and lengths by keeping overlap length constant as (windows length)/2. After that, we compared different overlap lengths just for Kaiser at the end. Moreover, there are some explanation about critical parts in our code. We just write .mlapp file (MATLAB app) and details can be found in code view. All plots in this report were taken from our running application and the time axis represents the number of samples. All comments can be found below the last spectrogram of each input signal.

I- SINUSOIDAL SIGNAL:

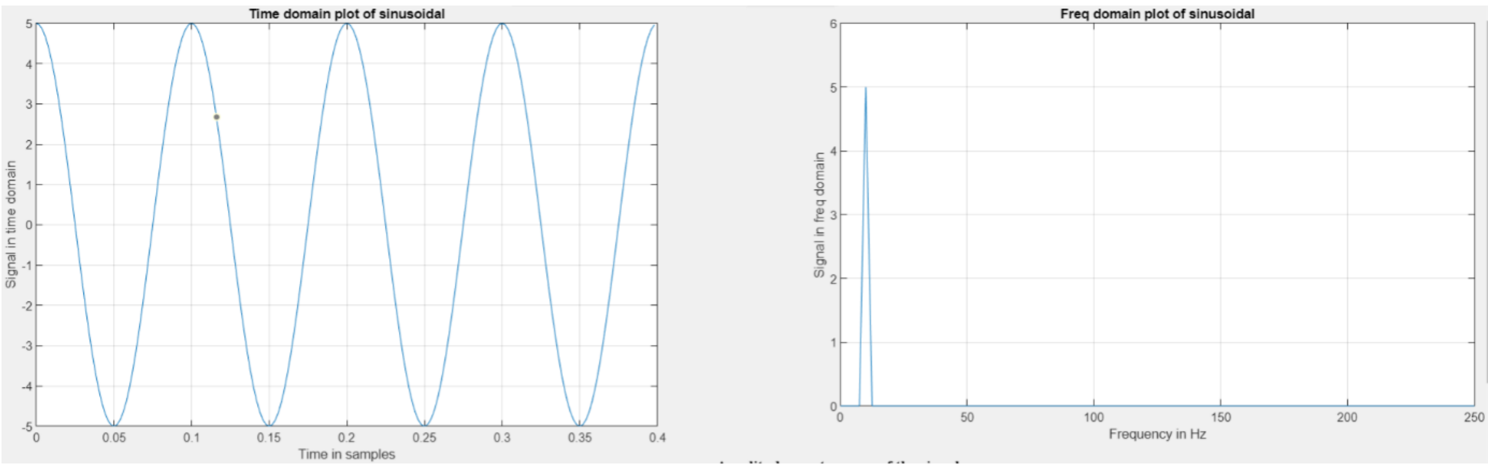

Figure 1. Generated Sinusoidal Signal both in Time domain and Frequency domain.

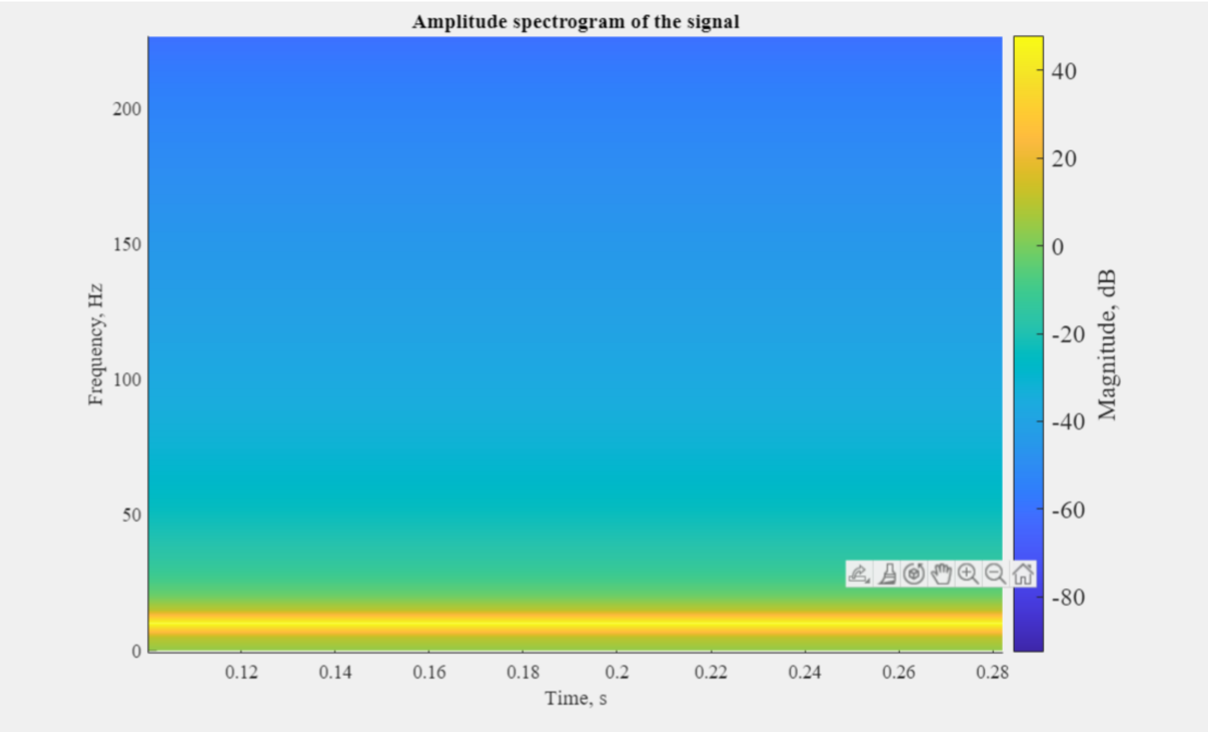

Figure 2. Spectrogram of the sinusoidal signal with window Kaiser (100).

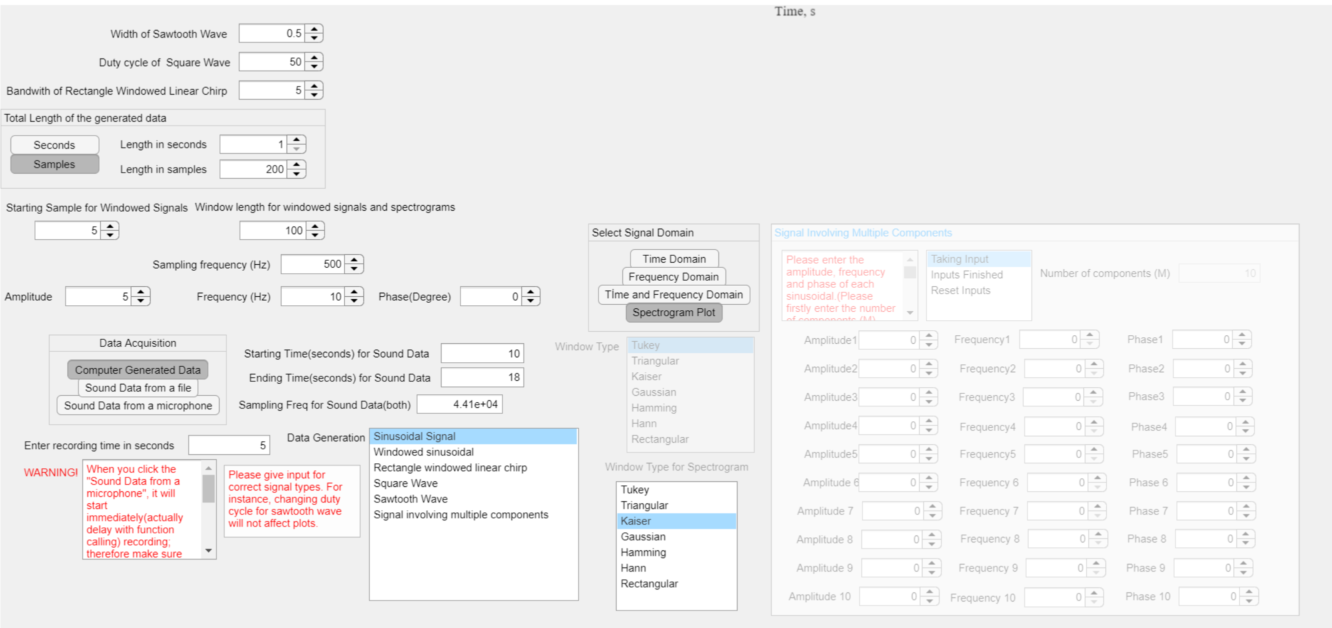

Figure 3. Parameters of our program interface.

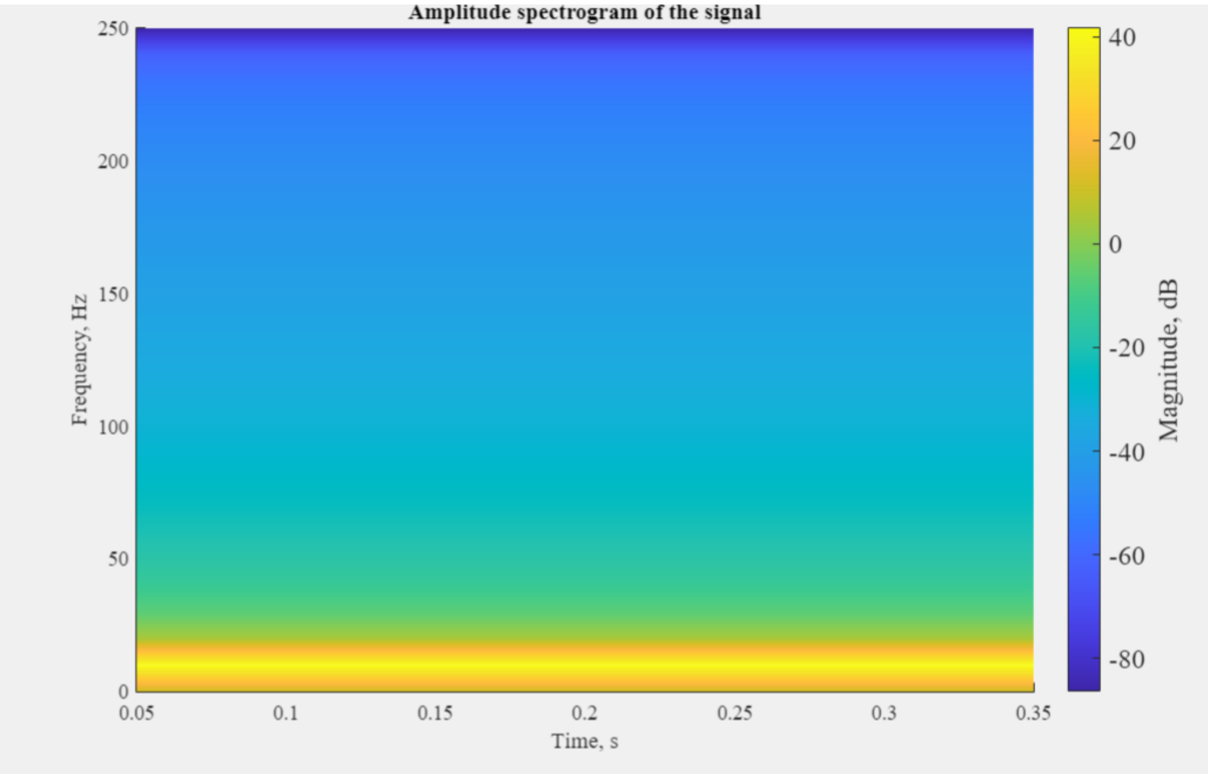

Figure 4. Spectrogram of the sinusoidal signal with window Kaiser (50).

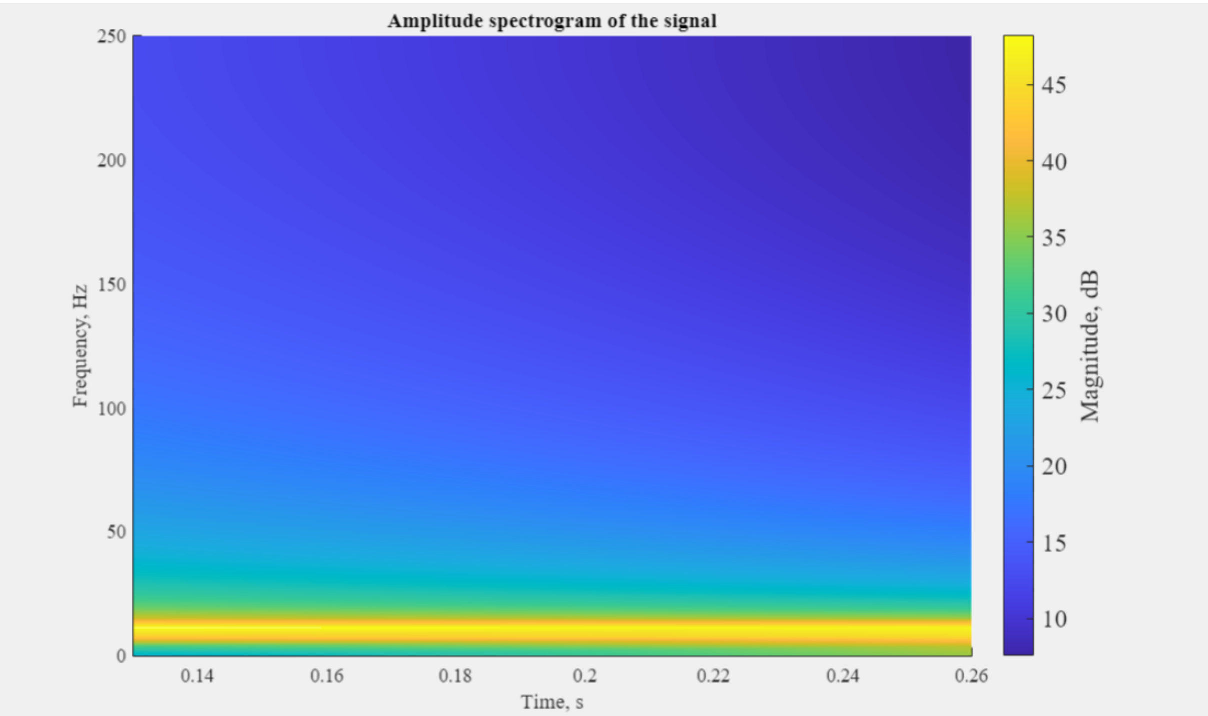

Figure 5. Spectrogram of the sinusoidal signal with window Kaiser (130).

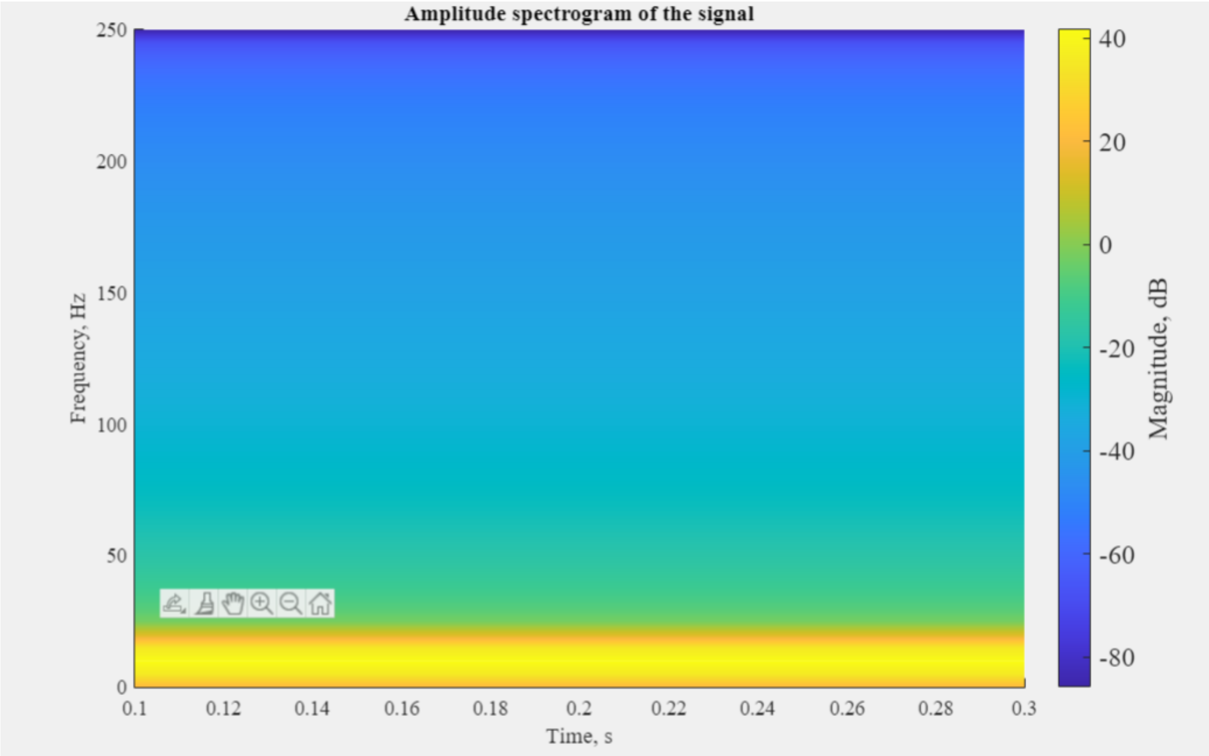

Figure 6. Spectrogram of the sinusoidal signal with window Gaussian (100).

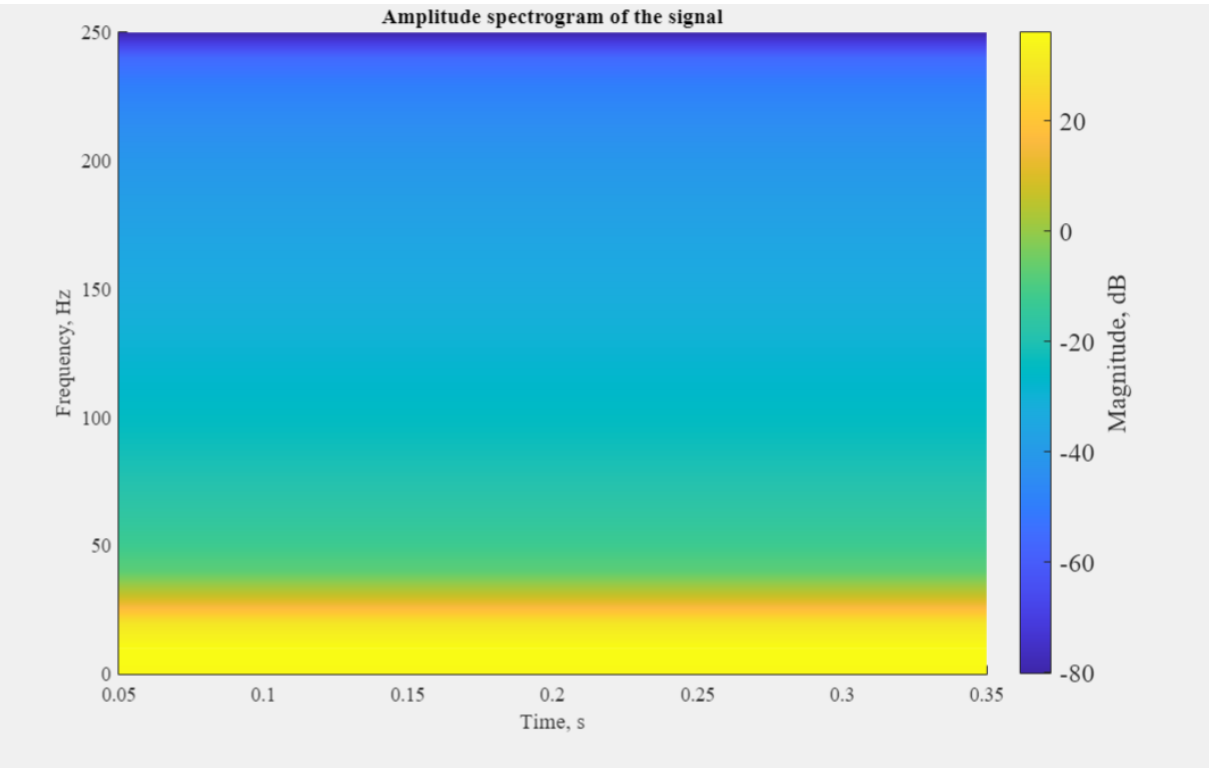

Figure 7. Spectrogram of the sinusoidal signal with window Gaussian (50).

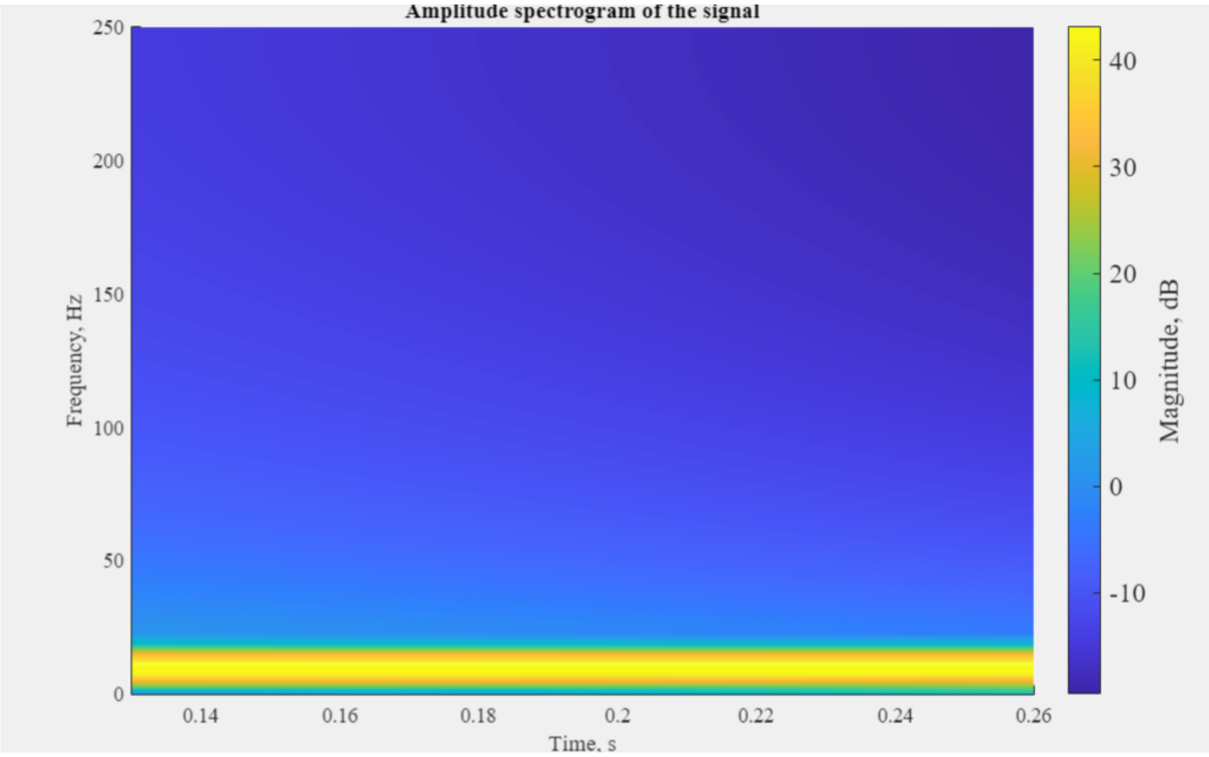

Figure 8. Spectrogram of the sinusoidal signal with window Gaussian (130).

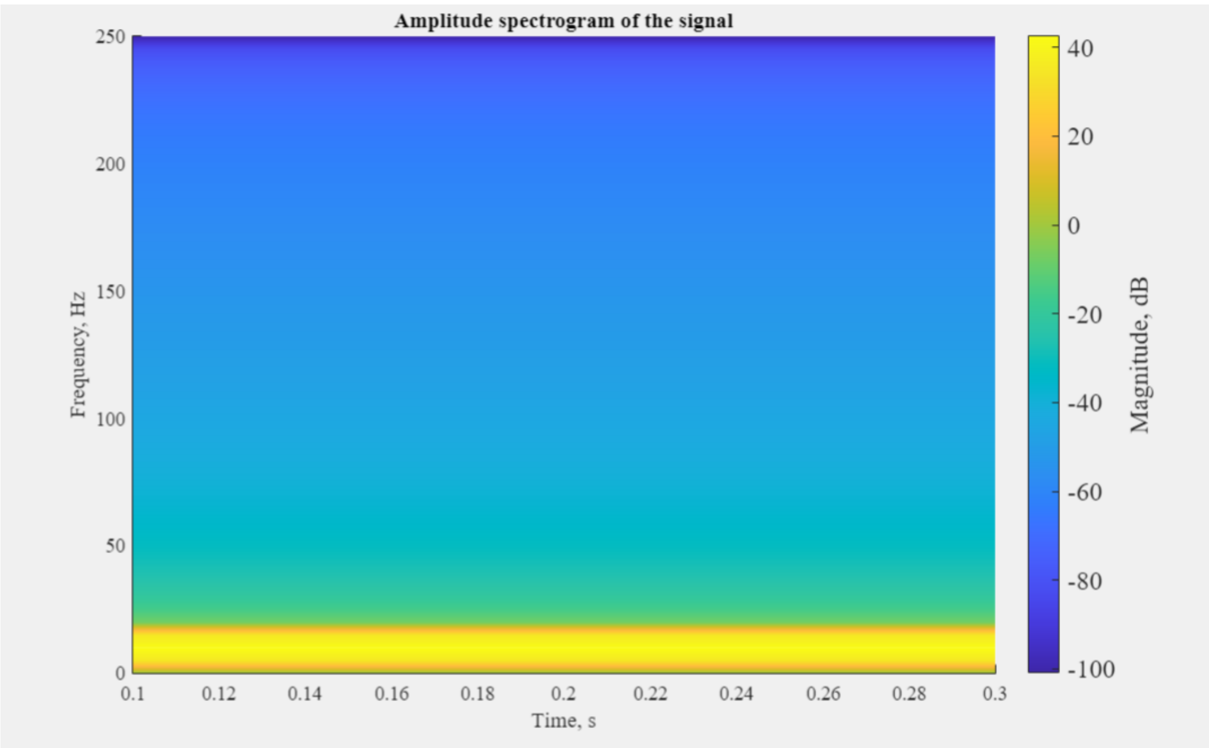

Figure 9. Spectrogram of the sinusoidal signal with window Hamming (100).

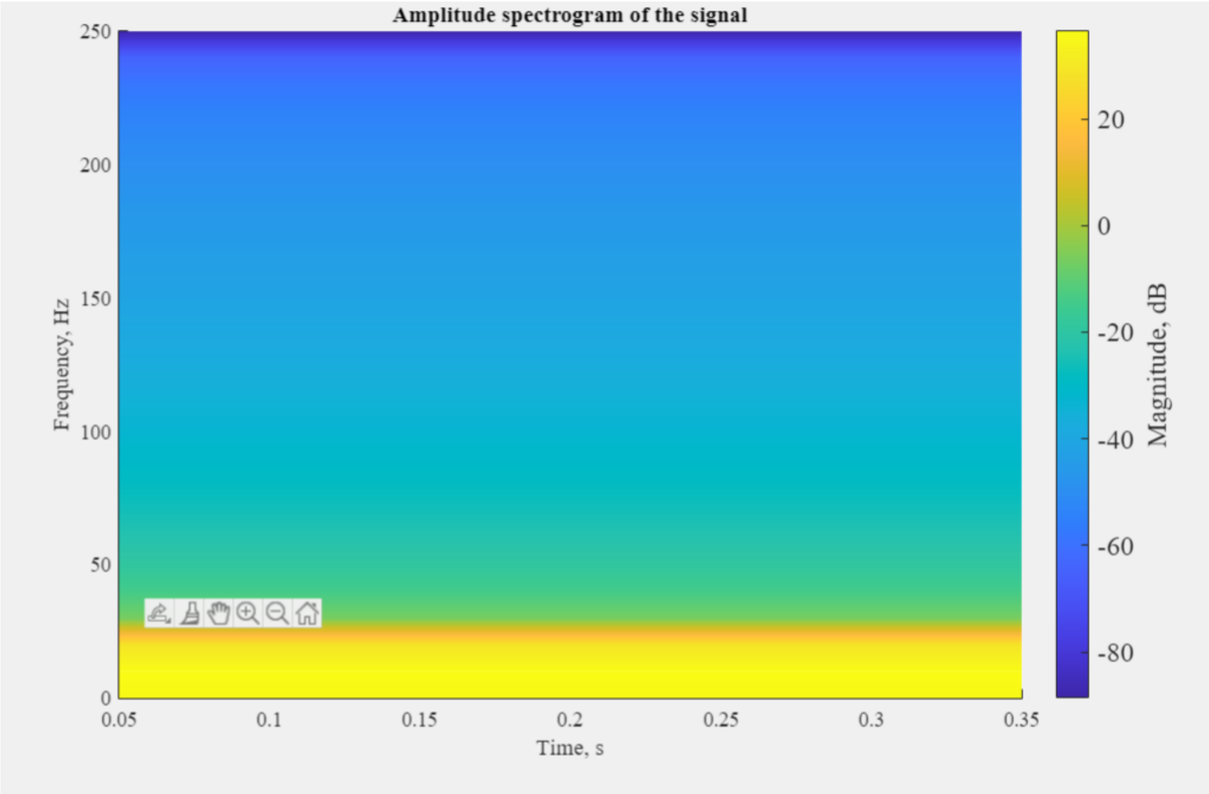

Figure 10. Spectrogram of the sinusoidal signal with window Hamming (50).

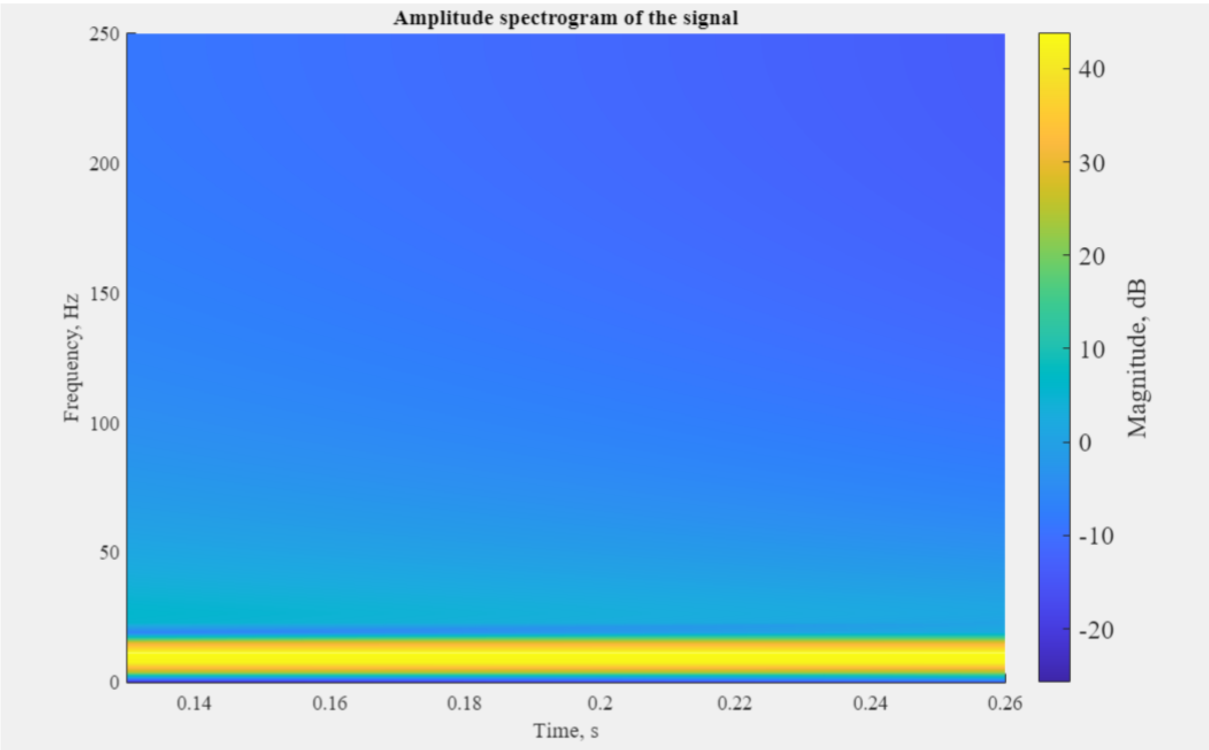

Figure 11. Spectrogram of the sinusoidal signal with window Hamming (130).

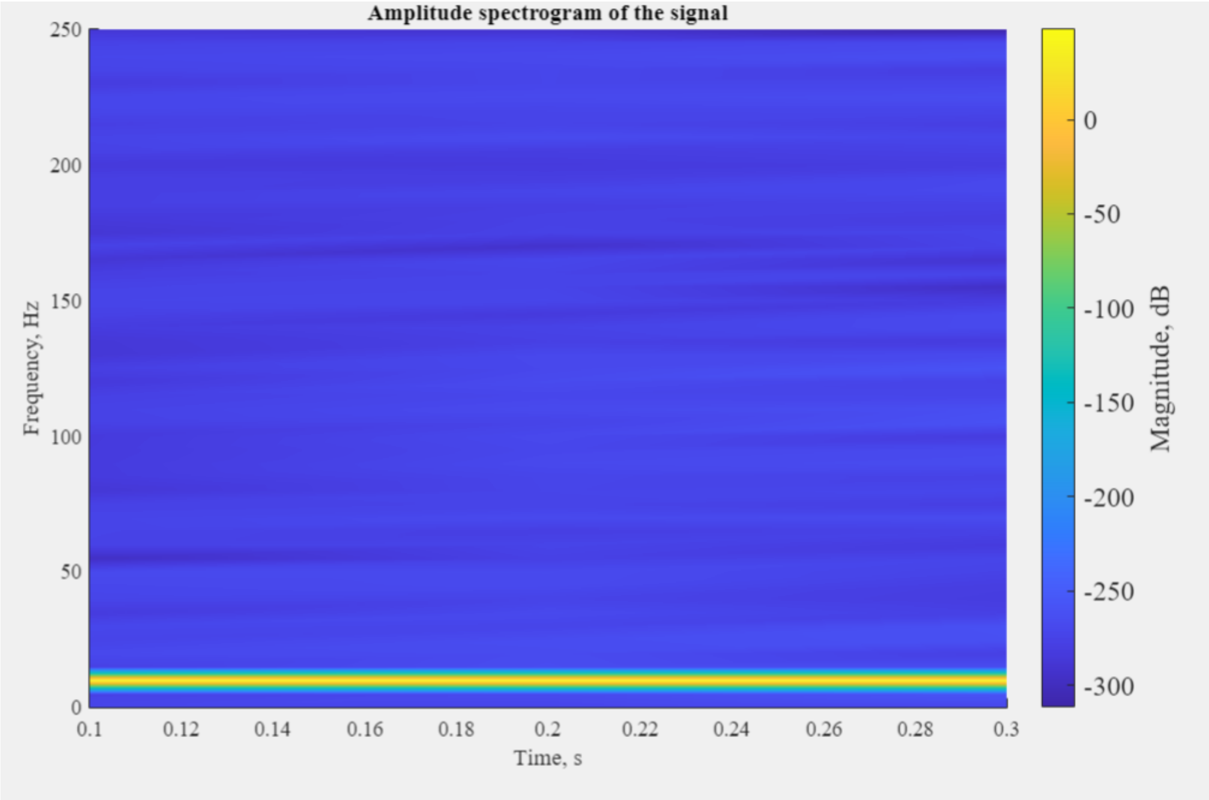

Figure 12. Spectrogram of the sinusoidal signal with window Rectangular (100).

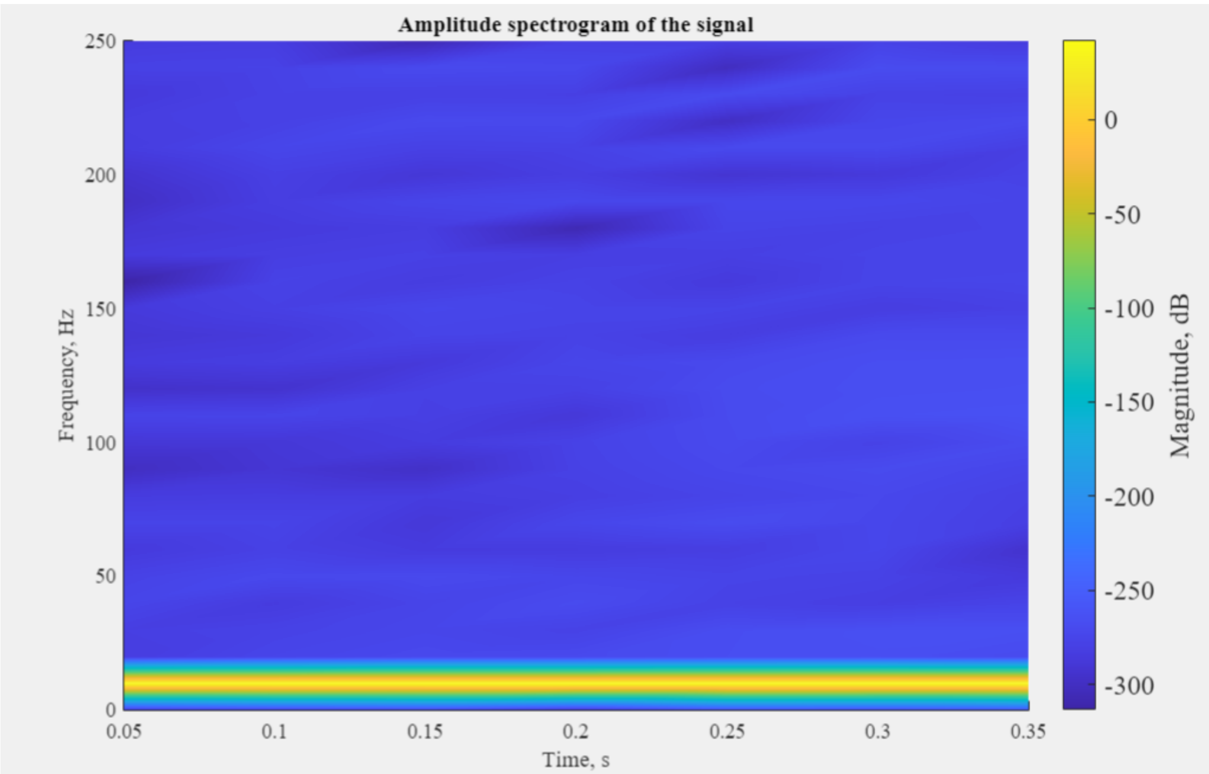

Figure 13. Spectrogram of the sinusoidal signal with window Rectangular (50).

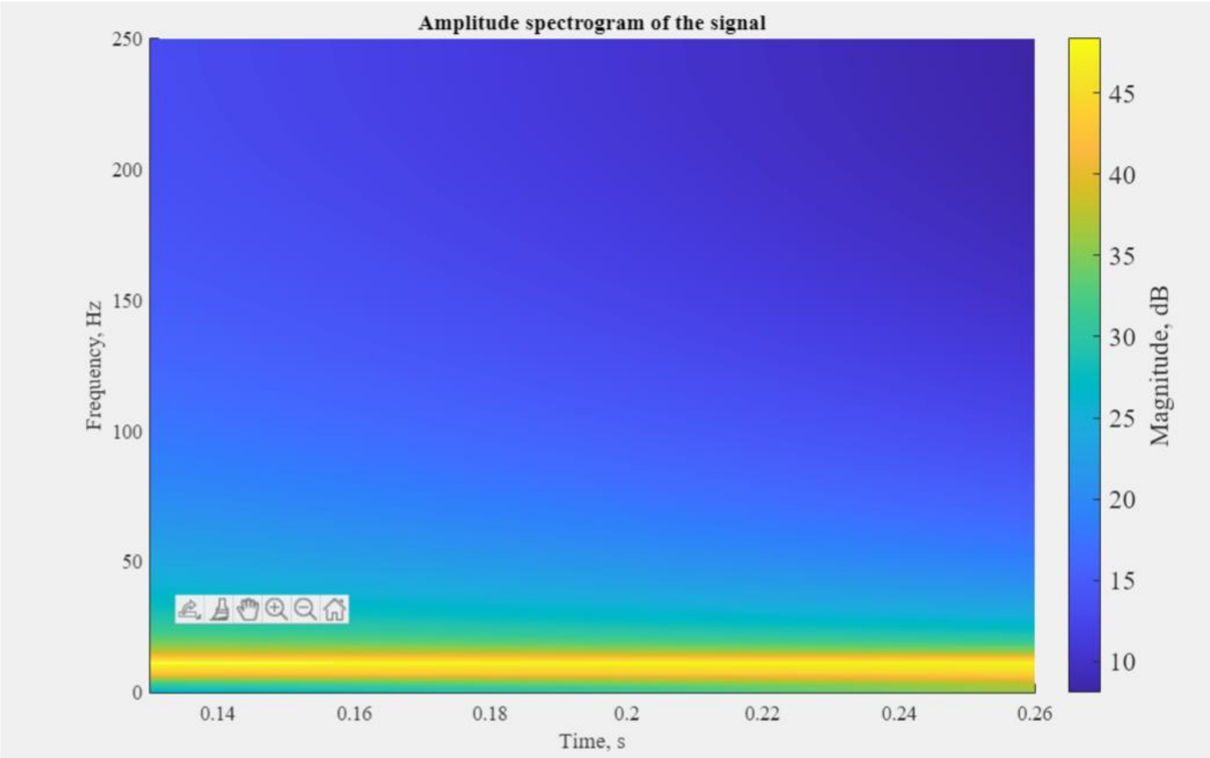

Figure 14. Spectrogram of the sinusoidal signal with window Rectangular (130).

The best window for sinusoidal signal is Rectangular type with length 100. It can be understood that the highest window length will not always give the best result.

II- RECTANGLE WINDOWED LINEAR CHIRP (Bandwidth 5)

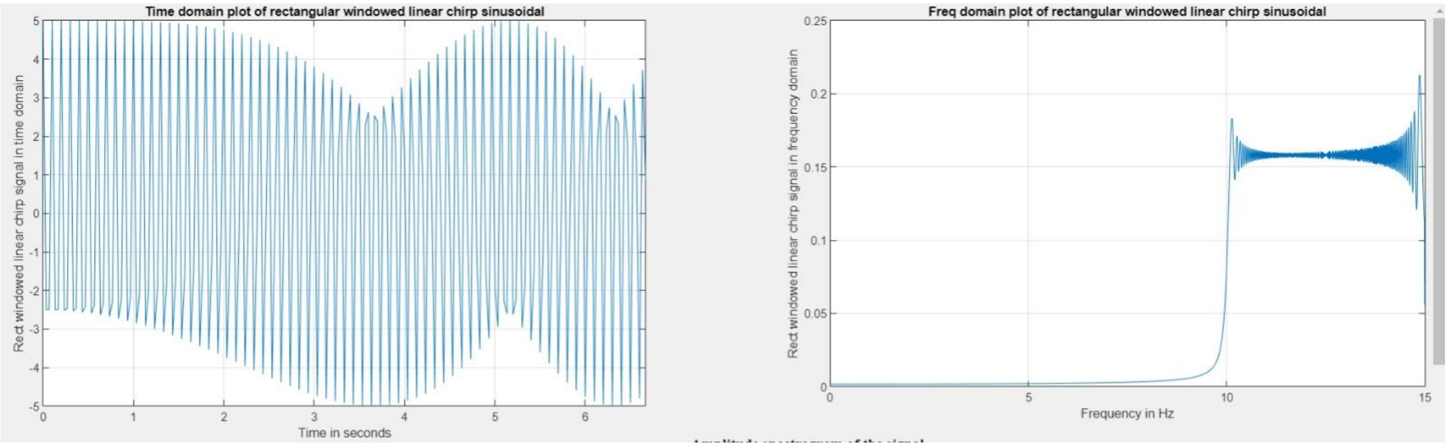

Figure 15. Generated Rectangle Windowed Linear Chirp Signal both in Time domain and Frequency domain.

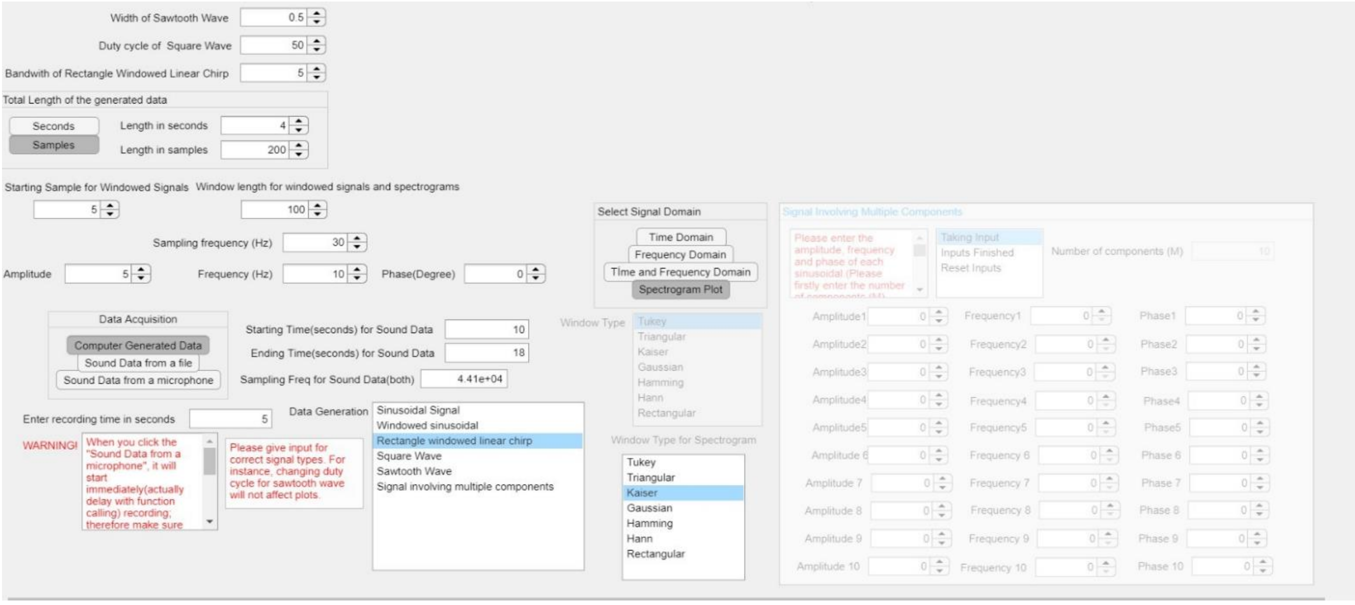

Figure 16. Parameters of our program interface.

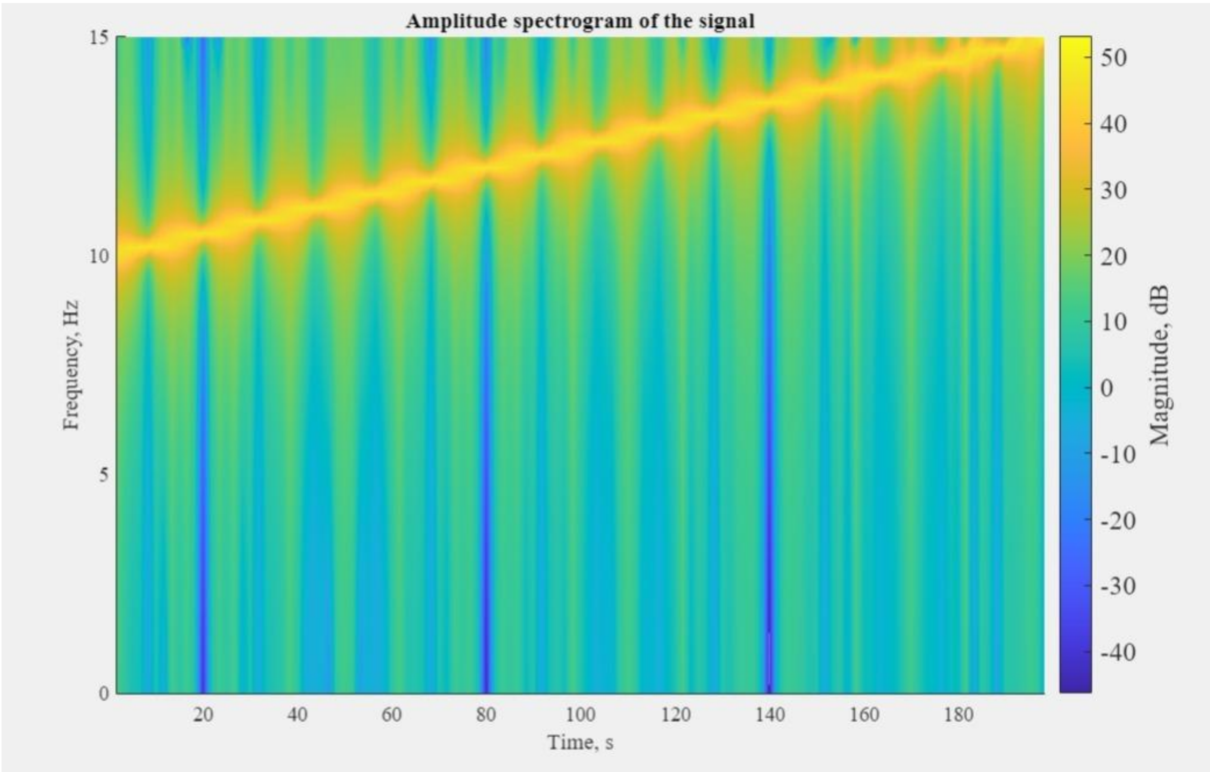

Figure 17. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Kaiser (100).

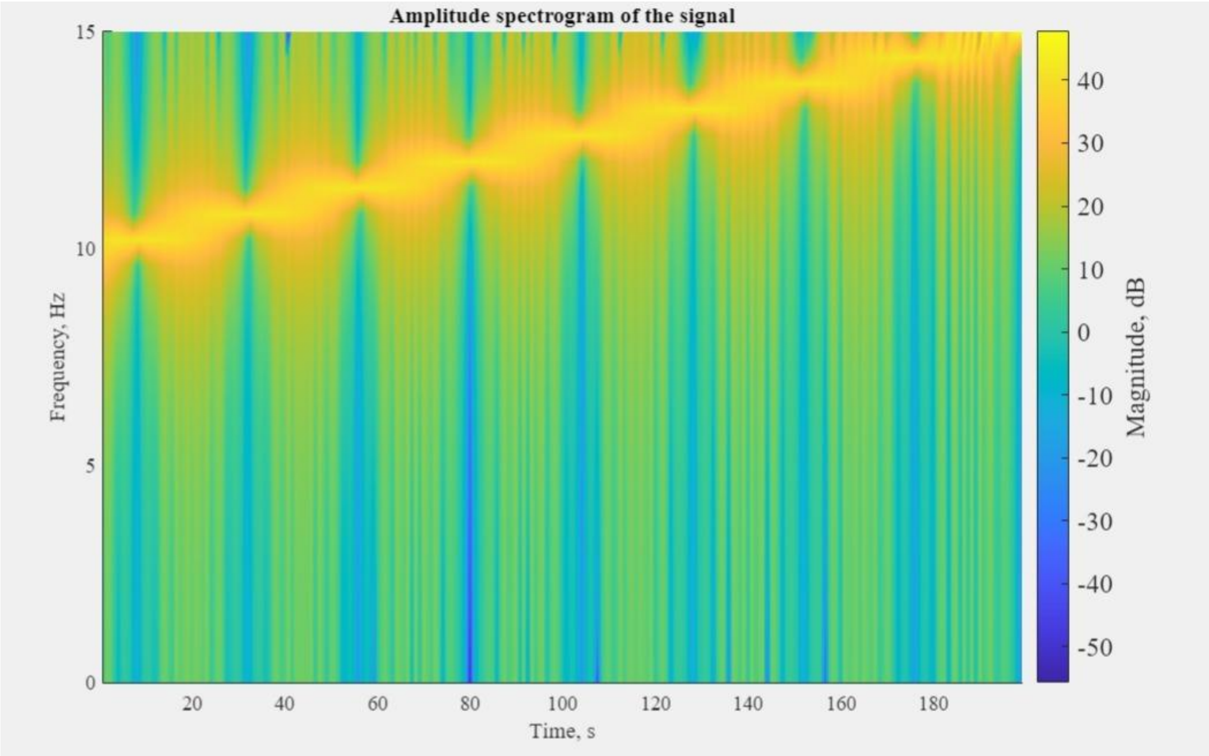

Figure 18. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Kaiser (50).

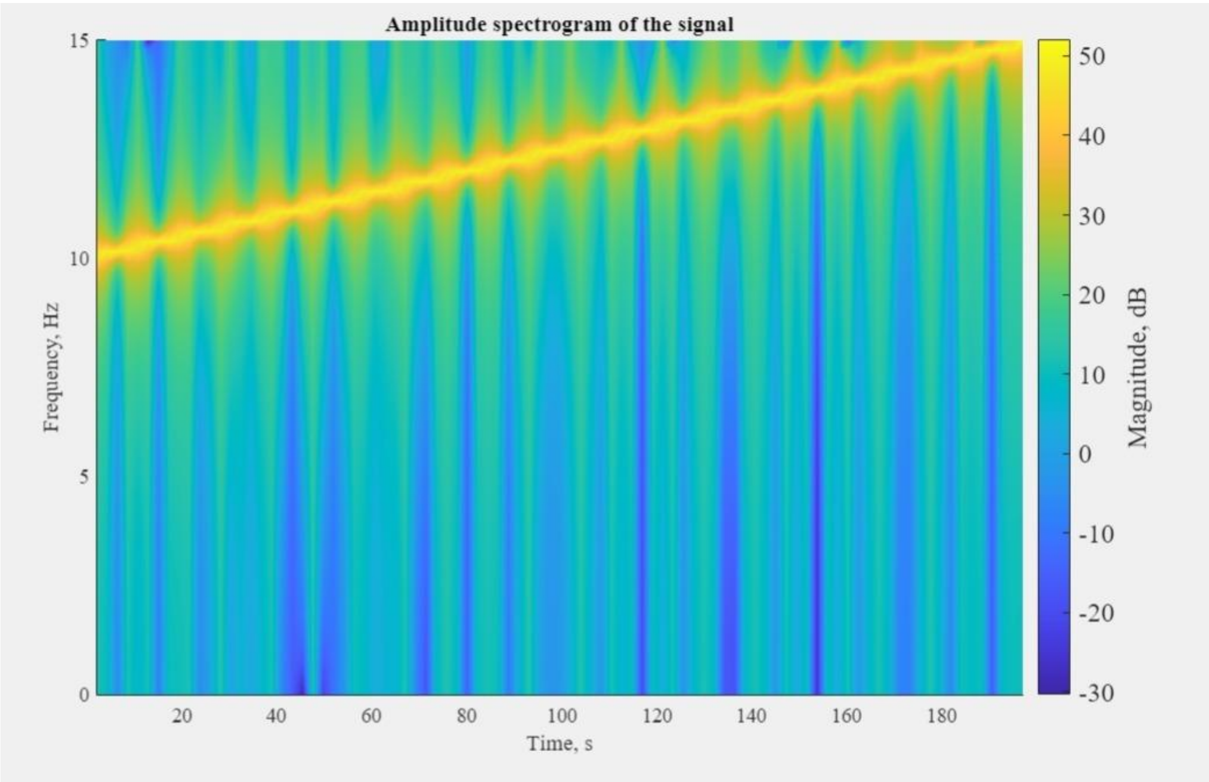

Figure 19. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Kaiser (130).

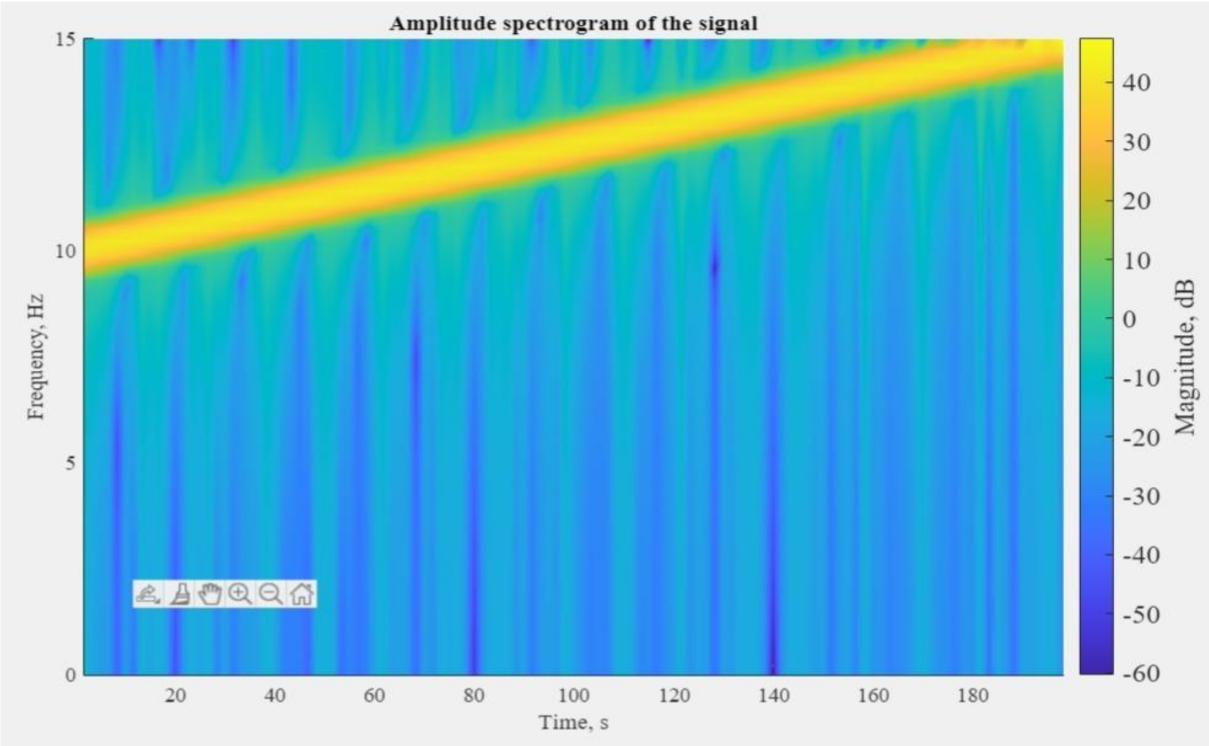

Figure 20. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Gaussian (100).

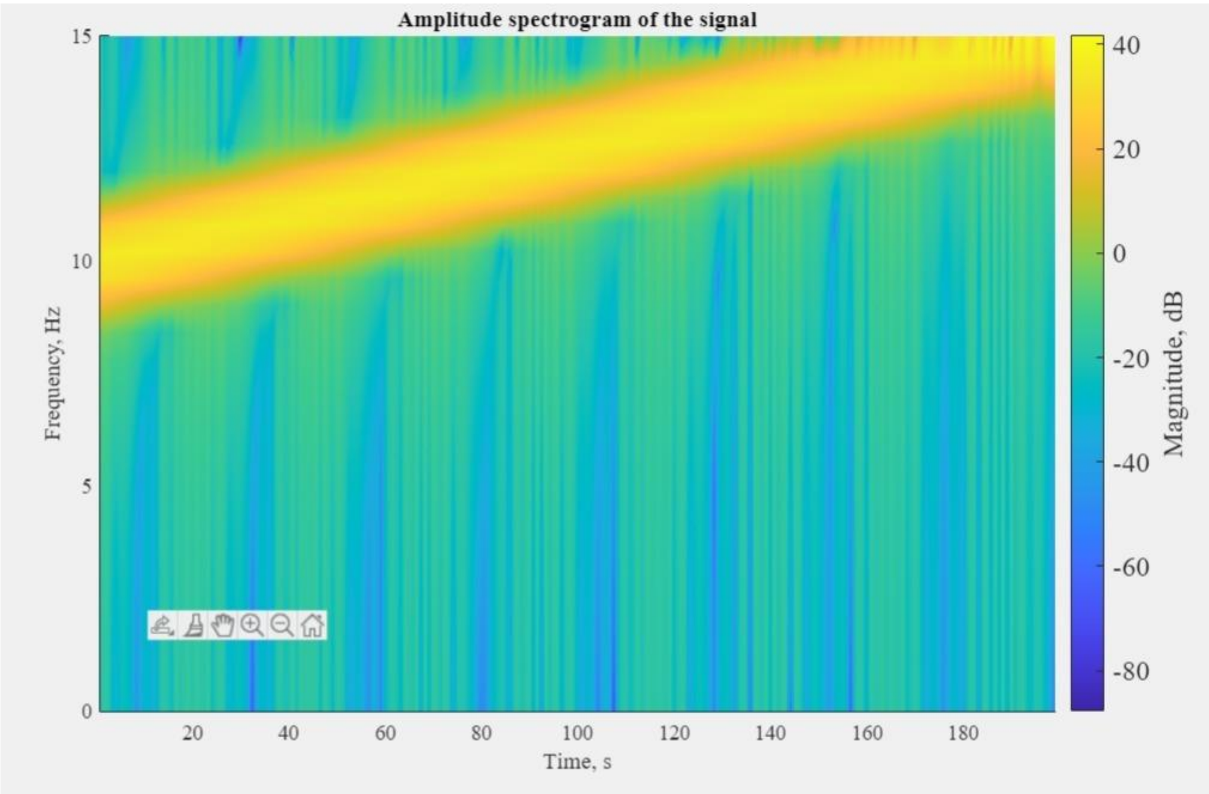

Figure 21. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Gaussian (50).

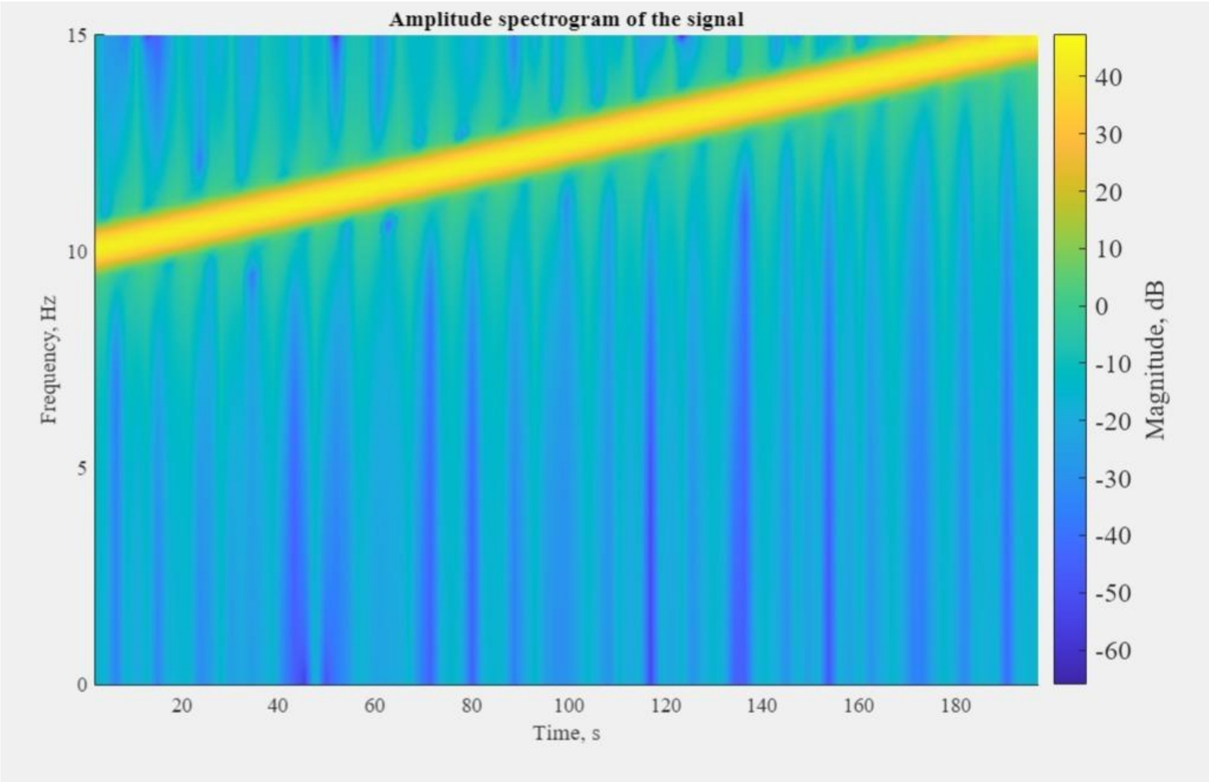

Figure 22. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Gaussian (130).

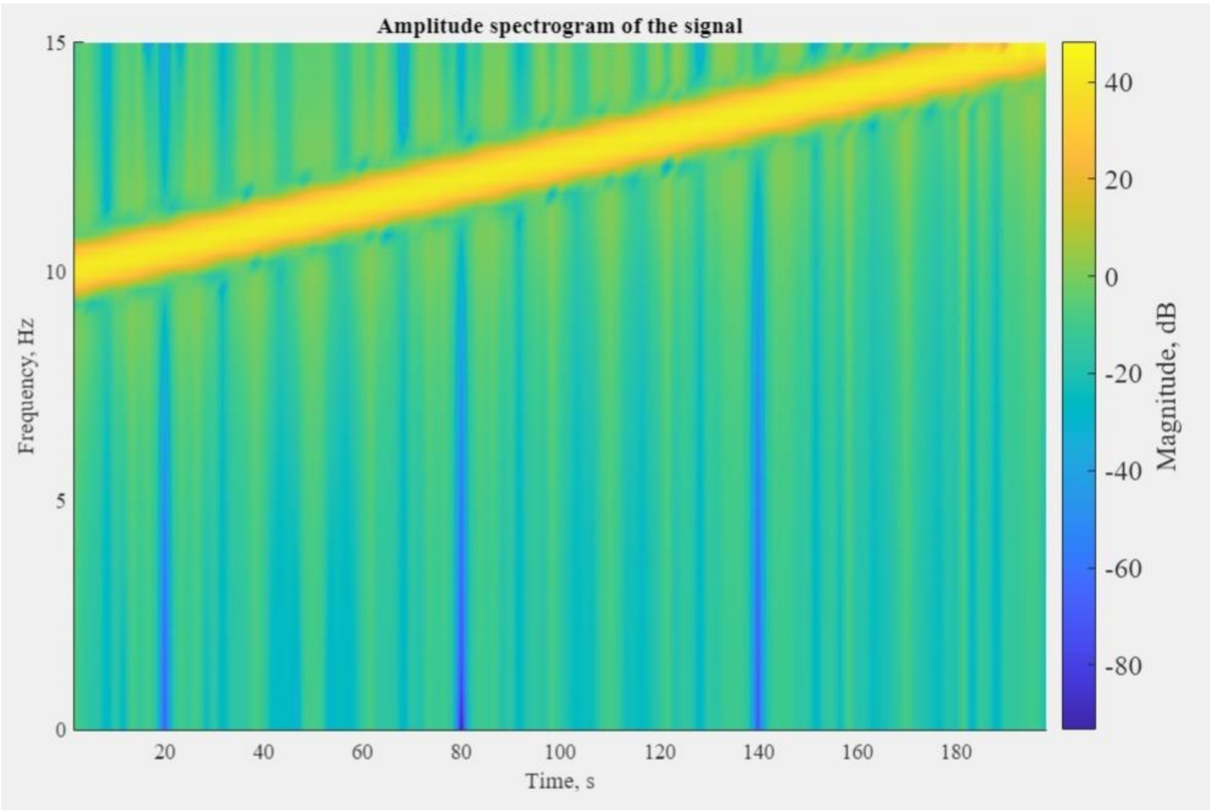

Figure 23. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Hamming (100).

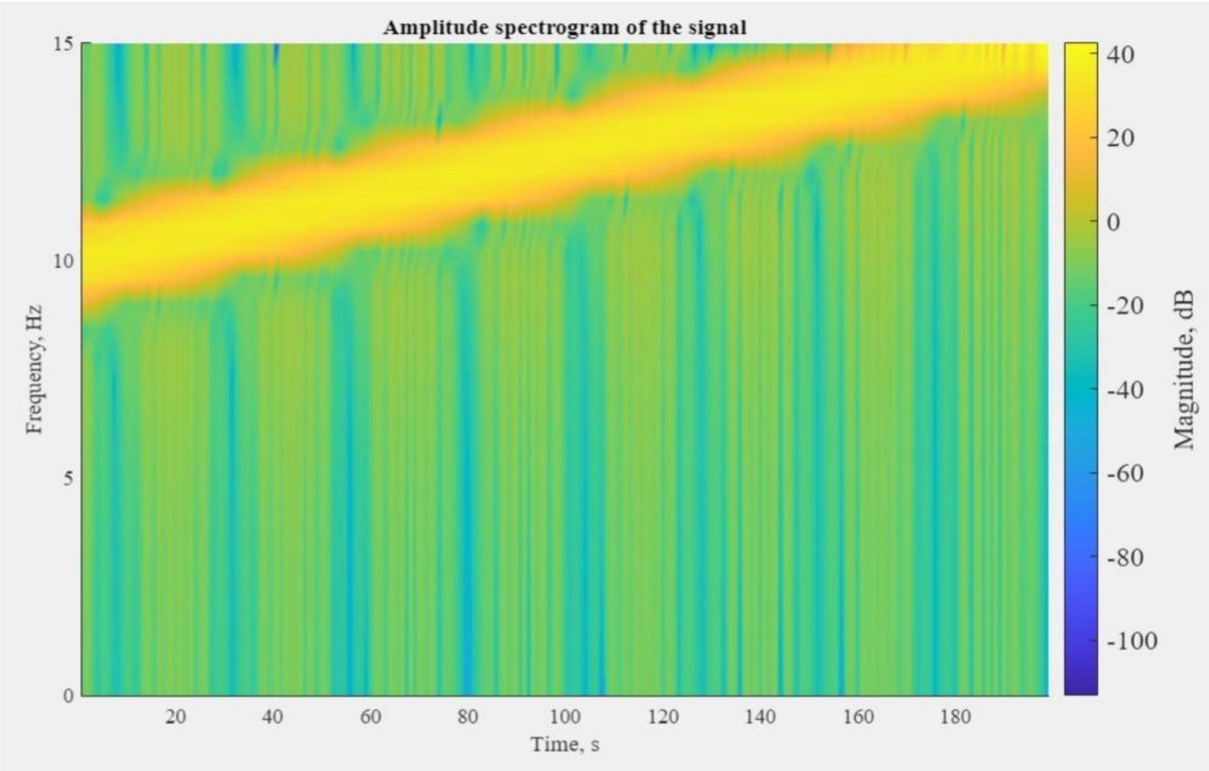

Figure 24. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Hamming (50).

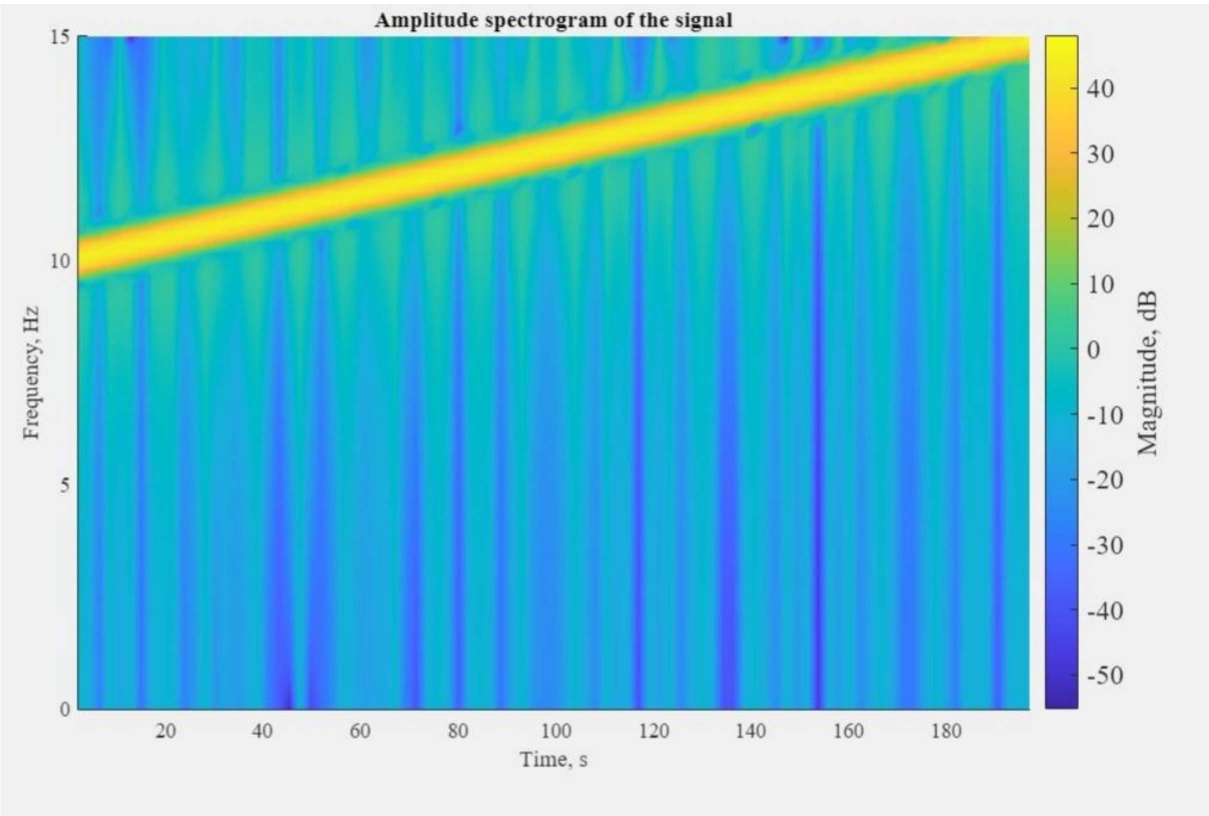

Figure 25. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Hamming (130).

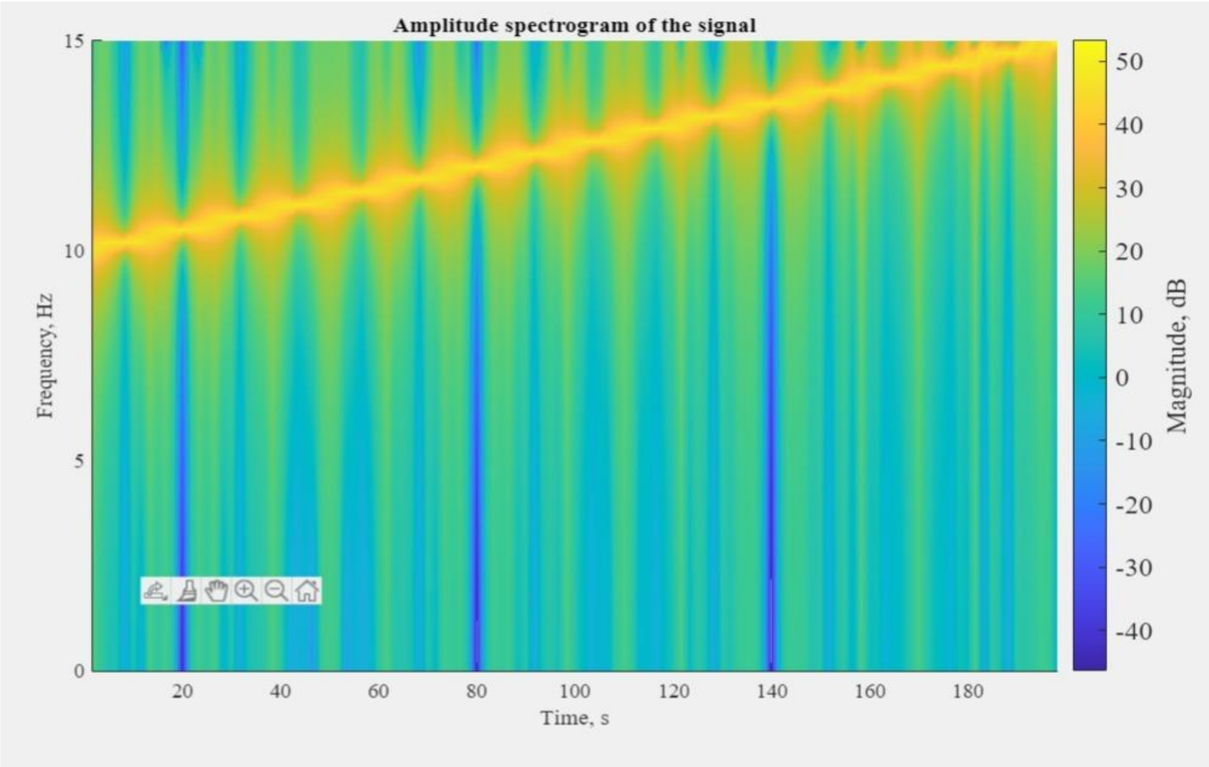

Figure 26. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Rectangular (100).

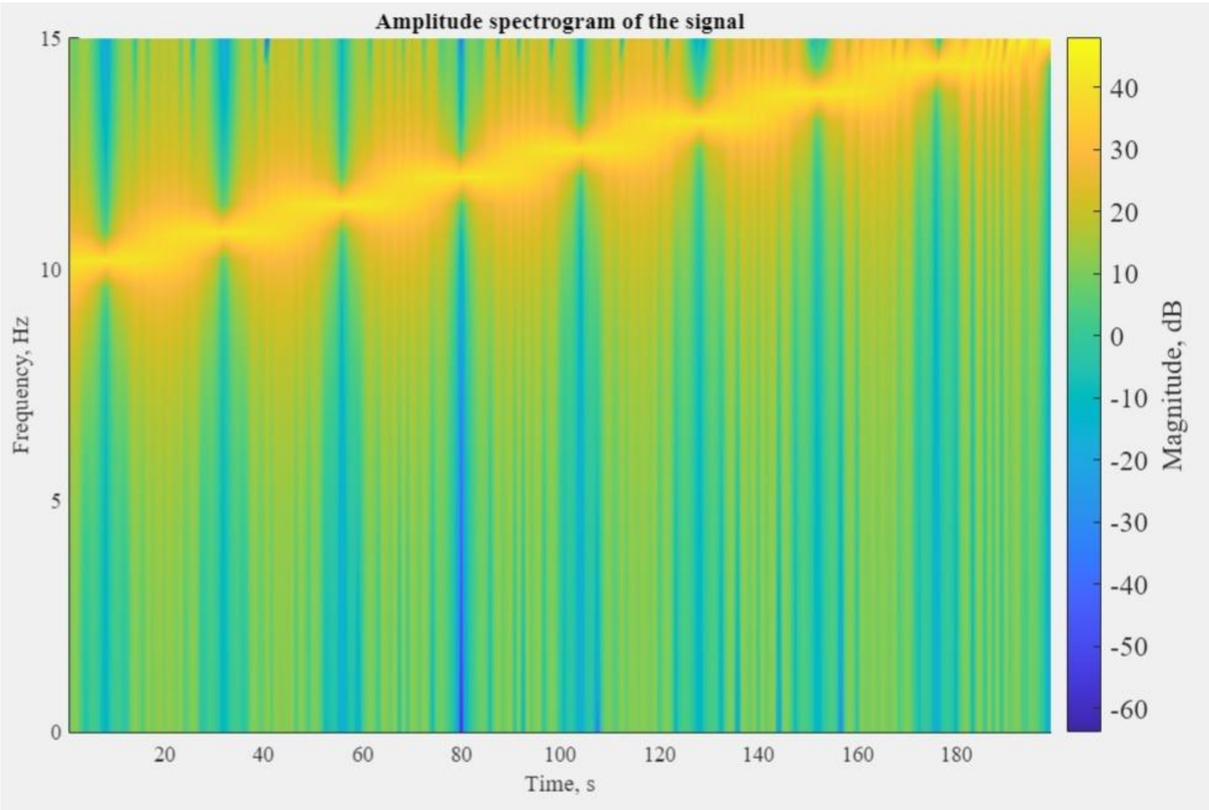

Figure 27. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Rectangular (50).

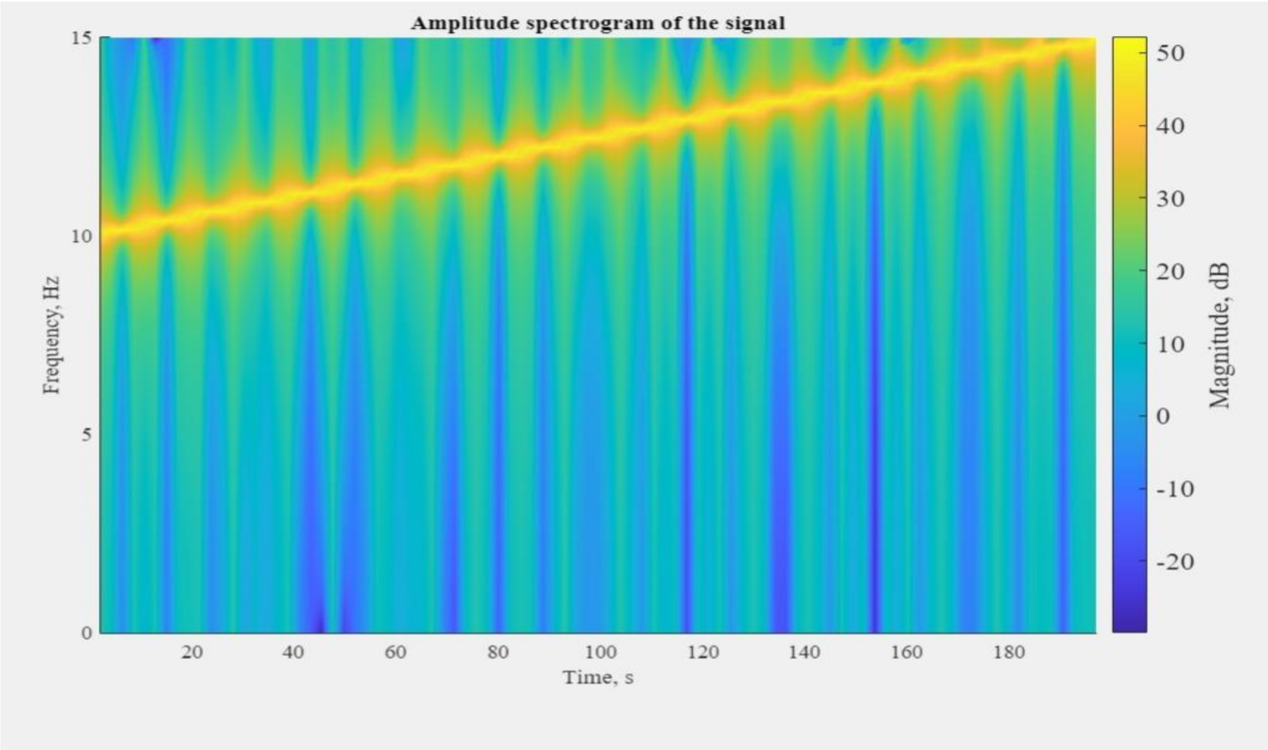

Figure 28. Spectrogram of the Rectangle Windowed Linear Chirp signal with window Rectangular (130).

Kaiser and Rectangular type windows with length 130 samples give the best result.

III- SIGNAL INVOLVING MULTIPLE COMPONENTS

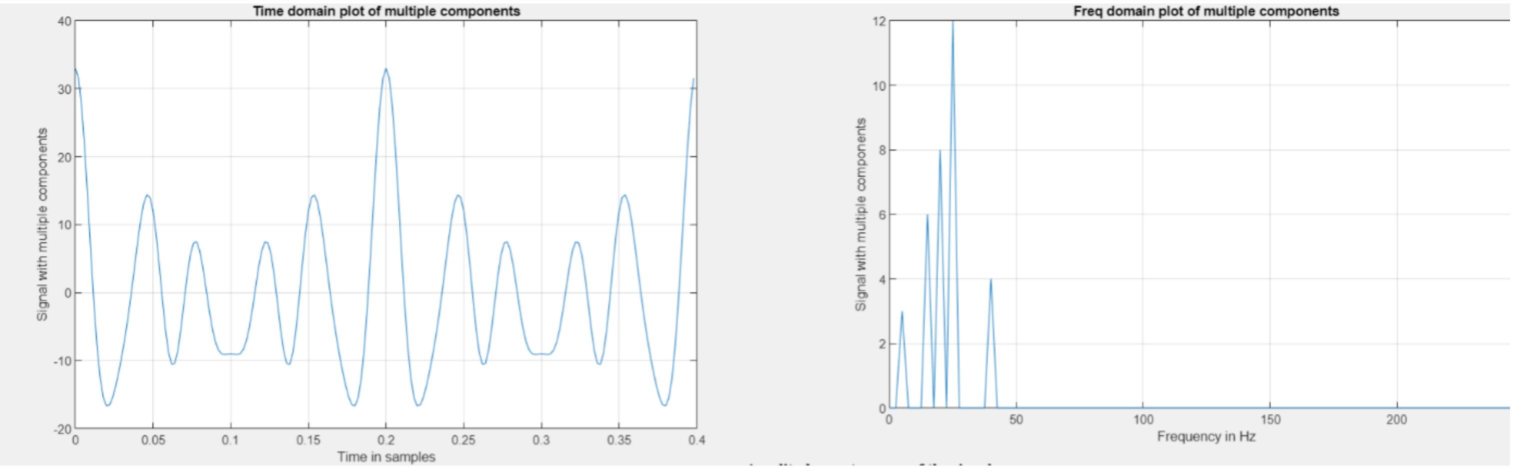

Figure 29. Generated Signal involving multiple components both in Time domain and Frequency domain.

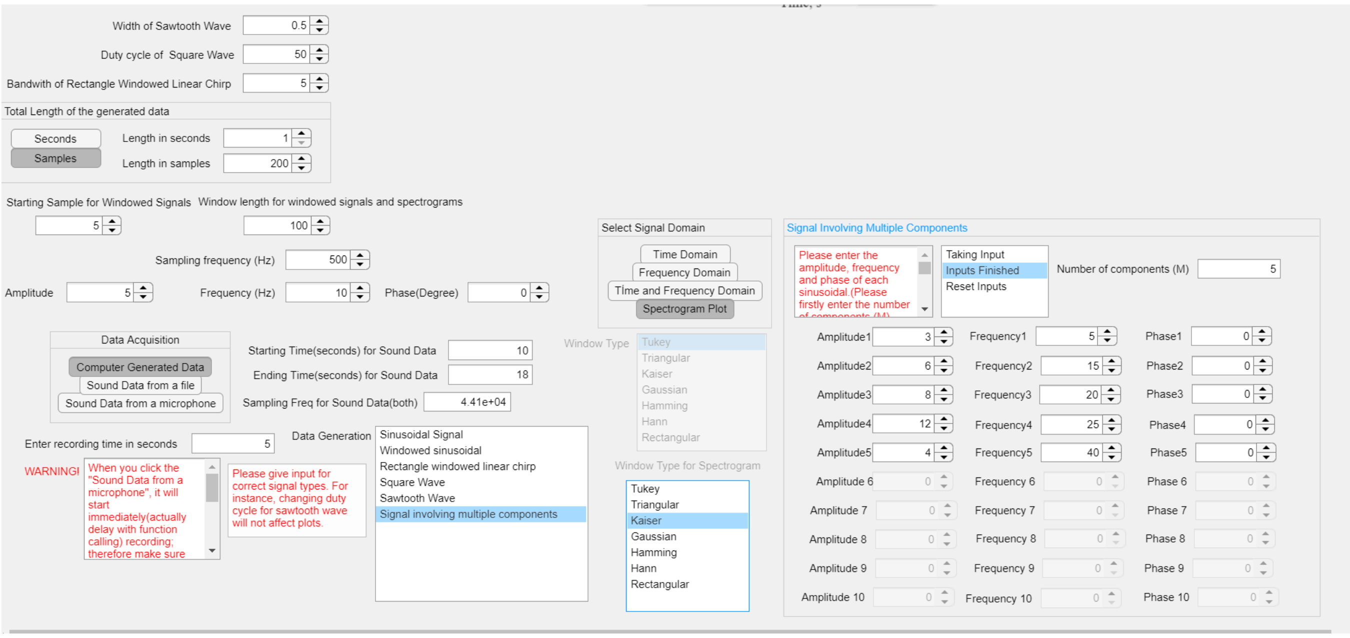

Figure 30. Parameters of our program interface.

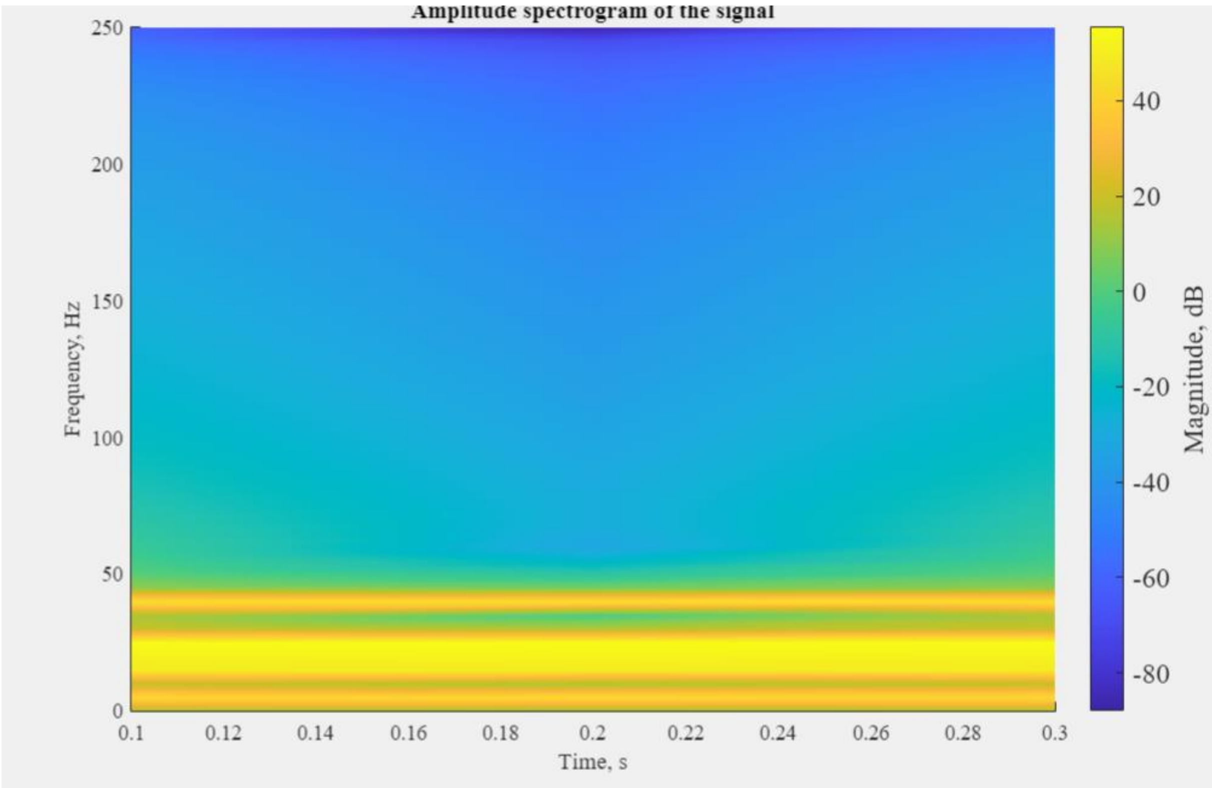

Figure 31. Spectrogram of the Signal involving multiple components with window Kaiser (100).

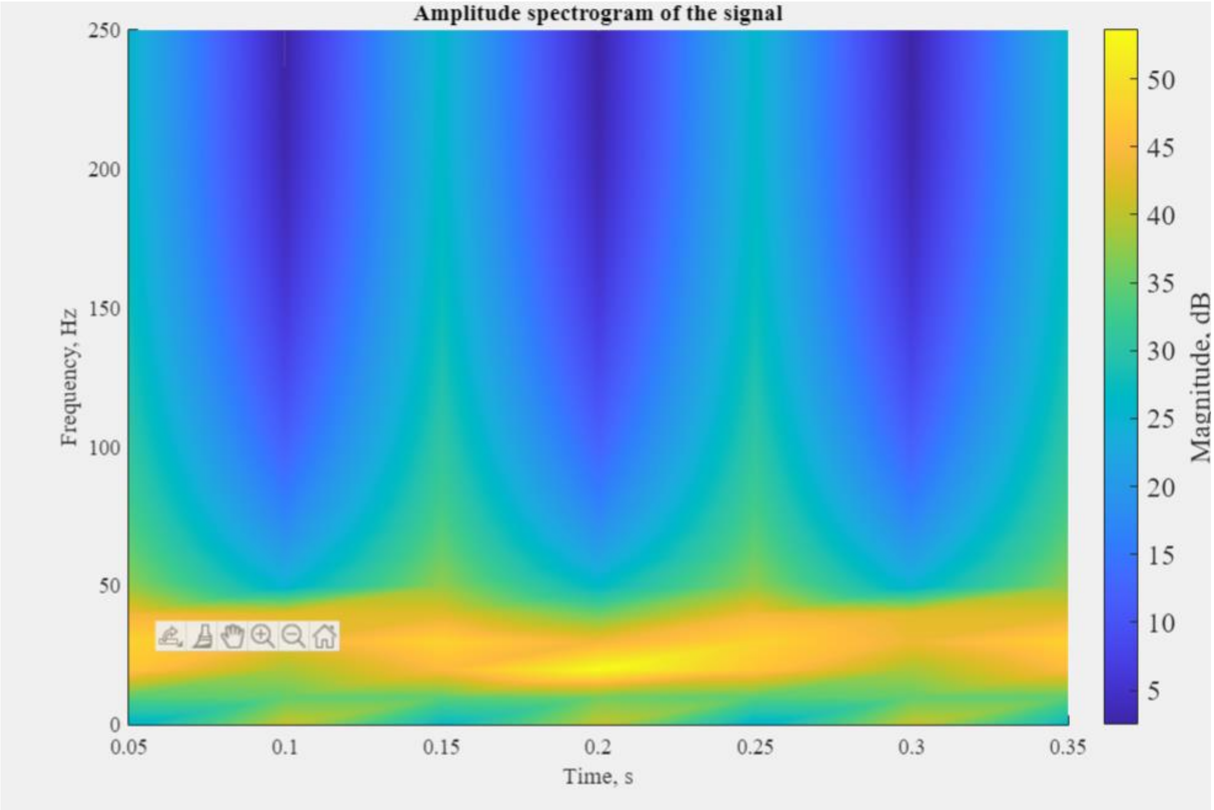

Figure 32. Spectrogram of the Signal involving multiple components with window Kaiser (50).

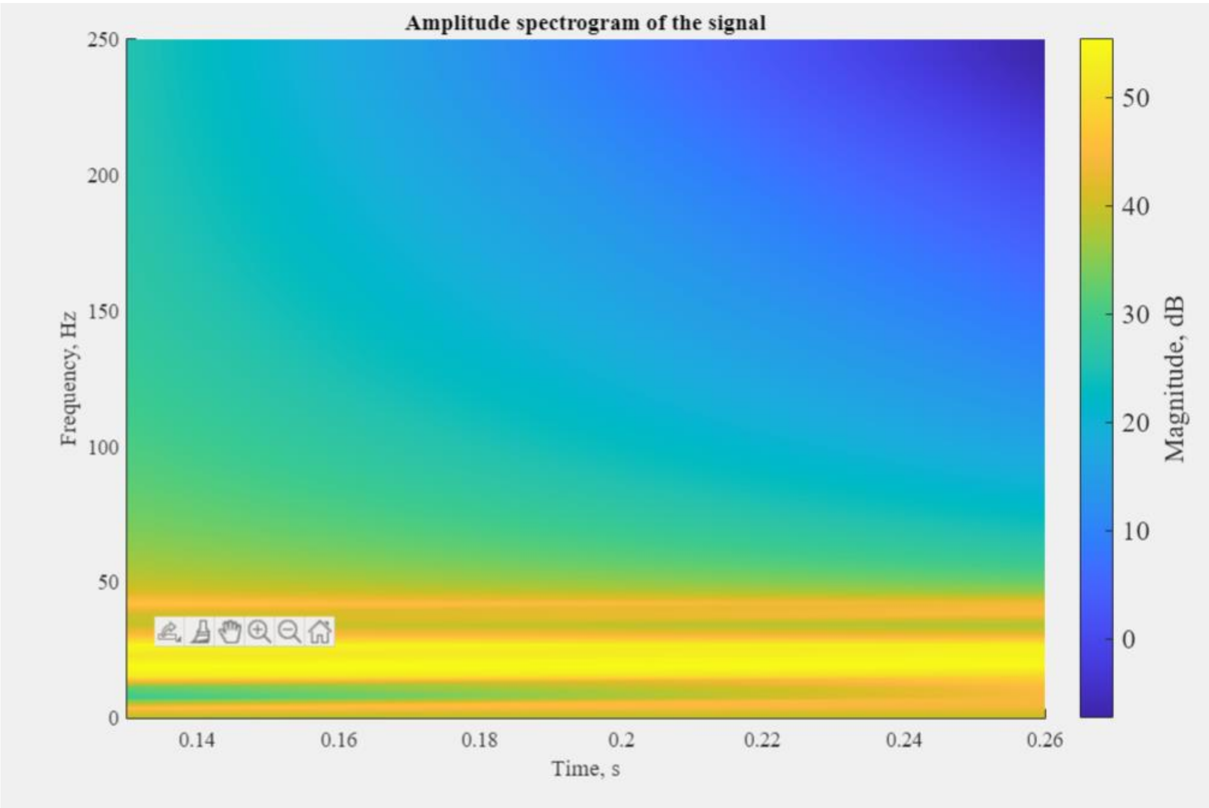

Figure 33. Spectrogram of the Signal involving multiple components with window Kaiser (130).

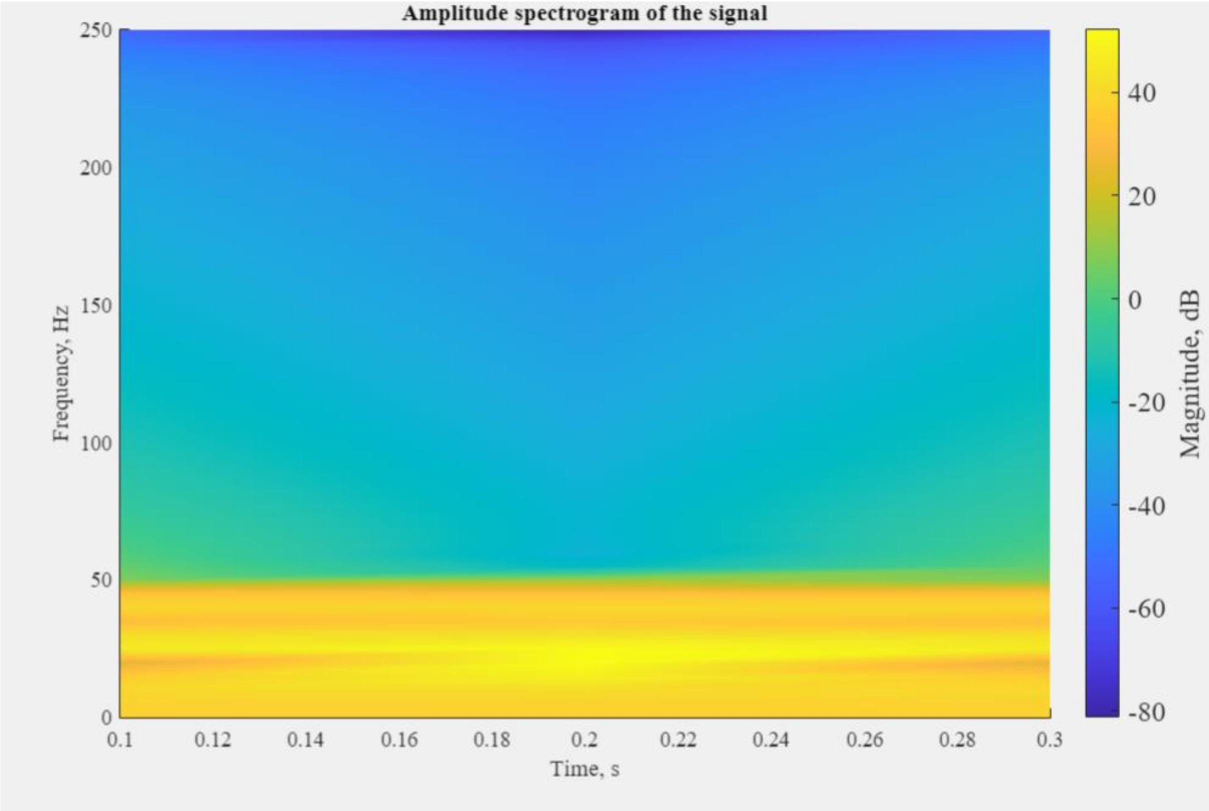

Figure 34. Spectrogram of the Signal involving multiple components with window Gaussian (100).

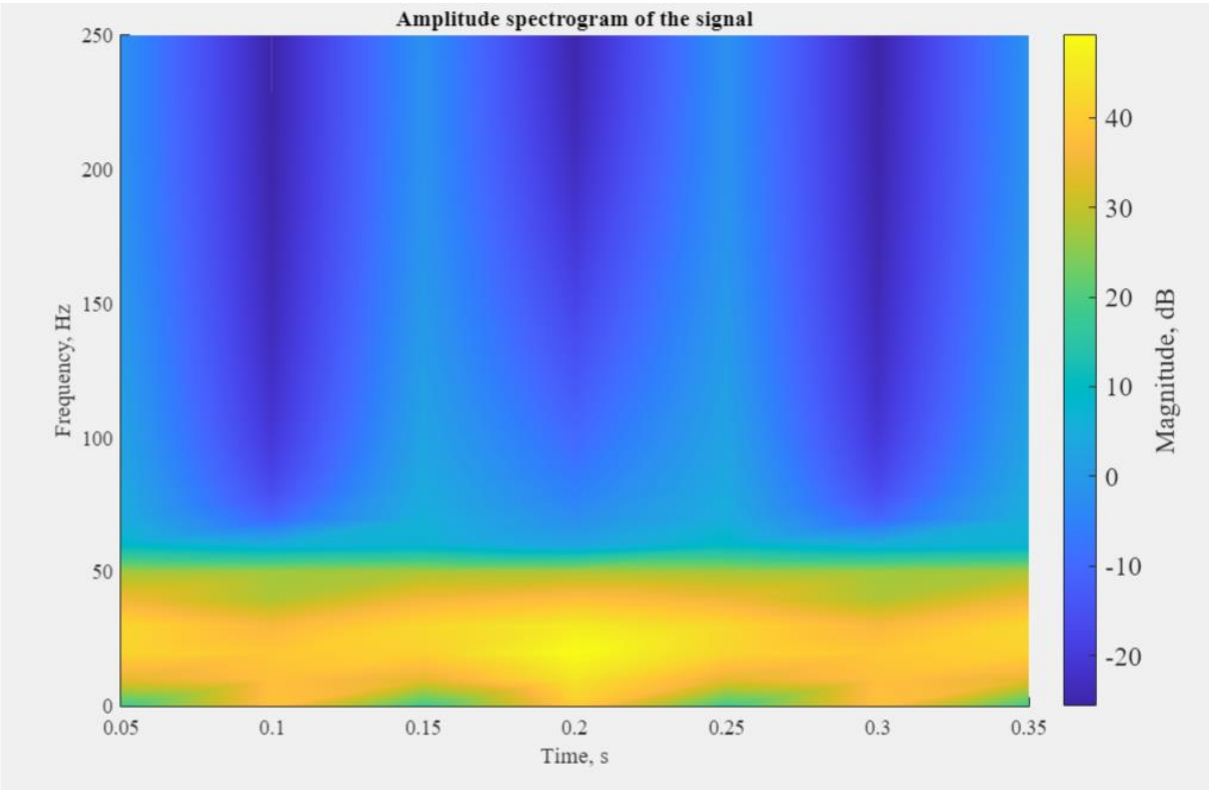

Figure 35. Spectrogram of the Signal involving multiple components with window Gaussian (50).

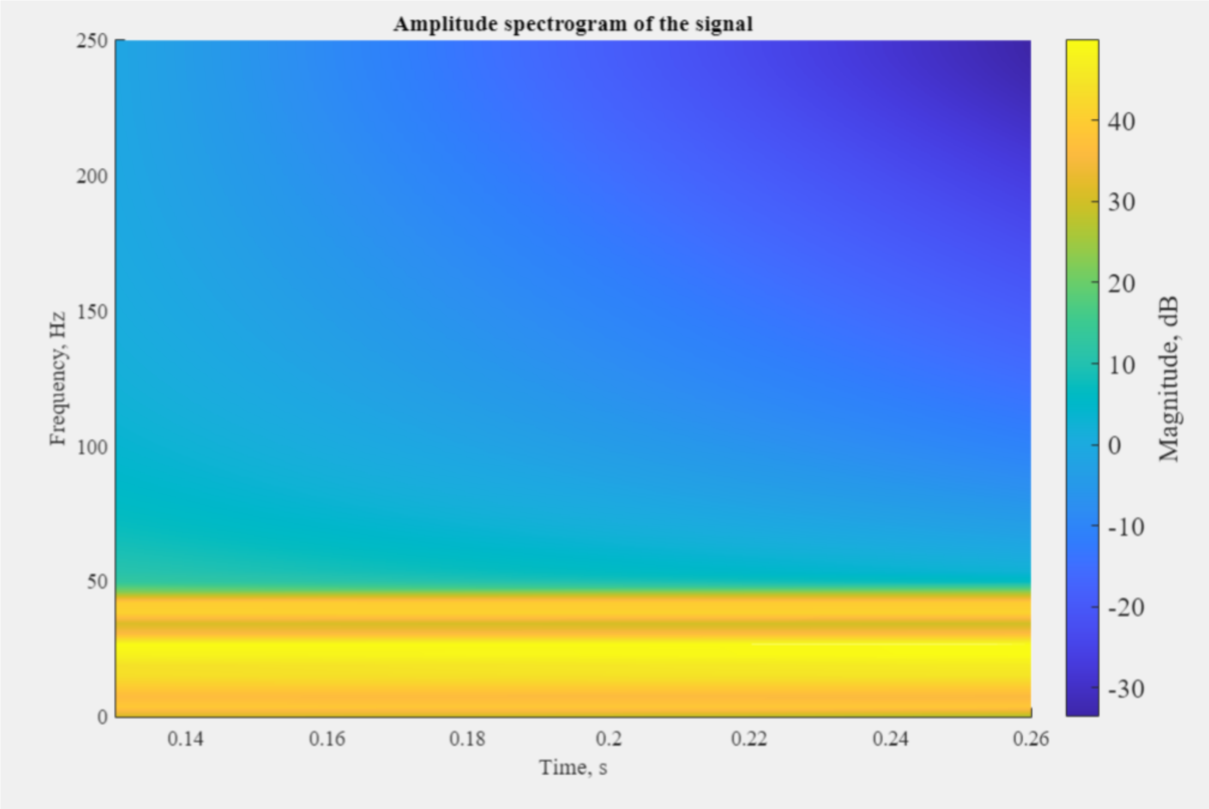

Figure 36. Spectrogram of the Signal involving multiple components with window Gaussian (130).

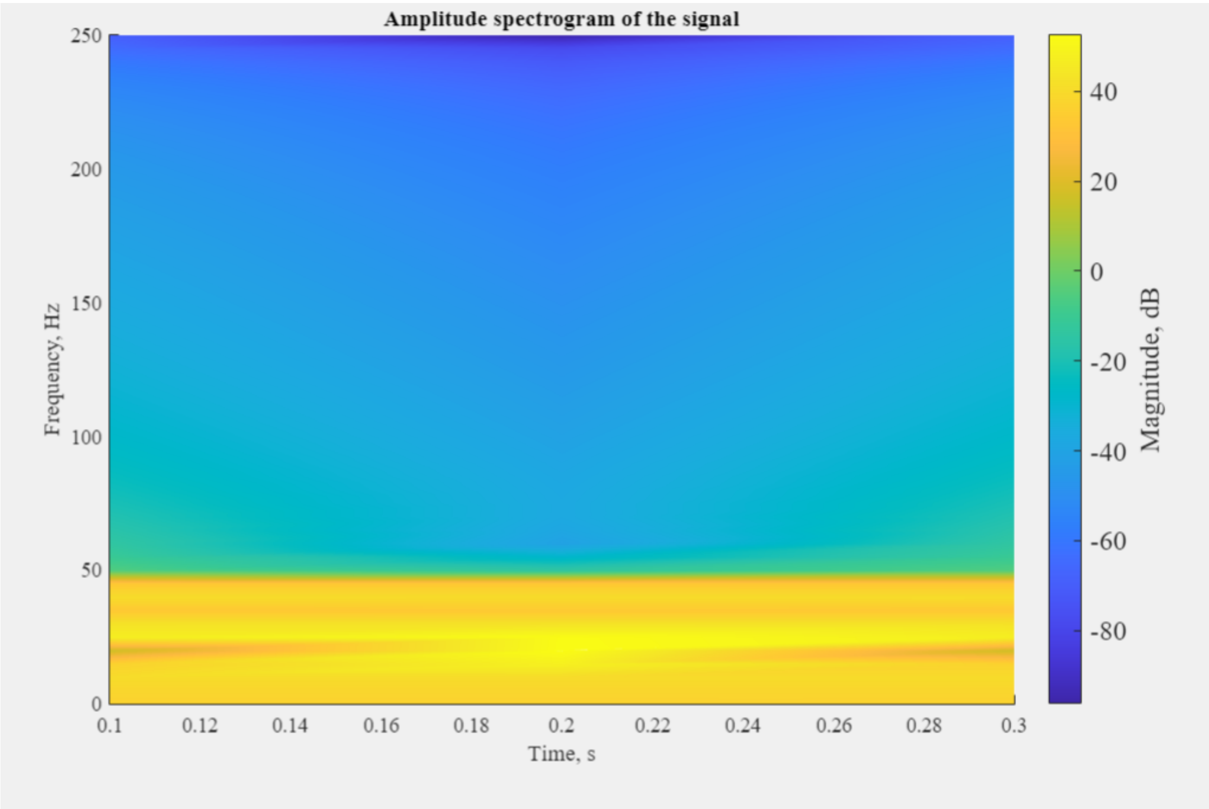

Figure 37. Spectrogram of the Signal involving multiple components with window Hamming (100).

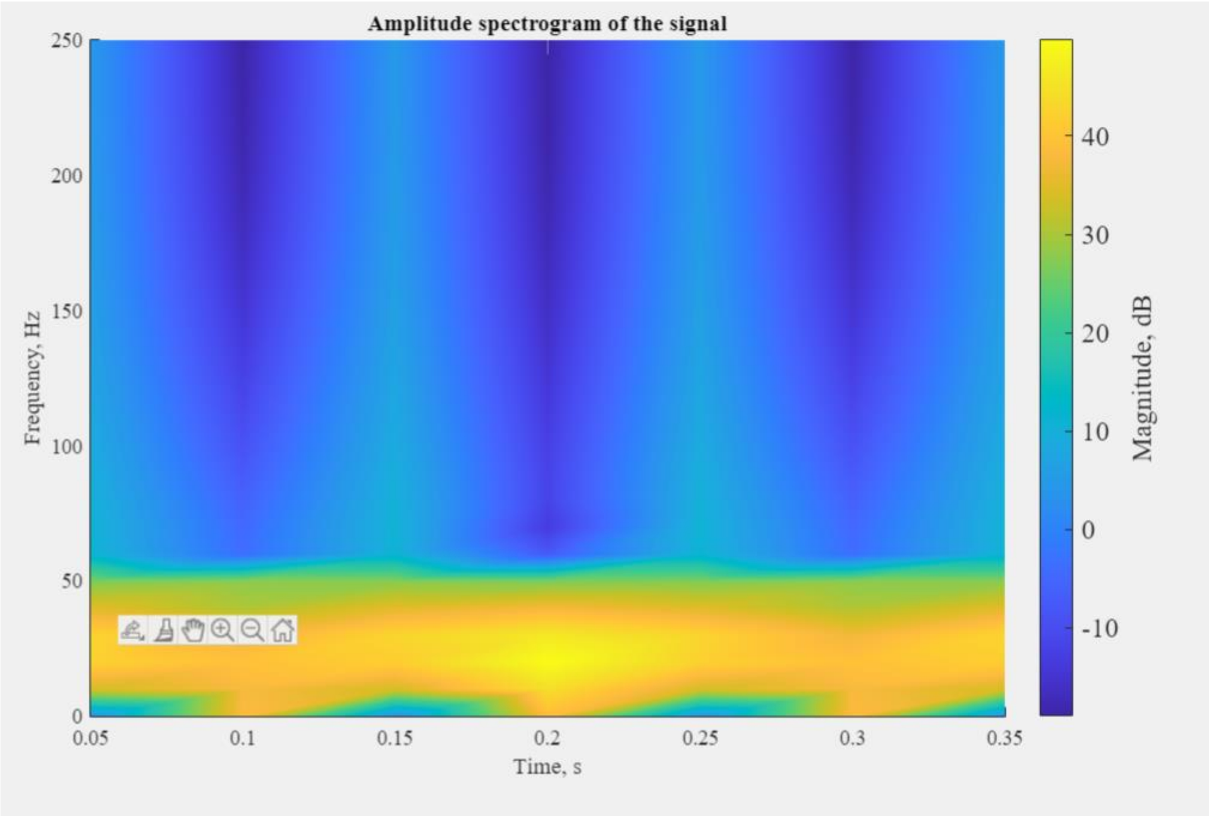

Figure 38. Spectrogram of the Signal involving multiple components with window Hamming (50).

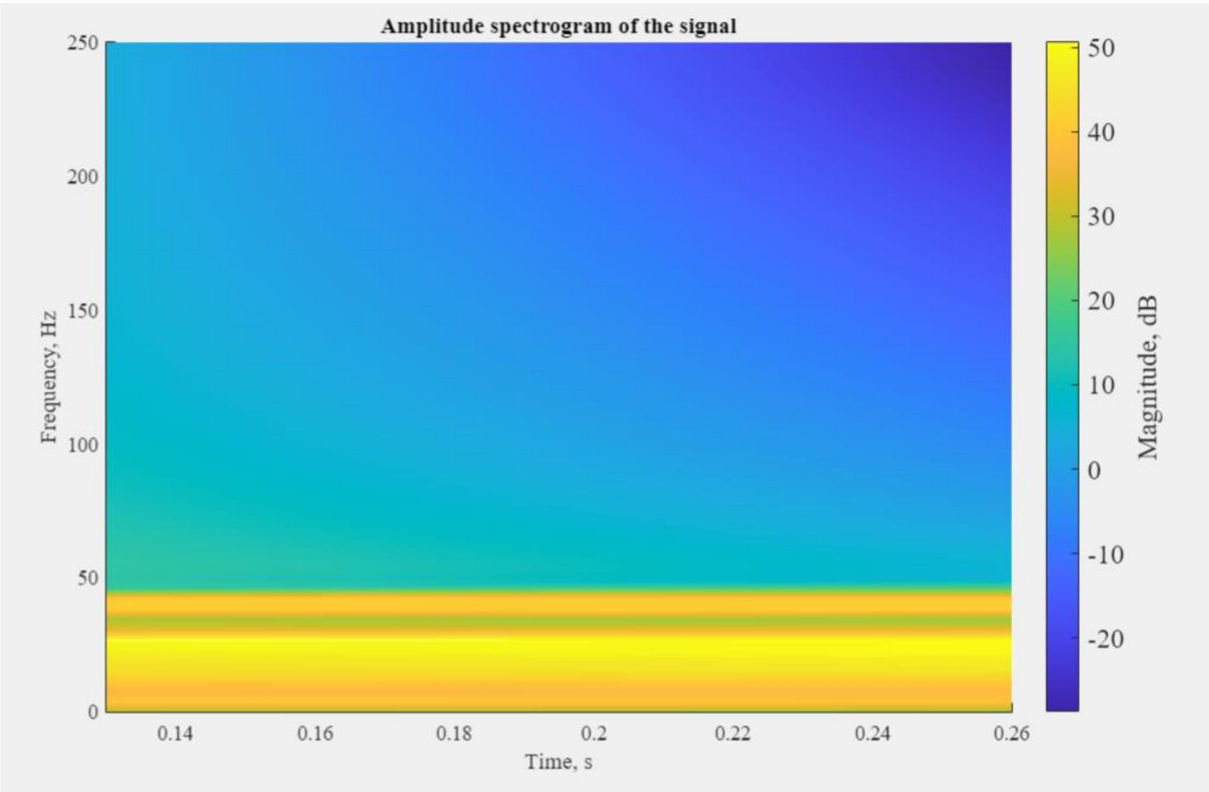

Figure 39. Spectrogram of the Signal involving multiple components with window Hamming (130).

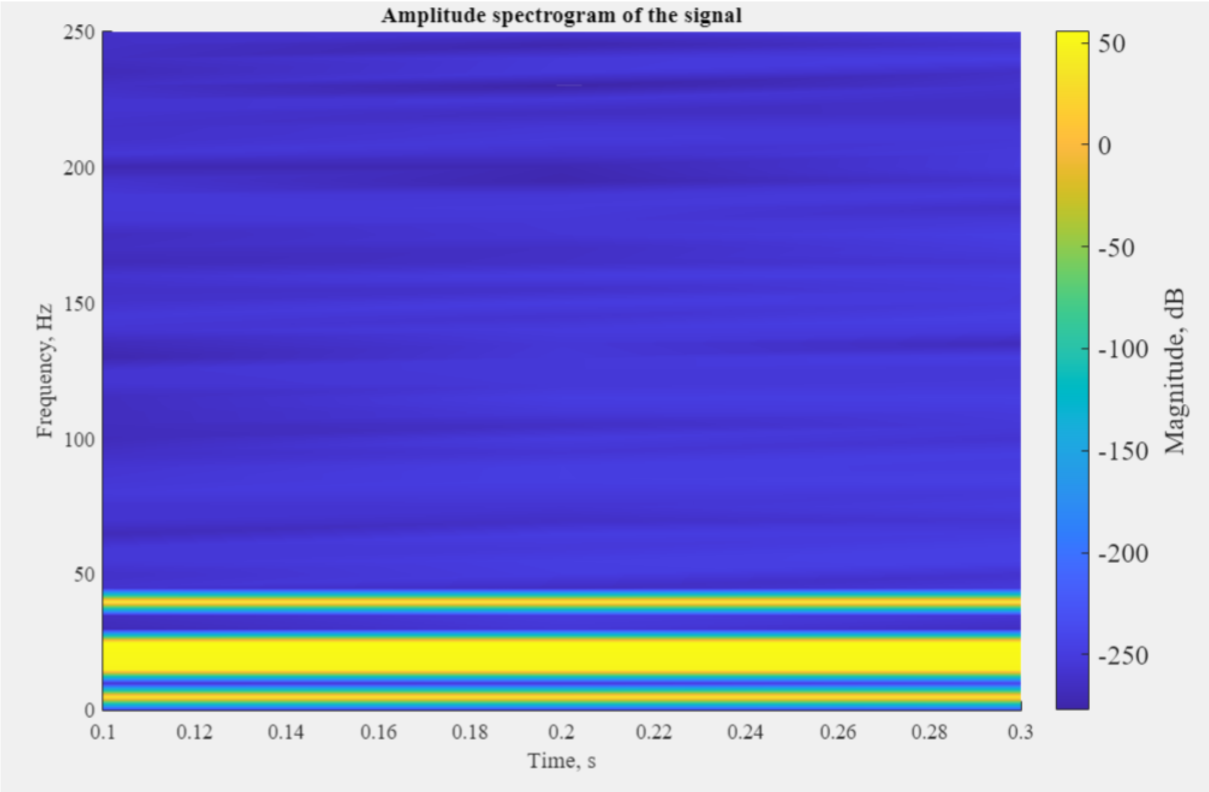

Figure 40. Spectrogram of the Signal involving multiple components with window Rectangular (100).

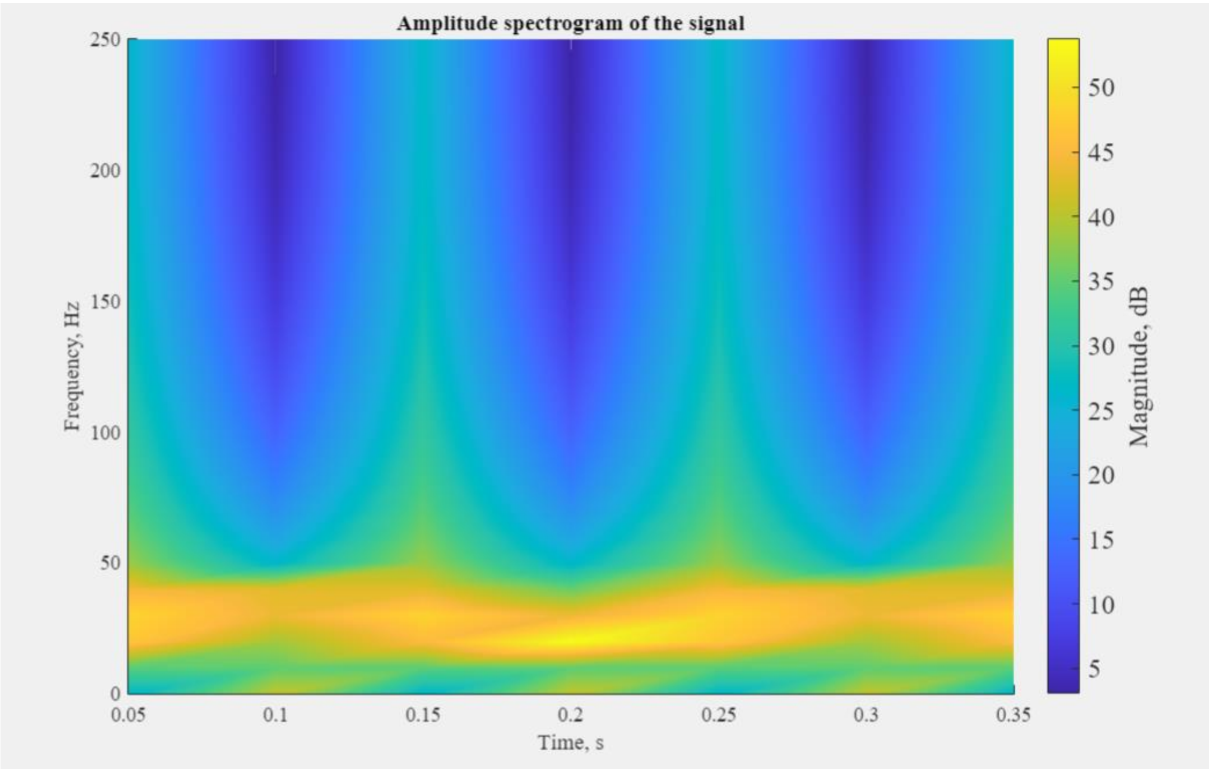

Figure 41. Spectrogram of the Signal involving multiple components with window Rectangular (50).

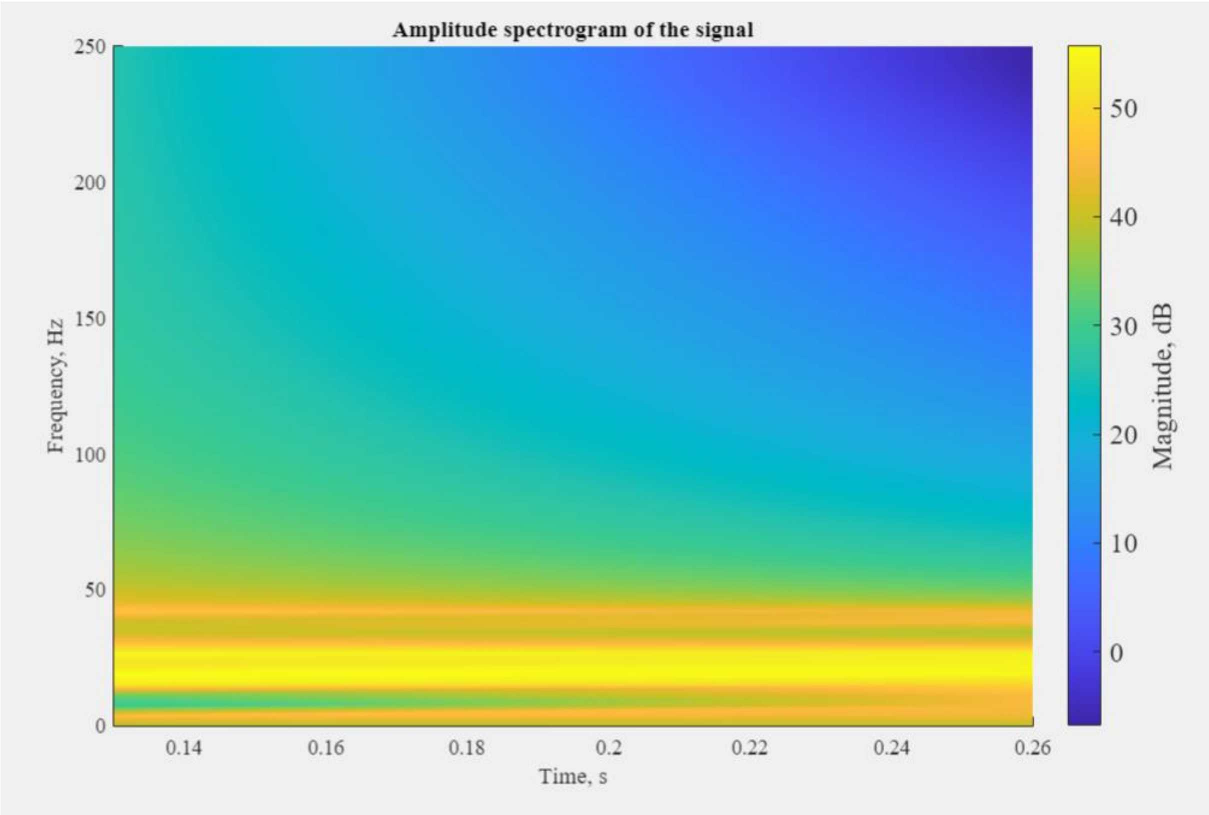

Figure 42. Spectrogram of the Signal involving multiple components with window Rectangular (130).

Rectangular type with length 100 gives the best result. This is expected, since Rectangular type window is good for separating close amplitude signals.

IV- TUKEY WINDOWED SIGNAL

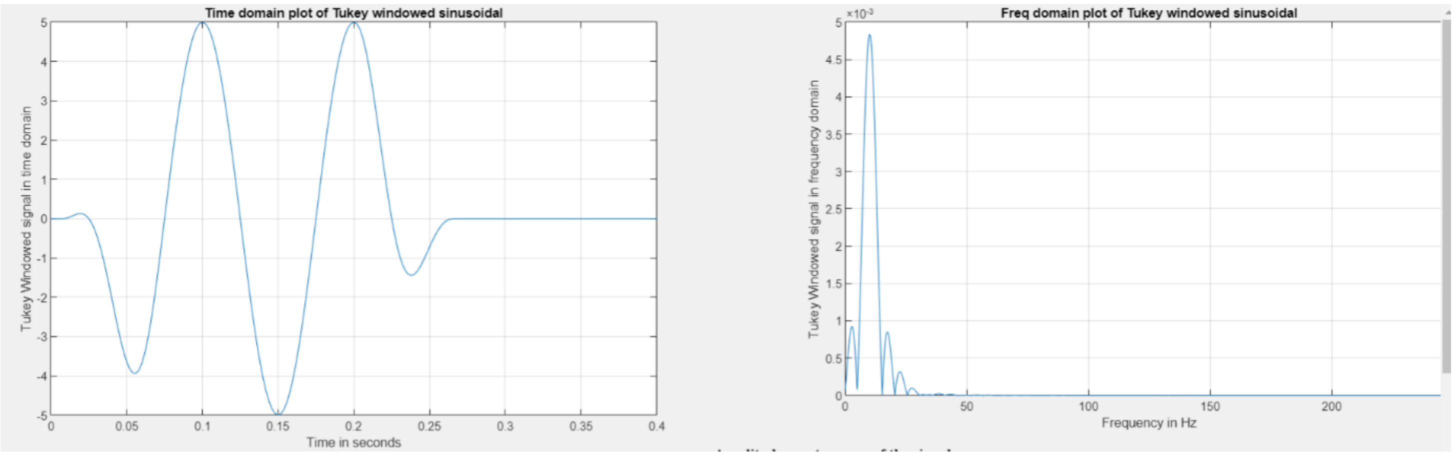

Figure 43. Generated Tukey Windowed Signal both in Time domain and Frequency domain.

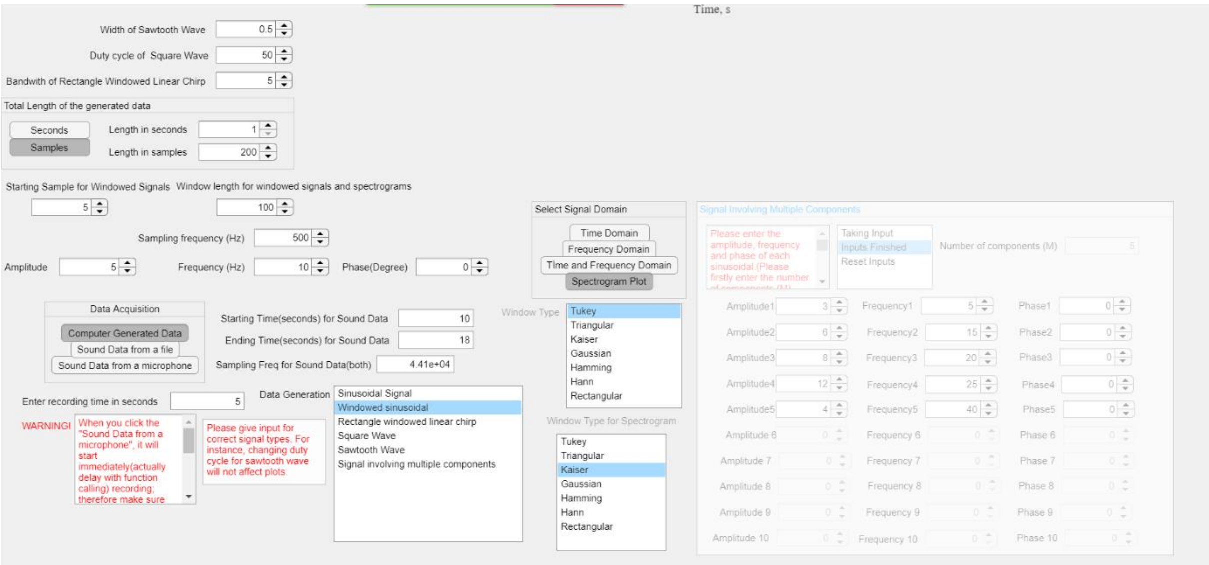

Figure 44. Parameters of our program interface.

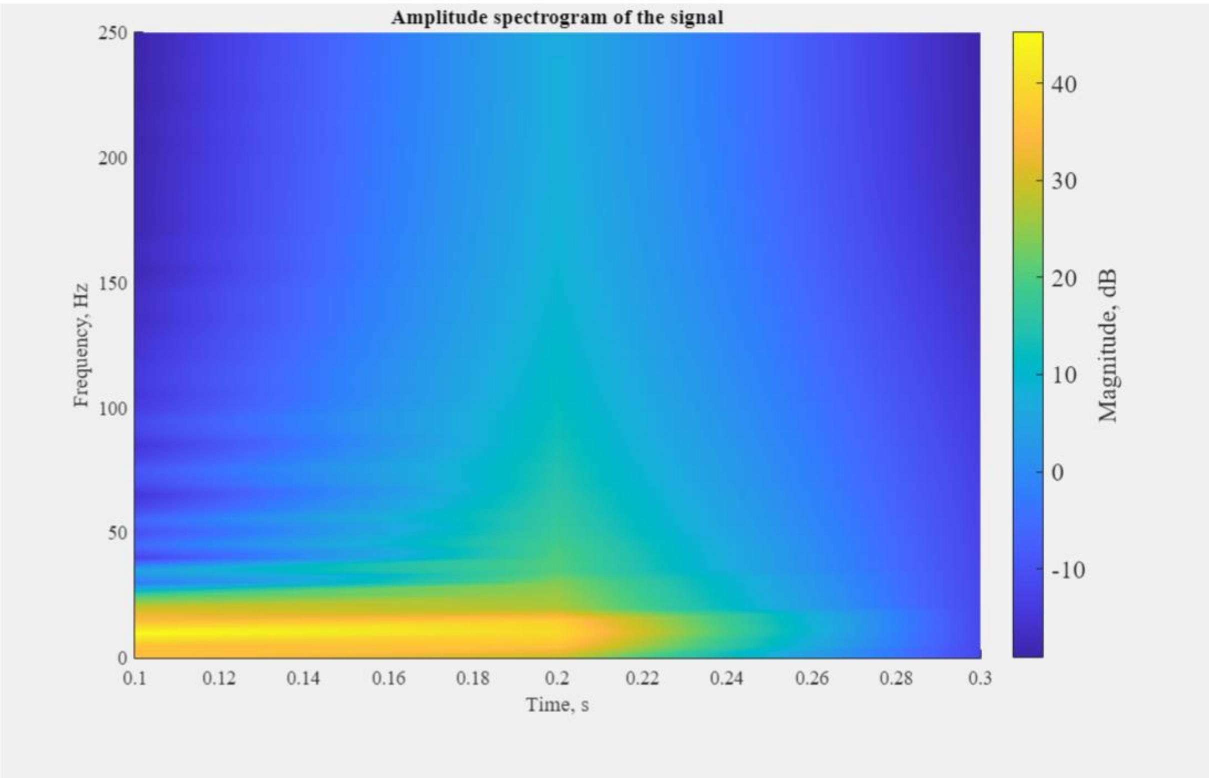

Figure 45. Spectrogram of the Tukey Windowed Signal with window Kaiser (100).

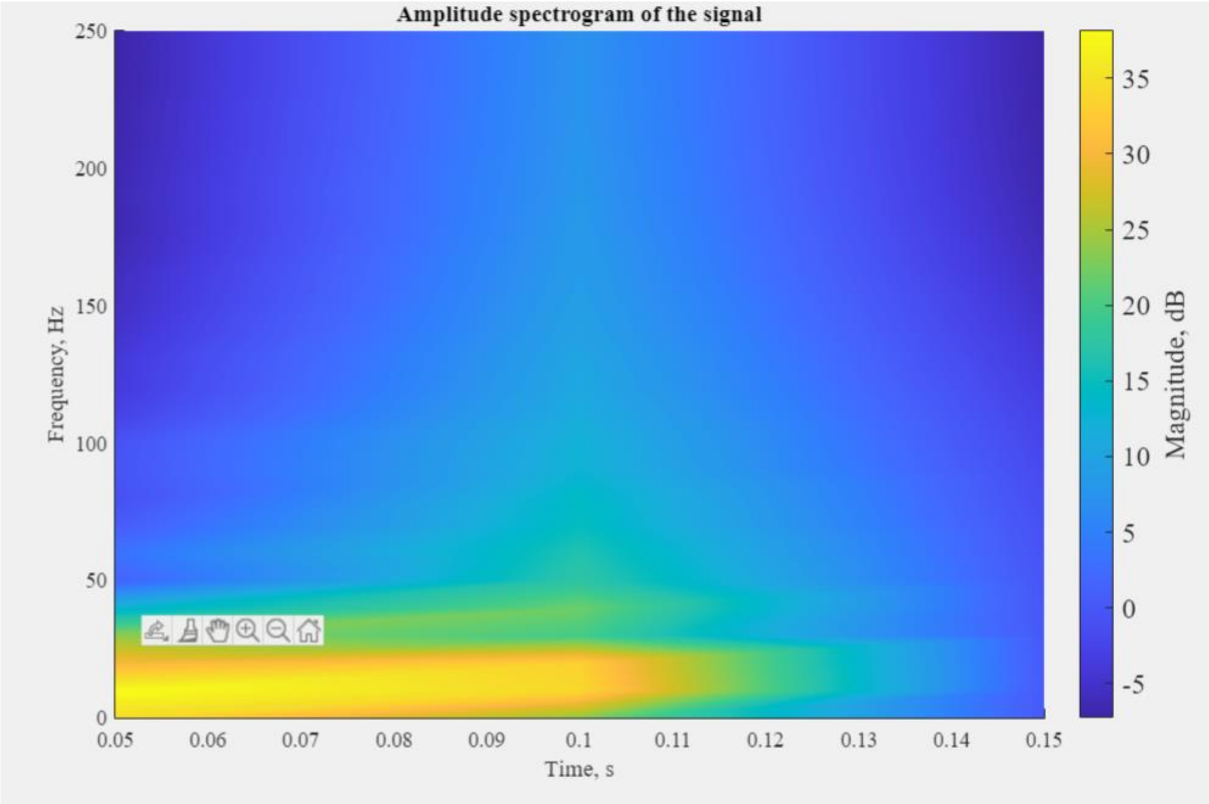

Figure 46. Spectrogram of the Tukey Windowed Signal with window Kaiser (50).

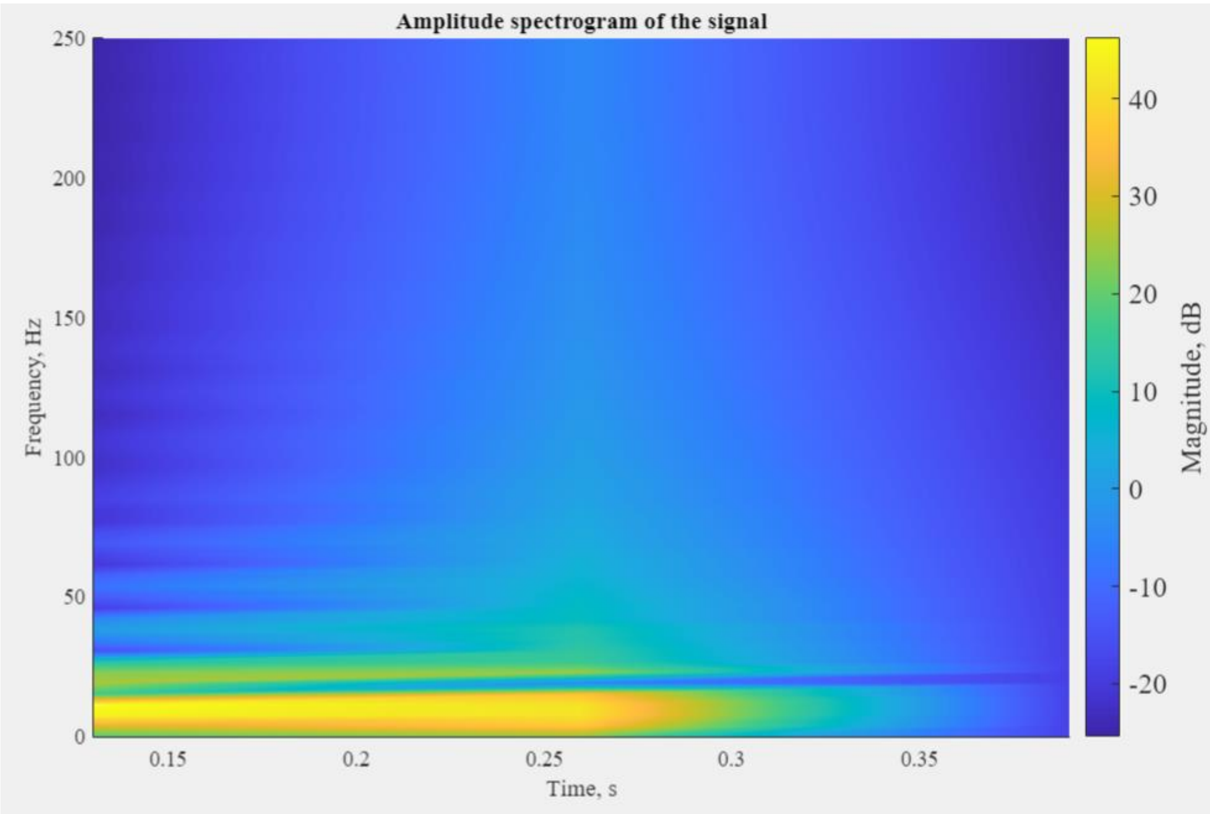

Figure 47. Spectrogram of the Tukey Windowed Signal with window Kaiser (130).

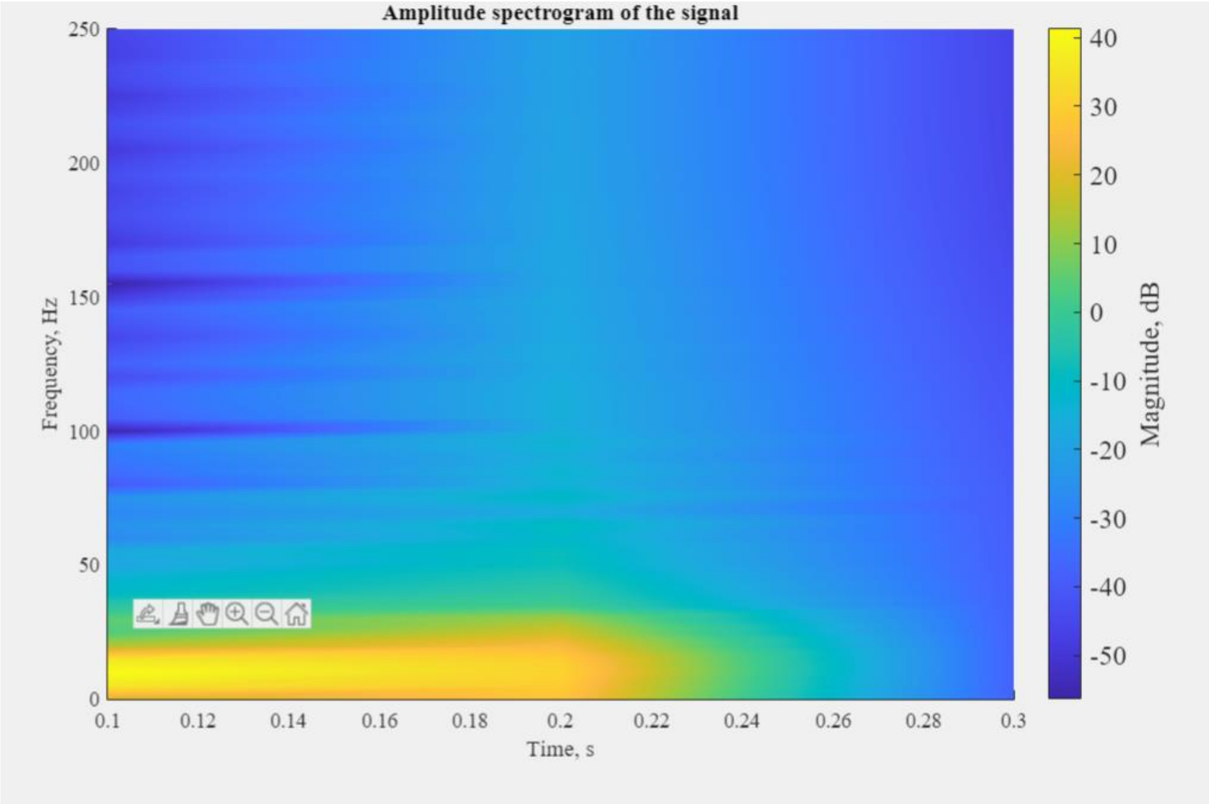

Figure 48. Spectrogram of the Tukey Windowed Signal with window Gaussian (100).

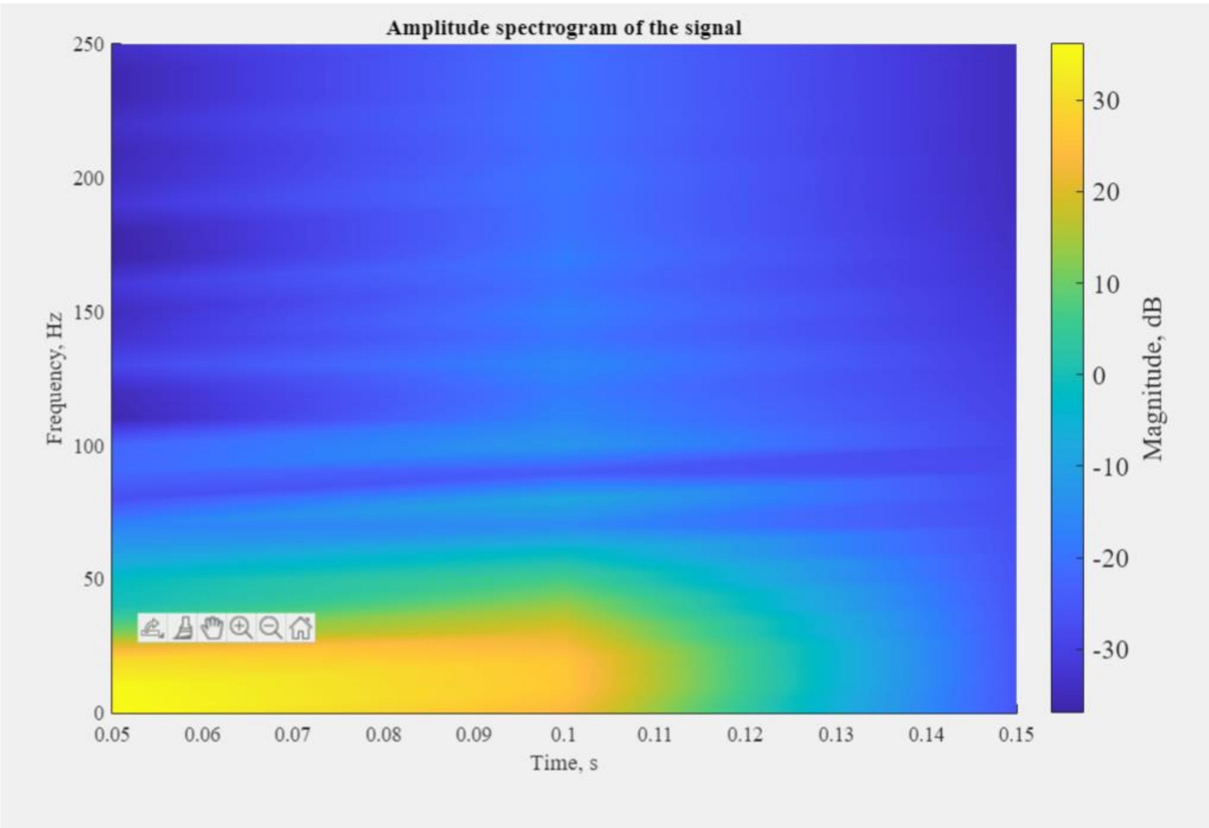

Figure 49. Spectrogram of the Tukey Windowed Signal with window Gaussian (500).

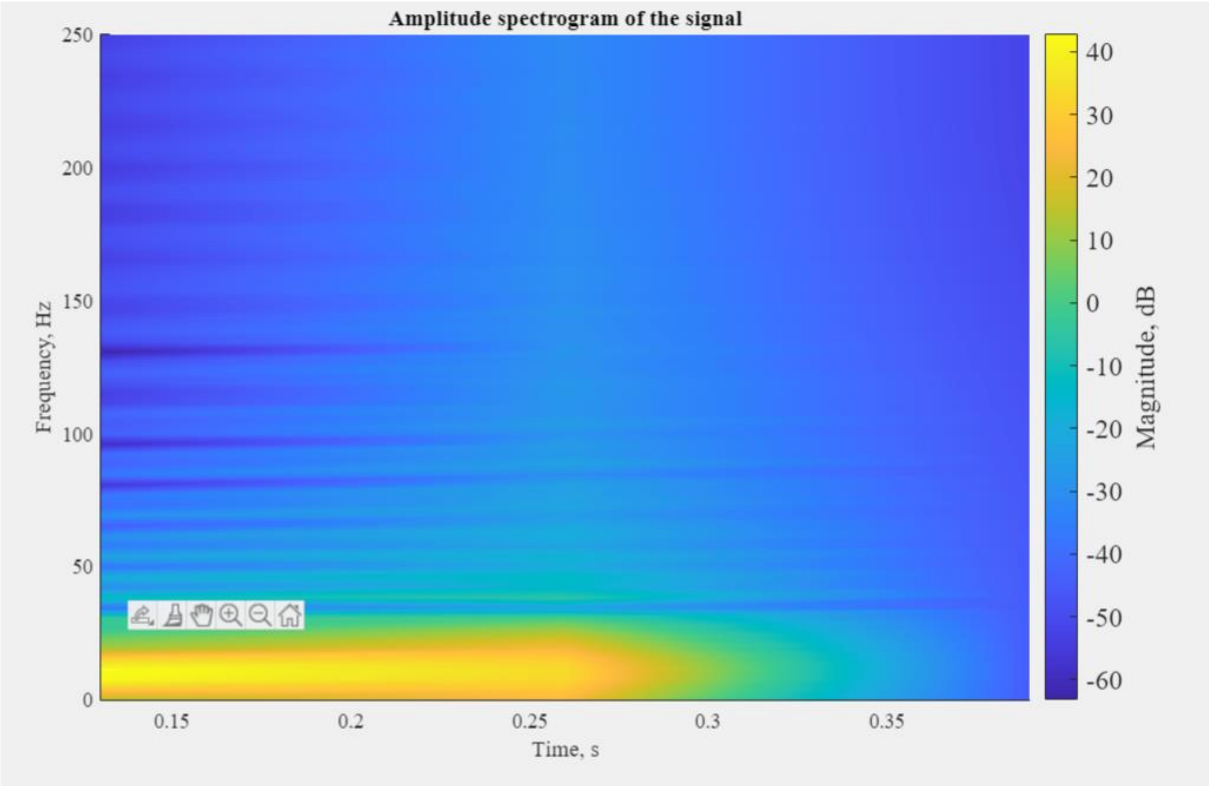

Figure 50. Spectrogram of the Tukey Windowed Signal with window Gaussian (130).

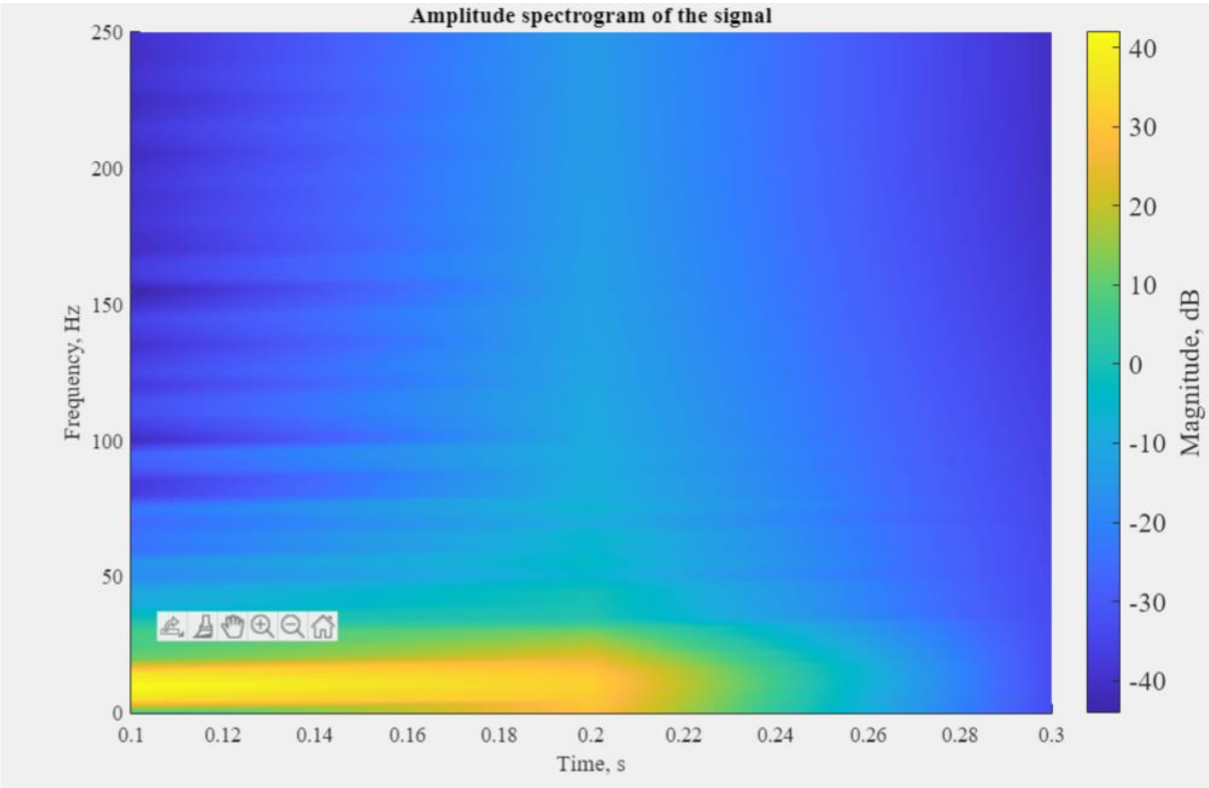

Figure 51. Spectrogram of the Tukey Windowed Signal with window Hamming (100).

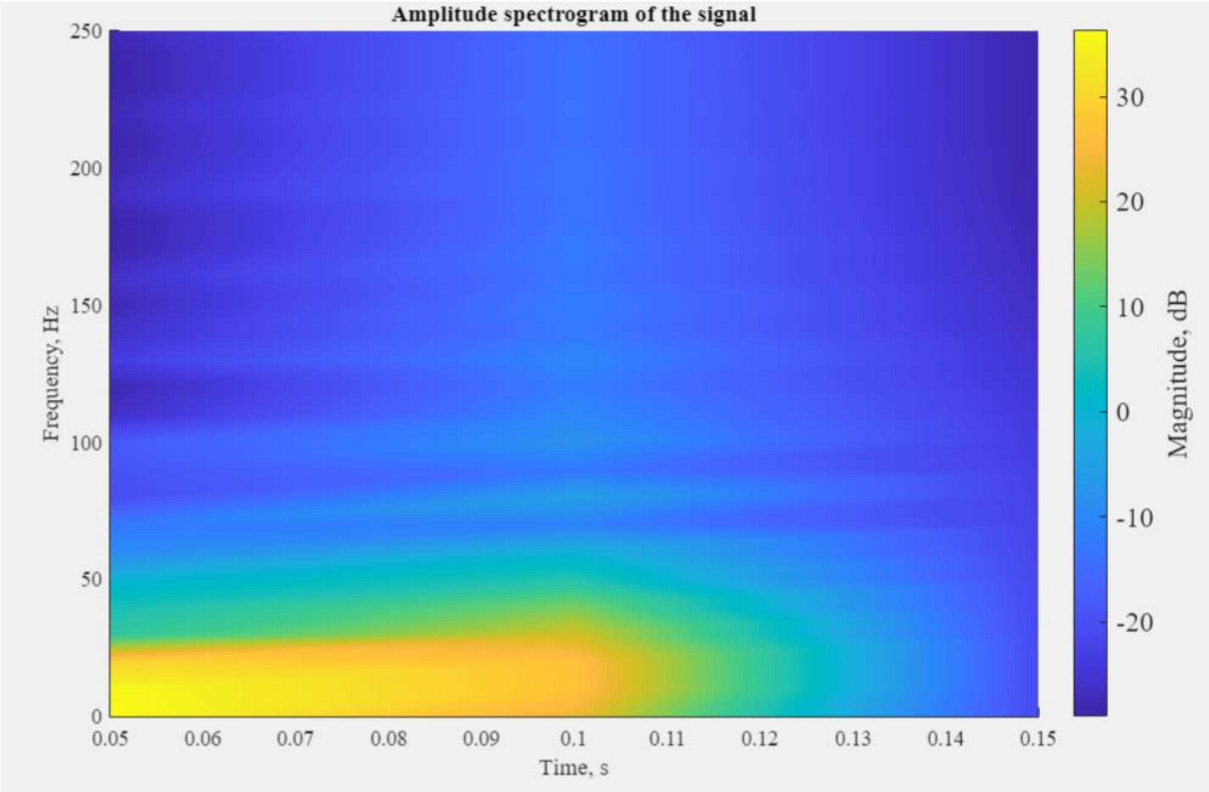

Figure 52. Spectrogram of the Tukey Windowed Signal with window Hamming (50).

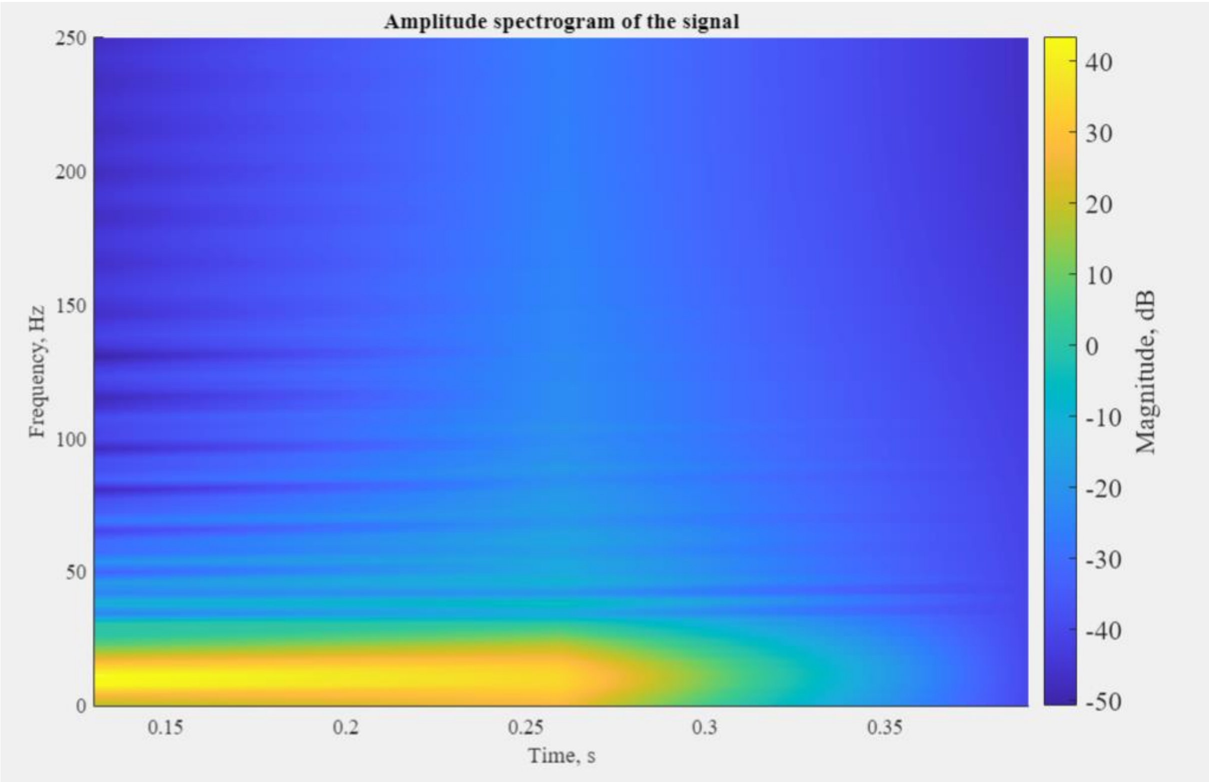

Figure 43. Spectrogram of the Tukey Windowed Signal with window Hamming (130).

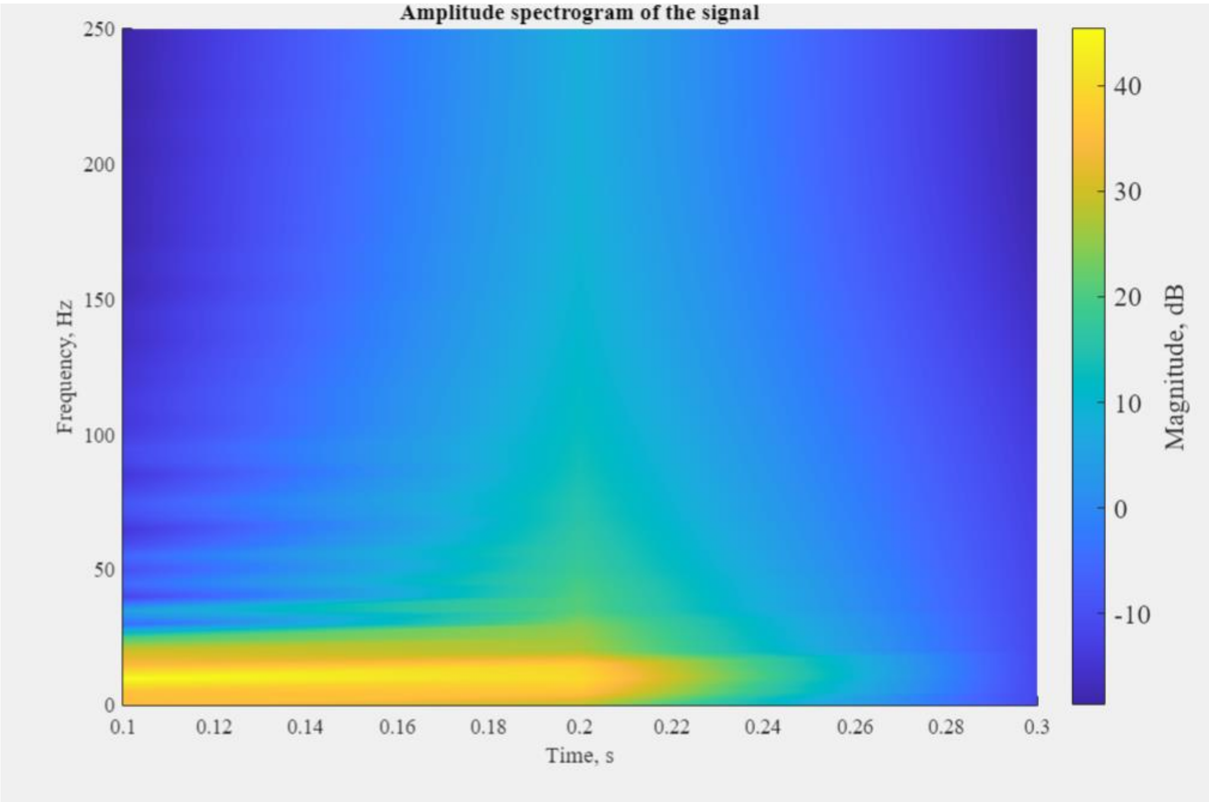

Figure 54. Spectrogram of the Tukey Windowed Signal with window Rectangular (100).

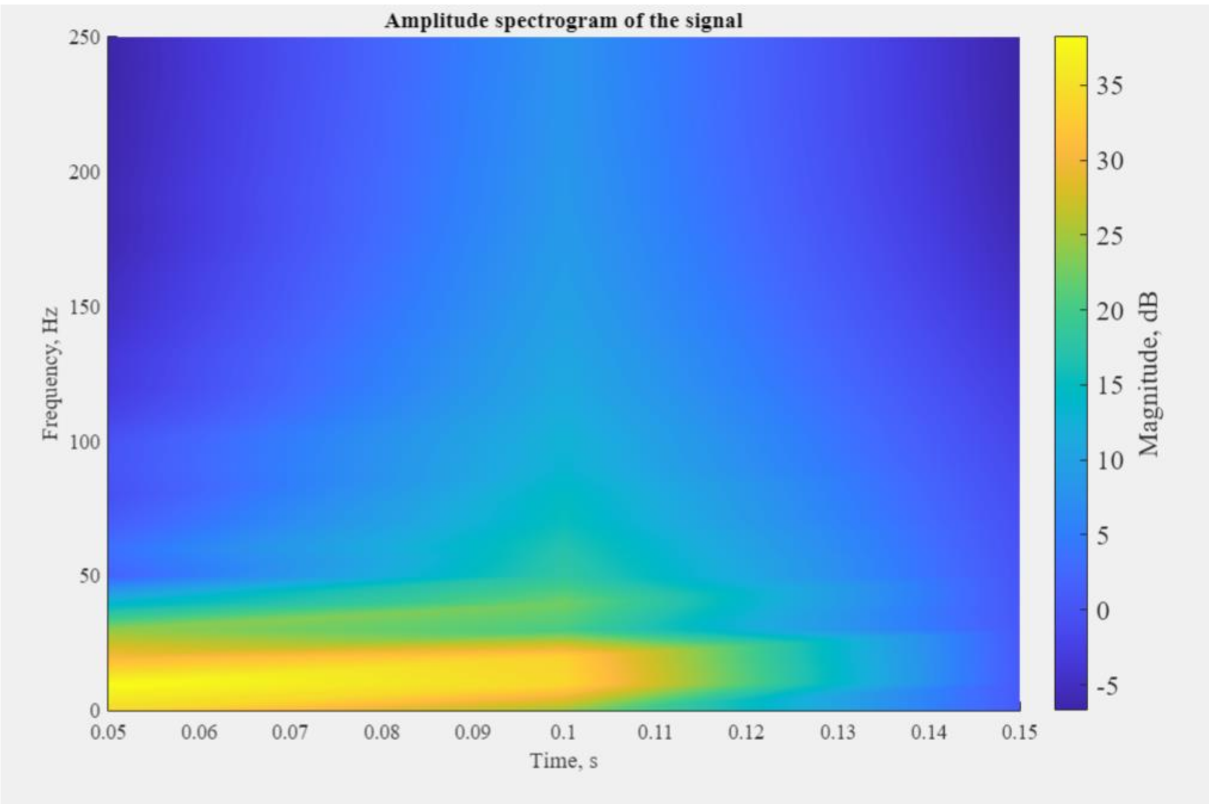

Figure 55. Spectrogram of the Tukey Windowed Signal with window Rectangular (50).

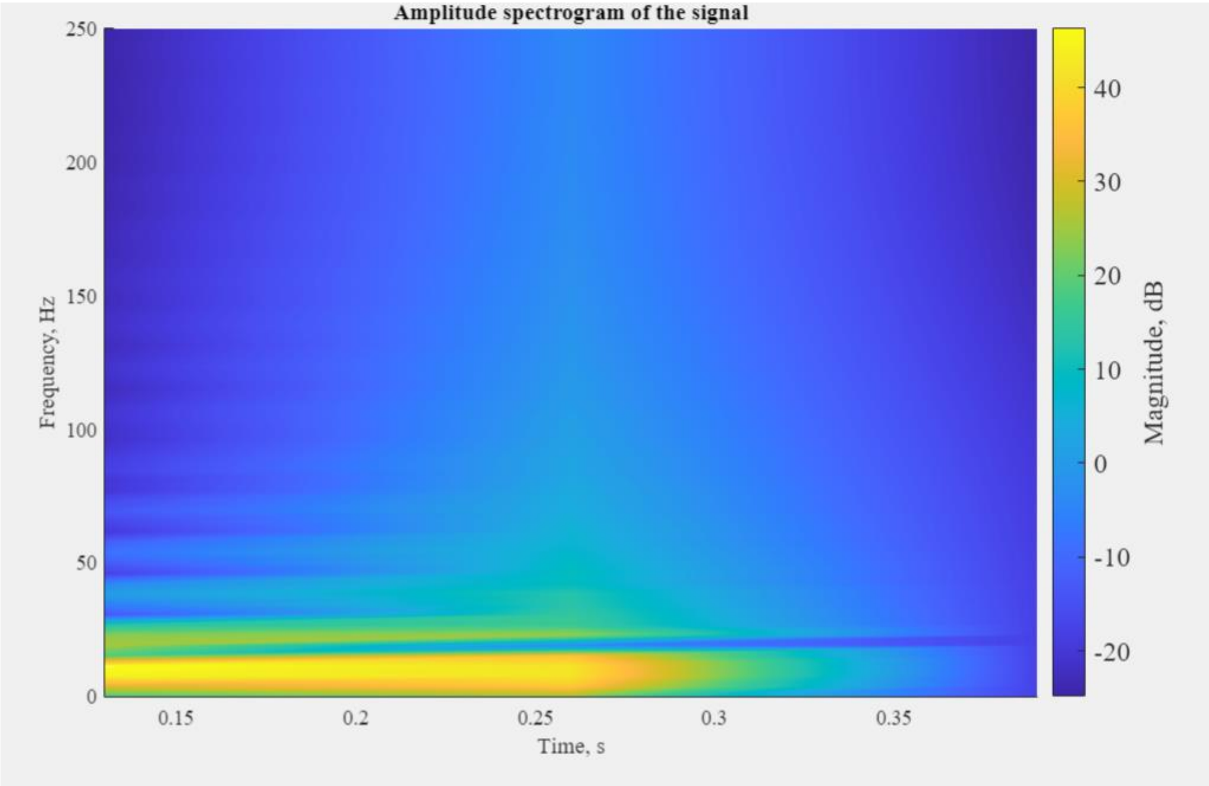

Figure 56. Spectrogram of the Tukey Windowed Signal with window Rectangular (130).

V- Square Wave Signal Outputs: (50% Duty Cycle)

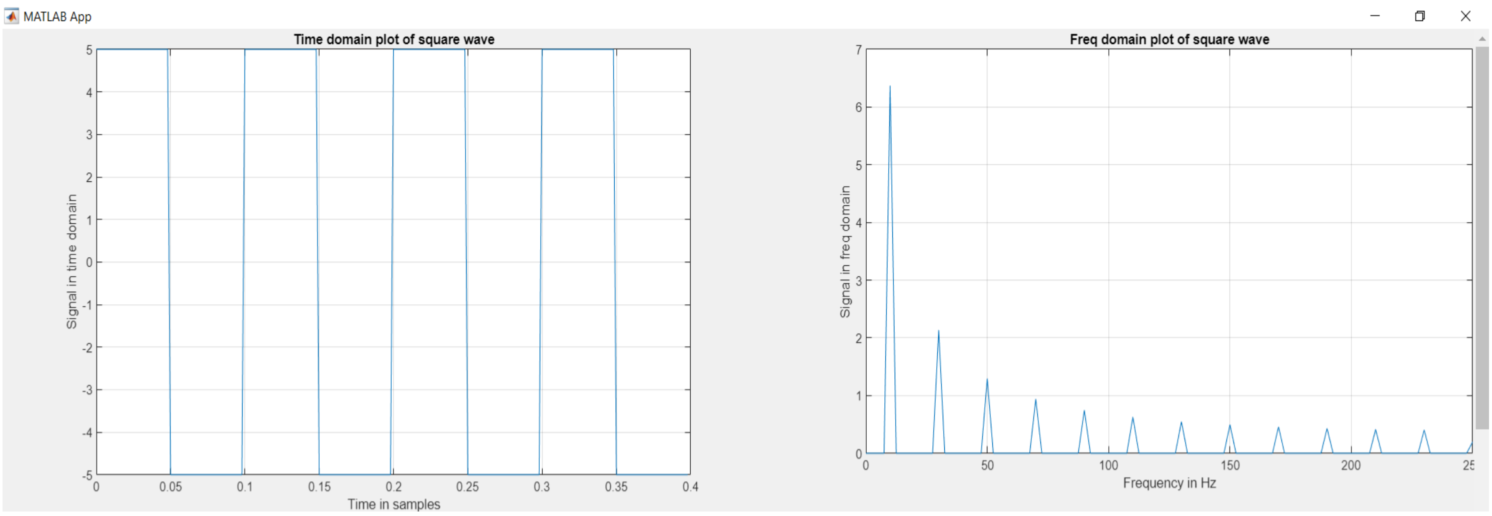

Figure 57. Generated Square Wave Signal both in Time domain and Frequency domain.

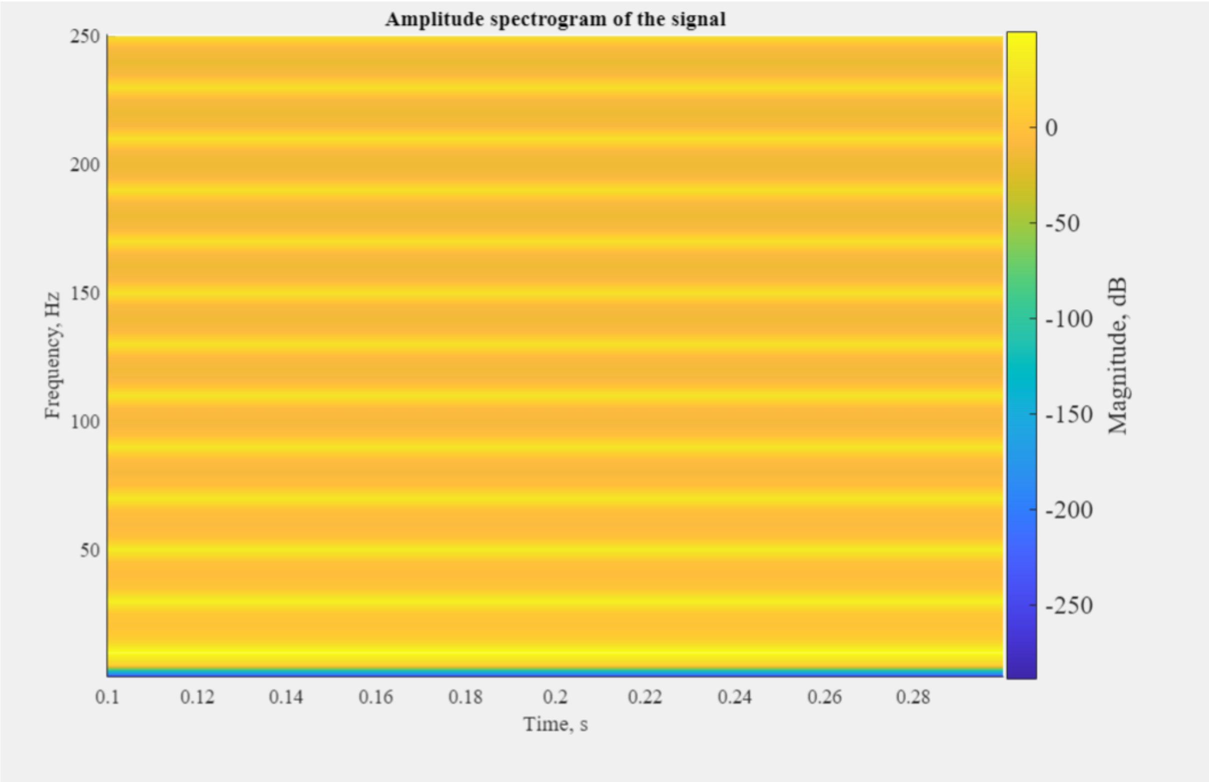

Figure 58. Spectrogram of the Square Wave Signal with window Kaiser (100).

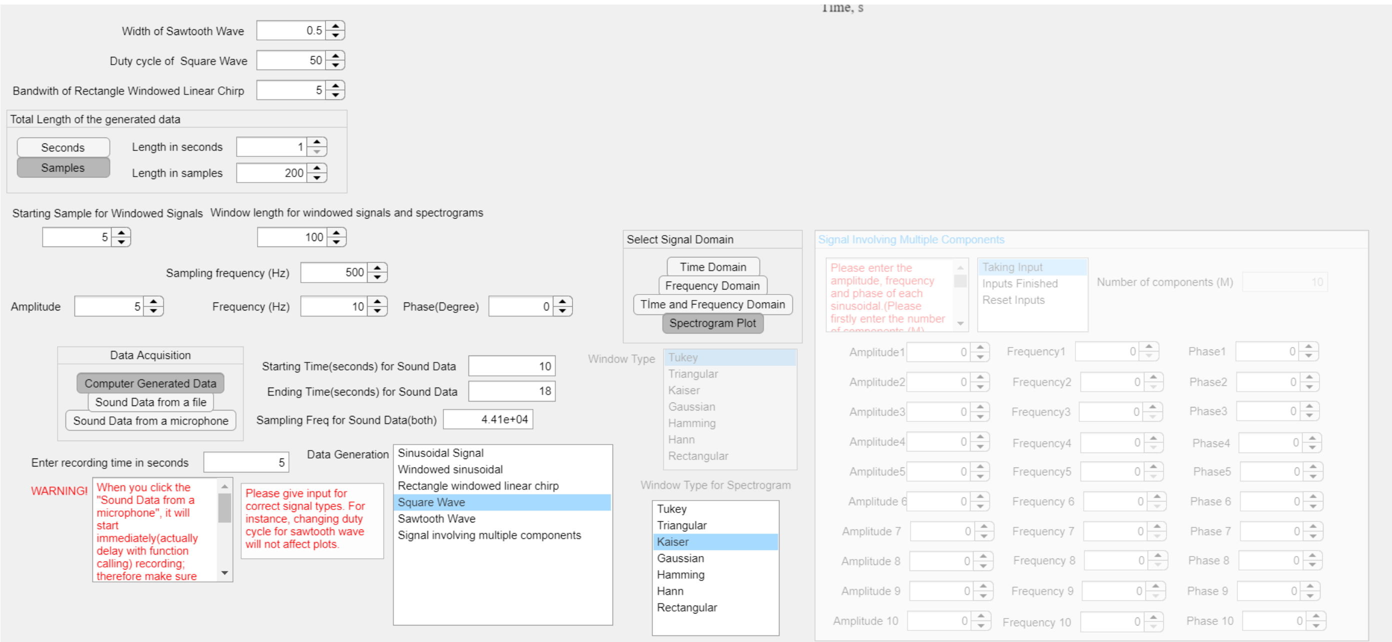

Figure 59. Parameters of our program interface.

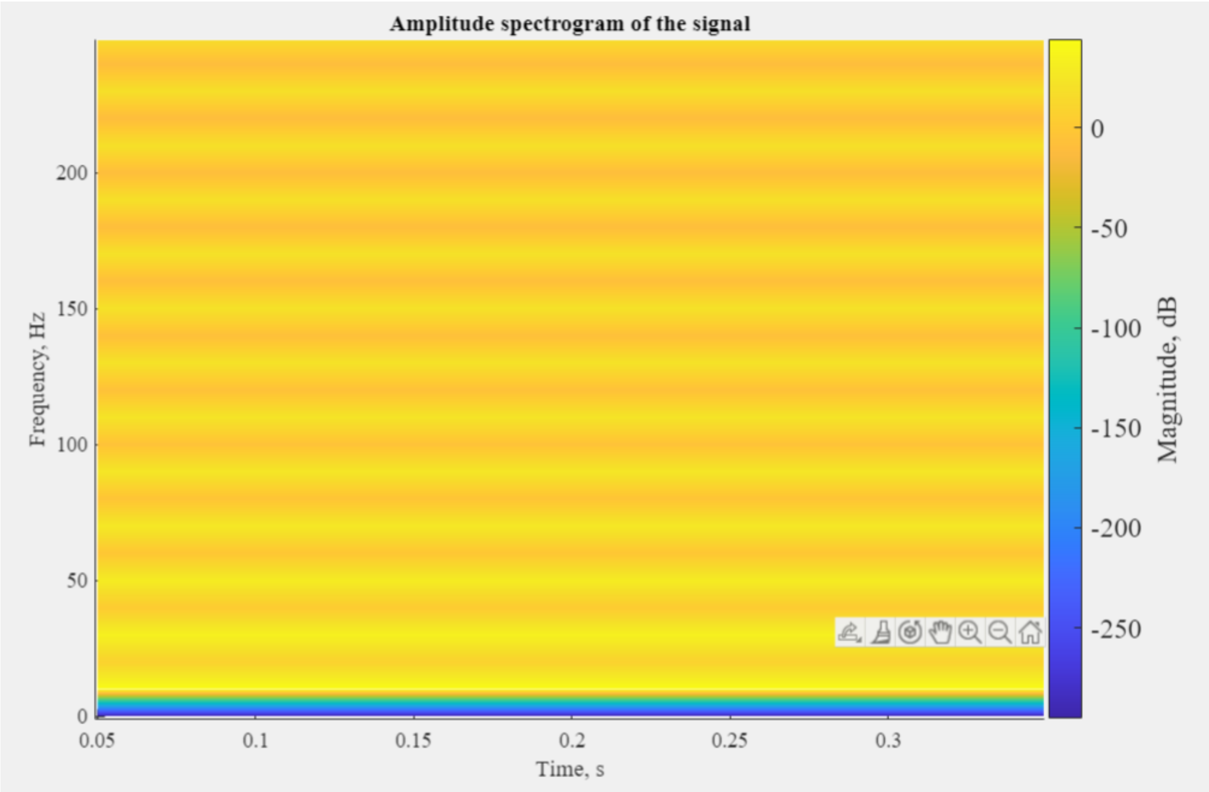

Figure 50. Spectrogram of the Square Wave Signal with window Kaiser (50).

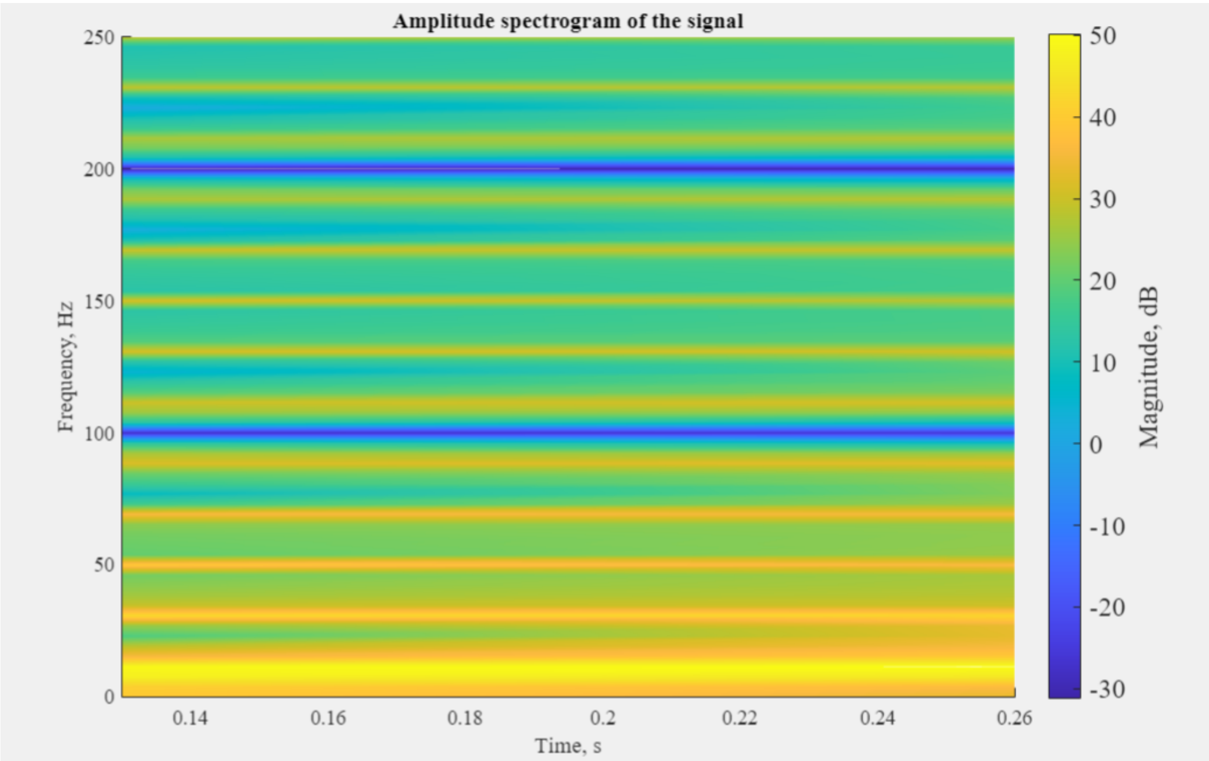

Figure 71. Spectrogram of the Square Wave Signal with window Kaiser (130).

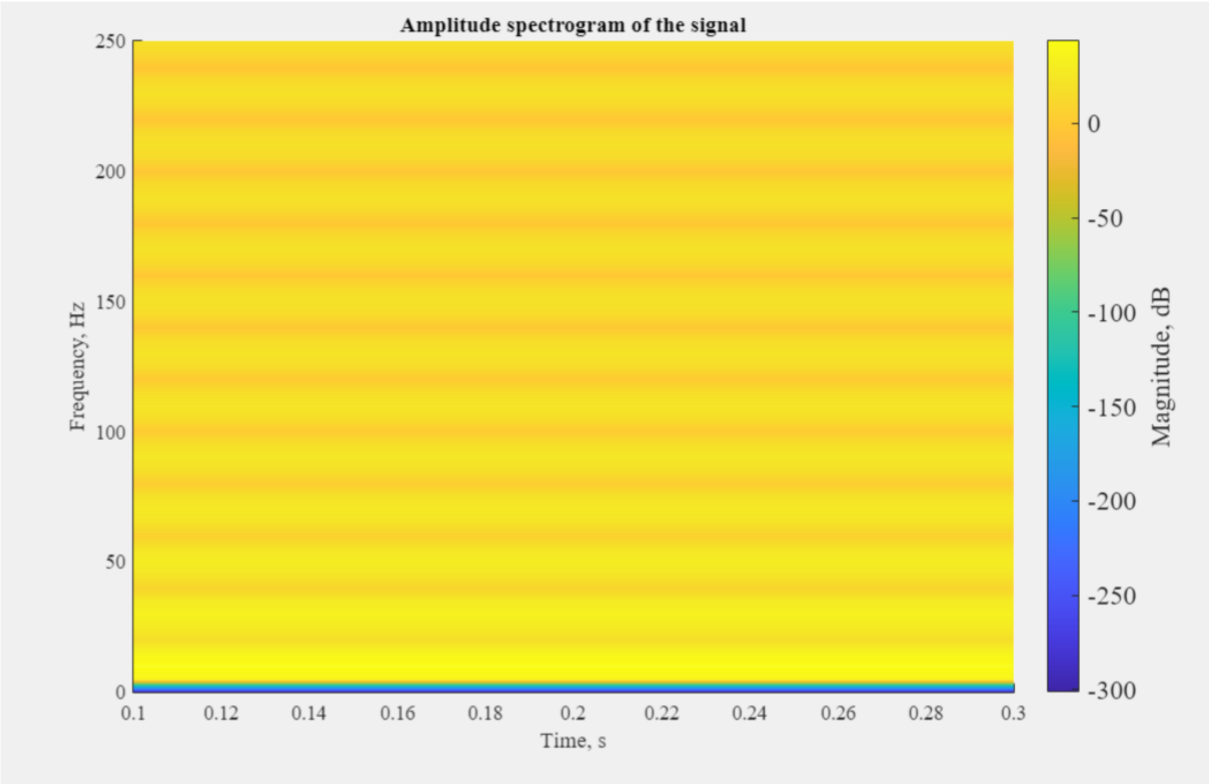

Figure 72. Spectrogram of the Square Wave Signal with window Gaussian (100).

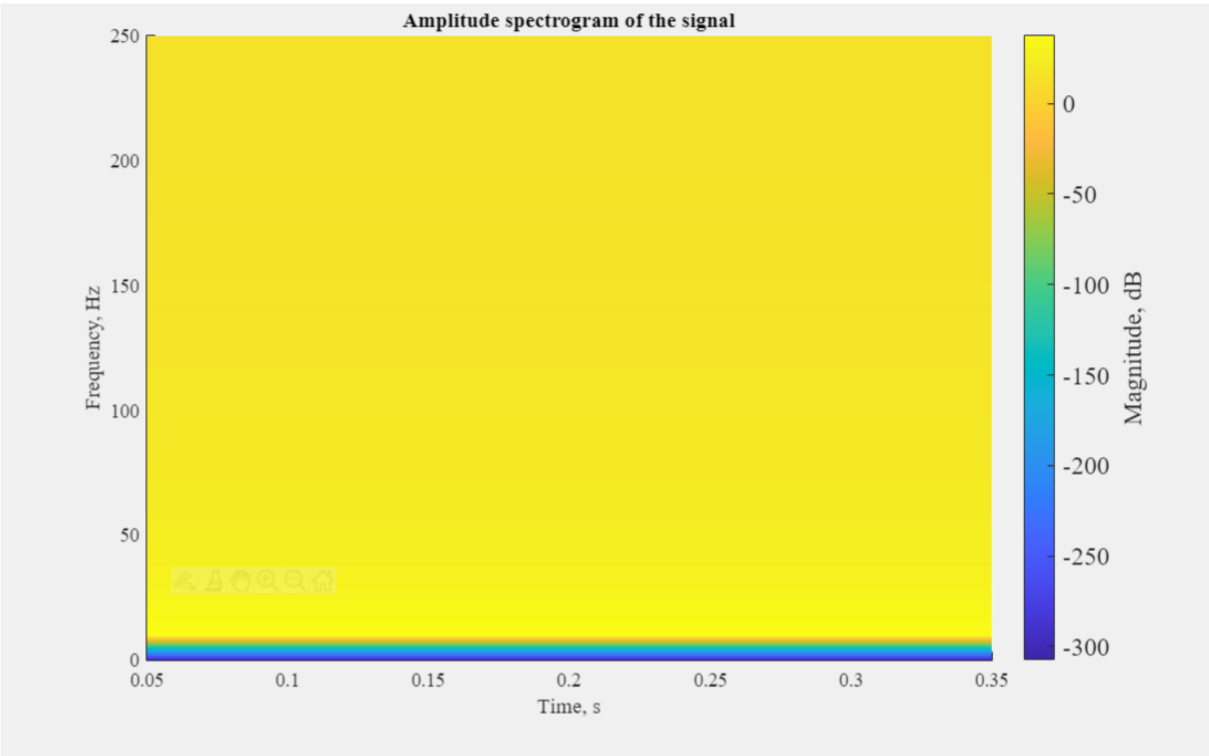

Figure 73. Spectrogram of the Square Wave Signal with window Gaussian (150).

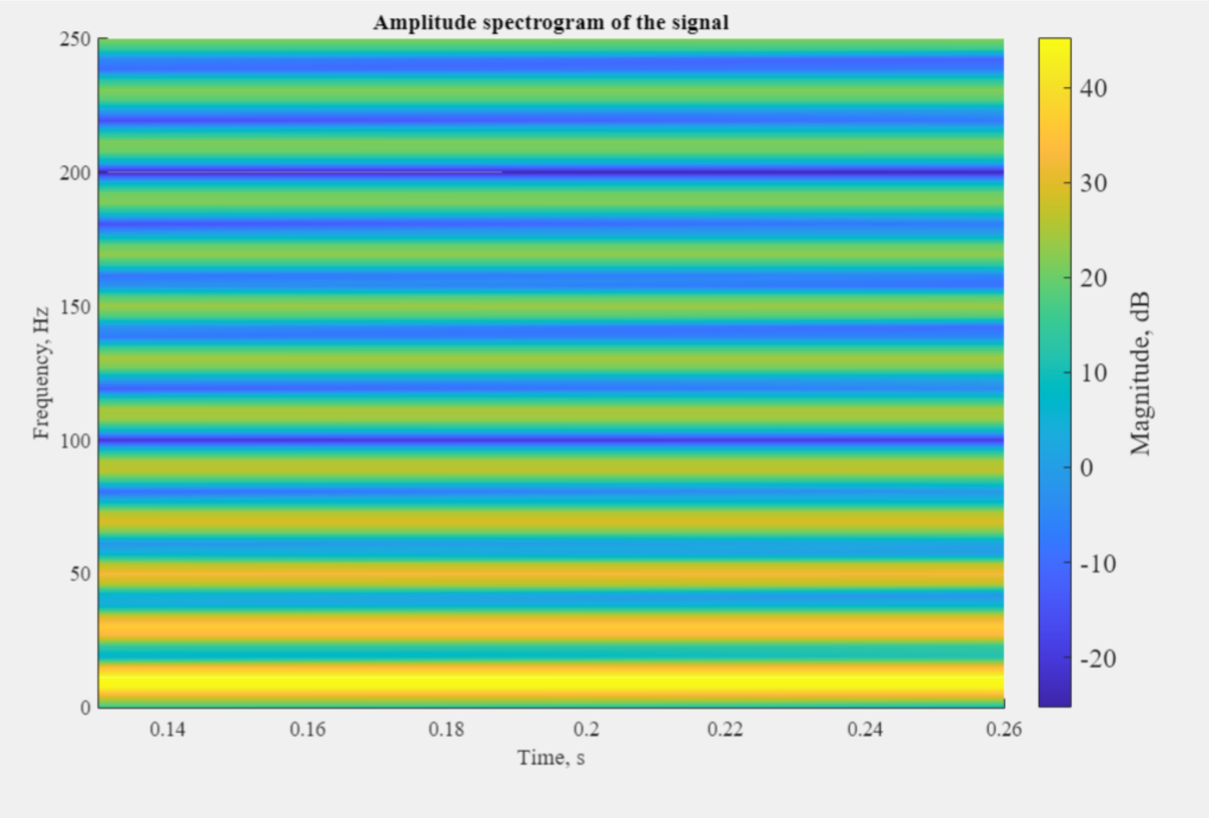

Figure 74. Spectrogram of the Square Wave Signal with window Gaussian (130).

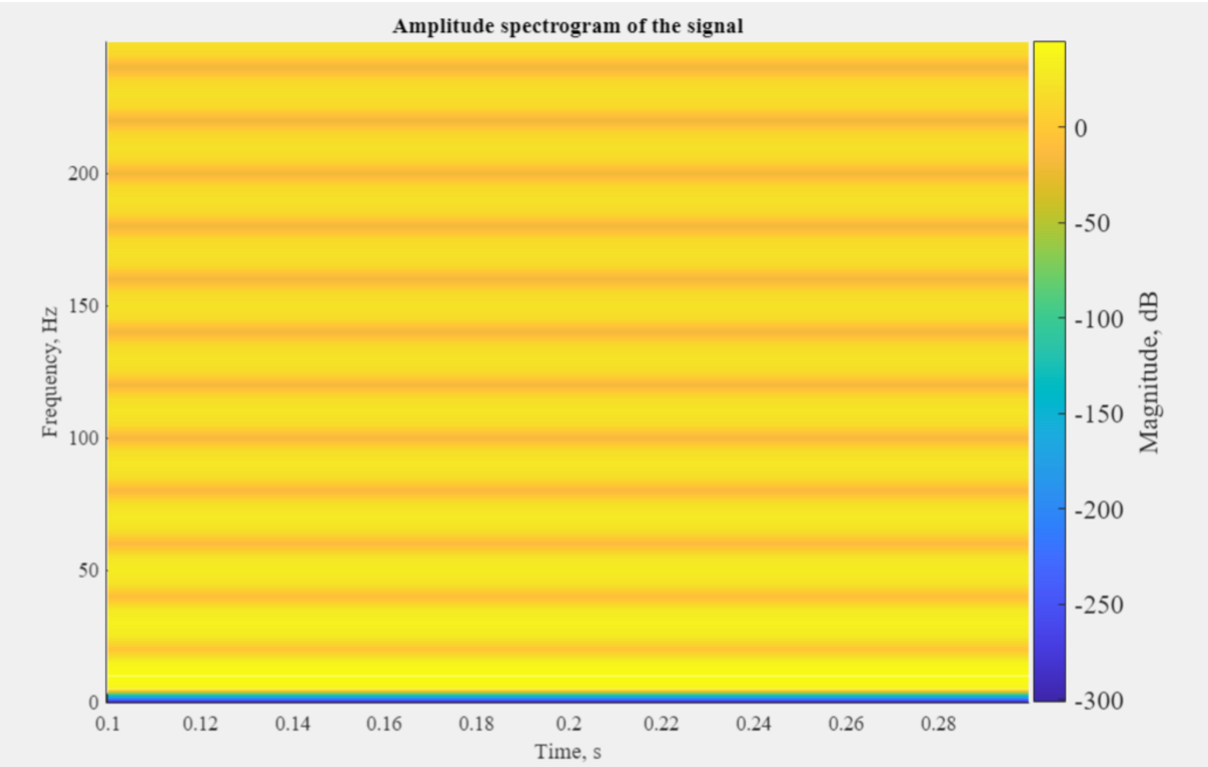

Figure 75. Spectrogram of the Square Wave Signal with window Hamming (100).

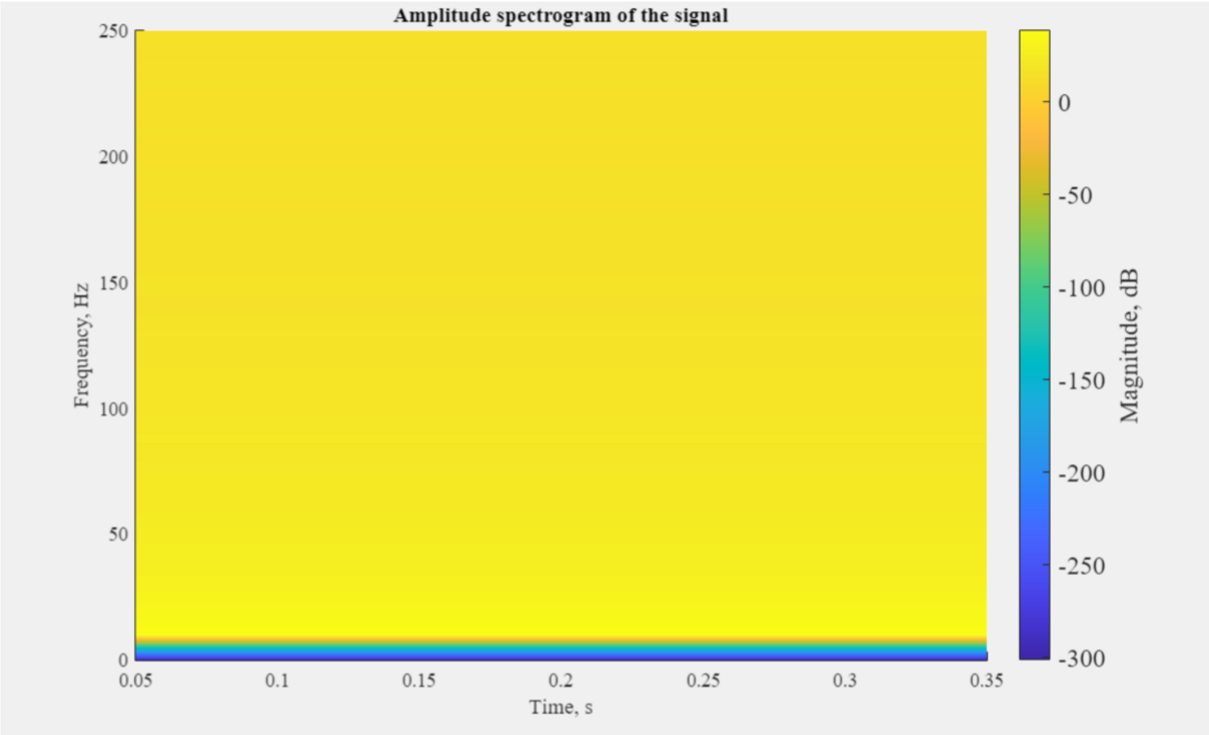

Figure 76. Spectrogram of the Square Wave Signal with window Hamming (50).

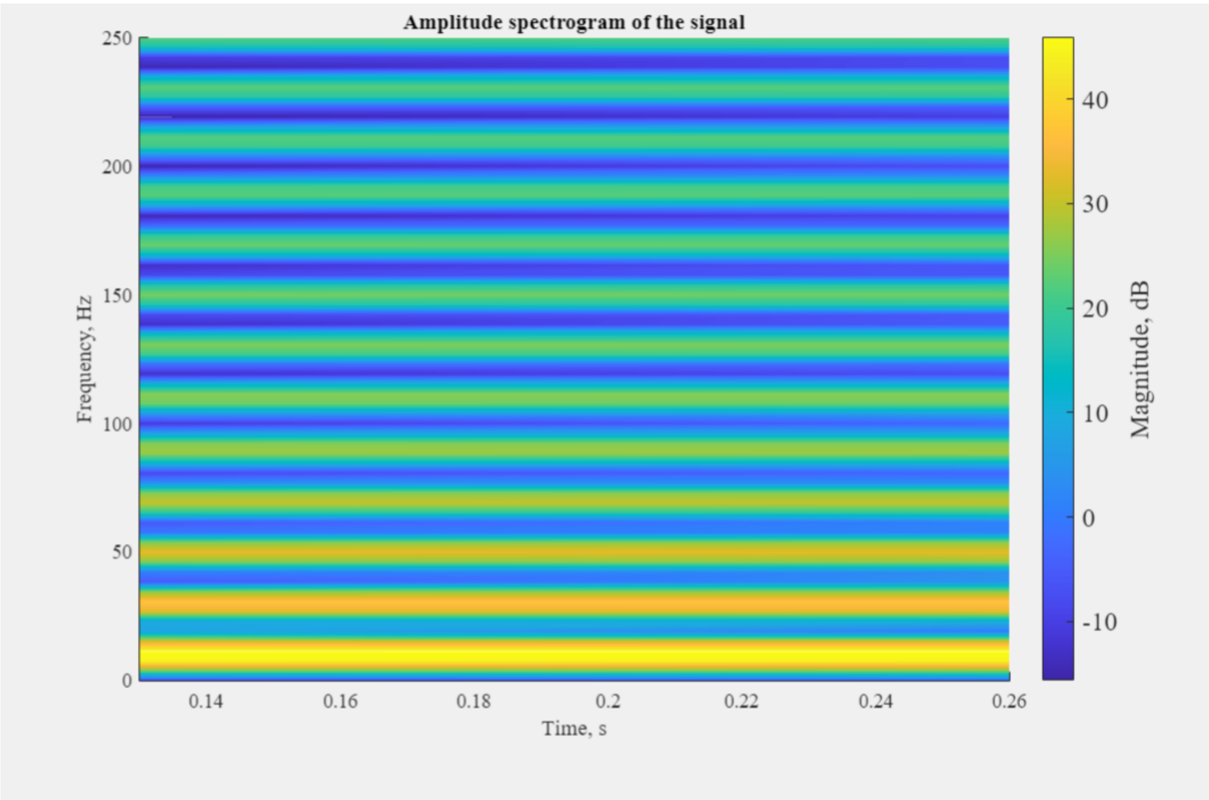

Figure 77. Spectrogram of the Square Wave Signal with window Hamming (130).

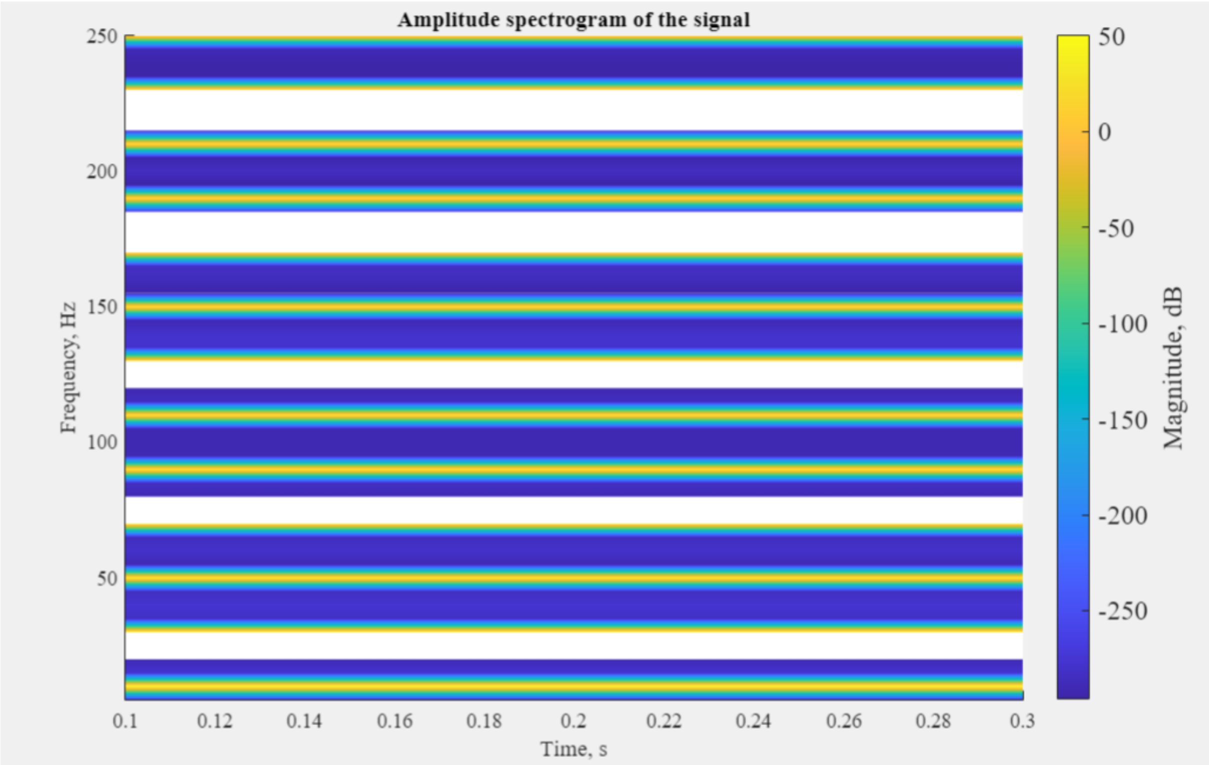

Figure 78. Spectrogram of the Square Wave Signal with window Rectangular (100).

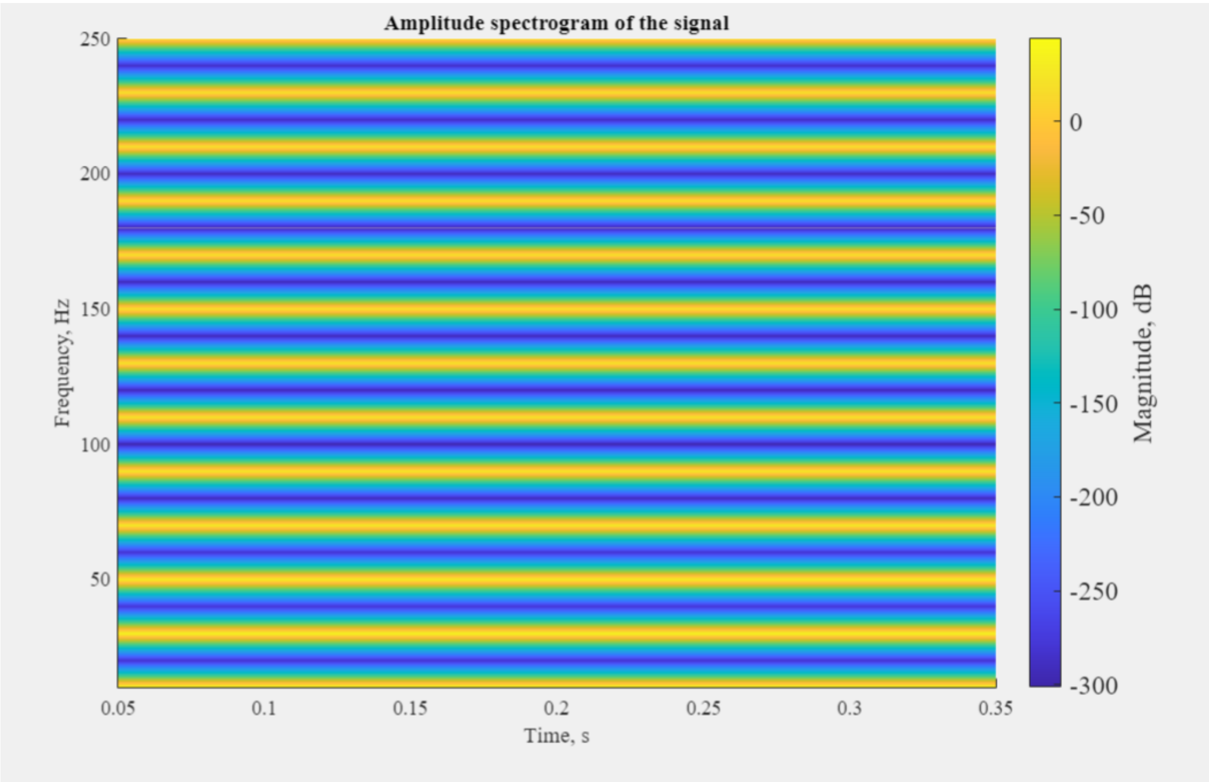

Figure 79. Spectrogram of the Square Wave Signal with window Rectangular (50).

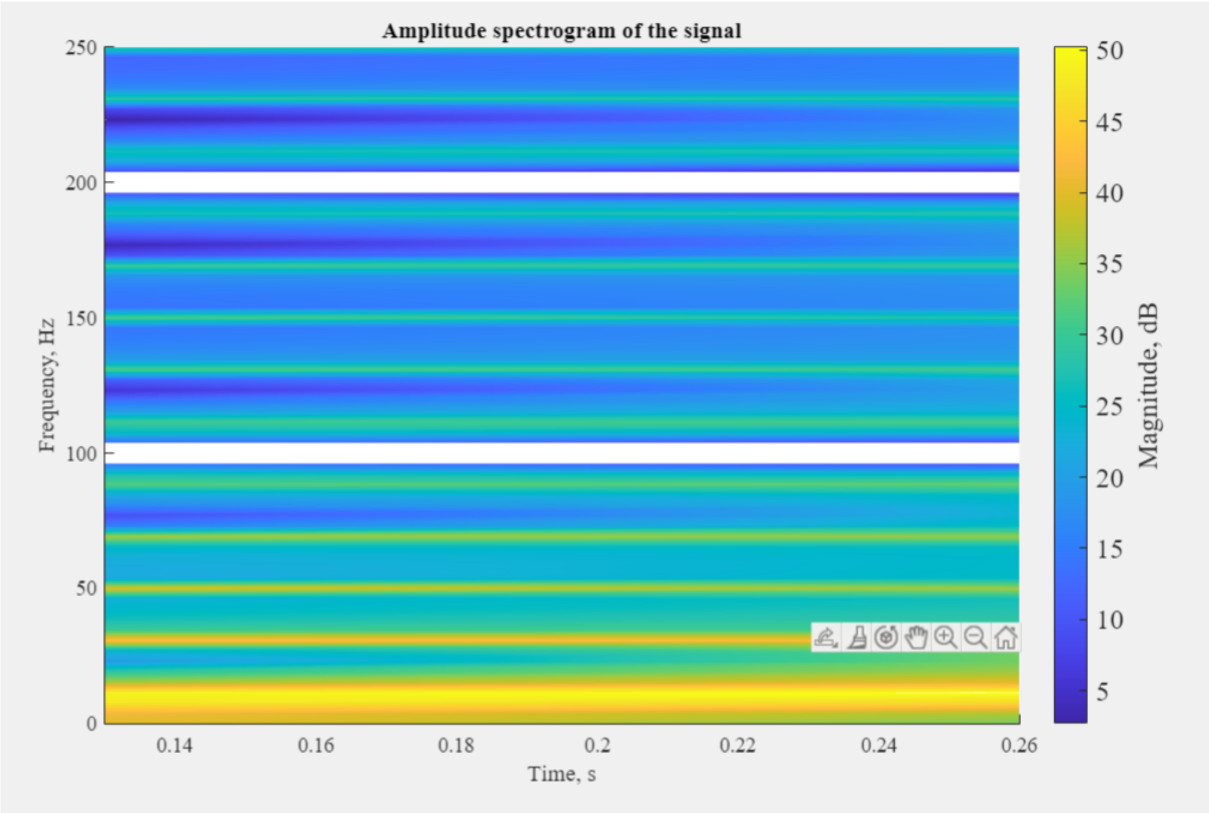

Figure 80. Spectrogram of the Square Wave Signal with window Rectangular (130).

Rectangular type with length 50 gives the best result**.**

VI- SAWTOOTH WAVE:

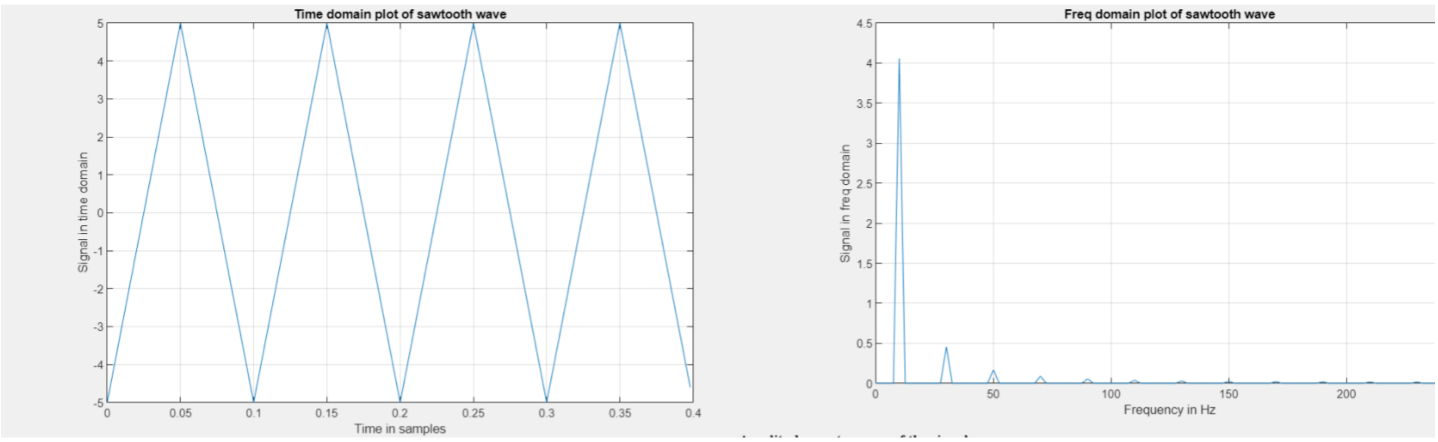

Figure 81. Generated Sawtooth Wave Signal both in Time domain and Frequency domain.

Amplitude: 5

Frequency: 10 Hz

Sampling Frequency: 500 Samples

Signal Length: 200 Samples

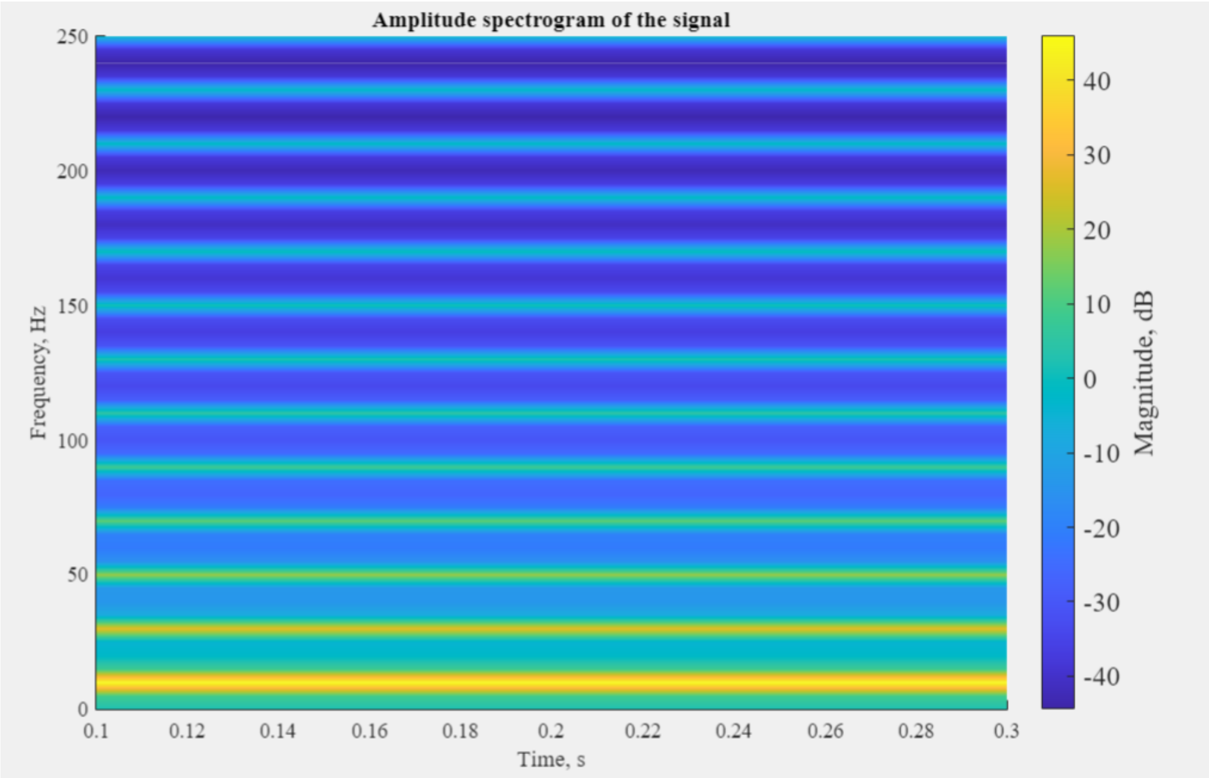

Figure 82. Spectrogram of the Sawtooth Wave Signal with window Kaiser (100).

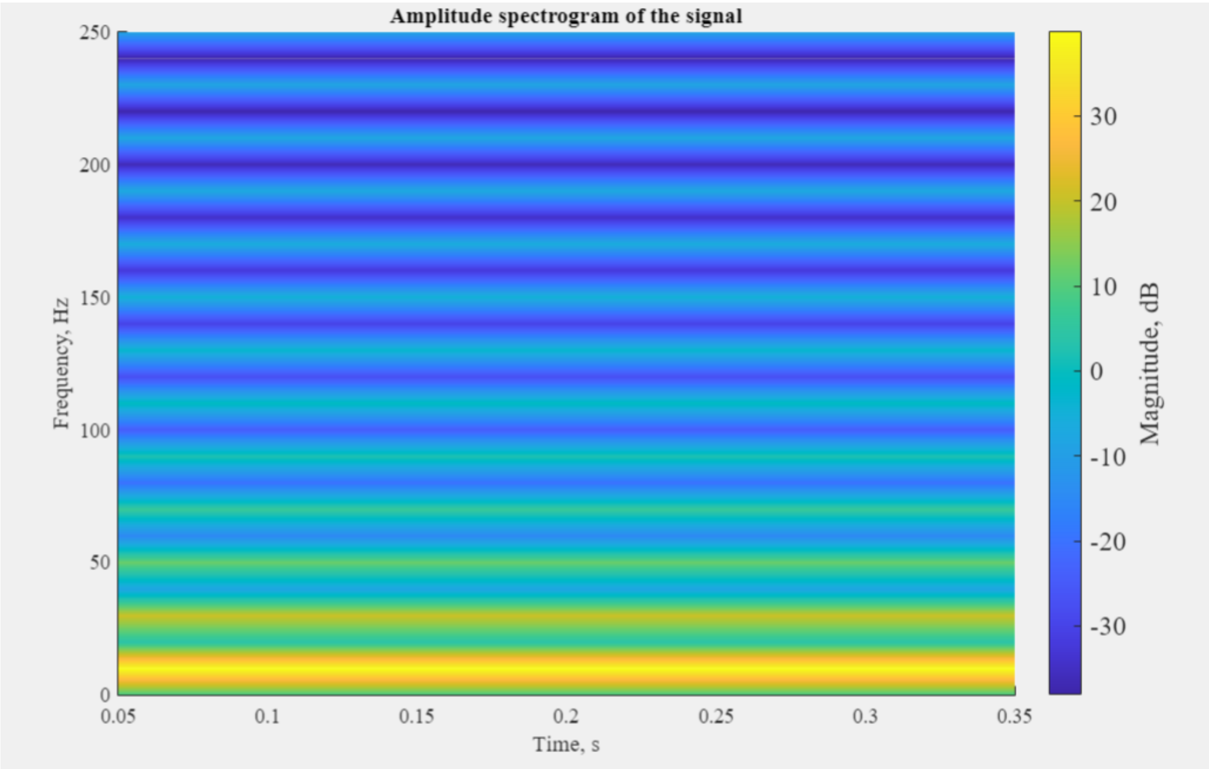

Figure 83. Spectrogram of the Sawtooth Wave Signal with window Kaiser (50).

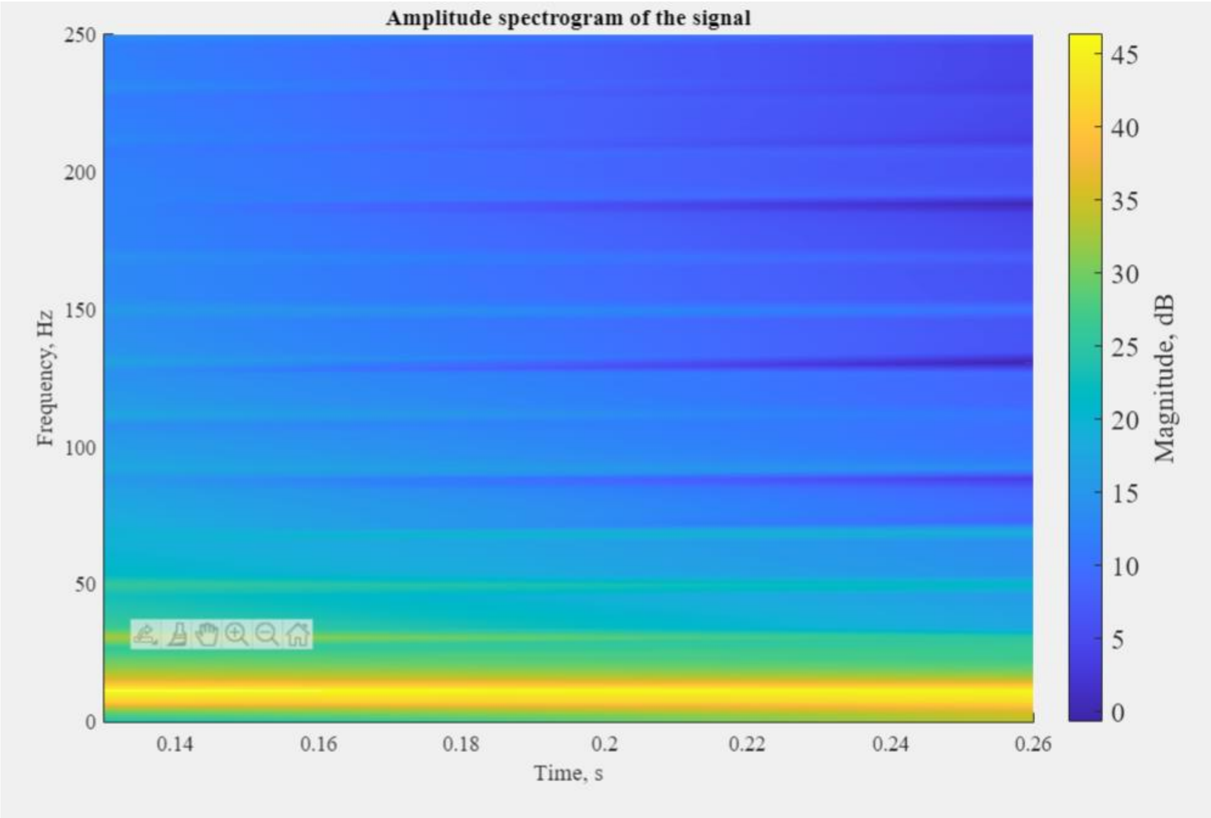

Figure 84. Spectrogram of the Sawtooth Wave Signal with window Kaiser (130).

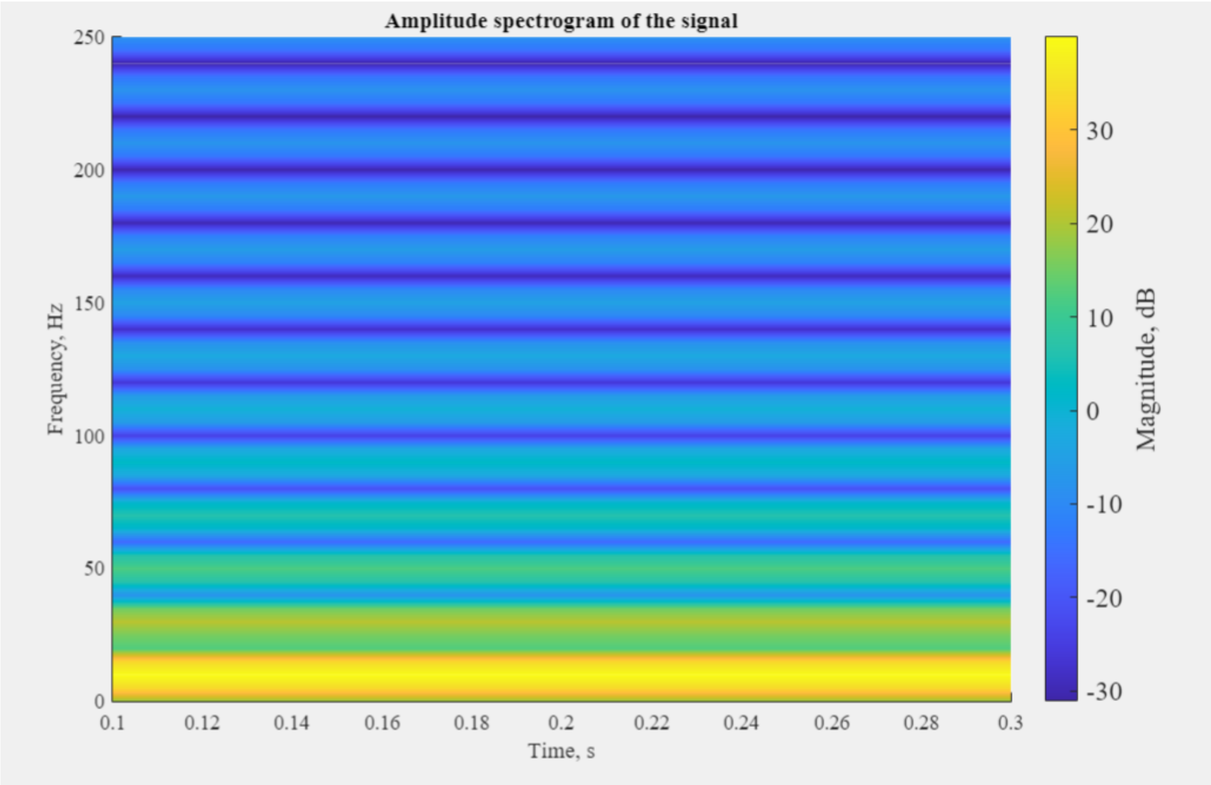

Figure 85. Spectrogram of the Sawtooth Wave Signal with window Gaussian (100).

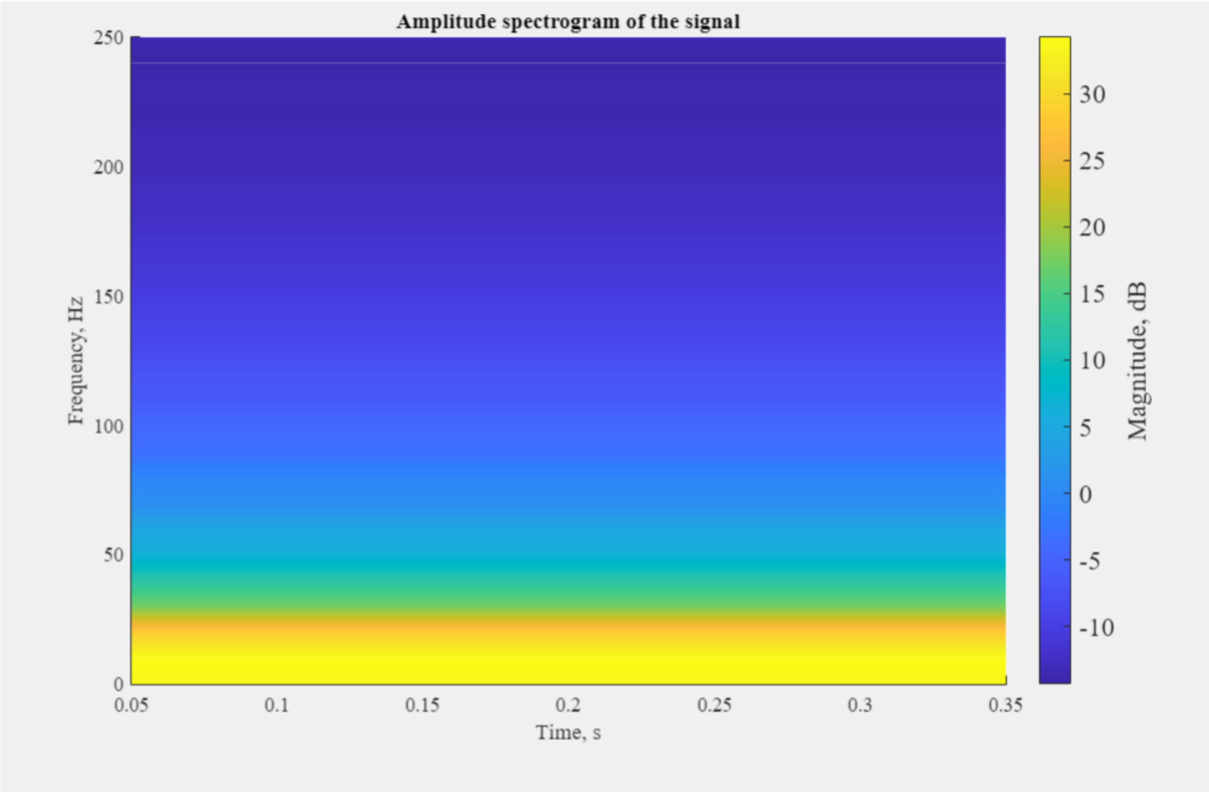

Figure 86. Spectrogram of the Sawtooth Wave Signal with window Gaussian (50).

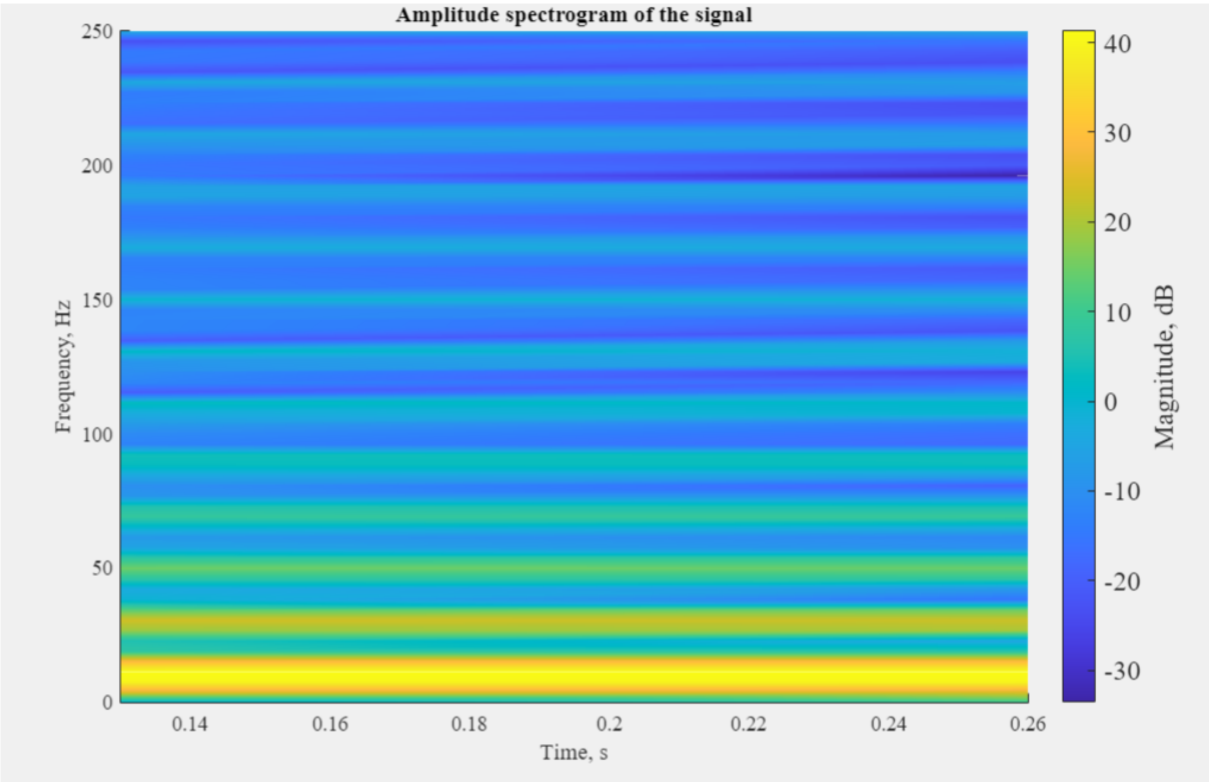

Figure 87. Spectrogram of the Sawtooth Wave Signal with window Gaussian (130).

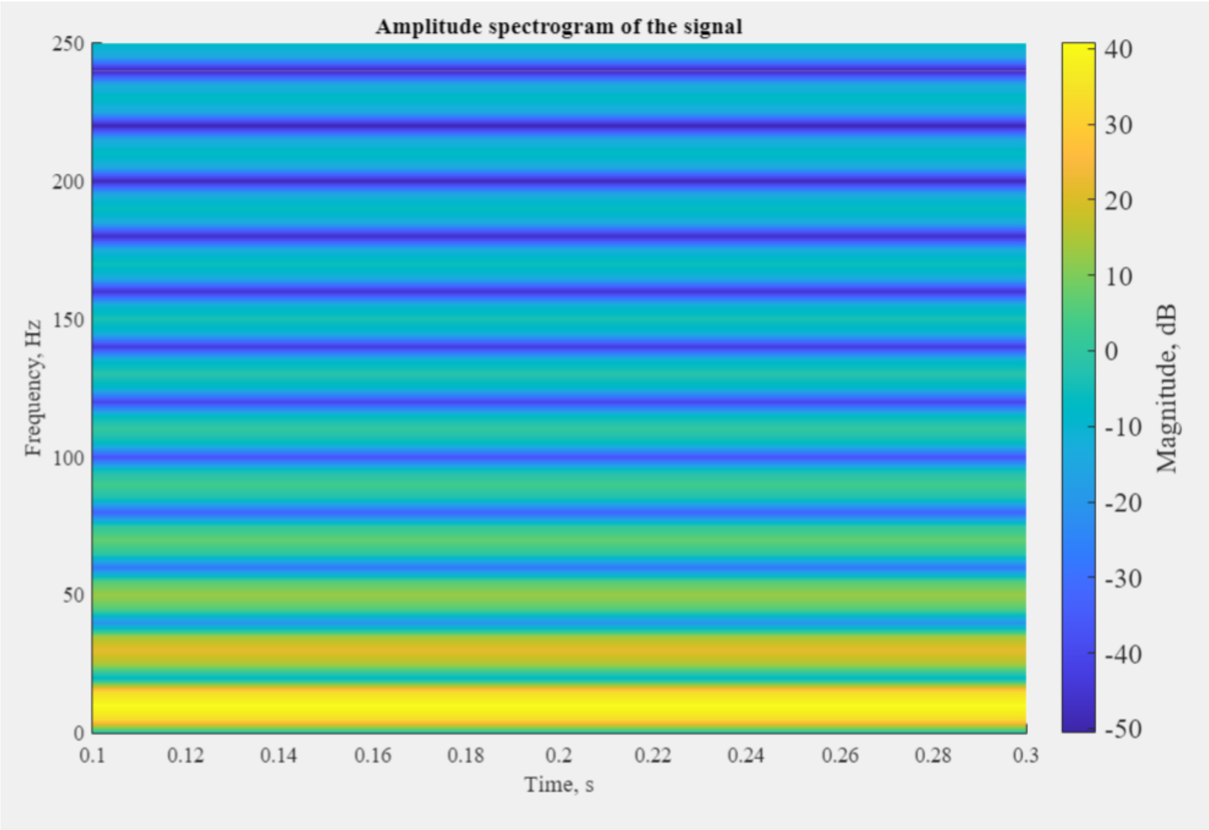

Figure 88. Spectrogram of the Sawtooth Wave Signal with window Hamming (100).

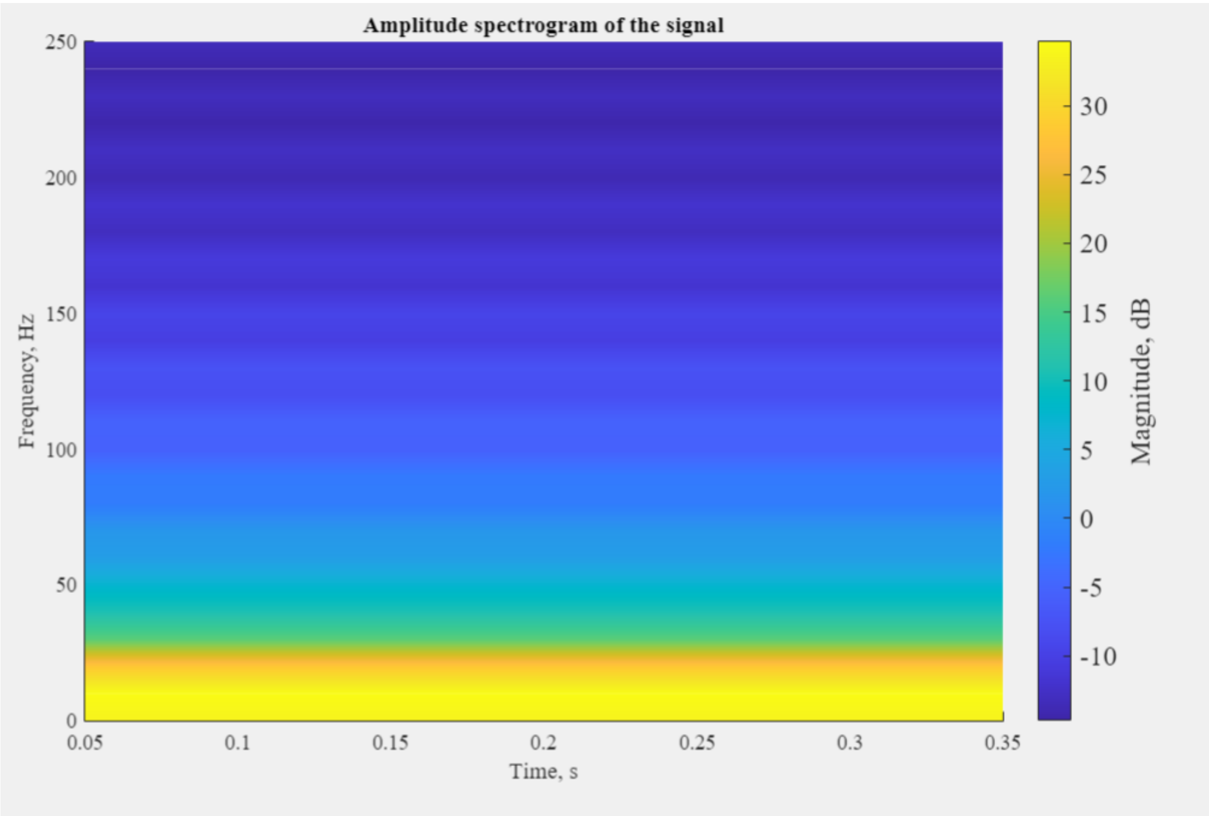

Figure 89. Spectrogram of the Sawtooth Wave Signal with window Kaiser (50).

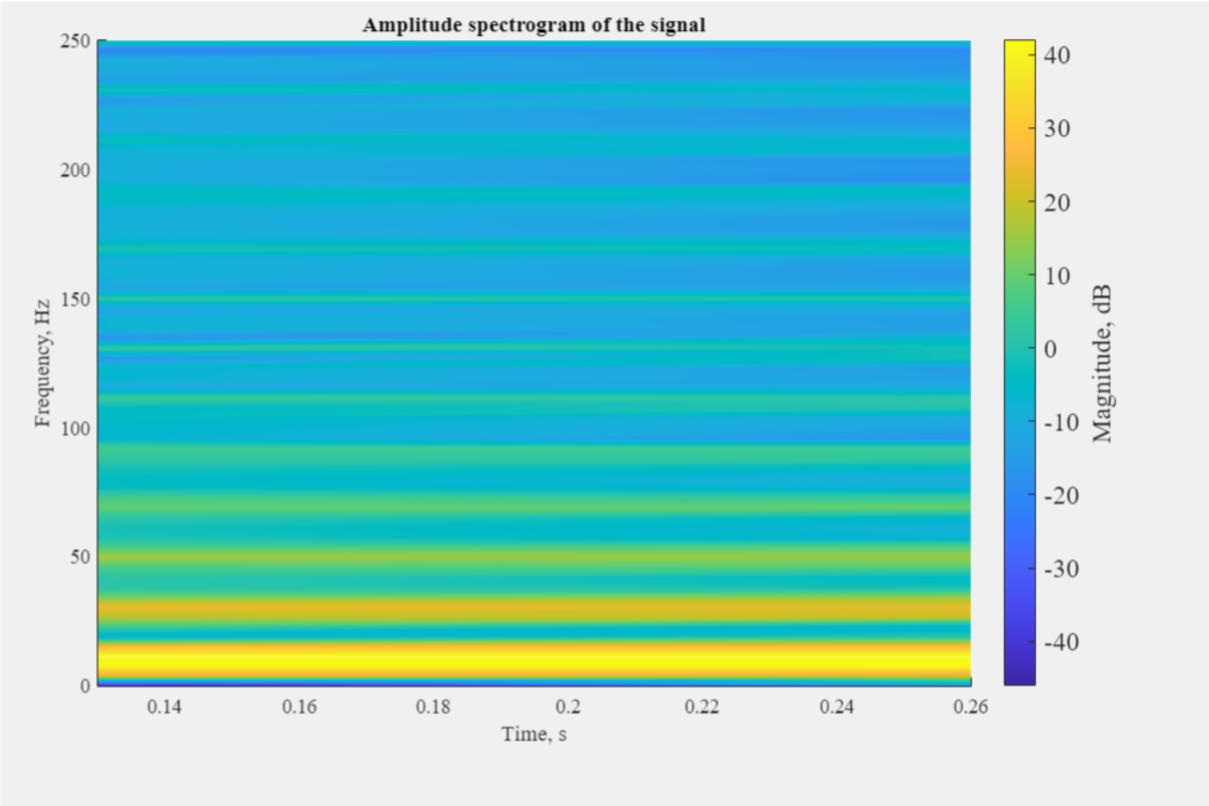

Figure 90. Spectrogram of the Sawtooth Wave Signal with window Hamming (130).

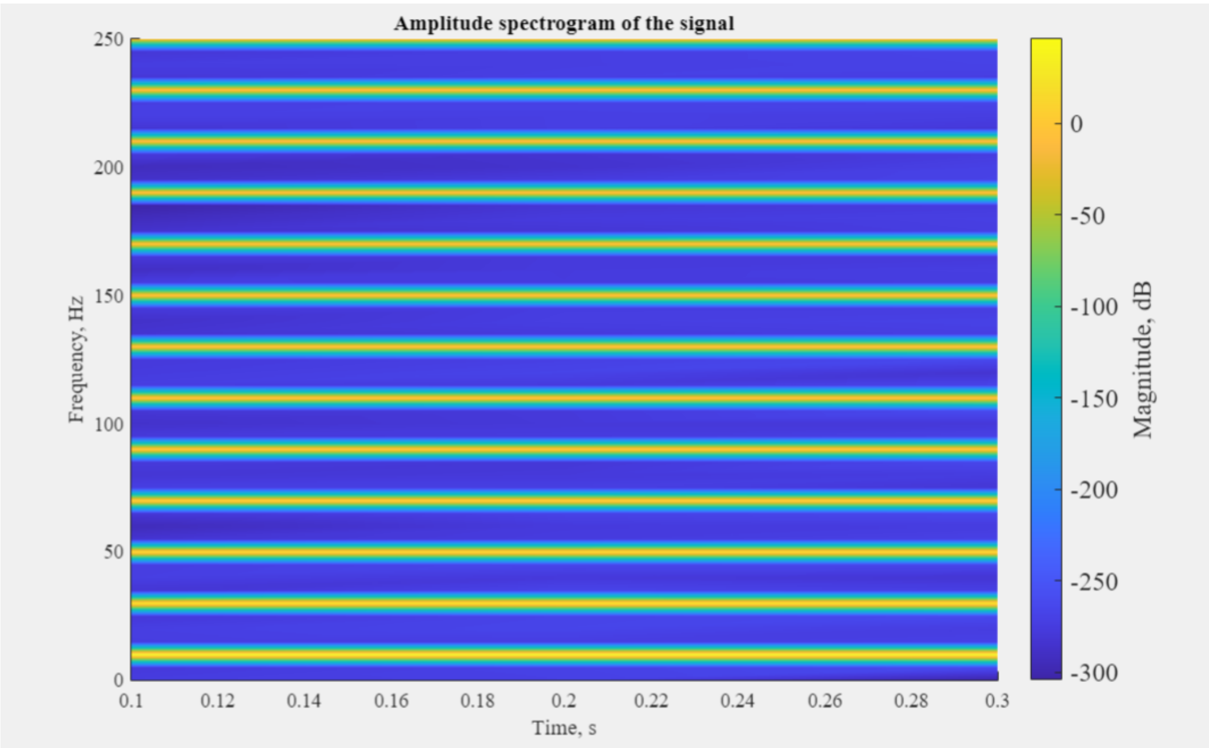

Figure 91. Spectrogram of the Sawtooth Wave Signal with window Rectangular (100).

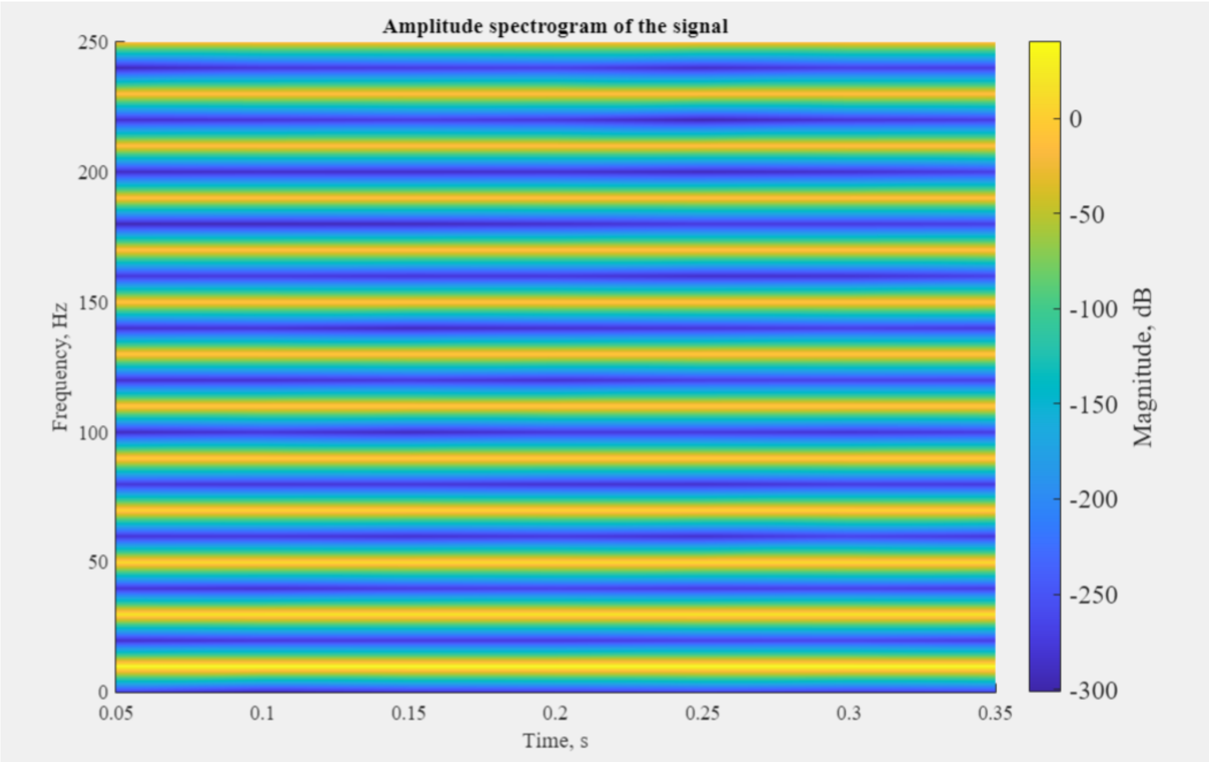

Figure 92. Spectrogram of the Sawtooth Wave Signal with window Rectangular (50).

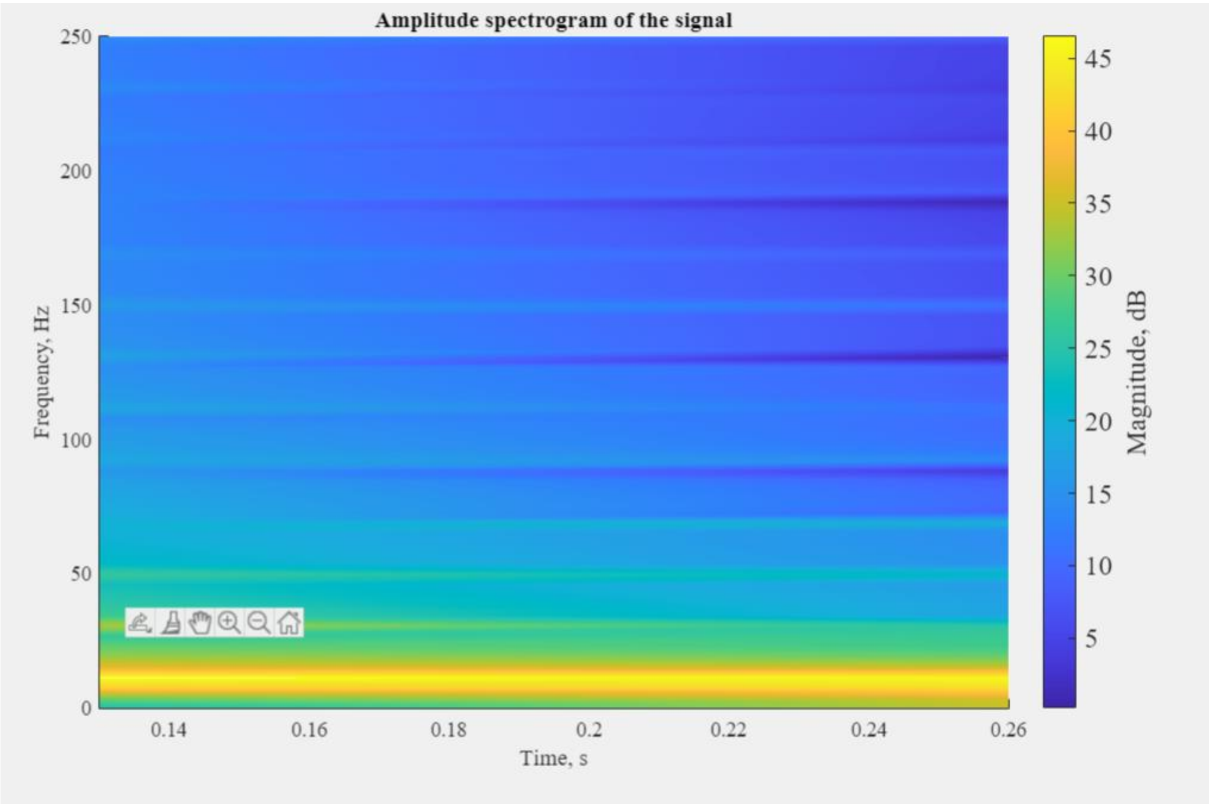

Figure 93. Spectrogram of the Sawtooth Wave Signal with window Rectangular (130).

VII- Windowed Sinusoidal (Rectangular windowed sinusoidal)

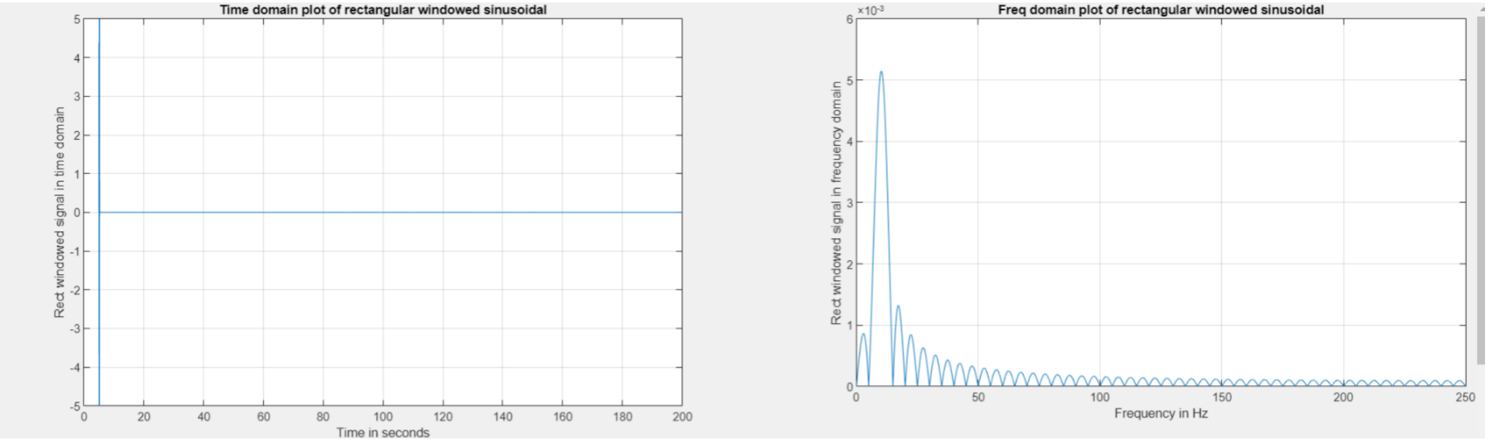

Figure 94. Generated Rectangular Windowed Sinusoidal Signal both in Time domain and Frequency domain.

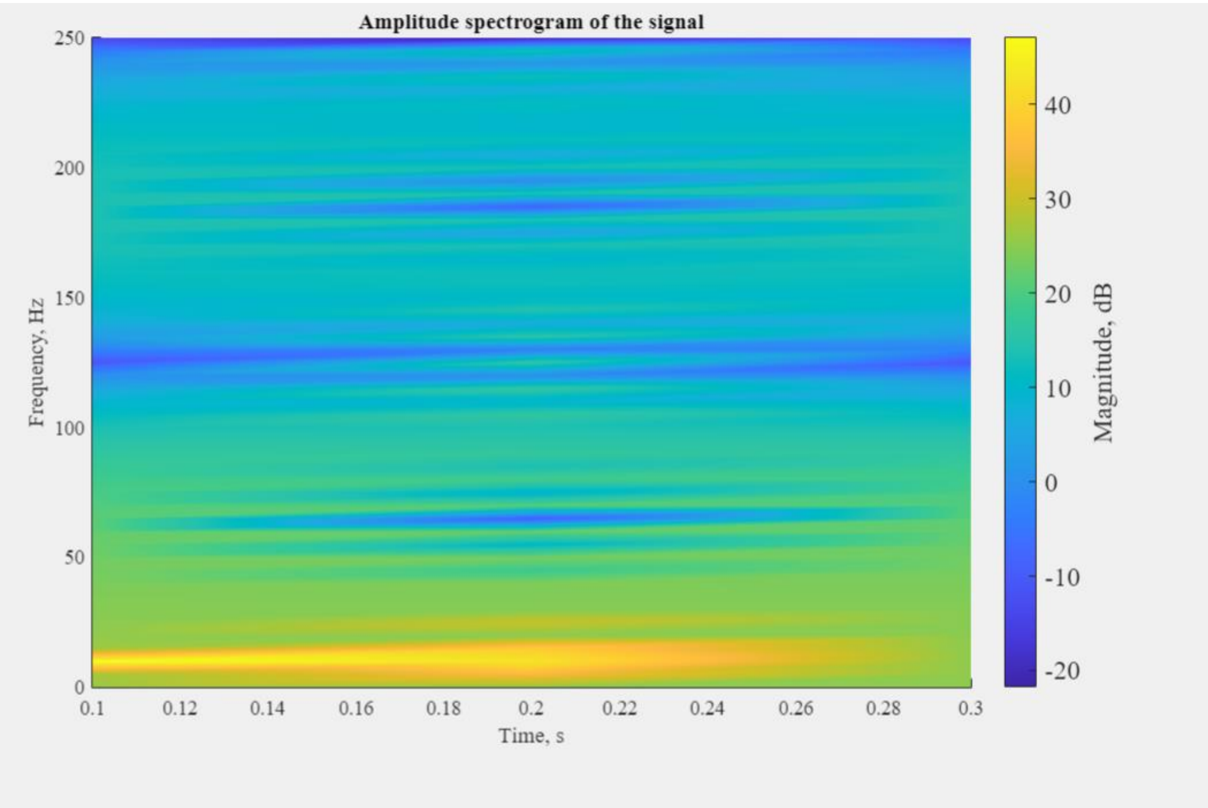

Figure 95. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Kaiser (100).

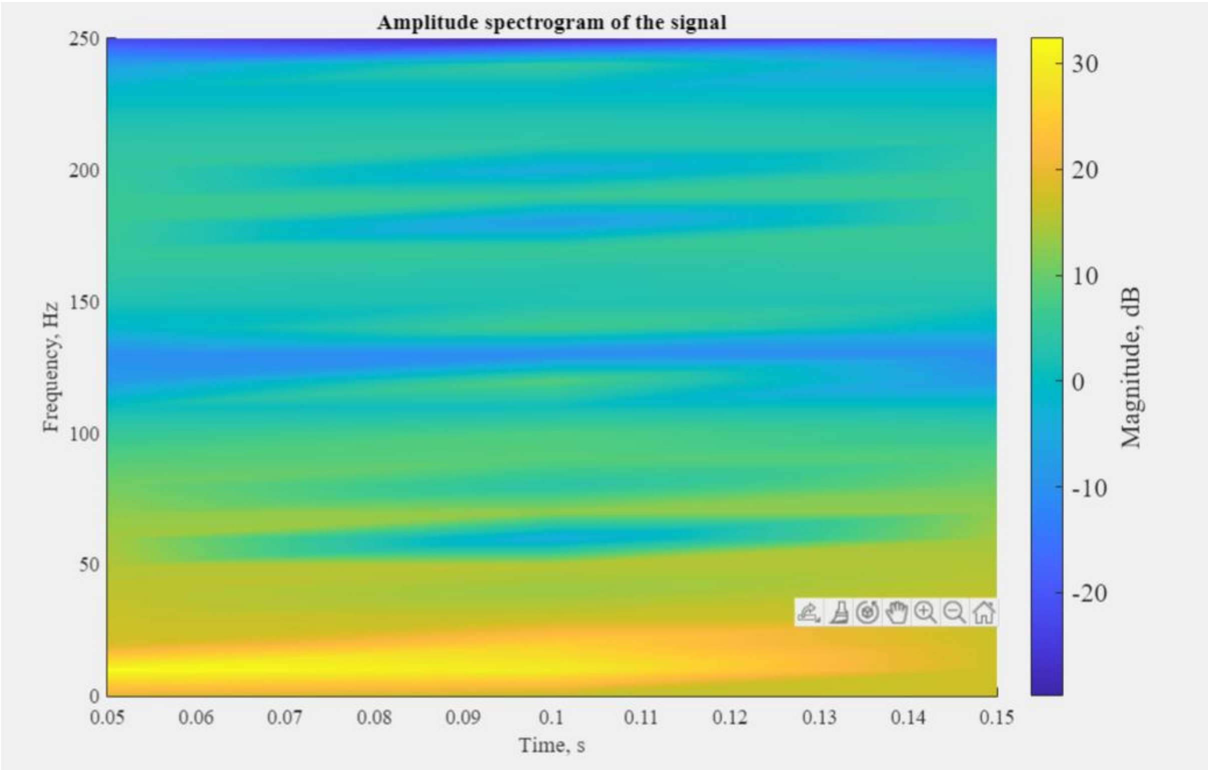

Figure 96. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Kaiser (50).

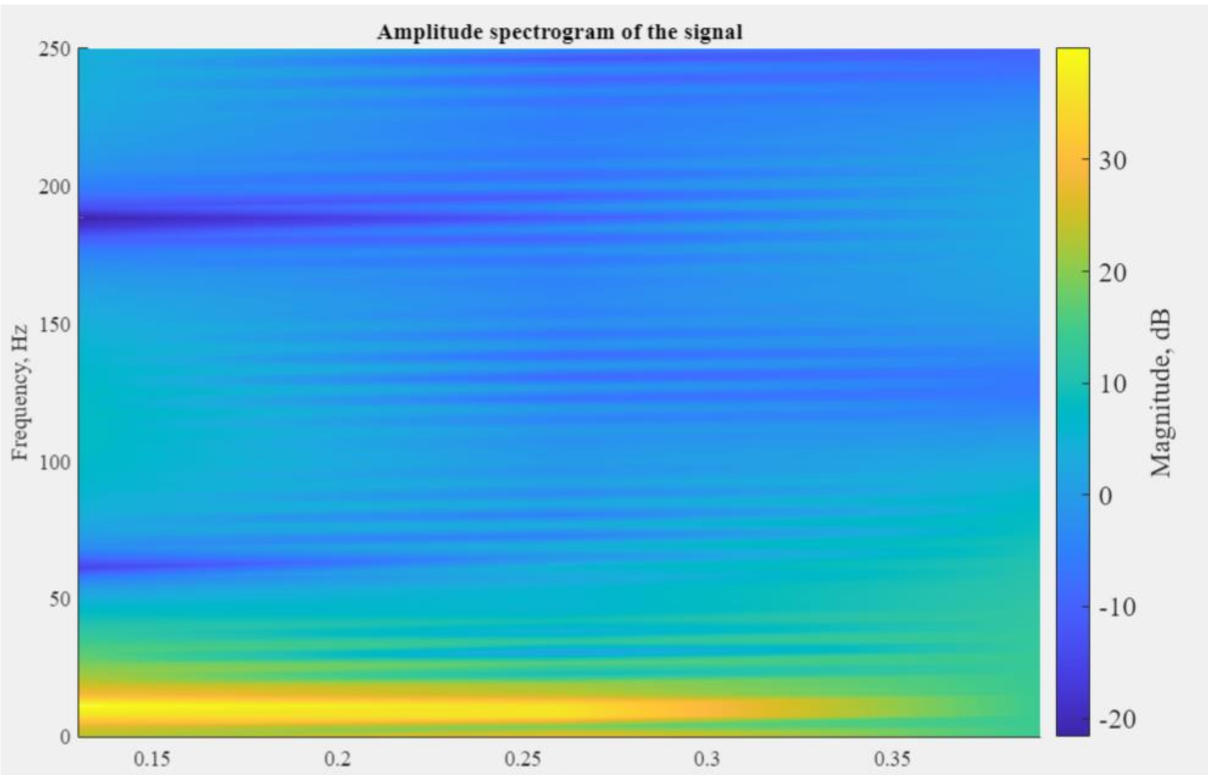

Figure 97. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Kaiser (130).

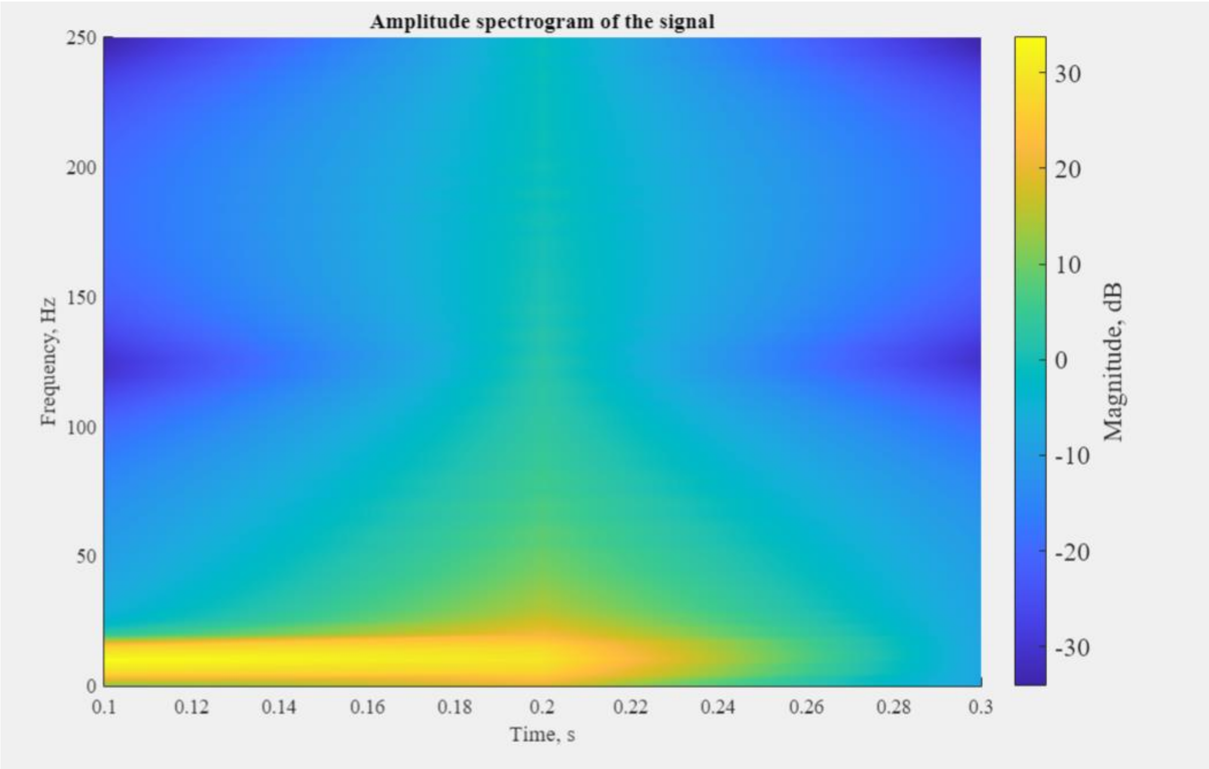

Figure 98. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Gaussian (100).

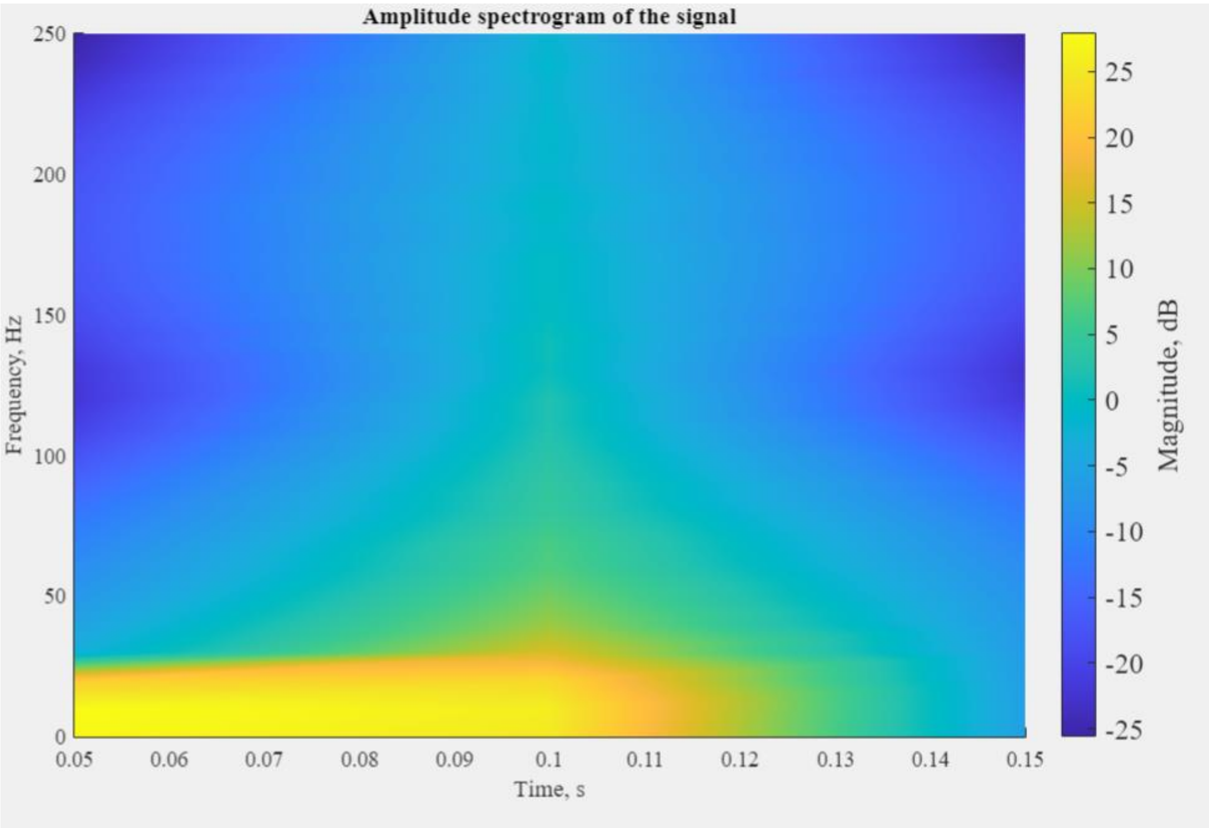

Figure 99. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Gaussian (50).

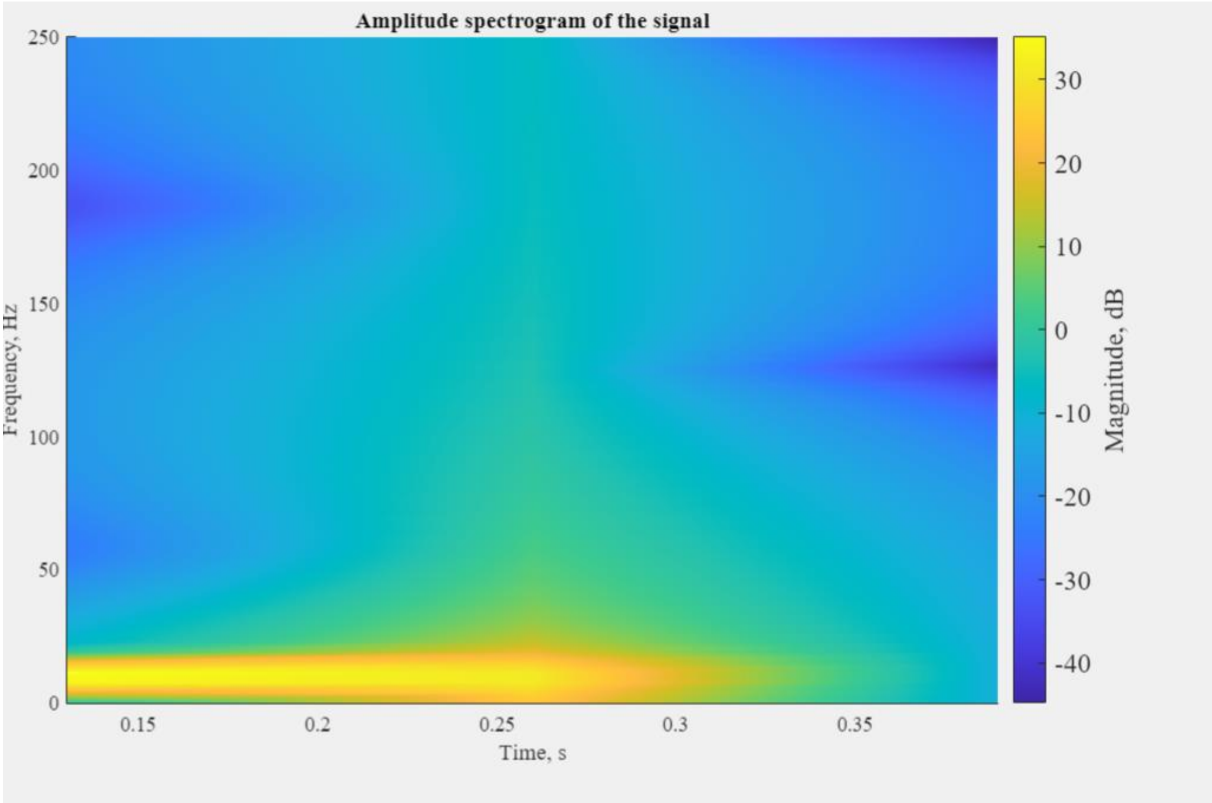

Figure 100. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Gaussian (130).

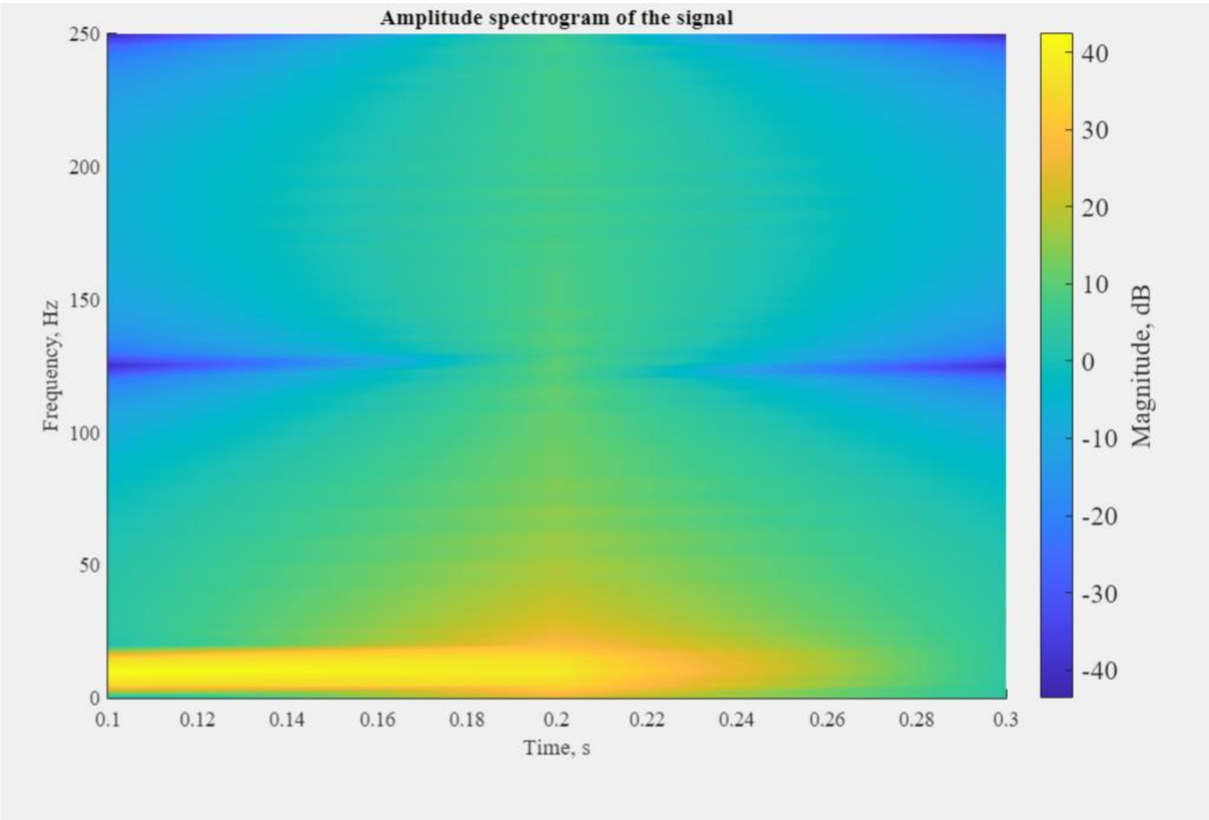

Figure 101. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Hamming (100).

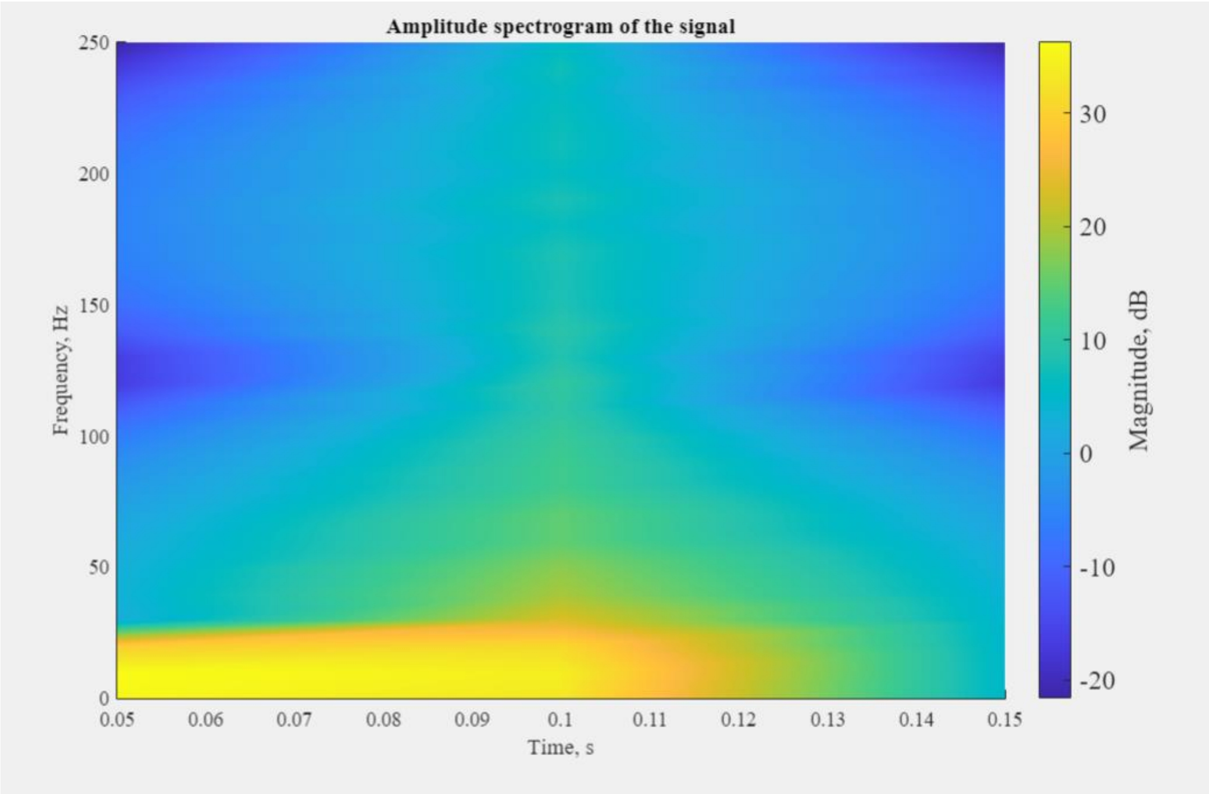

Figure 102. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Hamming (50).

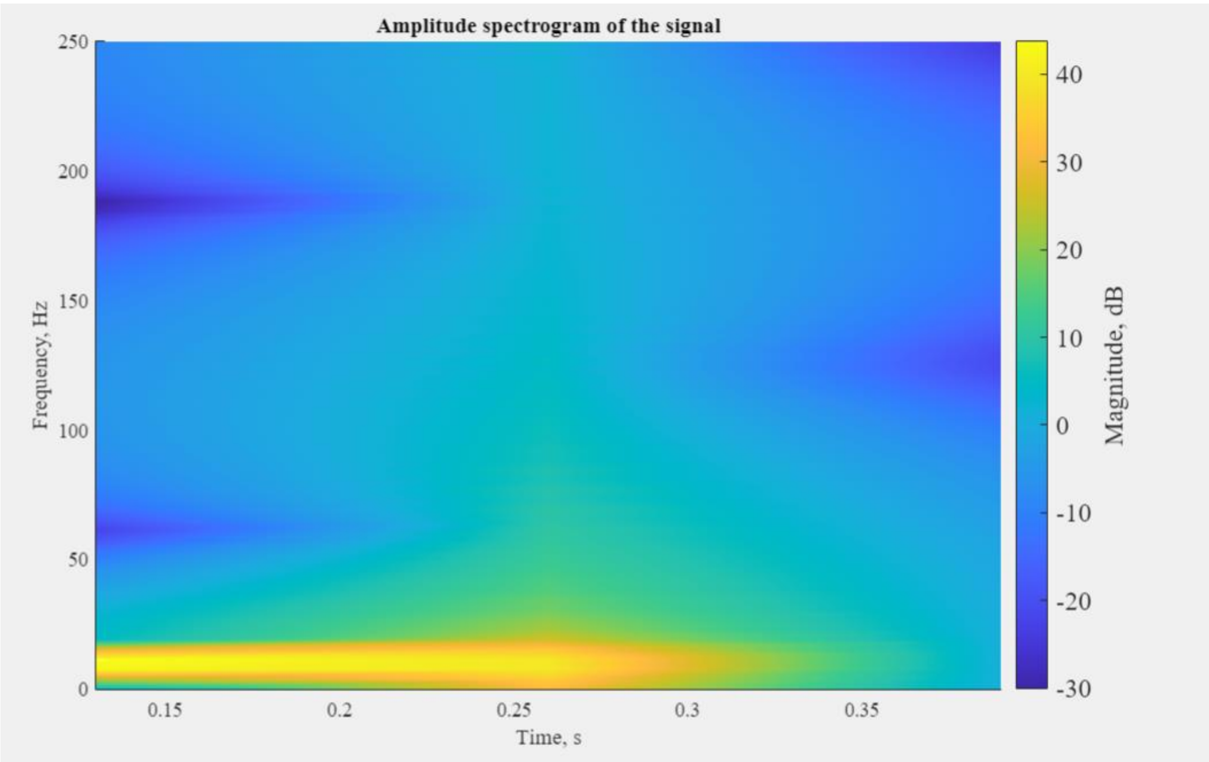

Figure 103. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Hamming (130).

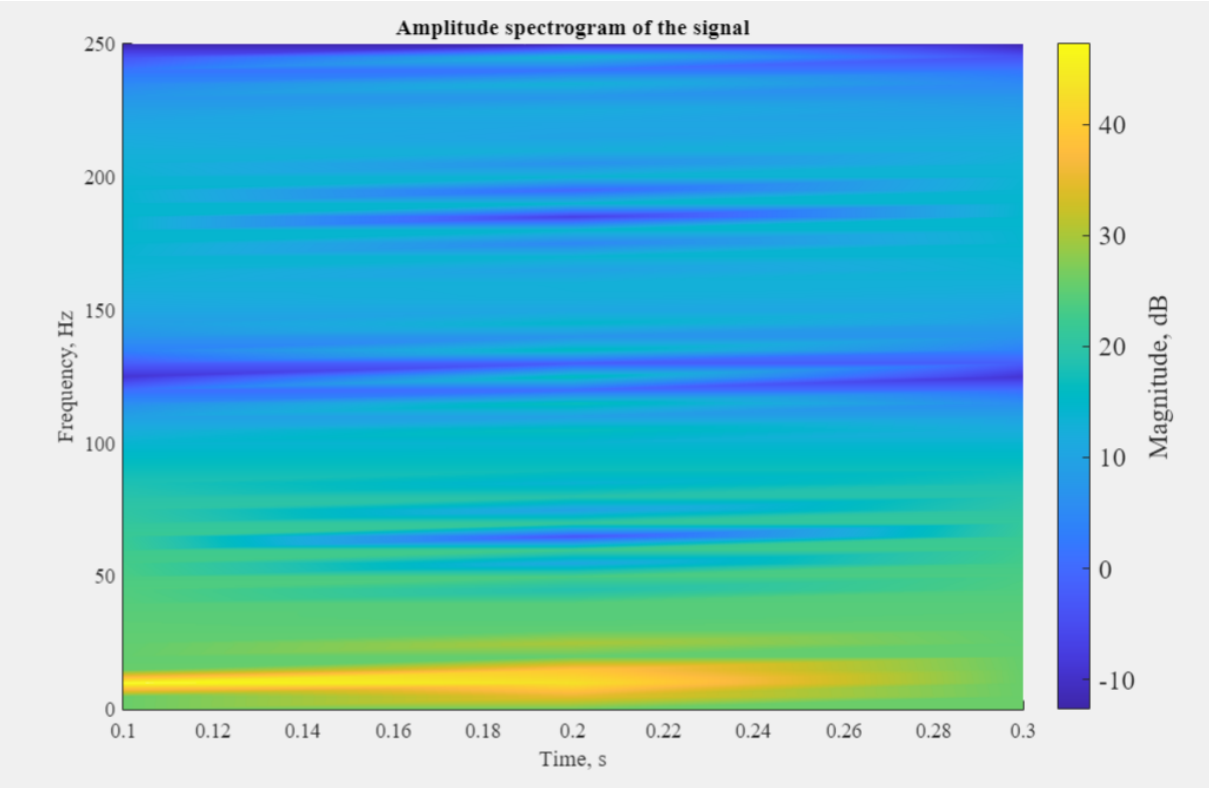

Figure 104. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Rectangular (100).

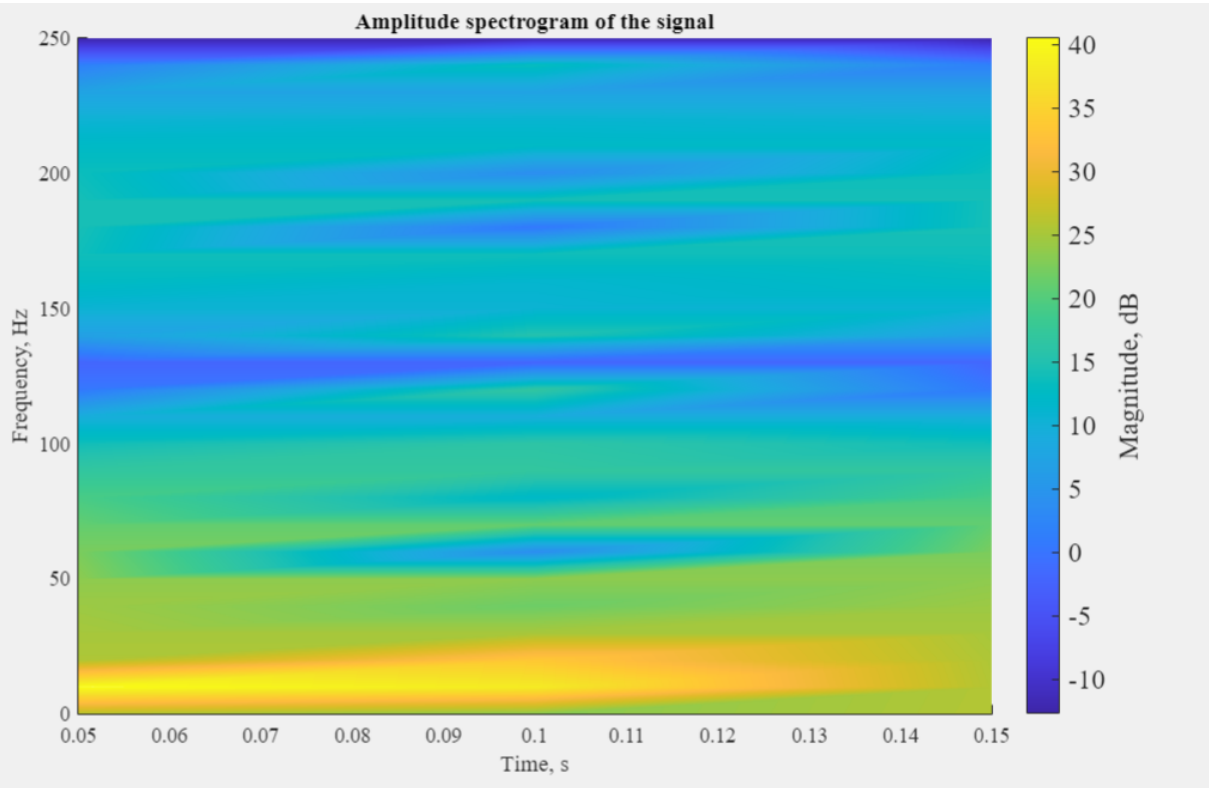

Figure 105. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Rectangular (50).

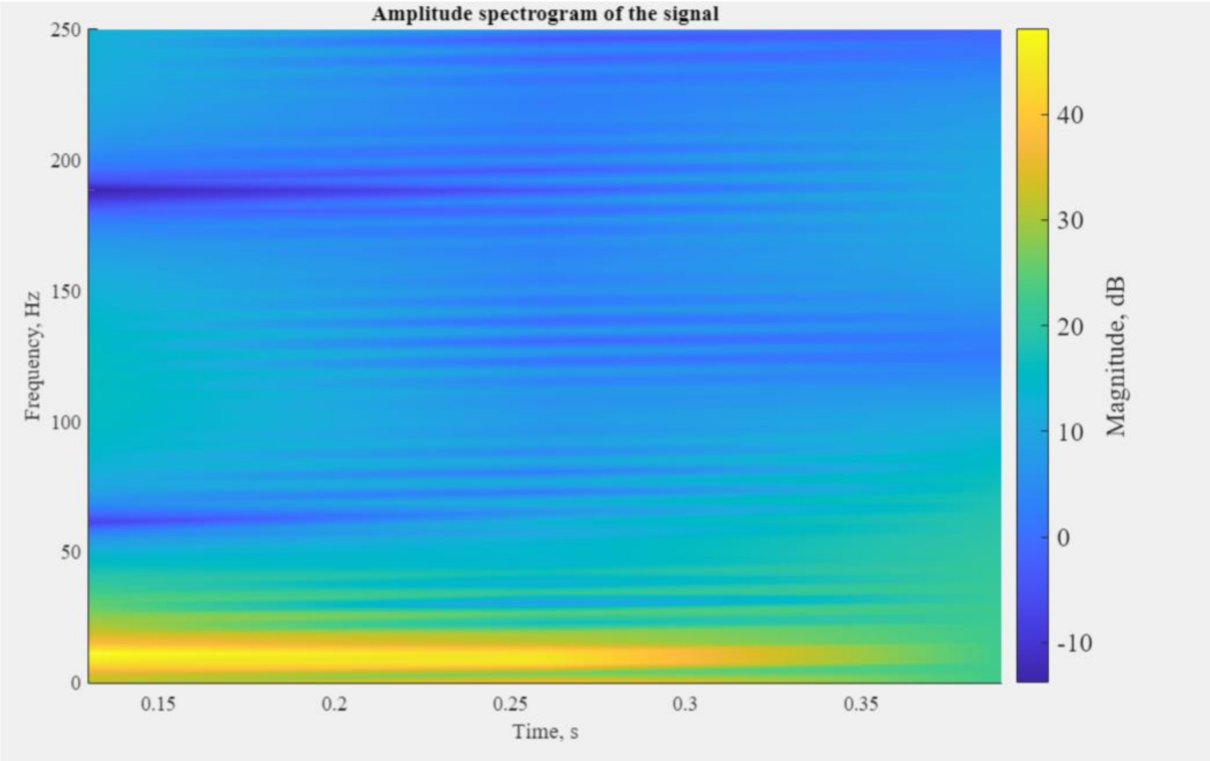

Figure 106. Spectrogram of the Rectangular Windowed Sinusoidal Signal with window Rectangular (130).

Rectangular Windowed Multiple Sinusoidal with Close Amplitude and Far Frequency:

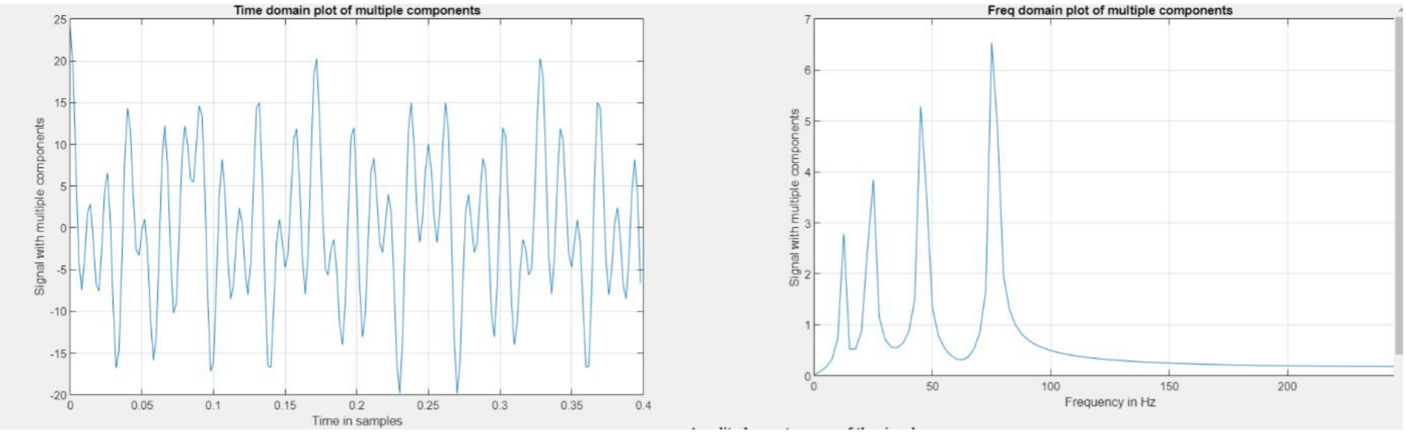

Figure 107. Generated Rectangular Windowed Multiple Sinusoidal Signal both in Time domain and Frequency domain.

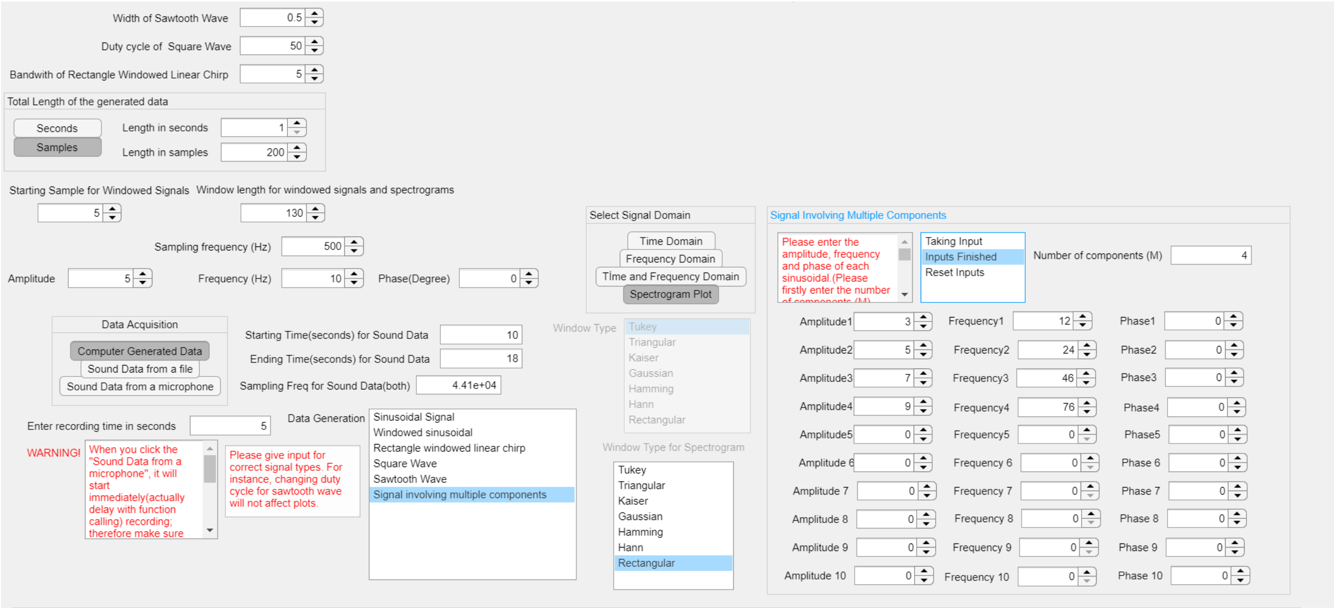

Figure 108. Parameters of our interface.

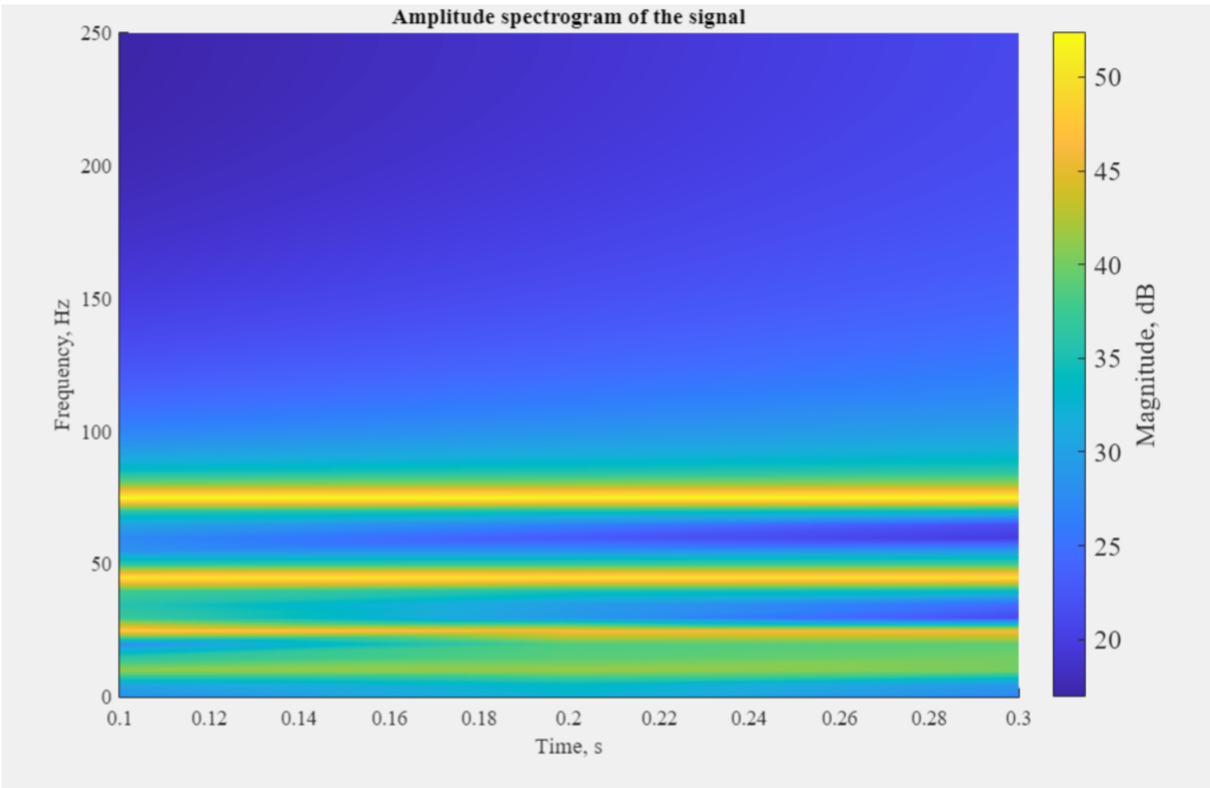

Figure 109. Spectrogram of the Rectangular Windowed Multiple Sinusoidal Signal with window Rectangular (100).

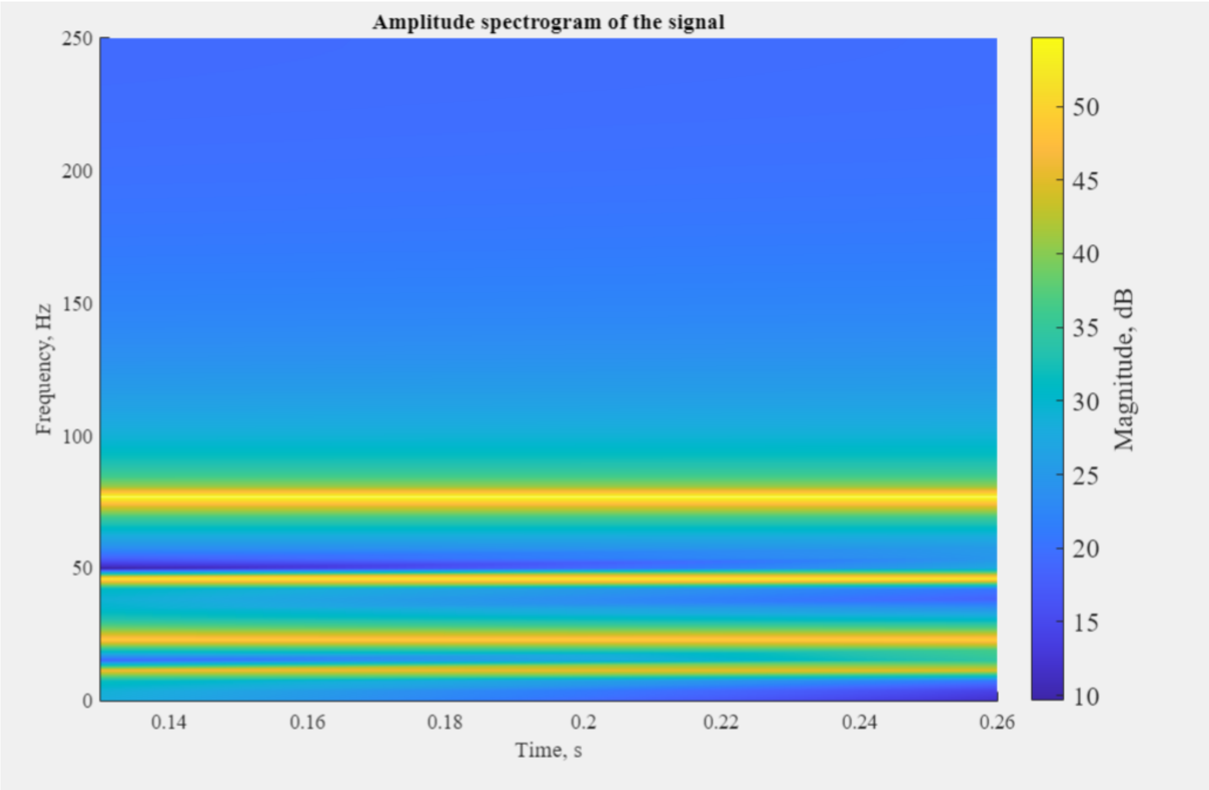

Figure 110. Spectrogram of the Rectangular Windowed Multiple Sinusoidal Signal with window Rectangular (130).

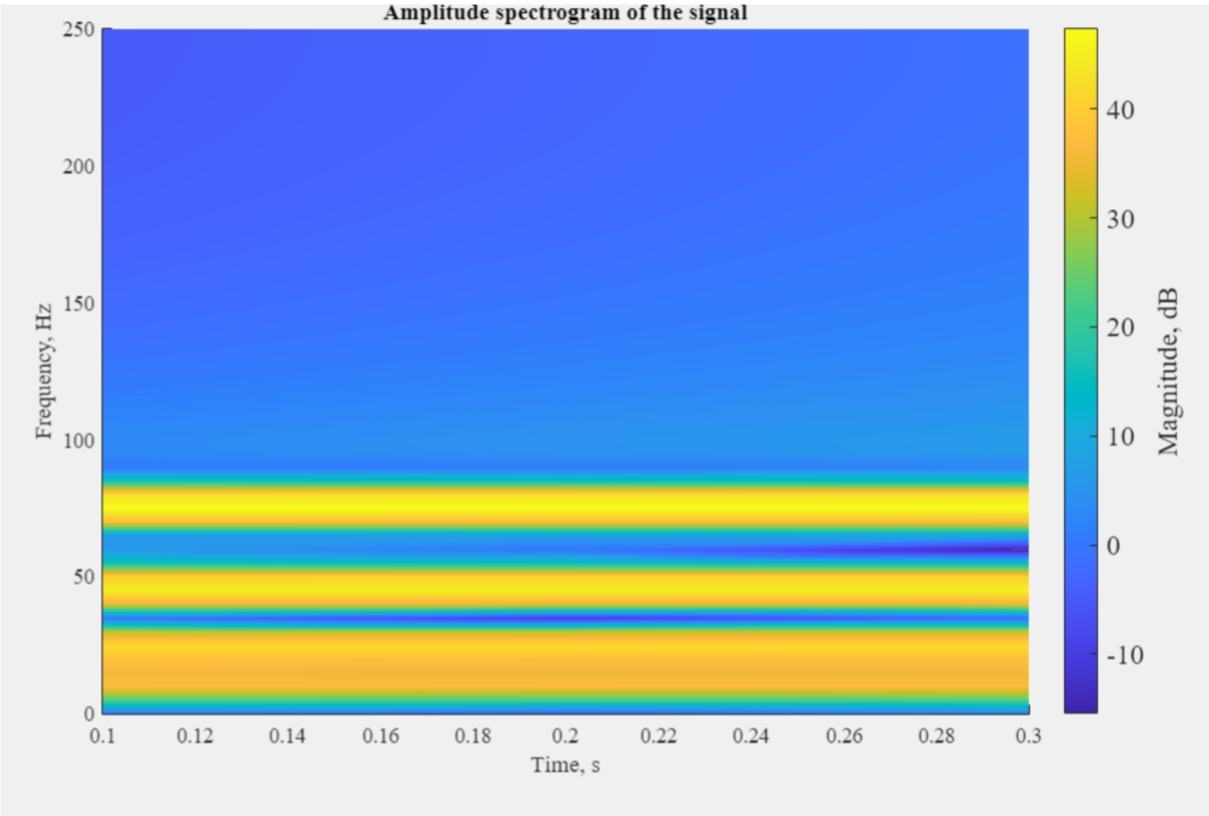

Figure 111. Spectrogram of the Rectangular Windowed Multiple Sinusoidal Signal with window Hamming (100).

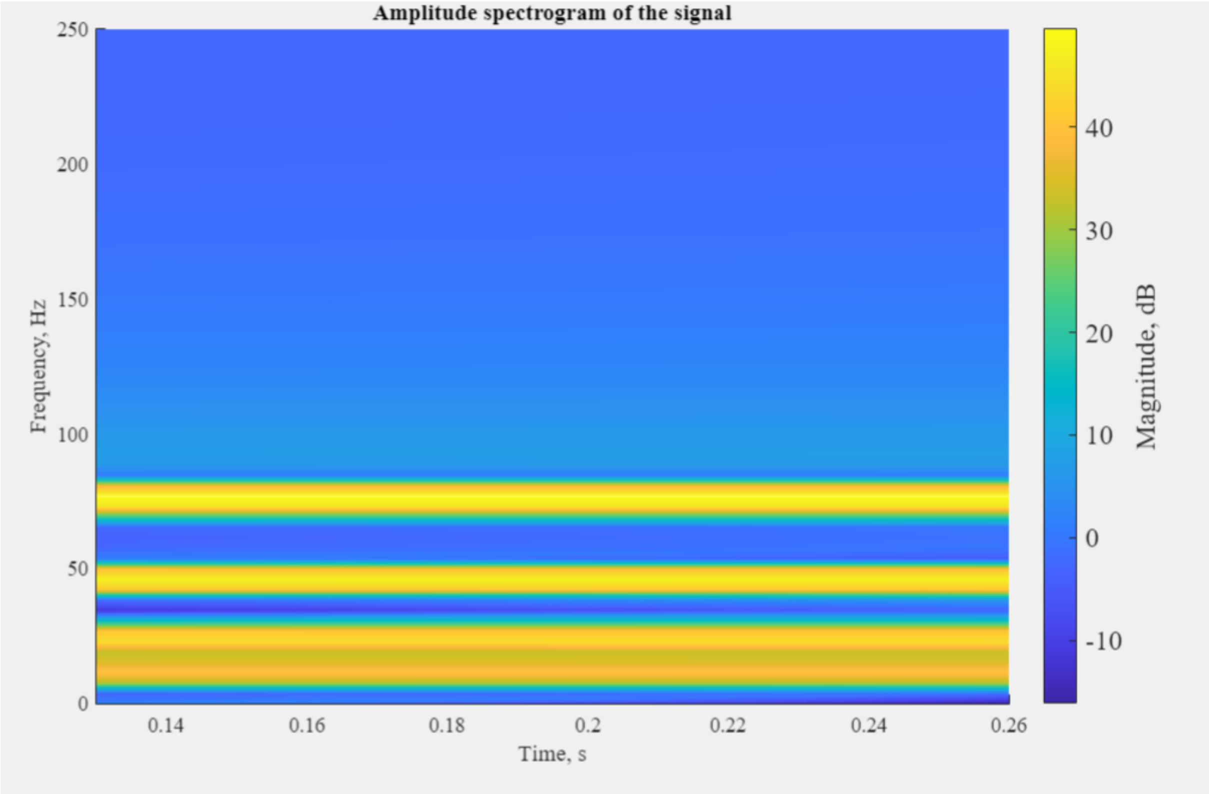

Figure 112. Spectrogram of the Rectangular Windowed Multiple Sinusoidal Signal with window Rectangular (130).

As we can see here rectangular did a better job than hamming for close amplitudes with far frequencies because rectangular window is a high resolution with low dynamic range. Hamming can be considered as a more moderate window that is used in narrowband applications such as telephone channels. Now let's examine different amplitudes with close frequencies.

Rectangular Windowed Multiple Sinusoidal with Far Amplitude and Close Frequency:

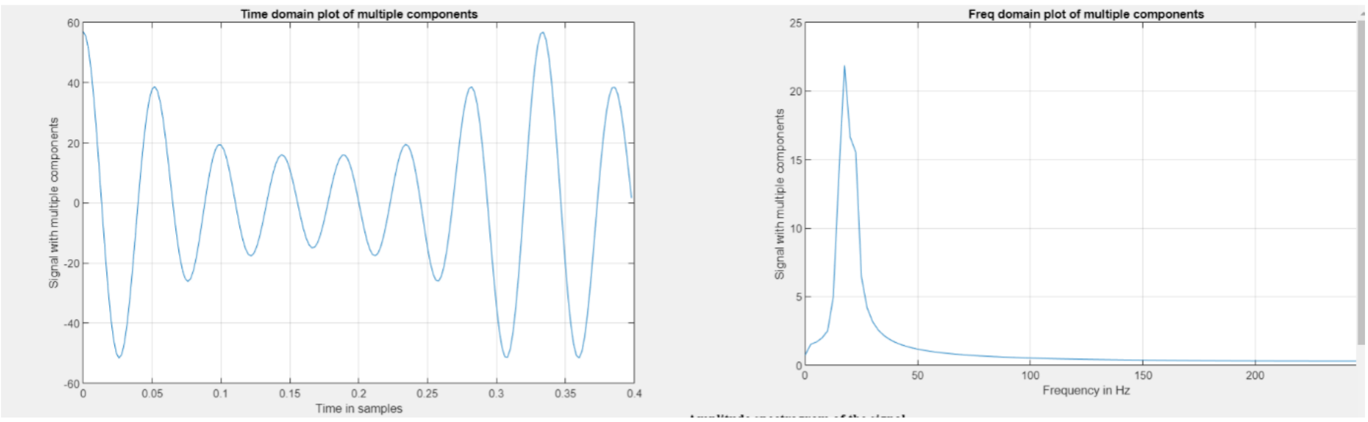

Figure 113. Generated Rectangular Windowed Multiple Sinusoidal Signal both in Time domain and Frequency domain.

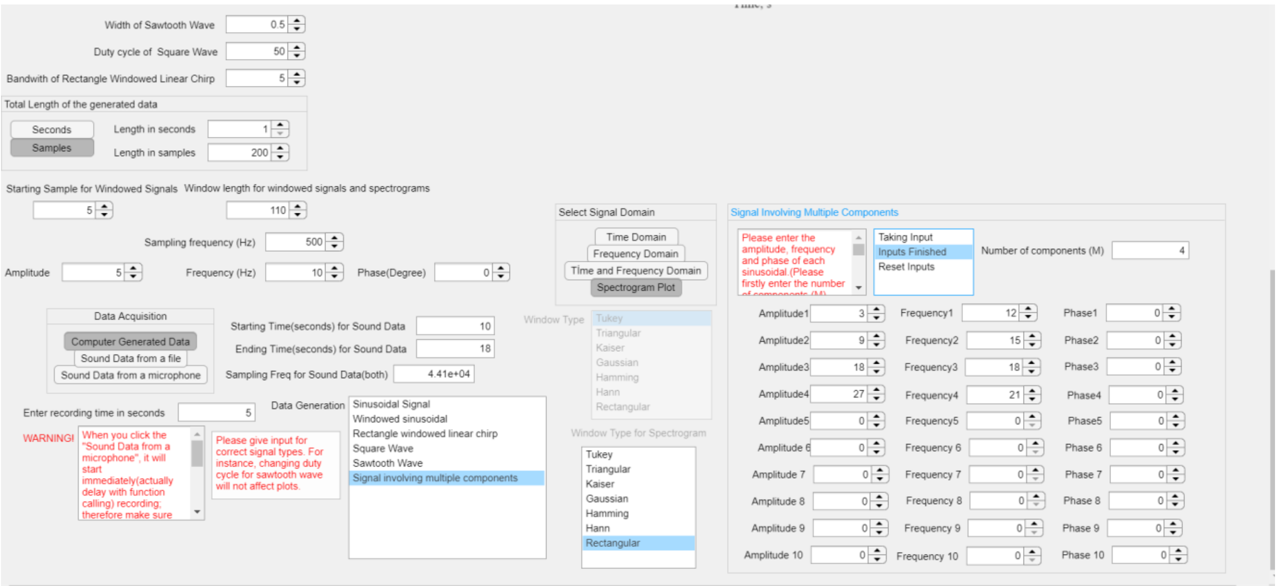

Figure 114. Parameters of our interface.

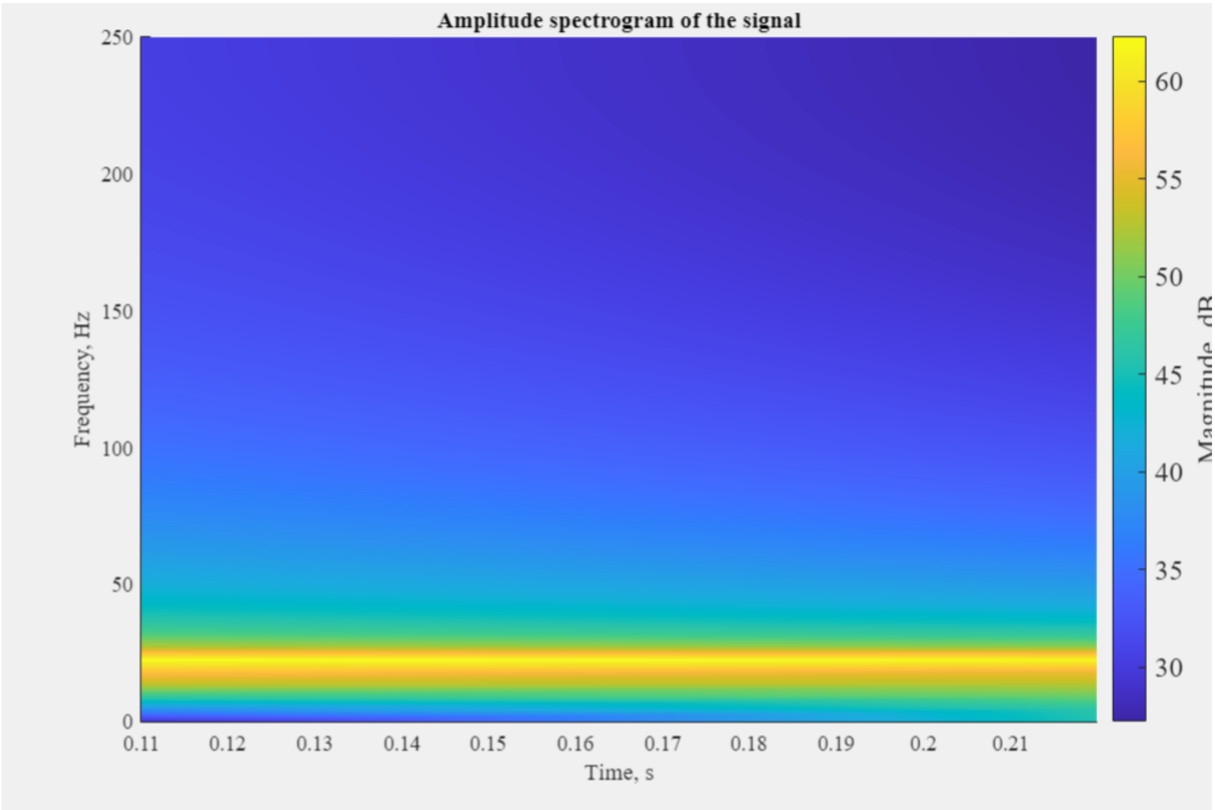

Figure 115. Spectrogram of the Multiple Sinusoidal Signal with window Rectangular (110).

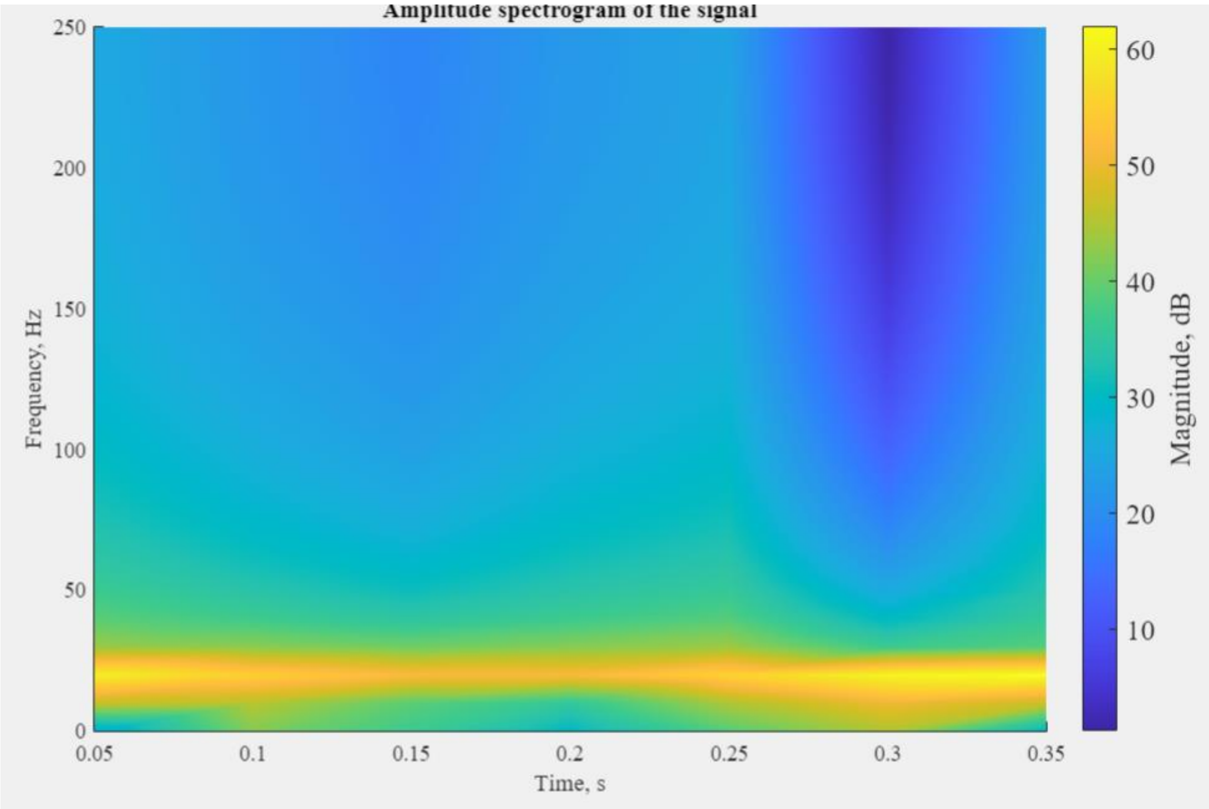

Figure 116. Spectrogram of the Multiple Sinusoidal Signal with window Rectangular (50).

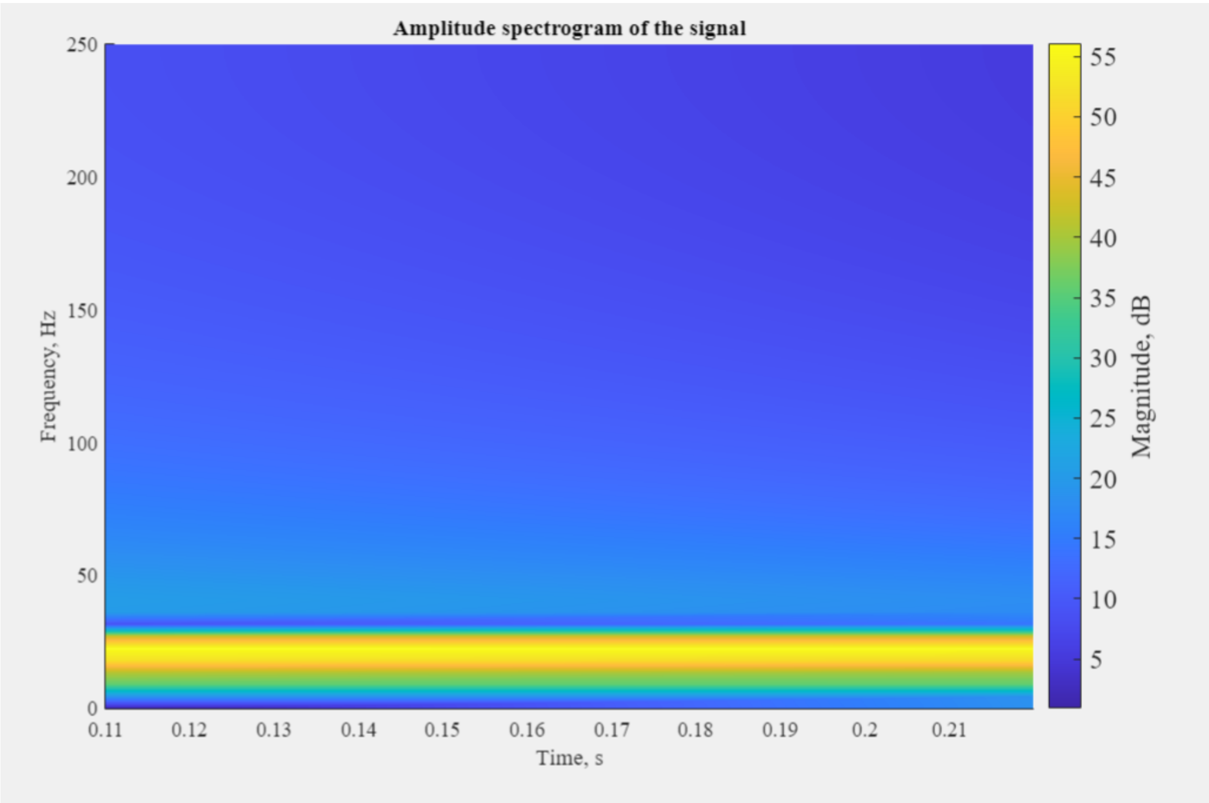

Figure 117. Spectrogram of the Multiple Sinusoidal Signal with window Hamming (110).

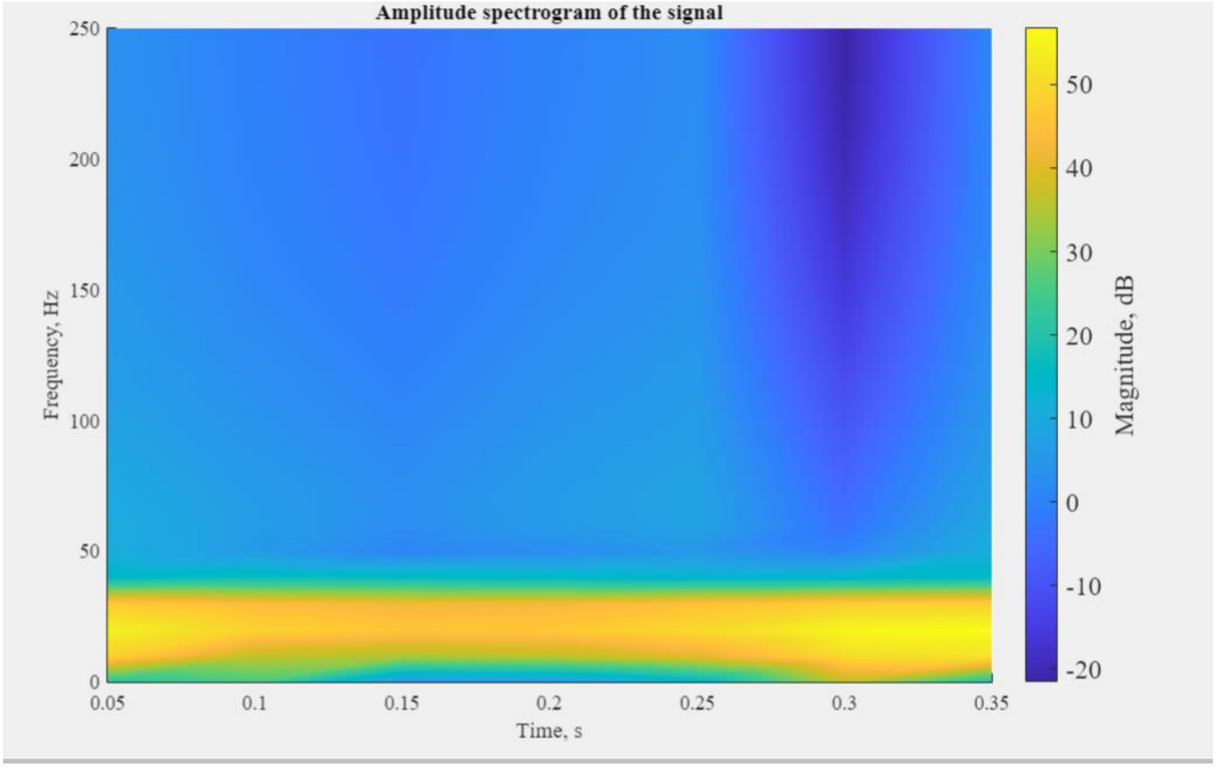

Figure 118. Spectrogram of the Multiple Sinusoidal Signal with window Hamming (50).

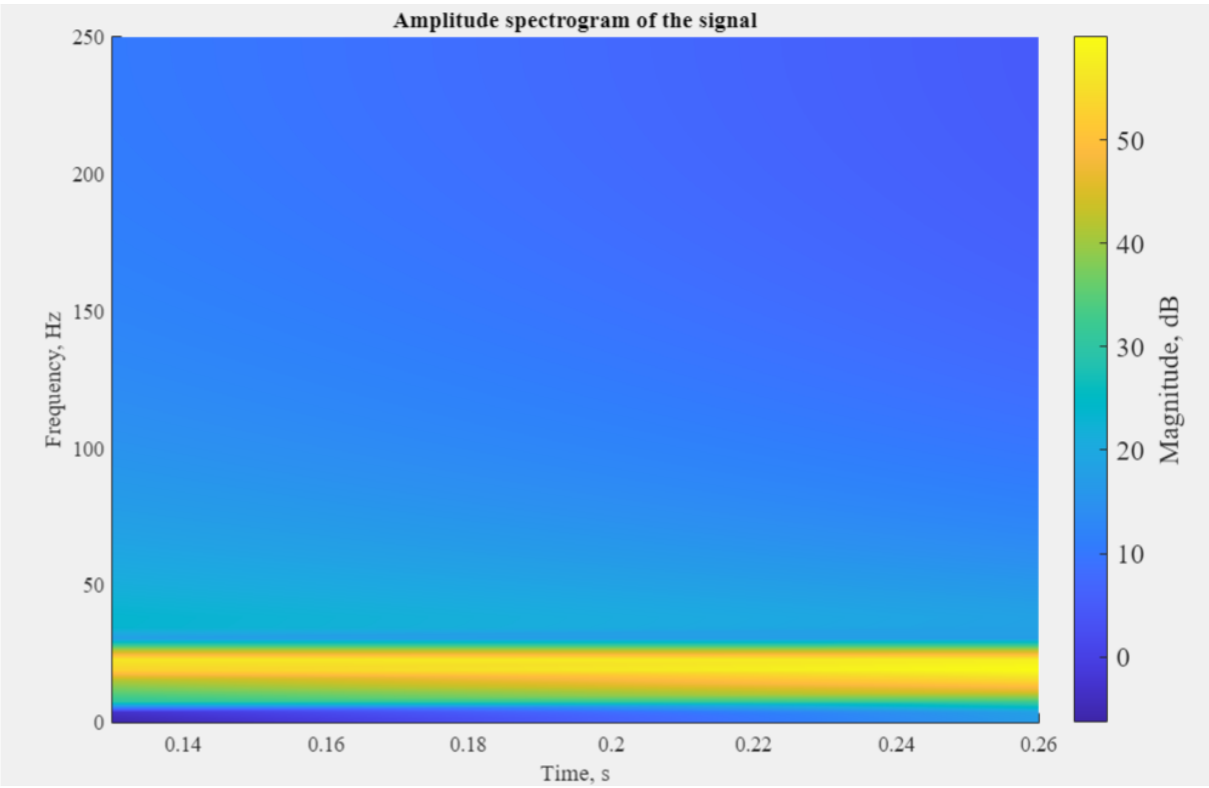

Figure 119. Spectrogram of the Multiple Sinusoidal Signal with window Hamming (130).

As we can see here, hamming did a better job than rectangular for this case. Moreover, please check the window length differences between same window types. Window length should be adjusted so that neither it should be short nor too long because short window length means insufficient information and long window length means it cannot observe enough difference therefore, window length should be selected appropriately according to signal length.

Let’s compare Kaiser and Gaussian Windows for same amplitudes with close frequencies.

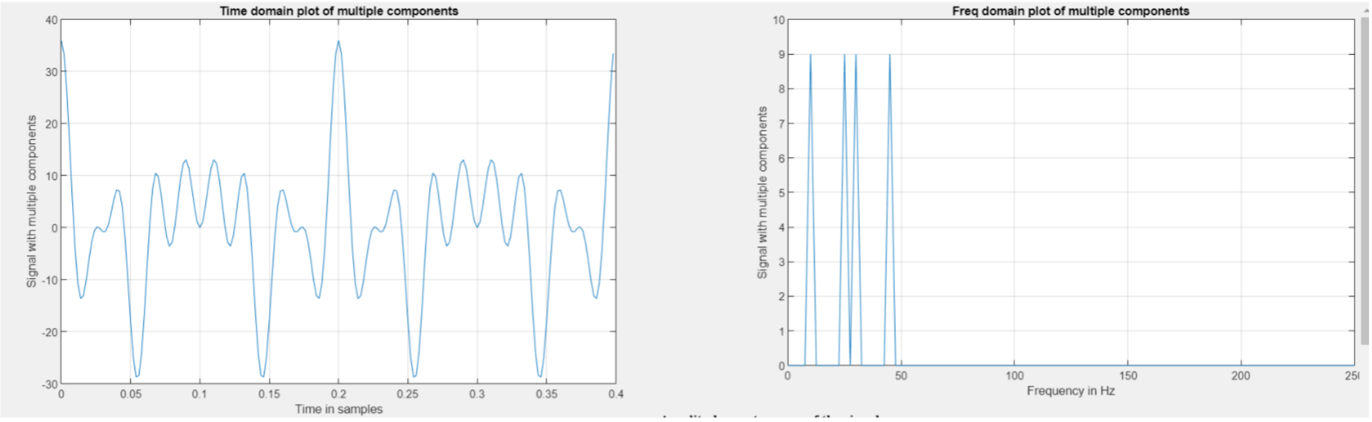

Figure 120. Generated Multiple Sinusoidal Signal both in Time domain and Frequency domain.

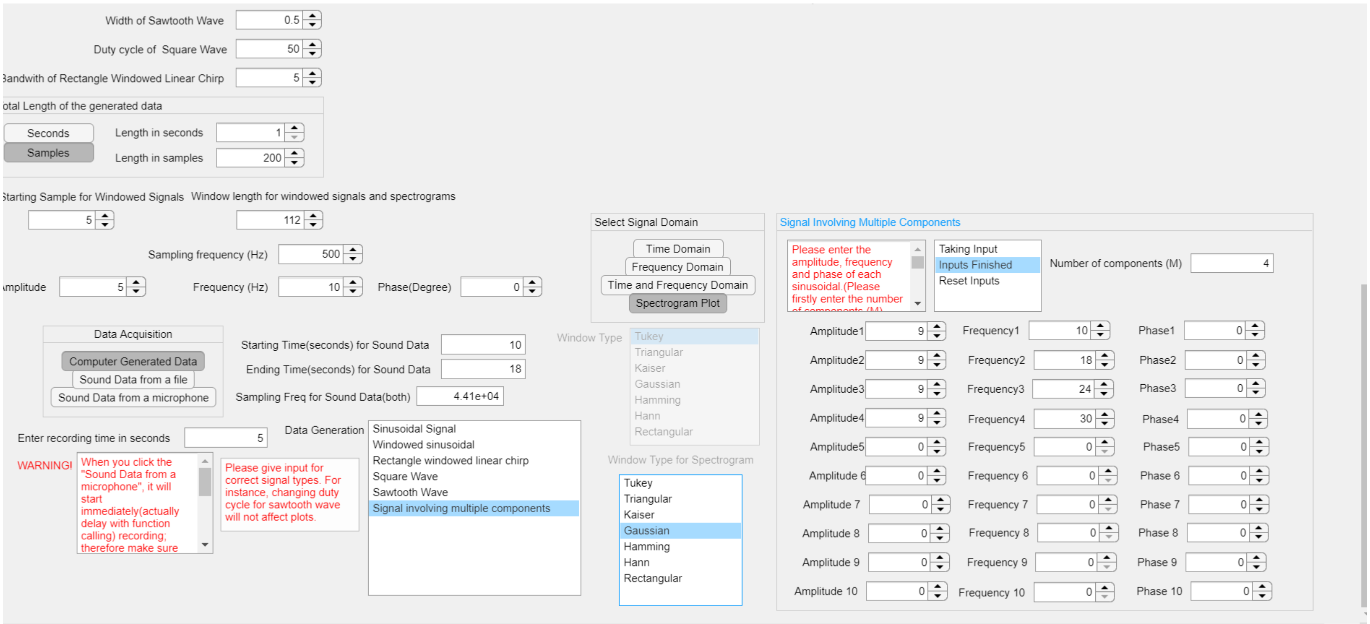

Figure 121. Parameters of our interface.

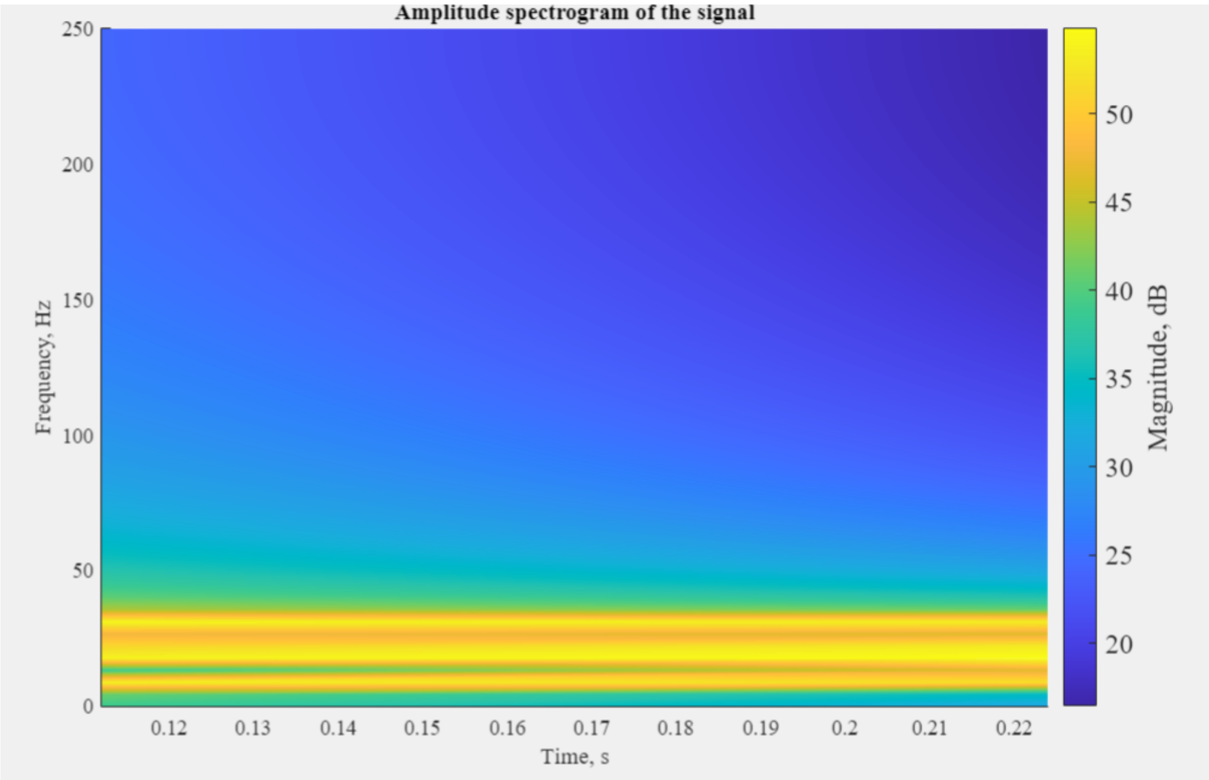

Figure 122. Spectrogram of the Multiple Sinusoidal Signal with window Kaiser (112).

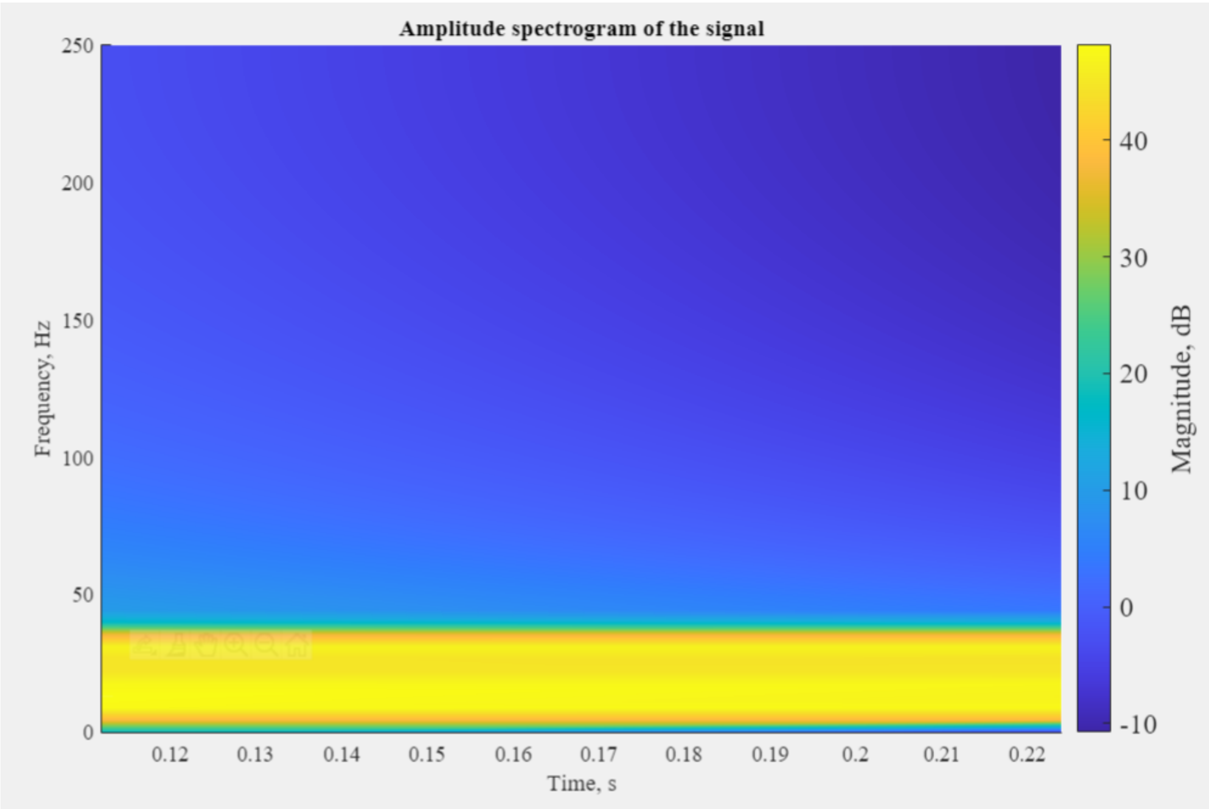

Figure 123. Spectrogram of the Multiple Sinusoidal Signal with window Gaussian (112).

Kaiser is used for differentiating main lobe from side lobes and as we can see here it did a good job. However, we cannot say same thing for Gaussian window. Gaussian is more affected side lobes.

Now we will change overlap length. It was equal to (window length)/2 up to now and we will consider overlap length as: 0, (window length)/2, (window length) *(19/20). We will only consider Kaiser window for this comparison. (In order to change overlap length, you need to change the code, we did not make it as an input argument.)

Signal length: 4000 samples.

Window length: 200 samples.

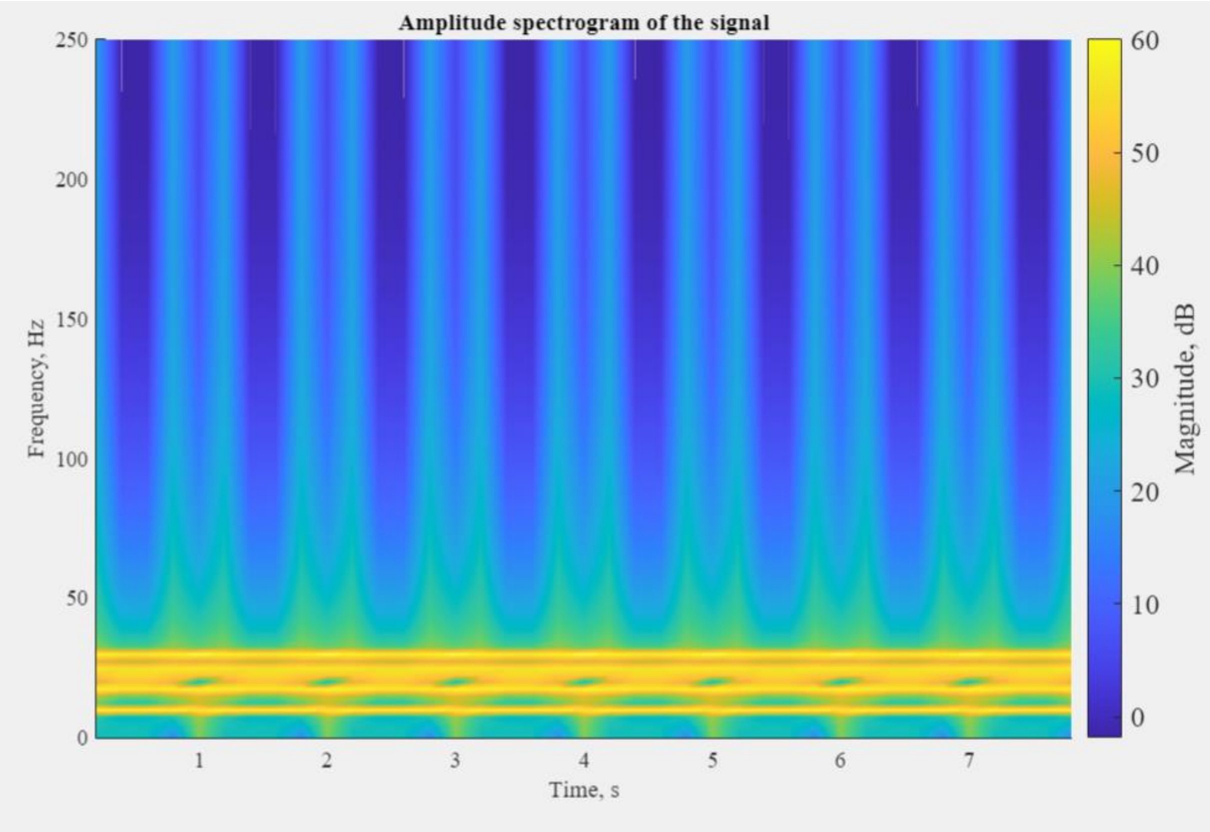

Figure 124. Spectrogram of the Multiple Sinusoidal Signal with window Kaiser (200) with overlap 100.

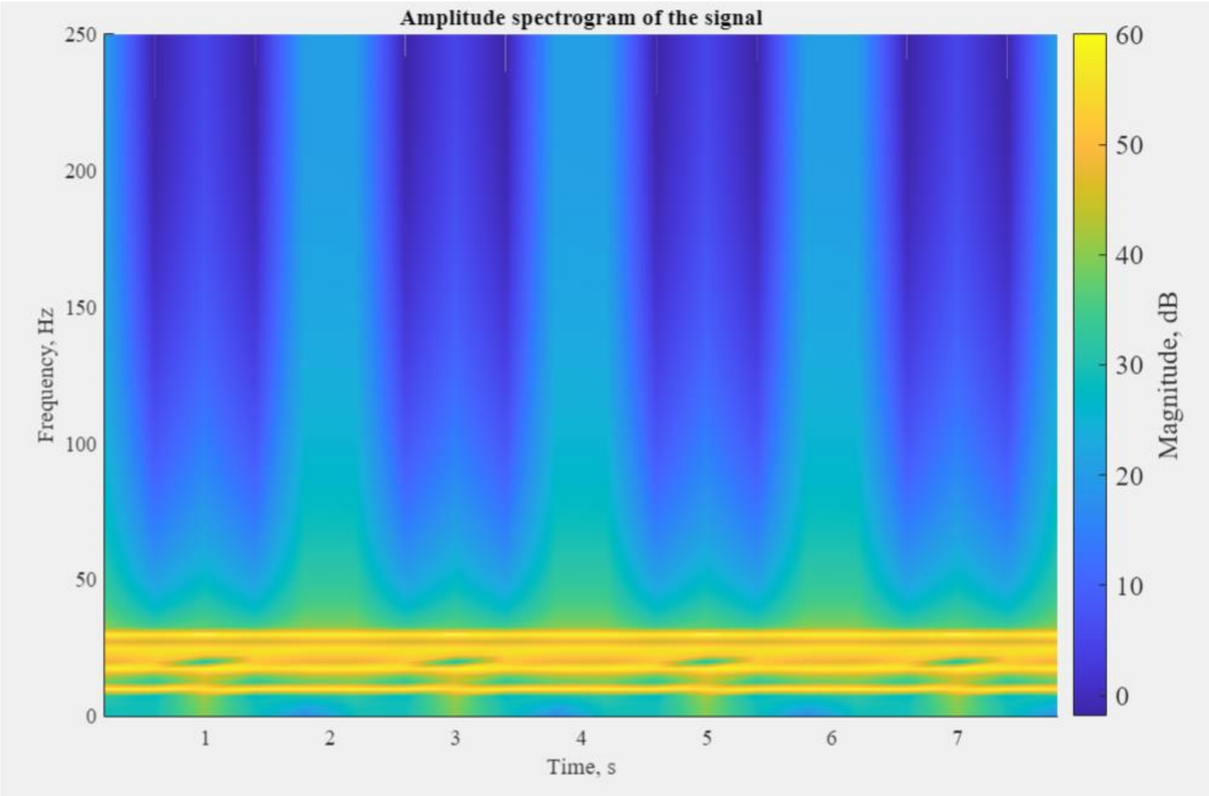

Figure 125. Spectrogram of the Multiple Sinusoidal Signal with window Kaiser (200) with overlap 0.

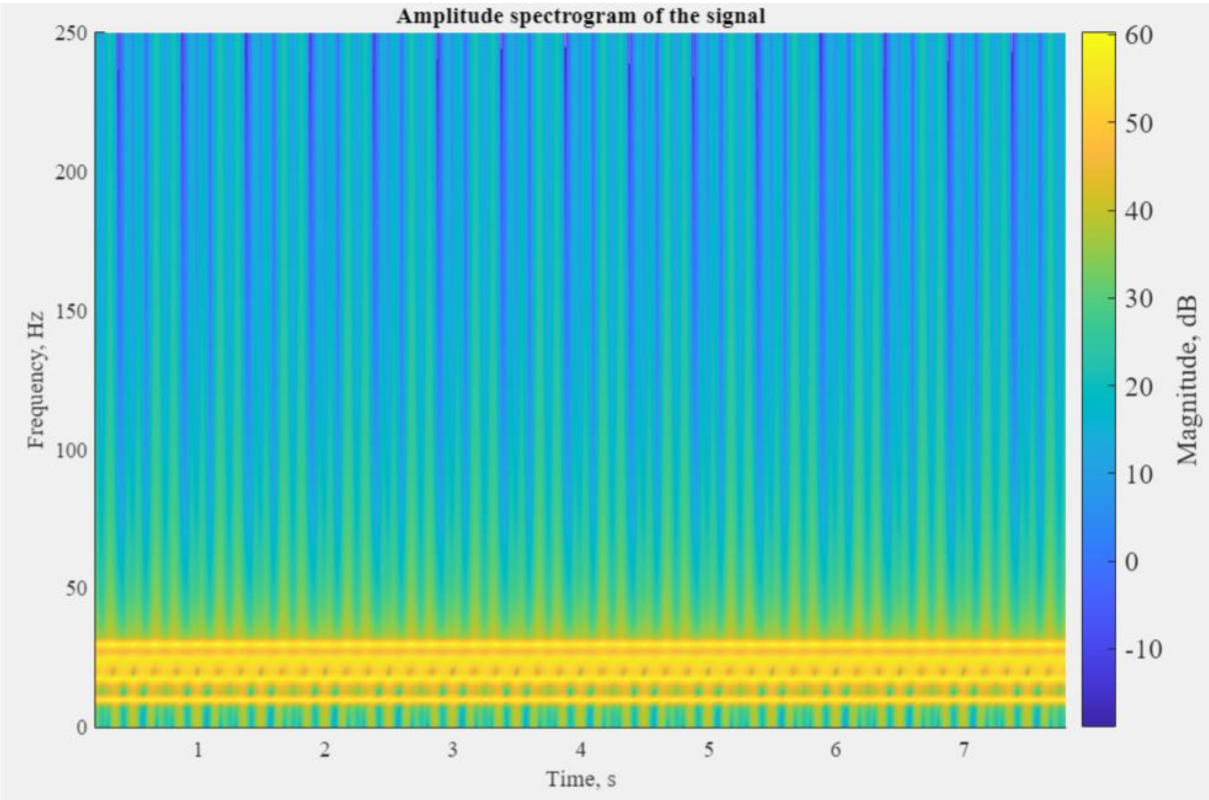

Figure 126. Spectrogram of the Multiple Sinusoidal Signal with window Kaiser (200) with overlap 190.

As we can see from the spectrogram figures, as overlap length increases it gives more accurate results. Decreasing overlap length may cause data loss.

Our Spectrogram Function:

In our spectrogram function, we mainly used stft() function of MATLAB. This stft function takes the signal, window type and length, overlap length, fft length as inputs. Firstly, STFT helps to visualize the signal both in time and frequency domain together. To obtain STFT of a signal, DFT of the sum of windowed frames of the signal needs to be computed. Since we know that DFT can be obtained by sampling the DTFT, we used fft function in our code, and fft length represents the DFT length actually. Moreover, overlap length is important to obtain the spectrogram of the signal clearly, since not all window types are constant through time such as Kaiser, Gaussian etc. Therefore, after windowing signal, there may be data loss in these nonlinear regions. To overcome this problem, some portions of windowed signal should overlap. Then, by taking the absolute value of STFT result in dB scale, we get the spectrum of signal. Also, since stft function involves fft function, it plots both positive and negative frequencies. Therefore, we clipped the negative frequency part which is the same as positive frequency part since our signals are real.

Conclusion:

In this project, window types and their applications were discussed. It is shown that window types must be used according to user needs because not all window types give same output for same input, and some of them are more useful for different applications. Also, window length should be chosen according to window type and input signal length. Signals can be analysed using spectrogram. This spectrogram can be constructed from STFT of the signal. STFT is used to analyse the frequency spectrum of the signal for selected time interval. We observed different spectrograms for same inputs to understand the usage of different window types. Also, we observed the input signals both time and frequency domain to compare the correctness of the spectrogram results. Moreover, we changed the overlap length to understand its effect on spectrogram.