Three Calculation-Based Questions from the Paper

Question 1: DMRS Overhead and Spectral Efficiency Calculation

Based on the paper's DMRS configurations, calculate:

Given a 5G NR system with:

- 14 OFDM symbols per slot
- 3,300 active subcarriers
- QPSK modulation (2 bits/symbol)
- Code rate 1/2

For configuration T4F12 (4 DMRS symbols in time, DMRS every 12th subcarrier):

a) Calculate the total number of resource elements (REs) per slot

b) Calculate the number of DMRS REs per slot
c) Calculate the percentage overhead due to DMRS

d) Calculate the effective data rate if slot duration is 0.25 ms

Solution: a) Total REs per slot = 14 symbols × 3,300 subcarriers = 46,200 REs

b) DMRS REs = 4 symbols × (3,300/12) subcarriers = 4 × 275 = 1,100 REs

c) DMRS overhead = (1,100/46,200) × 100% = 2.38%

d) Data REs = 46,200 - 1,100 = 45,100 REs

Bits per slot = 45,100 × 2 bits/symbol × 0.5 code rate = 45,100 bits

Data rate = 45,100 bits / 0.25 ms = 180.4 Mbps

Question 2: Link Budget Impact of PAPR Reduction

From the paper's results, calculate the link budget improvement:

Given:

- Original system with 6 dB back-off requires SNR = 3.2 dB for BER = 10^{-4}
- System with 2 dB back-off requires SNR = 4.0 dB for BER = 10^{-4} (T7F6 configuration)
- Power amplifier output capability: 100W at saturation

Calculate: a) Actual transmit power with 6 dB back-off

b) Actual transmit power with 2 dB back-off

c) Net link budget improvement considering both power increase and SNR penalty

Solution: a) $P_{6dB} = \frac{100W}{10^{\frac{6}{10}}} = \frac{100W}{3.98} = 25.1W = 14.0\ dBW$

b) $P_{2dB} = \frac{100W}{10^{\frac{2}{10}}} = \frac{100W}{1.58} = 63.3W = 18.0\ dBW$

c) Power gain = 18.0 - 14.0 = 4.0 dB

SNR penalty = 4.0 - 3.2 = 0.8 dB

Net improvement = 4.0 - 0.8 = 3.2 dB

Question 3: Doppler Shift and CFO Estimation for Multi-arm Receiver

Based on the paper's PSS detection approach for LEO satellites:

Given:

- Carrier frequency: 30 GHz
- LEO altitude: 600 km
- Maximum Doppler shift: ±720 kHz
- PSS signal duration: 1 OFDM symbol = 16.67 μs (at 60 kHz SCS)
- Multi-arm receiver spacing: Δf = 1/(2T_sig)

Calculate: a) The frequency spacing between adjacent arms in the multi-arm receiver

b) The number of arms required to cover the full Doppler uncertainty

c) The residual CFO after initial acquisition (worst case)

Solution: a) $\Delta f = \frac{1}{2\times 16.67\times 10^{-6}} = \frac{1}{33.34\times 10^{-6}} = 30\ kHz$

b) Total Doppler range = 2 × 720 kHz = 1,440 kHz

Number of arms = 1,440 kHz / 30 kHz = 48 arms

c) Worst-case residual CFO = Δf/2 = 30 kHz / 2 = 15 kHz

This is within the ±15 kHz range that standard 5G NR receivers can track