# MULTIPATH DELAY CHARACTERISTICS IN KYOTO CITY

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## ABSTRACT

Spatial variations of average power delay profiles and cumulative distributions of delay spread measured in Kyoto city are shown.

## INTRODUCTION

Multipath delay characteristic is an important factor to clarify the performance of high speed digital mobile radio system. The authors have measured the average power delay profiles in the neighborhood of Kyoto University campus in 1987 to compare the multipath delay characteristics with the bit error rate measurement by using DSK and BPSK [1]-[3] showing a good correspondence between bit error and delay. This paper describes the results of extended measurements conducted in Kyoto city, discussing the spatial variation of average power delay profile and the statistics on multipath delay spread.

## DELAY PROFILE MEASUREMENT

In 1988, power delay profile measurements have been extended to wide areas of Kyoto city including urban and suburban areas. Two transmitter sites were used, one in the Kyoto University campus and the other in southern urban part of Kyoto. The conditions of test courses are listed in Table 1, including streets surrounded by tall buildings in urban areas and streets opened to mountains.

A channel sounder of spread spectrum signal was used, which has 0.8μs delay time resolution and about 40dB amplitude dynamic range. Sounding signal of 10 watts in the 400MHz band was transmitted by a three-element Yagi-antenna directed to each test course. The receiver and measuring equipments were mounted in a mobile van, and a mono-pole antenna was used as a receiving antenna, which was mounted on the roof of the van at 2.5m above ground.

A power delay profile was measured every 65cm and successive sixteen profiles were averaged to give an average delay profile of 10.4m section of test course.

## RESULTS OF MEASUREMENT

Fig.1 shows the results of power delay profile measurements in urban and suburban areas. Each curve corresponds

Table 1 List of test courses

| Name of test course | Urban/ Suburban | Building density/ building height* | Propagation distance (km) | Transmitter site and Tx antenna height |
|---|---|---|---|---|
| Kyoto Univ. campus | U | dense/middle | 0.3 | Kyoto Univ. campus, 27m |
| Neighborhood of Kyoto Univ. | U | dense/low and scattered/middle | 0.7 | do. |
| Imadegawa street | U | do. | 1.3 | do. |
| Kitayama street | S | residential and mountainous | 2.7 | do. |
| Neighborhood of Kyoto station | U | dense/low and scattered/middle | 2.9 | NTT Kyoto south office, 73m |
| Karasuma street | U | dense/high | 5.7 | do. |
| Oike street | U | dense/high | 5.9 | do. |
| Horikawa street | U | dense/low and scattered/middle, high | 5.5 | do. |
| River side street (Katsura River) | S | mountainous | 7.6 | do. |

* Building height: low=lower than 3 stories, middle=4 to 5 stories, high=8 to 10 stories

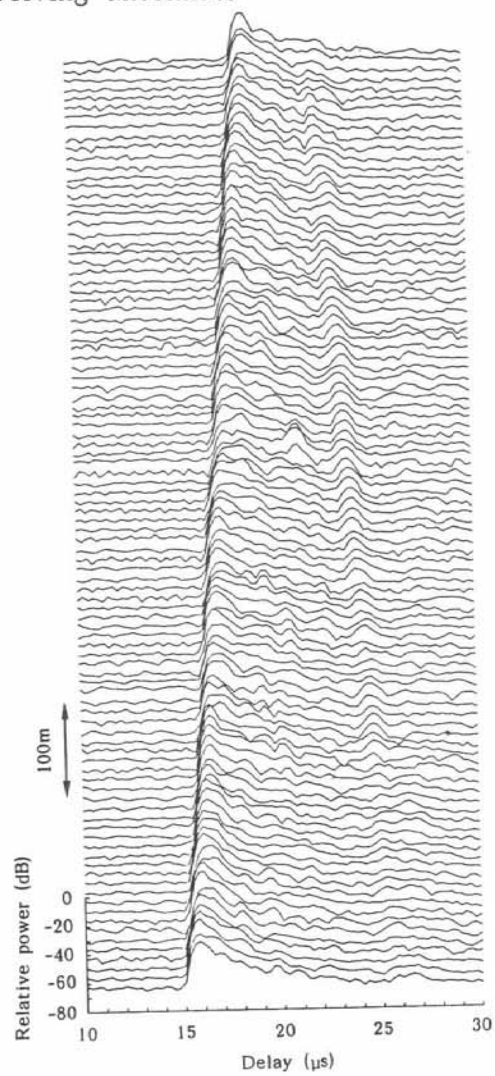
to an average power delay profile of 10.4m section. Vertical axis is a relative power in dB and horizontal one is propagation time from the transmitter site.

Fig.1(a) is an example measured on a typical urban street with a small street angle (street angle is an angle that a street makes with direction of transmitter). Many delayed waves continuously distributed up to 5μs excess delay are observed, the amplitudes decreasing with increasing delay time. A long delayed wave with an excess delay relative to the first-coming wave varying along the run up to 10μs is clearly seen almost throughout the course, which can be a reflected wave from a building wall visible from both transmitting and receiving antennas.

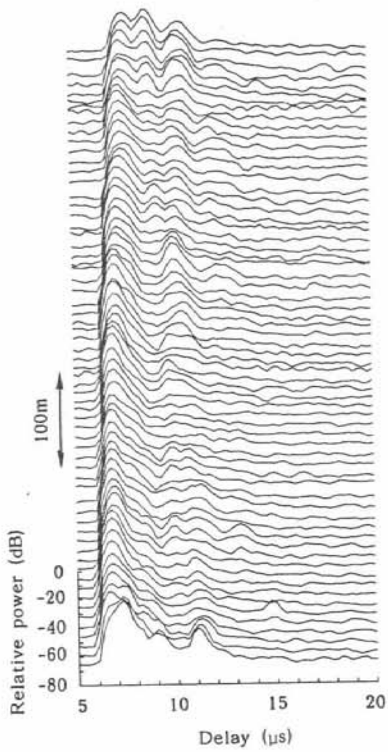
Fig1.(b) is an example of the result measured on a street with a large street angle, about 65°. There is observed a peak of 4μs excess delay almost constant along a large portion of the street. It seems to be caused by the long wall of an elevated railroad platform (Kyoto station) and nearby tall buildings, which are visible from the transmitting antenna and lining in parallel with the test course.

Fig.1(c) is the result measured on a wide (about 50m) street with a small street angle, where the visibility of distant tall buildings is good. There are seen two groups of delayed waves: the one with linearly changing delay along the street (waves 1, 2, 3 and 4) which denotes single reflection, and the other with constant excess delay (waves 5, 6 and 7) which denotes double reflection.

Fig.1(d) shows the result on a river-side street in a suburban area opened to mountains. Long-delayed waves of more than 30μs excess delay are seen. It is noted that the spatial variations




(a) Karasuma street



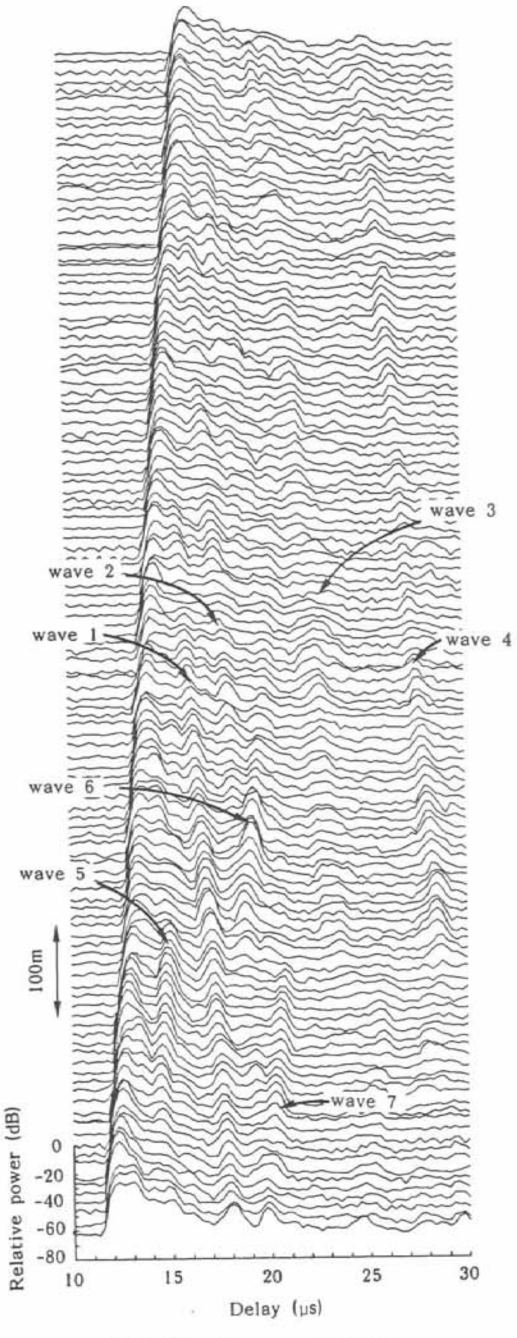

(b) Kujo street

Fig.1 Results of measurement

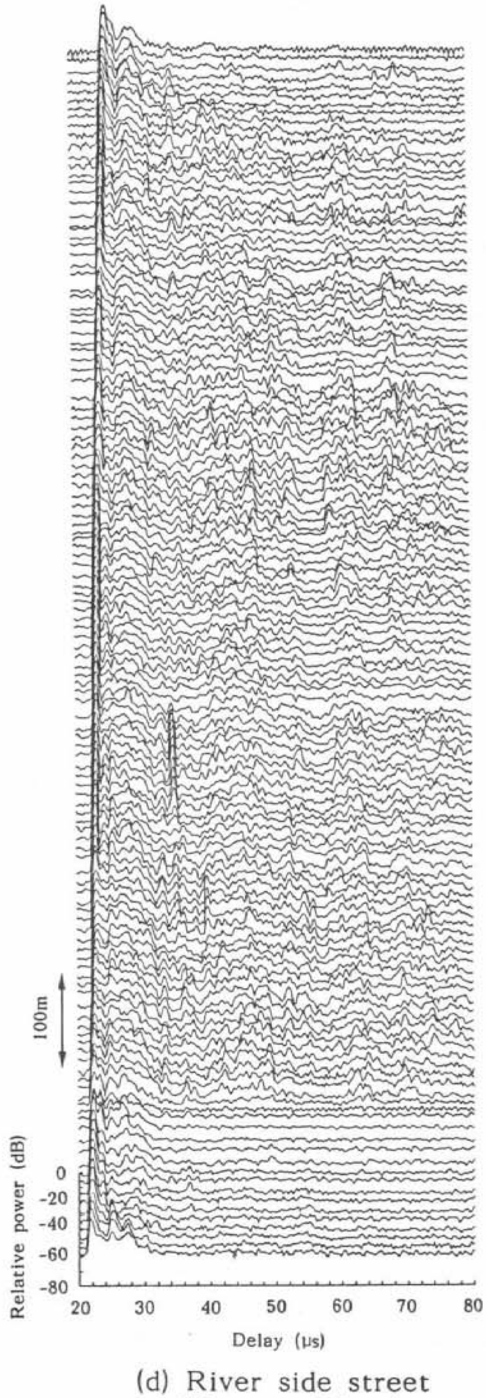
are irregular in a sharp contrast with those on urban streets. Another measurement using a directive antenna confirmed that they were reflected on the slopes of mountains visible from both transmitting and receiving antennas.

## DELAY SPREAD STATISTICS

The delay spread [4] of every 10.4m section was calculated from the average power delay profiles. Fig.2 shows the cumulative distribution of delay spread on each test course. The curves are divided into two groups, clearly dependent on the influence of mountain-reflected waves with extremely large excess delay. Oike street, in spite of an urban street, has large delay spread because of 20μs excess delay due to the mountains which are seen on the half portion of the course.




(c) Horikawa street




(d) River side street (Katsura River)

Fig.1 Results of measurement (continued)

## MICROSCOPIC MEASUREMENT

Fig.3 shows microscopic power delay profiles measured every 5.2cm over 5.2m section in the neighborhood of Kyoto University campus. Fading is seen on the first-coming wave, but less fading on the second-coming one, which is a reflected wave from a building 300m apart. The other long-delayed waves with more than 4μs excess delay can be seen. A fine structure of incident waves can be better indicated by a microscopic measurement.

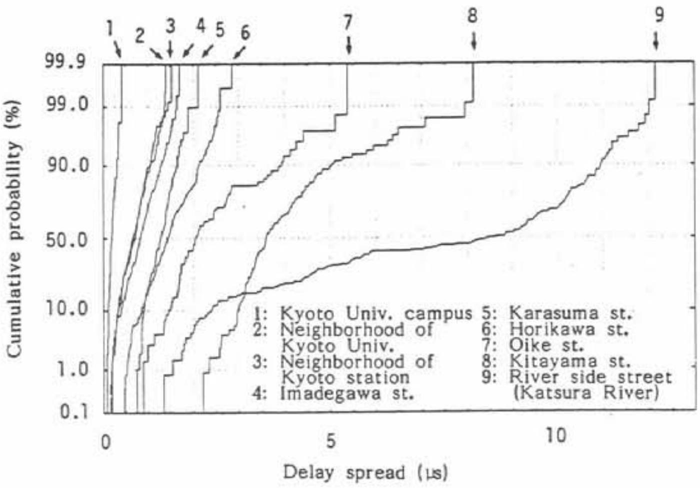



Fig.2 Cumulative distribution of delay spread

## CONCLUDING REMARKS

From the results of power delay profile measurement, visible walls can be significant causes of delayed waves on urban streets. Especially, if a street angle is small and a road is wide, relatively strong reflected waves from visible walls can be propagated long distances. The buildings which generate reflection can be well determined by comparing the spatial variations of excess delay with a building map. This is also the case in mountainous terrain, where mountains are commonly visible from both transmitting and receiving antennas.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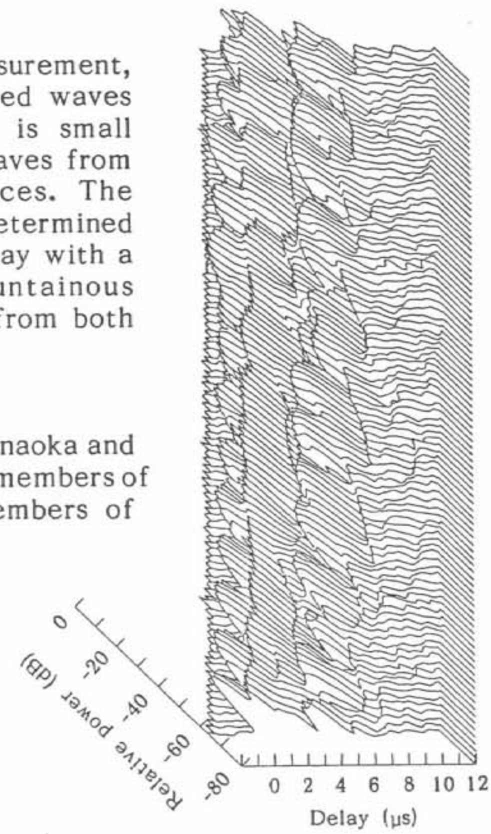


Fig.3 Result of microscopic measurement

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