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AN OVERVIEW OF VISIBLE LIGHT COMMUNICATION SYSTEMS

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Abstract— Visible light communication technology similar to wireless routers will enter our lives and complement the existing RF technology applications. This paper expounds the background of the development of visible light communication technology which uses light emitting diodes as a transmitting module and the development status at home and abroad analysis its system advantages, limitations, key technologies, characteristics and existing problems, looks forward to future research trends, and introduces visible light communication for high speed data transmission, intelligent transportation for vehicle to vehicle communication and visible light communication for underwater communication. Such traditional network communication cannot cover the innovative applications and prospects of the field. Also introduces visible light communication directions, future and challenging issues.

Keywords— Visible light communication, Light emitting diode, vehicle to vehicle communication, underwater communication, optical wireless communication

1. INTRODUCTION

After the introduction of white light-emitting diodes (LEDs) the luminous efficiency has gradually increased and its application fields have gradually expanded from display to illumination. Compared with traditional lighting equipment white LED has the advantages of low driving voltage low power consumption and long service life. It is a green lighting device and is regarded as the fourth generation energy saving and environmentally friendly lighting equipment [1]. The proportion of LEDs in the global lighting market is increasing year by year. According to professional predictions with the continuous development and improvement of white LED lighting technology by 2021 LED will occupy the above market share of commercial lighting bulbs [1]. Because white LEDs have high response sensitivity they can be used for high-speed data communication. Visible light communication (VLC) is a white LED technology developed new wireless optical communication technology. A schematic diagram of an indoor visible light communication system is shown in Figure 1. In the visible light communication system the white LED has the dual functions of communication and illumination. Since the modulation rate of the LED is very high the human eye does not feel the flicker at all [2]. The visible light communication system can replace the wireless local area network base station with indoor white LED lighting equipment and the communication speed can reach tens of megabits to hundreds of megabits per second. As long as the indoor light is illuminated long term high speed data transmission can be realized visible light communication system has the characteristics of high security and the indoor information is not leaked to the outside since the radio wave communication is not used the system can be freely used in an environment sensitive to electromagnetic signals. In addition compared with traditional

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radio frequency communication and infrared wireless optical communication technology visible light communication also has the advantages of human body safety and rich frequency resources. Visible light communication contains huge communication capacity and activates a new spectrum resource which is the biggest value of this technology. According to the calculation the amount of network data will exceed the existing radio frequency resource withstand capability and the visible light band is between 400THz and 800THz. It is nearly 10,000 times of the radio spectrum which contains huge communication capacity and does not require authorization at present there are about 44 billion lamps and lanterns in the world and the integration of tens of billions of LED lighting devices with other devices will build a huge visible light communication network. It is conceivable that in the future if large scale visible light communication is realized each light can be used as a high speed network hotspot. People can download movies under the street light and high speed Internet access can be achieved by using LED light sources on airplanes and high speed rails [12].

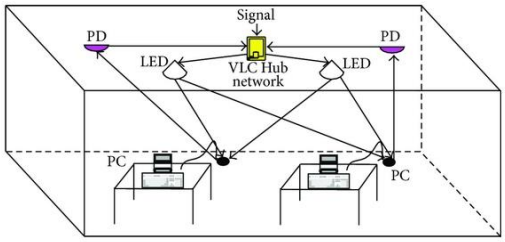

Fig. 1 A schematic diagram of an indoor visible light communication

In addition, the visible light communication frequency band avoids the common radio frequency band and there is no electromagnetic interference problem with the existing electronic equipment and the compatibility with the existing electronic equipment is good and it is sensitive and strict to radio frequency electromagnetic radiation in aviation medical and mine. In the limited area the non-electromagnetic radiation characteristics of visible light communication can make it stand out.

2. VLC FOR HIGH SPEED DATA TRANSMISSION

Accessing to information such as high definition (HD) video streaming, high speed streaming and high speed data backup has become an integral part of modern life. Beam of light can be used to transmit visible light with a small divergence angle and its low transmission path loss makes it possible to download and transmit secure data streams at high speeds the European OMEGA project developed a VLC data transmission with 4 HD data streams of 100 Mb/s. Data transmission is performed on a photodiode detector in a range of 10 m2 by 16 LED light sources using (OFDM) orthogonal frequency division multiplexing technology [13]. A demonstration system for (5 x 5 x 3) m indoor video and audio high quality broadcast transmission by adding a focus lens between the VLC receiver and the transmitter the Nd LOS link has a network compared to the (LOS) line of sight link The node has good mobility and strong tracking, but its link loss leads to low transmission rate. In order to conduct research on this problem, a typical indoor two-way optical wireless communication (OWC) system with a transmission rate of 2M, 400 Mb/s and a bit error rate RBE<10-8 is realized (IR is an uplink transmission source visible light LED as a downlink data transmission source. RGB LEDs use (WDM) wavelength division multiplexing to achieve higher data transfer rates. The document records the first VLC system based on (WDM/DMT) wavelength division multiplexing/discrete multi-tone modulation technology, which modulates a single white RGB LED and reach 803 Mb/s data communication [18][2].

3. VLC FOR VEHICLE TO VEHICLE COMMUNICATION

Led lights has been adopted by the car manufacturers during the last decade now with this development the car manufacturers looking for a way to exchange data related to driving condition and other necessary information between the vehicles. Vehicle to vehicle (V2V) communication it is an application aims for safer driving experience and using the roads more efficiently (Figure 2) shows an approach of using light emitting diodes (LEDs) of cars for V2V communication.

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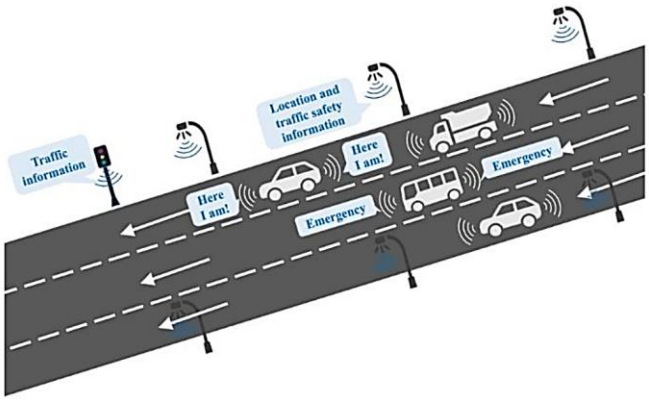

Fig 2 Visible light V2V communication

Intelligent Transportation Systems or (ITS) reduce traffic accidents, traffic congestion, and consumption of fule by timely acquiring and transmitting information about traffic conditions. Image processing can be used to help drivers identify traffic lights, obstacle detection, vehicle and vehicle, and information capture between vehicles and road facilities. It is a key technology for ITS. High-speed data image sensors combined with VLC have broad application prospects on ITS. The document records the connection between the roadside device and the vehicle using LED light and a camera with a frame rate of 1000 frames/s and a resolution of 1024 pixels x 1024 pixels mounted on the car. The real vehicle test verified that system can accurately receive data transmitted from 256 LEDs arrays in a 35m range at a speed of 30km/h [22]. At present there are some technical problems to be solved in the application of high speed image sensors in VLC if the installation facilities are expensive, complex real-time image processing technology is required, and the camera frame rate is lower than the reaction speed of the LEDs, thereby limiting the communication speed. The literature reports on the application of the newly developed Optical Communication Image Sensor in Wireless Optical Communication (OWC) systems. The newly developed optical communication image sensor with complementary metal oxide semiconductor (CMOS) image sensing technology has two features: communication pixels for high-speed signal reception (CPx) and 1-bit flag image output for fast and accurate LED detection. The OWC system is known as the world's first pixel transmission communication system with a 16.6ms delay and 20Mb/s transmission rate [3][16][17]. A recent study from Korea in this field resulted in developing a visible light V2V communication system using LED lights with 10kbps and 30m distance on daylight. (Figure 3) Inverse pulse position modulation 4-PPM [4] has been used in the system because this type of modulation scheme provides high data rate and gives high percent of dimming for pulse width modulation PWM [5].

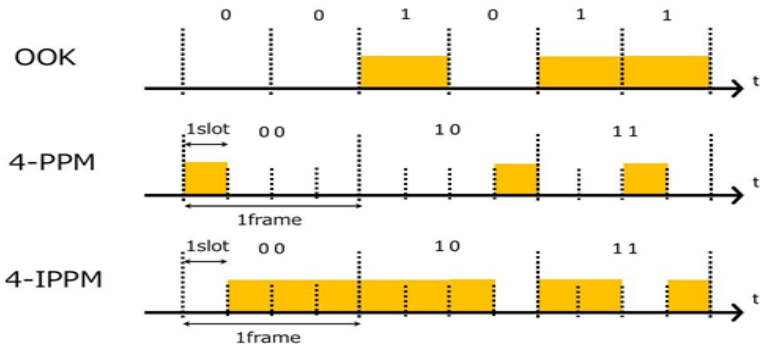

Fig. 3 inverse pulse position modulation 4-PPM

4. VLC FOR UNDERWATER COMMUNICATION

Underwater communications become an interesting point for some researchers and scientific community because of its wide applications. The incapability of radio frequency waves for underwater communication due to the attenuation [6]. Underwater communication using VLC technique has its advantages and disadvantages [7]. Underwater Communication plays important role in military, industrial and scientific fields. Underwater communication rate requirements starts from a few megabits to tens of megabits or even higher. Seawater in radio waves is highly attenuated sound waves transmit at a speed of 1500 m/s in the ocean with long delay times [7]. limited bandwidth and high bit error rates. Sound waves can also interfere with marine animals such as dolphins and whales. VLC can overcome the problems of attenuation and electromagnetic interference under water. The transmitter in this system consists of 70 LED light sources, supporting data transmission in the 120°

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viewing angle range, and the transmission rate is up to 20Mb/s. The literature records the specific application of underwater VLC systems in nuclear power plant machine testing. The underwater remote transport vehicle is equipped with a video and control signal transmission between the camera and a 20m remote station. At present, the main challenge of underwater visible light communication systems is that it is difficult to achieve long-distance communication due to underwater nature especially turbidity. In response to this problem, the National University of Singapore and the Massachusetts Institute of Technology carried out research and demonstration of a 1.2 Mb/s underwater optical communication system within a distance of 30 m.Visible light waves has better directional characteristics than radio frequency waves and high data rates can be achieved in underwater VLC systems for medium and short distances [8]. (Figure 4) and (Figure 5) shows the block diagram of underwater VLC transmitter and receiver.

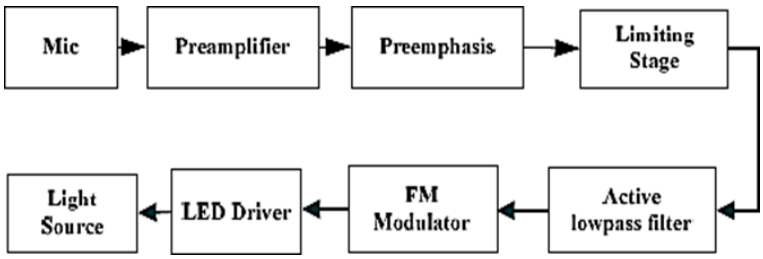

Fig. 4 the block diagram of underwater communication transmitter

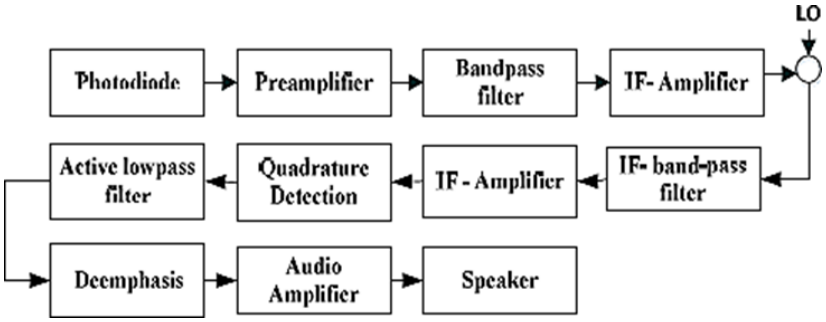

Fig. 5 the block diagram of underwater communication receiver

5. VLC DIRECTIONS AND FUTURE

VLC systems that take advantage of light emitting diodes advances have been considered as one of the promising technologies LED lighting market grew steadily in response to global policies such as green growth and electricity saving, while the price is being lowered by 50%, the technology is more than doubled Visible light communication technology is a high value-added and specialized domestic and expect to be a source of technology to enter the world market Visible light communication is a technology that is fused with LED lighting and can create a mutual growth industry new convergence service can be created using visible light characteristics [23]. Visible light communication has very high LOS, so it can communicate only in specific area and can be used for physical information protection communication it can be used in places where there is no interference Have the advantage of not having permission now, in the era of IOT, communication LEDs have evolved into 'smart lighting'. It can control the lightness and color of light according to the people presence and the atmosphere of the interior, and it is also effective in reducing the efficiency of the energy in large building and cities. Along with smart lighting, the development of light emitting communication technology is proceeding rapidly. Particular LED-ID is a technology capable of transmitting and receiving unique information with LED-based screens and smart cameras. The VLC system using LED lighting as a transmitter was led by Samsung Electronics completing the IEEE 802.15.7 standard in November 2011[19]. Although research and develop and standardization proceeded, commercialization of visible light communication systems based on smart devices such as smart phones was difficult due to the necessity of additional hardware changes and the use of visible light communication dongles Photo diodes. IEEE 802.15 IG-LED operated in May 2012 In order to solve this problem OCC (Optical Camera Communications) [9][10]. Recent study It focuses mainly on systems that receive signals and patterns from LED screens, LED displays, LED digital signage or LED lighting using smart device cameras (image sensors) rather than IEEE 802.15.7, which deals with photo detectors (PDs). With the final approval of IEEE 802 EC, the OWC Task Group TG was officially in operation since the IEEE 802.15

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Extension Meeting held in January 2015. The optical wireless communication TG will focus primarily on OCC technology and will further standardize high-speed OWC technology based on LED-ID and Li-Fi.

6. VLC STANDARDIZATION

According to the national stander platform information, the Technology Stander the technical Committee proposed and managed the State Administration of Market Supervision and the Standardization Administration issued the "Information Technology System Remote Communication and Information Exchange Visible Light Communication Media Access Control The overall requirements of the physical layer and the standard number: GB/T 36628.1-2018 were officially implemented [10]. it shows that GB/T 36628 Information Technology System Remote Communication and Information Exchange Visible Light Communication standard is divided into four parts the first part is the media access control and physical layer requirements the second part based on visible light communication indoor positioning technology Specification the third Part High-speed visible light communication media access control and physical layer specifications the fourth Part Low-speed narrow band visible light communication media access control and physical layer specifications. Also issued this time is the first part, which is composed of the Electronics Technology Standardization Research Institute high Silicon Semiconductor Liberation Army Information Engineering University and Tsinghua University were drafted also specifies the requirements for high-speed visible light communication, low speed visible light communication, and indoor positioning physical layer requirements based on visible light communication and the overall requirements of the media access control layer also applies to the development and use of visible light communication systems and equipment

7. VLC CHALLENGING ISSUES

Visible light communication systems have some challenging issues despite of the large number if its benefits some of the issues and challenges are:

1. Range limitation: due to the requirements of the LoS, the technology is adequate for short communication distances.
2. Higher data rate: because of the LEDs limited bandwidth this creates another big challenge issue to obtain higher data rates.
3. Environment intense noise: artificial and natural lights is another challenge for VLC it is a main issue for outdoor VLC applications minimizing or overcoming the effect of artificial and natural lights is a challenging issue.
4. Uplink supply: making the lighting sources is naturally suitable for transmission and broadcasting applications will be problematic.
5. Modulation difficulty: the simplest and most useful technique for modulation based on the direct intensity detection modulation is insufficient to solve many problems and challenges a difficult modulation method would be necessary to support desirable and effective data communication.
6. Parallel communication ((MIMO) multiple input multiple outputs): an Interesting setup idea of visible light communication. Although, in theory, it may be achievable, the challenging part is the implementation part.
7. The receiver complexity: some proposed studies proposed that using equalizer will the receiver complexity.
8. Regulatory issues: regulations of visible light communication such as automotive standards eye safety standards.

8. CONCLUSION

Visible light communication can realize the functions of illumination and communication at the same time. It has the advantages of high transmission data rate strong confidentiality no electromagnetic interference no spectrum authentication etc. It is one of the ideal indoor high-speed wireless access solutions. Visible light communication has become a research hotspot in the world In particular Europe and the United States have invested a lot of manpower and material resources in the research of visible light communication and have made certain progress. In the research of visible light communication LED light source with high modulation bandwidth large current drive and nonlinear effect compensation technology of LED layout optimization of light source optical MIMO and technology high-sensitivity wide-angle receiving technology and technology for eliminating inter-symbol interference. The convergence of visible light communication with existing networks has become a research trend. Visible light communication will occupy an important position in the future communication field and will greatly promote the development of the information society.

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