EE451 LAB REPORT

LAB 3 – Optimum Receiver for the AWGN Channel

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Procedure

3.1 Creating Signal Waveforms

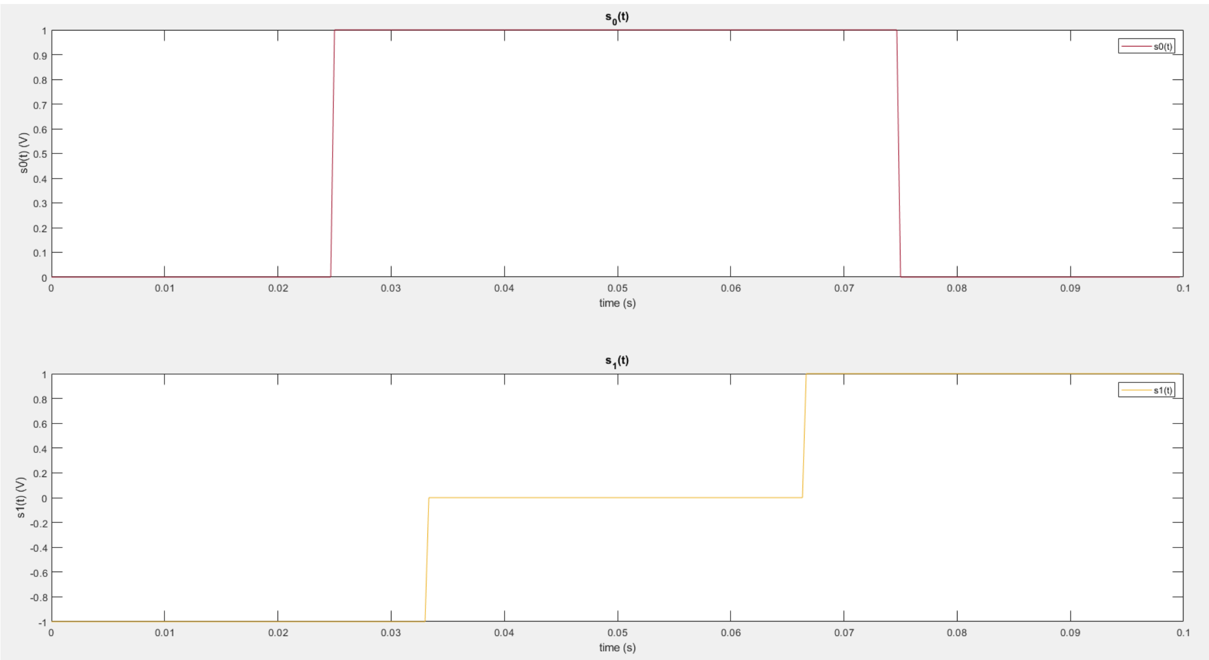

Figure 1: Representation of the symbol waveforms

```
s0=[zeros(1,Tb/(4*Ts)) ones(1,Tb/(4*Ts)) ones(1,Tb/(4*Ts)) zeros(1,Tb/(4*Ts))];
s1=[(-1)*(ones(1,Tb/(3*Ts))) zeros(1,Tb/(3*Ts)) ones(1,Tb/(3*Ts))];
```

Two symbol waveforms, s0(t) and s1(t), are generated in accordance with Figure 1. These waveforms represent binary 0 and 1 bits. The code plots these waveforms using the subplot function, providing a visual representation of the symbols.

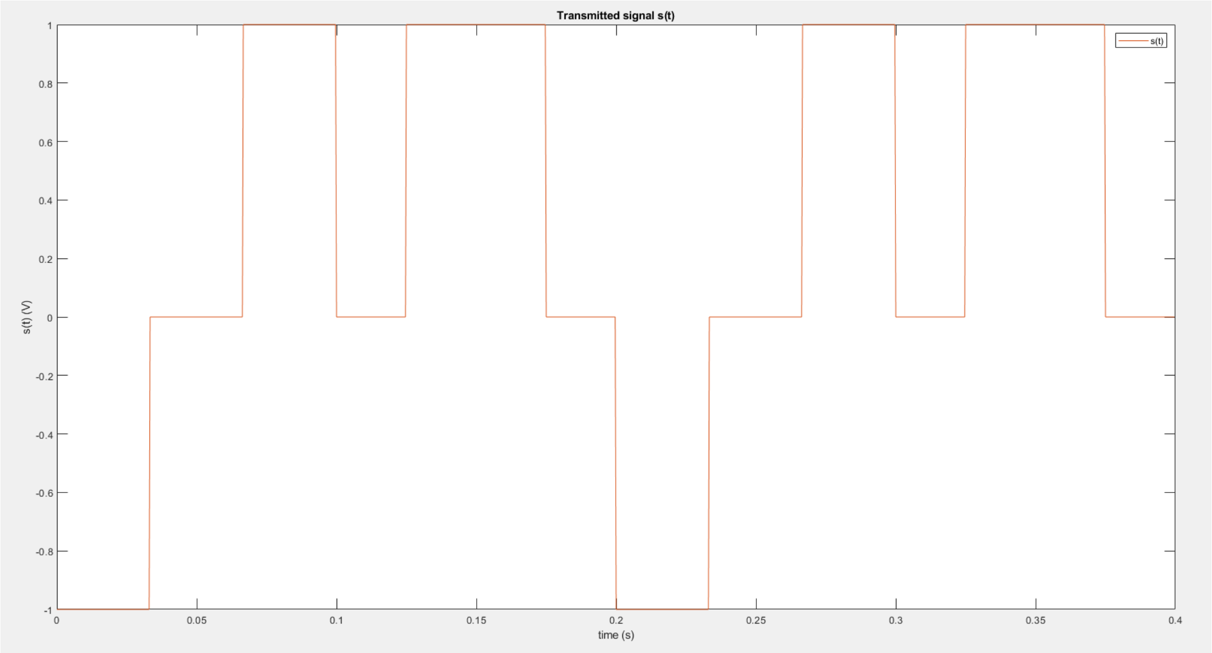

Figure 2: The Transmitted Signal s(t) Depending on the Binary Sequence

```
b=[1 0 1 0];
st = [];
for k=1:length(b)
    if (b(k)==0)
        st =[st s0];
    else
        st =[st s1];
    end
end
```

The code constructs the transmitted signal (st) based on a given binary sequence (b). For each bit in the sequence, it appends the corresponding s0(t) or s1(t) waveform to the transmitted signal. The resulting signal is then plotted to show how the binary sequence translates into the transmitted signal.

```
Pavg= sum(abs(st).^2)/length(st);
```

which calculates the average transmit power (Pavg) of the transmitted signal, which is a key parameter for assessing signal quality and performance.

The calculated average transmit power (Pavg) of 0.5833. It reflects the signal's energy content and power efficiency. This value is essential for evaluating signal performance, especially in the context of transmission over an additive white Gaussian noise (AWGN) channel and varying signal-to-noise ratios (SNR).

3.2 Additive White Gaussian Noise (AWGN) Generation

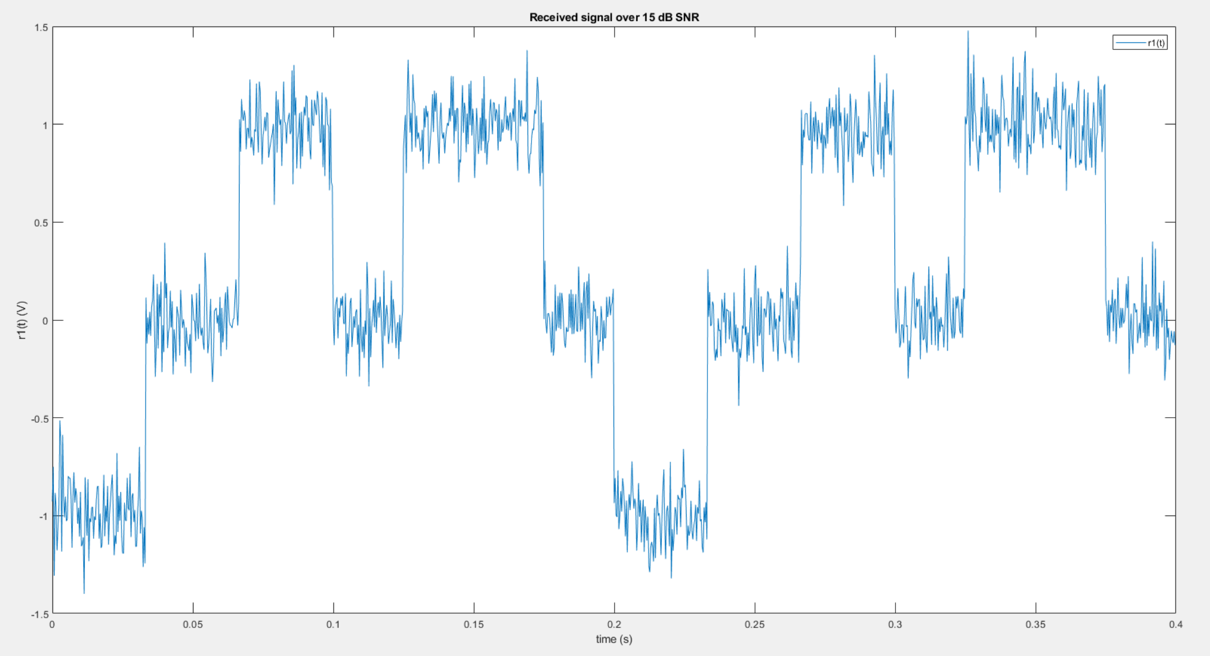

Figure 3: Received Signal Over 15 dB SNR

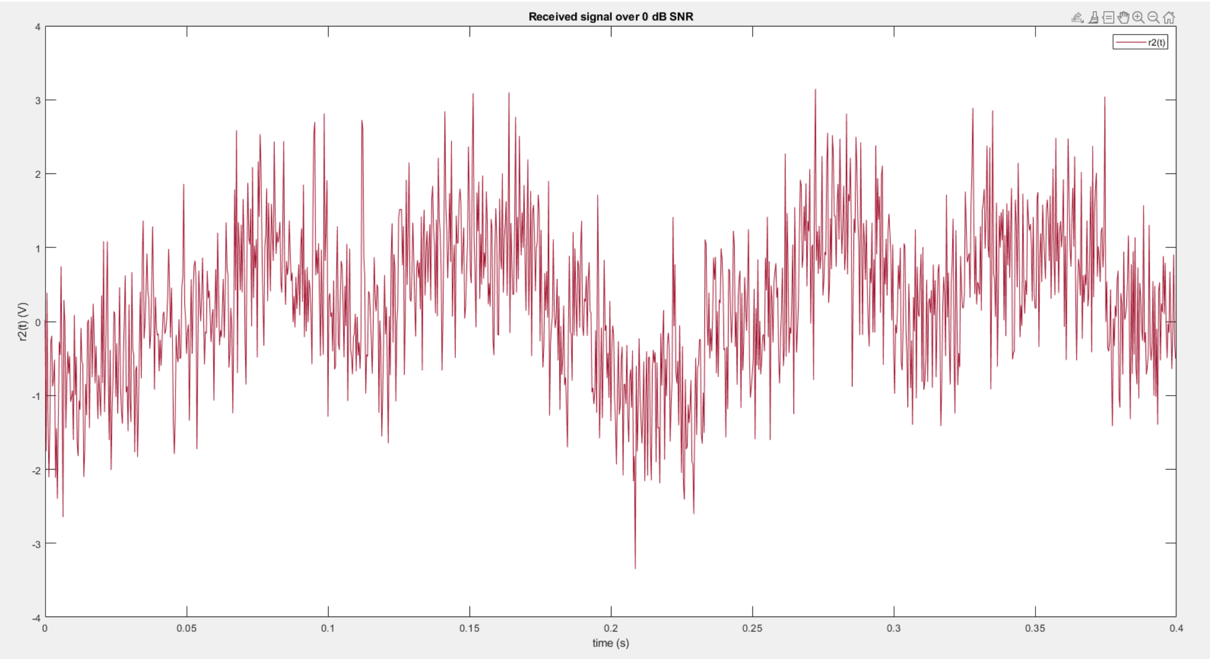

Figure 4: Received Signal Over 0 dB SNR

```
snr_db=[15 0];
snr_lin(1)=10^(0.1*snr_db(1));
snr_lin(2)=10^(0.1*snr_db(2));
var(1)=Pavg/snr_lin(1);
var(2)=Pavg/snr_lin(2);
awgn1=sqrt(var(1))*randn(1,length(st));
awgn2=sqrt(var(2))*randn(1,length(st));
rt1 = st + awgn1;
rt2 = st + awgn2;
```

The code simulates the transmission of the signal over an additive white Gaussian noise (AWGN) channel. It introduces random noise (AWGN) to the transmitted signal based on specified signal-to-noise ratios (SNR) of 15 dB and 0 dB. The received signals (rt1 and rt2) are calculated for both SNR conditions and plotted to demonstrate the effects of noise on the signal.

In this step, it can be observed that SNR represents the power of the signal compared to the power of noise. When SNR value is 0 dB, it is not power efficient and not possible to save the information on the message signal since the noise is too much.

3.3 Correlation Receiver

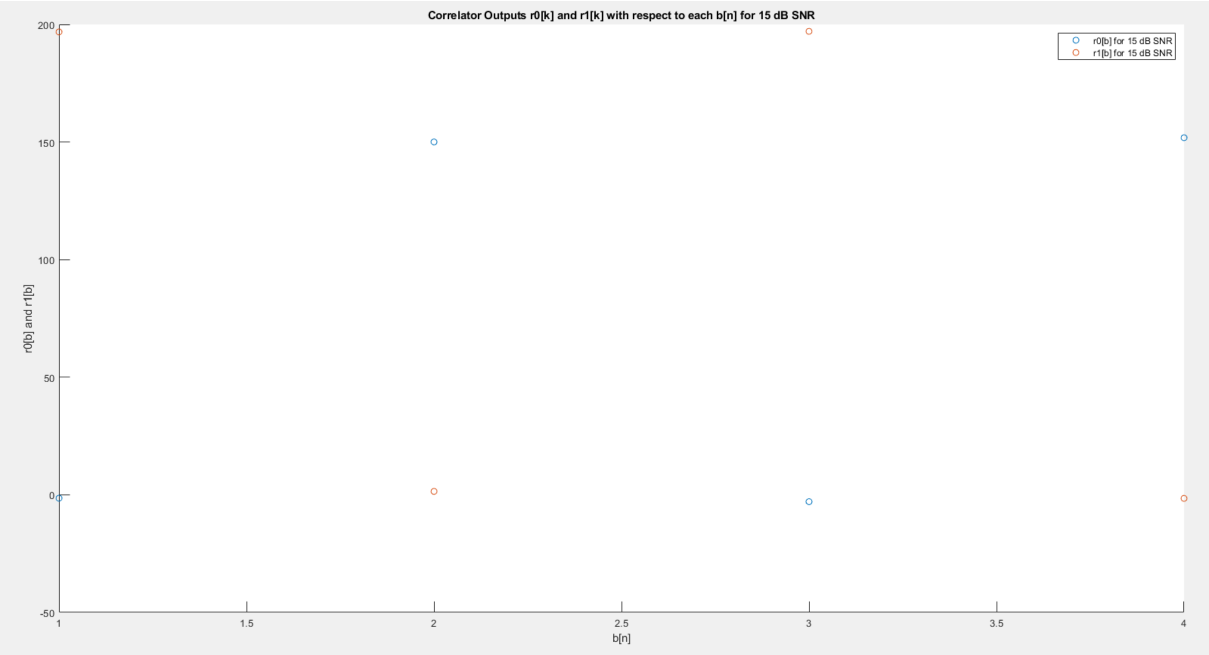

Figure 5: Correlator Outputs r0[k] and r1[k] with respect to each b[n] for 15 dB SNR

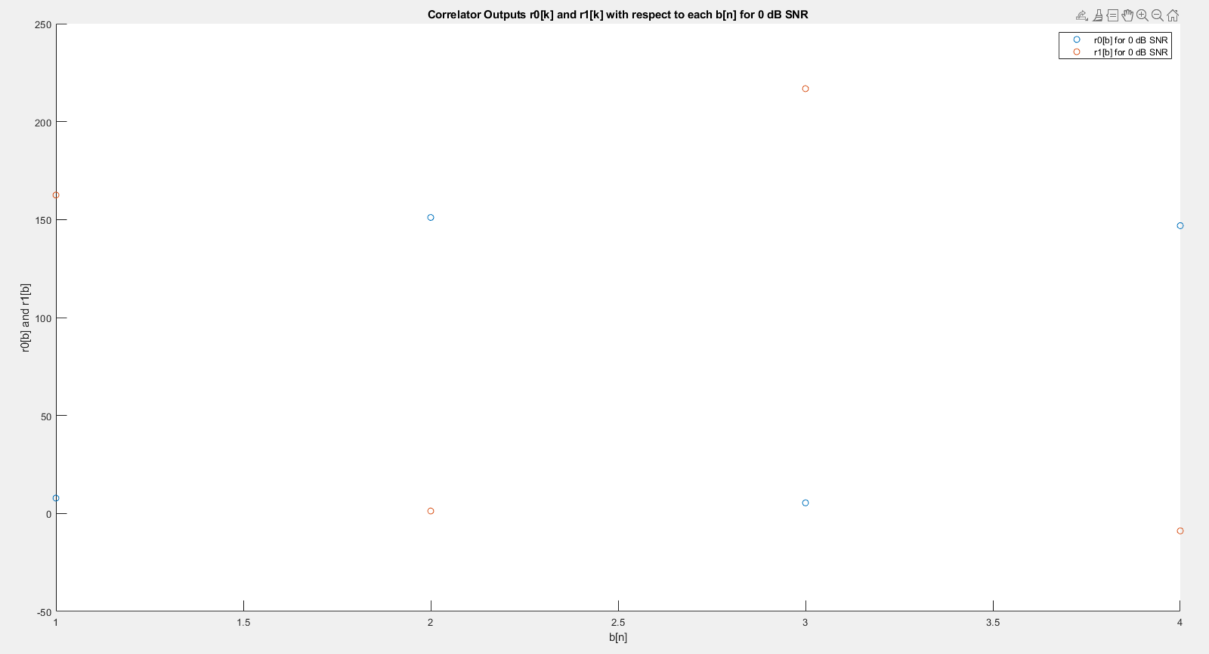

Figure 6: Correlator Outputs r0[k] and r1[k] with respect to each b[n] for 0 dB SNR

```
Wb=Tb/Ts;
r10=[];
r11=[];
r20=[];
r21=[];
for k=1:N
    sum10=0;
    sum11=0;
    sum20=0;
    sum21=0;
    for n=((k-1)*Wb+1):k*Wb
        sum10 = sum10+rt1(n).*s0((n-(k-1)*Wb));
        sum11 = sum11+rt1(n).*s1((n-(k-1)*Wb));
        sum20 = sum20+rt2(n).*s0((n-(k-1)*Wb));
        sum21 = sum21+rt2(n).*s1((n-(k-1)*Wb));
    end
    r10(k)=sum10;
    r11(k)=sum11;
    r20(k)=sum20;
    r21(k)=sum21;
end
```

A correlation receiver is designed to evaluate the relationship between the transmitted symbols and the received signal. The code calculates the correlator outputs (r0[k] and r1[k]) for both SNR conditions. These outputs are plotted and presented in a scatter plot, allowing a clear visualization of the correlation results with respect to each symbol (k).

Comment

The main difference between SNR at 15 dB and SNR at 0 dB for correlation in this case is the level of noise relative to the signal. Here's a brief comparison:

- **SNR at 15 dB:**

At 15 dB SNR, the signal power is 15 decibels higher than the noise power. This indicates a relatively strong and clean signal compared to the noise.

Correlators tend to work well in high SNR conditions because the signal is dominant and easily distinguishable from noise.

Correlation outputs (r0[k] and r1[k]) are likely to show tight clusters around the expected values, and symbol detection is expected to be highly accurate.

- **SNR at 0 dB:**

At 0 dB SNR, the signal power is equal to the noise power. This signifies a challenging scenario where the signal is on par with the noise.

Correlators may face greater difficulty in distinguishing the signal from noise, leading to a potentially larger overlap in correlation outputs.

Symbol detection accuracy might be affected, and the bit error rate (BER) may increase as the noise level becomes more significant relative to the signal.

In summary, the main difference between an SNR of 15 dB and an SNR of 0 dB for correlation is the relative strength of the signal compared to the noise. High SNR values typically result in more accurate and reliable correlation, while low SNR values can introduce challenges and potential errors in the correlation process. Therefore, correlators are expected to perform better and more robustly at higher SNR levels.

3.4 Remaining Questions for Report

Q1. What is the AWGN channel, and why is it considered a fundamental model in communication systems?

A1. The Additive White Gaussian Noise (AWGN) channel is regarded as a fundamental model within communication systems owing to its capacity to authentically emulate the noise encountered in real-world communication situations. Its mathematical simplicity, linearity, and universal applicability render it a pragmatic instrument for the examination and evaluation of the efficacy of diverse communication strategies.

Q2. Explain the concept of the optimum receiver for AWGN channels. How does it maximize the Signal to-Noise Ratio (SNR)?

A2. The concept of the optimal receiver for Additive White Gaussian Noise (AWGN) channels is centered on enhancing Signal-to-Noise Ratio (SNR) to achieve the best communication system performance. AWGN channels model noise in communication systems using a Gaussian distribution. The optimal receiver, also called the "matched filter" or "maximum likelihood receiver," focuses on maximizing SNR for reliable data reception. It works by representing the transmitted signal as a waveform and then estimating the original signal using maximum likelihood estimation (MLE). The receiver correlates the received signal with potential signal waveforms to identify the one that best matches it, leading to a decision on the most likely transmitted information. This MLE process optimizes SNR by minimizing the noise impact, ensuring reliable data reception in AWGN channels.

Q3. Explain the steps involved in designing a correlator for a specific communication system application.

A3. Considering the example of designing a correlator for a specific communication system application involving digital signals, such as a GPS receiver for global positioning.

- **Define the Requirements:**

Develop a correlator for a GPS receiver that can accurately and quickly determine the user's position.

- **Signal Characteristics Analysis:**

GPS signals are transmitted in L1 and L2 bands, have known frequency and phase relationships, and experience delays due to the user's position.

- **Choose Correlation Technique:**

Use a cross-correlation approach to compare incoming GPS signals with known GPS satellite codes.

- **Define the Reference Signal:**

GPS satellite codes, which are known pseudo-random noise (PRN) sequences for each satellite.

- **Digital Implementation:**

Choose a digital implementation for the correlator.

- **Design the Correlator Architecture:**

Design a digital signal processing (DSP) system with dedicated hardware to perform fast and efficient cross-correlation.

- **Signal Processing:**

Implement efficient algorithms for cross-correlation, including fast Fourier transforms (FFTs) and code-phase search.

- **Noise and Interference Handling:**

Employ signal filtering and error correction to mitigate noise and interference from atmospheric conditions and multipath reflections.

- **Performance Optimization:**

Optimize the correlator for fast signal acquisition and tracking, considering factors like power consumption and sensitivity.

- **Simulation and Testing:**

Simulate the GPS correlator's performance under various conditions and test it with recorded GPS signals.

- **Iterative Design:**

Fine-tune the correlator's parameters to ensure optimal performance.

- **Integration into the GPS Receiver:**

Integrate the correlator into the GPS receiver, ensuring it interfaces with other components like the antenna and navigation algorithms.

- **Real-World Testing:**

Perform field tests in real-world GPS environments to validate the correlator's accuracy and speed in determining the user's position.

- **Documentation and Compliance:**

Document the GPS correlator's design, specifications, and operating procedures, ensuring it complies with GPS signal standards.

- **Maintenance and Upgrades:**

Plan for maintenance and potential future upgrades to keep the GPS receiver and correlator up to date with evolving GPS systems and technologies.

Q4. What are the advantages of using correlators in the presence of noise, and how do they contribute to improving the overall system performance?

A4. Correlators improve system performance in noisy conditions by enhancing signal detection, increasing signal-to-noise ratio, rejecting interference, and ensuring accurate data recovery. They are versatile tools suitable for various applications, offering real-time operation and efficient noise suppression.