Optical Wireless -Optical indoor communication systems

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Abstract—In this paper , I will introduce the basic concepts of optical wireless communication systems , and the optical indoor communication with the main focus on the application of multiple-input-multiple-output (MIMO) techniques

Index Terms- Optical indoor communication systems, Optical wireless MIMO,

1. Introduction

An optical wireless communication (OWC) system relies on optical radiations to convey information in free space, with wavelengths ranging from infrared (IR) to ultraviolet (UV) including the visible light spectrum. Especially for indoor scenarios, like office and home environments, OWC can provide significant spectrum relief for the crowed radio frequency (RF) spectrum used by traditional wireless communications systems such as wireless local area networks (WLANs). As more and more wireless home networks are being installed, the public ISM (Industrial, Scientific and Medical) band gets increasingly crowded leading to a shortage of available bandwidth, increased interference and compromised system throughput. In addition, RF communications can interfere with electrical equipment preventing its application in sensitive environments like hospitals or aircraft cabins [1].

2. History and current status

The proliferation of wireless communications stands out as one of the most significant phenomena in the history of technology. Wireless technologies have become essential much more quickly during the last four decades and they will be a key element of society progress for the foreseeable future. The radio-frequency (RF) technologies wide-scale deployment has become the key factor to the wireless devices and systems expansion. However, the electromagnetic spectrum where the wireless systems are deployed is limited in capacity and costly according to its exclusive licenses of exploitation. With the raise of data heavy wireless communications, the demand for RF spectrum is outstripping supply and they become to consider other viable options for wireless communication using the upper parts of the electromagnetic spectrum not just RF.

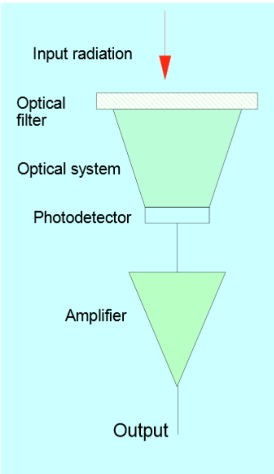
Over the decades, the interest in OWC remained mainly limited to covert military applications, and space applications including inter-satellite and deep-space links. OWC’s mass market penetration has been so far limited with the exception of Infrared Data Association (IrDA) which became a highly successful wireless short-range transmission solution. With the growing number of companies offering terrestrial OWC links in recent years and the emergence of visible light communication (VLC) products the market has begun to show future promise[2].

3.Optical indoor systems

a. Optical transmitter/source-LED

With the advent of high luminance light-emitting diodes(LEDs), efficient and inexpensive illumination devices are available which will progressively replace existing light bulbs and fluorescent lamps. In contrast to the latter, LEDs, being electronic devices, can be switched must faster. Therefore, an additional benefit can be generated if LEDs are not only used for illumination, but also for high data rate wireless communications to establish flexible and ubiquitous communication networks. For instance, the ceiling lights in an office can be used to transmit data to a receiver placed on a desk within a room. Apart from the visible light spectrum, the near- IR band between about 780 nm and 950 nm is also a potential transmission medium for indoor communications. Commonly, OWC transfers data by modulating the intensity of the optical signal. Typical light fixtures achieve more than 400 lux to provide sufficient indoor illumination. Those illumination levels are enough to transmit data at high SNRs. At the receiver side, a photo-detector converts the optical signals into electrical signals which are used to decode the information. This direct detection enables the implementation of simple low-cost transceiver devices without the need for complex high-frequency circuit designs [1]. As the information can only be received by a photo-detector which is within the emitted light beam and the signals do not penetrate opaque boundaries, the propagation can be restricted to specific spots or areas (rooms). This prevents interception and creates less interference compared to RF devices whose signals propagate through walls. Moreover, the line-of sight (LOS) characteristic between transmitter and receiver can provide high SNRs of more than 60 dB at the receiver [3].

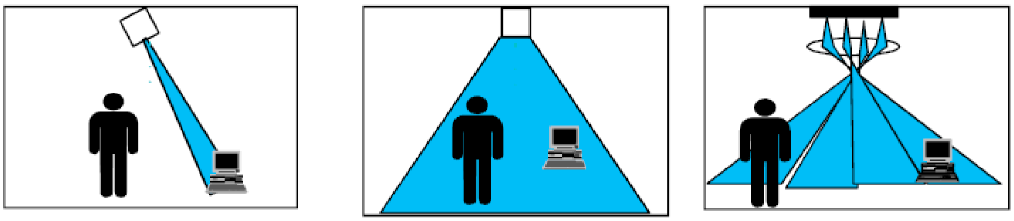
b. Optical receiver.



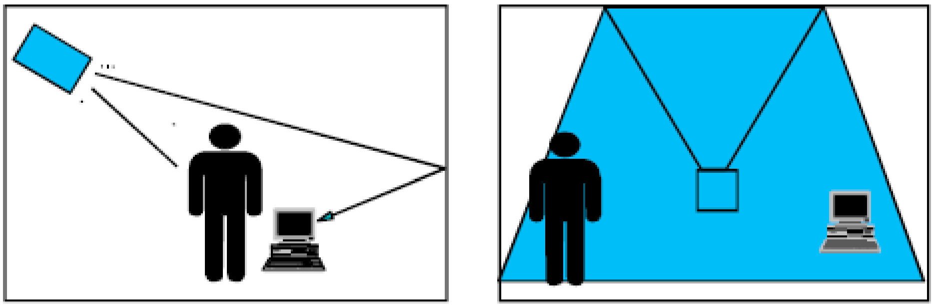
The receiver/detector converts the optical power into electrical current. Optical filter rejects ‘out of band ’ ambient illumination noise. Lens system or concentrator collects and focuses radiation. Photodetector (or array of detectors) converts optical power to photocurrent .It has Incoherent detection. Amplifier determines system noise performance .

c. Optical Channels

In comparison to outdoor, indoor optical wireless systems are characterized with smaller distances free from environmental degradation such as fog, rain, snow and mist. The loss in the indoor link takes place only due to free space loss. There are two indoor optical wireless transmission techniques: Direct line of sight and diffused configuration. The direct line of sight configuration requires alignment between the transmitter and receiver to establish communication by transmitting optical signals from the transmitter to the receiver without any reflection. Such a system has superior power efficiency; low multipath dispersion and lower path loss and can achieve higher transmission rates. The drawback of this configuration is that it suffers from shadowing and a concern for eye safety that limits the average transmitter power, hence affecting overall power efficiency. Diffuse configuration does not require the alignment of transmitter-receiver in which the transmitters send optical signals in a wide angle to the ceiling and arrive at the receiver after one or several reflections. Diffuse configuration as a result is robust against shadowing and easy to use allowing more mobility. The diffused system, however, suffers from higher path loss and requires higher transmitter power levels and larger size photodetecting area at the receivers. It also suffers from multipath dispersion, which occurs when the transmitted signal follows different paths due to its reflection by ceiling, walls, and other objects in its way to the receiver. The multipath propagation of diffused systems gives rise to intersymbol interference and becomes critical at higher data rate.



LOS



Non- LOS

4. Data transmission

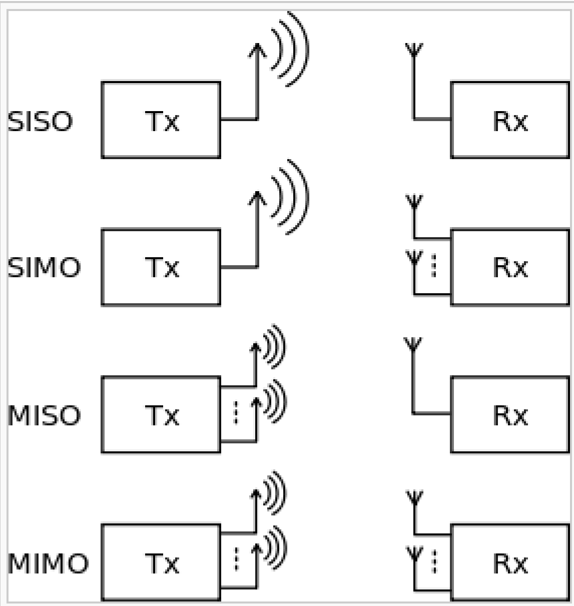
Visible light communications (VLC) allows the use of the indoor solid-state lighting infrastructure to transmit data as well as to generate the required level of illumination. However, VLC is constrained by the bandwidth of the LED sources used for illumination, and schemes such as equalization and complex modulation have to be used to increase data rates[4].

Orthogonal frequency division multiplexing (OFDM) has found favour for VLC because of the high SNR, low bandwidth characteristic of typical white-Light LED based systems. Using a single chip blue-phosphor LED, a transmission rate at 513 Mb/s has been demonstrated at 1000 lux[5].

Parallel transmission offers a linear capacity gain with the number of channels in an ideal crosstalk-free configuration. However, in a practical set-up with terminal mobility, precise mechanical alignment is difficult. MIMO processing relaxes this requirement and effectively moves alignment to the electronic domain. Such MIMO and similar multiple transmitter-receiver configurations is an active area of research .

So what is MIMO, in radio, multiple-input-multiple-output (MIMO) is the use of multiple antennas at both the transmitter and receiver to improve communication performance. Today the term “MIMO” usually refers to a method for multiplying the capacity of a radio link by exploiting multipath propagation. This modern MIMO is an essential element of wireless communication standards such as IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), 4G, 3GPP Long Term Evolution and WiMAX.

In order to provide sufficient illumination, light installations are typically equipped with multiple LEDs. This property can readily be exploited to create optical MIMO communication systems. MIMO techniques are well-established and widely implemented in many RF systems as they offer high data rates by increasing the spectral efficiency. Off-the- shelf LEDs provide only a limited bandwidth of about 30- 50 MHz for incoherent IR light and even less for visible light [1]. Consequently, these incoherent light sources restrict the available bandwidth of practical OWC systems. Therefore, it is equally important to achieve high spectral efficiencies in OWC. It has been shown that spatial diversity can combat the fading effects due to scattering and scintillation caused by atmospheric turbulences. Ongoing research activities intend to increase the capacity of OWC indoor systems by MIMO techniques.



Differences between SISO, SIMO, MISO and MIMO

However, for indoor OWC it is still not clear to what extent MIMO techniques can provide gains. This is because in indoor environments there are no fading effects caused by turbulence etc., especially if LOS scenarios are considered. Therefore, indoor optical wireless links are envisaged to be highly correlated enabling only minor diversity gains. Provided that MIMO techniques mostly rely on spatially uncorrelated channels, it is unclear whether the optical propagation channel in indoor environments can offer sufficiently low channel correlation.

5. Conclusion

The concept of OWC and the optical wireless indoor communication system was discussed in this paper. Composed of transmitter, receiver, channels. By using MIMO techniques in signals transmission, OWC system will gain more available bandwidth.

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