Exp-9:-Flat Fading

1 Theory for Experiment 9:-Flat Fading

Small scale fading characterizes the fluctuation of signal(strength) over a spatial distance of fraction of wavelength.

The fluctuation is also observed in both time and frequency domain at a gain location.

The variation of signal (strength) at the receiver is due to random interference between the different copies of the transmitted signal. The interference is sometimes constructive and sometimes destructive. The multiple copies of the transmitted signal are generated due to scattering,reflection and defraction due to obstacle present in the path of radio signal between the $T_x and R_x$ movement of the $T_x and R_x$ or the obstacle cause time domain variation of the signal (strength) and the phenomenon is called Doppler effect.Since each path of the radio wave may exhibit difference doppler its cumulative effect results in spread of the carrier/ frequency content of the signal and hence is also known as Doppler spread.

If v is the maximum velocity (m/s)then the maximum Doppler shift is given by

$$f_m = \frac{v(m/s)}{c} * f_c(Hz)$$

where,

- c= velocity light =$3 * 10^8$m/s.
- f_c= carrier frequency.

Coherence time is defined as interval in time overwhich the signal remains correlated. it is defined as

$$T_c = \frac{9}{16\Pi f_m}(s)$$

If symbol duration $T_s \ll T_c$ it experience slow fading while if $T_s > T_c$ it experience fast fading. The enveloped **level crossing rate** is defined as the rate at which the signal signal envelope crosses a specified level R in the positive (or negative) going direction.

It requires the joint pdf $(\alpha, \dot{\alpha})$ of the enveloped level $\alpha = |r|$ and enveloped slope $\dot{\alpha} = |r|$

$$L_R = \sqrt{2\pi(k+1)} f_m \rho e^{-k-(k+1)\rho^2} I_0(2\rho\sqrt{k(k+1)}) \qquad \rho = \frac{R}{\sqrt{\Omega_\rho}} = \frac{R}{R_{rms}}$$

$R_{rms} =^{\Delta} \sqrt{\Omega_\rho}$ is the enveloped level

For Rayleigh fading (k=0) and isotropic scattering $L_R = \sqrt{2\pi} f_m \rho e^{-\rho^2}$

Level Crossing Rate For Selection Combinning

$$L_R = f_m \sqrt{\pi} M \frac{\gamma}{\sqrt{\sigma}} exp(-\frac{\gamma^2}{2\sigma}) \left[1 - exp(-\frac{\gamma^2}{2\sigma})\right]^{M-1}$$

where,

- f_m is the Maximum doppler frequency.
- σ is the r.m.s value of the received signal voltage.
- γ is the threshold voltage.
- M = No.of channels

Level Crossing Rate For MRC Combinning

$$L_R = 0.5 f_m \left[\frac{\sqrt{2\pi}\left(\frac{\gamma}{\sqrt{M^2+M}}\right)^{M-\frac{1}{2}}}{(M-1)!} \right] exp\left(- \frac{\gamma}{\sqrt{M^2+M}} \right)$$

Average enveloped fade duration

The average duration the enveloped remains below a specified level R.

$$t = \frac{1}{N_R} P_r[r \leq R]$$

Average fade duration For Selection Combinning

$$ADF = \frac{\sqrt{\rho} * exp(\frac{\gamma^2}{2\sigma} - 1)}{\sqrt{2\pi} f_d M \gamma}$$

For rayleigh distribution fading

$$P(r)[r \leq R] = \int_0^R P(r)dr = 1 - exp(-\rho^2)$$

$$\bar{t} = \frac{e^{\rho^2 - 1}}{\rho f_m \sqrt{2\pi}}$$

In case of flat fading the plot of signal enveloped of transmitting 'r' is given as

$$p(r) = \frac{r}{\sigma^2} exp\left(- \frac{r^2}{2\sigma^2} \right) \qquad (0 \leq r \leq \infty)$$

$$= 0 \qquad (r < 0)$$

where,

- σ is the r.m.s value of the received voltage signal before detection.
- σ^2 is the time average power of the received signal before enveloped detection.

Probability of outage is defined as

$$P(R) = Pr(r \leq R) = \int_0^R p(r)dr = 1 - exp\left(- \frac{R^2}{2\sigma^2} \right)$$

The mean value r_{mean} of rayleigh distribution is given by

$$r_{mean} = E[r] = \int_0^\infty rp(r)dr = \sigma \sqrt{\frac{\pi}{2}} = 1.2533\sigma$$

$$\sigma_r^2 = E[r^2] - E^2[r] = \int_0^\infty r^2 p(r)dr - \frac{\sigma^2 \pi}{2}$$

$$= \sigma^2 \left(2 - \frac{\pi}{2}\right) = 0.4292\sigma^2$$