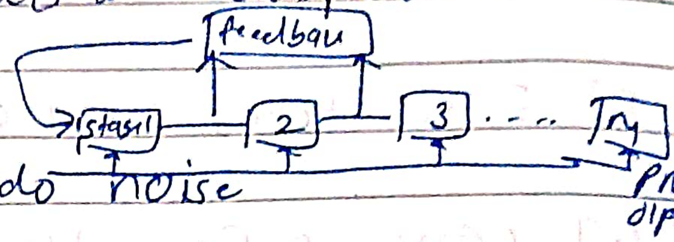
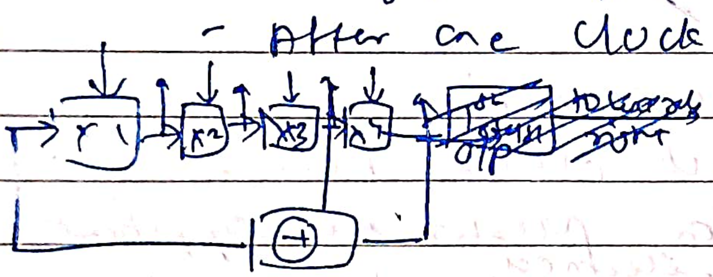
- Physical, data, network, transport
  Application



I) PN Sequence generator - Pseudo noise
- appears random
- Used for spread-spectrum technologies, error checking, encryption

① - PN sequence generator using linear feedback shift register (core components)
  - 4 storage Registers - x1, x2, x3, x4
  - modulo 2 adder (XOR)
- feedback path
  - x3 ^ x4 fed back into x1

② Shift Register operation:
- After one clock pulse, content of each register shift one position to right



x3 → x4
x2 → x3
x1 → x2
(feedback result) x3 ^ x4 → x1

- Initial condition 1000 after every 15 clock pulses, seq repeats

③ Properties of PN:
- Balance condition: no. of 1s = no of 0s
- Run property: 0's 1's appear in specific pattern & lengths

④ PN sequence Type:
- $2^n - 1$: maximal length
  n = no. of stage registers (4)

* Real life usage: several BS operating in service areas & using same frequency are differentiated from one another by using PN seq.

Shift Registers: a series of stages that store bits temporarily.

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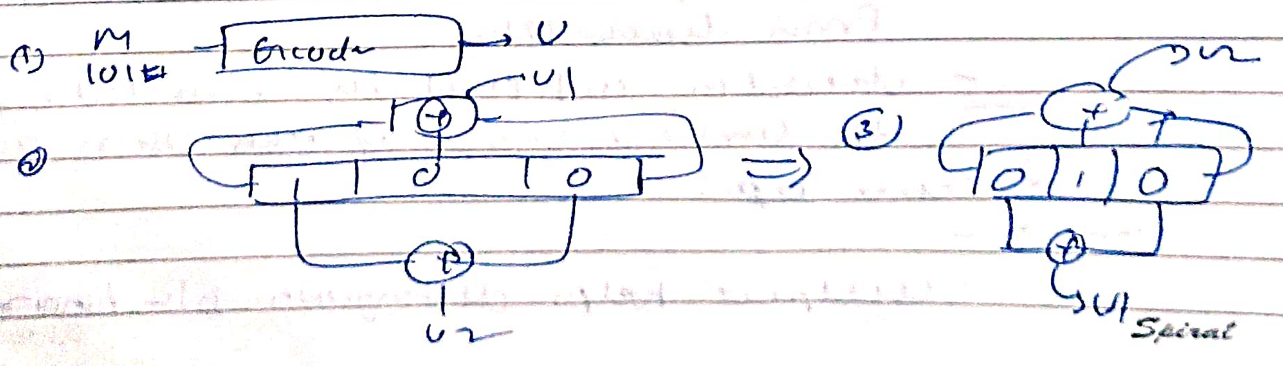
II) Convolution Codes

1. Convolution codes:
   - type of error correction codes, detect & correct errors during transmission
   - (Block codes - data ÷ into fixed-size blocks)
   - CC continuously encode data in a flowing sequence

2. Working:
   - Redundant bits are added to the message
   - Redundancy introduced by passing message thru shift register
   - A finite state shift register processes the input bit-by-bit & outputs multiple encoded bits (per) input bit

3. Code Rate: Ratio of i/p bits to o/p bits
   - $R = k/n$ k: no. of msg bits
     n: no. of encoded bits / (per) message bit
   - e.g. i/p = 100   o/p = 111011

CODE: 1. t (5): original message bits to encode
2. x1, x2, x3: store current & previous bits
3. Encoding process:
   - x1: updated to next bit of t
   - u1: 1st encoded bit (x1 ^ x2 ^ x3)
     u2: 2nd -||- (x1 ^ x3)
4. u1, u2: Redundant bits



Ak, Bk → spreading codes for A & B
Ad, Bd → Data

I) As, Bs → Spread signal → $Ak*a$ & $Bk*b$
~~Ak~~ → a $As(i) = Ak(i) * a$

II) $CS = as + bs$
III) Decoding: $cs * Bk = ds$
IV) $\Sigma ds = e (Carr)$
V) $e < 0 → 0$ bits, 1 bits

(III) CDMA

1. Code Division multiple Access:

- Communication method
- Multiple users share the same frequency by assigning spreading code, often generated thru pseudorandom sequences
- (Spreading codes / chip sequence) –
  - spreads a users narrow band over a wider BW
  - hiding the signal in noise
- Chip Rate vs Data Rate
  - Chip rate >> data rate
  - ↳ Increasing security & reduces interference
- Orthogonality:
  - two codes → inner product = 0
  - ensures minimal interference
  - e.g. A [a_1 a_2 a_3]   B [b_1 b_2 b_3]
    $IP = a_1 \times b_1 + a_2 \times b_2 + a_3 \times b_3$
    if $IP \neq 0$: would interfere w/ e/o
- Auto correlation:
  - ~~Sorted~~ - correlation of a signal w/ a delayed copy of itself
- CDMA Transmission eg.
  - Each user multiplies their data by respective spreading code
  - Combined channel signal contain contri from both users
  - decoding achieved by correlating the combined signal w/ each users code seq
- Receiver op:
  -
- Output helps distinguish b/w binary data

e: 0
- received signal does not strongly correlate w/ users spreading code
- low probability that user sent "1"

e: 1 received signal
- strongly correlation w/ users spreading code
- User sent a "1"

SC   DATA
×
SS $CSS = SS(A) + SS(B)$
Decoded = SS × SC
Inner = decoded (c) Σ
↳ < 0 : 0
  > : 1

Ad – Ak
Bd – Bk

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(IV) Path loss prediction formula:
- Calculat Received signal strength based on distance between Transmitter & Receiver

(1) Path loss prediction
- Reduction in power density of EM wave as it propagates thru space

(2) Larg scal fading:
- predicts avg received signal strength over distances ranging from a ~~few hundred m~~ mtr to kms
- considers effect like reflection, diffraction & scattering which can influence signal strength

(3) Friis free space propagation loss
$$P_r(d) = \frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi d)^2}$$

- do : Distance Reference pt
a close-in reference distance

1A: $P_r(d) = P_r(d_0) + 20\log\left(\frac{d_0}{d}\right)$

1B: Tx Pow OR Pt OR Pt(do) & n or np
$PL(d_0) = P_t(d_0) - P_r(d) = P_t(d_0) - P_r(d_0) + 10 n_p \log_{10}\left(\frac{d}{d_0}\right)$

1C: $PL(d) = P_t - P_r(d)$
$PL(d) =$

STEPS: (1) calculation of Received Power
(2) Pathloss exp (np)
Carrier freq
Receive Antenna height
BS Antenna height

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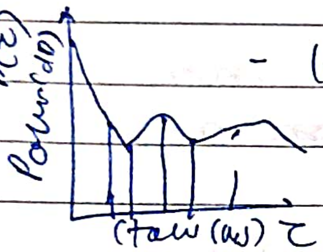
V) Fading:

- Variations in signal amplitude, phase & delays caused by multipath propagation
- In urban environments,
  - mobile antenna – obstructed by
    - surrounding structures



  - leading to signals arriving via
    - various paths, due to
      - reflection
      - diffraction
      - scattering
  - This results in combination of signals w/ different amplitude, phases & propagation delays

① RMS Delay (RMS) $= \sum_k (P(\tau_k) \cdot \tau_k)$

$\tau_1 = 0.02$ $P(\tau_1) = -15$

$\tau_2 = 0.03$ $P(\tau_2) = -17$

$\tau_3 = 0.04$ $P(\tau_3) = -20$

$\tau_4 = 0.09$ $P(\tau_4) = -14.5$

$\vdots$

$= 0.02 \times -15 + 0.03 \times -17 + 0.04 \times -20 + 0.07 \times -14.5$

$= -2.915$

②

dB - linear

$$P_{linear}(\tau_i) = 10^{\left(\frac{P(\tau_i)}{10}\right)} = P_e(\tau_i)$$

0.43

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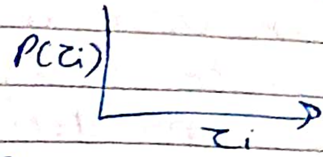
V) FORMULAS Urban microcellular Line of Sight

① Root mean square (RMS)



$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2}$$

$$\bar{\tau} = \frac{\sum P_e(\tau_i) \cdot \tau_i}{\sum P_e(\tau_i)} \qquad \overline{\tau^2} = \frac{\sum P_e(\tau_i) \cdot \tau_i^2}{\sum P_e(\tau_i)}$$

② Mean Excess Delay (MEDelay)

$$\bar{\tau} = \frac{\sum P(\tau_i) \cdot \tau_i}{\sum P(\tau_i)}$$

③ Coherence BW for correlation ≥ 0.5 in MHz

$$B_c(0.5) \approx \frac{1}{5 \cdot \sigma_\tau} \approx \frac{1}{5 \times RMS}$$

④ Coherence BW for correlation ≥ 0.9 in MHz

$$B_c(0.9) \approx \frac{1}{50 \cdot \sigma_\tau}$$

⑤ Maximum excess delay (τ_{max}) in μs

$$\tau_{max} = \tau_x - \tau_0$$

max delay ↗ ↳ usually minimum delay

4+2+1

$N = (4) + (2)(1) + (1)$
$= 7$

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VI) FR:

- Each User connects to a N/W using a radio resource, (freq/code), dedicated for duration of that session
- Due to broadcast nature of wireless signals, once a radio resource is allocated, it remains w/ user until session ends
- This limits the no. of user a base station can support simultaneously

① Signal Attenuation:
- As signal travels further from a BS, strength
- Beyond a certain distance then drop
- At this distance, the same frequency can be reused in other areas w/o interference

② Cluster ~~or co-channel~~ Co-channel use same set of frequencies within a system
- group of cells
- each cell has unique set of frequencies
- within a cluster no

Formula: (6A)

① Cluster size $(N) = i^2 + ij + j^2$

② System capacity $= M \times K \times N$
M = no. of cluster
$K \times N$ = total freq in each cluster

③ FR factor $= 1/N$

(6B). No. of clusters $= \dfrac{\text{Total coverage area}}{N \times \text{Area of cluster}}$, Area $= \dfrac{3\sqrt{3}R^2}{2}$ cell radius

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