Ex1

large-scale fading (shadowing) $S_{dB} = 10\log_{10} S \sim N(0, \sigma_s^2)$

$M: x = 10\log_{10} S \sim N(0, \sigma_s^2)$

calculate $S = 10^{\frac{x}{10}}$ → shadowing realisation

multiple realisations of shadowing

```
for i = 1:1000
    x = randn(0, σs^2);
    S[i] = 10^(x/10);
end
```

Plot(S)

$\sigma_s^2 = 8\,dB \qquad \sigma_s^2 = 10^{\frac{8}{10}}$

Ex2:

$h_i \sim CN(0,1)$

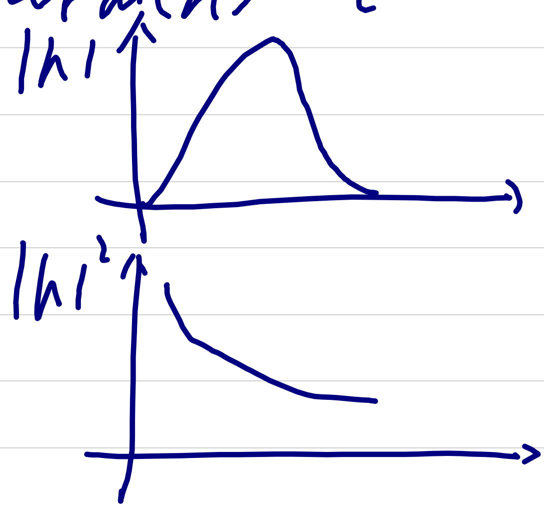
real   imag

$h_i = h_{real} + i\, h_{imag}$

$CN(0,1)$ $N(0, \frac{1}{2}) = \frac{N(0,1)}{\sqrt{2}}$ $N(0, \frac{1}{2})$

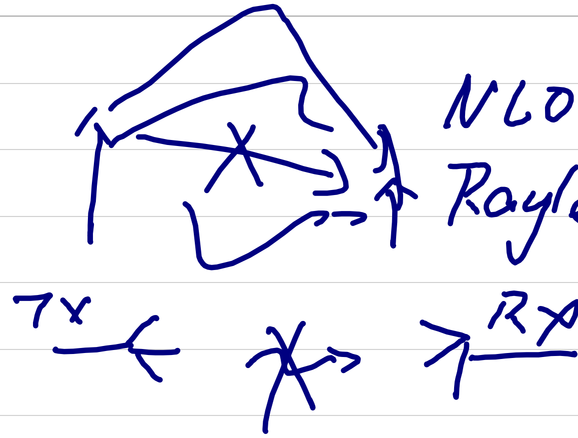
M:

```
for i = 1:10000
    hR = N(0,1)/√2 ~ 1/√2 * randn
    hI = N(0,1)/√2
    h = hR + i hI
    norm[i] = abs(h)
    square abs.[i] = norm(h)^2
end
plot(norm)
plot(square abs)
```



① Ex2

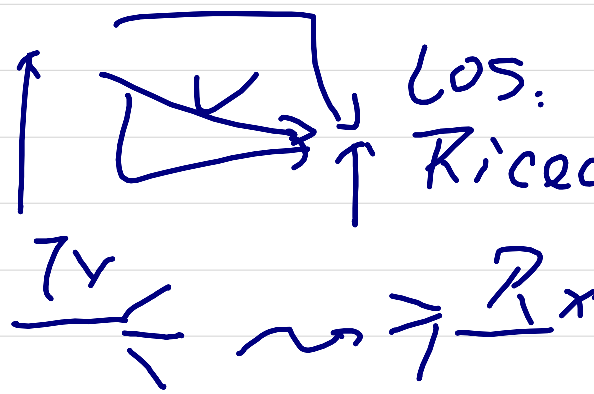
$h \sim \mathcal{CN}(0,1)$



NLOS: Rayleigh

② Ex3

$h = h_{LOS} + h_{Rayleigh}$



LOS: Ricean

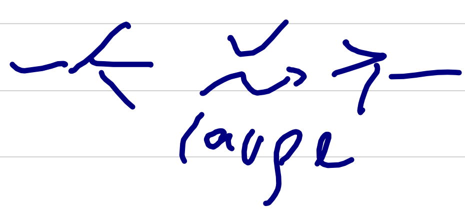
$$h = \sqrt{\frac{K}{K+1}}\,\bar{h} + \sqrt{\frac{1}{1+K}}\,\tilde{h}$$

K : how much energy is in LOS

Ricean factor

$K=0 \Rightarrow h = \tilde{h}$ (Rayleigh)

$K \to \infty \Rightarrow h \approx \bar{h} = e^{j\phi}$



fix K

for i = 1:10000

$$h_R = \frac{N(0,1)}{\sqrt{2}}$$

$$h_I = \frac{N(0,1)}{\sqrt{2}}$$

$$\tilde{h} = h_R + i h_I \rightarrow \text{Rayleigh}$$

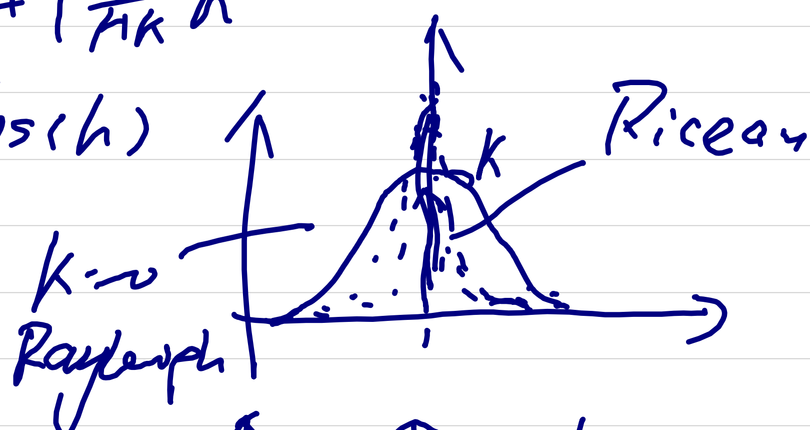
$$\bar{h} = e^{j\phi} = 1$$

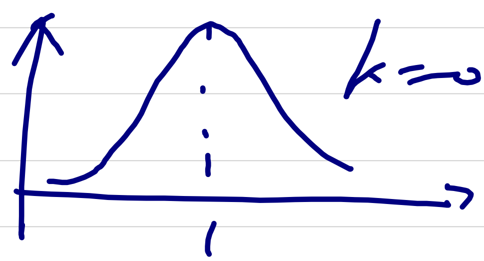
$$h = \sqrt{\frac{K}{1+K}}\,\bar{h} + \sqrt{\frac{1}{1+K}}\,\tilde{h}$$

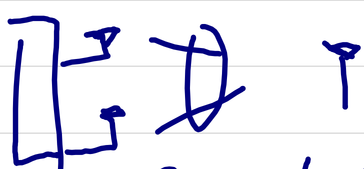
norm[i] = abs(h)

end

plot(norm)

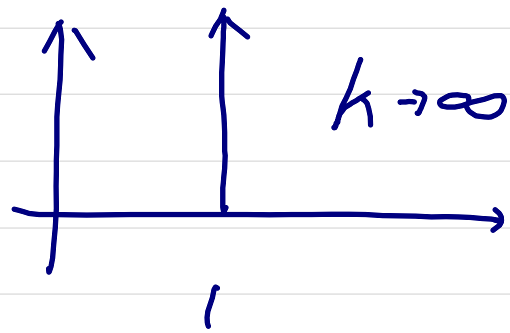






correlated

uncorrelated

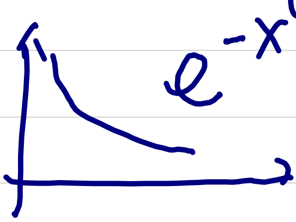


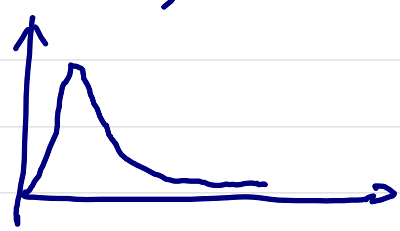
Ex4:

n complex normal RV

$$X_1 \cdot X_2 \cdot\cdot X_n \Rightarrow Y = |X_1|^2 + |X_2|^2 + \cdots + |X_n|^2$$

$n=1 \Rightarrow |X_1|^2$ conj (RV) $\qquad n=3$





$n=3$

for $i = 1:100$

$h_R = \frac{N(0,1)}{\sqrt{2}}$

$h_I = \frac{N(0,1)}{\sqrt{2}}$

$h_1 = h_R + i h_I$

$\vdots$

$h_2 = h_R' + i h_I'$

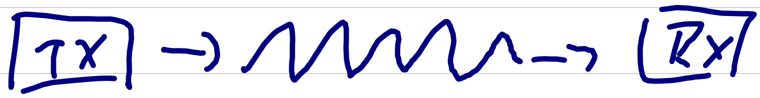
sum_norm_h[i] = abs(h_1)^2 + abs(h_2)^2

plot(sum_norm_h)

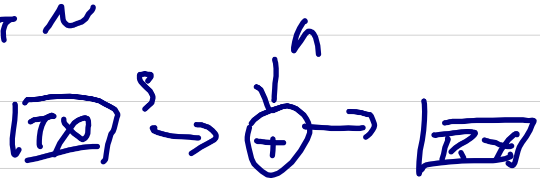
```
for i=1:1000
  for j=1:n
    h=hR+jhI
    sum_norm.h[i] = sum_norm[i-1]
                     + abs(h)^2
```

Ex 5:

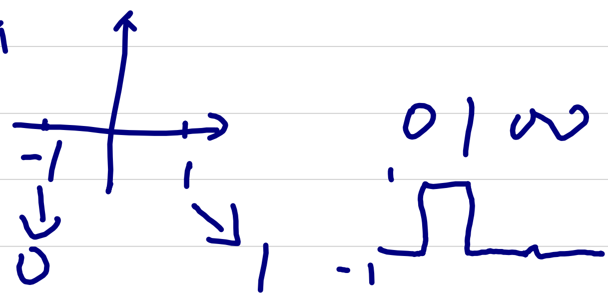
BPSK



① AWGN

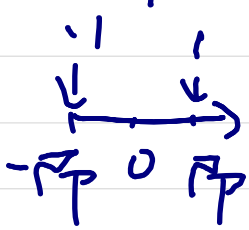


BPSK

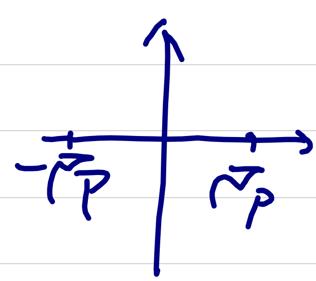


Power $= |s|^2$

$110100 \rightarrow \{1, 1, -1, 1, -1, -1\}$

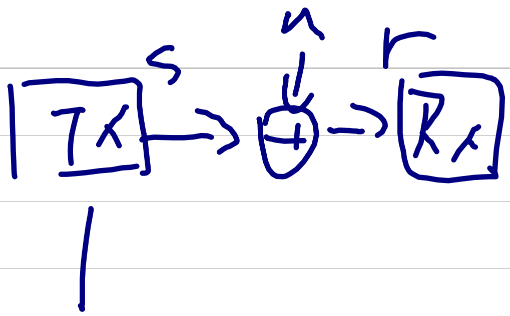


BPSK with power $P \Rightarrow$ symbols



$P = 10\text{dB} \Rightarrow 10 \Rightarrow 3..$

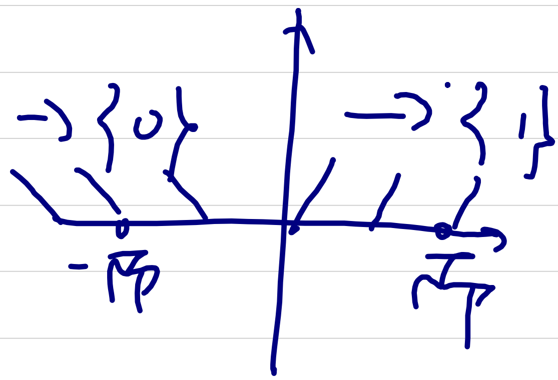
$P = 20\text{dB} \Rightarrow 100 \Rightarrow 10$



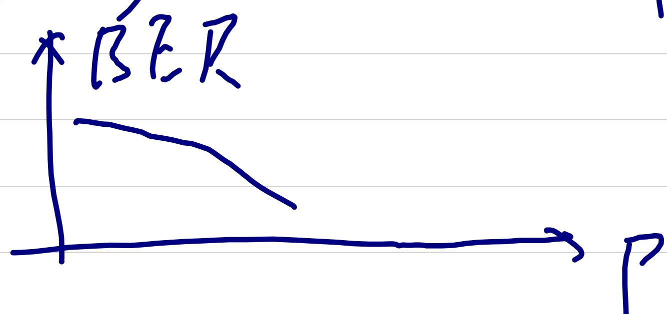
generate 10000 random bits

$0 \to (-1) \to -\sqrt{P}$

$1 \to \sqrt{P}$



$r = s + n \sim \mathcal{CN}(0, 1)$



$b_i \in \{0, 1\} \longmapsto s_i \in \{-\sqrt{P}, \sqrt{P}\}$

$\oplus \leftarrow n$

$\left.\begin{matrix} >0 \to 1 \\ <0 \to 0 \end{matrix}\right\} \leftarrow \mathrm{Re}\{y_i\} \leftarrow y_i = s_i + n$