Southwestern Bell
Technology Resources

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March 18, 1994

Dr. Thomas P. Stanley, Chief Engineer
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 Seven

Dear Dr. Stanley:

In accordance with the Federal Rules and Regulations Part 5, Section 5.204(b), attached please find the seventh 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 personal communications systems.

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

Sincerely,

John A. Moore
Director, Wireless Communications

Attachment

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FCC Quarterly Progress Report Number Seven (7) in Connection with Personal/Wireless Communications Testbeds in St. Louis, Missouri

Conducted by Southwestern Bell Technology Resources, Inc.

March 18, 1994

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

1.0 Introduction

The following report summarizes the results of tests and progress in the Wireless Local Loop experiment.

The tests reported here were conducted in and around Southwestern Bell Technology Resources' facilities in St. Louis, MO, under the experimental license granted to Southwestern Bell Technology Resources, Inc. (TRI). For further information on SBC's view of PCS/PCN, and background on Wireless Local Loop and PBX/Centrex, please consult our first quarterly report filed with the FCC on September 19,1992.

2.0 Wireless Local Loop Progress

This section describes an initial propagation study performed by TRI in support of wireless local loop equipment deployment in the West St. Louis County test bed. As such, it was necessary to keep the study appropriately focused to ensure that the specific testbed objectives could be met. A more extensive propagation study, which will characterize 2.1 GHz propagation in residential microcell environments (e.g., system deployments using rather low antenna heights and radiated power levels below 1 Watt) is currently being conducted. Results of this study will appear in future FCC Quarterly Report filings.

2.1 Study Overview

Since the last progress report, TRI has conducted an initial 2.1 GHz propagation study in and around the West St. Louis County Wireless Local Loop test bed. The purpose of the study was to the verify the radio port placement strategy for the upcoming deployment of wireless local loop equipment within the test bed. Verification of the radio port placement strategy was provided by a series of narrow band propagation measurements collected at participant sites (dwellings). For the measurements, a fixed frequency source was situated at each planned radio port location and received signal strength data was recorded in areas around each participant site. Using the processed signal strength data, and the known characteristics of the radiated signal, median path loss values were computed. These path loss values were compared against the RF link budget requirements (e.g., maximum allowable path loss) for the wireless local loop radio equipment to determine if a particular residence could be served by the radio port in question. A final set of five radio port locations was selected from the comparison results.

The propagation study was necessitated by the particular testbed requirements and restrictions. For the equipment testing, it is desirable to have different loading characteristics on each radio port so best-server, call blocking, and call handoff can be tested. It is also desirable to have sufficient separation between at least two of the five radio ports for co-channel interference tests. Providing adequate service to a specific set of testbed participants, scattered throughout the testbed, complicated the radio port strategy; field measurements was the best method to ensure that all test objectives could be met. A commercial wireless local loop deployment should not require field measurements.

2.2 Measurement System

The radio port transmitter consisted of a synthesized signal generator and Low Noise Amplifier (LNA). A vertically polarized 2.1 GHz omnidirectional antenna with 3.0 dBi gain was mounted on a portable antenna mast and raised to approximately twenty feet above local terrain. A low loss coaxial cable was used to connect the LNA to the antenna. The transmitter had nominal Effective Isotropic Radiated Power (EIRP) of +30 dBm. The signal generator synthesized an unmodulated carrier (CW tone) at a frequency of 2147.6 MHz. The specific test frequency was selected based on a frequency coordination study performed by TRI. The results of this study were reported in Quarterly Report #6. Conditioned AC power was supplied to the transmitter by a portable AC generator and uninterruptible power supply.

The receiver system was based on the spectrum measurement system described in previous Quarterly Reports to the FCC. However, the system was re-configured for narrow band measurements. A diagram of the modified receiver system is provided in Figure 2.2-1. The heart of the measurement system is a spectrum analyzer controlled by a portable computer. A cascade of two LNAs placed in the path from the receive antennas to the spectrum analyzer serve to increase system sensitivity. A computer controllable variable attenuator separates the two LNAs, providing automatic attenuation in the presence of strong signals to increase the dynamic range of the measurement system. A vertically polarized omnidirectional antenna, identical to the transmitter antenna, was used with the measurement receiver. All measurement data was stored in the PC, along with location information collected by a Global Positioning System (GPS) receiver, not shown in the diagram. An uninterruptible power supply provided conditioned AC power to the receiver components.

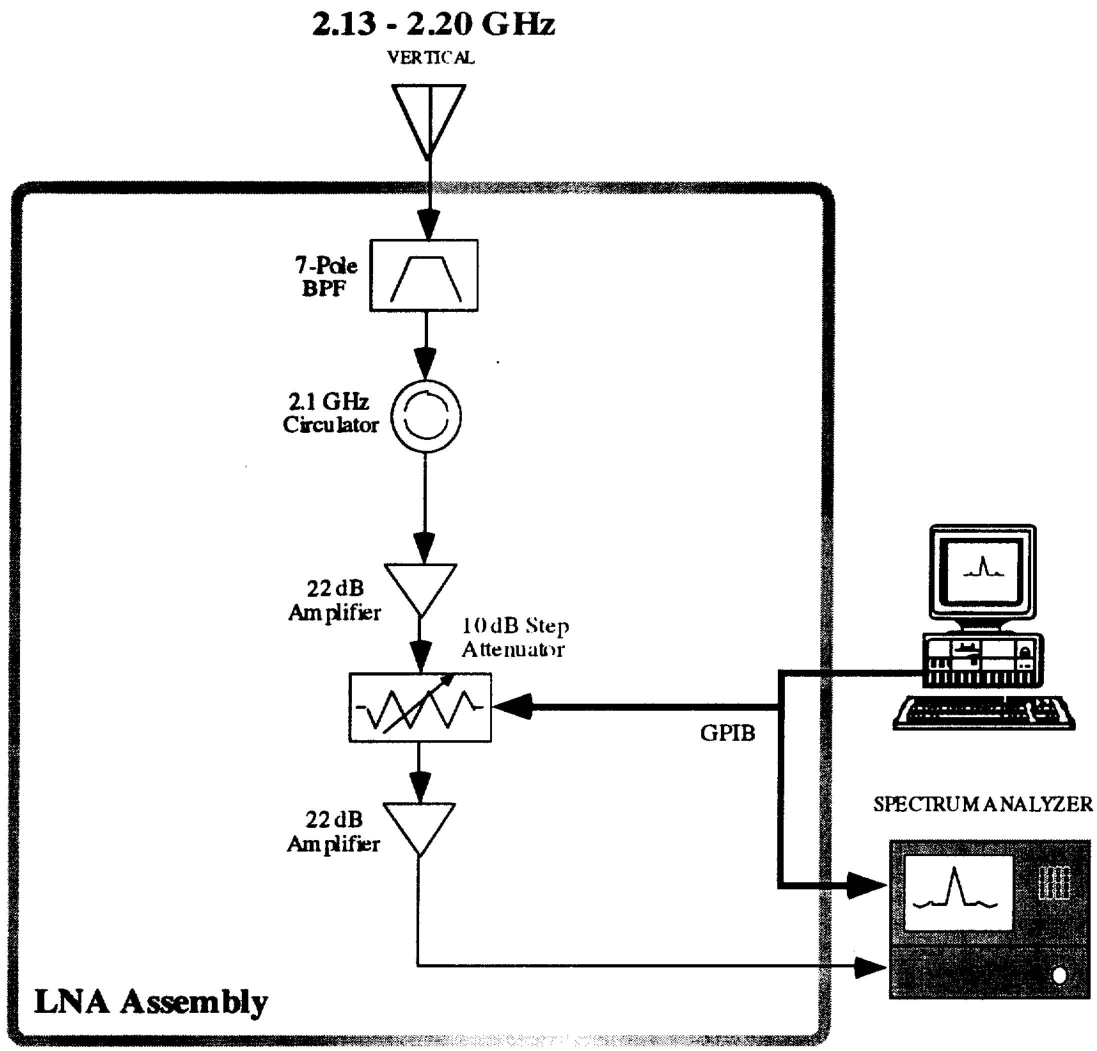

Figure 2.2-1. Block Diagram of the 2.1 GHz Narrow Band Receiver System

For the measurements, the spectrum analyzer was operated in a zero span mode with a 10 kHz resolution bandwidth and a 10 kHz video bandwidth. With the additional signal amplification provided by the two LNAs, the receiver could detect signals at a -115 dBm with a 10 dB signal-to-noise ratio. For a +30 dBm transmitter EIRP, the system could measure path loss values up to 145 dB.

2.3 Measurement Procedure

The 2.1 GHz propagation measurements were made using a stationary transmitter located at the radio port site and a mobile (van based) receiver system. Several median signal strength values were recorded at each participant site. Median signal strength values were generated from a spatial average of the instantaneous (received) signal strength data. Median signal strength, or more specifically median path loss[1], was used for RF link budget calculations as the impact of multipath fast fading has been removed.

Median signal strength values were generated at each location by displacing the mobile receiver over a straight line path between 20 to 40 wavelengths while continuously recording the received signal strength. Measurement runs were typically done in the driveway and along curbside at each participant site. In most cases, these two measurement runs were sufficient to provide a median signal strength value along both dimensions (e.g., front and side) of the dwelling.

A daily measurement session was conducted as follows. Power was supplied to the transmitter and receiver and sufficient time was allowed for the equipment to stabilize to ambient temperature conditions. The injected transmitter signal level (i.e., LNA output power as measured through the antenna feedline) was measured with a power meter. This measured value was used for the path loss calculations. A free space calibration measurement was then made for the transmitter using the custom receiver system. The measurement van was driven to a nearby location (at a known distance from the transmitter, typically between 50-150 feet depending upon local terrain conditions) so that the dominant propagation mode was via a direct line (e.g., free space) path. A measurement run was taken and a median path loss value was computed from the measured data. This path loss value was compared against theoretical free space path loss to verify that the transmitter and receiver systems were operating correctly. Actual field measurements began after the system calibration was completed.

Measurements were done at both primary and secondary participant sites for each radio port location. A primary participant site is one which was located approximately 1000 feet from the radio port and should receive service from that port. Secondary sites were located more than 1000 feet from the radio port. These sites were situated such that two or more radio ports may provide service (due to overlap in the coverages). Multiple measurements were made at each secondary site to determine which radio port location may have the best coverage to that site. Only one series of measurements were made at a primary site.

2.4 Analysis and Results

Median signal strength values, and the corresponding median path loss values (using the known transmitter EIRP), for each measurement run were computed. A representative sampling of the measurement data is summarized in Table 2.4-1.

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[1]Median path loss is defined as the difference between the effective isotropic radiated power (EIRP) of the transmitter and the median received signal strength. Median path loss is measured in decibels (dB).

Propagation Distance (ft)	Median Path Loss (dB) Driveway Measurement	Median Path Loss (dB) Curbside Measurement
1009.6	114.7	93.9
739.9	113.5	114.5
246.6	75.8	74.2
1145.8	111.2	109.6
1428.9	120.3	128.4

Table 2.4-1. Sample Path Loss Values for Radio Port Coverage Testing

Median path loss values ranged between 70 dB and 145 dB for propagation distances between 200 feet and 3000 feet. The corresponding path loss exponents (e.g., power law exponents) for the measured data ranged between $n = 3.2$ and $n = 4.8$ for a 1 meter free space path loss reference distance. The relatively large path loss exponents (a $n = 4$ value is typical for suburban and urban propagation environments) were attributed to terrain and natural clutter.

The test bed area is open residential area populated with typical one and two story homes, apartment buildings, small shopping complexes, schools, and churches. Few buildings exceed three stories so excessive shadowing due to human made obstructions (i.e., large path loss values induced by buildings obstructing the propagation path) is unlikely. It is more likely that terrain and foliage caused the excess propagation loss. The test bed 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. Although the radio ports were located at elevated locations the direct propagation path between the radio port and the participant site was often obstructed by trees or a hillside.

Path loss was generally greater for the driveway measurement than for the curbside measurement. In general, the driveway measurement exhibited 5 to 10 dB more path loss than the curbside measurement. The specific difference in path loss was a function of the propagation distance, the characteristics of the propagation path (line-of-sight or obstructed), and the separation distance between the two measurement locations. The difference tended to decrease as the propagation distance decreased and the propagation path became more line-of-sight. The additional path loss for the driveway measurement was attributed to the shadowing induced by the dwelling.

The median path loss values were compared against the RF link budget for the wireless local loop equipment in the following fashion. First an evaluation criterion was defined in terms of the maximum allowable path loss for acceptable service. The median path loss data for each participant site was compared against the service criterion. For primary sites (those potentially served by only one radio port) both the driveway and curbside path loss readings had to exceed the service criterion. For secondary sites (those potentially served by at least two radio ports) at least one median path loss value had to exceed the service criteria for service from that radio port site. A sample site evaluation for a primary participant site is provided in Table 2.4-2.

Maximum Allowable Path Loss in dB (1)	140
Shadowing Allowance in dB (2)	-12
Signal Fading Allowance in dB (3)	- 8
Service Criterion	**120 dB**
Median Path Loss Driveway Measurement (dB)	111.2
Median Path Loss Curbside Measurement (dB)	109.6
Result	**Serviceable**

(1) Maximum allowable path loss is defined by from the technical specifications for the wireless local loop equipment. Additional loss factors for excess propagation loss due to terrain and clutter are included.
(2) Shadowing allowance is included to account for additional path loss that the dwelling will induce when a wireless access unit is mounted directly on the home.
(2) Signal fading allowance accounts for both short term signal fading caused by motion in the channel and long term signal fading due to atmospheric changes.

Table 2.4-2. Service Evaluation for a Primary Participant Site

Notice that the service criterion defined in Table 2.4-2 is relatively conservative, as it accounts for additional shadowing and signal fading losses that may be experienced under actual operating conditions. The maximum allowable path loss value defined for the RF link budget of the wireless local loop equipment accounts for some multipath loss propagation factors such as terrain and clutter loss. However, the additional loss factors were included in the evaluation to ensure that a particular participant site will have adequate service even if the wireless access unit is mounted in a sub-optimal location.

Using the service evaluations, radio port locations were adjusted slightly to ensure that adequate coverage can be provided to the testbed participant sites. For the final set of radio port sites, 25 residences will receive service from the 5 radio ports. Under this port placement strategy, all of the desired test parameters can be investigated.

The current schedule calls for the first trial participant to begin receiving telephone service over the wireless local loop system in early July. As mentioned in the introduction to section 2, additional detailed propagation studies will be conducted within the testbed area at 2.1 GHz. The purpose of these measurements will be to better understand and characterize the environment as a whole, as opposed to selecting specific radio port sites for the testbed. These results will be described in the next quarterly report.