Outdoor/Indoor Propagation Experiment for Estimation of Interference Level Caused by Terrestrial Mobile Terminal in Satellite/Terrestrial Integrated Mobile Communication System

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1. Introduction

Satellite/Terrestrial Integrated Mobile Communication System (STICS) has been proposed and studied [1]. The expected STICS system possesses integrated terrestrial and satellite mobile communication services and provides proper service to terrestrial/satellite system shared terminals depending on the terminal's location and traffic state. To realize high spectral efficiency in STICS, a condition to share same frequency band between terrestrial and satellite link has been studied including estimation of interference level between terrestrial and satellite system. One possible interference path is terrestrial system uplink interfering to satellite uplink (interference sources are terrestrial mobile terminals, and interfered station is satellite). The important point in estimating the interference level generated by terrestrial mobile terminals is that the interference level varies depending on the usage condition of the terrestrial mobile terminals. This is because the propagation loss in ground-to-satellite interference path differs depending on the propagation state (LOS/NLOS). Moreover, if conventional IMT-2000 system is considered as a terrestrial service, interference level also varies by the change of transmit signal power of mobile terminal caused by transmit power control (TPC). Past studies on ground-to-satellite propagation only focus on the propagation loss in ground-to-satellite channel [2,3].

This paper describes outdoor/indoor propagation experiment to estimate the interference level in STICS. To mimic STICS situation, a mobile station (MS) equipped with the IMT-2000 cellular phone (as a terrestrial mobile terminal in STICS) is located at the outdoor/indoor environments and a pseudo satellite (PS, as a STICS satellite) is located on top of a tower. Both the transmit signal power (TX power) at the MS controlled under TPC and the received signal power (RX power) at the PS are measured simultaneously. The TX power, the RX power, and the derived propagation loss between the MS and the PS are analyzed for outdoor and indoor environments.

2. Experimental System

The experiment was carried out on December 2009 in the site of NICT headquarter in Koganei, Tokyo Japan. Figure 1 illustrates the outline of the experimental system. An MS equipped with IMT-2000 cellular phone is located at outdoor/indoor measurement point. A transmit signal from the cellular phone is divided by a coupler into two signals, one of which is radiated from the external dipole antenna and the other is measured at the spectrum analyzer. A PS is located on top of the 50-m tower with horizontal distance toward the MS of 50m-100m. A high gain (19dBi) directive antenna is utilized to the PS to compensate low signal level. Therefore, in every measurement the antenna is pointed at the direction of maximum RX power. The TX power at the MS and the RX power at the PS are measured simultaneously while the MS moves 15m (~100λ) at maximum distance to measure short-term variations of the signal. In every measurement, operators at the MS and the PS identify the channel of the signal transmitted from the cellular phone in the MS by observing the spectrums in the spectrum analyzers. While measurement the operators also checks if signals from other mobile users are not observed at the channel. After the measurement, the propagation loss for each measurement point is derived by using the TX/RX power, and the calibration values of the experimental system (e.g. TX and RX antenna gain, cable loss, amplifier gain, etc.). Figure 2 shows eighteen measurement points in the experimental site. The site consists of concrete office buildings with average height of 12m (maximum 21m). Eleven outdoor points and seven indoor points are selected. The base station (BS) near the site is located 0.7-0.9km apart from measurement points. For each point three repetitive measurements are carried out to check the repeatability of the measurement. The deviations of median value of TX/RX power for all eighteen points are 2.2dBrms and 2.4dBrms respectively. Table 1 lists the measurement conditions.

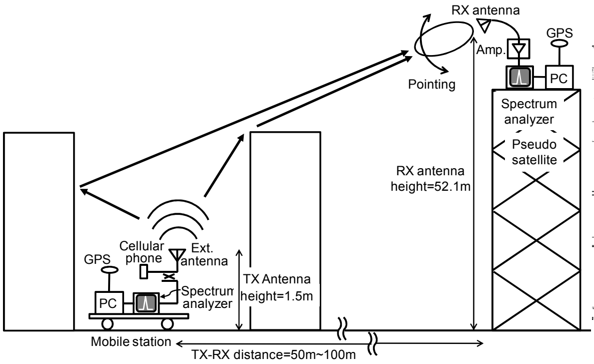

Figure 1: Outline of Experimental System

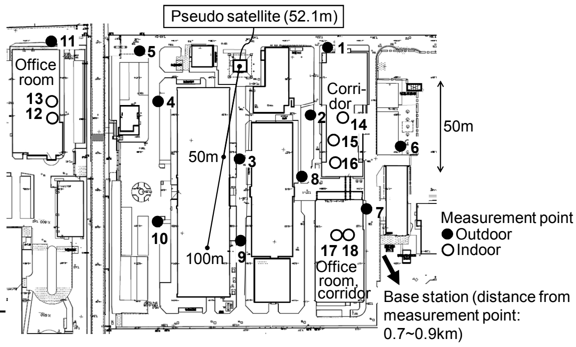

Figure 2: Measurement Points in Experimental Site

Table 1: Measurement Conditions

Item		Condition
Mobile station (TX)	Antenna height	1.5m
	Antenna type	Dipole as external antenna
	Polarization	Linear (V)
	Gain	2dBi
	Half-power Beamwidth	(Omni in horizontal plane)
Pseudo satellite (RX)	Antenna height	52.1m
	Antenna type	Parabola
	Polarization	LHCP
	Gain	19dBi
	Half-power Beamwidth	10deg
TX-RX distance in horizontal plane		50m~100m
Elevation angle		27deg~46deg
Frequency		IMT-2000 Cellular phone 2GHz-band uplink frequency
Resolution bandwidth		3MHz (TX), 1MHz (RX)

3. Results

3.1 Received Signal Power at Pseudo Satellite and Transmit Signal Power of Cellular Phone with Outdoor/Indoor Cellular Phone Locations

Figure 3 shows the RX power at the PS for all measurement points. Variations of the signal power are observed (27dB in outdoor, 16dB in indoor). Note that the measurable RX power in this experimental system is more than the noise floor of -106dBm/MHz, and that the variations is potentially larger than the measured if more sensitive measurement is possible. The RX power in each outdoor measurement is composed of TX power and propagation loss. From next subsection TX power and propagation loss are separately analyzed since these parameters independently vary depending on the propagation environment between base station and the MS, and the environment between the PS and the MS, respectively. Propagation losses in the indoor measurements is composed of the attenuation caused by indoor-to-outdoor wave transmission and the attenuation caused by obstacles in outdoor toward the PS. Therefore, to simplify the problem, the attenuation caused by the indoor-to-outdoor wave transmission is analyzed by using measured data at point 12 and 13, where the PS is line-of-site from the room window.

Figure 4 shows the TX power of the cellular phone for all measurement points. Variation of TX power controlled under TPC is observed. The average TX power in indoor points (-

11.6dBm/5MHz) is 6dB higher than the average TX power in outdoor points (-17.6dBm/5MHz). The point with minimum power in outdoor (point 7) is nearest point to the BS and there are fewer obstacles between the MS and the BS than the other points. The point with maximum power in outdoor (point 11) is non-line-of-site for the BS (blocking caused by building). The point with minimum power in indoor (point 17) is the corridor with windows at both sides. The point with maximum power in indoor (point 18) is the office room inside the building with no window. From these observations the signal variation property agrees with the propagation environment between the MS and the BS. The TX power ranges from -26.2 to -5.5dBm/5MHz, which indicates that the TX power range in this measurement is in the middle of the dynamic range for IMT-2000 cellular phone (80dB with maximum power of +24dBm [4]).

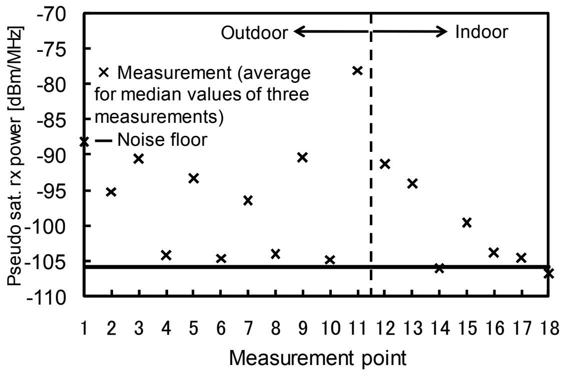

Figure 3: Received Signal Power at Pseudo Satellite

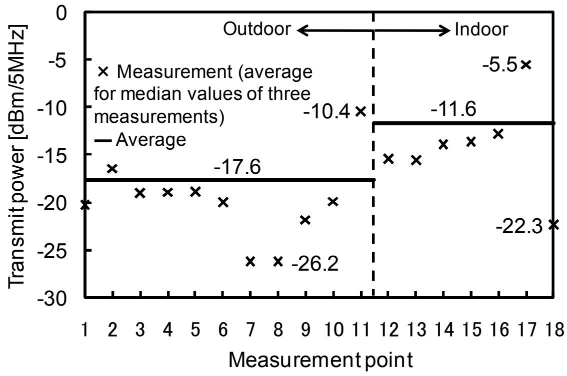

Figure 4: Transmit Signal Power of Cellular Phone

3.2 Analysis of Outdoor Experiment

Figure 5 shows the propagation loss in outdoor environment calibrated by the free space loss. Eleven measurement points are classified by the propagation environment. The figure indicates that the losses in line-of-site environments agree with the free space loss (especially losses in points 1 and 11 agree well where there is no high building between the MS and the PS). The loss in non-line-of-site environment ranges from 8dB to 18dB, which is caused by trees or buildings. The losses in points 4 and 10 agree with calculated diffraction losses where median value in point 4 is 16.4dB in measurement, 18.2dB in calculation, median value in point 10 is 17.9dB in measurement, and 20.9dB in calculation. Figure 6 shows the measured propagation loss and calculated diffraction loss in point 10. These results indicate that the experimental system works properly.

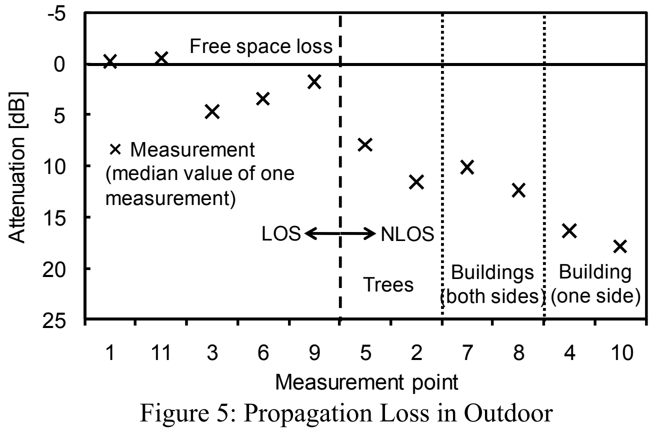

Figure 5: Propagation Loss in Outdoor

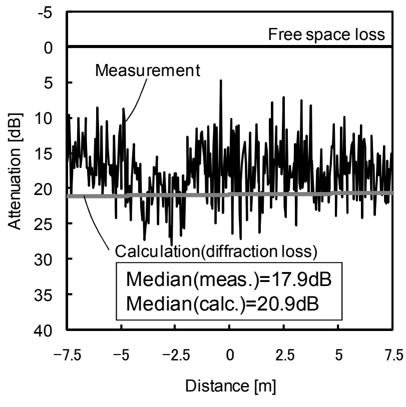

Figure 6: Propagation Loss in Point 10

3.3 Analysis of Indoor Experiment

As shown in Figure 7, the indoor experiments for point 12 and 13 are carried out in the office room (8.1m×11.7m) in the 1st floor of the building with a window from which the BS and the PS is line-of-site. The MS is moved from 1m to 9m from the window. Figure 8 shows the TX power at the MS and the RX power at the PS as a function of position of the MS from the window. The figure indicates that the RX power at the PS decreases as the MS is apart from the window. On the other hand, the TX power does not change drastically. These results can be explained by the propagation environment for the point 12 and 13 (i.e. the PS is non-line-of-site at the inside of the room because of high elevation angle toward the PS (29°) while the BS is line-of-site even at the inside of the room because of low elevation angle). Figure 9 shows the 1-m step median of the RX power as a function of distance from the window. The maximum attenuation of the transmitted wave between 1m and 9m is 13dB, 7dB, and 8dB for point 12 (three repetitive measurements), point 13 (three repetitive measurements), and all six measurements respectively.

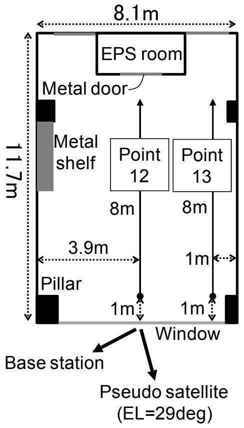

Figure 7: Points 12 and 13 for Indoor Experiment

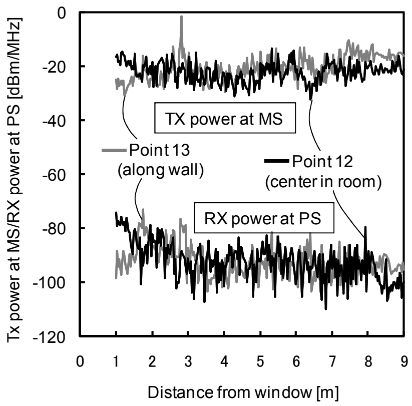

Figure 8: TX/RX Powers as a Function of Distance from Window

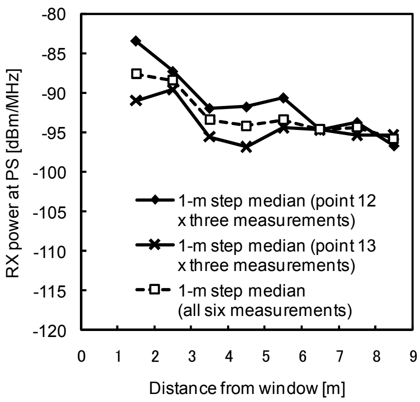

Figure 9: Median of RX Power as a Function of Distance from Window

4. Conclusions

A propagation experiment has been carried out in outdoor/indoor environment in office building site to measure TX power of cellular phone and RX power at the PS. The average TX power in indoor measurement points is 6dB higher than the average TX power in outdoor points. In the outdoor experiment, measured propagation losses in line-of-site environment and that in part of non-line-of-site environment agree with calculated losses. This result indicates that the experimental system works properly. In the indoor experiment, the RX power at the PS decreases as the MS moves inside the room (attenuation between 1m and 9m from the window is 8dB for all six measurements). These results are useful in deterministic estimation of the interference level in satellite uplink caused by terrestrial mobile terminals in STICS (e.g. estimation of worst case interference level).

Further measurement with increased number of measurement points is needed to estimate the interference level statistically. Dynamic range enhancement of received signal power at the PS to improve the measurement accuracy (especially in measuring heavy attenuation) is a future work.

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