

Full Length Research Paper

Doppler fading communication channel performance simulation

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Fading is commonly used to describe the properties of the communication channel. Large efforts have been made to describe characteristics of the channel in wireless communication system. The performance of wireless signal propagation in a conventional environment needs Doppler fading channel schemes by assuming a perfect knowledge about the channel frequency response at both the transmitter and the receiver sides. Two models were used to depict the characteristics of Doppler fading channel in term of source velocity, where the first is free space transmission model consists of two antennas at a given distance (r) to calculate the received signal strength for transmission links at relative motion between the transmitter and receiver antennas. The second model is simulation based on Matlab (2013B) to compute and plot the received signal envelope taking into account the source velocity over the multipath fading. The analysis and employing the information of Doppler fading can enhance the characteristics of channel estimation.

Key words: Doppler, fading, frequency, receiver, transmitter.

INTRODUCTION

The relative motion between the transmitter and receiver introduces Doppler shift. It affects the received signal frequency and causes frequency broadening. The transmission radio link between the transmitter source and destination receiver varies from flat earth model to multipath propagation mechanisms which the electromagnetic waves are severely obstructed by the mountains, high buildings and skyscrapers (Bernard, 1997; William, 1974; Proakis and Masaoud, 2008; Rappaport, 1999; Clarke, 1968; Dent and Bottomley, 1993). The different mechanisms of multipath propagation such as diffraction, scattering, reflection and refraction (Keller, 1962) play as important factors to create multiple

propagation paths.

Fading can be defined as the fluctuations in received electromagnetic wave as a consequence of multipath signal components. Many different replicas of the received electromagnetic waves can be arrived to the receiving end. These replicas came from different paths and interference constructively or destructively according to their amplitude, phase and time delay.

Fading can be classified into fast fading or slow fading. In addition, fading be classified into flat or frequency selective. However, the fast fading is more draw attention to the communication engineers because the fluctuations may affect dramatic problems in communication system

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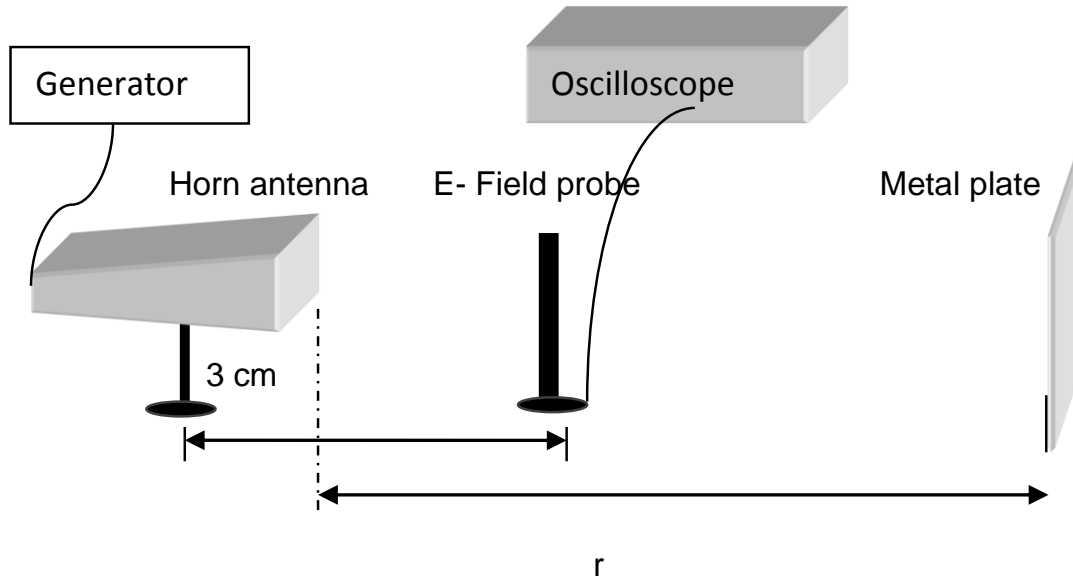


Figure 1. The experimental setup.

reliability (Kumar and Grover, 2012; Wang, 2011).

There are two models to determine the instantaneous value of signal strength; large scale model which is used to calculate the average power of received signal based on the distance between the transmitter and the receiver. The other is small scale model of fading which is used to calculate the fluctuations of average power of the received signal (Rappaport, 1999).

High speed railway is good example about commercial practical application for global demand in the modern communication system (Fan et al., 2012).

At the receiver, the reduction of the delay time and the different mobile speeds is obtained by applying variable coding or updating power density (Abdi et al., 2008; Zhang and Abdi, 2009); however, Doppler spread is used to decrease the surplus handoffs (Stuber, 2011). Special autoregressive fading channel was suggested in (Nissila and Passpathy, 2006). The restrictions that cause path loss and multipath such as noise, distortion, inter symbol interference are results of relative motion between the transmitter and receiver (Goldsmith, 2005). There are many schemes of Doppler spread estimation such as level crossing rate (Chen et al., 2011), covariance (Huang et al., 2013), power spectral density (Muralidhar et al., 2007) and maximum probability (Bellilil and Affes, 2013). Fading models work depend on assumption that the total fading arises from set of uncorrelated partial signal which have identically distributed of amplitudes and uniformly distributed of random phases (Xiao et al., 2003, 2006).

Finally we list two important factors that play as important impacts in multipath wave propagation. There are the relative movements between the transmitter and receiver and the signal bandwidth (Matthias, 2002).

MATERIALS AND METHODS

Experimental details

The experimental setup shown in Figure 1 consists of microwave function generator (Gunn Oscillator), horn antenna, E- field probe, oscilloscope, 2 coaxial cables with BNC/BNC connectors, metal plate with moving parts and stand bases. The horn antenna is connected to the Gun Oscillator by 2 m coaxial cable. The function of E- field probe is as separate mixer and positioned at distance of 3 cm approximately in front of horn antenna. The metal plate will be moved in the range of 20 cm to the 23 cm in the steps of 2 mm. The oscilloscope corresponding received voltage in each step will be stored in data file.

The relation of reflected voltage and the distance between the metal plate and the horn antenna was shown in Table 1. The received voltage was varied in sinusoidal form along the distance from 190 mm to 230 mm.

In the setup, the calculation of Doppler frequency depends on the metal plate velocity which was 100 cm/s and the half wavelength ($\frac{\lambda_0}{2}$) was equal to 1.6 cm which is the distance between two adjacent fades, therefore the Doppler frequency is equal to (Rappaport, 1999):

$$T \approx \frac{\lambda_0}{2V_r} \quad (1)$$

$$= \frac{1.6\text{cm}}{\frac{100\text{cm}}{\text{s}}} = 1/fd$$

$$fd = 62.5 \text{ Hz}$$

Where T is time duration over which the channel's response to a sinusoid has a correlation greater than 0.5, V_r is relative velocity and fd is Doppler frequency.

Simulated details

The fading loss is the combination of two factor effects; first is the

Table 1. The corresponding reflected voltage to the change of distance.

Distance (mm)	Reflected voltage (mv)
200	139
202	60
204	50
206	64
208	130
210	162
212	150
214	122
216	83
218	50
220	54
222	100
224	143
226	156
228	144
230	120

multi path propagation and second is Doppler frequency shift. These factors will produce random fluctuation in received signal at receiver side. The mathematical model to find the envelope of the received signal (R) for the fading loss depends on the parameters in following equations (Haykin and Moher, 2005):

$$X = \sum_{n=1}^N an \cos(2\pi fd \cos(\theta n)t + \varphi n) \quad (2)$$

$$Y = \sum_{n=1}^N an \sin(2\pi fd \cos(\theta n)t + \varphi n) \quad (3)$$

$$R = \sqrt{X^2 + Y^2} \quad (4)$$

Where we have the three random variables an , φn , and θn . an are the amplitude coefficients which are Gaussian distributed and the phase coefficients φn , and θn are the n th multipath arrival angle with direction of wave movement supposed to be a uniform distribution values such that $0 \leq \varphi n$ and $\theta n \leq 2\pi$, where N is the number of scatter paths, fd is the Doppler frequency shift and R is the signal envelope.

For simulation, the standard deviation is taken 0.001 therefore, the Doppler fading shift at receiving site thus shifted with respect to the transmission frequency signal is 62.5 Hz, when the vehicle velocity (V) is 9.375 m/s, the carrier frequency (f) is 2 GHz and the speed of light (C) is 3×10^8 m/s as shown in Equations 5 and 6:

$$\lambda = C/f \quad (5)$$

$$\lambda = 3 \times 10^8 / 2 \times 10^9 = 0.15 \text{ m}$$

$$fd = V/\lambda = 9.375 / 0.15 \quad (6)$$

$$= 62.5 \text{ Hz}$$

It is necessary to mention that the value of wavelength in this method which is equal to 0.15 m is different from the value of the wavelength at that practical method as a result of our selection of different relative velocities in the two cases.

RESULTS

Figure 2 shows the relationship between the received voltage and distance change from 195 mm to 235 mm. Thus, the distance travelled by metal plate (mobile) in the time interval corresponding to the two adjacent dips (small scale fading) is on the order of a half wavelength. Moreover, from Figure 2 and Equation 5 the coherence time is that required to traverse a distance of $\lambda/2$ when travelling at constant mobile velocity.

Using the Matlab program to include the parameters that define the Doppler fading, the results of received signal are drawn. We can plot the results as demonstrate as shown in Figures 3, 4, 5 and 6. Figures depict the relation between received voltage in (dB) as function of time. It would be useful to compare the received signal envelope through transmitting of the signal from source to destination taking into account the multiplicity of paths toward the destination which is named as Multi-path propagation which is the most crucial type of transmission link problems. So, the scattered signal as consequence of colliding signals with others will be received in the destination side from different paths. Bringing up the signal from the first direct path, and then followed by the reflected signals.

DISCUSSION

In simulation, figures illustrate the effect of increasing the multipath fading numbers on the received signal. It is clear that the amount of fading signal will be increased with respect to increasing the number of scatter paths from $N=5$ to $N=20$ in step of 5.

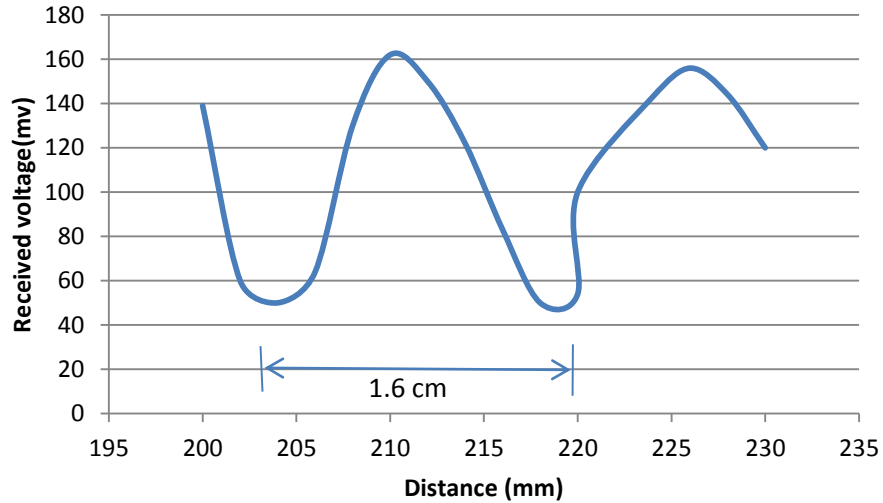


Figure 2. The relation of received voltage with respect to change of the distance.

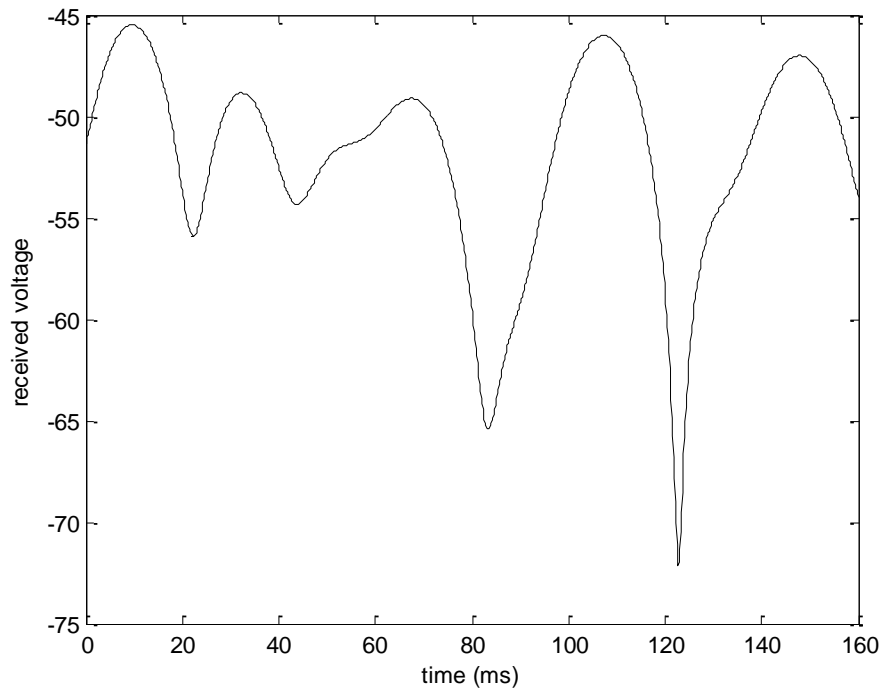


Figure 3. Doppler fading channel for $N=5$, $fd=62.5$ Hz.

We have set the threshold voltage to -55 dB; thus, the increasing of scatters will cause the envelope of the received signal to go below the level of threshold. On other hand, the outage probability can be introduced by the ratio of the samples number under the threshold level to the number of total samples. It is possible to increase the outage probability by increasing the threshold power. The degradation of the received signal is consequence of dynamically changed multipath and Doppler effects.

Conclusion

Since the Doppler fading is one of the major restrictions in transmission system, we have implemented experimental setup of free space transmission link and Matlab simulation model for Doppler fading. We can conclude that, the number of scatter paths affects the signal, where the increasing of scatter paths result distortion of the signal occurs due to interactions of the

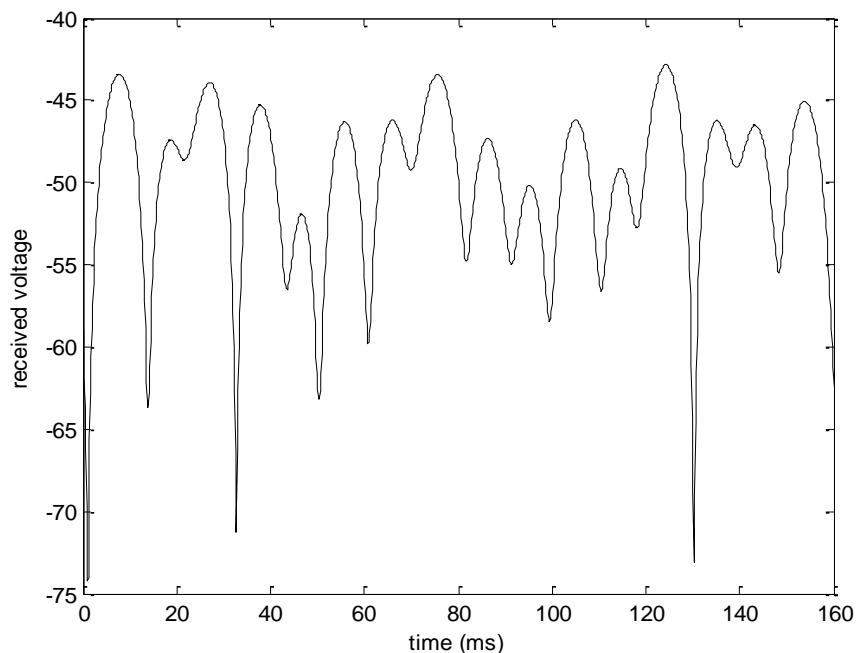


Figure 4. Doppler fading channel for $N=10$, $fd=62.5$ Hz.

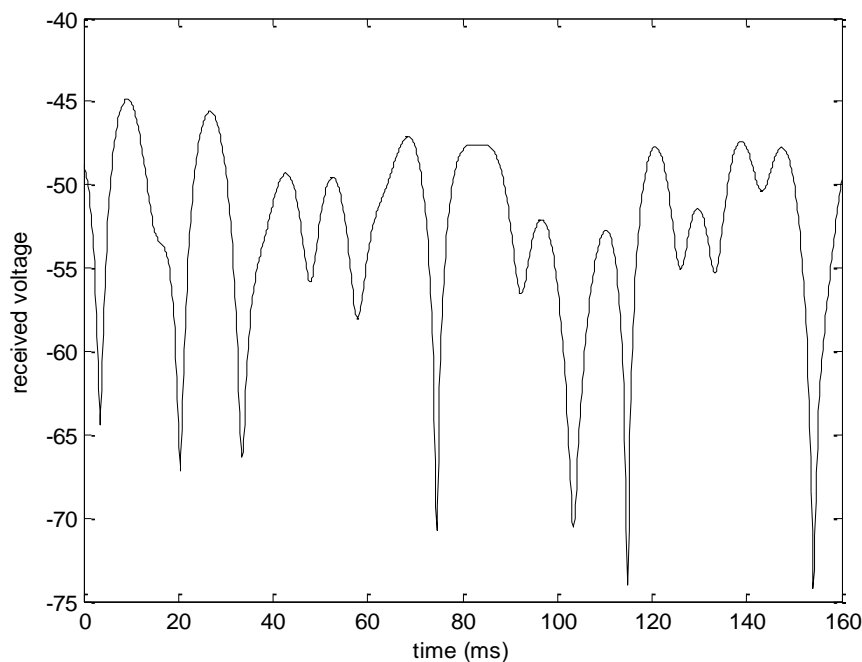


Figure 5. Doppler fading channel with $N=15$, $fd=62.5$ Hz.

many copies of receiving at different times. Doppler frequency affects the received signal by pulse mutilation, irreducible bit error rate and dispersion. The difference between the spectrum in the figures based on the fact that the theoretical spectrum assumes that the number of scatters is large sufficient to implement the Central Limit

Theorem. Moreover, there is a true Gaussian distribution on the scattering amplitudes and a true uniform distribution on the angles. However, we will report in the future the development of a generic model for other types of fading such as Rayleigh, Rician, Nakagami- N and Nakagami- q .

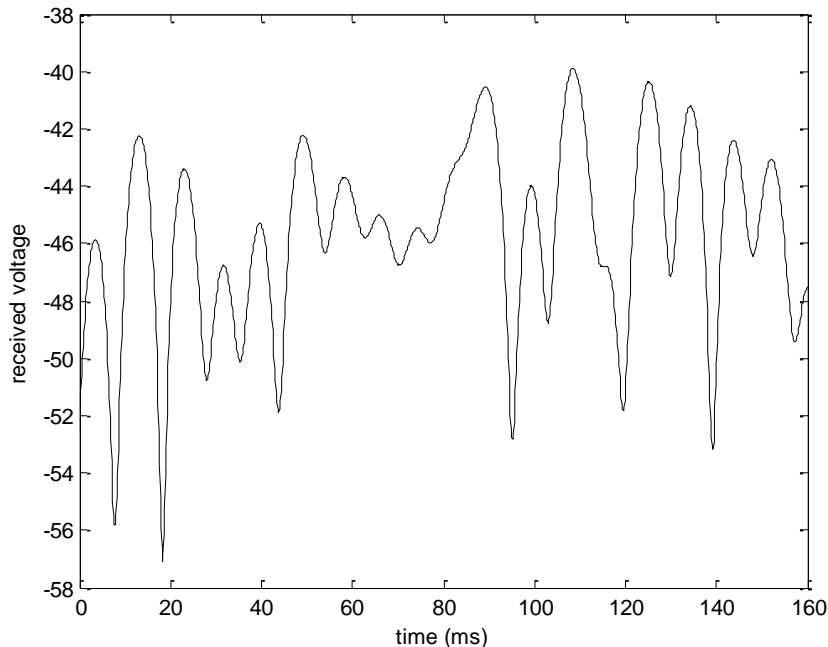


Figure 6. Doppler fading channel for $N=20$, $f_d=62.5$ Hz.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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