Southwestern Bell
Technology Resources

September 19, 1994

Mr. Richard M. Smith
Chief - Office of Engineering and Technology
Federal Communications Commission
2025 M Street, NW
Washington, DC 20554

Re: Southwestern Bell Technology Resources, Inc.
Call Sign KM2XBI
File Number: 3037-EX-PL-92
Quarterly Progress Report Number Nine

Dear Mr. Smith:

In accordance with the Federal Rules and Regulations Part 5, Section 5.204(b), attached please find the ninth quarterly progress report for Southwestern Bell Technology Resources, Inc. in connection with our personal/wireless communications testbed in St. Louis, Missouri.

The main objective in our St. Louis testbed is to verify performance of the emerging wireless communications systems and technologies prior to integration into one of Southwestern Bell Corporation's business units. Attached we are reporting our progress and test results in the area of wireless local loop.

Please direct any inquiries to me at 314-529-7567.

Sincerely,

John A. Moore

John A. Moore
Director, Wireless Communications

Attachment

FCC Quarterly Progress Report Number Nine (9) in Connection with Personal/Wireless Communications Testbeds in St. Louis, Missouri

Conducted by Southwestern Bell Technology Resources, Inc.

September 19, 1994

Authorized by FCC Experimental License
Call Sign KM2XBI, File Number 3037-EX-PL-92

1.0 Introduction

This report describes progress in the Wireless Local Loop experimental testbed during the period from June 17, 1994 through September 19, 1994. The propagation testing reported here was conducted in St. Louis, Mo., under the experimental license granted to Southwestern Bell Technology Resources, Inc. (TRI) .

2.0 Wireless Local Loop Progress

This section of the report will describe studies performed in support of the Wireless Local Loop (WLL) program at Southwestern Bell. In September, a technical testbed will be deployed in west St. Louis County wherein 25 Southwestern Bell Telephone Company (SWBT) employees will begin receiving telephone service via a low power radio system based on the Bellcore-specified Wireless Access Communications System (WACS)[1]. In order to better understand the testbed environment, and thus the environment in which such a system will eventually be deployed, we conducted a study on the propagation effects of foliage at 2 GHz in the suburban residential environment. This section of the report will detail the initial results of this study.

2.1 The Testbed Environment

These test was conducted in west St. Louis County. A map of the testbed area is shown in Figure 2.1-1 below.

In the figure, the triangles represent radio port locations, the nominal radio coverage of the wireless local loop system is shown for each radio port, and the dots represent potential test participants.

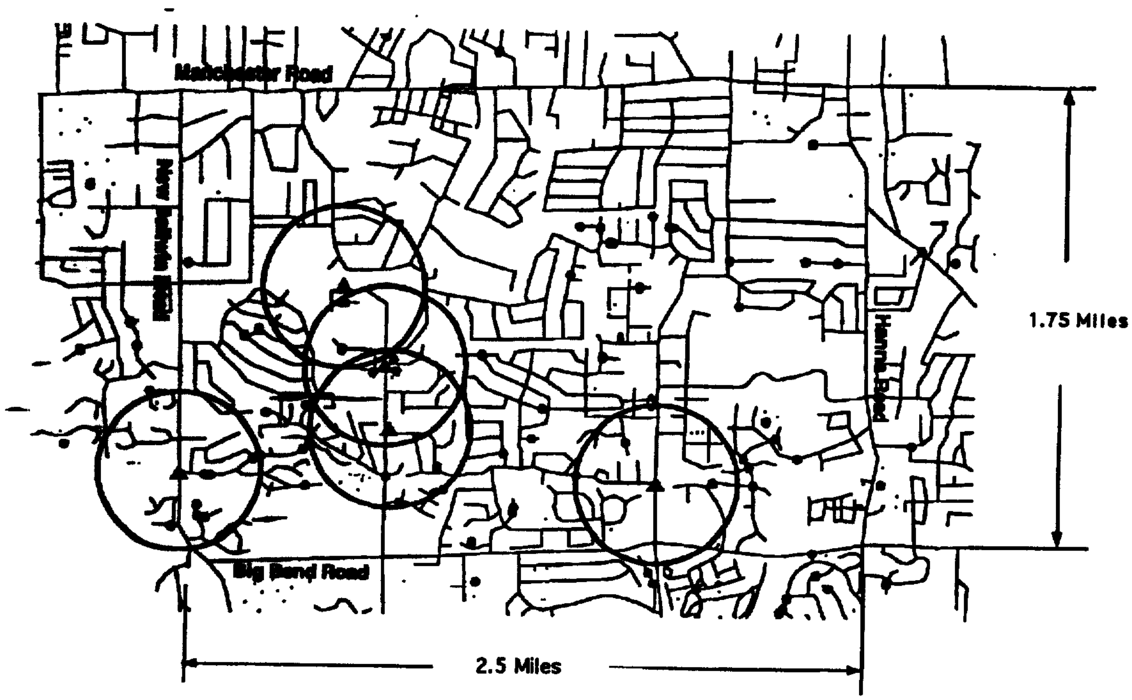

Figure 2.1-1 Testbed location with radio port sites and coverage

The testbed is an open residential area populated with typical one and two story homes, apartment buildings, small shopping complexes, schools, and churches. Few buildings exceed three stories. The area is typified by rolling hills, with some areas having rather abrupt elevation variations. Large trees are scattered throughout the test bed, and some areas are heavily wooded. The homes are typically of frame construction with decorative brick, and/or composition or vinyl siding. The telephone and/or electric plant in most of the testbed is aerial; the radio ports will be mounted on the utility poles at heights ranging from 4.6 to 6.0 meters (15 to 20 feet) above the ground. Although the selected radio port sites are placed at elevated terrain locations, the direct propagation path between the radio port and the test site was typically obstructed by trees, a hillside, and/or other homes. Under these conditions, excess path loss will be dominated by shadowing induced by terrain, foliage, and human made obstructions.

2.2 Foliage Effects Study

The purpose of this study is to understand and characterize the effects that foliage has on the propagation of radio signals at 2 GHz in the suburban residential environment. Unlike macrocellular deployments, in this application, not only are the subscriber radios down in the foliage, but so is the radio port (base station). Thus, the RF path through the foliage can be quite long.

The first phase of this test was conducted before leaves began to appear on the trees; the second phase was conducted this summer where identical tests were run with full foliage. The path loss values were compared between these two measurement cycles to determine the impact that foliage has on signal attenuation. This study was conducted as a collaborative effort between TRI and Motorola.

The measurement system consisted of a van with GPS reference equipment and transmitting equipment(herein referred to as the fixed equipment), and a portable cart with a receiver system, differential GPS equipment and a PC for data recording (referred to as the portable equipment).

Specifically, the fixed equipment consisted of:

- an RF signal generator operating at 1947.5 MHz,
- an RF amplifier,
- a 3 dBd transmit antenna ,
- a differential GPS reference station, and
- a UHF data modem.

The portable equipment consisted of :

- an RF receiver operating at 1947.5 MHz,
- a 0 dBi receive antenna,
- a differential GPS mobile station,
- a UHF data modem, and
- a laptop computer acting as a controller and data logging device.

The portable measurement receiver system was calibrated in the lab prior to field measurements by injecting a - 40 dBm signal at 1947.5 MHz through a step attenuator into the base of the receive antenna and then recording the signal strength samples at 2 dB and 3 dB steps as the power was decreased to -130 dBm. The calibration procedure was performed under software control and resulted in a calibration table which was used in the data collection process.

The transmitter (signal generator/RF amplifier) was adjusted to provide +23 dBm into the base of the transmit antenna at a frequency of 1947.5 MHz, and the transmit antenna was raised on a mast to a height of 5.5 meters (18 feet) above the ground. The antenna for the GPS reference station was placed on a fixed, identifiable landmark (e.g. a street sign) for repeatability. The correction data from the GPS reference receiver was transmitted via a UHF data modem for use by the receiver system. A picture of the typical transmitter site configuration is shown in Figure 2.2-1.

Figure 2.2-1 Transmit site equipment van and mast

A differential GPS system was used to obtain accurate position data for the measurements. The GPS receivers and associated UHF data modems allow the location subsystem to operate in the differential mode, providing 3 foot RMS location accuracy by eliminating the error due to Selective Availability. The differential correction signal is sent, using the RTCM SC-104 format, at a one second update rate.

The signal strength data was collected by moving the measurement cart at a nearly constant speed along sidewalks in the residential testbed area. During measurement, the receiver takes Received Signal Strength (RSS) measurements every 9 milliseconds (msec) and averages these samples over a 150 msec window. The averaged RSS data, along with corrected differential GPS information was recorded in the laptop PC once per second. In addition, markers were inserted in the data at specific, identifiable, and repeatable locations for future comparison. These locations typically included street intersections and home locations. The data was stored for later post processing. The receiver system is shown in Figure 2.2-2.

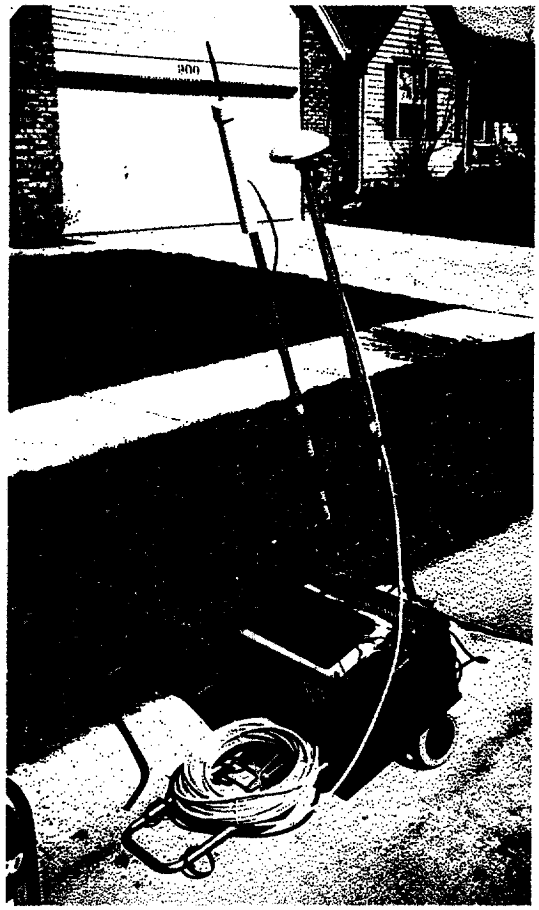

Figure 2.2-2 Portable receiver and data logging system

In our last quarterly report, a sample of the processed output for one measurement route with no foliage was shown. The measurements were repeated this summer under full foliage conditions, and the results were compared to the winter measurements. This allowed us to characterize the effects of foliage on the 2 GHz RF signal in this type of environment. The coverage was significantly reduced. However, most locations within a 1000 ft radius of the transmitter would still have sufficient signal strength to provide service.

The scatter plots of received signal strength vs range for the measurement route shown in the figures above are given in Figures 2.2-5 and 2.2-6 for winter and summer, respectively.

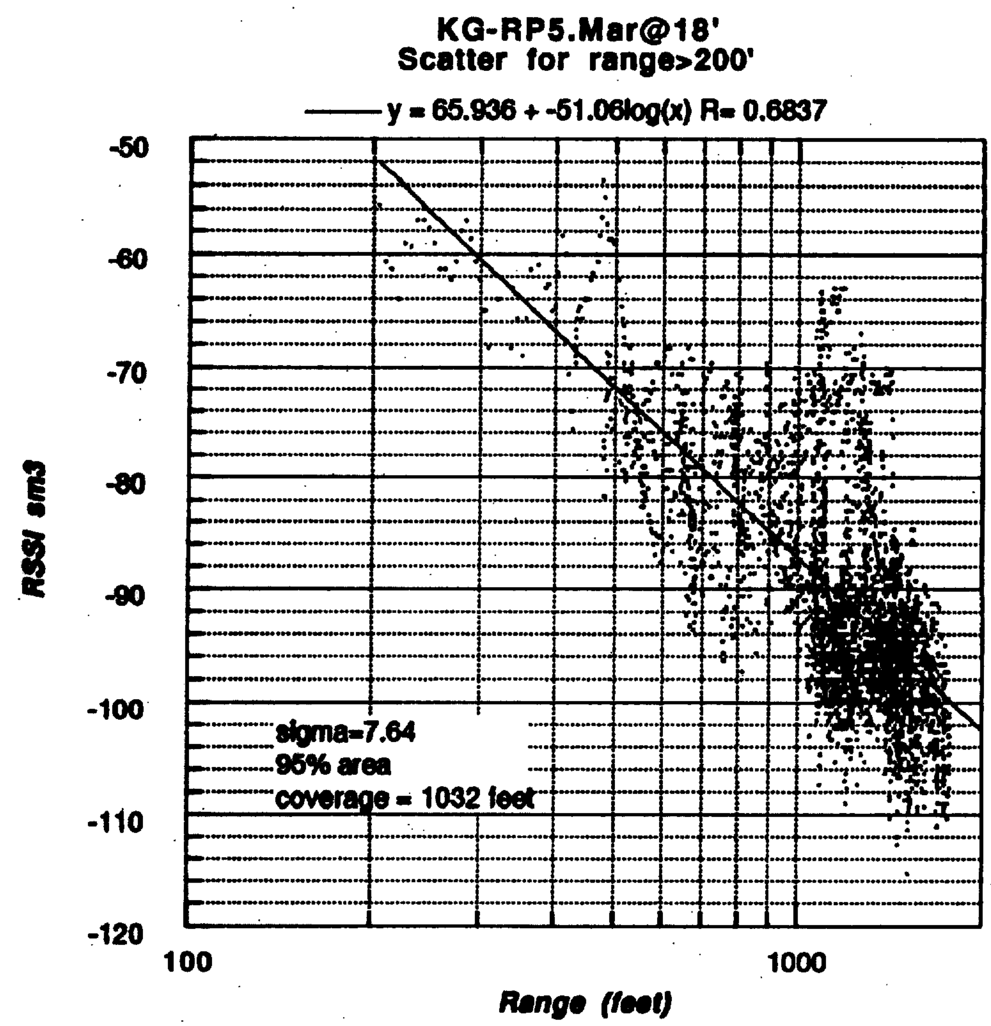

Figure 2.2-5 Signal strength vs. range, no foliage

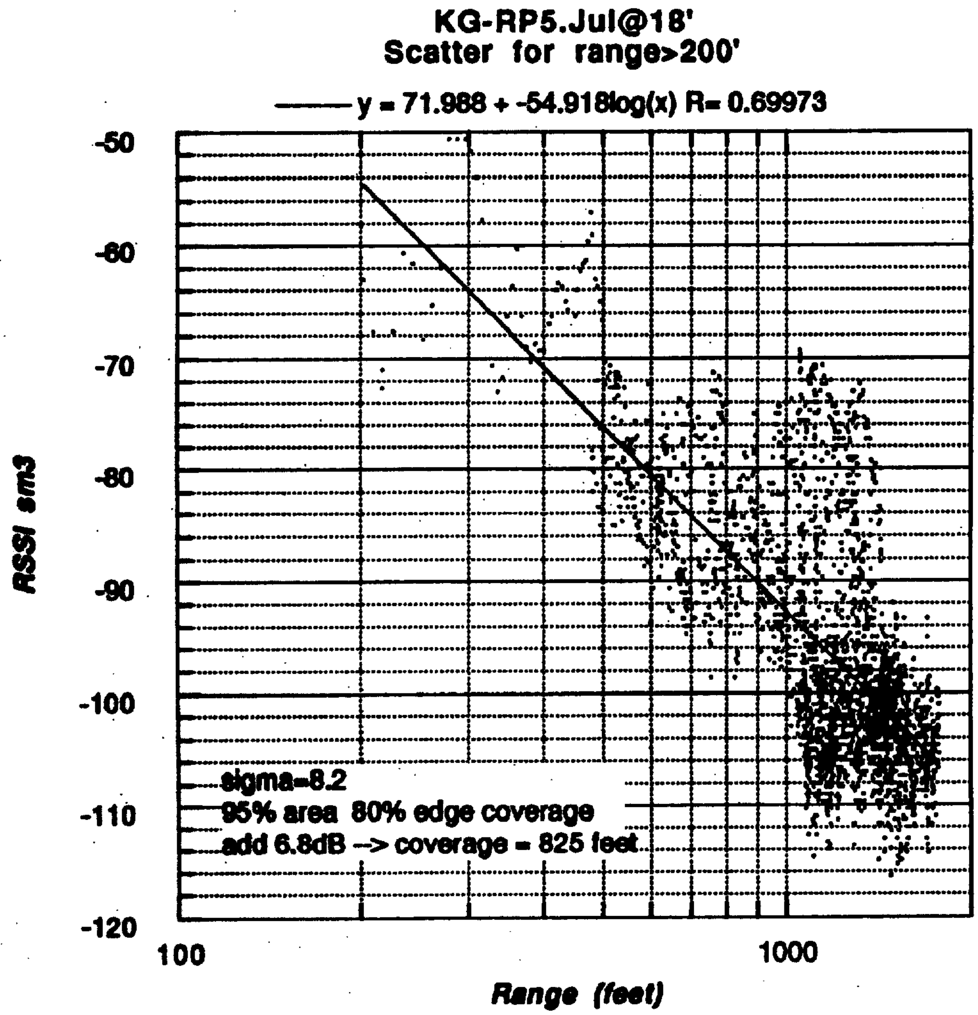

Figure 2.2-6 Signal strength vs. range, full foliage

The distance exponent of propagation was approximately 5 in each case (slightly larger for the foliage case), and the intercept values were different by about 6 dB. This difference was confirmed in direct comparisons of the data along the route. The analysis of the propagation data is not complete, three other routes were measured. The results presented in this report represent a fairly small sample set, and should be used with caution. The results including all data will be presented in the next progress report.

The data for this measurement path were sorted and analyzed by range from the transmitter. The plots shown in Figures 2.2-7 and 2.2-8 show the probability density functions for signal strength vs. percent of samples below the given signal strength. Each plot shows curves for various transmission ranges. Comparing the curves for the 1000 ft. separation shows approximately 5-6 dB loss of signal due to foliage. This data is also useful from the point of view of deployment. For a given grade of service goal, and system link budget, the maximum cell size may be determined. Once again, the limited amount of data processed to this point means that these results provide interesting information, but must be used with care. Further information will be made available in the next quarterly report.

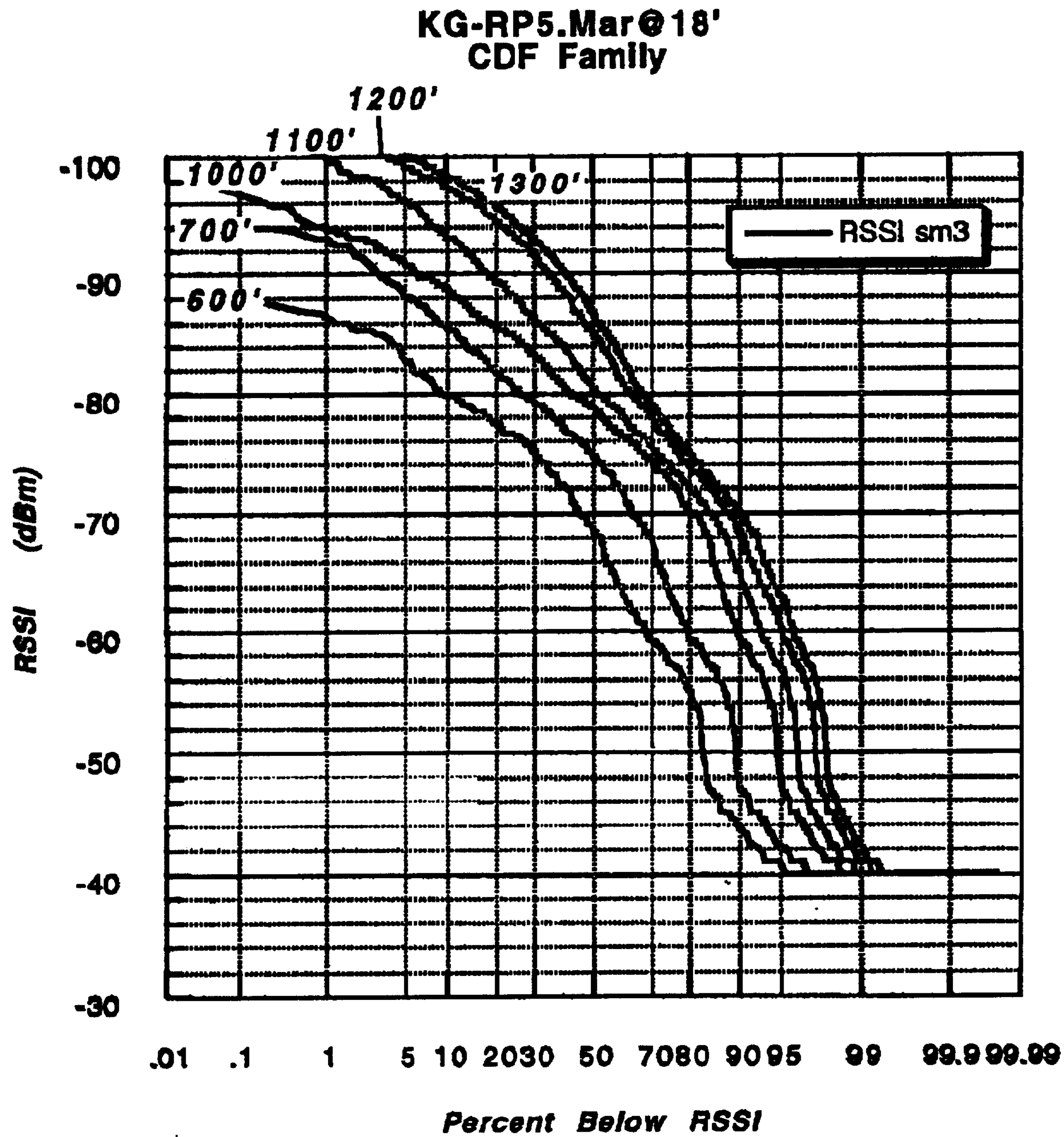

Figure 2.2-7 CDF of RSS at different ranges with no foliage

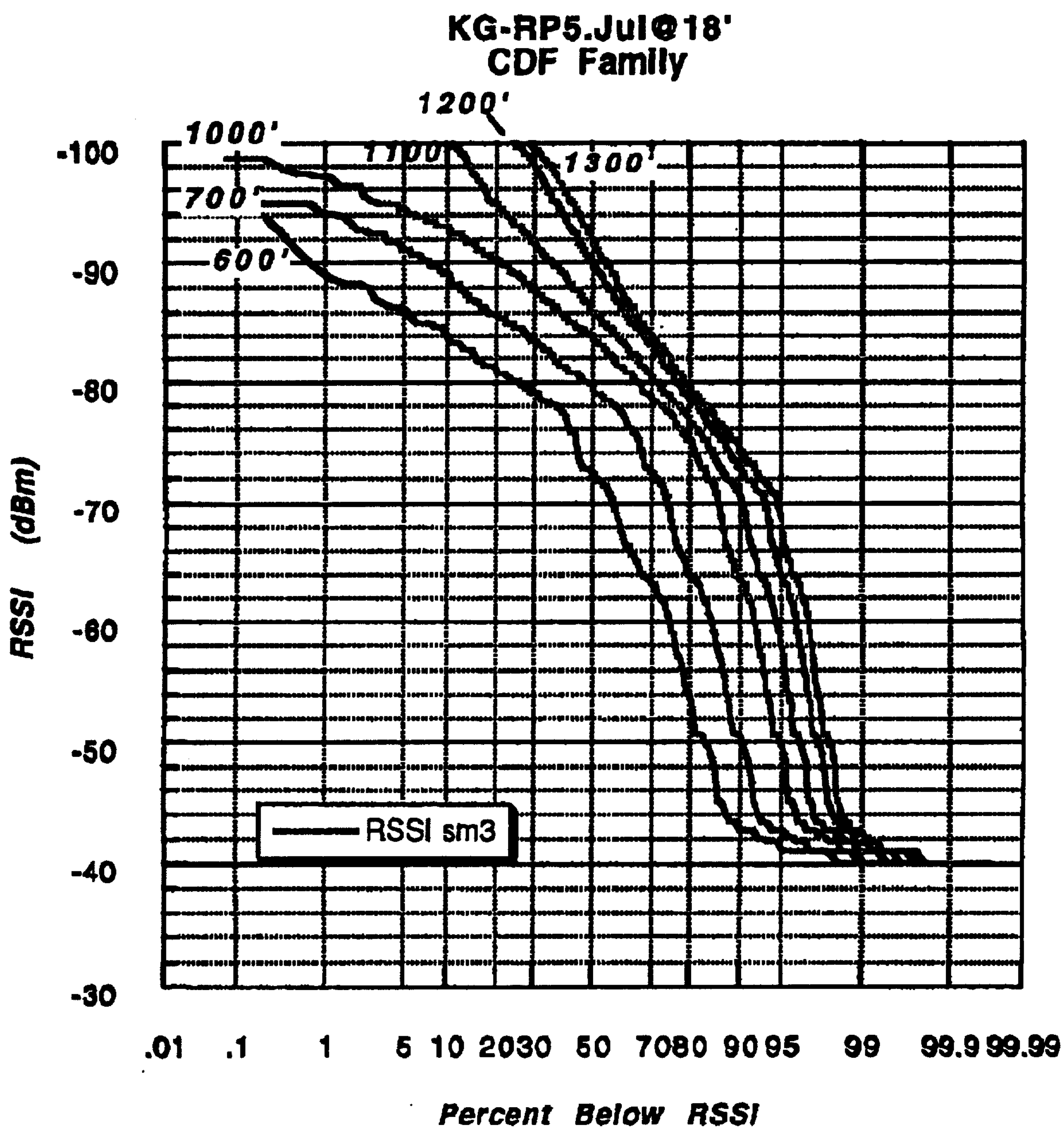

Figure 2.2-8 CDF of RSS at different ranges with foliage

Figure 2.2-9 shows a plot of the foliage effect in the range from 500 to 1000 feet.

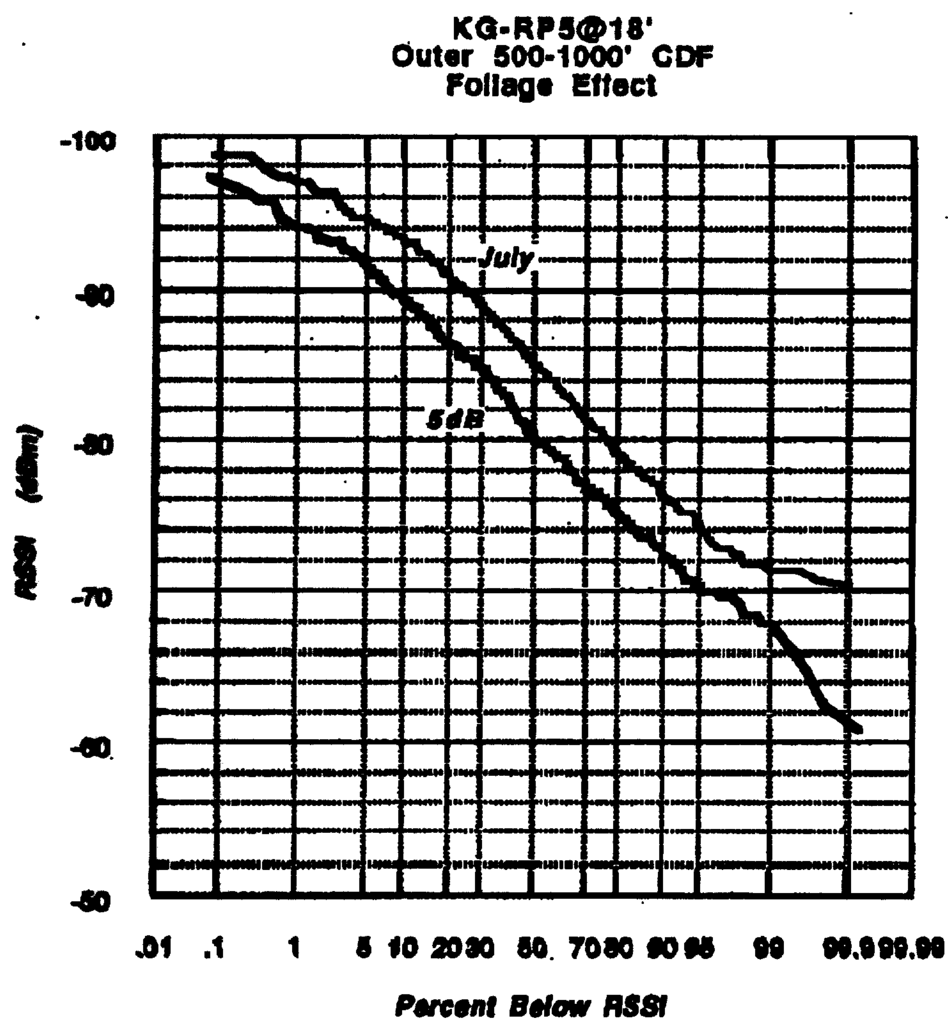

Figure 2.2-9 Foliage effects in the range of 500 to 1000 feet.

In addition to the measurements at 18 feet, we also made a series of measurements at each location with the antenna at 36 feet. The CDF of RSS vs. percent below RSS is shown in figure 2.2-10. As can be seen from the figure, the improvement in signal strength is about 3.5 dB relative to the 18 foot measurement for route 5. This compares with a theoretical difference of 6 dB. This is a preliminary result with the received signal data points not perfectly aligned between the two runs. In addition, the small number of data points may have influenced the result. Further information will be provided in the next quarterly progress report.

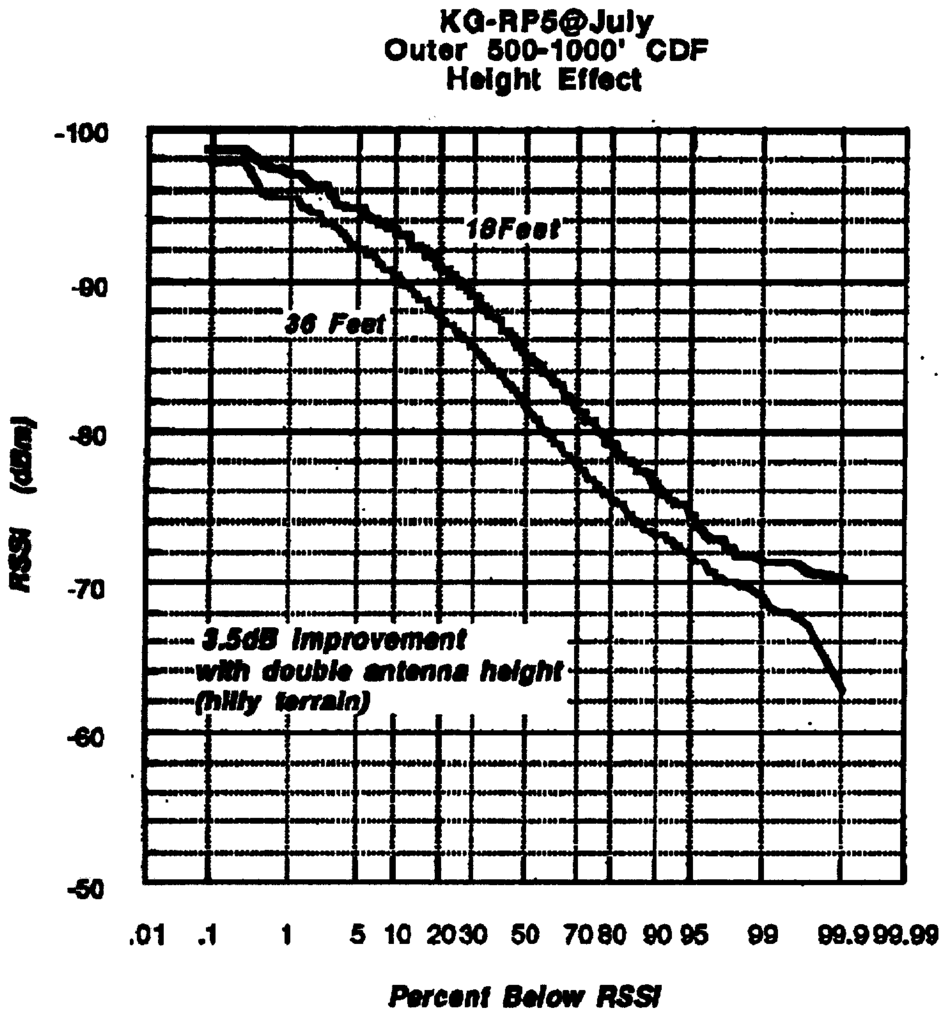

Figure 2.2-10 Antenna height effects, 18 vs. 36 feet, full foliage

2.3 Summary

This quarterly report on FCC experimental license 3037-EX-PL-92 has presented some preliminary results of a study on the effects of foliage on propagation at 2 GHz. Initial results indicate that the foliage induces a 5-6 dB loss in signal power. It was also found that doubling the antenna height from 18 to 36 ft increased signal power by 3.5 dB. The amount of data analyzed to this point has been rather small, further results will be presented in the next quarterly progress report.