Proposal of a free-space communication technique using laser light scattered by artificial mist

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Although Wi-Fi is conveniently available as an access network, there are problems of electromagnetic interference with other wireless devices and from microwave oven. Additionally, there is a risk of being eavesdropped, since the radio waves are hardly confined in the facility. Therefore, in this report, we focus on a visible light communication technique to improve electromagnetic immunity because their carrier frequencies are totally different. It is also expected to improve security because the laser beam can be easily confined in the room.

In our experiment a red laser light pointing at water spray from an ultrasonic humidifier were used. Measured angular intensity distributions of the scattered light were agreed with the calculations based on Mie-scattering theory when assuming 11.2 μm diameter for the mist particle. It was confirmed that the intensity was 2.3 dBm at the 0 ° point and -35 dBm at the 55 ° point. The visible LD light being modulated with PRBS7 could be detected with either PD or APD. These waveforms were clearly observable on an oscilloscope as predicted.

In this paper, we report a possibility of utilizing scattered laser light by artificial mist for communication. Not only line-of-sight of the laser light is no longer important, but also it will make possible to communicate from one to many users.

Keywords : Visible light communication, Free space communication, Scattered light

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1. Introduction

Currently, wireless LAN (Wi-Fi) is most popular for Internet connection, and is installed in major commercial facilities and educational institutions, and many houses. The wireless communication band including Wi-Fi is filled with waves from many radio devices. Electromagnetic interference between them and leaking from active microwave oven can cause communication delay or interruption. A hospital in Japan reported the case that a medical equipment had malfunctioned due to radio interference from a smartphone, in September 2017 [1]. Additionally, there is a risk of being eavesdropped [2] and/or being used illegally by others, since the radio waves are hardly confined in the facility. On the other hand, laser light can be blocked easily.

In a commercially available free-space communication system using laser transmitter is intended for one-on-one (P2P) link between buildings. Good line of sight is crucial there. We propose a new approach that receives scattered laser light by an artificially sprayed mist, where line-of-sight path is no longer needed. A miniature size of over-the-horizon P2P communication should be possible (Fig.1). In addition, multiple access will be possible as shown in Fig. 2. This report describes the result of examining experimentally the possibility of such free-space transmission system through the small fog.

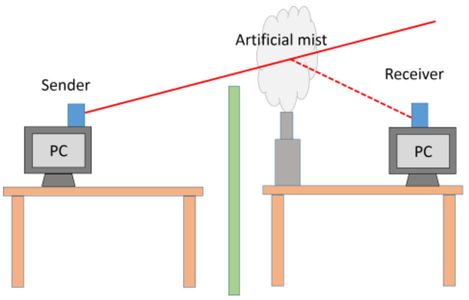


Fig.1 Example of P2Pcommunication using scattered light

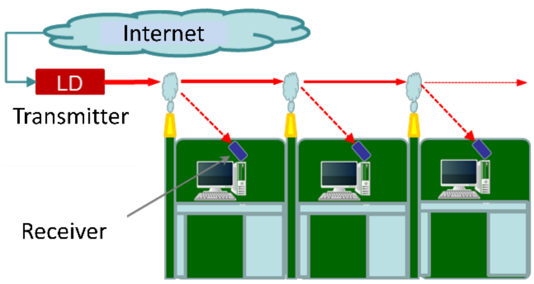


Fig.2 Example of multiple reception through scattered light

Firstly, the angular intensity distribution of the scattered LD light by the mist from a humidifier was measured. The intensity pattern was compared with theoretical ones [3] in order to determine the mist particle size. Secondly, the intensity of the LD was directly modulated with a pseudo-random binary sequence of seven stages (hereinafter referred to as PRBS7), and the received waveform of the scattered light was observed on an oscilloscope.

2. Experiments

Measured intensity angular pattern of the scattered LD light was compared with calculated values. In order to determine the particle size of the mist from the humidifier the particle size parameter was changed from 10 μm to 15 μm with 0.1 μm step. Mie Scattering Calculator [4] created by S. A. Prahl was used for the simulation. Conditions are listed in table 1.

Table 1 Simulation conditions

Contents	Parameters
Particle size	10 - 15 μm (0.1 μm)
Light wavelength	0.635 μm
Refractive index around / inside the particle	1 (Air) / 1.33 (Water)
Number of angles	360 (±180°)
Concentration	0.1 spheres/micron^3

In the experiments, as shown in Fig. 3, a red laser-diode light source (5 mW output, 635 nm wavelength) was placed on an arc-shaped rail with the radius of curvature of 45 cm. The LD was movable between ±55°, and emitted light aiming the center of the arc. The ultrasonic-type humidifier was set in the arc center, about 10 cm below the light path, and sprayed upward. A light receiving part was placed about 10 cm behind the mist. For the receiving experiment of the intensity modulated signal with PRBS7, either a photodiode (Si-PD) or an avalanche photodiode (Si-APD) was employed for the light receiver (Fig.3). The received signal was observed with an oscilloscope with 1 MΩ termination.

3. Results and discussion

A simulation result with assuming the particle size of 11.2 μmϕ showed best fit with the experimental data within ±1° scattering angle range, as shown in Fig.4. For larger angles than ±1°, measured scattered power was lower than the noise floor of the power meter, about -70 dBm. This is because the power sensor head was covered with a pinhole in order to obtain angular resolution of 1°. When compared with the experimental results with theoretical one with 11.2 μm diameter particle, experimental results were well explained for both polarizations, as shown in Fig.5. At the 0 ° point, the received power was 2.3 dBm.

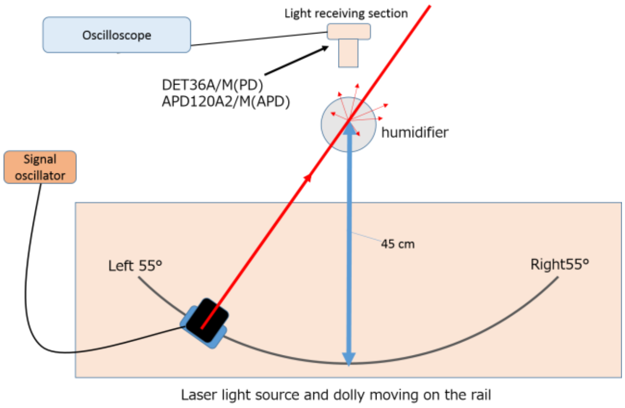


Fig.3 Modulated signal receiving experiment

The red LD was directly modulated with PRBS7, and located at 55° point. Observed waveforms with PD (100 bit/s) and APD (780 kbit/s) are shown in Fig.6 (a) and (b), respectively with yellow lines (top traces). Illuminating room light (50 Hz) superimposing on the LD signal was subtracted from row waveform (yellow) and displayed with red line (middle). Considering -35 dBm input and detector responsibility of 0.5 A/W, and 1 MΩ load resistance, signal amplitude of 160 mV$_{p\text{-}p}$ was expected. It was close to the amplitude of 200 $mV_{p\text{-}p}$ observed in Fig. 6(a). For the APD with responsibility 16 A/W @650 nm, 50 kV/A transimpedance gain for 50 Ω termination, expected amplitude of 256 $mV_{p\text{-}p}$ was more than 10 times larger than the measured 20 $mV_{p\text{-}p}$. It is probably due to the smaller detector area (1 mmϕ).

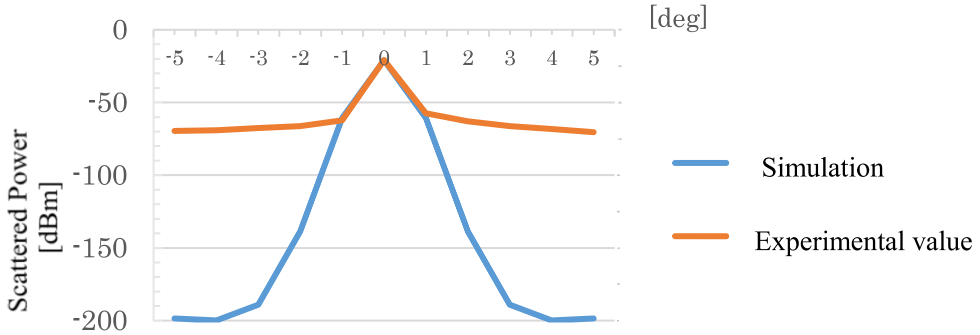


Fig.4　Scattered intensity pattern comparing with theory (a = 11.2 μm)

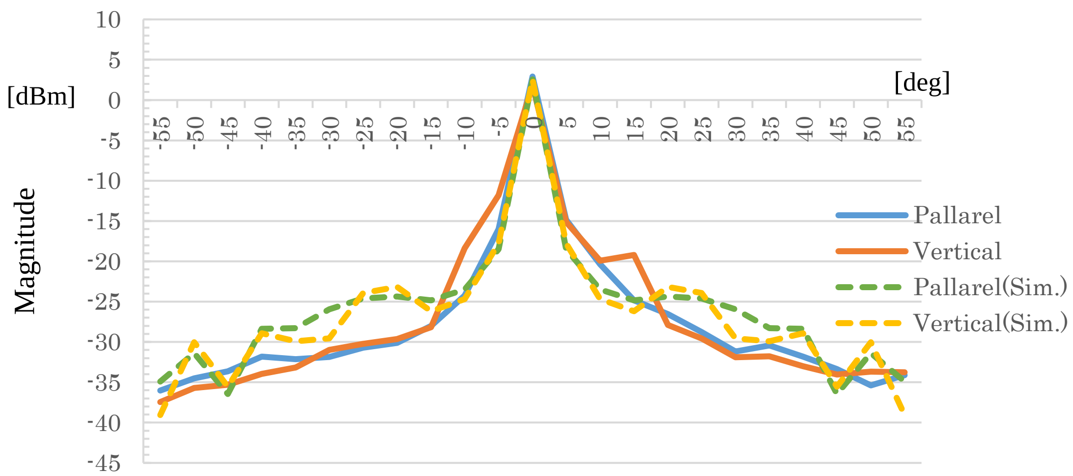
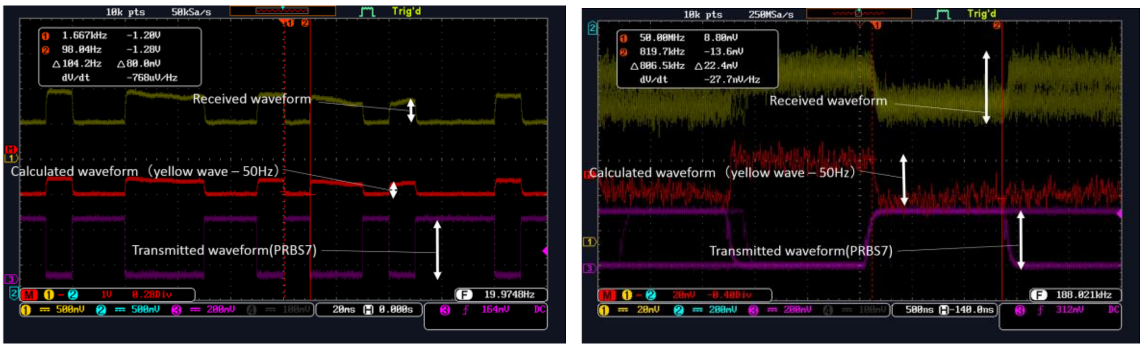


Fig.5 Measured and simulated values up to 55° left and right for both polarization



(a)　　　　　　　　　　(b)

Fig. 6 Observed waveforms at 55° by PD (a) and APD (b)

4. Conclusions

We proposed a novel free-space communication configuration using scattered light, where red laser light pointing at water spray from an ultrasonic humidifier were scattered. Measured angular intensity distribution of the scattered light was agreed with the calculation based on Mie-scattering theory when assuming 11.2 μm diameter for the mist particle. It was confirmed that the intensity was 2.3 dBm at the 0 ° point and -35 dBm at the 55 ° point. The visible LD light being modulated with PRBS7 could be detected with either PD or APD. These waveforms were clearly observable on an oscilloscope as predicted. For the APD case, the signal amplitude was less than the theoretical prediction and accompanied with severe noise. The results reported here indicates the possibility of a miniature size of over-the-horizon P2P communication. Not only line-of-sight of the laser light is no longer important, but also it will make possible to communicate from one to many users by adding the set of mist and detector.

References

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