An Evaluation of a Wireless LAN System Using Leaky Transmission Line by Indoor Propagation Simulation

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1. Introduction

In a wireless LAN system of a usual cell division method, some access points are set up on a ceiling, and communicate with radio stations in each coverage area. In this method, there might be many dead areas under the influence of obstacles unless much access points exist. Further when we change the layout of the indoor space where the wireless LAN system is to be worked, the dead areas may also change. Therefore we should consider the arrangement of radio stations, because it is difficult for user to move the access points.

In this paper, we describe some simulation results of indoor propagation, which compared the wireless LAN system using leaky transmission lines and usual antennas. In the former system, radio stations communicate with an access point through many slots, which lie on a leaky transmission line such as a leaky coaxial cable (LCX) or a leaky wave guide (LWG). From these simulation results, we have been able to confirm that the leaky transmission line has a remarkable effect for elimination of dead areas.

2. Wireless LAN System

2.1. Usual System

Figure1 shows an example of a usual wireless LAN system of a cell division method. Usual system consists of access points set up on a ceiling of an indoor space, radio stations such as a personal computer, and a printer arranged in cells. In a case of infrastructure mode, each station communicates mutually through the access points. However, in actual environment, some obstacles exist on a propagation path between radio station and access point. Therefore, there might be some dead areas where sufficient communication is impossible.

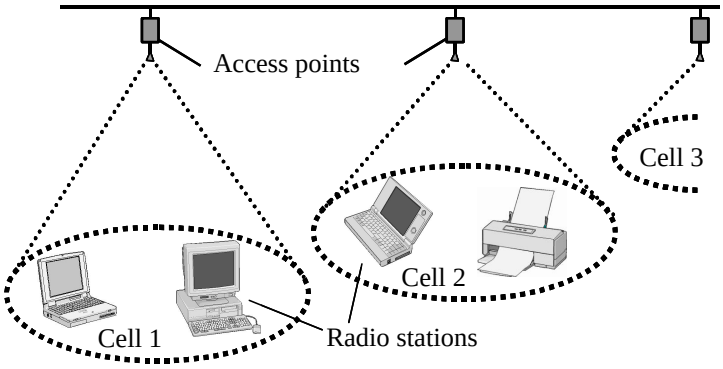

Fig. 1 Usual wireless LAN system

2.2. System of Using a Leaky Transmission Line

Figure2 shows an example of a wireless LAN system using a leaky transmission line. The leaky transmission line is laid on a ceiling of an indoor space, and an access point is connected with an end of the line, and a terminator is put up to the other end. The whole leaky transmission line acts as one antenna with which many slot antennas stand in a row.

Transmission power from access point is transmitted in the leaky transmission line, and is radiated as radio wave from the all slots on the line. Therefore, if the radio waves radiated from certain slots do not arrive at the radio station by the influence of obstacles, another radio waves from other slots surely arrive at the radio station.

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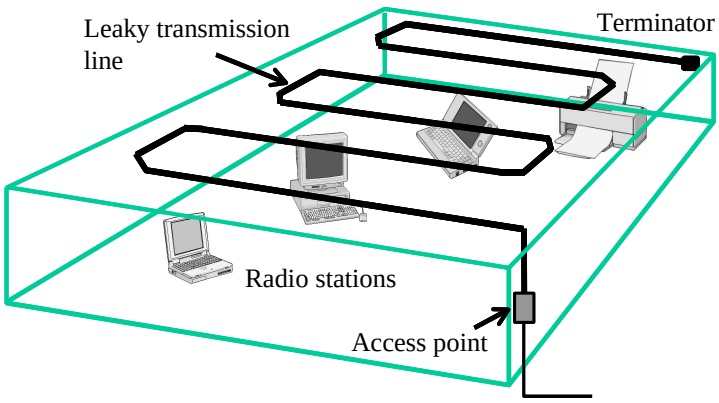

Fig. 2 System of using a leaky transmission line

However, there are time differences in the incoming waves from each slot at the receiving point. It may become a cause of reducing the transmission quality in high-speed data transmission, like the conventional multipath interference. If the system uses orthogonal frequency division multiplexing (OFDM), adopted in IEEE802.11a and 11g, and the time differences are in the range of specified guard interval, the incoming waves can be correctly demodulated.

3. Simulation of Indoor Propagation

3.1. Simulation in Usual System

We simulated an indoor propagation that the radio wave radiated from an access point to radio stations at 5.2GHz band. The access point, which has an isotropic antenna, is set up on a ceiling of an indoor space.

The simulation method calculates a propagation loss based on the distance between the access point and the radio station, and obtains the distribution of the received power with an isotropic antenna of the whole area. We consider the influence of a penetration loss of a ceiling board, reflections up to 2 times at a floor or wall, and 1 time reflection and penetration of obstacle placed on arbitrary indoor space. Then we evaluated whether the point is dead area or not through comparing the received power with the required power for minimum receiver sensitivity of IEEE802.11a.

3.1.1. Store Model of Usual System

We modeled a store where the access point was set up on a ceiling, and simulated its propagation. The store layout is shown in Figure 3, and the simulation conditions are shown in Table 1. The store is separated into a selling floor and a office area. There are commodity shelves in the selling floor, and there are a locker, a refrigerator, and a repository in the office area. The height of the commodity shelves are assumed to be 1.5m. The height of the locker, the refrigerator, and the repository are assumed to be 3m.

The access point is arranged near the partition wall of the selling floor and the office area, to cover both areas. The height of the radio station is assumed to be 1.0m. Further the radio station is equipped with two antennas, which have an effect of space diversity.

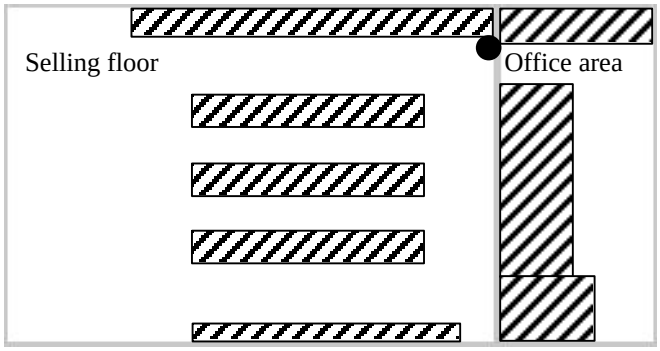

Fig. 3 Store layout

Table 1 Simulation conditions

Number of access points	1
Height of radio station	1.0 m
Transmitting power	40 mW
Frequency band	5.2 GHz
Store size	18m * 9.4m * 3m

3.1.2. Simulation Results

Figure 4 and Table 2 show the simulation results. Figure 4 shows the distribution of the received power. Table 2 shows the static value of the received power, the ratio of dead area to whole area of the store, and the ratio of area, which fills the minimum receiver sensitivity of IEEE802.11a.

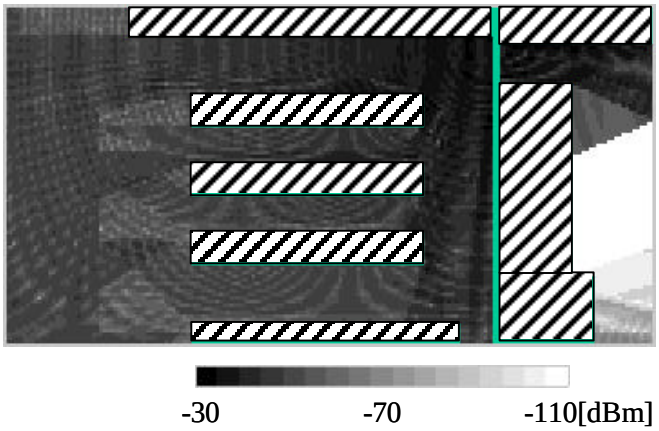

Fig. 4 Distribution of the received power

Table 2 Received power

Received power(MAX)	-31.1 dBm
Received power(MIN)	-109.0 dBm
Received power(AVE)	-51.9 dBm
Dead area	6.6 %
Above -65dBm	88.9 %
Below -82dBm	9.3 %

According to Figure 4, even near area of the access point, a wide dead area exists in the office area due to an influence of the obstacles. If we evaluate statistically, the ratio of the dead area is 6.6% of the whole area as shown in Table 2. Therefore, it is necessary to set up another access point to cover this area. The area where the received power is above -65dBm is 88.9% of the whole area. The value of -65dBm is the minimum receiver sensitivity for 54Mbps of IEEE802.11a. Further the area below -82dBm, which is the minimum receiver sensitivity for 6Mbps, is 9.3%. Therefore, it is impossible to communicate in about 10% of the whole area.

3.2. Simulation in Leaky Transmission Line System

Next, we simulated an indoor propagation from a leaky transmission line laid on a ceiling to radio stations above a floor, and evaluated the result of the simulation as with the usual system.

The simulation method prepares slots on a leaky transmission line at arbitrary intervals, and calculates a transmission loss, delay through the leaky transmission line, a coupling loss, and propagation delay based on the distance between each slot and the radio station. Then it add up the coming waves from each slot, and obtains the distribution of the received power with an isotropic antenna of the whole area. We consider here influences of a penetration loss of a ceiling board, reflections up to 2 times at a floor or wall, and 1 time reflection and penetration of obstacle placed on arbitrary indoor space, just like the simulation of the usual system. In addition, we consider influences of lamp and shade placed on the ceiling, too.

3.2.1. Store Model of Using a Leaky Transmission Line

We modeled a retail store environment with a leaky transmission line laid on a ceiling, and simulated its propagation. The store layout is shown in Figure 5, and the simulation conditions are shown in Table 3. The leaky transmission line is LCX of 30m in total length, and constructs in S character shape to cover both the selling floor and the office area by one line. An access point is connected with an end of the selling floor side, and a terminator is put up to the office area side.

Further, the radio wave is not radiated from the part where the slot of LCX overlaps with the lamp and shade. Other conditions are the same as the simulation of the usual system.

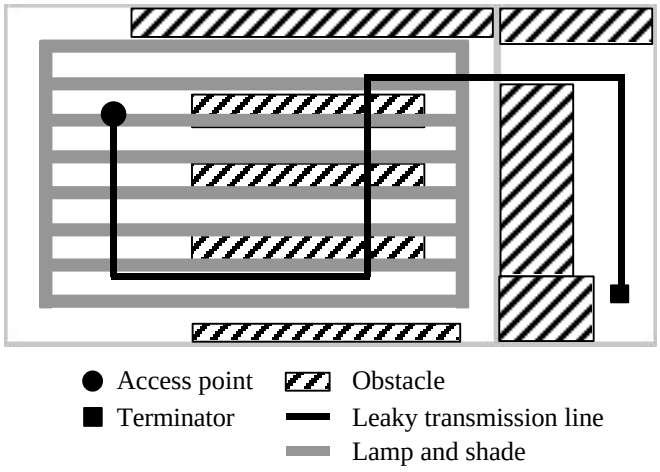

Fig. 5 Store layout

Table 3 Simulation conditions

leaky transmission line	LCX
length	30 m
coupling loss	63.8 dB
transmission loss	0.15 dB/m

3.2.2. Simulation Results

Figure 6 and Table 4 show the simulation results. Figure 6 shows the distribution of the received power. Table 4 shows the statistic value of the received power, the ratio of dead area to whole area of the store, and the ratio of area, which fills the minimum receiver sensitivity of IEEE802.11a.

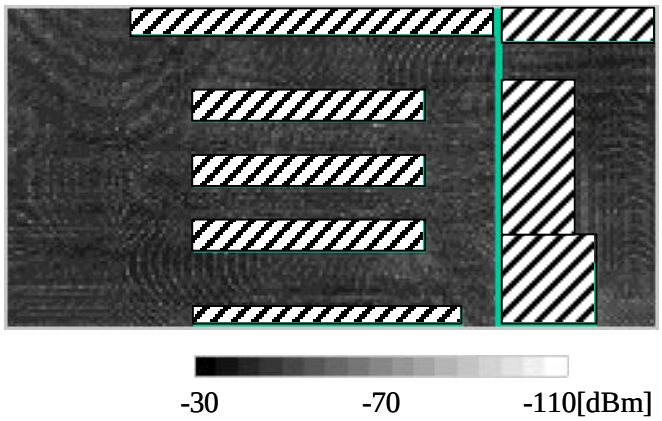

Table 4 Received power

Received power(MAX)	-39.4 dBm
Received power(MIN)	-80.1 dBm
Received power(AVE)	-49.7 dBm
Dead area	0 %
Above -65dBm	99.7 %
Below -82dBm	0 %

Fig. 6 Distribution of the received power

When Figure 6 is compared with Figure 4, the radio wave radiated from the leaky transmission line has arrived more uniformly at whole area of the store. If we evaluate statistically, the area above -65dBm, which is the minimum receiver sensitivity for 54Mbps of IEEE802.11a, is 99.7%, and the area below -82dBm, which is the minimum receiver sensitivity for 6Mbps, does not exist. Especially, the received power of office area is improved remarkably compared with the usual system, and the dead area where communication is impossible is eliminated completely. This result indicates that we can keep the stable propagation path between slot and radio station by laying the leaky transmission line on the near areas where should be covered.

4. Conclusions

In this paper, we compared the indoor propagation characteristics where a usual antenna or a leaky transmission line was used respectively for the access point of wireless LAN, by computer simulation. In the usual system, a lot of dead areas exist in the environment with many obstacles, unless the access points are increased. However, without increasing the access points, the leaky transmission line system can make the radio wave arrive at required area uniformly by laying the line according to the structure of the space where should be covered. Therefore, we confirmed that this leaky transmission line system was effective to the elimination of dead area.

In the future, we would also reflect the influence of more complicated reflection and diffraction in the simulation result, and improve the simulation accuracy comparing with results of actual measurement.

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