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Microwave Band LOS Path Loss Characteristics in Microcellular Mobile Communications

Yasuhiro ODA, Tetsu TANAKA and Kohei SATOH
NTT MOBILE COMMUNICATIONS NETWORK INC.
1-2356, TAKE, YOKOSUKA, KANAGAWA-KEN,238, JAPAN

INTRODUCTION

With the rapidly increasing demand for mobile communications in the last several years, efficient spectrum utilization and the development of new frequency bands have become very important themes. Furthermore, advances in technology are leading to the development of multimedia-mobile communication systems with voice, image and mass-data transmission capability. Microwave or millimeterwave bands will be suitable for the broad-band, high-speed transmission. But because these frequency bands are higher than the UHF bands used in current mobile communication systems such as Personal Digital Cellular (PDC) system or Personal Handy-Phone System (PHS), propagation loss is larger and cell radius is smaller than in current systems. Therefore, it will be necessary for microcellular systems to be used in mobile communication over microwave or millimeterwave bands.

Although microcellular path loss characteristics have been thoroughly investigated for UHF and lower bands[1], they have not for microwave or millimeterwave bands. This paper describes the experimentally results of microwave line-of-sight (LOS) path loss characteristics by comparing them with UHF band characteristics in a microcellular system.

Another problem with microcellular systems is that because of the low-height antennas used in them, propagating waves are very strongly influenced by vehicular traffic, roadside trees, and other objects in the surrounding environment. Therefore took measurements we carried out under three separate sets of conditions.

MEASUREMENT OVERVIEW

Measurements were performed using three different base station (BS) antenna heights (3.0m, 14m and 24m) and four different frequencies (457.2 MHz, 2.2GHz, 4.7GHz, and 10.7GHz). All frequencies were transmitted simultaneously from a mobile station (MS), and the radio waves at the different antenna heights and frequencies were received simultaneously at the BS. Both the transmission and reception antennas were omnidirectional, vertical-polarization antennas. The experimental vehicle used as a BS was parked on the side of the road in the measurement area. The station wagon used as the MS had an antenna height of 2.5m, and moved continuously around the LOS roads.

Four test settings (urban areas of Sapporo and Yokohama in mid-day, an urban area of Sapporo at night, and a suburban area of Sapporo at night) were chosen so that we could study propagation in a variety of environments. Both cities have similar structural characteristics--flat terrain, straight roads, right angle corners and a high building density. The average height of the buildings in the urban areas was about 40m, and in the suburban areas about 5m. Received path loss data were sampled at a distance of 0.1m, and a median value of 10m was used.

LOS PATH LOSS CHARACTERISTICS

Figure 1 shows the LOS path loss characteristics measured in the Sapporo urban area at mid-day for a 3m BS height. LOS data for 14 driving courses are plotted in the figures. The two lines in the figures are the free space propagation loss line and the line decrease at the inverse proportion of the 4th power of the distance; the latter is set using the two line regressions. We defined the crossing point of the two lines the experimental breakpoint. In all four frequencies, before break point the free space path loss is very suitable, the path loss after break point decreases in inverse proportion to the 4th power of the distance, and the break point becomes longer as the frequency becomes higher.

Figure 2 shows LOS path loss characteristics in Yokohama for the same conditions as in Fig. 1. This leads to the conclusion that the same results will be obtained in general for measurements taken in similar city-structure environments.

BREAK POINT CHARACTERISTICS

Several parameters (e.g. BS antenna heights, measurement locations, time of measurements, frequencies) were considered through the measurements. The breakpoints measured under such parameters determine the definition of breakpoint described earlier.

Two breakpoint models were proposed for the UHF and lower bands frequency range, a two-ray model[2] and a first fresnel zone model[3]. The formulas for these models are as follows:

$$\text{breakpoint} = A * hb * hm / \lambda \qquad (1)$$

where A : $2*\pi$ or 4 , hb, hm : BS, MS antenna height (m)

λ : radio wave length (m)

There is a linear relationship among these variables. Figure 3 shows, however, that the relationship is not linear but logarithmic, and that the curve differs from the curve of formula (1) at frequencies higher than 2.2GHz. This showed us that it is difficult for a microwave band to explain a breakpoint position using such a simple model as formula (1).

Therefore, the empirical formula for the breakpoint is derived from the data in Fig. 3 (urban area at mid-day).

$$\text{breakpoint} = 516\,X - 81.6 \qquad (X = \log(0.7*hb) / \log(2*\lambda)) \qquad (2)$$

The coefficient of determination of this formula is 0.98, and the standard deviation to all measured data in the urban area at mid-day is 6.3 dB.

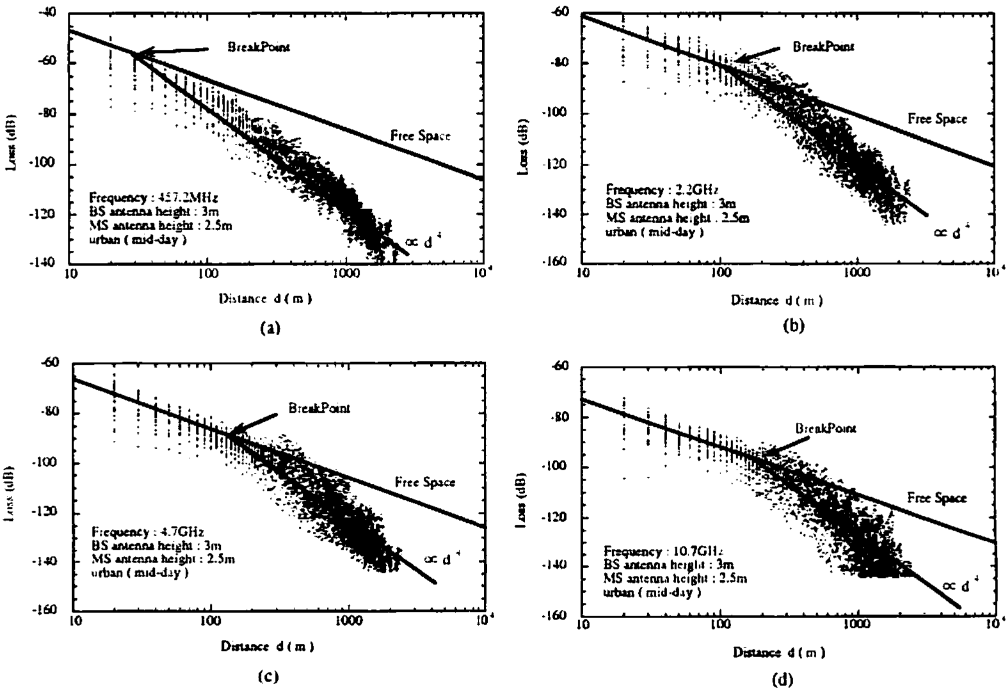
Figure 3(a) shows the frequency characteristics of break point at a low BS antenna height (3m). Different results are obtained for the three different vehicular traffic conditions (urban area at mid-day, suburban area at mid-day , and urban area at night). The heavier the vehicular traffic is, the shorter the break point is. At the middle-level BS antenna height (14m; see Fig. 3(b)), the break point becomes longer for all three conditions, but the breakpoint for the urban area at mid-day is shorter than that for either the suburban area at mid-day or the urban area at night. It was found that at the highest BS antenna height (24m; see Fig. 3(c)), nearly the same results were obtained for all three conditions, and these results appear to represent the maximum obtainable.

Because microcellular radio waves at a low BS antenna height are influenced by vehicular traffic, the distances propagating in free space loss become shorter and are different according to the vehicular traffic conditions in effect. In other cases, the higher the BS antenna height is, the longer the free space distance is and the less the vehicular traffic affects the waves. This is because the probability of the waves being negatively affected by the shadows of vehicular traffic is larger at a low BS antenna height than at a high one.

These break point distances can be used to define the size of the microcells. Microcells at a low BS antenna height can increase system capacity because their break point and frequency reuse distance are short. Because the break point varies considerably with vehicular traffic conditions, however, the *traffic margin* (variation due to traffic conditions) must be considered. This makes it difficult to increase total system capacity in a low BS microcell system. In other cases the *traffic margin* decreases at a high BS antenna height, but because the cells are longer than the low base microcells, system capacity will not increase. High base microcells also increase the quantity of interference waves propagating to non-LOS areas.

CONCLUSION

LOS path loss characteristics in microwave band were studied and found to have the same characteristics as in the UHF and lower bands frequency range. It was found, however, that the breakpoint characteristics are different, the breakpoint has a logarithmic relationship to frequency and antenna height, and the empirical formula for the breakpoint can be derived from measured data. Since the influence of vehicular traffic on the breakpoint is higher at a low than at a high BS antenna height, it is possible to minimize the influence by using a high BS antenna. Finally, it was found that the same results are obtained for areas whose building structural characteristics and general environment are the same. Further studies are required to clarify non-LOS path loss characteristics.



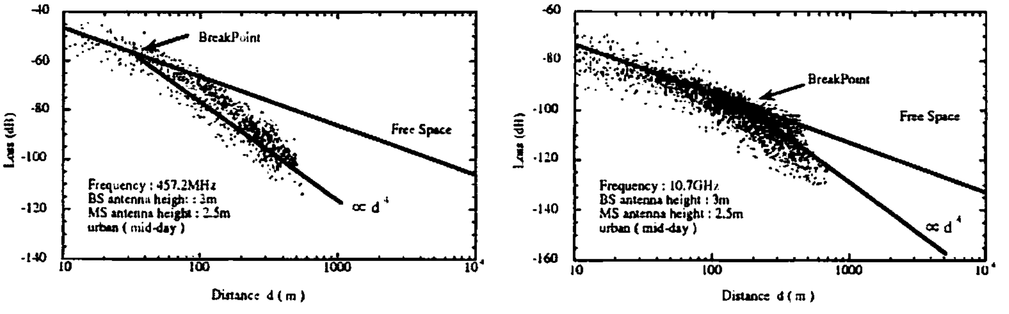
(a)

(b)

(c)

(d)

Fig. 1 LOS path loss characteristics in Sapporo



(a) (b)

Fig. 2 LOS path loss characteristics in Yokohama

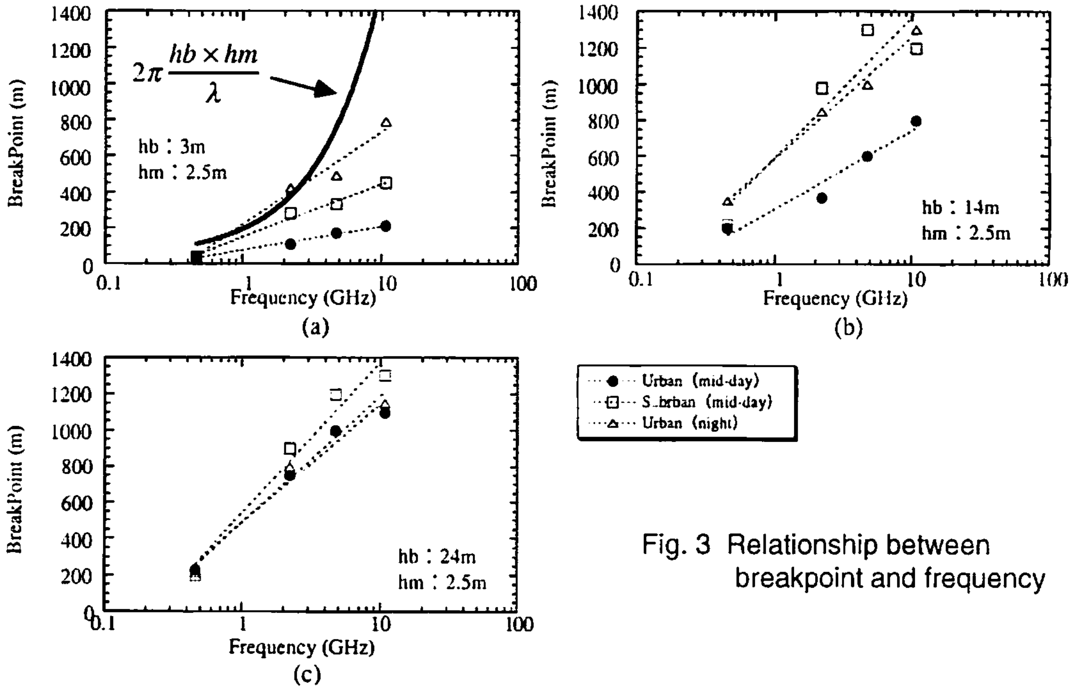


Fig. 3 Relationship between breakpoint and frequency

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