LAB V

Introduction to Fading Channel and Computer Simulation

Agenda

- Introduction to fading channel
- Types of fading
- Generation and statistics of fading samples
- Channel Estimation
- Link level simulation in fading channel
- LAB Assignment+Quiz

Radio Propagation

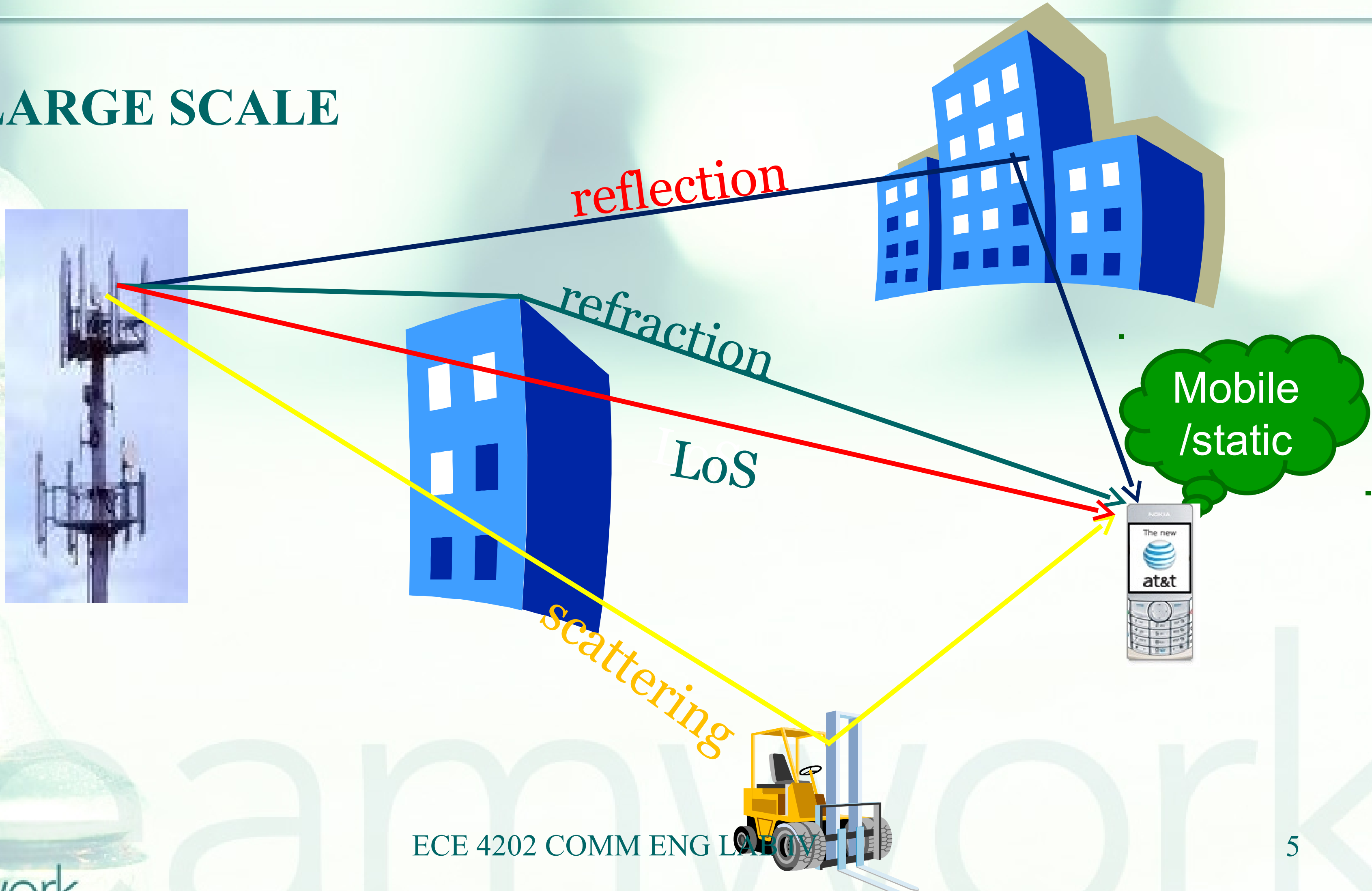
- Radio propagation is classified into
  - Large-scale propagation (path loss)
  - Small-scale propagation (fading)
- Large-scale propagation
  - Behavior of radio waves over ‘long’ distance (several tens to hundreds of meters)
- Small-scale propagation
  - Behavior of radio waves over ‘short’ distance (5 to 40 wavelengths)
- **THIS LAB IS ABOUT SMALL-SCALE FADING**

Introduction to Fading Channel

- Fading is the time variation of received signal as observed by a receiver antenna
  - Multiple paths exist between the transmitter and receiver. Relative delay differences between paths can't be resolved
  - Movement of mobile terminal. Received signals have random phases.
  - Random superposition creates largely fluctuating resultant vector

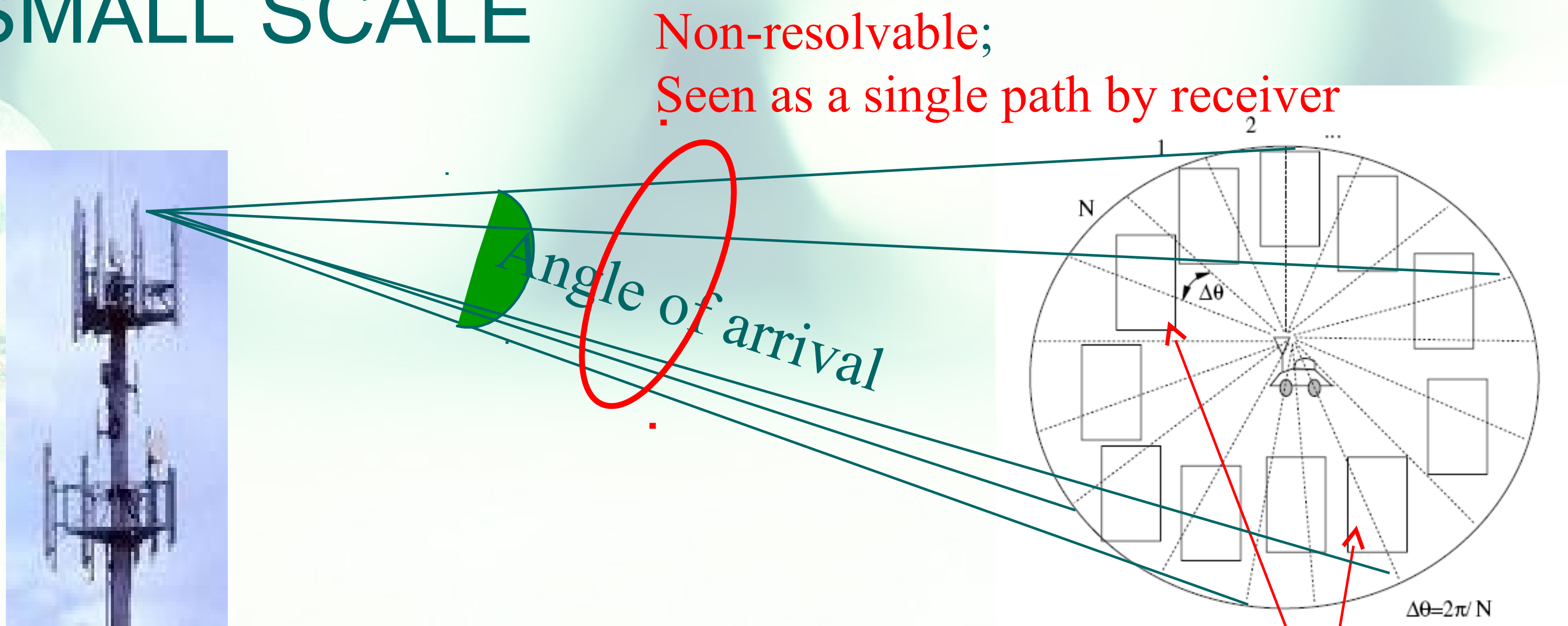
Radio wave propagation scenario

LARGE SCALE



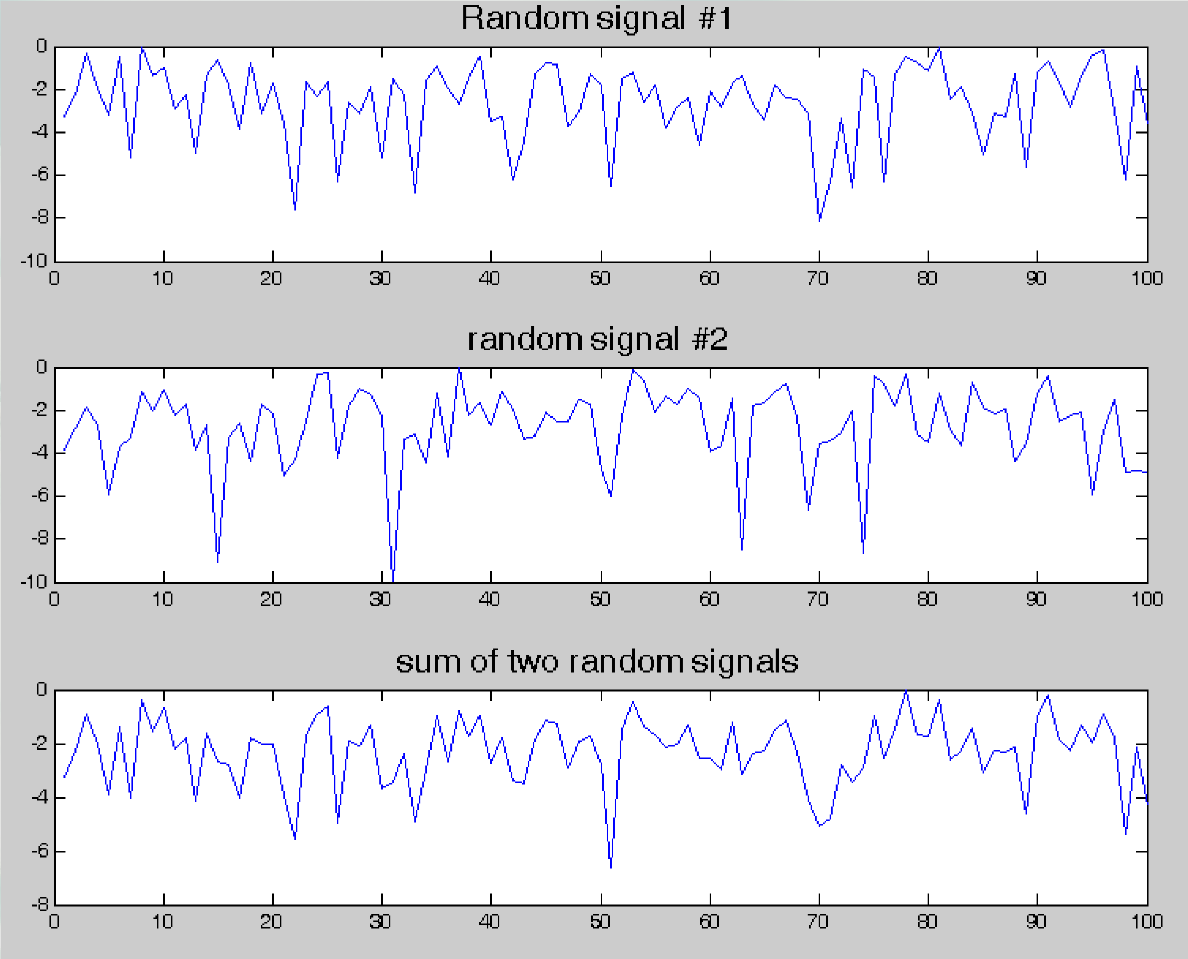
Cont’d

SMALL SCALE



Each of the wave has random phase and amplitude.
All are randomly superpositioned.

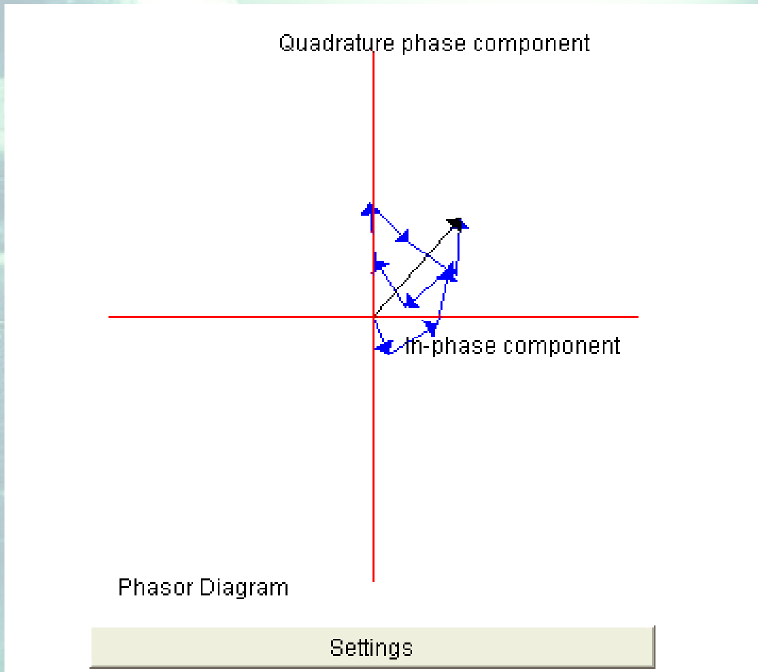
Random superposition



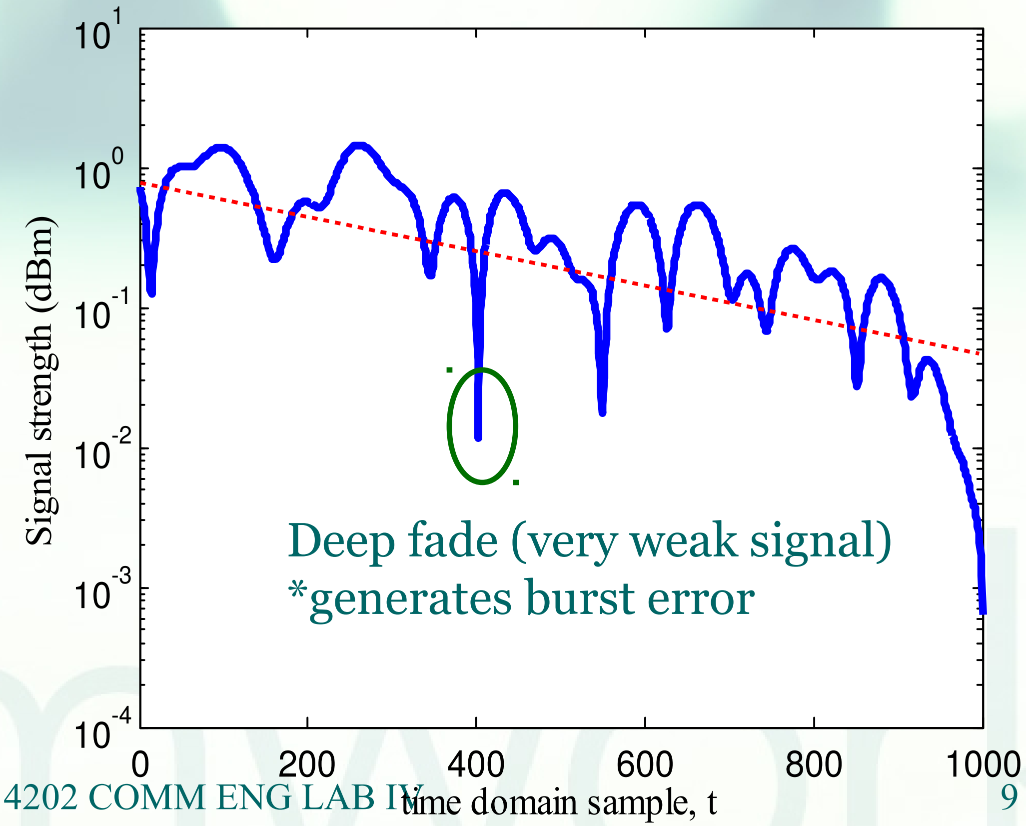
Fading statistics

- Rayleigh fading
  - No Line of Sight (LoS) component presents
- Rician fading
  - Line of Sight (LoS) component presents
  - Deterministic component, contributes significantly to the total received power

Cont'd

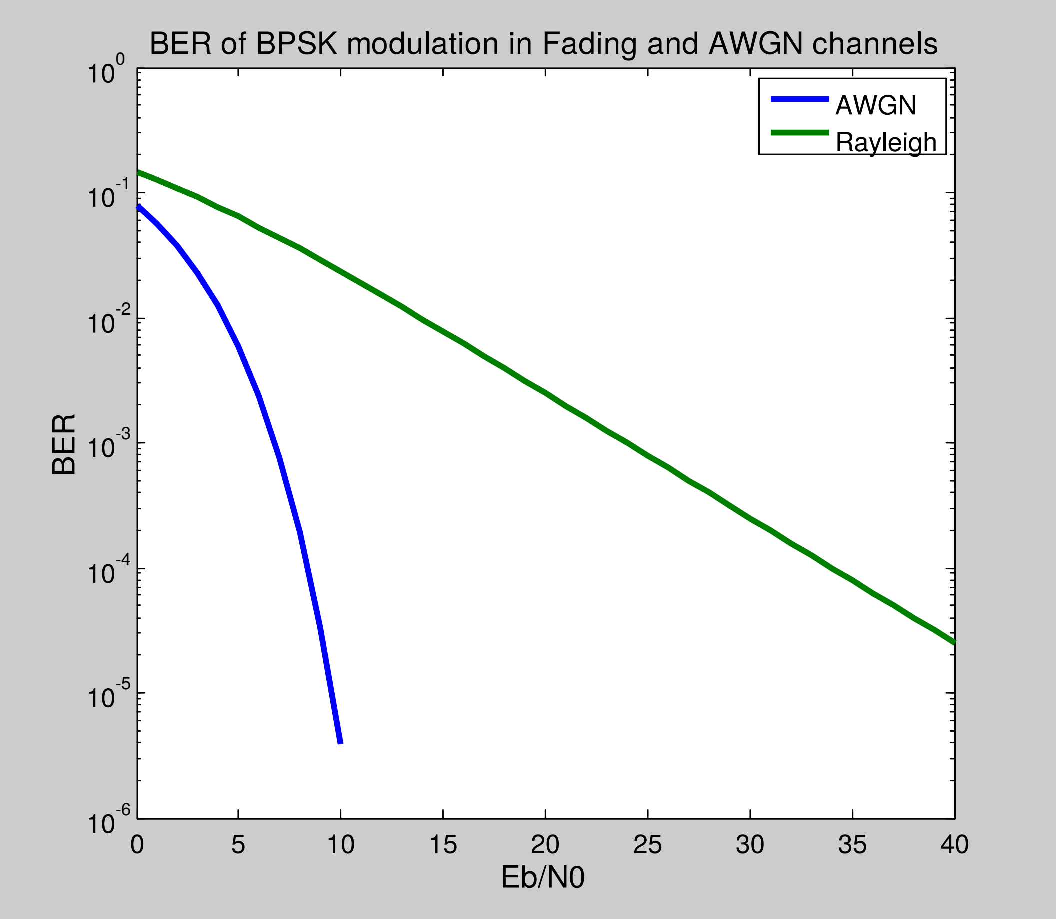


Java Applet: Phasor diagram of 9 scattered waves (in blue), resulting an approximately Rayleigh-fading envelope (in black).

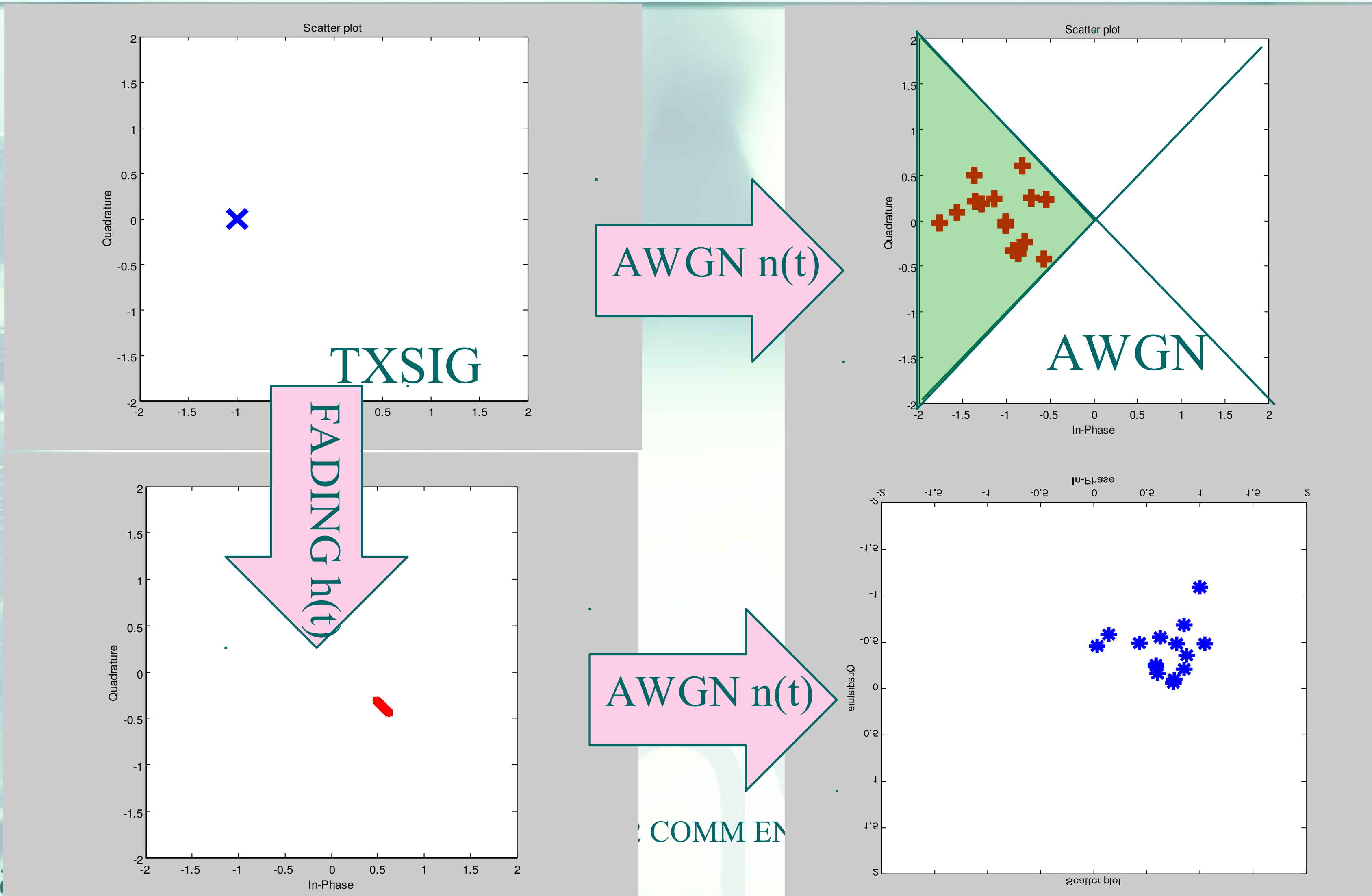


Fading Effect to BER

- Fading makes BER decreases only linearly with SNR/ Eb/N0



What happen to the tx signal?



Cont'd

- Fading effect is multiplicative to the transmit signal

$$y(t) = s(t) * h(t) + n(t)$$

- It causes rotation to the transmit signal
- If we do not "undo" the rotation caused by fading, the whole information will be detected erroneously

Generating fading samples

- Create a fading object
- Generate a transmit signal
- use filter() which does not require generation of fading sample

- Create a fading object
- Generate fading samples by filtering all one sequence with the fading object as above
- Generate a transmit signal
- Convolve the fading sample with the transmit signal
  - In case of no multipath, it reduces to multiplication

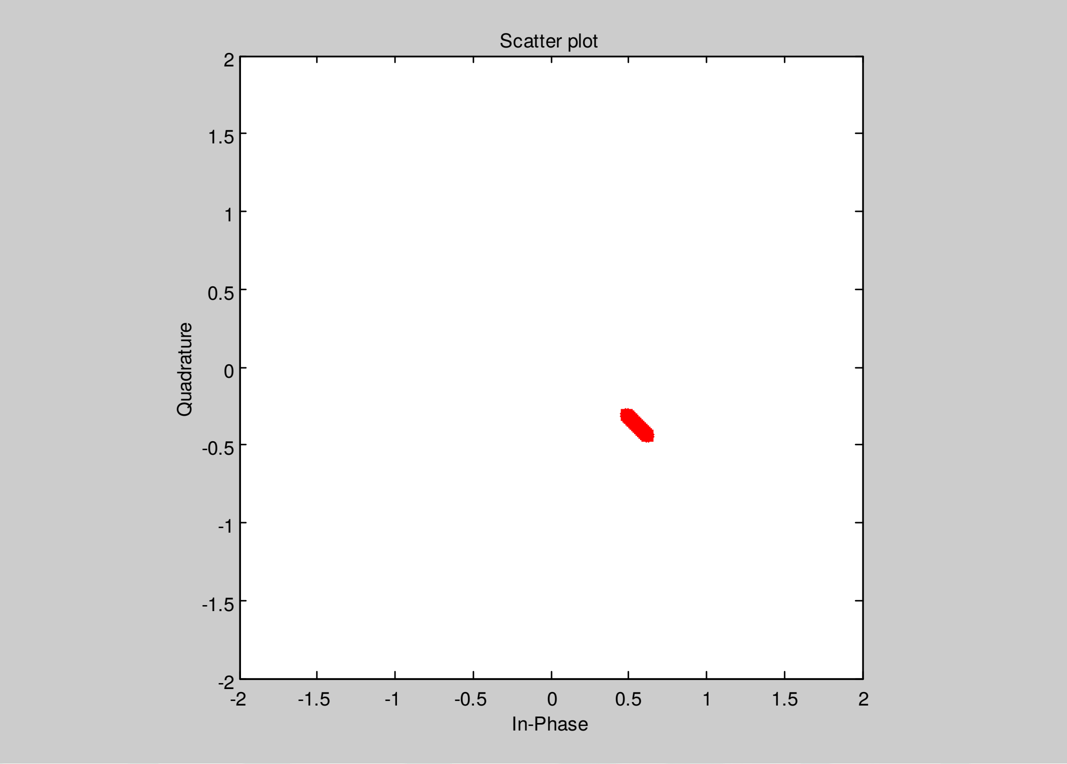
teamwork

```
%create fading object with sampling period of 0.1ms,
   fD=50Hz
channel= rayleighchan(1e-4,50);
%generate transmit signal (BPSK)
data=randint(1,50);
txsig=pskmod(data,2);
scatterplot(txsig);
%generate faded signal (before adding noise)
fadesig=filter(channel, txsig);
scatterplot(fadesig);
%add noise
rxsig=awgn(fadesig,15);
%demodulate
recsig=pskdemod(rxsig,2);
%calculate the number of errors
sum(recsig~=data)
```


teamwork

“undo” the fading

- How can we undo the fading effect???
- Fading is caused by the (radio) channel. Fading is not known by transmitter and receiver
- What observed by a receiver is y(t)



teamwork

Cont'd

- Assume noise free condition

$$y(t) = s(t) * h(t)$$

  - *Note that, when h(t)=d(t), the convolution reduces to multiplication*
- Frequency domain representation (after Fourier transform)

$$Y(f) = S(f) \bullet H(f)$$

$$H(f) = \frac{Y(f)}{S(f)}$$

Channel Estimation

- The process of estimating H(f) from Y(f)
  - In case of delta function is equivalent to estimating h(t) from y(t)
- How do we know H(f)?
  - The receiver needs to know S(f)
  - Transmitter must send sequence which is known to the receiver : **pilot sequence**
  - How many pilot symbols are enough (provide good channel estimate)?

Cont'd

- Pilot sequence can be any sequence which is known to both transmitter and receiver
- Pilot sequence
  - p= 1 1 1 1
  - p= 1 -1 1 -1
  - p= 1 1 -1 -1

Cont'd

- In digital communication, user's information/data is grouped into blocks/frames before transmission
  - Add pilot sequence to each frame before modulation
  - Pilot sequence is <u>known to the receiver</u> and hence <u>does not carry information</u>

Cont'd

$$\tilde{h}(t) = \frac{1}{N_p} \sum_{n=0}^{N_p - 1} y(n) \bullet p(n)$$

$\tilde{h}(t)$: Channel estimate

N_p : number of pilot symbols

y(n) : received signal samples

p(n) : n-th pilot symbol

demodulation

- Before we perform demodulation on the user information carrying signal we need to compensate for the fading effect

$$y'(t) = y(t) \star conj(\tilde{h}(t))$$

- y'(t) is the input to the demodulator, not y(t)

```
%create fading object with sampling period of 0.1ms, fD=20Hz
channel= rayleighchan(1e-4,20);
%generate transmit signal (BPSK)
data=randint(1,50);
%BPSK modulation
modsig=pskmod(data,2);
%generate pilot signal
pilot= [1 1 -1 -1] ;
txsig =[pilot modsig];
scatterplot(txsig);
%generate faded signal (before adding noise)
fadesig=filter(channel, txsig);
scatterplot(fadesig);
%add noise
rxsig=awgn(fadesig,15);
%scatterplot(rxsig);
%channel estimation and compensation
h_tilde = channelestimate(pilot, rxsig(1:4))
modemin= rxsig(5:end)*conj(h_tilde);
%scatterplot(modemin);
%demodulate
recsig=pskdemod(modemin,2);
%calculate the number of errors
sum(recsig~=data)
```

```
%function to perform channel estimation on
%bpsk modulated sequence
%[h_tilde]=channelestimate(pilot,rxsig)
function [h]=channelestimate(pilot, rxsig)
 h = mean(rxsig.*pilot); %element wise multiplication followed by averaging
```

Cautions

- Simulating fading channel requires much more samples compared to AWGN channel
  - Insufficient number of samples may lead to incorrect results