EE5801: CSP Lab/EE5301: DSP Lab
EE3701: Communication Systems Lab
(Aug – Nov 2022)

Lecture 5

Today’s Topic

- BER/SER performance evaluation of digital modulation techniques such as BPSK,QPSK over AWGN channel.

System model

- Wired channel or AWGN channel

$$y = x + n$$

- Wireless SISO(Single Input Single Output) channel

$$y = h * x + n$$

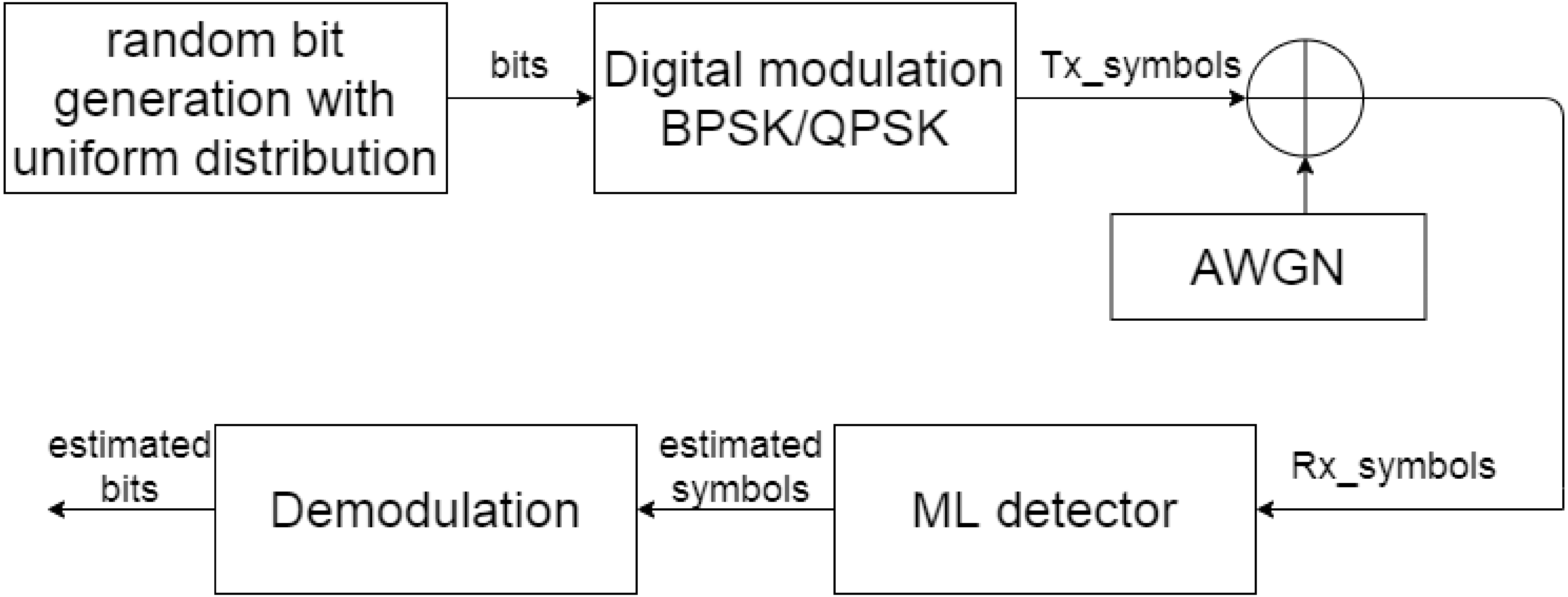
where $\mathrm{x} = Transmited\ symbol$

$\mathrm{h} = \mathrm{wireless\ channel\ gain\ or\ channel\ coefficient}$

$\mathrm{y} = Recived\ symbol\ at\ reciever$

$\mathrm{n} = AWGN(Adittive\ White\ Gaussian\ Noise)$

Block diagram of AWGN or wired channel



Explanation of each blocks

- In Matlab use ‘randi’ command to generate random bits with uniform distribution.
- Map bits to symbols
  - **BPSK** symbol set = {1,-1};
    Ex: $0 \rightarrow 1, 1 \rightarrow -1$
  - **QPSK** symbol set = {1+1i,1-1i,-1+1i,-1-1i};
    Ex: $00 \rightarrow 1 + 1i$
- Complex AWGN noise generation(Device noise at receiver)
  - $n = sd * (randn + 1i\, randn)$

Explanation of each blocks(contd…)

- ML detector(minimum distance decoder)

$$estimated\ symbol(\hat{x}) = \min_{x \in C} |y - x|^2$$

- Ex: For BPSK, $C = \{1, -1\} = \{x_1, x_2\}$

  1. find $d_1 = y - x_1$ and $d_2 = y - x_2$

  2. if $d_1 > d_2$, then $\hat{x} = x_2$

     else if $d_1 < d_2$, then $\hat{x} = x_1$

- In demodulation estimate the bits from symbol

Points to be noted for simulation

- Average Energy of a $Symbol\ set(C)$ is

  $E_s = \frac{1}{M}\sum_{i=1}^{M}|x_i|^2$ where $x_i \in C$ and M=length of C
- BPSK symbol set={1,-1}

  Average energy: $E_s = 1$
- QPSK symbol set={1+1i,1-1i,-1+1i,-1-1i}

  Average energy: $E_s = 2$

  To make total energy of symbol set=1, we need to multiply the set with a factor of $1/\sqrt{2}$

Points to be noted for simulation(contd…)

- Method to find the normalization factor
  - Method-1 :

    Find Average Energy E_s of symbol set and multiply $1/\sqrt{E_s}$
  - Method-2 :

    Multiply a constant factor 'a' with all the symbols in the set and then find 'a' by setting $E_s = 1$
- $SNR\_lin = \frac{E_s}{N_0}$ where N_0 is variance of Complex Gaussian Noise.

  Var(real part)= Var(img part)= $N_0/2$

Points to be noted for simulation(contd…)

- Since we are multiplying σ with real and imaginary part of Complex Gaussian Noise, so we need to find standard deviation of real Gaussian.

$$SNR_{dB} = 10 * \log_{10} SNR_{lin}$$

$$SNR_{dB} = 10 * \log_{10} \frac{E_s}{2 * \sigma^2}$$

$$\Rightarrow \frac{E_s}{2 * \sigma^2} = 10^{SNR_{dB}/10} = SNR\_lin$$

$$\Rightarrow \sigma = \sqrt{\frac{E_s}{2} * 10^{-\frac{SNR_{dB}}{20}}} = \sqrt{\frac{E_s}{2 * SNR\_lin}}$$

Points to be noted for simulation(contd…)

- Case-1 : Make $E_s = 1$ by multiplying with a normalization factor and find standard deviation of AWGN.
- Case-2 : Don't normalize the constellation and use corresponding E_s to find standard deviation of AWGN.
- Question is if we can simulate with case-2 then why case-1 is required?

  Ans: When we try to compare BER/SER of two different modulation scheme they have different energy, so the comparison is not fair. We need to compare them with same E_s, so normalization is required.

Points to be noted for simulation(contd…)

- If we plot BER vs $\frac{E_s}{N_0}$ then comparing different modulation schemes is fair or not?

  Ans: No, because E_s is different for different modulation schemes. But E_b is same for all modulation scheme. So comparing BER vs $\frac{E_b}{N_0}$ is fair.
- $E_s = nE_b$, where n is no. of bits per symbol,

  E_s is Symbol enegy and E_b is bit energy.
- $\left(\frac{E_s}{N_0}\right)_{dB} = \left(\frac{E_s}{N_0}\right)_{dB} + 10\log_{10} n$

Conclusion

For fair comparison between different modulation schemes

1. Normalize the constellation set.
2. Plot Probability of error with respect to $\frac{E_b}{N_0}$.

Pseudo code

```
for  Eb/N0 = 0:10 dB
        Es/N0_BPSK = ?
        sd_BPSK = ?
        for iter = 1:N
                1. bit generation
                2. mapping to symbol
                3.  AWGN
                4. ML detector
                5. estimate bits
                6. find no. of symbols in error
                7. find no. of bits in error
        end
SER = no. of symbols in error/total no. of symbols
BER = no. of bits in error/total no. of bits
Plot SER vs SNR and BER vs SNR
```