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Multipath Fading Absorption and Reflection in Wireless Networks

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Abstract

This paper attempts to study the **multipath fading, absorption** environment, the relative motion between the transmitter and receiver may also cause broadening of the power spectrum. In **Wireless Networks**, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. When the same signal is received over more than one path, it can create interference and phase shifting of the signal. Destructive interference causes fading; this may cause a radio signal to become too weak in certain areas to be received adequately. For this reason, this effect is also known as multipath interference or multipath distortion.

Where the magnitudes of the signals arriving by the various paths have a distribution known as the Rayleigh distribution, this is known as Rayleigh fading. Where one component (often, but not necessarily, a line of sight component) dominates, a Rician distribution provides a more accurate model, and this is known as Rician fading. Where two components dominate, the behavior is best modeled with the two-wave with diffuse power (TWDP) distribution. All of these descriptions are commonly used and accepted and lead to results. However, they are generic and abstract/hide/approximate the underlying physics. The multipath fading and Doppler effect are well-known phenomena affecting channel quality in mobile wireless communication systems. Within this context, the emergence of reconfigurable intelligence surfaces (RISs) brings a chance to achieve this goal. RISs as a potential solution are considered to be proposed in sixth generation (6G). The core idea of RISs is to change the channel characteristic from uncontrollable to controllable. This is reflected by some novel functionalities with wave absorption and abnormal reflection. In this paper, the multipath fading and Doppler effect are characterized by establishing a mathematical model from the perspective of reflectors and RISs in different mobile wireless communication processes. In addition, the solutions that improve the multipath fading and Doppler effect stemming from the movement of mobile transmitter are discussed by utilizing multiple RISs. A large number of experimental results demonstrate that the received signal strength abnormal fluctuations due to Doppler effect can be eliminated effectively by real-time control of RISs. Meanwhile, the multipath fading is also mitigated when all reflectors deployed are coated with RISs.

Keywords: Multipath fading, absorption, Doppler effect, reflection, Wireless Networks

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Introduction

Before the 6G mobile communication system, people are always exploring physical layer (PHY) technologies to improve system performance as fundamentally as possible, such as orthogonal frequency division multiplexing (OFDM) technology, massive multiple-input multiple-output (MIMO) technology, and millimeter wave (mmWave) communication . The famous Nobel Prize winner George Bernard Shaw told us “Reasonable men adapt themselves to their environment; unreasonable men try to adapt their environment to themselves.” As we all know, the wireless channel is the medium of information transmission. Traditional technologies cannot bring revolutionary ideas in improving PHY layer solutions, and they are at best a supplement to existing technologies. Hence, researchers have started research on revolutionary ideas from beyond 5G, especially on 6G technologies . In this era, people expect new communication solutions could bring high spectral, energy efficiencies, reliability, and so on to satisfy the potential demands of various users and applications in future wireless communication systems, particular at the PHY.

Back to essence, the final goal of modern wireless communications is to build truly propagation channel and provide interference-free connection and high quality-of-service (QoS) to multiple users. The uncontrollable and random channel of wireless propagation environment is the culprit for the deterioration of communication performance, including multipath fading, severe attenuation, Doppler effect, and intersymbol interference. To overcome these difficulties, many modern PHY technologies are proposed in the next several decades . However, the overall progress is still relatively slow as of the random behavior of wireless channel. In the past researches on wireless channel, researchers often assume it is an uncontrollable entity and brings a negative effect on the performance of wireless communication system. Fortunately, the progress of electromagnetic (EM) material brings the dawn of victory. This technology facilitates the emergence of reconfigurable intelligent surfaces (RISs), which are manmade surfaces composed of EM material. RISs have unique functions on wave absorption, anomalous reflection, phase modification, and wave regulation for EM wave transmission. In addition, the structure of communication system is simplified when RISs can replace the complex baseband processing and radiofrequency (RF) transceiver operations . The novelty paradigm of intelligent communication environments is exploited on the communication efficiency and the QoS. In short, the major contributions in this paper can be summarized as follows:(1)The novel and specific mathematical model is proposed to analyze the received signal in mobile communication environments facing multipath fading and Doppler effect. Specifically, the amplitude and phase are considered to represent signal information in process of exploring the new paradigm(2)The analysis of multiple reflectors and RISs-assisted communication cases are discussed on the proposed mathematical model when the transmitter is moving. For these cases, the directed transmission signal and multiple signals stemming from multiple reflectors or RISs are included in mobile communication environments(3)By comparison, the corresponding model is also proposed and discussed to analyze the received signal when the directed link between the transmitter and receiver is blocked in the multiple reflectors and RISs-assisted systems(4)The results on the multipath fading and Doppler effect are verified in simulation environments for reflectors-/RISs-assisted communication environments. And the specific analysis are provided in the received signal strength when multiple reflectors are coated with RISs

Objective:

This paper intends to explore and analyze **Multipath fading ; the propagation phenomenon** that results in radio signals' reaching the receiving antenna by two or more paths. With absorption the signals fade completely away, whereas at other times the fading may not cause the signal to fall

SMALL-SCALE FADING

The multipath components can add constructively or destructively depending on the carrier frequency and delay differences. The over all effect is that received signal level fluctuates with time, which leads a phenomenon called 'fading'. Fading refers to the time variation of received signal power caused by changes in the transmission medium or traveling paths. In a mobile environment, where one is moving relative to the other, the relative location of various obstacles changes over time which leads to path loss and fading.

Small scale fading is used to described the rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period of time or travel distance so that the large scale path loss effects may be ignored. These rapid changes occur because the signal is received at receiver from many directions. Depending on the different paths the signals take, each signal may have a different phase and cancel each other. However, if these changes are too fast, such as driving on a highway, through a city, the signal level fluctuates rapidly and increases fading on that channel.

FACTORS AFFECTING SMALL-SCALE FADING

Following factors in the radio propagation channel may affect small scale fading: 1. Speed of the mobile 2. Speed of surround objects 3. Bandwidth of the transmitted signal 4. Multipath propagation 5. Dopper shift

REASONS OF SIGNAL FADING

There are three basic reasons of fading of wireless signals 1. Absorption 2. Free-space loss 3. Multipath propagation

Absorption Absorption simply describes how a radio signal is absorbed by objects. When a radio wave strikes on object, there is possibility that it can be absorbed. Radio frequencies can be absorbed by buildings, trees or hills. It is usually seen that the objects made from organic materials tend to absorb more RF signal than the objects made from inorganic materials. Absorption can be compensated by using higher gain antennas and higher power levels in order to cover the same geographic area. The greater the amount of absorption of an RF signal, the higher the fading and the less geographic area covered.

Free-Space Loss

It is also known as path-loss It describes the attenuation of a radio signal over a given distance. It is directly proportional to the radio frequency. As the frequency of a radio signal increases, free space path loss also increases. 3.4.3 Multipath Propagation In multipath propagation, multiple signal paths are established between the base station and the user terminal (mobile phone). The fading due to multipath propagation is known as 'Multipath fading' or 'Rayleigh fading'. One signal path arrives at an antenna (either mobile or base station) as a direct signal, while other signals are multipath or indirect signals. Indirect signal generated due to reflection; refraction or diffraction of signals from any or all objects lie in the path of transmitting antenna and receiving antenna. These indirect signals can add to or subtract from the direct signal arriving at the antenna This depends on whether or not the indirect signals are in-phase or out-of-phase with the direct signal.

DOPPLER SHIFT IN MULTIPATH RECEPTION

If the mobile and base station have relative motion between them then there is an apparent shift in frequency of each multipath wave. The shift in received signal frequency due to motion is called the doppler shift. Doppler shift is directly proportional to the velocity and direction of motion of the mobile with respect to the direction of arrival of received multipath wave. If a mobile unit takes Δt time to travel from point A to point B with a constant velocity 'v' then the doppler shift (fd) is

There are many modern PHY technologies, including modulation technology, coding, nonorthogonal multiple access (NOMA) technology, cooperation communication, beamforming, and smart antenna array to overcome wireless propagation problems, such as deep fading, propagation attenuation, and Doppler effect, in the presence of harsh communication environments. These problems lead to the slow progress from 1G to 5G networks. Meanwhile, they will bring challenges in the beyond 5G and 6G networks. In essence, the random and uncontrollable propagation environment degrades the received signal quality and communication QoS . In traditional wireless networks, researchers make great efforts on transmitter and received ends to explore enhancing communication efficiency and QoS by setting a negative factor term in the communication process .

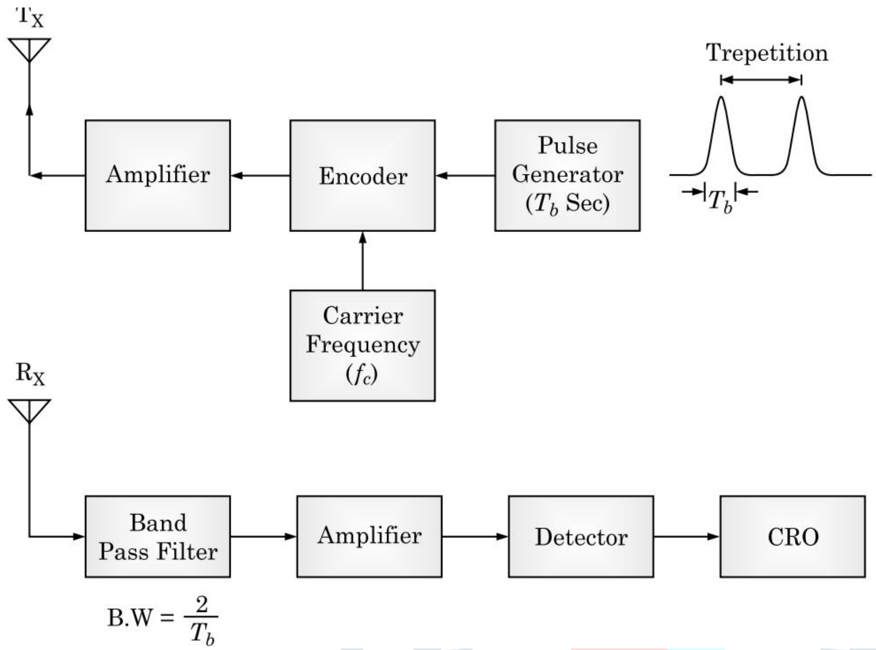
Recently, the emergence of RISs reshapes the random and uncontrollable communication environments to improve the performance of mobile wireless networks. Meanwhile, RISs provide a new paradigm in 6G communication, denoted as RISs-assisted wireless networks. An unreasonable communication entity and distinguishing feature, including passive units, reconfigurable mechanism, and simple deployment, attract the attention of researchers in RISs-assisted wireless networks . The main objective of this paper is to challenge signal quality and QoS by exploiting this intelligent communication networks. To achieve signal quality and QoS, rich channel information is a really good way in communication environments. and propose novel physical modulation technologies to exploit reconfigurable antennas or scattering wireless environments. Furthermore, the change of wireless communication environments could improve communication quality by adopting reflector and scatter such as intelligent walls , programmable metasurfaces , reconfigurable intelligent antenna array , and intelligent metasurfaces . These works affect complexity, power consumption, and performance analysis of wireless networks.

The concept of RISs as a controllable device enhance aforementioned function as of its controllability on propagation environments. Many works focus on link transmission metric , channel estimation , PHY security , and practical applications to analyze performance of RISs-assisted systems. Specifically, optimizes transmission power and reflection coefficient to achieve sum-rate maximization when each mobile user has QoS guarantee. Considering link budget guarantee of a user in downlink communication, proposes an energy-efficient scheme by joint optimization transmission power allocation and RIS phase shift. Combined with transmitter and receiver, optimizes beamforming vector, combining vector, and phase shifts at transmitter to maximize SNR at the receiver. When interference is introduced to user, the transmit power is allocated in by joint active and passive beamforming to improve the performance of RISs-assisted wireless networks. When facing transmission distance, the quantitative analysis with wireless coverage and SNR gain is presented in for RISs-assisted system. These works require to acquire accurate channel information in application. Two efficient channel estimation schemes are proposed in in RISs-assisted multiusers communication systems. Then, proposes a pilot-assisted method to solve channel estimation problem in receiver. To reduce training overhead, exploits the channel information by using the inherent sparsity and designs a low complexity channel estimation method to attain the separate channel state information in MIMO system. For PHY technologies, security is also an important issue, beside RISs-assisted networks. In , RISs as a backscatter device to process scatter jamming signal in secure transmission when the transmitter is radiofrequency source. And proposes an effective conjugate gradient algorithm to enhance PHY security by joint optimization the active and passive beamforming in downlink communication. For adopting channel state information, RIS units are investigated in to improve the secret key capacity in RISs-assisted secret key generation. The performance analysis of RISs-assisted system on physical technologies has been extensively discussed in ideal conditions in prior works. Considering practical applications, studies phase shift model by capturing the phase-dependent amplitude variation in RISs-assisted system. Furthermore, study minimization power problem in downlink communication and channel aligning on cell-edge users in communication systems.

The existing works have brought us momentum on PHY technologies in RISs-assisted systems. In this paper, we focus on the multipath fading and Doppler effect in RISs-assisted wireless networks. They are ubiquitous in wireless networks and have huge impact on network performance. Hence, the in-depth discussion on multipath fading and Doppler effect mitigation is important in RISs-assisted systems.

MULTIPATH MEASUREMENT TECHNIQUES

Some techniques that are used to measure multipath propagation are given below: 1. Direct pulse measurement 2. Spread spetrum sliding Correlator measurement 3. Swept frequency measurement These techniques are also known as sounding techniques. 3.6.1 Direct Pulse Measurement Technique This technique permits the measurement of multipath phase and therefore determines the power delay profile of any channel. Working Detail The basic principle of this technique is that a repetitive pulse of width Tb is transmitted from transmitter which is received at receiver through RF link. The receiver section is a combination of band pass filter, amplifier, detector and digital storage oscilloscope. Band pass filter bandwidth (2/Tb Hz) is twice of transmission bandwidt (1/Tb). This signal is then amplified and detected and finally displayed at CRO. If the CRO is set on averaging mode, then this system can provide a local average power delay profile. The minimum delay between multipath components is equal to the pulse width (Tb). Advantages: 1. Lack of Complexity 2. Determines rapidly the power delay profile of any channel. Disadvantages: 1. Subjected to interference and noise 2. Phase of the individual multipath components are not received due to envelope detector, This measurement technique (or sounding technique) of multipath measurement improves the dynamic range of the system as compared to the direct pulse system



The time resolution (Δτ) of multipath components using a spread spectrum system with sliding correlation is Δτ = 2TC = 2 RC We can conclude, that the system can resolve two multipath components as long as they are equal to or greater than two chip durations, (2TC seconds apart). It must be ensured that the sequence length has a period which is greater than the longest multipath propagation delay. It is denoted as τPN

Conclusion

Multipath interference is a phenomenon in the physics of waves whereby a wave from a source travels to a detector via two or more paths and the two (or more) components of the wave interfere constructively or destructively. Multipath interference is a common cause of "ghosting" in analog television broadcasts and of fading of radio waves. The signal arrives at receiver (RX) by means of two different paths which have different lengths. The main path is the direct path, while the second is due to a reflection from the plane.

The condition necessary is that the components of the wave remain coherent throughout the whole extent of their travel. The interference will arise owing to the two (or more) components of the wave having, in general, travelled a different length (as measured by optical path length – geometric length and refraction (differing optical speed)), and thus arriving at the detector out of phase with each other. The signal due to indirect paths interferes with the required signal in amplitude as well as phase which enforces multipath fading.

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