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Application of Visible Light Communication Technology in Digital Operating Room: Experiment and Equipment Manufacturing

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Abstract

Visible Light Communication (VLC) is a wireless communication technology that uses visible light for illumination and communication at same time. Compared with the conventional wireless communication technology with radio channels, VLC transceiver units can be integrated with the existing lighting system. VLC system has advantages such as energy saving, easy deployment, no radio interference, electromagnetic compatibility and so on. It also has the disadvantages of being easily blocked by moving object, interrupted and interfered by sunlight. Finding the right application scenario for visible light communication has always been a challenge. With the technology progress

of medical digitization, traditional hospitals and are transforming into digital hospitals. More and more medical devices with wireless communication capabilities are being deployed, and more wearable devices are used in patients' body, such as pacemaker. Serious electromagnetic interference problem should be considered to affect medical safety. In this project, VLC technology is used in the digital operating room to reduce electromagnetic interference as an application experiment.

Keywords: Visible Light Communication; Interference; Transceiver; Application experiment; Electromagnetic compatibility

Introduction

Visible Light Communication (VLC) refers to communication method that directly transmits optical signals in the air by using Light in the visible band as information carrier. VLC technology is green and low-carbon, and can realize nearly zero energy consumption. It can also effectively avoid electromagnetic signal leakage and other weaknesses of radio communication, and quickly build an anti-interference and anti-interception safe information space. The idea is not new. On June 3, 1880, Alexander Graham Bell transmitted the first wireless telephone message on his newly invented "photophone," a device that allowed for the transmission of sound on a beam of light [1].

In the 21st century, with popularity of Light Emitting Diode (LED), VLC rises again and the technology is reinvented with new breakthroughs. LED can support faster switching on and off than traditional fluorescent and incandescent bulbs. By adding microchips to ordinary LED lights, they can be made to flash at extremely fast speeds and send data. As long as the overhead light is shining, it is theoretically easy to transfer data information, access the Internet, make voice and video calls, or adjust the switch of Internet of Things devices, and with the ultra-high transmission rate, the application experience is far better than Wi-Fi and 4G networks. In the future, VLC will interact with Wi-Fi, cellular networks (3G/4G/5G) and other communication technologies (such as Zigbee and WSN), bringing innovative applications and value experience to the Internet of Things, smart city and home, aviation, navigation, subway, high-speed rail, indoor navigation, underground operations and other fields [2,3]. Visible light communications can be interfered with by sunlight

and be blocked by objects, which physically limits the application range of VLC. The operating room has no sunlight interference and uses artificial light sources represented by LED. This makes operating room an appropriate scene for VLC applications naturally. From the perspective of necessity, the modern operating room is a small enclosing space with dense electronic equipment, which cause Electro Magnetic Compatibility (EMC) problems. VLC is exactly the best way to replace wireless communication method and reduce electromagnetic interference.

Electro Magnetic Compatibility (EMC) is defined as "the ability of equipment and systems to function properly in their electromagnetic environment without causing intolerable electromagnetic disturbance to anything in the environment." This definition has two meanings. First, the equipment should be able to work normally in a certain electromagnetic environment, a certain electromagnetic immunity (EMS). Secondly, the electromagnetic disturbance generated by the device itself should not have too much influence on other electronic products, namely electromagnetic disturbance (EMI). EMC is not only related to the safety and reliability of the product itself, but also related to the protection of electromagnetic environment. Therefore, meeting EMC requirements is also a very important condition for products to enter digital operating room. With the progress of technology, more and more electronic equipment and medical equipment is miniaturization and wireless. Wearable devices and implantable medical devices, such as pacemakers, are used for the patients in digital operating room, rehabilitation centre and elderly care community. The density of electronic equipment is becoming higher and higher, with the requirement for EMC becomes more and more serious. Electromagnetic interference (EMI) problem was report that Radiofrequency interference (RFI) between medical devices caused safety issue and made erroneous laboratory results **[4]**. The earth's EM environmental background noise is shown below, in **Figure 1**.

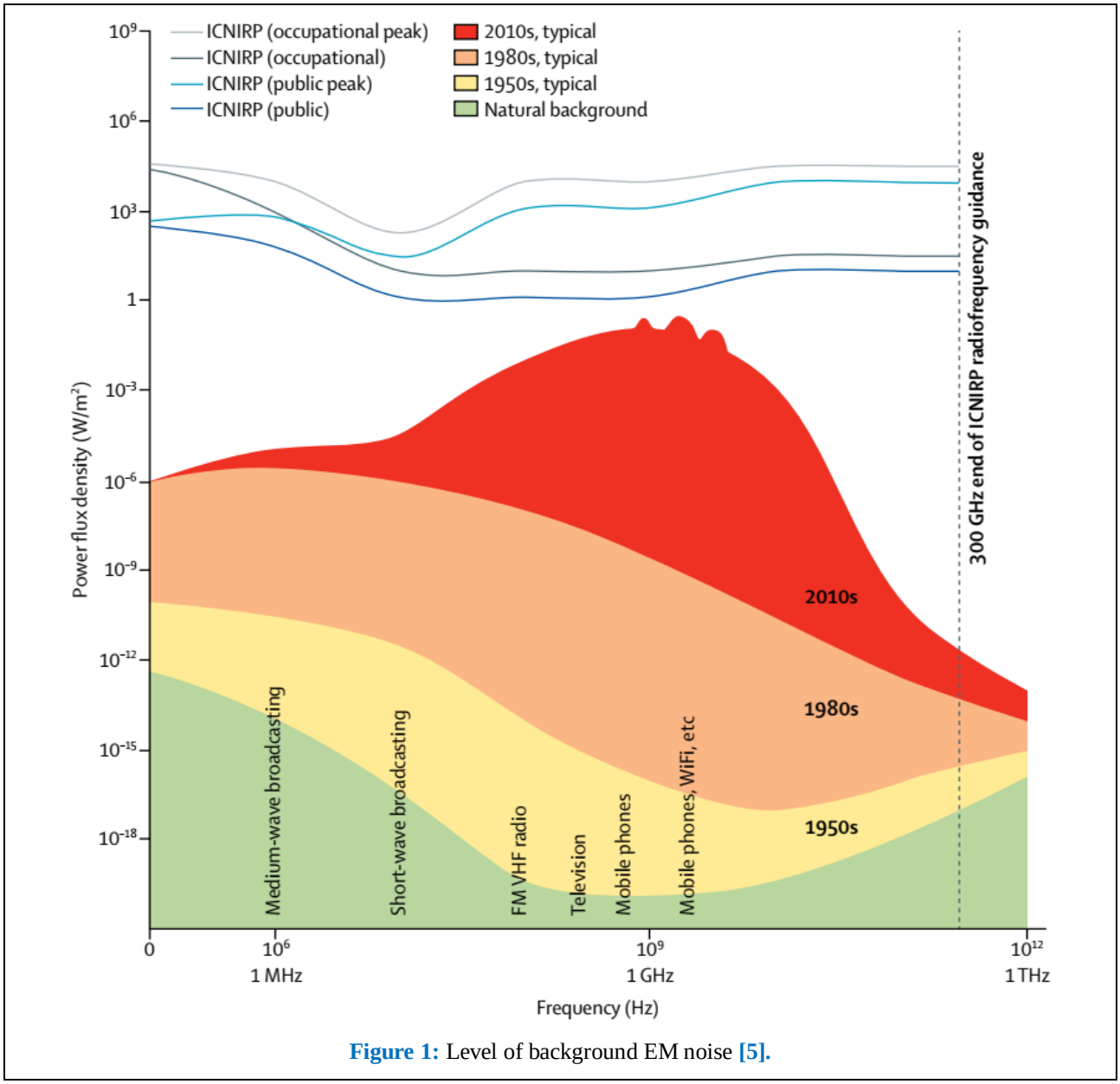

Figure 1: Level of background EM noise **[5].**

As shown in the figure above, we can see that the increase of electronic equipment causes the change of spectrum utilization and spectrum noise. The appearance of VLC makes it possible to develop an innovative method to solve the problem of EMC in digital operating room. With the architectural design of hospital and digital operating room, it is found that hospital operating room meet VLC requirement, no daylight and only artificial light. Therefore, in the research work of this paper, the possibility of using VLC in digital operating room to solve EMC problem is preliminary experimented and evaluated in a real world. Through this experiment,

we have verified the possibility of the VLC application in the operating room. Furthermore, we reformed a shadow less operating lamp used in the operating room. The VLC module and 8 camera modules are integrated into the shadow less operating lamp. VLC module take charge of communication and 8 camera modules take charge of multi-vision monitoring and surgical reconstruction. The work makes the shadow less operating lamp a novel digital operating room control arbiter.

Method

The operating room always uses artificial lighting system and is a good place for VLC usage without interference of sunlight. With the increase of digital equipment, digital operating rooms are plagued by more and more radio's interference. This situation will affect the safety of surgery and the patient's healthy with pacemaker and other important equipment inside the body. In the experiment, the project team with both electronic engineering ability and medical license, deploys VLC system in a real digital operating room and verified the effectiveness of VLC in operation. The application experiment consists of two tasks:

- Verify the digital operating room environment can support video-level VLC applications. The light source in the operating room will not interfere with the video transmission of the VLC system.
- Verify the multi-emission source technology can be used to ensure that the VLC senders (8 in the experiment) would not be completely blocked by the body of the doctor and nurse during the operation. At least one transmitter of VLC system can work to maintain the communication functions.

For task one, shadow less operating lamp is modified as VLC receiving unit (Signal receiving module), the core receiving and control module of VLC system. Shadow less operating lamp, as the lighting source in the operating room, can theoretically produce a full range of transceiver without dead angle and solve the problem of visible light interruption caused by shading. The system is shown in **Figure 2**. The sender of VLC video system is integrated with shadow less operating lamp.

Figure 2: VLC video transmission system used in the digital operation room.

For task two, in the operating room, eight potential device deployment points install the VLC sender (Signal transmitting module) module. In one hour simulated operation, the interference of doctors and nurses with VLC system at different locations was simulated. Experiment data are collected comprehensively as in **Figure 3.**

Figure 3: Eight potential device deployment points to verify the VLC video transmission continues in the digital operation room.

Experiment Result

The application of the VLC technology in the digital operating room achieved preliminary results. The experiment proved that it was feasible to carry out two-way data transmission through the multi-transmitting point method in the actual operation when shadow less operating lamp are used as the arbiter control. The communication would not be interrupted or interfered by the movements of doctors and nurses. The images of eight cameras with different view angles at the same time are shown in **Figure 4**. Video analysis of the entire procedure shows that the light from the eight VLC emitting units would not be completely blocked by the movements of doctors and nurses at the same time.

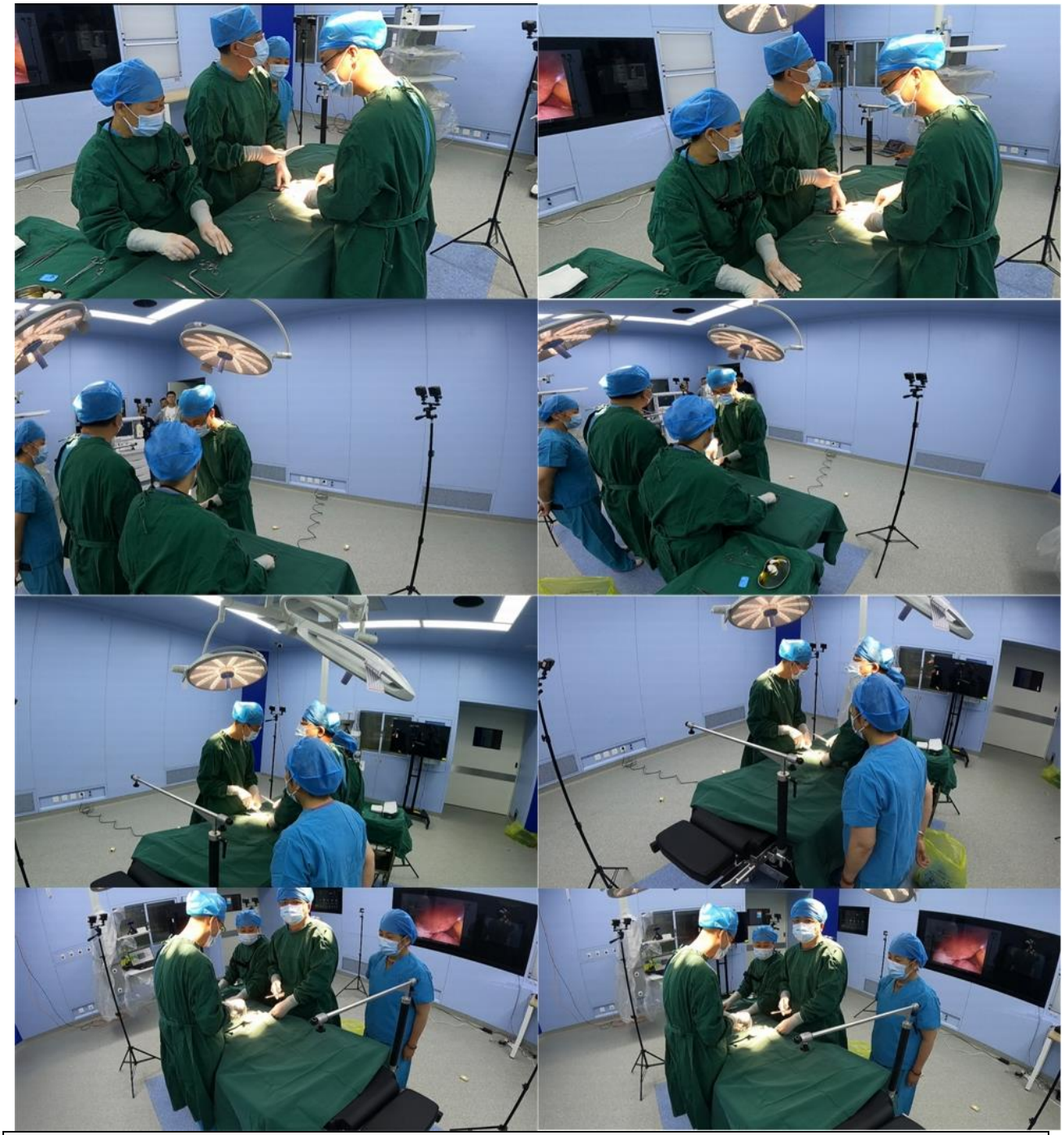

Figure 4: Video analysis shows that the light from the eight VLC emitting units would not be completely blocked by the movements of doctors and nurses at the same time (For example, at this time, the light units used for dummy VLC signal emission can be seen on six camera position).

Equipment Manufacture

Through the verification of practical experiments, VLC application in the digital operating room is verified. For further experiment and application promotion, it is decided to integrate the discrete modules in the experiment into a real shadow less operating lamp, as an arbitrator of VLC in operating room. In the manufacture process, a vertical shadowless operating lamp model is chosen, which can be automatically moved and mounted. Comparing with a cantilever fixed model, this lamp is easy to disassemble and deploy. It is more conducive to manufacture in present stage. As shown in **Figure 5**, the center of the lamp is used to deploy a new designed VLC transceiver unit. The circuit design and final product are also display in **Figure 5**.

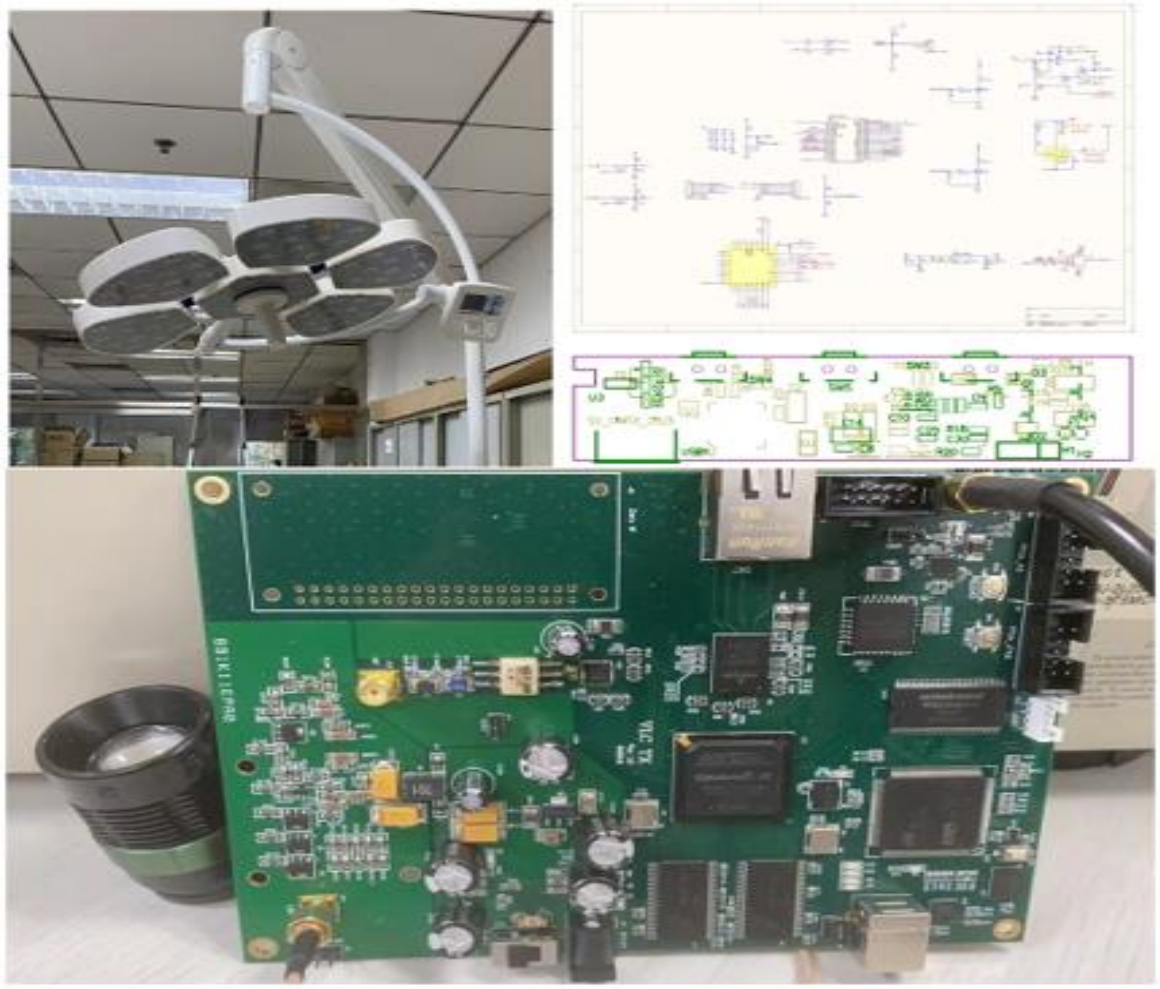

Figure 5: Modified Shadowless operating lamp, Redesigned VLC circuit and final product.

Conclusions

The experiment of VLC technology in the real digital operating room proved that VLC can be well applied in the digital operating room, especially relying on shadow less operating lamp as the base station. VLC is a potential way to reduce electromagnetic interference, maintain the safety of patients' implantable electronic devices, and improve the security of communications in digital operating rooms and medical environments. Particularly, shadow less operating lamp is the natural VLC center in the operating room. Through the actual manufacturing process, an integrated VLC and shadow less operating lamp system is produced. It is can be easily deployed in operating room for further experiment and practical usage.

Acknowledgements

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