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Wireless Communication:-

2G wireless system:-

family for 2G/2.5/2.7G.

	wireless standard	
2G	GSM (Global system for mobile Communication	Basic voice data rate 10 Kbps (kilo bits/sec)
2G	CDMA (Code Division multiple Access)	10Kbps
2.5G	GPRS (General packet Radio service) has Access of datarate.	~50Kbps
2.5G (or) 2.75G	EDGE (Enhanced Data for GSM Evolution).	~200 Kbps

3Generation wireless standards:-

		Data Rate
3G	WCDMA (wide band CDMA)/UMTS (universal mobile Telecom Standard	WCDMA (384 kbps) voice/video.
3G.	CDMA 2000	384 Kbps
3.5G	HSDPA / HSUPA (High speed downlink packet Access / High " uplink " ")	5-30 Mbps
3.5G	1XEVDO ; Rev A,B,C (Revision A,B,C version) (evolution Data optimized)	5-30 Mbps

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4G wireless system standards:-

4G	LTE (Long Term Evolution)	100 - 200 Mbps.
4G	WiMax (worldwide ~~interpolation~~ interoperability for micro wave Access)	100 - 200 Mbps.

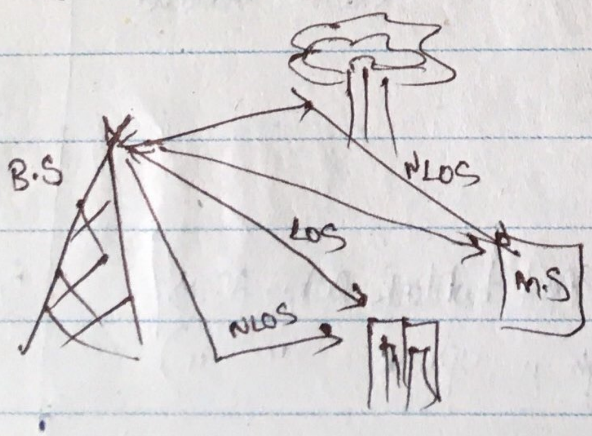
Prerequisites :-

1. Probability & Random Process
2. Digital Communication Systems
3. Introductory Course wireless systems
4. Linear Algebra

Relevant Nptel Courses

1. Communication Engineering
2. Digital Comm.
3. wireless Communication

Wireless Communication:-



Scatters occured. b/w Basestation to mobile Station

Eg:- Trees; cars; Buildings

Multipath Propagation Environment

→ Direct Path is known as LOS (Line of Sight) Components.
→ Scatter paths is " " NLOS (non-line of sight) Components.

→ Multipath Components add with different Components with different phases factors resulting as Constructive (or) Distructive Interferance
Constructive interferance is good, signal level goes up.
Distructive level is bad " " " down, (i.e no reception in signal)

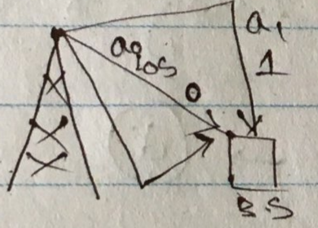
$x(t)$ → $\boxed{h(t)}$ → $y(t)$

impulse response: $h(t)$

T_x: transmitted signal from base station

R_x: Received signal

wireless channel



0^{th} path (LOS) ⟷ $a_0\,\delta(t-\tilde{\tau}_0)$ → impulse response

a_0 ↓ attenuation factor

$\delta(t-\tilde{\tau}_0)$ ↳ corresponding delay

1^{st} path (or) NLOS → $a_1\,\delta(t-\tilde{\tau}_1)$; $a_2\,\delta(t-\tilde{\tau}_2)$

⋮

$a_{L-1}\,\delta(t-\tilde{\tau}_{L-1})$

wireless channel impulse response

$$h(t) = a_0\,\delta(t-\tilde{\tau}_0) + \underbrace{a_1\,\delta(t-\tilde{\tau}_1)}_{\text{multipath component}} + a_2\,\delta(t-\tilde{\tau}_2) + \cdots a_L\,\delta(t-\tilde{\tau}_{L-1}) \quad \text{↳ (a)}$$

wireless channel

$$\boxed{h(t) = \sum_{i=0}^{L-1} a_i\,\delta(t-\tilde{\tau}_i)} \rightarrow \text{time domain} \rightarrow \text{(b)}$$

(4)

Wireless Signal $s(t)$:-

$$\boxed{s(t) = R_e\{s_b(t) \cdot e^{j2\pi f_c t}\}} \rightarrow (c)$$

Real part

Baseband - Pass band Representation.

f_c = Carrier frequency

$s_b(t)$ = Complex baseband Equivalent of the passband signal $s(t)$

$$f_c = \begin{cases} GSM = 900\ MHz \quad 900 \times 10^6 \\ \quad = 1800\ MHz\ (or)\ 1.8\ GHz \\ 3G/4G - 2.3 \times 10^9\ Hz\ (or)\ 2.3\ GHz\ \text{to}\ 2.4 \times 10^9\ Hz\ (or)\ 2.4\ GHz \end{cases}$$

$$s(t) = R_e\{s_b(t) \cdot e^{j2\pi f_c t}\} \rightarrow (d)$$

$$h(t) = \sum_{i=1}^{L-1} a_i\, \delta(t - \tau_i) \rightarrow (e)$$

$$\therefore y(t) = s(t) * h(t) \rightarrow (f)$$

0^{th} Component

$$y_0(t) = R_e\{a_0\, s_b(t - \tau_0) \cdot e^{j2\pi f_c (t - \tau_0)}\}$$

$$y_1(t) = R_e\{a_1\, s_b(t - \tau_1) \cdot e^{j2\pi f_c (t - \tau_1)}\}$$

$$\vdots$$

$$y_{L-1}(t) = R_e\{a_{L-1}\, s_b(t - \tau_{L-1}) \cdot e^{j2\pi f_c (t - \tau_{L-1})}\} \rightarrow (g)$$

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(5)

Net Signal $y(t)$ =

$$y(t) = R_e\left\{\sum_{i=0}^{L-1} a_i\, S_b(t-\tau_i)\cdot e^{j2\pi f_c(t-\tau_i)}\right\}$$ ⇒ Received Signal (Rx)

$$= R_e\left\{\underbrace{\left\{\sum_{i=0}^{L-1} a_i\, S_b(t-\tau_i)\cdot e^{-j2\pi f_c \tau_i}\right\}}_{\text{Complex signal}}\cdot e^{j2\pi f_c t}\right\} \rightarrow (h)$$

Complex Baseband Rx signal = $$\boxed{y_b(t) = \sum_{i=0}^{L-1} a_i\, S_b(t-\tau_i)\, \underbrace{e^{-j2\pi f_c \tau_i}}_{\text{complex phase factor}}} \rightarrow (i)$$

a_i - amplitude

τ_i - delay factor.

$$y_b(t) = \sum_{i=0}^{L-1} a_i\, S_b(t-\tau_i)\cdot e^{-j2\pi f_c \tau_i}$$

let narrow band ~~sign~~ assumption

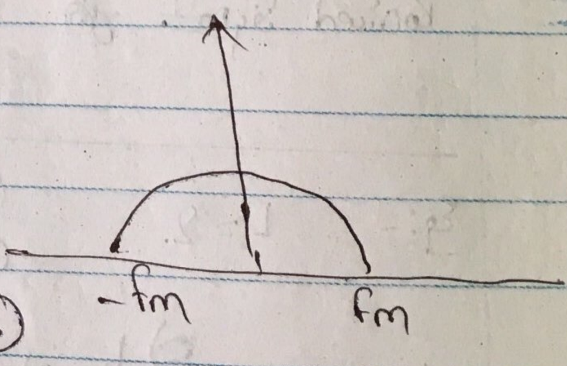
let f_m be maximum frequency component of $S_b(t)$

Eg:- GSM $f_m = 100$ KHz

Narrow band Condition: if $f_m \ll \frac{1}{\tau_i}$ $\forall$ → (1)

$\tau_i = 1\,\mu sec$ → (2)

$\frac{1}{\tau_i} = 1/1\mu sec = 1\,MHz$ → (3)



GSM is a narrowband signal.

For a narrowband signal :-

$$\boxed{S_b(t - \tau_p) = S_b(t)} \rightarrow (J)$$

$$\therefore y_b(t) = S_b(t) . \underbrace{\sum_{i=0}^{L-1} e^{-j2\pi f_c \tau_i}} \rightarrow (K)$$

Tx based band signal × Complex Received signal. / complex factor (or) Complex Co-efficient

Example :- $\underbrace{L = 2}_{\text{2-Paths}}$ $\begin{cases} a_0 = 1 ; & \tau_0 = 0 \\ a_1 = 1 ; & \tau_1 = \frac{1}{2f_c} \end{cases}$ (Attenuation, delay)

Complex Co-efficient

$$h = \sum_{i=0}^{L-1} a_i e^{-j2\pi f_c \tau_i}$$

$$= \sum_{i=0}^{1} a_i e^{-j2\pi f_c \tau_i}$$

$$h = \underbrace{1}_{\text{Path 1}} + \underbrace{1 \left(e^{-j\pi} \right)}_{2^{nd} \text{ Path}} = 1 + (-1) = 0$$

Recived Signal is $= S_b(t) \times 0$

$= 0$.

Eg :- $L = 2$ $\quad a_0 = 1 \quad \tau_0 = 0$

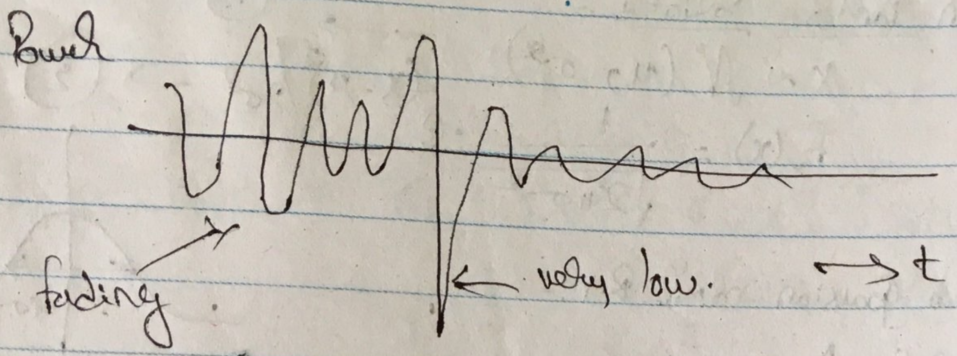
$a_1 = 1 \quad \tau_1 = \frac{1}{f_c}$

$\Rightarrow h \Rightarrow 1 + 1 = 2$

$\therefore y_b(t) = S_b(t) \times 2 = 2 S_b(t)$

here signal is twice in amplitude and in power.

where signal is recived in direct & indirect Path both are Combined as $2 S_b(t)$



* Analytical models :-

wireless systems

$$y_b(t) = \underset{\sim}{h}\, S_b(t) \longrightarrow (l)$$

Complex fading Co-efficient

wired (or) wireless systems

$$\boxed{y_b(t) = S_b(t)}$$ i.e only a single path $\longrightarrow (m)$

both cases have noise

* Statistics of the fading co-efficient :-

$$h = \sum_{i=0}^{L-1} a_i\, e^{-j2\pi f_c \tau_i} = x + jy = a \cdot e^{j\phi} \longrightarrow (n)$$

magnitude

$$= \sum_{i=0}^{L-1} a_i \cos(2\pi f_c \tau_i) - j \sin(2\pi f_c \tau_i). \longrightarrow (o)$$

$$x = \sum_{i=0}^{L-1} a_i \cos 2\pi f_c \tau_i \longrightarrow (p)$$

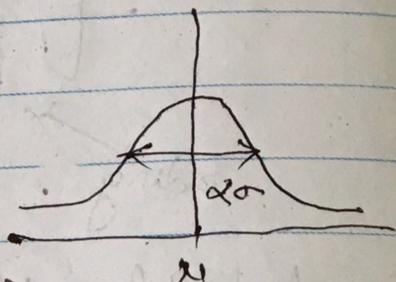
$$y = \sum_{i=0}^{L-1} -a_i \sin 2\pi f_c \tau_i \longrightarrow (q)$$

(6)

* Gaussian Random Variable :-

$$X \sim \mathcal{N}(\mu, \sigma^2) \longrightarrow (1)$$

$$f_X(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \cdot e^{-(x-\mu)^2/2\sigma^2} \longrightarrow (2)$$



a) Standard Gaussian normal R.V :-

$$\mathcal{N}(0,1)$$

$$\left.\frac{1}{\sqrt{2\pi}} \cdot e^{-x^2/2}\right\}$$ PDF of Standard Gaussian R.V, Probability Distribution function. $\longrightarrow (3)$

(b) Complex fadding Co-eff.

$$h = x + jy \longrightarrow (a)$$

sum of a large no. of random Components

x, y to be Gaussian in nature.

Central limit theorem

$$h = x + jy$$

$$x \sim N(0, 1/2) \longrightarrow (b)$$

mean variance

$$y \sim N(0, 1/2)$$

$$f_x(x) = \frac{1}{\sqrt{2\pi \cdot 1/2}} \cdot e^{-x^2/2 \times 1/2}$$

x, & y are independent R. Variables

$$= \frac{1}{\sqrt{\pi}} \cdot e^{-x^2}$$

$$f_y(y) = \frac{1}{\sqrt{\pi}} \cdot e^{-y^2}$$

$$\boxed{f_{x,y}(x,y) = \frac{1}{\pi} \cdot e^{-(x^2+y^2)}}$$ → Join distribution of Components x & y

$\longrightarrow$ (c)

(7)

$$\Rightarrow \quad h = x + jy = \underset{\text{magnitude}}{a} \cdot e^{j\overset{\text{phase}}{\phi}} \longrightarrow (4)$$

$$x = a\cos\phi \quad ; \quad y = a\sin\phi$$

$$\cancel{f_{A,\phi}(a,\phi)} \qquad x^2 + y^2 = a^2\cos^2\phi + a^2\sin^2\phi$$

$$= a^2(\cos^2\phi + \sin^2\phi)$$

$$= a^2.$$

Joint $f_{x,y}(x,y) = \frac{1}{\pi} \cdot e^{-(x^2+y^2)} \longrightarrow (5)$

$$\therefore \quad f_{A,\phi} = \frac{1}{\pi} e^{-a^2} \det(J_{xy}) \longrightarrow (6)$$

J_{xy} → Jacobian matrix

where $J_{xy} = \begin{bmatrix} \frac{\partial x}{\partial a} & \frac{\partial y}{\partial a} \\ \frac{\partial x}{\partial \phi} & \frac{\partial y}{\partial \phi} \end{bmatrix} \longrightarrow (7)$

$$J_{xy} = \begin{bmatrix} \cos\phi & \sin\phi \\ -a\sin\phi & a\cos\phi \end{bmatrix} \longrightarrow (8)$$

determinant $\det(J_{xy}) = (a\cos\phi \cdot \cos\phi - (-a\sin\phi) \cdot \sin\phi)$

$$= a\cos^2\phi + a\sin^2\phi$$

$$= a(\cos^2\phi + \sin^2\phi) \longrightarrow (9)$$

$$\det(J_{xy}) = a$$

$$f_{A,\phi} = \frac{1}{\pi} \cdot e^{-a^2} \cdot a$$

$$\boxed{f_{A,\phi} = \frac{a}{\pi} \cdot e^{-a^2}} \;/. \longrightarrow (10)$$

(8)

marginal distribution :-

$$\underbrace{f_A(a)}_{\text{marginal distribution}} = \int_{-\pi}^{\pi} f_{A,\phi}(a,\phi) \cdot d\phi$$

$$= \int_{-\pi}^{\pi} \frac{a}{\pi} \cdot e^{-a^2} d\phi$$

$$= \frac{a}{\pi} e^{-a^2} \int_{-\pi}^{\pi} d\phi$$

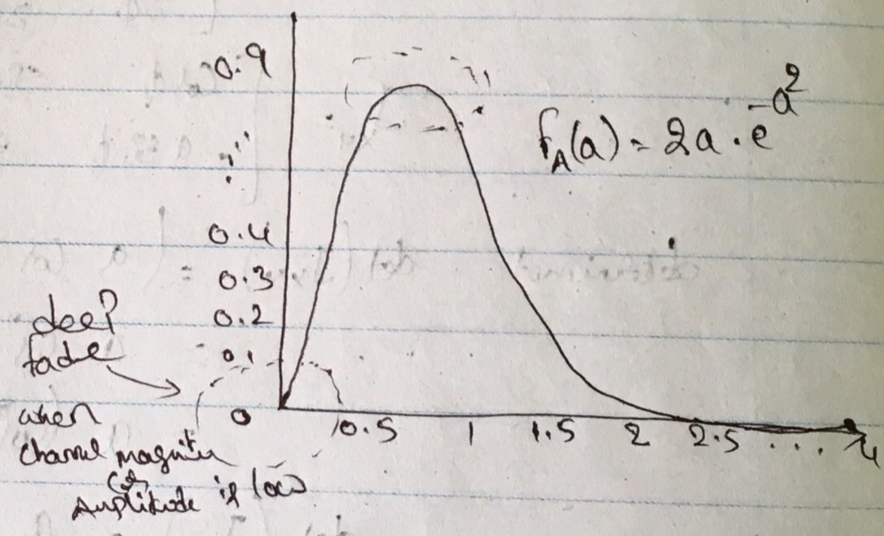
$$f_A(a) = 2\pi \frac{a}{\pi} e^{-a^2} = 2a \cdot e^{-a^2}$$

$\underset{\text{Envolope}}{a} = \sqrt{x^2 + y^2}$ *

Envolope ↓ fading channel

$$\boxed{f_A(a) = 2a \cdot e^{-a^2}} \rightarrow \text{Rayleigh fading distribution (or) density function.}$$

$0 \leq a \leq \infty$



$$f_\phi(\phi) = \int_0^a \frac{a}{\pi} \cdot e^{-a^2} \cdot da$$

$$= \int_0^\infty \frac{1}{2\pi} \cdot (2a e^{-a^2}) \cdot da$$

$$= \frac{1}{2\pi} \left(-e^{-a^2} \Big|_0^\infty \right)$$

$$= \left(\frac{1}{2\pi} \right)$$

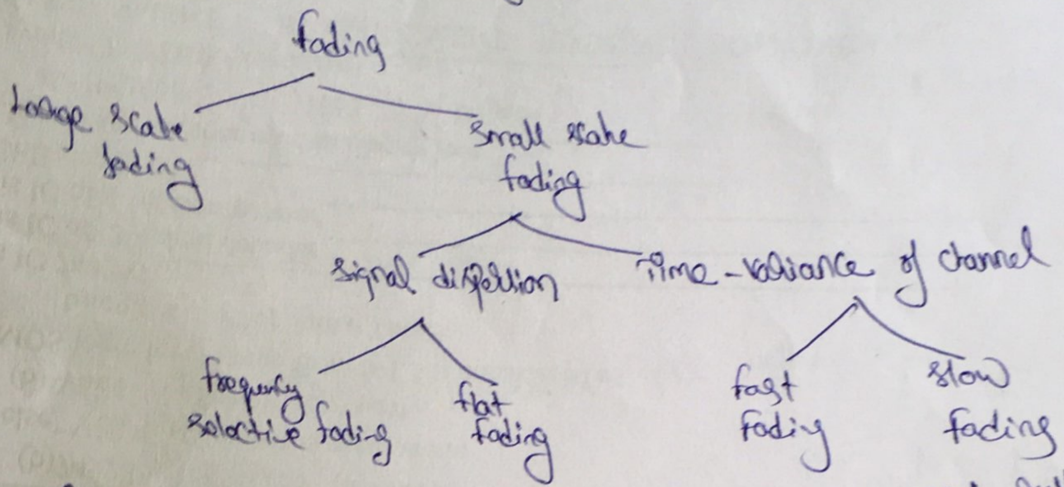
$$\Rightarrow \boxed{f_\phi(\phi) = \frac{1}{2\pi}} \leftarrow \text{uniform distribution in } (-\pi \text{ to } \pi)$$

FADING

1) **Fading:-** In Cellular Comm- Channels the time variant feature leads to a particular phenomenon - called fading.

(*) Fading is deviation of attenuation which affects a signal during propagation.

(*) " " caused by interference b/w 2 (or) more versions of transmitted signals which arrive at the receiver at slightly different times.



→ In wireless Comm the signal can travels t_x to R_x over multiple reflective paths, is called (multipath propagation)

→ Constructive and destructive interference and phase shifting of signals results from multipath propagation.

→ Destructive interference cause fading

→ When the magnitude of signals arriving by the various paths have a distribution resembling the Rayleigh distribution it is known as Rayleigh fading.

→ Where one component dominates, a Rician distribution is a better suited model known as Rician fading.

Techniques for avoiding:-

→ OFDM :- (orthogonal frequency Division multiplexing) is a method where digital data is encoded on multiple carrier frequencies. (wire & wireless digital communication).

→ MIMO :- In radio comm - Multiple i/p Multiple o/p is a method of using multiple antennas at both t_x and R_x to improve Comm- performance. It is a part of smart Antenna technology.

→ RAKE Receiver :- is a radio receiver designed to overcome the effective of multipath fading. Several sub receivers, each assigned to a different multipath are used.

→ Each independently decodes a single multipath component and the contribution of all combined to provide a higher signal to noise ratio or (E_b/N_0) in multipath environment.

→ Rayleigh fading :-

The Rayleigh distribution has a probability density function given by. (σ = signal)

$$P(r) = \begin{cases} \frac{r}{\sigma^2} \exp\left(-\frac{r^2}{2\sigma^2}\right) & (0 \le r \le \infty) \\ 0 & (r \le 0) \end{cases}$$

σ = rms value of received signal

$r^2/2$ = instantaneous power

σ^2 = low average power of received signal before detection.

→ Rayleigh fading channel :-

In mobile radio channels the Rayleigh distribution is commonly used to describe the statistical time varying nature of received envelope of a flat fading signal, (or) the envelop of an individual multipath component.

→ It is well known that envelop of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution

→ AWGN :- (Additive White Gaussian noise)

is a basic noise model used to replicate the effect of several random process that occur in nature.

→ 'Additive' bcoz it is added to any noise that might be intrinsic to information system

→ 'White' refers the fact that it has uniform power across the freq band for the information system. It is analogy to the color white has uniform emission at all frequencies in visible spectrum.

→ "Gaussian" :- bcoz it has normal distribution in the time domain with an average time domain value of zero.

→ AWGN model does not account for fading, frequency selectivity, interference non-linearity (or) dispersion.

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→ Bit Error Rate (BER). / Bit Error Ration (BER):-

is the no:- of bit errors divided by total no: of transferd bits during a studied time interval.

$$BER = \frac{\text{no:- of erred bits}}{\text{Total no: of bits sents}}$$

→ In a noisy channel the BER is often expressed as a function of the normalized carrier to noise ratio measure denoted (E_b/N_0) (Energy per bit to noise power spectral density ratio).

BER Condition:-

In the case of QPSK modulation and AWGN channel the BER as function of the E_b/N_0 given by

$$BER = \frac{1}{2}\, erfc\left(\sqrt{E_b/N_0}\right)$$

→ Nakagami fading:-