THE SUMMARY OF Ph.D. DISSERTATION

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Title

A Study on Optical Wireless Communication Systems and Their Applications

Abstract

Recent years, the idea of ubiquitous computing or networking is attracting much attention. "Ubiquitous computing" in this context does not just mean computers or communicators that can be carried anywhere. Mobile users are able to enjoy the same services as what they have in a wired network. The next generation network environment will be constructed of the high-capacity backbone network and a large number of access networks. In order to realize such access networks, high speed wireless networks are required. Therefore, wireless communication technology have demonstrated tremendous growth, and the number of mobile users also have increased rapidly over the previous five years. For this reason, the exhaustion of frequency resources has been a problem and utilized frequency bands are becoming highly allocated.

As a method of realizing high speed wireless networks, the optical wireless communication systems are capturing the spotlight, on the other hand. Optical wireless communication systems have the following various advantages compared with radio systems.

1. An optical carrier has wide bandwidth available, and is suitable for high speed communication networks.
2. The devices for an optical wireless transmission system are low in cost, thus the optical wireless communication system is suited for a consumer communication network.
3. A lightwave cannot penetrate the opaque objects such as walls. It is thought that the lightwave is secured against eavesdropping, therefore cell planning in networks is simple and easy.
4. The optical wireless networks occupy no radio frequency spectrum and it can be used where electro-magnetic interference is strictly prohibited, such as in hospitals, airplanes, and so on.
5. The lightwaves are worldwide unregulated by any law.

Because of these features, the optical wireless communication system attracts much attention as a medium which can realize high-speed wireless networks.

However, there are few researchers in this field, and many problems which should be solved also remains. For example, in case of constructing an optical wireless LAN with a diffuse channel, since a multipath arises by the reflection on walls and the other objects, a distortion is generated in a waveform. Consequently, a high-speed transmission is difficult in an optical wireless transmission. Moreover, since a lightwave cannot penetrate an opaque object, it also has the problem of shadowing.

Therefore, in this dissertation, new optical wireless transmission techniques and applications are proposed, solving these problems of an optical wireless communication system.

Chapter 1 introduces the outline of the optical wireless communication systems. The basic knowledges of optical wireless transmission techniques for this dissertation are explained also, and the position and motivation of the dissertation is described in this chapter.

In chapter 2, a multi-wavelength transmission scheme which can reduce the inter-symbol interference (ISI) effect is proposed. In an indoor diffuse channel, an ISI due to the multipath propagation is generated. Especially in the case of ultra high-speed optical wireless LANs such as 1 Gbit/s or more, this is a serious problem. This interference greatly degrades the quality of transmission. In order to mitigate ISI effects, the parallel transmission scheme utilizing a multi-wavelength transmission is applied to an optical wireless transmission system. This new strategy can improve the quality of transmission to a great extent. This technique makes the ultra high-speed optical wireless LAN feasible. A parallel coding technique, which permits divided pulses to encode in parallel without changing the system data rate, is proposed in this chapter, also.

Moreover, in indoor optical wireless channels, especially Line-of-Sight (LOS) links, a shadowing is an important issue. In chapter 3, an indoor visible light data transmission system utilizing white LED lights is proposed. White LEDs are the devices which have been attracting attention rapidly in recent years, and are considered to be future lighting sources for indoor lighting. They can be utilized not only for illuminating rooms but also for a wireless data transmission in the proposed system. Generally, illuminating engineers install many lighting sources on the ceiling so that a dark area may not be produced. From the view of communication engineers, the transmission in LOS links without a shadowing can be achieved because of many lighting sources which are arranged widely at the ceiling. Furthermore, since this system utilizing white LED lighting can use the high luminous intensity as a lighting source, it can attain the high quality transmission for an optical wireless communication system. In this chapter, the availability of this system is discussed. On the other hand, many LEDs are utilized in this system, and an inter-symbol interference (ISI) due to an optical path difference must be considered. Therefore, in this chapter, the influence of an optical path difference has been investigated and two approaches against this problem are introduced. One uses OOK-RZ (On-Off Keying, Return-to-Zero) coding and the other uses optical OFDM (Orthogonal Frequency Division Multiplexing). Through computer simulations, we found that these approaches are feasible for the indoor visible light data transmission system utilizing white LEDs.

In chapter 4, the wireless CATV up-link system with subcarrier modulation using infrared communications for apartment houses is proposed as an outdoor application of the optical wireless communication system. CATV channels, which have wide bandwidth and provide high quality channel, are drawing considerable attention as promising high speed channels, and many cable operators are offering an analog video distribution system and providing a two-way data transmission service in which subscribers can access the Internet constantly. However, ingress noise due to the tree and branch structure appears and degrades the quality of upstream communication channels. This is a serious problem especially in the old apartment houses. An old coaxial cable which is used in the old apartment houses is easy to be affected by noise. In this chapter, a wireless CATV system using infrared communications is proposed. By making the system wireless, transmission free from house-originated noises can be achieved in the apartment house. In this system, an optical transmitter is put in the veranda of each subscriber, and an optical access point is installed on the roof of the apartment house. This vertical LOS link is suitable for apartment houses because obstacles such as trees that exist at some distance from apartment house seldom interrupt communication. This system adopts an optical subcarrier modulation technique, also. In subcarrier modulation, signals are modulated directly into optical intensity. Thus, subcarrier modulation permits an optical access point to be simplified and the cable headend to control channels together with video signals. Moreover, the parallel transmission using two or more channels makes high-speed transmission available.

Finally the results of each chapter is summarized and this dissertation is concluded in chapter 5.