CHARACTERIZATION OF INDOOR PROPAGATION USING AMPLITUDE DISTRIBUTIONS

Mitsuhiko Mizuno
Communications Res. Lab.
Ministry of Posts and Telecom.
Koganei-shi, Tokyo 184 JAPAN

Christian Bergljung
Dept. Applied Electronics
Lund University
Box 118, S-22100 Lund, SWEDEN

1. INTRODUCTION

A micro-cell radio system for future personal telephones has been discussed in IWP8:13 of CCIR and Mobile-RACE. The required radio coverage is expected to be 99%.

In coventional cellular mobile radios, the variations of the received signals are separated into three components, short-term fading (multipath), long-term fading (shadowing) and path-loss [1]. If the variation is caused by multipath propagation, the distribution will be Rayleigh or Rician. On the other hand, if the variation is caused by shadowing including some reflection and wall penetration, by which the signal power is attenuated, the amplitude of the received signal has log-normal distribution. Therefore by examining the amplitude distribution, it will be possible to estimate the cause of the variations.

Generally, long-term fading and short-term fading are separated using moving average or filtering on the time sequential samples. But in the case of indoor propagation, the distance scale of the variations is so compressed that they are considerably overlapping.

In this paper, a modified definition of variation is primarily proposed. Then some considerations on the indoor propagation structure are presented, based on the amplitude distributions.

2. MEASUREING ARRANGEMENT

Measured frequencies are 950MHz and 1700MHz. For the measurement at 950MHz, modified NMT mobile units with omni-directional antennas are employed as a transmitter and receiver. For the 1700MHz, units from microwave link have been used, and a directional antenna is used for transmission in some measurements. A receiver is installed on a trolley. There are also batteries, an DC-AC inverter and a desktop computer on it. An extra fifth wheel provides distance pulses. Measurements were conducted in the building of the Department of Applied Electronics, Lund University. This is a three-story building, made from reinforced concrete.

3. RESULTS

3.1 General discussion

In this paper, classification of the variation is redefined into the following categories:

(a) short fading
(b) long fading
(c) path-loss

The difference between them is only their periods of variation. The fading whose period is shorter than a certain length (eg. feasible distance of space diversity) is called short fading, otherwise it is called long fading. The short fading may not always be caused by the multipath and vice versa. The nonperiodical, monotonous attenuating term is the path-loss.

This definition is related to the countermeasure techniques such as micro and macro diversities. Effective micro diversity, equalization or channel coding techniques will be available to improve the performance against the short fading. The influence of the long fading and path-loss will be reduced by means of macro diversity techniques, for instance, base-station diversity. The boundary of the short fading and long fading, based on the feasibility of diversity as mentioned before, will be less than 1.5 wavelength. The two kinds of fading are separated in the spatial-frequency domain, using moving average or filtering on the sequential samples. In this paper, a raised-cosine low-pass filter has been used, whose spatial cut-off is half a wavelength.

3.2 Short fading.

Short fading is obtained by subtracting the long fading and path-loss from the measured data. Results measured in a corridor are shown in Figures 1 to 3. They are the cumulative distributions plotted on Rayleigh papers. The RF frequency is 1700MHz transmitted from a directional antenna put in a corner of the corridor. All of the measurement route is in line-of-sight, however there is a door in the middle of the route.

Figure 1 is a result of the first half of the route, between the transmitter and the door. Its distribution is obviously Rician whose direct to scattered signal ratio is 10dB. Figure 2 shows the amplitude distribution of the second-half part, when the door is open. Figure 3 is when the door is closed. The direct wave is blocked, and the diagram shows a good fit to the Rayleigh distribution. It should be noted, though, that when the direct to scattered signal ratio is less than 5dB, the Rician distribution plotted on the Rayleigh paper looks almost similar to the Rayleigh distribution.

Figure 4 shows another example measured in an entrance hall. The measured area is also all in line-of-sight. The frequency is 950MHz. This distribution is also considered to be Rician.

3.3 Long fading

Distribution of long fading, which is obtained by subtracting the path-loss from the low-pass filtered samples, are shown in Figures 5 and 6. They are plotted on a log-normal paper. Figure 5 is the result of the whole route in the corridor, and Figure 6 is in the entrance hall. The results are fairly close to the log-normal distribution. But they do not fit so good as the short fading fits to the Rician distribution. Probably the variation caused by multipath still remains in the long fading. The standard deviation is approximately 3dB in both cases. This is less than the value of conventional mobile radio, which is usually 6 to 8 dB.

3.4 Path-loss

Distance dependence of the attenuation is usually expressed as d^{-n}, in which n is an attenuation factor. The path-loss measured in the corridor is approximated to the curve of $d^{-2.8}$, which is calculated by the least mean square method. The attenuation factor strongly depends on the circumstances.

3.5 Influence of people moving

The time variation is measured in a corridor using stationary antennas. These variations are mainly caused by people moving in the path between transmitter and receiver.

A cumulative distribution at 950MHz, when a few people are frequently walking in the radio wave path, is shown in Figure 7. This is measured between two crossing corridors and no line-of-sight. The distributions seem to be Rician, whose direct to scattered signal ratio is 10 to 12dB. According to the distribution, 10%time is 4-5dB below the median and 1%time is 8-10dB below the median. It is supposed that the variation is mainly caused by disturbance of the multi-path propagation and that a person makes little shadowing, except when being very close to an antenna.

There was a difference when many (ten and more) people were moving together. In this case, at 950MHz, in Figure 8(a), the distribution is deeper than the Rayleigh. 10%time is 15dB below the median. The same result is plotted in Figure 8(b) on the log-normal paper. The distribution above the median fits to Rayleigh distribution, and the lower is close to the log-normal distribution with the standard deviation of 7dB. A combination of shadowing and multipath will make this result.

The result depends on the frequency and number of moving people. The attenuation of the signal may not be in proportion to the number of people, because a few people cause the change of multipath environment but a crowd will make large shadowing.

It is also supposed that the influence of the person carrying the radio unit is unavoidable; he will cause shadowing.

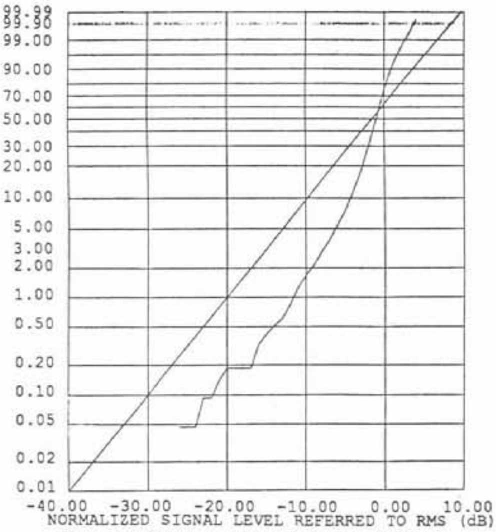


Figure 1 Distribution of short-fading, the first-half of corridor.

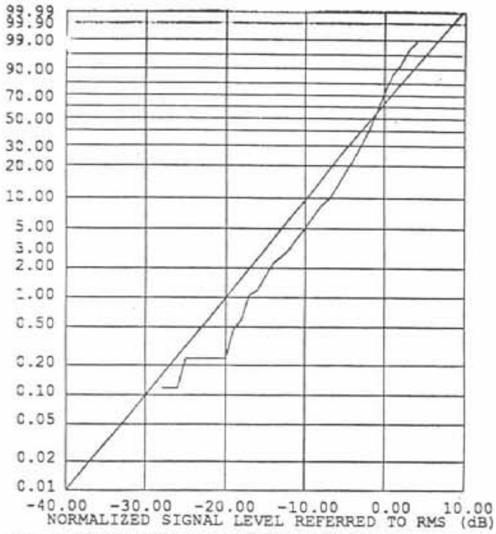


Figure 2 Distribution of short-fading, the second-half of corridor, door open.

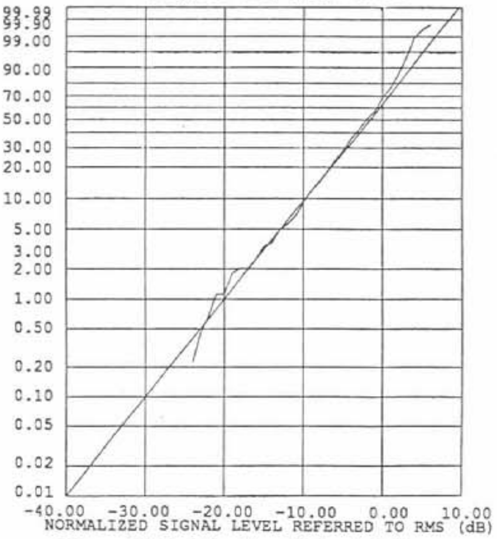


Figure 3 Distribution of short-fading, the second-half of corridor, door closed.

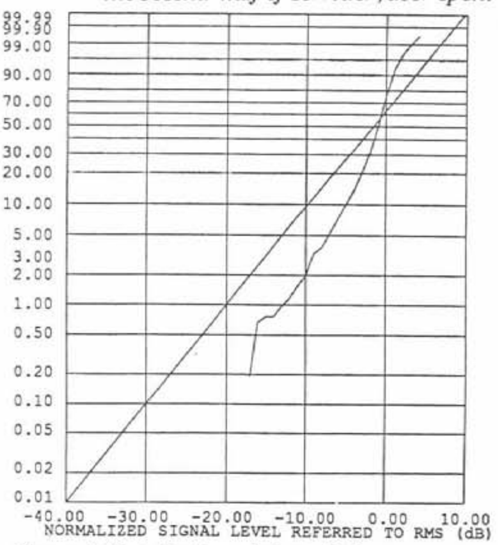


Figure 4 Distribution of short-fading, in an entrance hall.

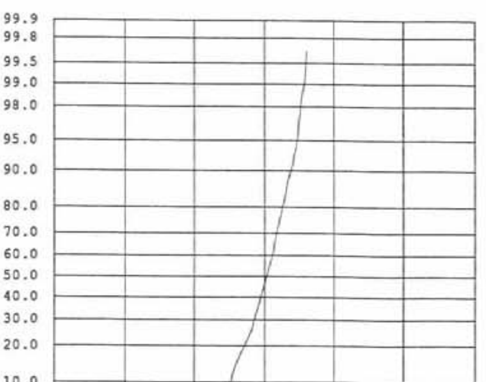


Figure 5 Distribution of long-fading, in a corridor.

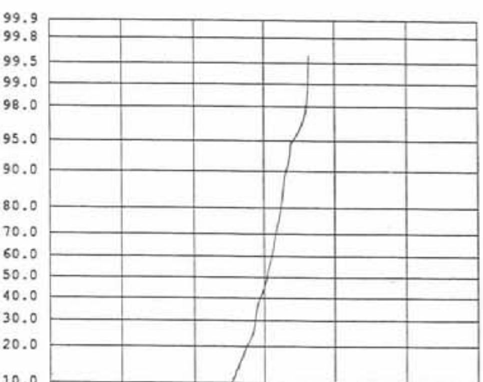
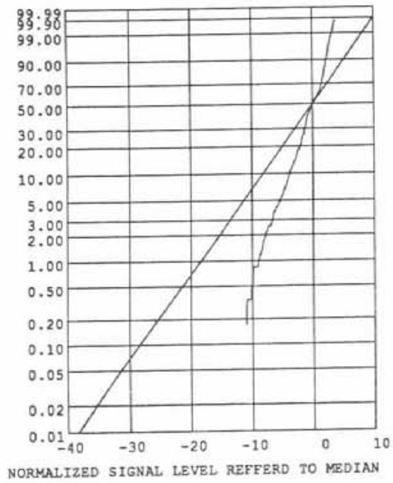


Figure 6 Distribution of long-fading, in an entrance hall.



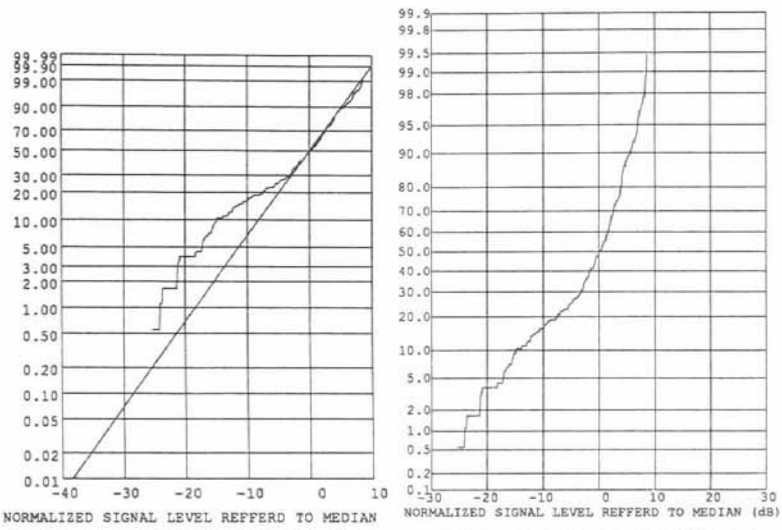


Figure 7 Influence of a few people moving. *Figure 8 Influence of ten and more people are moving (a)on Rayleigh paper, (b)on log-normal paper.*

4. CONCLUSION

According to our measurements, we conclude that the short fading is caused by multipath, while the long fading is caused by multipath and shadowing. Time variation caused by moving people is due to both multipath and shadowing, depending on the number of people.

It should also be emphasized that the path-loss plays an important role in micro-cell system for the following reasons:

1 The decrease of signal level is very quick in the vicinity of the transmitter, but change moderately in the area far from the transmitter. Thus, the smaller distance of the micro-cell system causes steeper variation.

2 Rician fading seems to be more often observed in the micro-cell with line-of-sight. This makes the contribution of short fading to the total variation less. Furthermore, there are more chances to operate in the vicinity of the transmitter, where received signal is so strong that factors other than the distance can be neglected.

3 According to our measurements, the standard deviation of long fading is smaller than in the small-cell case. This means that the variation range of the long fading is relatively smaller than the variation due to path-loss. But this result depends strongly on the measuring environment, and to be able to arrive at a conclusion, further measurements including rooms will be necessary.

The service area of a micro-cell system is so narrow that it is often difficult to obtain a number of samples high enough for the statistical reliability. Considerations on the appropriate statistical methods are also desired.

Acknowledgements

The authors would like to thank Sven-Olof Öhrvik for support and encouragement, and Lars Olsson, Peter Karlsson, Michael Faulkner and Ding Huaiyuan for discussions and help with the measurement.

The authors wish to acknowledge that this work was supported by the National Swedish Board for Technical Development under contact no 88-01-375P, and that the opportunity for M.Mizuno to study in Lund University was supported by Science and Technology Agency and Ministry of Posts and Telecommunications of Japan.

References

[1]. W.C.Y.Lee, Mobile communication design fundamentals, SAMS, 1986.