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Disconnection Time Improvement by using Artificial Multi Reflectors for Millimeter-wave Indoor Communications

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1. Introduction

In the indoor millimeter-wave communications, the human interruption of the communication path is an issue of disconnection. The disconnection probability improvement by using artificial reflectors and beam-forming technology was proposed by authors [1-2]. In this paper the disconnection time improvement effects has been evaluated. By using two reflectors, the disconnection time is reduced to 1/50 (0.02 sec/hour) compared to the situation without reflector. These results give a good improvement for millimeter-wave communications.

2. Millimeter-wave Communications using Artificial Reflector

An image of millimeter-wave indoor communications system using reflection waves is shown in Fig.1. In this system, it is assumed that Rx antenna has beam-forming capability. Rx antenna scans in Omni-directions to find out possible communication paths above the receiver sensitivity and memorize them before communications start. The receiver sensitivity is set to -55.0 dBm (bit rate: 3Gbps) and -59.7 dBm (bit rate: 1Gbps) by referring the IEEE802.15.3c specification [3].

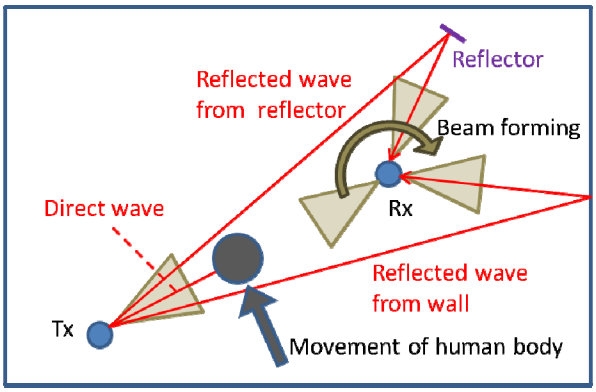


Figure 1: Millimeter-wave indoor communications system using artificial reflector

3. Human Interruption Model

A human interruption model as shown in Fig.2 is assumed to evaluate the proposed approach. By the following simulation procedure, the disconnection time is calculated.

(1) A human body, treated as a cylinder shape absorber with radius of 10cm, is moved at the speed of 1m/s over a path determined by θ and d.
(2) θ ($0° < \theta < 180°$, 1.8°step) and d (10cm$<d<$$d$-10cm, ($d$-20cm)/100cm step) are set. The total number of tries is 10000.
(3) Occurrence frequency when the receiving power in all paths becomes lower than the receiver sensitivity is counted, and the probability of occurrence is defined as disconnection probability.
(4) Disconnection time is calculated by the disconnection probability and the fading duration time.

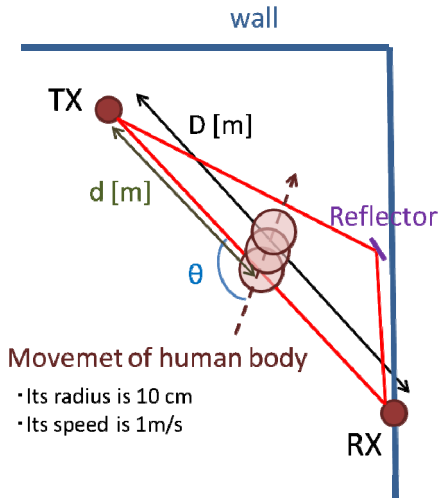


Figure 2: Human interruption model

When a human interrupts communication path, the received power attenuates as shown in Fig.3. The received power was measured for human moving at the speed of 1m/s, the maximum attenuation is -30dBc from static state. The fading velocity and duration time depended on incident angle to communication path. The fading velocity is estimated from experimental results as shown in Fig.4.

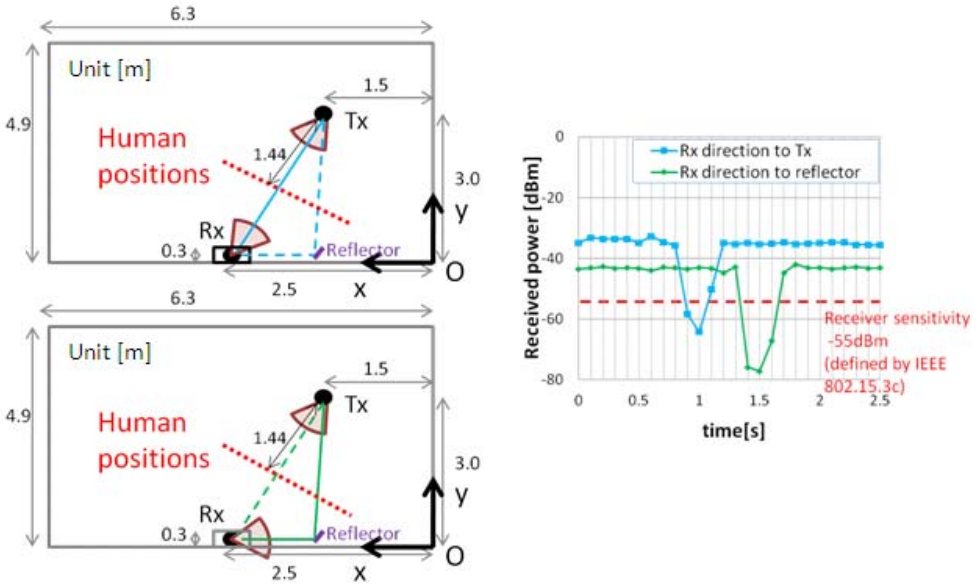


Figure 3: Received power variance when a human body passes through between Tx and Rx

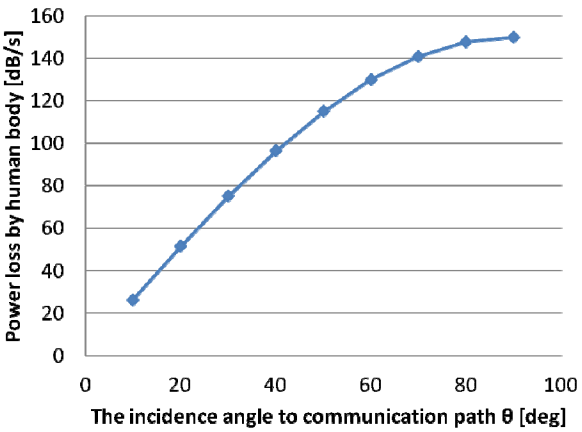


Figure 4: Fading velocity for each incidence angle of human body

The improvement effect of proposed method has been evaluated. The simulation condition is shown in Table.1. To evaluate the statistical improvement effect, the disconnection time for various TX and RX positions in the rooms (which was defined by IEEE802.11ad [4]) has been studied. The simulation procedure is described as following.

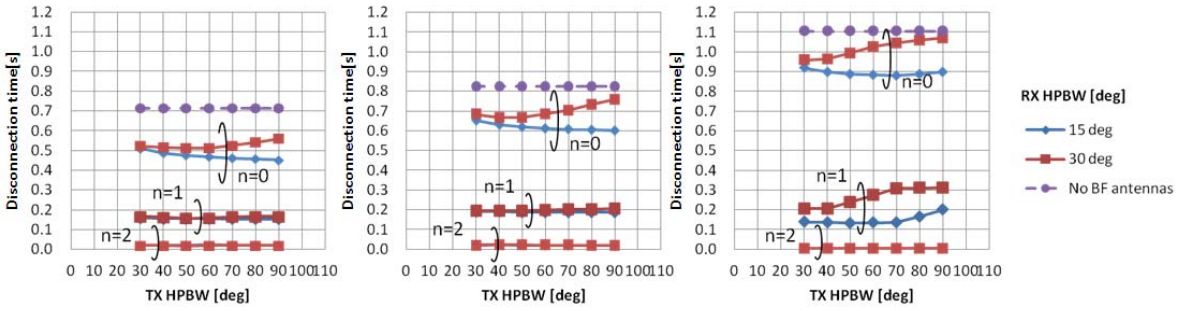
(1) TX antenna is set on any grid of sub-partitioned rooms by grid.
(2) RX antenna is set on any grids near the wall.
(3) Reflector is set at the optimal position for each TX and RX position to minimize the disconnection probability found by the developed simulator based on ray trace method.
(4) The average of disconnection time is calculated when the number of reflectors is 0, 1, and 2.

Table 1: Simulation condition

Room size	(i)4.5*4m:Conference room (ii)6.5*4.5m:Measurement room (iii)7*7m: Living room
Antenna HPBWs	Tx: 30-90 degree (10degree step)
Grid size	50cm
Tx power	10dBm
Receiver sensitivity	(i)-55dBm (3Gbps): Std 3c spec. (ii)-59.7dBm (1Gbps)
Number of reflector	n = 0, 1, 2
Radius of reflector	R: First order Fresnel radius
Human mobility	1m/s
Fading velocity of human interruption	Following Fig.4

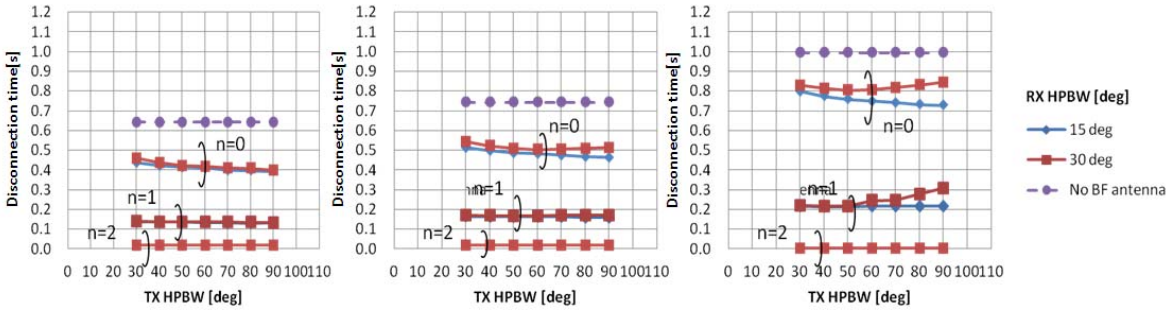
The simulation results for each room size and antenna HPBW when the receiver sensitivity is -55 and -59.7dBm are shown in Figs.5 and 6, respectively. The purple color curves indicate the result of not using beam-forming antenna as a reference. By using beam-forming antenna at Rx side, the disconnection time by human interruption is shortened for 0-0.2s and narrower RX beam width is much effective. By installing reflectors, the disconnection time was more shortened. One reflector improve for 0.3-0.8s disconnection time, it is more effective in the large room. By using two reflectors, the disconnection time is 0.02s in living room (7*7m room size), the disconnection time is 1/50 compared to the situation without reflector.

Furthermore, Fig.7 shows the disconnection time for each receiver sensitivity (according to bit rate) when both Tx and Rx antenna HPBW is 30 deg. When number of reflector is 0 or 1, the disconnection time is reduced in lower receiver sensitivity, and the difference of disconnection time due to the receiver sensitivity was reduced to nearly zero by using two reflectors. Thus the two reflector installation is enough for the improvement in the proposed approach.



(a) Room size:4.5x3.0m (b) Room size:6.5x4.5m (c) Room size:7.0x7.0m

Figure 5: Communication interruption time (receiver sensitivity: -55.0dBm)



(a) Room size:4.5x3.0m (b) Room size:6.5x4.5m (c) Room size:7.0x7.0m

Figure 6: Communication interruption time (receiver sensitivity: -59.7dBm)

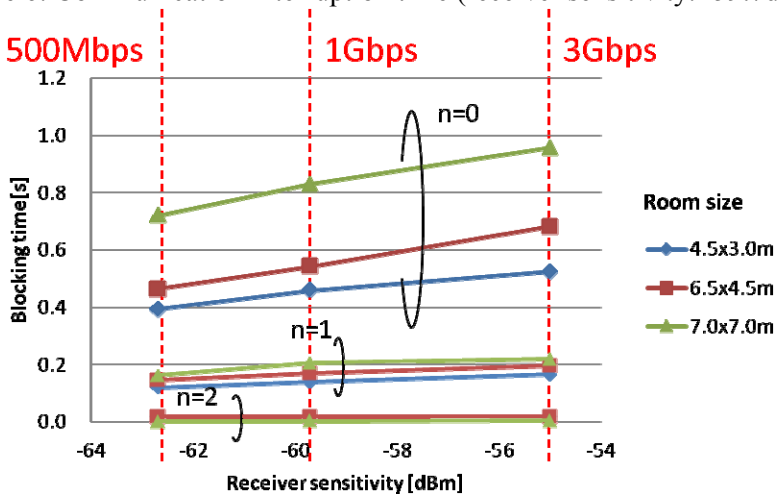


Figure 7: Disconnection time vs. receiver sensitivity (bit rate) when the antenna HPBW of both Tx and Rx is 30 deg

4. Conclusion

By using artificial reflectors and beam-forming technology in indoor millimeter-wave communications, the disconnection time caused by human interruption has been improved to 1/50 compare to situation without reflector. These results give a good improvement for millimeter-wave communications.

Acknowledgments

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References

[1] Hirokazu Sawada, Shunya Takahashi, Shuzo Kato, “Disconnection Probability Improvement by using Artificial Multi Reflectors for Millimeter-wave Indoor Wireless Communications,” Proceedings of IEEE 75th Vehicular Technology Conference (VTC Spring 2012), Paper ID: 2P-2, Yokohama, May 2012.

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[4] IEEE P802.11ad/D2.0, Draft standard, Part 11: Wireless LAN MAC and PHY Specifications, Amendment 4: Enhancements for Very High Throughput in the 60GHz Band.