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ANALYSIS OF RAYLEIGH VERSUS RICIAN MULTIPATH FADING MODEL IN GPS SIGNAL

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Abstract *- Global Positioning Systems (GPS) plays a vital role in day today life by providing a reliable and robust worldwide positioning for the increasing demand of precise positioning services. The RF signals transmitted by GPS satellites causes signal degradation due to interference, noise and fading affects the receiver leads to poor receiving positioning performance. The, Multipath fading is currently the major and largest error source. The channel between transmitter and receiver is affected by absorption, reflection, refraction, diffraction, and scattering. They are greatly affected by the ground terrain, the atmosphere, and the objects in their path, like buildings, bridges, hills, trees, etc. These factors lead to the fading of the transmitted signal and poor positioning accuracy of satellites. In this paper, different fading models are compared and also incorporation of indoor and outdoor propagation model in GPS signals based on the channel conditions are simulated and it is analyzed on the software GPS receiver.*

Keywords *- (Size 10, Italic) Component, formatting, style, styling, insert. (atleast 5 to 6 keywords should be mentioned)*

1. Introduction

1.1 Fading Effect

In most of the wireless communication systems, the height of the antenna may be smaller than the surrounding structures. Ths, the existence of a direct or line-of-sight path between the transmitter and the receiver is highly unlikely. In such a case, propagation is especially because of reflection and scattering from the buildings and by diffraction over and/or around them. So, in practice, the transmitted signal arrives at the receiver via several paths with different time delays causing a multipath situation as in Figure1. The software based implementation of multipath model has been implemented in [4,10] in which the propagation model which is suitable for indoor and outdoor scenario are discussed.

At the receiver side, these multipath waves with randomly distributed amplitudes and phases combine to give a resultant signal that fluctuates in time and space. Therefore, a receiver at one location may have a signal that is much different from the signal at another location, only a short distance away, because of the change in the phase relationship among the incoming radio waves. This causes significant fluctuations in the signal amplitude. This phenomenon of random fluctuations in the received signal level is termed as fading [1,2 and 3]. Many works [6,7 and 11,12,13,14] related to fading and noise, interference is listed in the literatures.

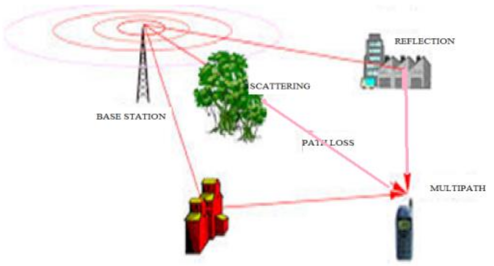

Figure 1: Multipath propagation and Fading effects

the further processing. There are several methods to resolve the problem illustrated in the literature [1-3,4-7 and 9].

2. TYPES OF FADING

2.1 RAYLEIGH FADING

The multipath signals are added constructively or destructively in the manner of different phenomenon affected on the GPS signals is given by [5]

$$s(t)=\sum_{i=1}^{N} a_i \cos(\omega_c t+\phi_i)$$

where N is the number of paths. The phase φ_i depends on the varying path lengths, changing by 2π when the path length changes by a wavelength. Therefore, the phases are uniformly distributed over the interval [0,2π]. If there is a relative motion between the transmitter and the receiver, eqn. (2) must be modified to include the effects of doppler shifts and phase shifts. The Doppler shift of the wave is given by

$$\omega_{d_i} = \frac{\omega_c v}{c} \cos\psi_i$$

the ith reflected wave with amplitude a_i and phase φ_i arrive at the receiver from an angle ψ_i ,relative to the direction of motion of the antenna.v is the velocity of the user, c is the speed of light (3×10^8 m/s), the ψ_i are uniformly distributed over $[0,2\pi]$.
Now, the received signal s(t) is written as [5],

$$s(t) = \sum_{i=1}^{N} a_i \cos(\omega_c t + \omega_{d_i} t + \phi_i)$$

Expressing the signal in in phase and quadrature form, eqn. (4) can be written as

$$s(t) = I(t)\cos\omega_c t - Q(t)\sin\omega_c t$$

where the in phase and quadrature components are respectively given as [5]

$$I(t) = \sum_{i=1}^{N} a_i \cos(\omega_{d_i} t + \phi_i)$$

$$Q(t) = \sum_{i=1}^{N} a_i \sin(\omega_{d_i} t + \phi_i)$$

The envelope R is given by

$$R = \sqrt{[I(t)]^2 + [Q(t)]^2}$$

When N is large, the in phase and quadrature components will be Gaussian. The probability density function (pdf) of the received signal envelope, f(r), can be shown to be Rayleigh distribution is given by

$$f(r) = \frac{r}{\sigma^2}\exp\left\{-\frac{r^2}{2\sigma^2}\right\}, \qquad r \geq 0$$

Level crossing rate is defined as the expected rate at which the Rayleigh fading envelop normalized to the local root mean square signal level crosses a specified threshold level in the positive going direction [8]. The Probability of envelop of the received signal does not exceed a specified value 'R' is given by $p(r \leq R) = \int_O^R p(r)dr = 1 - e^{-\frac{r^2}{2\sigma^2}}$ where σ is r.m.s value of the envelope of the received signal. The level crossing rate is given as $N_R = \sqrt{2\pi f_m \rho e^{-\rho^2}}$
Where $\rho = R/r_{rms}$ and $r_{rms} = \sqrt{2\sigma}$, here ρ=1 (Threshold=r.m.s value).The level crossing rate of fast and slow fade scenarios are calculated using the envelope detector while a moving vehicle is under deep fade. Based on this definition, the statistical parameters like how many times the envelope of the faded signal stay below a certain threshold, how long period the receiver is under deep fade and how the signal strength is varying are calculated.

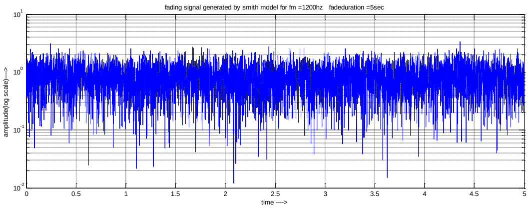

Figure 2.a: A typical Rayleigh fading envelope

2.2 RICIAN FADING

If there is stationary signal component present like non fading signal, such as a line of sight propagation path, the small-scale fading envelope distribution is Rician one. In such case, random multipath components arriving at different angles are superimposed on a stationary dominant signal. At the output of an envelope detector, this has the effect of adding a dc component to the random multipath [9].

Just as for the case of detection of a sine wave in thermal noise, the effect of a dominant signal arriving with many weaker multipath signals give rise to the Rician distribution. As the dominant signal becomes weaker, the composite signal resembles a noisy signal which has the envelope that is Rayleigh. Thus, the Rician distribution degenerates to a Rayleigh distribution when the dominant component fades away.

The Rician distribution is observed when, in addition to the multipath components, there exists a direct path between the transmitter and the receiver. In the presence of direct path or line of sight, the transmitted signal given in eqn. (10) can be written as [5],

$$s(t) = \sum_{i=1}^{N-1} a_i \cos(\omega_c t + \omega_{d_i} t + \phi_i) + k_d \cos(\omega_c t + \omega_d t)$$

where the constant k_d is the strength of the direct component, ω_d is the Doppler shift along LOS path, and ω_{di} are the Doppler shifts along the indirect paths given by equation. The envelope in this case has a Rician density function given by [5]

$$f(r) = \frac{r}{\sigma^2}\exp\left\{-\frac{r^2 + k_d^2}{2\sigma^2}\right\} I_o\left(\frac{r k_d}{\sigma^2}\right), \qquad r \geq 0$$

where $I_0()$ is the 0th order modified Bessel function of the first kind. The cumulative distribution of the Rician random variable is given as

$$F(r) = 1 - Q\left(\frac{k_d}{\sigma}, \frac{r}{\sigma}\right), \qquad r \geq 0$$

where Q (,) is the Marcum's Q function.

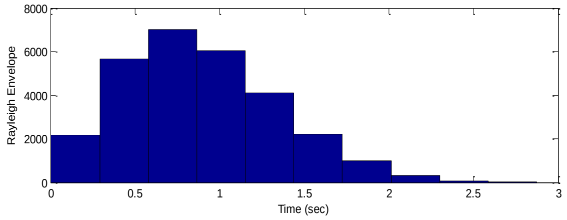

Figure 2.b: Rayleigh probability density function(pdf)

The Rician distribution is often described in terms of the Rician factor K, defined as the ratio between the deterministic signal power (from the direct path) and the diffused signal power (from the indirect paths). K is usually expressed in decibels as

$$K(dB) = 10\log_{10}\left(\frac{k_d^{\,2}}{2\sigma^2}\right)$$

In equation (13), if k_d goes to zero (or if $k_d^2/2\sigma^2 \ll r^2/2\sigma^2$) the direct path is eliminated and the envelope distribution becomes Rayleigh, with K(dB) goes to infinity.

3. Simulation Results

3.1 Comparison of Rayleigh faded and Rician faded envelope and power

To compare the performance of the Rayleigh fading and Rician fading by creating the GPS signal at the frequency of 1.5GHz and to find out the severely faded signal by applying to the indoor environment. Table 1 shows the simulation parameters used.

Table 1: Simulation parameters for Multipath fading

Parameters	Values
No. of paths	1,5,10
Carrier frequency(f_c)	1.5GHz
Doppler spread	10 KHz

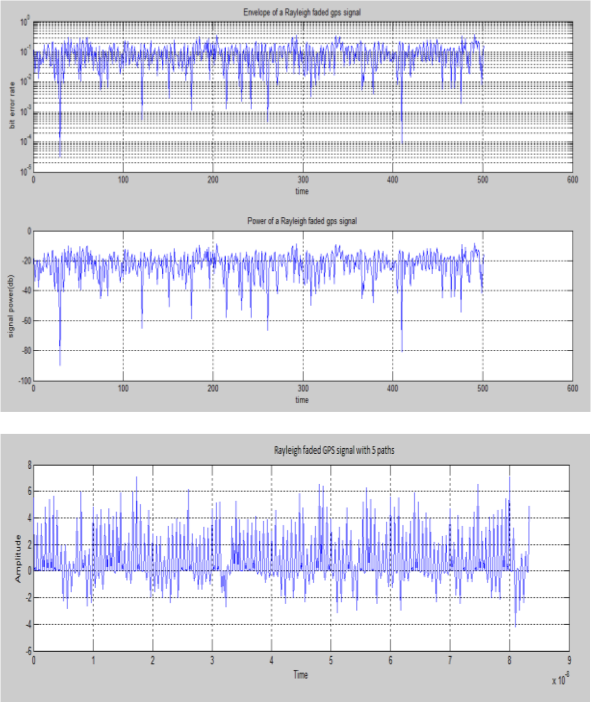

Figure 3: Rayleigh faded signal of 1.5GHz with one path and their envelope and power

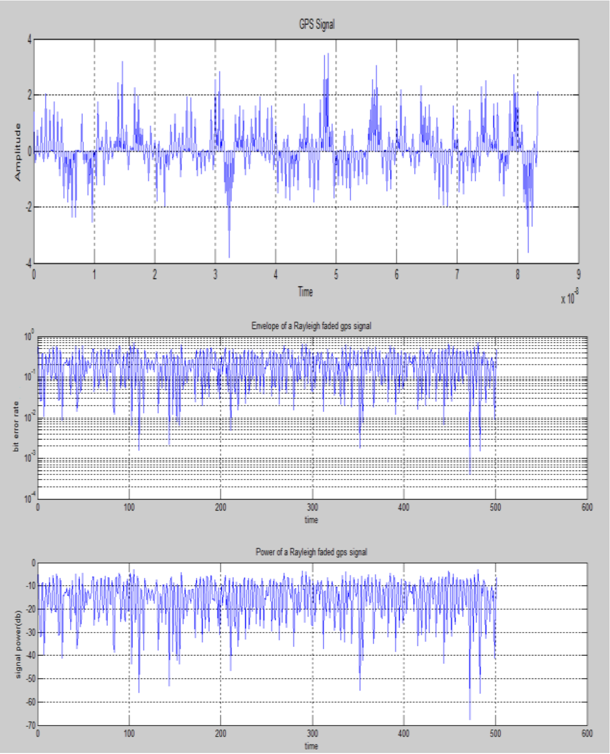

Figure 4: Rayleigh faded signal of 1.5GHz with 5 paths and their envelope and power

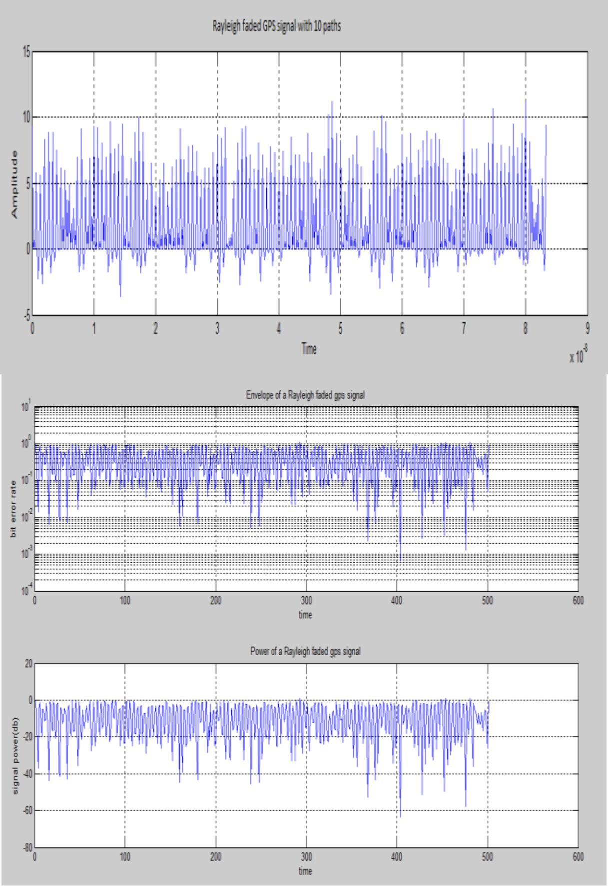

Figure 5: Rayleigh faded signal of 1.5GHz with10 paths and their envelope and power

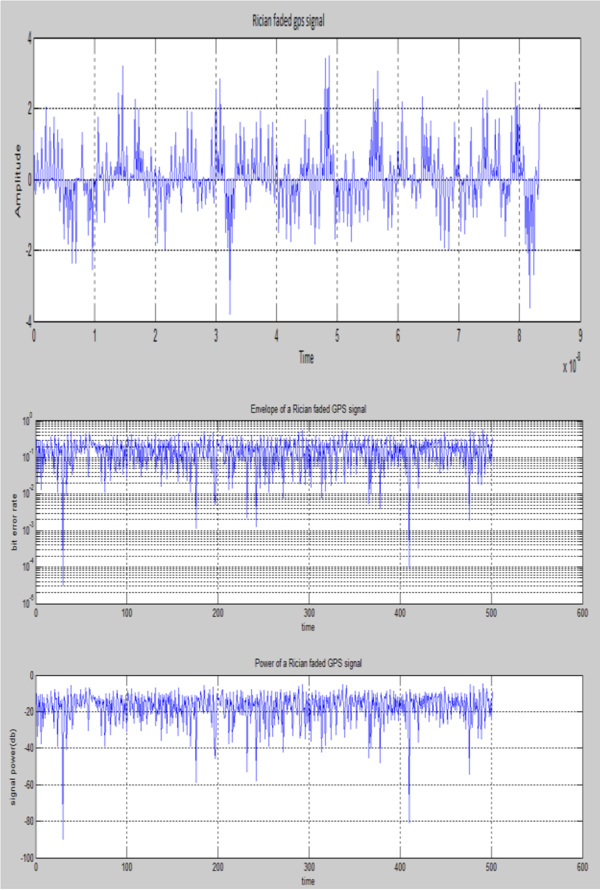

Figure 6: Rician faded signal of 1.5GHz with one path and their envelope and power

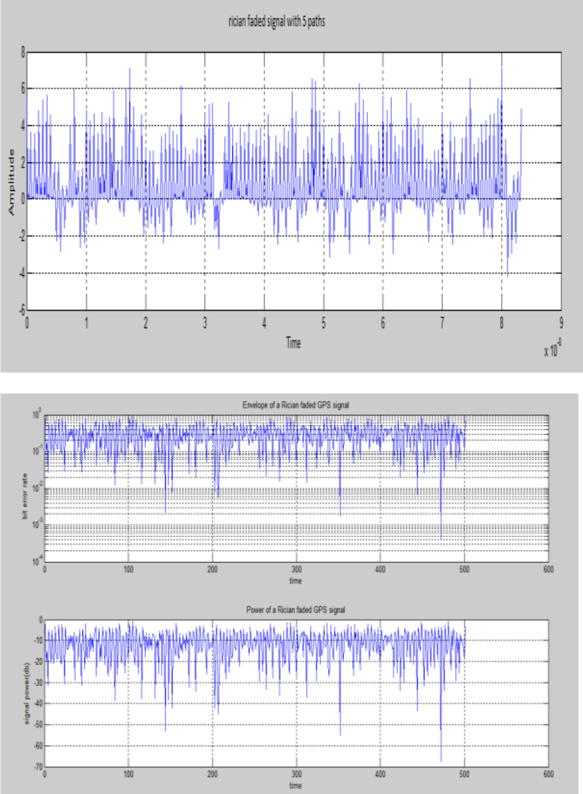

Figure 7:Fath paths envelope and power (Raician)

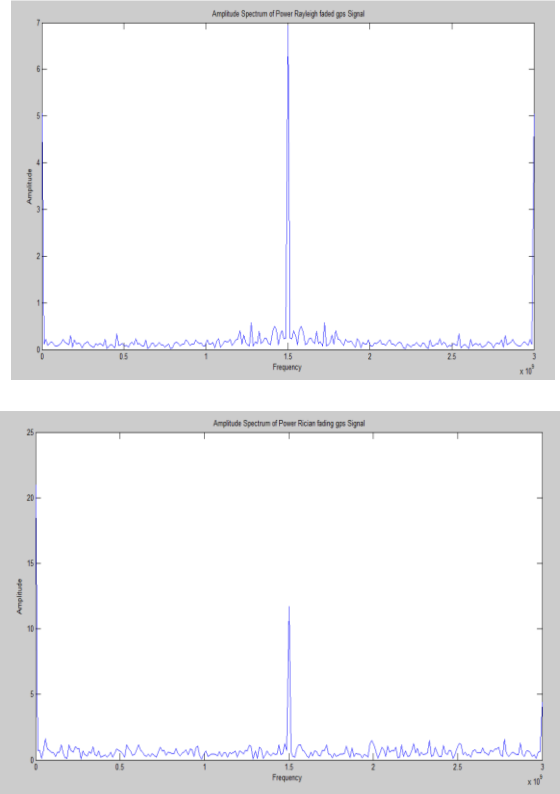

Figure 8: Rician faded signal of 1.5GHz with five paths and their envelope and power

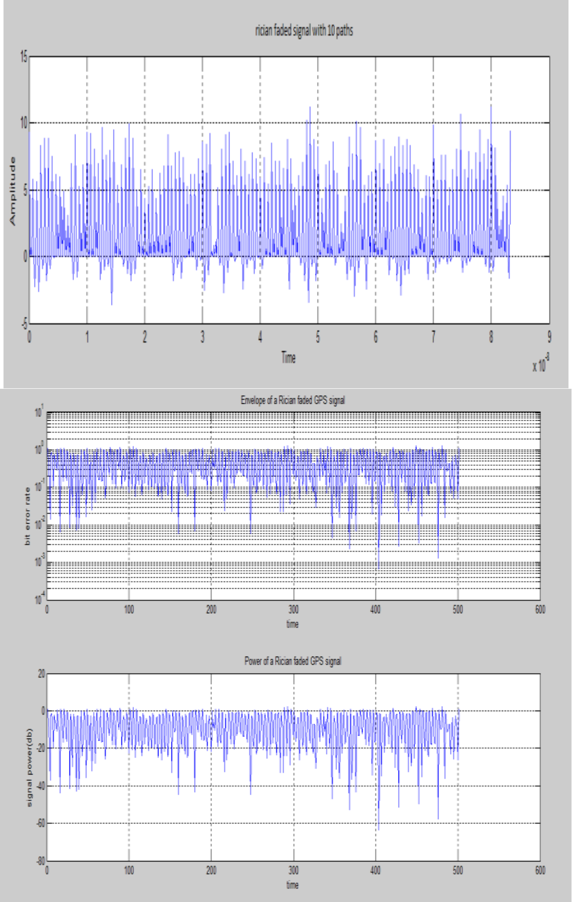

Figure 9: Comparison of power spectrum of Rayleigh fading and Rician fading to obtain the LOS

figure 9 shows the Rayleigh faded and Rician faded GPS signals at different paths and their corresponding envelopes and power level for various SNR with different number of paths is shown in Table 1. As the number of paths increases up to 5, the SNR of the peak is degraded to 4.5 dB.

Table 1: Comparison of different SNR values with Normalized difference between signal and noise peaks

SNR values (dB)	Signal-Noise peak for original GPS signal (dB)	Signal-Noise peak for 5 multipath signal(dB)	Signal-Noise peak for 10 multipath signal(dB)
15	0.8	1	2.0
-10	0.8	1.2	2.0
-15	0.8	1.7	2.5
-23	0.8	3.0	4.5

4. Conclusion

The different fading models have been examined and the causes of fading on GPS signals is studied. The Rayleigh fading model can be observed as one of the indoor fading models which does not have the LOS path. In this scenario, the receiver has to employ sophisticated technique to eliminate the multipath effects and to form the secondary path statistical parameters, the LOS path has to be constructed with highest degree of amplitude and the phase angle on the other hand, the racian fading model is the one which constitutes the LOS path and the secondary paths, so it can be easily modelled and the recovery of LOS path can be made in the outdoor scenarios.

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