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Mobile Systems

Lab Supp 3: Bit-error control

COMP28512

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Task 3

3.1: Effect on bit-errors & speech quality of reducing or increasing transmit power.

3.2: Effect of bit-errors on speech quality without FEC

3.3: Effect of bit-errors on speech quality with FEC
   (applying a (3,1) repetition scheme as FEC method)

3.4: Apply ARQ to text with CRC

3.5. Modified form of ARQ applied to text.

Part 3.1: Talk time & energy per bit

- Assume mobile phone is using 1 watt of power to send speech at 128 kbit/s.
- If battery holds 18000 joules*, how much talk time?
- Ans: 18000 joules at 1 joule/s (watt) gives:

  18000 s = 5 hours
- What is the average energy per bit at the transmitter?
- Ans: 1 joule/s $\div$ 128x10^3 bit/s = $(1/128)\times10^{-3}$ joules per bit

- Assuming 50 dB loss over channel to receiver, what is average energy per bit (E_b) at the receiver?
- Ans: $(1/128)\times10^{-3} \div 10^5 = (1/128)\times10^{-8}$ joules per bit

* 1000x(18000/3600)/3.7 mAh = 1351 mAh with a 3.7 volt battery

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Channel noise

- Radio channel has a certain bandwidth, say 30,000 Hz.
- Channel includes the receiver which also adds noise.
- (Receiver has a high gain amplifier which adds noise)
- Noise power can be measured in watts.
- It is common to measure channel noise in watts per Hz.
- This is ‘power spectral density’ N_0
- Typical value: $N_0 = 10 \times 10^{-12}$.

E_b/N_0 – a measure of signal-to-noise ratio

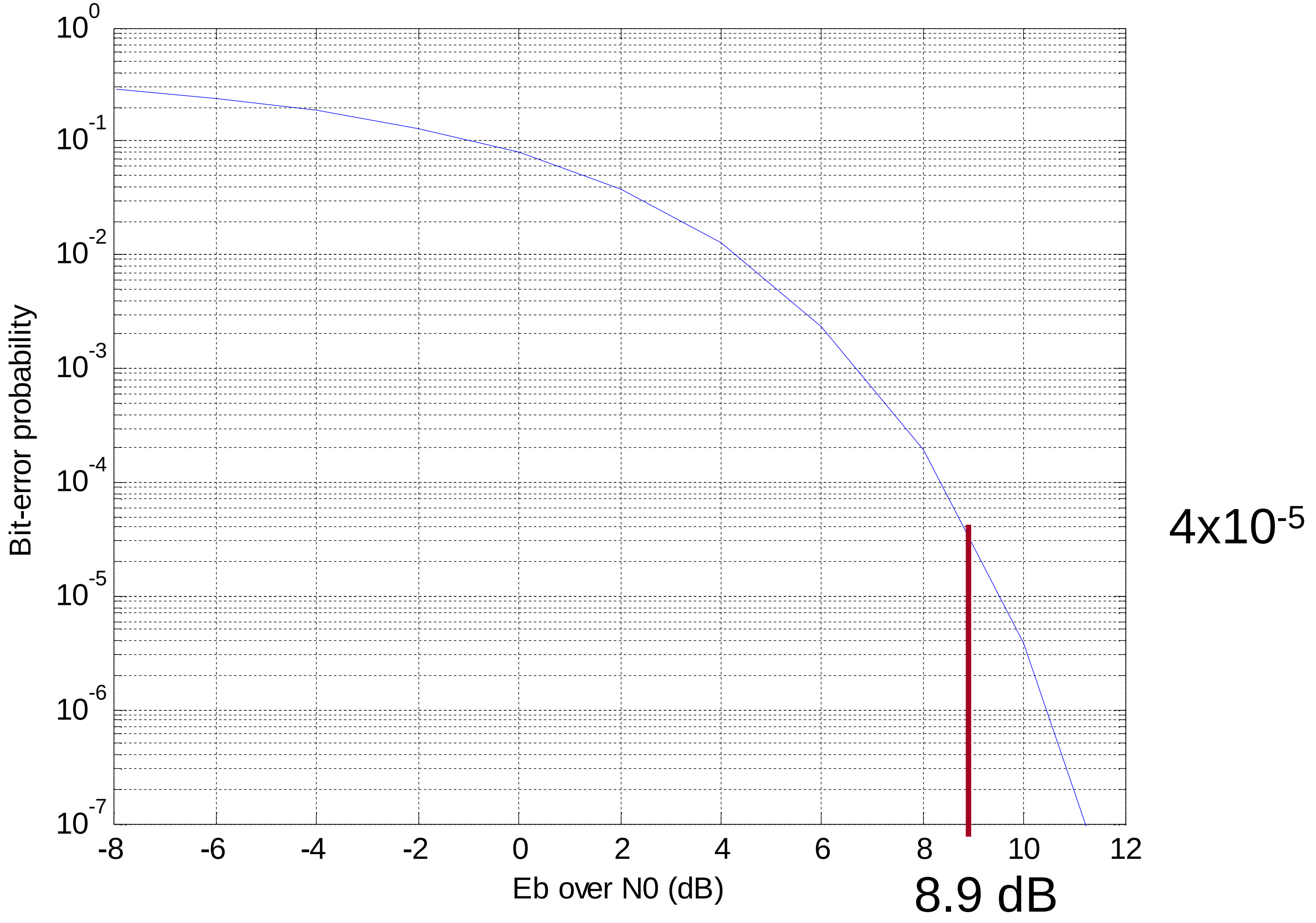
- What is Eb/N_0 at the receiver?
- Ans: $(1/128)\times10^{-8} / (10\times10^{-12}) = 7.8$

  Expressed in dB: $10\times\log_{10}(7.8) = 8.93$ dB.
- Assume bits are transmitted by "binary minimum shift keying" (binary msk) as used by 2G mobile phones.
- Form of frequency modulation:
  - a certain freq for '1' & a different freq for '0'
- Well known formula gives expected bit-error probability:

  $$beP = 0.5*\text{erfc}(\sqrt{(E_b/N_0)}\ ) \quad (E_b/N_0 \text{ not in dB here})$$
- Next slide plots this formula (with E_b/N_0 in dB).
- Allows you to deduce that:

  $$beP = 0.5*\text{erfc}(\sqrt{(7.8)}) \approx 4\times10^{-5}$$

Waterfall graph for msk



A thought about E_b/N_0

- Universally used, but a little difficult to understand.
- Multiply numerator & denom by channel bandwidth B Hz.

$$E_b / N_0 = \frac{E_b \times B}{N_0 \times B} = \frac{(Energy/bit) \times B}{Noisepower(watts)}$$

$$= \frac{(joules/second) \times B/(bits/second)}{Noisepower(watts)}$$

$$= \frac{Signalpower(w)}{Noisepower(w)} \div \underbrace{(bits/second)/B}$$

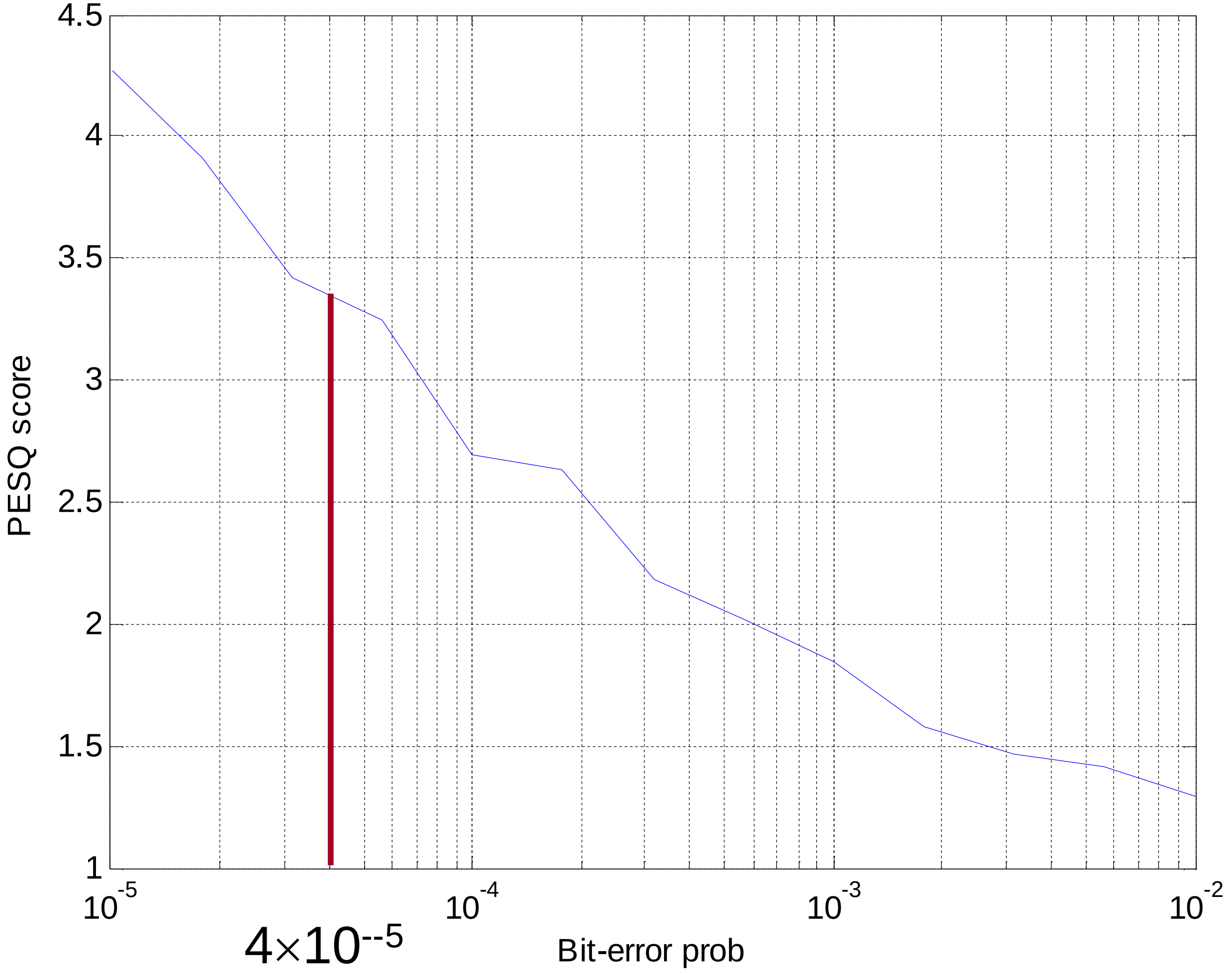
Bits/second per Hz (of channel)

“Bandwith efficiency”

PESQ score against beP

- We now know how bit-error probability varies with signal to noise ratio (E_b/N_0).
- Often called 'bit-error rate' (BER) rather than beP.
- Interesting to discover how speech quality varies with BEP (or BER).
- Measure speech quality automatically using PESQ.
- Task 3 produces a demonstration of how speech quality gets worse as BER increases.
- Following graph may be produced by experiment:

PESQ score against beP



For narrow-band speech at 128 kbit/s

3.4

Speech quality obtained

- From previous graph, PESQ obtained is about 3.4.
- Assume we try to extend battery life by reducing transmit power from 1 watt to 0.8 watt.
- Battery life increases from 5 to 6.25 hrs.
- E_b decreases to $(1/16)\text{x}10^{-3}$ joules/bit at transmitter

  $(1/16)\text{x } 10^{-8}$ at receiver
- E_b/N_0 at receiver decreases to $10^3/160 = 7.96\text{dB}$
- By waterfall graph, beP increases to $2\text{x}10^{-4}$
- By PESQ graph, PESQ reduces to 2.5.

∴Reducing transmit power from 1 to 0.8 watt increases battery life by 1.25 hrs, but reduces speech quality from PESQ 3.4 to 2.5.

Part 3.1: Effect of increasing/decreasing transmit power

- Relationship between battery life at mobile phone transmitter & speech quality at receiver to be demonstrated, when there is no FEC.
- Can FEC improve this result?

Part 3.2: Effect of changes in bit-error probability (no FEC)

- Demonstrate effect of evenly distributed bit-errors on narrow-band speech.
- Gradually increasing bit-error probability: starting from 0.00001 and ending at 0.01
- No FEC for bit-error correction

Part 3.3: Effect of a very simple FEC scheme

- Send each bit 3 times.
- Block coding scheme much easier than Hamming.
- Use majority voting at receiver.
- Is this an efficient scheme?

Part 3.4: ARQ applied to text

- Append 8-bit CRC to bit-array representing some text.
- Transmit over channel.
- Vary the BEP from 0.0001 to 0.1.
- Repeat transmission if CRC fails.
- Try up to 9 times & then give up.
- Is this efficient?
- Can it be improved?
- Pseudo-code for CRC on next slide.

Part 3.5: Modified form of ARQ

- Is ARQ efficient?
- Can it be improved by ‘Chase’ combining?
- (Combining failed transmissions)
- Try it out for up to 3 failed transmissions.

Pseudo-code for CRC

```
function check=CRC8(xa)
   # xa is array of bits transmitted or received as row vector
   # This function generates 8-bit CRC check remainder as 1x8 row-vector
   # Generator polynomial is g(x) = x^8 + x^2 +x + 1
   g8x = [1 0 0 0 0 0 1 1 1] ;  # Generator polynomial (row-vector)
   xae = [xa 0 0 0 0 0 0 0 0];  # Append 8 zeros to bit-stream
   xsa=xae(1:9);
   for i=1:length(xa):
      if xsa(1) == g8x(1):
         xsa = xor(xsa,g8x);
         end;
      xsa(1:8)=xsa(2:9);
      if i<length(xa):
           xsa(9)=xae(i+9);
           end;
      end; # of i loop
  check = xsa(1:8); % 8 bit CRC row-vector
  return check;
```

Summary of Task 3

- Relationship between energy & bit-error rate demonstrated.
- Also relationship between BER & speech quality.
- Simple (3,1) repetition FEC scheme investigated.
- ARQ implemented & improved for text