EXPERIMENT – 5

NOISE REALIZATION

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Aim:

To generate and analyze a Gaussian random process in MATLAB, compute its auto-correlation function, and study the frequency spectrum of the auto-correlation function. Additionally, to evaluate the effect of noise on a message signal with different amplitude values, analyze its auto-correlation, and observe the corresponding frequency spectra.

Theory:

NOISE REALIZATION:

Gaussian Random Process:

• A Gaussian random process has a normal distribution with mean (μ) and variance (σ^2).

• The power spectral density of white noise is given by:

$$S_{x(f)} = \frac{N_0}{2}$$

Autocorrelation Function:

• Measures signal similarity at different time shifts:

$$R\_x(\tau) = E[X(t)X(t+\tau)]$$

• The frequency spectrum of the autocorrelation function is obtained via Fourier Transform.

Message Signal with Noise:

• The message signal is given by:

$$x(t) = A\cos(2\pi f_c\, t + \theta) + w(t)$$

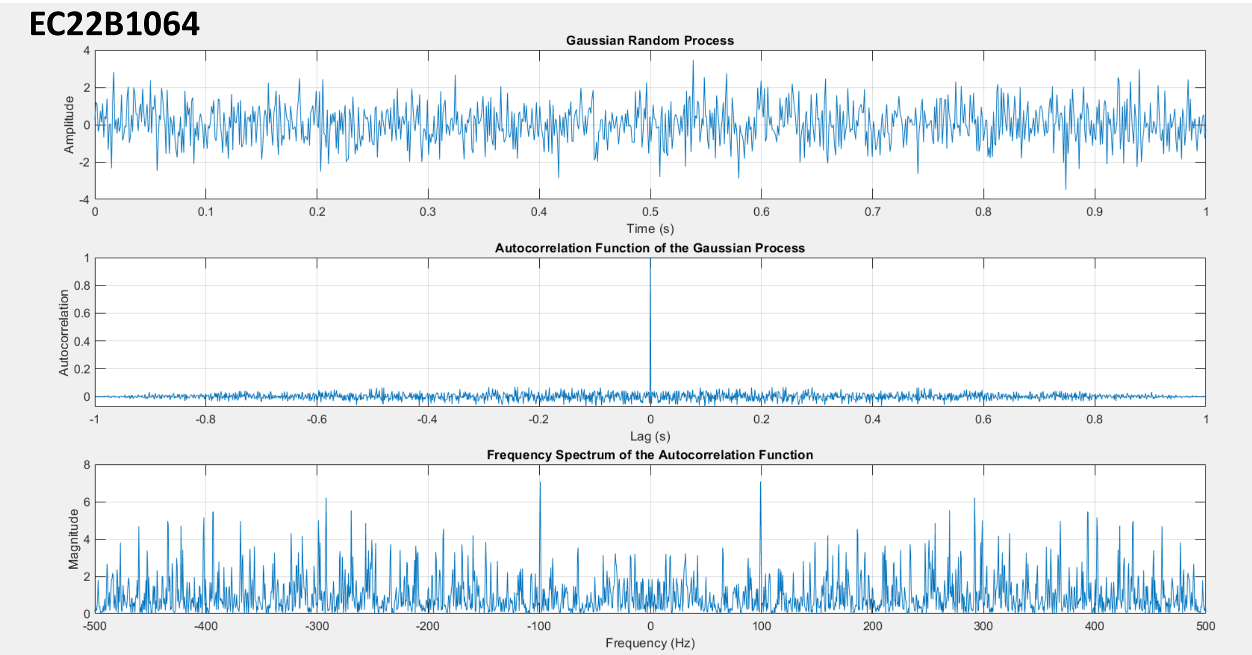
where θ ~ U(-π, π) and w(t) is white noise.

• The effect of noise on the signal is analyzed for different amplitudes (A = 10, 1, 0.1).

Q1) Plotting the Gaussian random process and its auto-correlation function and its frequency spectrum

```
N = 1000;
T = 1;
fs = N/T;
t = linspace(0, T, N);
x =randn(1, N);
figure;
plot(t, x);
title('Gaussian Random Process');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
```

```
[Rxx, lags] = xcorr(x, 'normalized');
tau = lags / fs;
figure;
plot(tau, Rxx);
title('Autocorrelation Function of the Gaussian Process');
xlabel('Lag (s)');
ylabel('Autocorrelation');
grid on;
Rxx_fft = abs(fftshift(fft(Rxx)));
freq = linspace(-fs/2, fs/2, length(Rxx));
figure;
plot(freq, Rxx_fft);
title('Frequency Spectrum of the Autocorrelation Function');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;
```



Q2) Plotting auto-correlations functions and spectra for the given equation at different values of the Amplitude

```
N = 1000;
T = 100;
fs = N / T;
t = linspace(0, T, N);
fc = 100;
w = randn(1, N);
theta = -pi + (2 * pi) * rand;
A_values = [10, 1, 0.1];
figure;
for i = 1:length(A_values)
    A = A_values(i);
    x = A * cos(2 * pi * fc * t + theta) + w;
```

```
    subplot(3, 3, (i - 1) * 3 + 1);
    plot(t, x);
    title(['Message Signal x(t), A = ', num2str(A)]);
    xlabel('Time (s)');
    ylabel('Amplitude');
    grid on;

    % Compute and plot autocorrelation function
    [Rxx, lags] = xcorr(x, 'normalized');
    tau = lags / fs;

    subplot(3, 3, (i - 1) * 3 + 2);
    plot(tau, Rxx);
    title(['Autocorrelation, A = ', num2str(A)]);
    xlabel('Lag (s)');
    ylabel('Autocorrelation');
    grid on;
    % Compute and plot frequency spectrum of the autocorrelation function
    Rxx_fft = abs(fftshift(fft(Rxx)));
    freq = linspace(-fs/2, fs/2, length(Rxx));

    subplot(3, 3, (i - 1) * 3 + 3);
    plot(freq, Rxx_fft);
    title(['Spectrum of Autocorrelation, A = ', num2str(A)]);
    xlabel('Frequency (Hz)');
    ylabel('Magnitude');
    grid on;
end

sgtitle('Message Signal, Autocorrelation, and Spectrum for Different Amplitudes');
```

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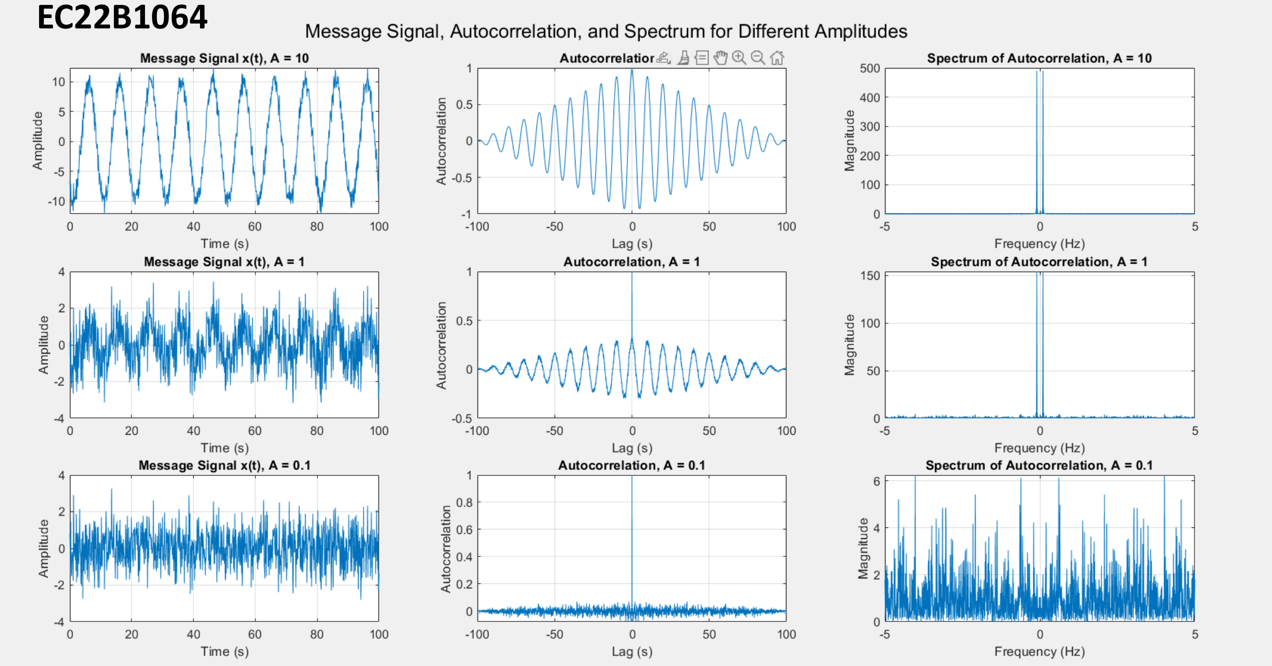

Inference:

• The Gaussian random process exhibits random variations but follows a normal distribution.

• The autocorrelation function shows the degree of similarity between signal instances over time.

• The power spectrum analysis reveals the frequency distribution of noise and signal components.

• The message signal's shape changes with different A values, affecting its autocorrelation and frequency spectrum.

Conclusion:

The experiment successfully demonstrated noise realization and its impact on signal characteristics. The autocorrelation and spectral analysis provided insights into how noise alters a message signal, emphasizing the significance of amplitude variations in signal processing.

References:

[1] Simon Haykins, Communication systems, 2nd ed. (New York John Wiley and Sons, 2005).