Multipath fading channels and transmitted signals computer science

Multipath fading is a phenomenon of fading of transmitted signals due to refraction, reflection and diffraction from objects or obstacles present in the line or way of transmission. In this article, we have be realized an example of multipath fading channels such as in case of Rayleigh fading channels using MATLAB and would be analysing the variations incurred after varying system parameters such as samples per second and Doppler shift of the respective blocks of the Rayleigh fading system. Also, here screen shots of the respective variations have been provided for clear understanding of induced variations.

1. Introduction

As mentioned earlier as well, multipath fading is the occurrence of fading of transmitted signals by refraction, reflection and diffraction due to obstacles present in the line or path of transmission and channels affected due to this type of fading are called multipath fading channels. Rayleigh fading is nothing but the statistical model that communication engineers use to study the characteristics propagation of radio signals, in case of wireless propagation channels. In general, Rayleigh fading model is used for studying ionospheric and tropospheric signals propagation and such that the signals are transmitted in a widespread manner i. e. they are transmitted in form of concentric rings throughout the atmosphere. Thus, these are not used to study the fading that occurs in line of sight propagation (for that Rician is preferred over it).

The Rayleigh fading channel can be used to study fading characteristics such as in cases of densely populated cities with a large number of skyscrapers (such as Central London and NYC). The central limit theorem limits this concept such that the amount of scatter can be considered as a function of irrespective of individual function of Gaussian distribution. The impulse response can be modelled a random function varying from 0 to 2pie [1]. The probability distribution function R(of Rayleigh fading) can be given as;

Where, AZA© = A E(R2). [1]

As mentioned in abstract that we would be varying the Doppler shift in case of Rayleigh fading and will be explaining the observed variations in the generated output, it’s better to have an understanding of what Doppler shift actually means as well for better understanding of concepts. Doppler effect (or Doppler shift) can be described as the increase or decrease in Doppler frequency in case of a moving object (for e. g. the Doppler frequency increases when the object is moving towards the stationary or moving object and vice versa for moving away from the desired moving or stationary object). The mathematical expression for Doppler frequency can be given as;

f = left(frac{v + v_r}{v + v_{s}} right) f_0 ,

Where Vr is the velocity of receiver relative to the medium and Vs is the velocity of source relative to the medium and V is the velocity of waves in the medium [2].

Also, Doppler power spectral density which is also an important parameter of Rayleigh fading is the measure of spectral broadening caused in the waveform characteristics of the transmitted signal (such that the received signals appears to be faded and broadened as compared to the actual signal sent). The mathematical expression for Doppler power spectral density can be shown as [3];

$$S(\nu) = \frac{1}{\pi f_d \sqrt{1 - \left(\frac{\nu}{f_d}\right)^2}}$$

Realization of Rayleigh fading using MATLAB

A sample program of Rayleigh fading can be accessed in MATLAB 2010a by typing the command “ doc_qpsk_rayleigh_derotated” in the command window. The MATLAB operator gives us a block diagram of the Rayleigh fading. It consists of a Bernoulli binary sequence generator, two QPSKs, one error rate calculator, one Rayleigh fading block (where adjustments regarding Doppler shift can be made), one phase removal of path gain block and in the end an AWGN block for simulation of faded signal (4). The screenshot of block diagram for Rayleigh fading had been shown below;

Figure 1. MATLAB screenshot of the block diagram for simulating the Rayleigh fading

2. 1 Simulation with basic values of Doppler shift and sample rate

The simulation results into three possible outputs. These are transmitter output, Rayleigh channel output with no phase component and Rayleigh noisy channel output with no phase component. These outputs for sample simulation with bit sample rate/sec of 100logbase2 (M) and maximum Doppler shift of 1000 hertz is shown below. The screenshots of respective output of QPSK modulator output, Rayleigh channel output and noisy Rayleigh channel output has been shown below;

Figure 2. screenshot of MATLAB simulated QPSK modulator output for Rayleigh fading

Figure 3. screenshot of Rayleigh channel output for Rayleigh fading (simulated using MATLAB)

Figure 4. screenshot of the noisy Rayleigh channel output for Rayleigh fading (simulated using MATLAB)

2. 2. Simulation with changed values of Doppler shift and sample rate

In the second simulation i have changed the values in Doppler shift and sample rate per second. The Doppler shift can be changed by changing masking parameters in the Rayleigh fading channel. Here, in this simulation I have kept the Doppler shift to 10000Hz while in previous case it was 1000Hz. Also, in Bernoulli bit sequence generator the value of samples per second had been changed to 1000logbase2 (M). The observed variations have been shown below.

Figure 5. QPSK modulator output of the Rayleigh fading (simulated using MATLAB)

Figure 6. Rayleigh channel output for the Rayleigh fading (simulated using MATLAB).

Figure 7. Noisy Rayleigh channel output for Rayleigh fading (simulation using MATLAB)

2. 3. Explanation of the observed variations

It can be seen that in first case the outputs (amplitude) of QPSK modulator lies in the range of -1 to 0 and 0 to +1 while it varies from -2 to 0 and 0 to +2 which obviously should be observable as the samples per second gets increased from 1000 to 10000 samples per second. However, as the Doppler shift is increased the fading becomes more visible in case of the Rayleigh fading and noisy Rayleigh fading channels. The explanation can be given using Jake's model which relates the Doppler shift and Rayleigh fading. Jake's model relates the Rayleigh fading for kth wave to Doppler shift in following manner;

R(t, k) = 2sqrt{2}left[sum_{n= 1}^{M}left(cos{beta_n} + jsin{beta_n}right)cos{left(2 pi f_n t + theta_{n, k}right)} + frac{1}{sqrt{2}}left(cos{alpha} + jsin{alpha}right)cos{2 pi f_d t}right]

Also, fn= fd(cosa) [5]

Hence, it can be said that the amount of Rayleigh fading is directly proportional to the cosine of Doppler shift experienced by the transmitted wave. Also, worth mentioning over here is that is cosine decreases from 0 to increasing values of angle. It can be also seen that from expression mentioned above for power spectral density for Doppler shift that if the Doppler shift is increased the corresponding power spectral density is also increased. Thus, the results shown in the screenshots are explained and justified and it can be said that with the increase of Doppler shift the transmitted waves the Rayleigh fading is increased and so is the power spectral density related to it.

Conclusion

Rayleigh fading is an important phenomenon used to explain multipath fading in case of the dense populated areas. Rayleigh fading affects a transmitted signal by making broadened and faded in nature and it also does effects it's power spectral density in a big way. Also, with increase in Doppler shift the Rayleigh is increased as well. In this setup, channel distortion parameters such as gain and phase are defined as a complex number consisting of real and imaginary parts. Thus, Rayleigh fading can be said to be composed of two paths (real and imaginary) and can be considered as independent paths which can be added in order to get net magnitude of Rayleigh fading occurred in the transmission [6].

To counter the effects of Rayleigh fading a number of techniques were used in the past but the most common one used these days is using a White Gaussian simulator for maintaining bearable effects of Rayleigh fading. This had been shown in the block diagram shown above.

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Spread Spectrum ModelsAbstract

Spread spectrum is a statistical modulation technique that is been used for increasing the available channel bandwidth. In this article we have focussed on the one the spread spectrum models i. e. two users real spreading with BPSK modulation using MATLAB. Also, a brief study of variations and the explanation of such observations are made in this article. Here, I'll be varying the SNR value of the AWGN block in the given block diagram for the spread spectrum model and would be observing and explaining the variations occurred.

1. Introduction

Spread spectrum modulation is a type of modulation in which we intentionally increase the available bandwidth in frequency domain i. e. we stretch the available bandwidth. This leads to a broadened or widened signal for with increased bandwidth. This is generally done to increase bandwidth for signals that require more bandwidth for transmission (it has an effect similar to aliasing but the difference we take anti-aliasing measures against the later). The system models that use such spread spectrum techniques are called spread spectrum models.

Two user model for real spreading with BPSK modulation basically utilizes two different orthogonal codes for spreading of the codes. The process of spreading is independent in nature i. e. a different pn sequence for each of the two users. This model uses the orthogonal frequency division multiplexing access technology (OFDM) for communication between the two users simultaneously. In this scheme, there are a large number of orthogonal sub carriers separated by a very small distance. The data is then divided into small but same sized chunks and then are loaded (modulated) on these orthogonal sub carriers through multiple paths [1]. The subcarriers then can use any of the conventional technologies for modulating these data packets (such as QAM or PSK) for transmission over the channel. Also, the symbol rates for individual data packets are maintained such that those comparable to its conventional counterparts. However, OFDM is more popular with wireless systems.

2. 1. Realization of spread spectrum model using MATLAB

Two user orthogonal real fading with BPSK can be realized in MATALAB by typing commspreading_orthobpsk2u in the MATLAB command video. The result shown on the MATLAB simulation window is a block diagram of two user real spreading with BPSK. The screenshot of this has been shown below;

Figure 1- Two-user orthogonal real spreading with BPSK modulation (simulated in MATLAB)

As shown in the block diagram here the system setup can be broadly classified into three sections. These are transmitter section, the channel and then receiver section. Receiver section is further extended into one more section known as error calculation section. Let us have a brief look into each of the sections mentioned above.

2. 1. 1 Transmitter section

The transmitter section is responsible for transmitting signals to receiver section via channel section of the system setup. Transmitter section is basically made up 5 major components, these are Random integer (signal generator), real BPSK modulator, Hadamard code generator, normalized gain and spreader blocks. Random integer block is used for the generation of signals that could be used for sending over the channel. These signals are then BPSK modulated where it is also mixed with the actual user signals and sent to spreader section. The sequence generated is of 64 bits length.

Then on the lower side of the transmitter contains Hadamard code generator which generates unique Hadamard codes for the signals encryption and security to protect it from hacking and noise addition over the channel. The gain of the Hadamard code is then normalized and mixed with the BPSK modulated signal in the spreader section. The spreader is responsible for the deliberate spreading of signals in the frequency domain to increase the bandwidth of transmitted signal.

2. 1. 2. Channel section

Channel section here refers to actual channel or medium through which transmission is done. But here it’s not wireless as it is an experimental setup. This section here contains AWGN correction blocks. These are responsible for deciding SNR values for the transmitted signals as to gain knowledge about the actual signal transmission through wireless medium. Here, a person can set values of SNR such that to determine the low and high noise environment and the results of these variations of the error rate at receiver section.

2. 1. 3. Receiver section

The receiver section is responsible for the reception, decryption, de-spreading and calculation of error rate in the received signals after travelling through the physical medium. The process carried out here is just opposite as of transmitter section of the setup. The received signal is first sent to de-spreader for removing the spreading done in transmitter section. The integrator and dump section is used to detect or separate out RZ and NRZ parts of bit sequence [3]. Then the sequence is sent to demodulating BPSK section and then to error rate determination section for error rate estimation.

2. 2. Effects of Variations in SNR on the Error rate

The effects of variations of SNR on the error rate have been summarized below. The table below shows the variations in values of SNR and the corresponding changes in error rate i. e. eRx/Rx (number of erroneous bits transferred /total bits received [2]) with de-spreading. Also, worth mentioning here is that the time period for which the simulation is carried by the system is set to 0. 125 seconds in this sample spread spectrum modulation. The table is as under;

Figure 2. Table above depicts the effect of variation of SNR on the error rate of the system setup explained above (all values are realized in MATLAB and written down in the table)

The table above shows that with increasing values of signal to noise ratio the value of bit error rate is reduced. But it is different in first two readings for receiver1 and receiver2 while it ends out to be zero for SNR value 100 dB for all of the values simulated in a time defined range of 0. 125 seconds. This pretty understandable that the dispreading used is here is of ideal nature thus the value of erroneous bits goes down as value of SNR increases. The difference in the error rates between the first two readings of receiver1 and receiver2 is pretty understandable as the two different signals have different error rates when they are transmitted through two different Hadamard codes (i. e. initial seed for first receiver was set to 37 and for second it was set 631).

3. Conclusion

Two user orthogonal real fading with BPSK modulation is used as an experimental to study the characteristics of spread spectrum. The OFDMA as we know splits the large data into small equally sized fragments and transmits it through multiple paths thus is also affected by multipath fading. This particularly affects wireless channels even makes is even more difficult to maintain SNR and low error rates. To counter the effects AWGN simulator is used such that the effects of multipath fading are neutralized.

The observations made with this system setup prove that value of SNR affects the error rate percentage in the transmission. As the value of SNR is increased the value of error rate goes down and vice versa for a lower value of SNR.

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IEEE 802. 11 WLANAbstract

IEEE 802. 11 is the standard adopted by IEEE for design of wireless network systems. Here, in this article a sample simulation of 802. 11 standard is done using MATLAB and Simulink. Also, a brief description of operation and functional characteristics of blocks (i. e. components) used for attaining and maintaining wireless networks have been made. Also, certain parameters of WLAN system setup are varied to make a brief study of changes that incur in the system due to these variations.

1. Introduction

Secure, dependable and fast wireless systems have become a need of current growing world that touches everyone ranging from individuals to large organizations. Wireless networks are needed for small private area networks such as Bluetooth and Ad Hoc and large networks for wider network coverage such as 3G and 4G networks are currently being employed for providing internet and communication services to people with mobility.

The WLAN 802. 11 standard is used for wireless communication networks in 2. 4, 3. 6 and 5 GHz frequency bands [1]. There is a complete family of 802. 11 which uses a number of over the air modulation techniques for transmission and reception of signals. There a number of versions launched by IEEE under the name of 802. 11, this includes 802. 11a, 802. 11b, 802. 11g and 802. 11n. The most frequently employed among these are 802. 11b and 802. 11g. The data to be transmitted is first broken in small and equally sized packets and then modulated and transmitted on multiple channels (through different paths) to the destination. Thus, it uses OFDMA access for setting up communication.

802. 11 standard has a complete frame stack for secure and dependable communication. These include certain frames for controlling and maintaining the wireless connection among wirelessly connected hosts. These are Protocol version, Type, Sub type, ToDS and FromDS, More fragment, Retry, Power management, More data and WEP [2]. All these play important part in setting, maintaining, controlling and releasing the wireless connection

among a number of wirelessly connected hosts on 802. 11 system. Below is shown a sample example of how 802. 11 WLAN standard system looks like.

Figure 1. The Linksys WRT54G contains an 802. 11b/g radio with two antennas [3].

2. 1. Realization of IEEE 802. 11 WLAN standard in MATLAB

A sample MATLAB program for IEEE 802. 11 WLAN can be realized in MATLAB by typing the same in help command box of the MATLAB. The output shows an experimental setup containing block diagram of the IEEE 802. 11 WLAN system. This has been shown below.

Figure 2- The screenshot above shows the block diagram of the sample IEEE 802. 11 WLAN standard simulated in MATLAB

The block diagram broadly contains variable-rate data source, BPSK modulator and demodulator, OFDM symbol generation block and disassemble OFDM frame block, multipath channel and a packet error calculation block. Also, the signal visualization block for opening the signal characteristics of such setup. These signals characteristics are shown below.

Figure 3-The signals transmission and receiver characteristics of the 802. 11 system setup using sample settings (simulated in MATLAB)

2. 2. Operations and working of the Block diagram

The signal characteristics can be visualized in the above screenshot. The transmitted data consists of a binary stream of data send with OFDMA modulation. In this model shown above the variable rate data source is used to generate a binary string of variable data rates which could be considered as similar to the real life scenario as data rates vary with time and need of the users. This binary string is then BPSK modulated using BPSK modulator which is the case with OFDMA as it uses any other general modulation technique for the modulation of signals and then OFDMA codes are added to it. The signals are now undergo a number of alterations before reaching the multipath channels. These include adding a cyclic code to the signals and going through IFFT which is inverse fast Fourier transform to the signal. The signals are then sent through multiple paths which is the case with the OFDMA. This completes transmitter section.

After all these processes the signal enters the receiver section of the WLAN. The signals go through cyclic code removal block and then FFT or fast Fourier transform block to anti the effects of IFFT. Then signals are equalised in frequency domain as these get disturbed in frequency domain as shown in the figure 2 signal equalization. The disassemble OFDM block takes off the OFDM codes from the signals and then the signals is demodulated using a BPSK demodulator after which the signal output is sent to the error collection block where the original and received signals are compared to get error rate in the transmission. Also, one more output wire goes to adaptive modulation control block where the degree of modulation is controlled according to the bit error rate achieved by the system. Also, the value of SNR is varied according to the values entered in the stack. This also changes the adaptive modulation control.

2. 3. Effects of variations in certain parameters of IEEE 802. 11 WLAN setup

The effects of inducing variations in certain parameters such as SNR or hysteresis are visible in the transmission characteristics of the block diagram shown below.

These values are achieved after changing the value of hysteresis value for adaptive modulation to 10dB from 3dB and lower SNR threshold values to [10 11 14 18 22 24 26 32] decibels from earlier value of [10 11 14 18 24 26] decibels. It can be seen from the two figures 3 and 4 that the unequalized signal spreads out more. Also, the per i. e. packet error rate is increased from 6% to 12%. This due to increased hysteresis for adaptive modulation control.

Conclusion

The IEEE 802. 11 standard for wireless LAN is used as a standard for setting up the wireless network for communication of multiple numbers of hosts. Also, in this sample simulation we concluded that with varying values of SNR and hysteresis the BER and PER also changes.

Thus, it can be also concluded that data rates and packet loss rates are also variable at variable places in the parts of networks. This due to different distances, landscapes and congestion is different for different areas as the signal transmission follows multiple paths for transmission and every single path has a different type of obstacles available. Also, the system is greatly affected by noise present in free space. The reception quality always decreases with increase in distance between the service provider and host.