CHEATSHEET

January 17, 2025

1 MobCom Cheatsheet

Creating a cheat sheet for **David Tse's "Fundamentals of Wireless Communication"** involves summarizing the key mathematical concepts and principles in a compact format. Here's an organized breakdown:

1.0.1 1. Signal Representation

- **Baseband and Passband Signals**:
    - $x(t) = \text{Re}\{\tilde{x}(t)e^{j2\pi f_c t}\}$
    - Complex baseband: $\tilde{x}(t) = x_I(t) + jx_Q(t)$
- **Fourier Transform**:
    - $X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}dt$
    - Parseval's Theorem: $\int |x(t)|^2 dt = \int |X(f)|^2 df$

1.0.2 2. Channel Models

- **Additive White Gaussian Noise (AWGN)**:
    - $y(t) = h(t) * x(t) + n(t)$
    - $n(t) \sim \mathcal{CN}(0, N_0)$
- **Multipath Channel**:
    - $h(t) = \sum_{l=1}^{L} h_l \delta(t - \tau_l)$
    - Coherence Bandwidth: $B_c \sim \frac{1}{\Delta\tau}$
- **Doppler Shift**:
    - $f_d = \frac{v}{\lambda}$
    - Coherence Time: $T_c \sim \frac{1}{f_d}$
- **Rayleigh and Rician Fading**:
    - Rayleigh: $|h| \sim \text{Rayleigh}(\sigma)$
    - Rician: $|h| \sim \text{Rice}(K)$

1.0.3 3. Capacity

- **Shannon's Capacity**:
    - $C = B\log_2(1 + \text{SNR})$ for AWGN.

- **MIMO Channel Capacity**:
    - $C = \log_2 \det \left(I + \frac{\text{SNR}}{M_t} H H^\dagger \right)$
- **Water-Filling Algorithm**:
    - Power allocation: $P_i = \left(\mu - \frac{\sigma_i^2}{|h_i|^2} \right)^+$

1.0.4   4. Diversity

- **Order of Diversity**:
    - $P_{\text{outage}} \propto \text{SNR}^{-d}$
    - $d = $ Number of Independent Paths
- **Combining Techniques**:
    - Maximal Ratio Combining (MRC): $y = \sum h_i^* y_i$
    - Selection Combining: Select the best h_i.

1.0.5   5. Modulation

- **PSK**:
    - $s_k = e^{j2\pi k/M}$, $k \in [0, M-1]$
- **QAM**:
    - Constellation points: $\sqrt{E_s} \cdot (\pm 1 \pm j)$
- **Probability of Error**:
    - $P_e \sim Q \left(\sqrt{2\text{SNR}} \right)$ for BPSK.

1.0.6   6. Coding

- **Channel Coding Theorem**:
    - $R < C$: Reliable transmission possible.
- **Hamming Bound**:
    - Minimum distance $d_{\min}$: $2t + 1$, where t is the error-correcting capability.
- **LDPC and Turbo Codes**:
    - Iterative decoding with near-capacity performance.

1.0.7   7. OFDM

- **Orthogonality**:
    - $\int_0^T e^{j2\pi f_n t} e^{-j2\pi f_m t} dt = 0$, $n \neq m$
- **Subcarrier Spacing**:
    - $\Delta f = \frac{1}{T}$, $T = $ Symbol duration.
- **Cyclic Prefix**:
    - Prevents ISI by appending $T_{\text{CP}} \geq \tau_{\max}$.

1.0.8 8. MIMO

- **Spatial Multiplexing**:
  - $y = Hx + n$, $H \in \mathbb{C}^{N_r \times N_t}$
  - Rank: $\min(N_t, N_r)$
- **Diversity-Multiplexing Tradeoff**:
  - $d + r = N_t \cdot N_r$

1.0.9 9. Random Matrices

- **Wishart Distribution**:
  - $W = XX^\dagger, X \sim \mathcal{CN}(0, I)$
- **Eigenvalue Distribution**:
  - Marchenko-Pastur law.

1.0.10 10. Estimation and Detection

- **MMSE Estimator**:
  - $\hat{x} = \frac{\sigma_x^2 h^* y}{\sigma_x^2 |h|^2 + N_0}$
- **ML Detection**:
  - $\hat{x} = \arg\min_x ||y - Hx||^2$

This cheat sheet simplifies key formulas and principles. For deeper understanding, refer to the text for derivations, examples, and insights.

[ ]: