Communication Theory Project – Report

Introduction

This document includes all my explanations and answers for the Communication Theory project.

I used the course project tasks and example code as a starting point, then expanded them in MATLAB into a complete working simulation covering all requested tasks. The implementation includes oversampling, RRC pulse shaping, multipath filtering, and noise scaling.

All simulations use R = 10 MHz, oversampling factor r = 4, N_symbols = 10000, and roll-off α = 0.2.

There are 31 figures in total for project, but as the instructions asked, I chose the most relevant figures for each part which are 11 in total.

Tasks 1 – TX Pulse, Spectrum, and Observations

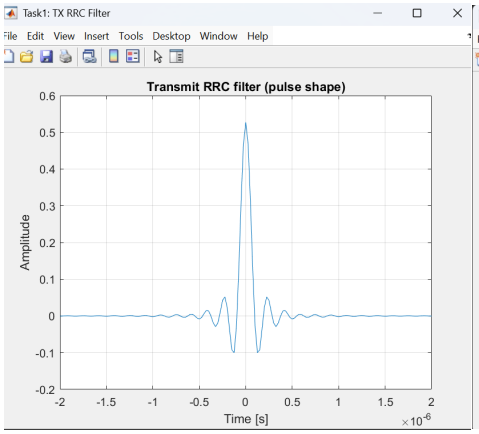
• I generated the RRC pulse using MATLAB's rcosdesign() function.

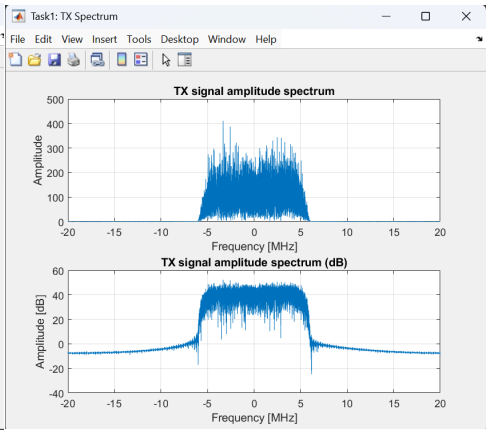
• The pulse has the expected main lobe and decaying side lobes. Because the roll-off factor was 0.2, the bandwidth is around R(1+α).

• The TX spectrum looks clean and smooth and matches what we expect from a square-root raised cosine filter.

• The dB plot shows the roll-off clearly and the attenuation outside the main band.

• The side lobes decay due to the time-domain sinc-like shape of the RRC pulse.





Tasks 2 – SNR Effects, Multipath, Fading Notches, and Channel Responses

• When I lowered the SNR (0–10 dB), the noise floor rose and the RX spectrum looked messy.

• At higher SNR (20–50 dB), the spectrum becomes almost identical to the TX spectrum.

• Multipath created strong dips (fading notches) in the RX spectrum. These are easy to see in both linear and dB scales.

• I plotted the channel frequency response using the FFT of the impulse responses b1, b2, and b3 (as suggested in the PDF).

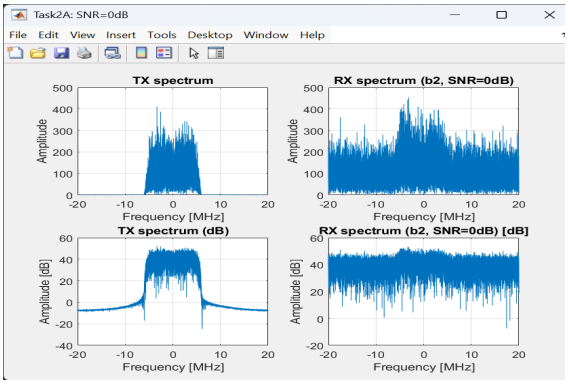
– b1 is flat (no multipath).

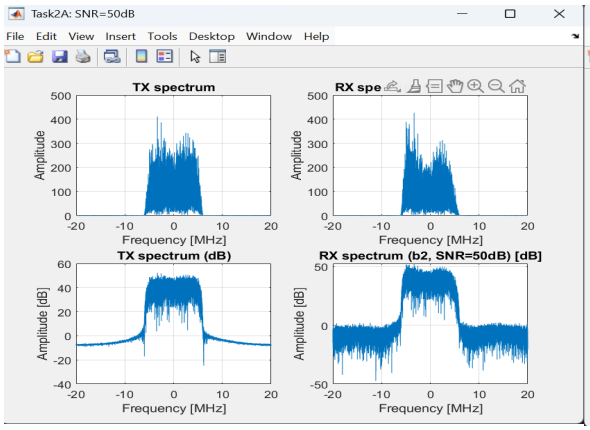
– b2 shows some frequency selectivity.

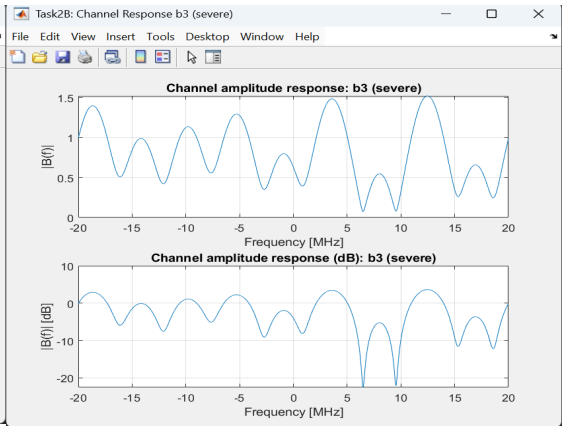
– b3 produces deep and sharp notches.

• These notches explain why even at very high SNR, the received signal can still be distorted.

• **The fading notches occur at frequencies where multipath components destructively interfere, creating frequency-selective fading**







Tasks 3 – RX Constellations vs SNR, Multipath, and Modulation Order

• I used the matched filter (same RRC pulse) for the receiver, exactly as recommended in the PDF.

• I sampled every r-th sample to recover qk (the symbol-rate samples).

SNR effects:

– At 35 dB, the constellation is tight.

– At 20 dB, the clouds are larger but still separate.

– At 10 dB, the clouds start overlapping and errors become likely.

Multipath effects:

– With b2 or b3, the clusters shift and smear even at high SNR.

– This happens because multipath introduces ISI that noise cannot fix.

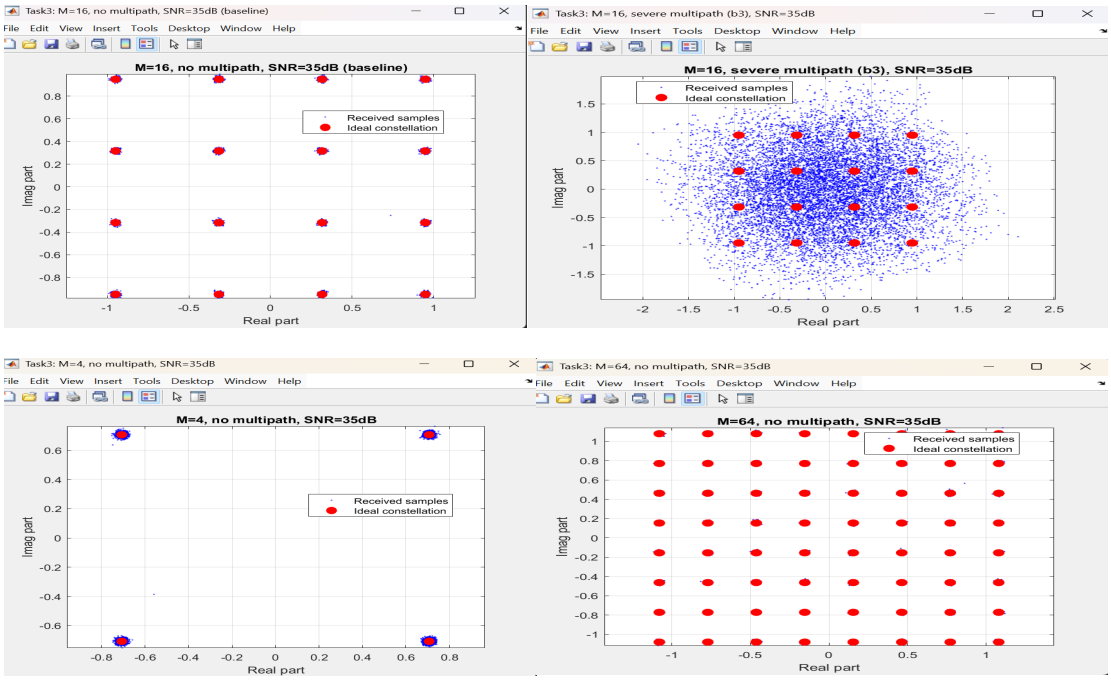
Modulation order effects:

– QPSK (M=4) behaves very well even at lower SNR because symbols are far apart.

– 16-QAM is a middle ground (used for most of the project).

– 64-QAM becomes very sensitive; even small distortion spreads clusters enough to overlap.

_ At 10 dB with multipath, the receiver would likely need equalization to reliably decode the signal.



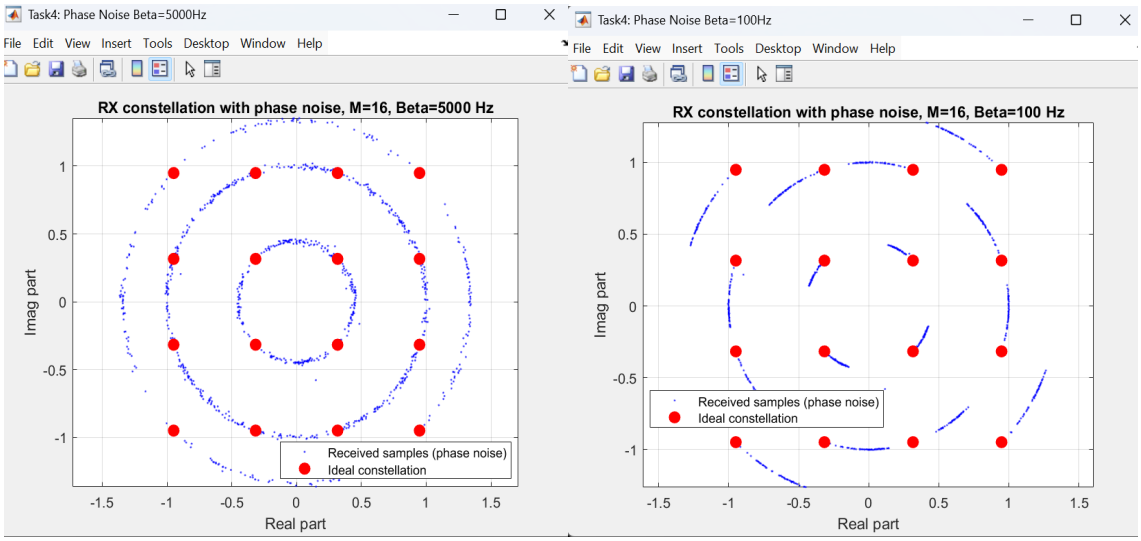
Tasks 4 – Phase Noise

• I used the provided phasenoise() function to model phase noise.

• With Beta = 100, the phase changes slowly, so the constellation rotates slightly but stays readable.

• With Beta = 5000, the phase wiggles very fast, causing the constellation to smear into arcs or circles.

• This makes symbol decisions very difficult, even though there is no AWGN or multipath in this part.



Summary

Across all tasks, I simulated pulse shaping, multipath, noise, and phase noise.

I integrated and extended the provided code for oversampling, filtering, and IQ noise scaling into the complete simulation.

The project clearly shows how SNR, channel distortion, and phase noise affect QAM constellations and system performance.

The results demonstrate the fundamental trade-off between spectral efficiency (higher M) and robustness to impairments.

References

These references support the technical background, standards, and tools used in this report.

[1] Tampere University, "Communication Theory: course project instructions and example MATLAB code," course material, 2025.

[2] MathWorks, "rcosdesign - Raised cosine FIR pulse-shaping filter design," MATLAB documentation.

[3] J. G. Proakis and M. Salehi, Digital Communications, 5th ed. New York, NY, USA: McGraw-Hill, 2008.