PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

MICROCELLULAR PROPAGATION CHARACTERISTICS

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To enhance the spectral efficiency and to improve service quality for cellular radio systems, a new microcellular system has been proposed [1-5] that operate over a relatively short radio path (on the order of 200 m to 1000 m), using relatively low antennas (about the same height as lamp posts), and transmitting at relatively low power (typically on the order of 10 mW). This new concept of microcells utilizes some of the special properties of radio propagation for small cells to reduce the severe multipath fading and shadow fading in the land mobile propagation environments. Over a relatively short propagation path, it is possible to arrange the radio link between the transmitter and receiver to be a clear line-of-the-sight (LOS) path, so that the microcell can operate in a Rician channel, which has significantly less multipath fading than the Rayleigh channel of conventional cellular systems. On the other hand, the relatively low antenna can be located above the local vehicular traffic but below the surrounding buildings. This benefits the microcellular systems in two ways: first, the shadow fading due to the local traffic can be eliminated; and secondly the radio signal can be confined and directed into a limited size microcell. Signal delay due to multipath reflection may cause intersymbole interference (ISI) in digital radio systems. The lower microcellular base station antenna reduces excess delay spread since the distant reflectors are blocked [6]. LOS paths are expected to play a major role in providing signal coverage for microcell systems. However, any provident cellular system design must consider not only the signal coverage, but also potential cochannel and adjacent channel interference. Unlike the conventional macrocellular systems where the mechanisms of carrier and interference signal propagation are essentially the same, e.g. propagation over buildings, the interference in a microcellular system can come from radio paths other than the LOS path used for the carrier signal.

Microcellular radio propagation measurements have recently been carried out by various researchers around the world [4-5,7]. However, most of these measurement were made at a single transmitting antenna height, a single test area and/or a single frequency, and mainly examine the LOS signal coverage along city streets. None of these measurement programs have broadly delimited radio propagation characteristic for microcellular systems in different environments, as was done for example by Okamura et. al. [8] or AT&T Bell Lab [9-10] during the development of cellular systems with elevated antennas.

A comprehensive radio propagation measurement program was conducted by Telesis Technologies Laboratory (TTL) in the San Francisco Bay area. The measurements were performed using two frequency bands, 900 MHz and 1900 MHz. Five test settings were chosen in Sherman Island, Sunset District, Mission District, Downtown Oakland, and Downtown San Francisco with extreme care to represent a variety of propagation environments. In addition, for urban and suburban areas, the receiving mobile was driven following pre-selected LOS, zig-zag and stair routes to gather information about direct propagation along streets, as well as diffraction over the roofs in suburban areas, and diffraction around the corners in urban areas. The three transmitting antenna heights of 3.2 m, 8.7 m and 13.4 m were used for each of the two measurement frequencies and at every site tested. The receiving antenna was fixed at 1.6 m, which is considered to be the natural preference of the public.

For all LOS paths, the variation of signal strength with distance was found to show distinct near and far regions. These regions are separated by a break point whose distance from the base station is equal to the maximum distance that has the first Fresnel zone clearance. This distinction serves as the basis for a two segment regression fit to the LOS measurements, where one segment applies to the signal before the break point, and the second segment to the signal beyond it. These fits are characterized by a slope that is less than two before the break point, while it is greater than two after the break point.

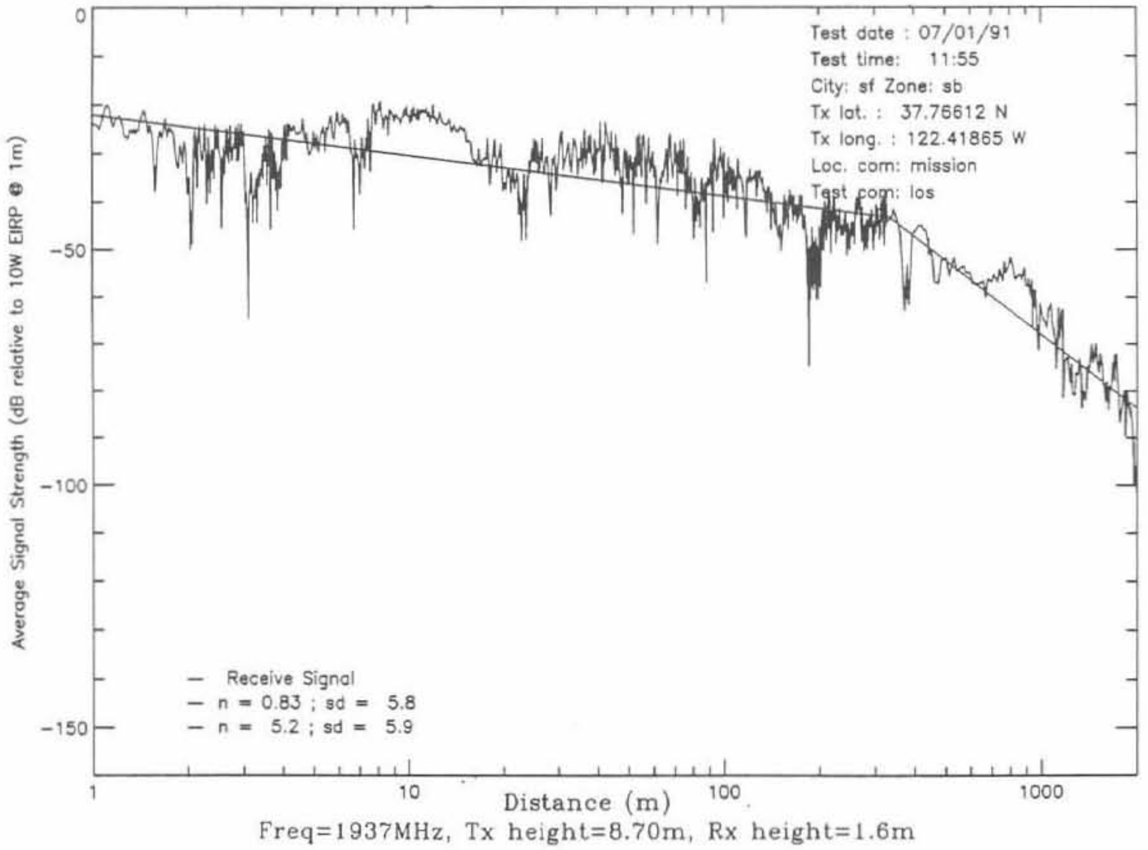

Fig. 1. Received Signal Strength along a LOS path in the Mission District.

Figure 1 shows an example of the normalized average signal strength on a LOS path in Mission Street for an antenna height of 8.7 m and a frequency of 1937 MHz. The two-segment regression lines are also shown. The break point based on Fresnel zone theory does split the average signal curve into two regions with distinct physical characteristics. The slope index n is close to 1 for the near-in segment, and increases substantially for the segment beyond the break point. The break distance can be used to define the size of the microcell and to design for fast hand-off. No significant path loss is experienced within the cell, so that a low transmitter power can be employed. Yet, outside the cell, the radio signal attenuates more rapidly due to the high slope index. This results in a natural radio propagation "wall", which tends to cause very limited interference to adjacent cells.

For non-LOS paths, radio path loss is found to be significantly higher than for LOS paths. As an example, the average signal strength obtained along a zig-zag route in the Sunset District (normalized to that for isotropic antennas separated by 1 m in free space) is shown in Figure 2 for antenna height of 8.7 m and a frequency of 1937 MHz. Data for measurements made mid-block on route segments that are essentially perpendicular to the propagation path (transverse streets) are associated with the low values of signal and are shown by solid lines, while data for route segments that are essentially parallel to the propagation path (lateral streets) are associated with the high signal values and are shown by dash lines. The horizontal axis represents distance traveled by the mobile van.

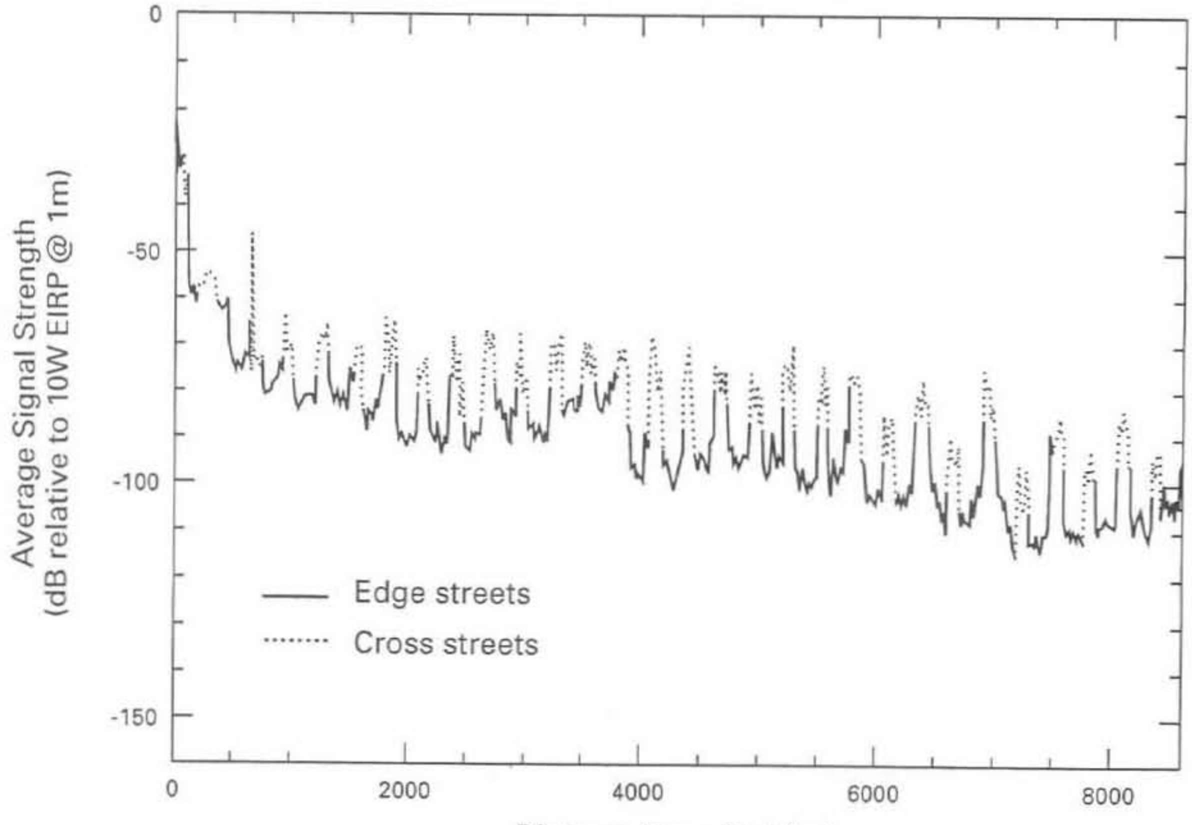

Fig. 2. Received Signal Strength along a zig-zag path in the Sunset District.

Some interesting observations can be immediately obtained from Figure 2. First, the radio signal drops suddenly as much as 30 dB once the receiving van turns a street corner. As expected throughout the whole test run, the radio signal level of the lateral zig-zag segments is always above that of the transverse zig-zag segments (about 25 dB).

Regression analysis has been performed for the results of the LOS, staircase and zig-zag routes for all frequencies and antenna heights in different environments. While the LOS path loss in urban and suburban areas is essentially the same as that in rural areas, which can be described by the two segments regression, the non-LOS path loss is significantly modified by the environments. This difference in radio path loss results in different cell pattern for different environments. In an open rural area, a circular cell can be achieved. In contrast, a linear cell is contained by the buildings along both sides of the street in an urban environment, with only limited interference to the neighboring streets. In a suburban area with low houses, the cell pattern may be an ellipse with the longest axis oriented along the LOS paths.

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