northern telecom

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September 3, 1992

Frequency Liaison Branch
Federal Communications Commission
2025 M Street, N.W.
Room 7326
Washington, D.C. 20554

Attention: Frank Wright

RE: File # 1820-EX-PL-91; Call Sign KI2XAG

Dear Sir:

On behalf of BNR Inc., and pursuant to the referenced license, enclosed is the report for the fourth reporting period.

Please communicate with the undersigned if you have any questions at (202) 347-4610.

Sincerely,

Raymond L. Strassburger
Director Government Relations-Telecommunications Policy

RLS:dc

Enclosure

BNR

File # 1820-EX-PL-91
Call Sign K I 2 X A G

EXPERIMENTAL RESULTS

for the

FEDERAL COMMUNICATIONS COMMISSION

Frequency Liaison Branch
2025 M Street N.W.
Room 7326
Washington D.C. 20554

by

BNR Inc.
P. O. Box 833871
Richardson, Texas 75083-3871

August 27, 1992

BNR

File # 1820-EX-PL-91
Call Sign K I 2 X A G

INTRODUCTION

This progress report is a summary of the types of emissions used and the technical findings from experimental tests conducted by BNR Inc., using license #1820-EX-PL-91. The tests were authorized by Experimental Radio License file number 1820-EX-PL-91 for tests in the vicinity of:

(1) Richardson, Texas
(2) Mountain View, California, and
(3) Research Triangle Park, North Carolina.

The license authorized BNR Inc. to use and operate the radio transmitting facilities, hereinafter described, for radio communications as shown in Table 1.

Table 1

Authorized Frequency MHz	**Authorized Power** Power (watts)
864-868	10 milliwatts (ERP)
902-928	1 (ERP)
930-960	10 milliwatts (ERP)
1850-1990	1 (ERP)
2400-2483.5	1 (ERP)
5725-5850	1 (ERP)

The authorization was effective August 14,1991 and will expire 3:00 a.m. EST January 1, 1993

EXPERIMENTAL TESTING IN THE VICINITY OF RICHARDSON, TEXAS

TYPE OF EMISSIONS USED

For the period from May 14, 1992, to August 14, 1992, emissions were from equipment transmitting in the 864.1 to 868.1 MHz range. As of 8-14-92, the testing program used Northern Telecom base stations, zone controller, and mobility manager, and Motorola 2000 "Silverlink" handsets.

ACTIVITIES

The BNR *in situ* trial program in the Richardson, Texas, BNR and NT buildings has focused on using radio frequency engineering to achieve commercial wireline voice quality from CT-2 type handsets. RF engineering models were used to position base stations to achieve high quality voice transmission from a given number of base stations. Further, during the past quarter, significant focus on the controller software targeted improving efficient hand-offs between base stations in the same cell. The trial involves wireless to wireline, wireline to wireless, and wireless to wireless calls by participants. Surveys of the communication patterns and needs of the participants are being evaluated to determine how much increased employee efficiency would result from providing continuous reachability with the wireless system. The new 1,000,000 sq. ft. NT/BNR campus is covered by a system in which the zone controller provides intra-zone hand-off and enables participants to maintain full communication service as they travel through the campus. Two-way calling throughout the coverage area is handled by the prototype Mobility Manager being developed at the BNR laboratory in Richardson.

During late March and into May the BNR facilities in Richardson moved to a new building campus in Richardson, Texas. As part of the move to the new campus, antennas were redeployed and systematic reception and stress tests were performed. BNR has developed a deployment scheme that simplifies locating base stations to ensure coverage and handle traffic loads. As part of the testing, voice quality was monitored for clearness compared with commercial wireline telephone service. During the test, participants maintained their conversation on the wireless set as they moved through RF-blocking areas in the buildings.

BNR designers use the test results to evaluate voice quality and call completion using different system configurations. Knowledge gained during this redeployment will be used in prototype redesign as well as impact product definition.

Additional testing is being conducted in the new facility to identify in-building antenna and environmental factors that affect reception and voice quality. An in-house, in-building test executed in mid-July included testing of improved antenna configurations and improvements to the base station system.

Functionality Tested

Bi-directional (incoming and outgoing) calling functions were tested; these included hand-offs between base stations within the zone as participants maintained their calls while moving through the building. The controller optimizes signal strength by selecting the base station with an available channel with the best signal strength. The bi-directional calling test exercised the NT system as the portable registers in a Mobility Zone (a location with base stations connected to a wireless controller) and the home location register (HLR) at the Mobility Node is updated with the zone information necessary to effect portable registration. Once registered, an incoming call received by the Mobility Node is routed within the zone to where the portable is located. The Mobility Node HLR updates information every time a portable registers in a new zone, allowing the user to move across zones, and maintain bi-directional calling capability.

Besides the above functionality, several new service functions were demonstrated and included in some of the tests. The additional functionality demonstrated includes (1) multi-device simultaneous ringing, (2) personal number reachability across networks, (3) device-independent call retrieval, (4) user-defined call-rerouting options on set busy or no-answer, and (5) device interchangeability independent of access technology. The new service functions will be experienced *in situ* and evaluated for utility. In summary, the trials help demonstrate that the Mobility Node successfully integrates across access networks to deliver or manage a call.

TECHNICAL FINDINGS

The new base station placement and software improvements achieved spectrum efficiency and wireline voice quality with the handsets for most test calls including those in potentially RF blocked areas. The efficient hand-off between base stations within a zone permits the user to maintain a call while moving through the building without disrupting call quality. Continuous communication was achieved in several potentially RF-blocking areas such as elevators, stairwells, and rest rooms without the use of a leaky antenna or installing base stations in the RF-blocked areas.

The Mobility Node was very effective in connecting calls to the CT-2 wireless sets to provide two-way calling. The learning has helped BNR improve the design for the next product generation. Trial data indicate that the Motorola handsets, Northern Telecom base stations, connected with the Northern Telecom controller and mobility manager can provide a multi-functional bi-directional communication system for commercial in-building use. Testing continues to aid the BNR laboratories to improve the Mobility Node, Mobility Manager, and the Mobility Zone (base stations, zone controller, and application processor).

In summary, results for the mid-July test and the on-going trial at Richardson demonstrated wireline quality reception in virtually all locations (including RF-blocking areas) with virtually no disruption in quality during hand-off as the user moved through the building.

EXPERIMENTAL TESTING IN THE VICINITY OF MOUNTAIN VIEW, CA.

TYPE OF EMISSIONS USED

No tests were run during the reporting period of May 14, 1992, to August 14, 1992, in the Mountain View, CA. area.

The testing in Mountain View began on August 17, 1992 and test results will be identified in the next report.

Northern Telecom base stations and Motorola "Silverlink" handsets operating in the 864.1 to 868.1 MHz range will be used in the tests at Mountain View, CA.

TECHNICAL FINDINGS

There are no findings to report for the reporting period of May 14, 1992, to August 14, 1992, from tests in the Mountain View, CA. area.

BNR

File # 1820-EX-PL-91
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EXPERIMENTAL TESTING IN THE VICINITY OF RESEARCH TRIANGLE PARK, N.C.

TYPE OF EMISSIONS USED

For the period from May 14, 1992, to August 14, 1992, tests were conducted at the Research Triangle Park, N.C. site using the Shaye base stations and the Shaye handsets operating in the 864.1 to 868.1 MHz range.

Equipment used for testing consisted of six Shaye base stations and six Shaye hand sets (an increase of one base station from our last report). Each of these are single base station and hand set installations. In contrast to the Richardson trial, hand-off between base stations is not supported.

ACTIVITIES

The *in situ* trial tests at Research Triangle Park allow the participants to experience wireless business service in their daily work activities. Continued testing helps determine the acceptability of this technology in day-to-day business operations. Interaction with NT DMS-100 Multiple Appearance Directory Numbers and Centrex Feature Sets has also been tested.

TECHNICAL FINDINGS

The on-going trial testing, for the period May 14, 1992, to August 14, 1992, has continued to be valuable to understand the value sets end-users will place on this technology. The testing demonstrated that the voice quality and single base station range for stationary and moving portables are acceptable for commercial applications.

The on-going nature of the trial has revealed that hand-off between base stations, to allow full building roaming, is an essential element for commercial acceptance. We have noted the need for increased volume control for handsets as well as noise canceling microphones to mask or block ambient noise. We have also noted that in-building structures (high metal partitions and building support structures) have a detrimental effect on handset reception. Installation of in-building systems supporting multiple handsets and full building coverage must be engineered to eliminate or avoid these factors.

CONCLUSIONS

Testing of the systems and equipment, at Richardson and Research Triangle Park, demonstrated the low-power wireless systems can provide wireline-quality voice service for stationary and mobile uses. Software improvements for the NT controller significantly increased the probability of a call being completed and improved the hand-off from base station to base station as participants moved through the building. Locating base station sites using detailed RF engineering can greatly improve the voice quality from and to the CT 2 type handsets without the need to add additional base stations or a leaky antenna. A Personal Number greatly simplified a calling party's access to a called party and, as well, the technology ensured reachability of the called party. The technology permits workers to conduct business more efficiently by providing them with constant two way communication capacity throughout the business day. The system eliminates time that otherwise would have been wasted when other workers are waiting for a key decision from a co-worker who otherwise cannot be located. Further, the handset user avoids time consuming telephone tag with important clients by maintaining a constant two-way link with the communication network. Additional user benefits were discovered and studied because of the Mobility Node's ability to provide multi-device ringing, device-independent call retrieval, user-defined call rerouting options (what they are, timing, etc.), and device interchangeability.

FCC STAFF INQUIRIES

Regarding this report, FCC staff inquiries should be directed to:

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Telecommunications Regulation Analyst
BNR
P. O. Box 833871
Richardson, Texas 75083-3871
(214) 684-1723

TEST SITE	AVERAGE COVERAGE RADIUS* 18'	36'	MINIMUM COVERAGE AREA DIFFERENCE**
A	1050'	1580'	2.26
B	900'	1210'	1.81
C	1370'	1950'	2.03
E	1020'	1130'	1.22
F	1320'	1610'	1.49
G	820'	1350'	2.71
H	920'	1210'	1.73
I	1640'	1740'	1.12
J	1290'	1690'	1.72
[illegible]	1190'	1350'	1.09
L	1060'	1430'	1.82
O	1290'	1480'	1.32
P	2110'	2640'	1.56

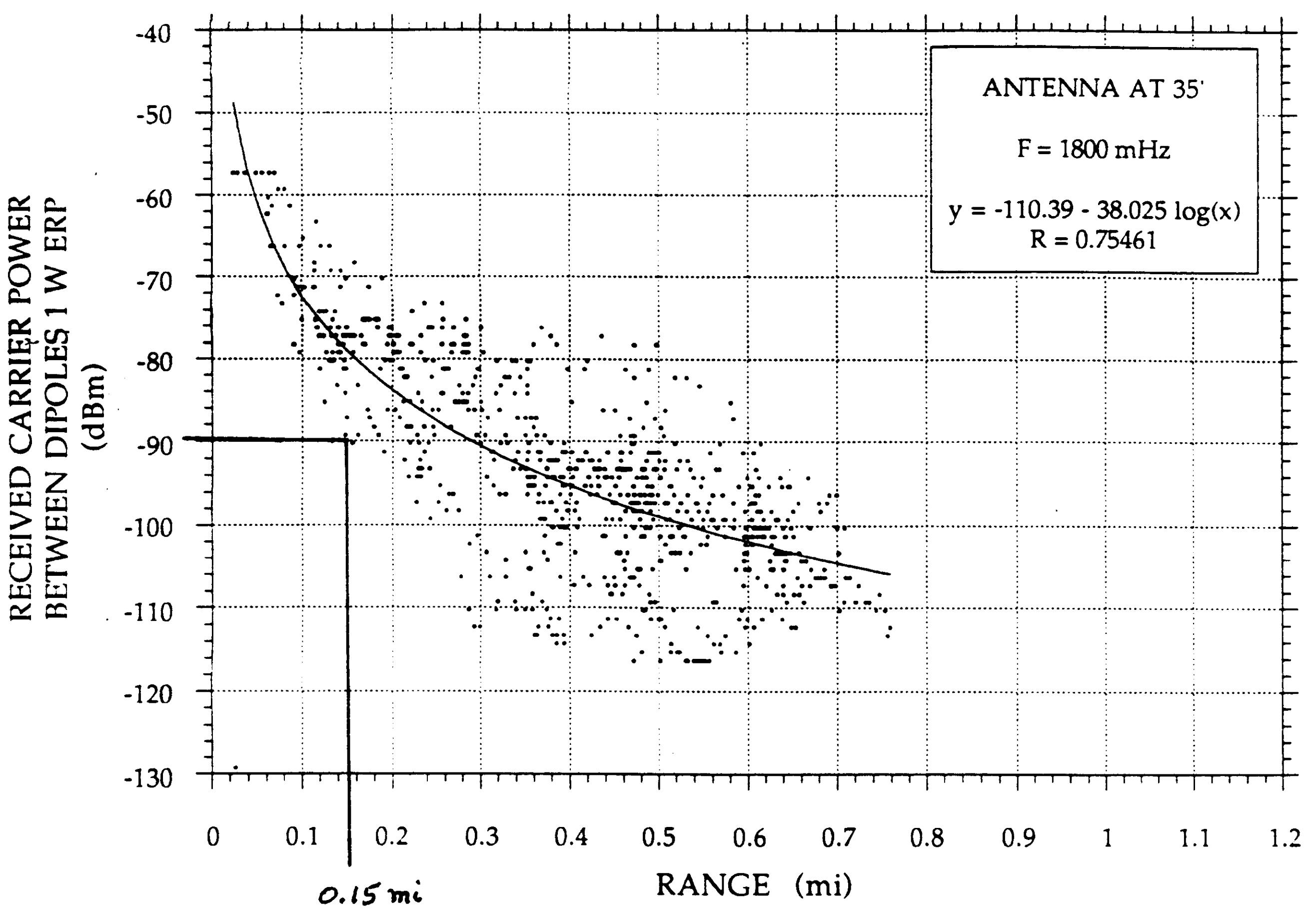
****DEFINED AS THE DISTANCE TO THE LOG CURVE FIT TO THE SCATTER POINT DATA, AT THE 120 dB PATH LOSS VALUE***

*****COMPUTED AS $\left(\frac{R_{36}}{R_{18}}\right)^2$, WHERE R36 AND R18 ARE THE AVERAGE COVERAGE RADIUS AT 36 AND 18 FOOT ANTENNA ELEVATIONS, RESPECTIVELY.***

TABLE 2 - EFFECT OF ANTENNA ELEVATION ON COVERAGE ARA - 1.895 GHz

SITE A

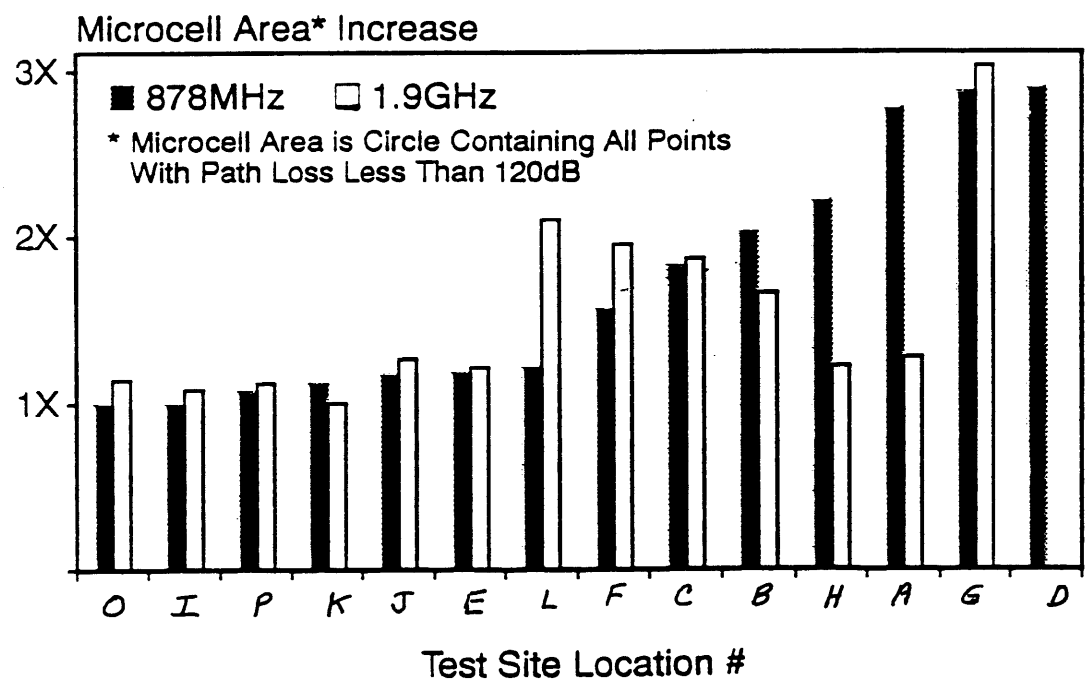
PRELIMINARY



aNom6.data

LD 5/19/92

FIGURE 1 - PROPAGATION LOSS VS. DISTANCE
TEST SITE A - 36 FT. ANTENNA



Effect of Doubling Microcell Antenna Height Above CATV Strand Level (36' vs. 18')

FIGURE 2 -

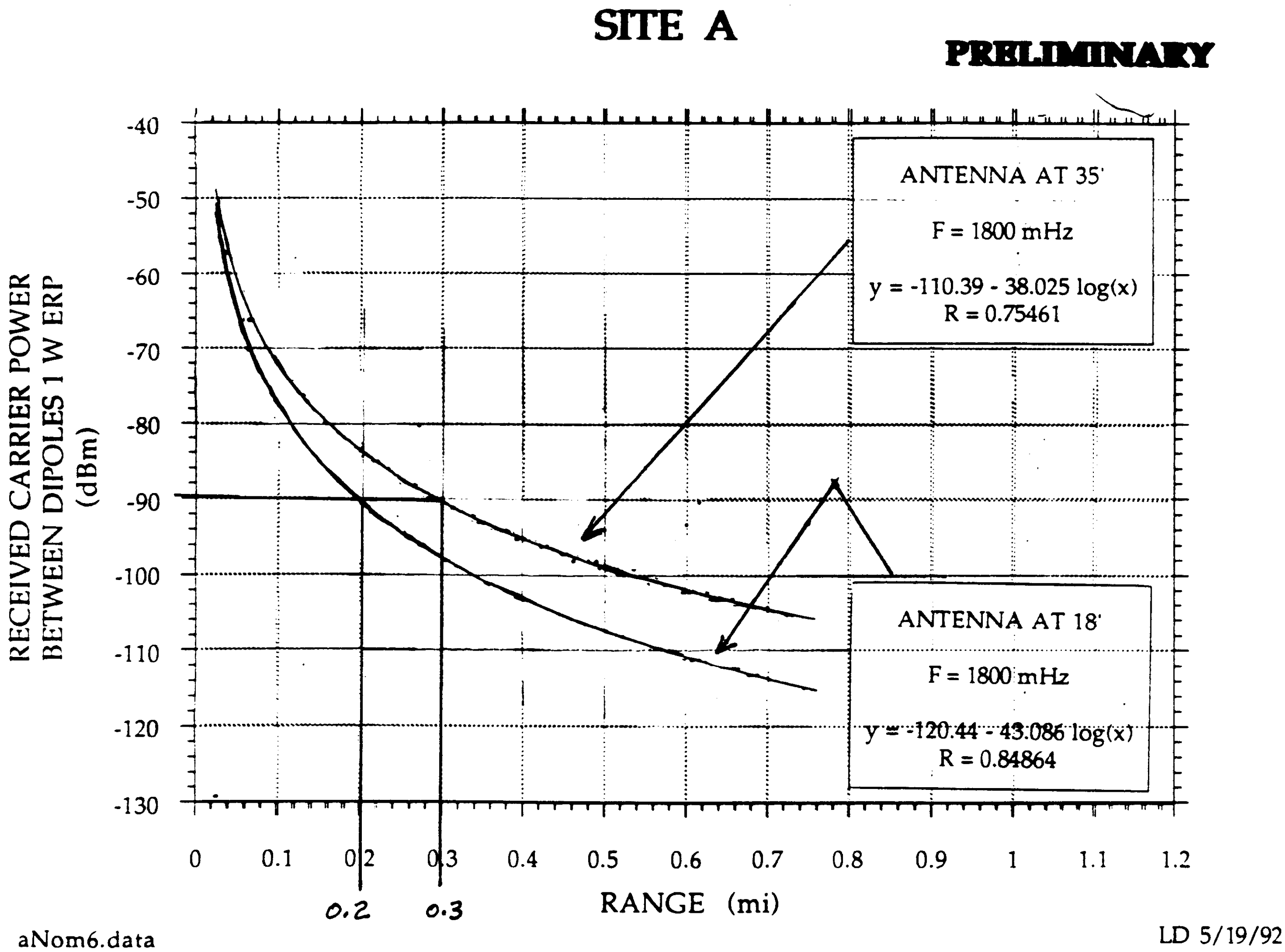
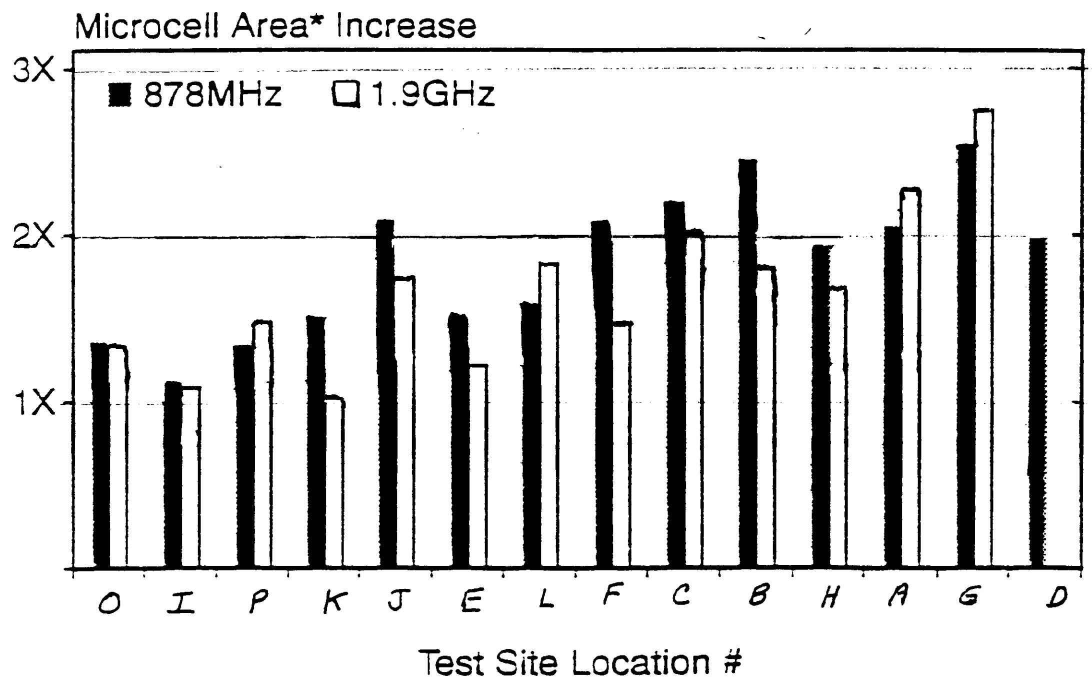


FIGURE 3- PROPAGATION LOSS VS. DISTANCE
TEST SITE A - LOG CURVE FIT TO SCATTER
PLOT DATA



Effect of Doubling Microcell Antenna Height Above CATV Strand Level (36' vs. 18')

*Microcell area is circle with radius equal to the distance to log curve fit to scatter plot data, at the 120dB path loss value.

FIGURE 4 -

FIGURE 5 - IN-BUILDING MEASUREMENT EQUIPMENT - SMARTSAM (TM) WITH LAPTOP COMPUTER

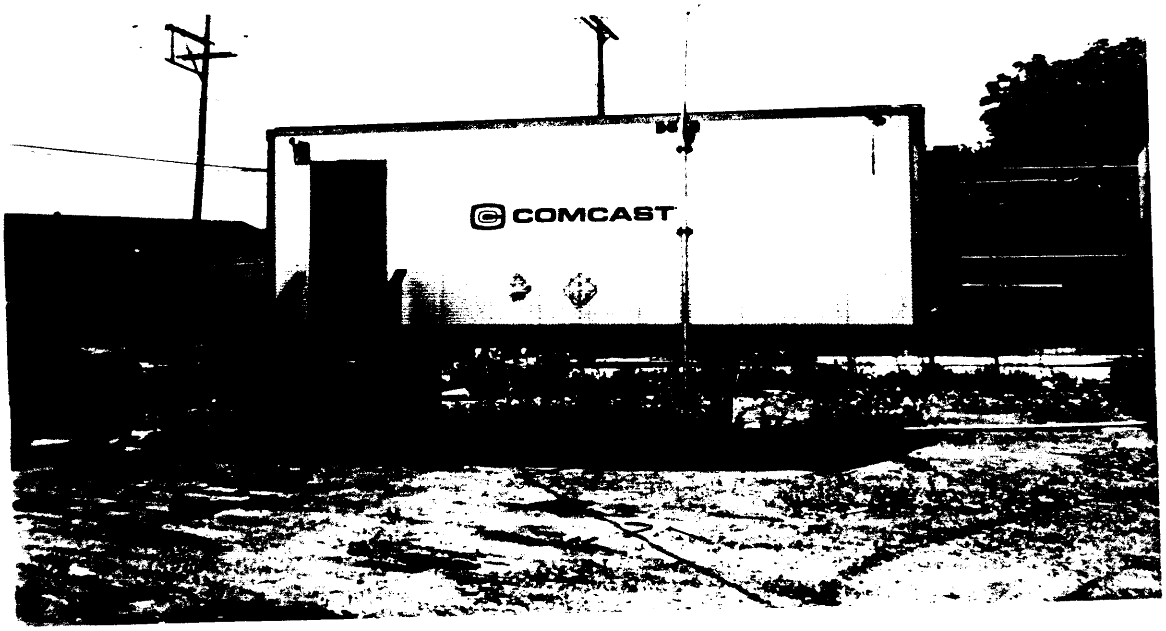


FIGURE 6 - TEMPORARY TRAILER SITE
BASE STATION LOCATION AT CABLE TV
HEADEND IN TRENTON, NJ

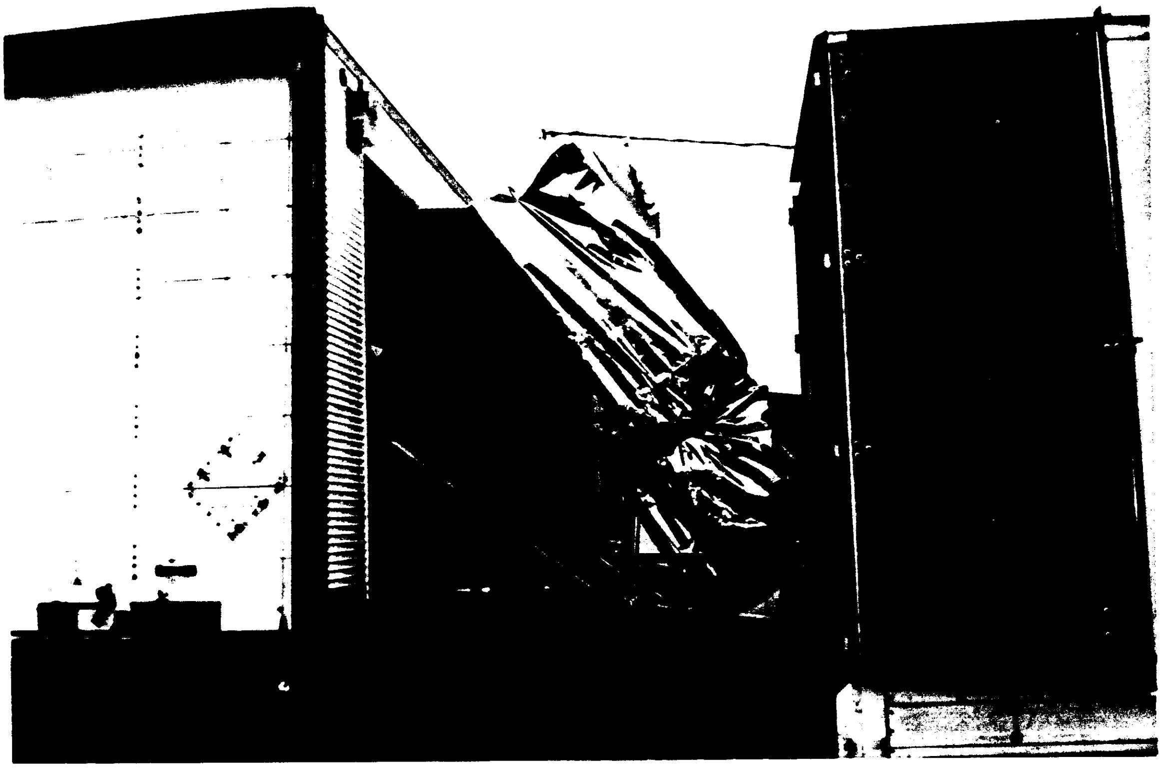


FIGURE 7 - MODIFIED HD-2 BASE STATION
FRAME BEING MOVED INTO TRAILER

FIGURE 8 - INTERVAL VIEW OF PART OF
BASE STATION COMPLEX

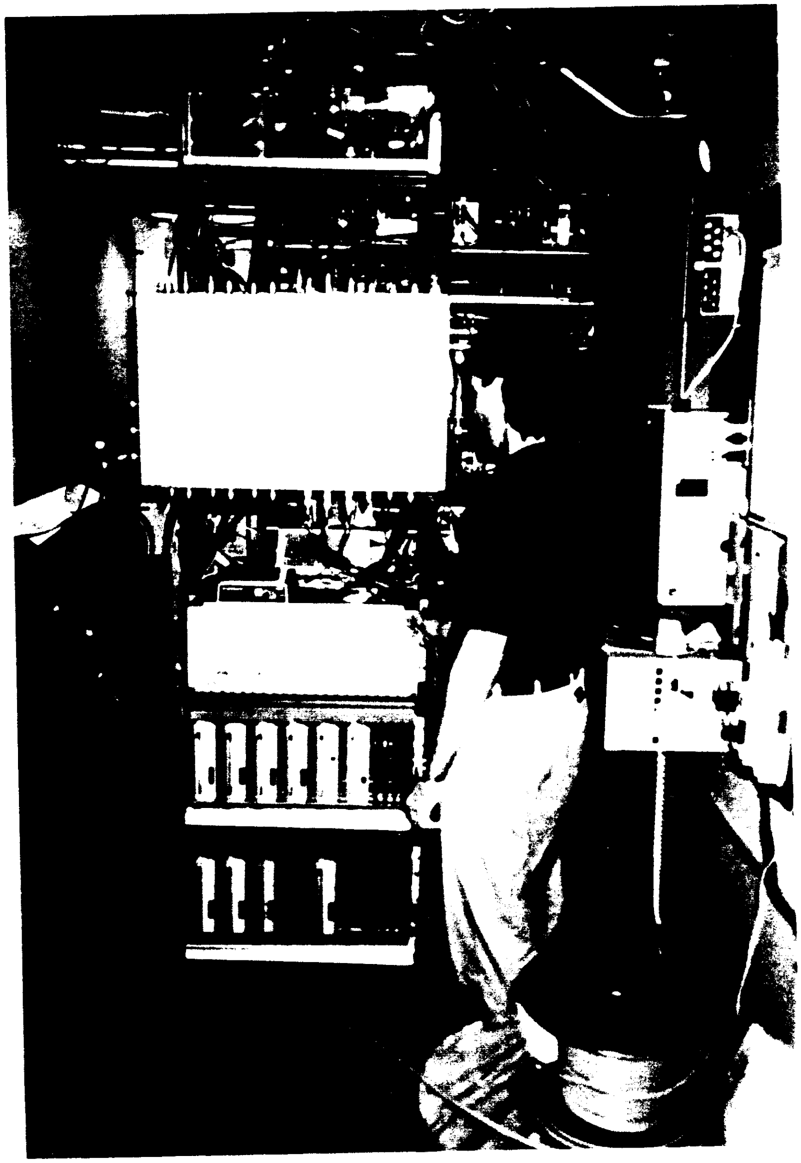


FIGURE 9 - MODIFIED HD - 2 BASE STATION
FRAME WITH LOW LEVEL COMBINER

FIGURE 10 - SPLICE BOX BEING RETURNED TO STRAND LEVEL

FIGURE 11 - INSTALLATION OF OUTDOOR ANTENNA PORT AB

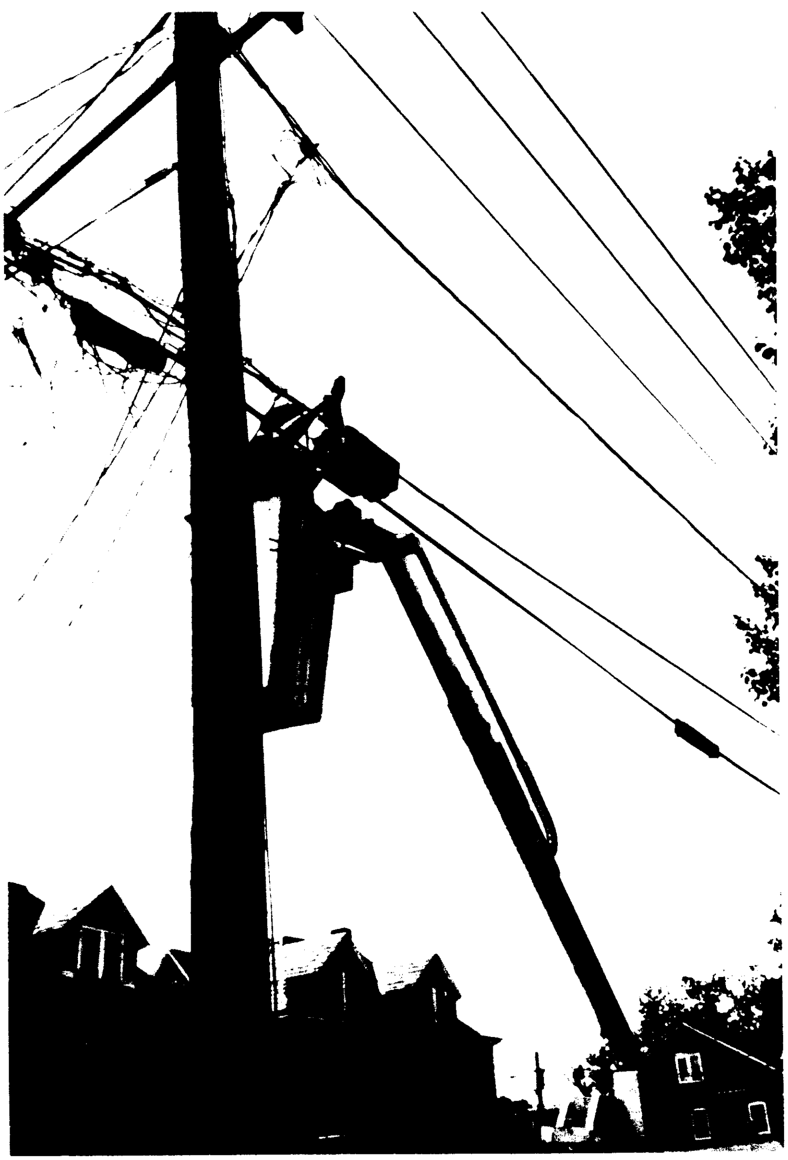
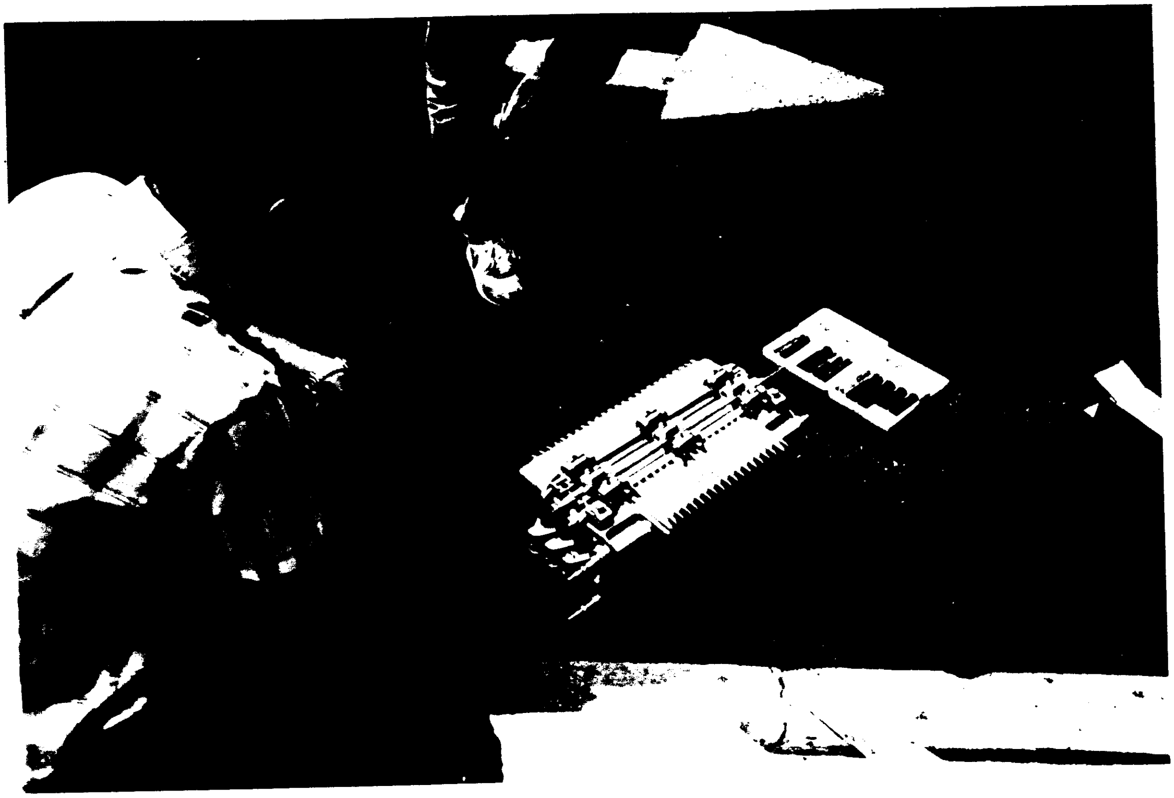


FIGURE 12 - INSTALLATION OF OUTDOOR ANTENNA PORT CD



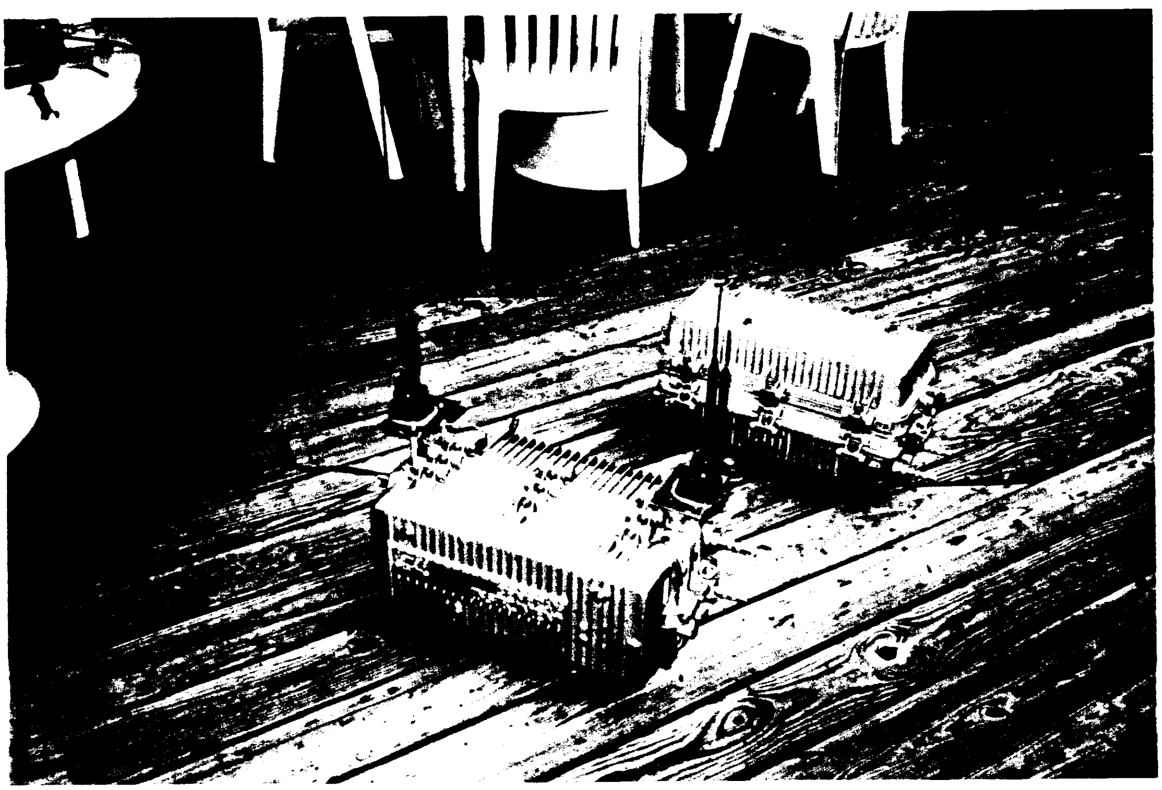


FIGURE 13 - OUTDOOR ANTENNA PORT

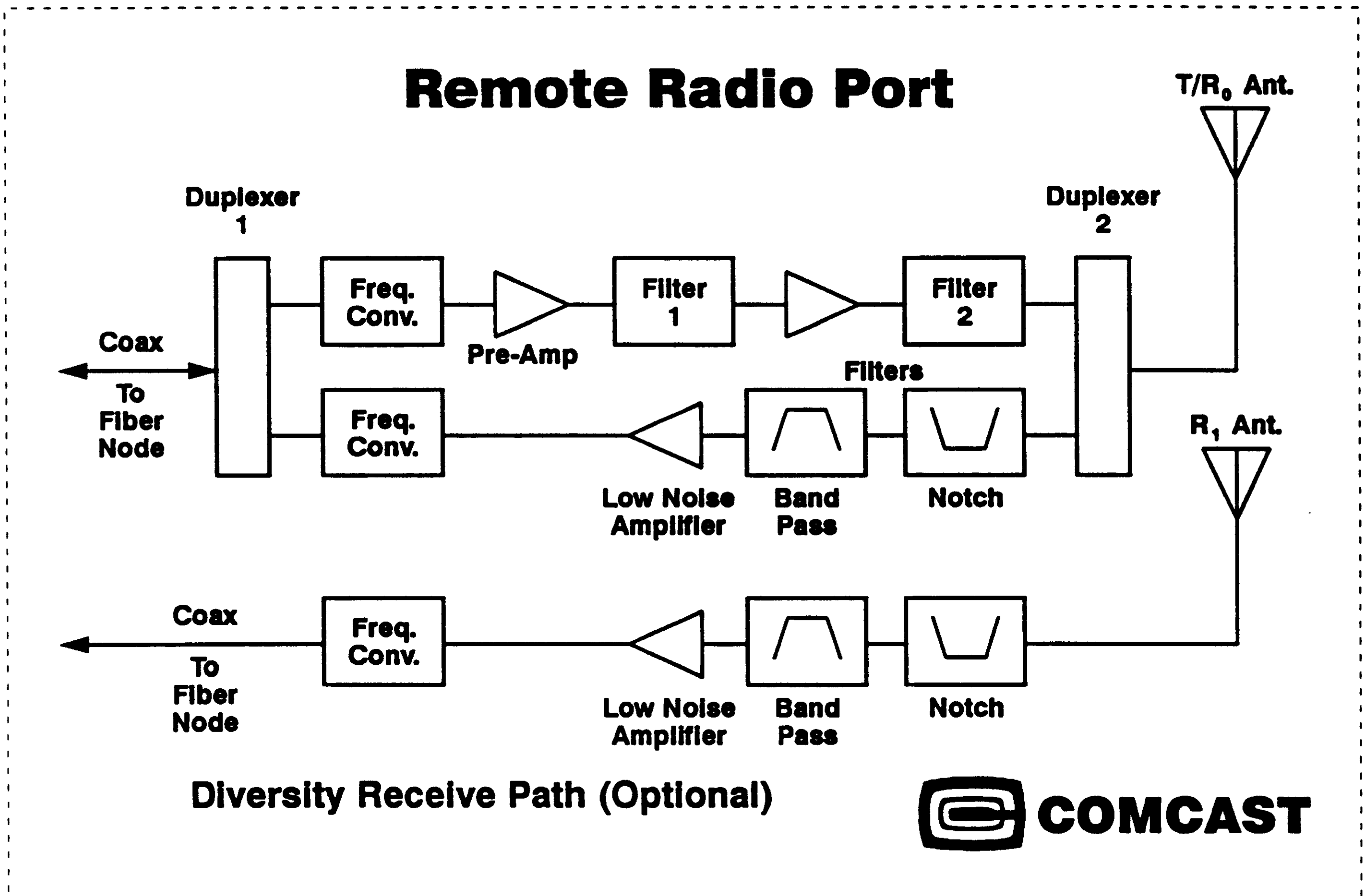


FIGURE 14 - ANTENNA PORT BLOCK DIAGRAM

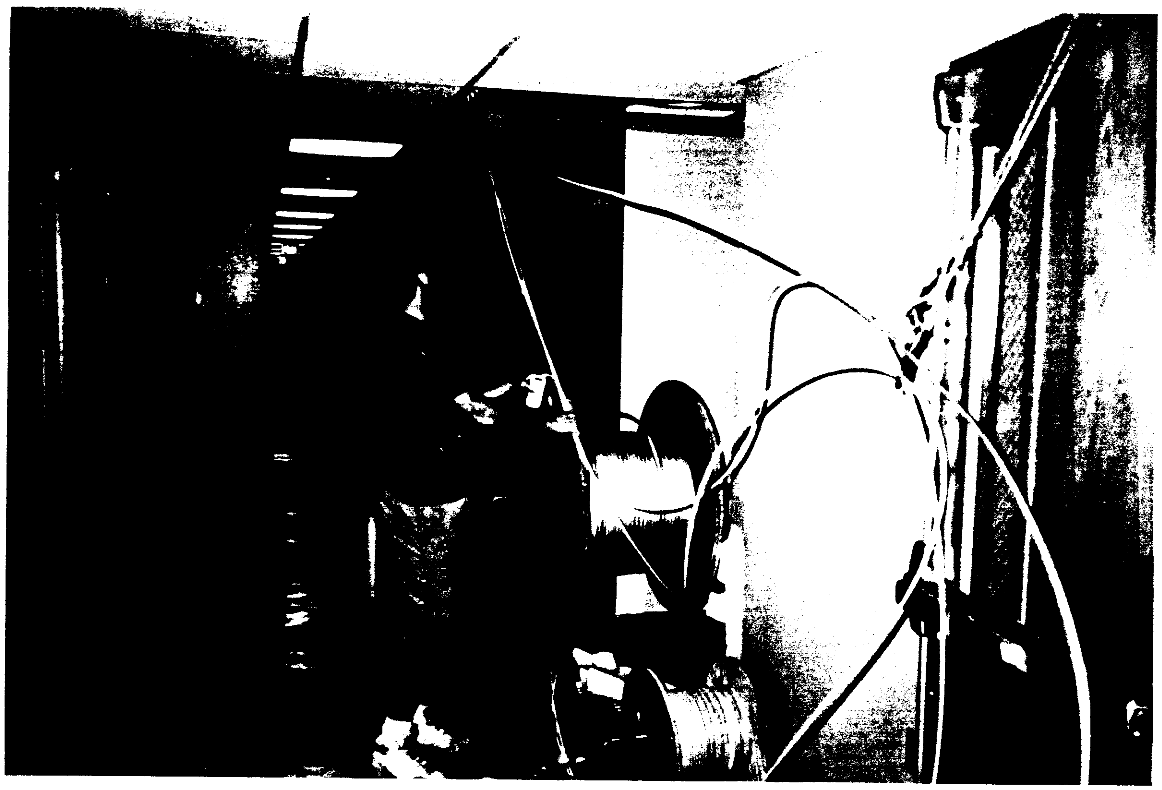
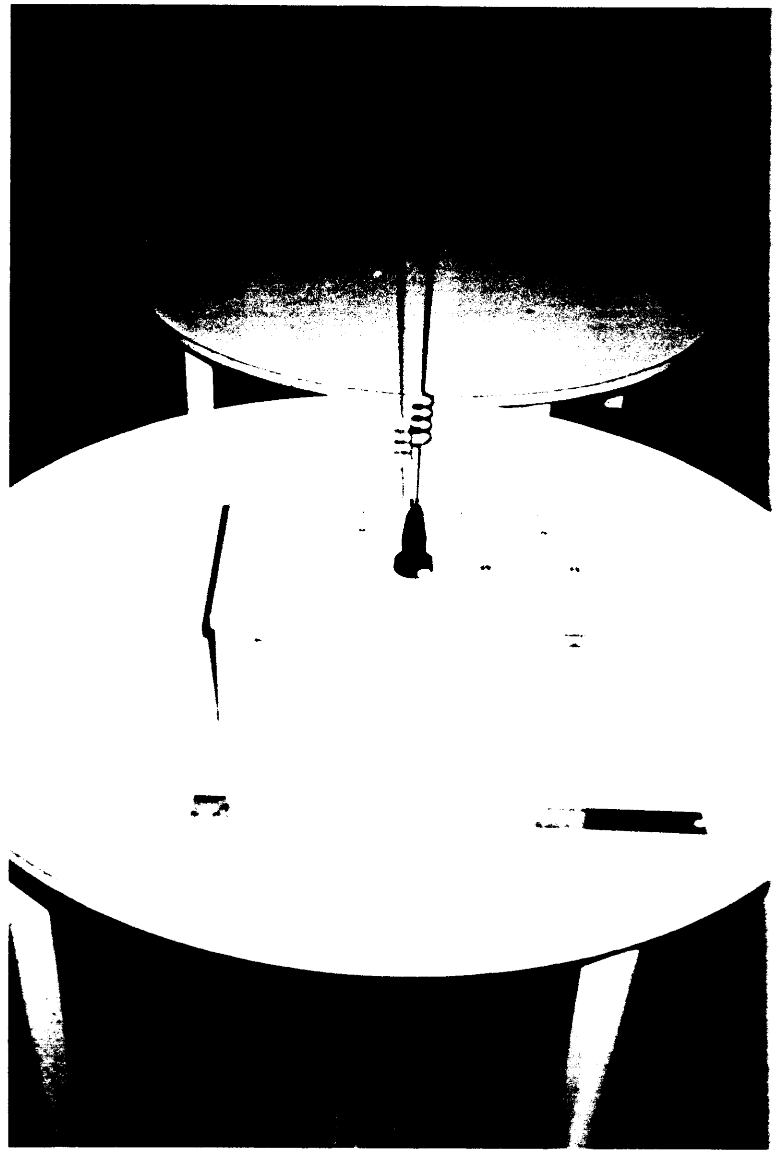


FIGURE 15 - COAXIAL CABLE INSTALLATION
IN TEST VENUE BUILDING



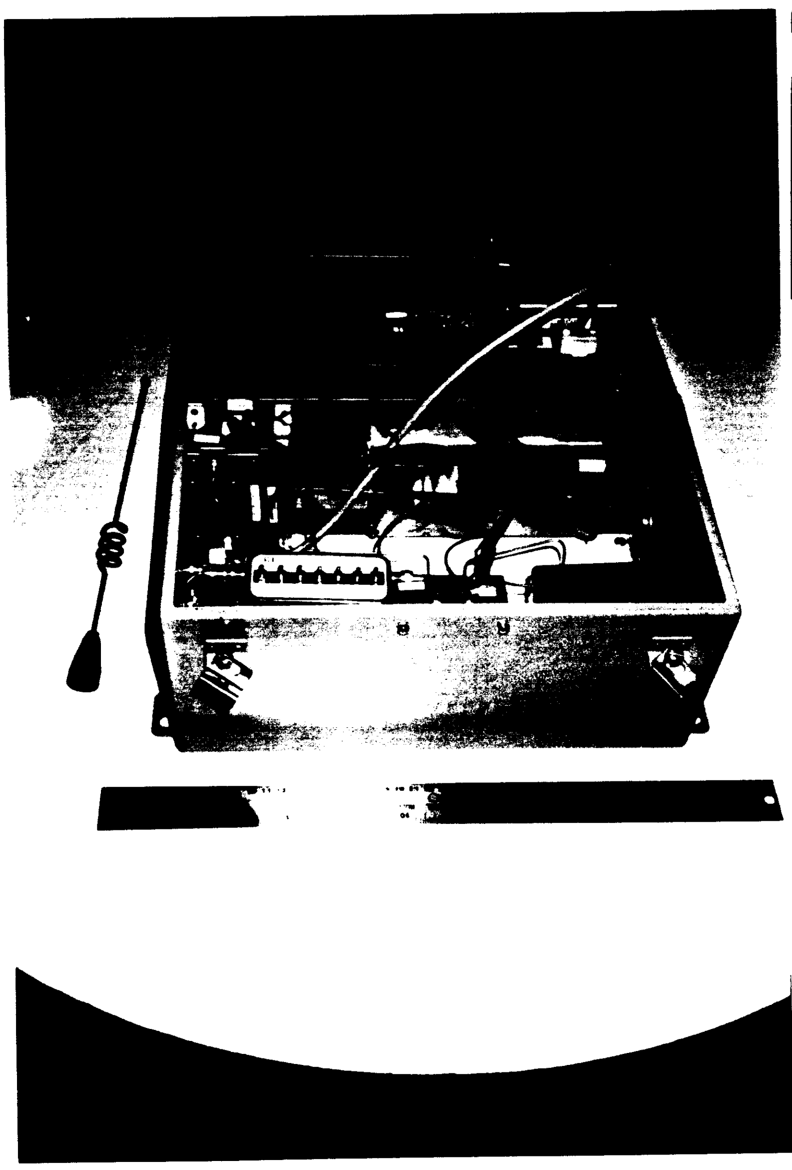


FIGURE 16 - INDOOR ANTENNA PORT

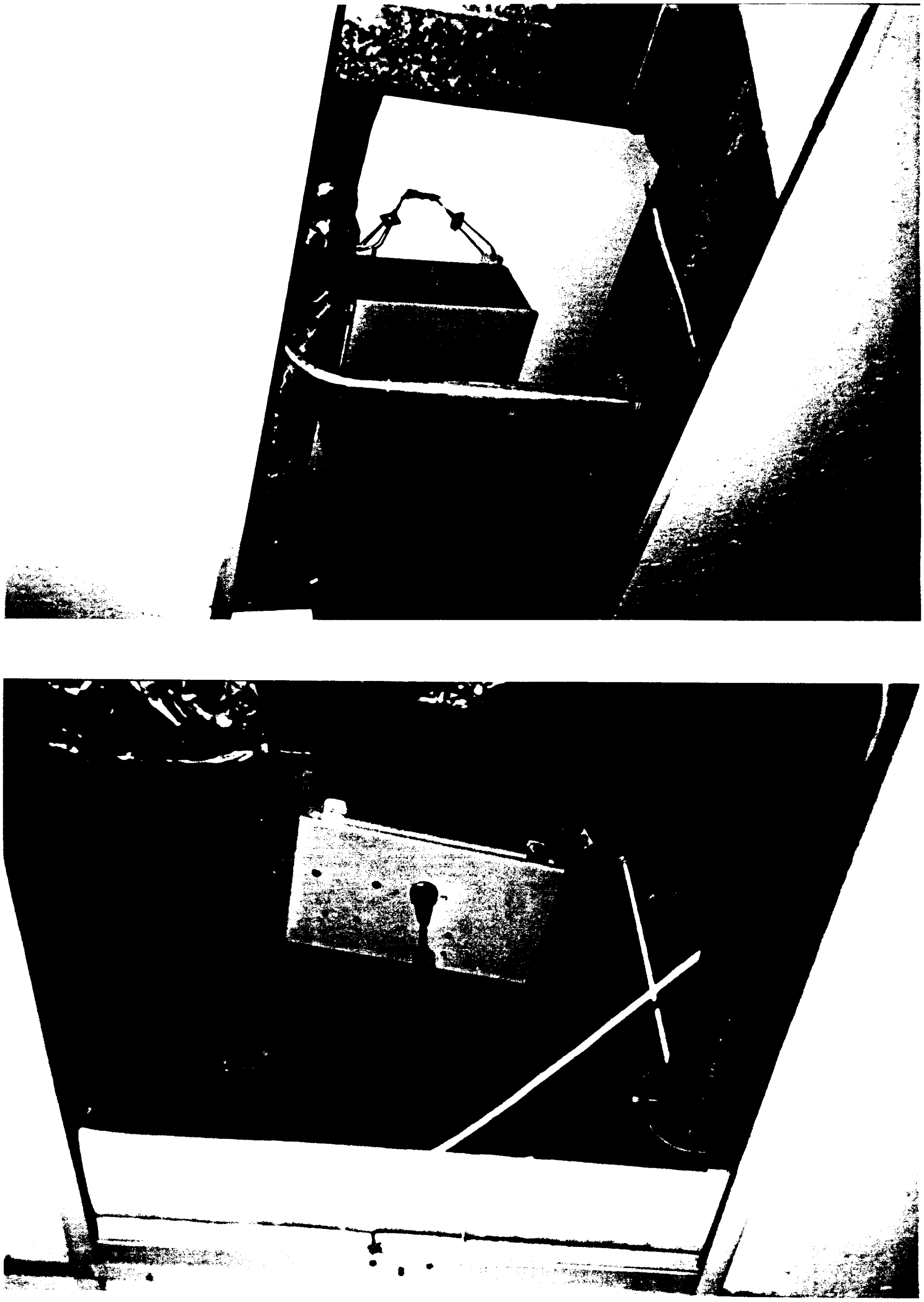


FIGURE 17 - TYPICAL INDOOR ANTENNA PORT LOCATIONS

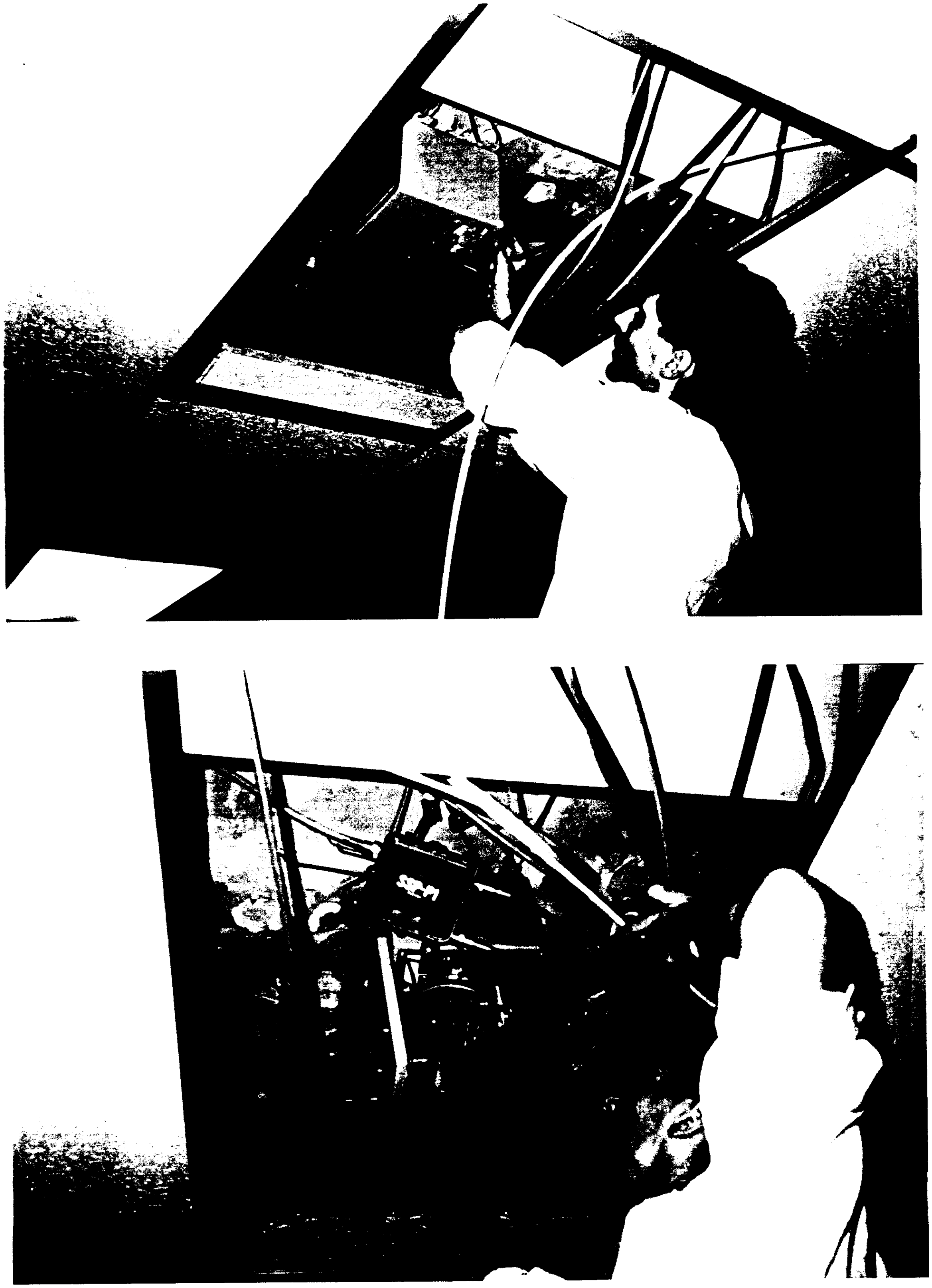


FIGURE 18 - TYPICAL INDOOR ANTENNA PORT LOCATION

TRENTON PROPAGATION MODELS

Motorola
Personal Communications
Systems

Preliminary
Version 3

July 7, 1992

APPENDIX

GENERAL

In the microcellular environment RF field conditions around the base site are as disturbed as around the subscriber unit. Reflections from the ground and from buildings close to the base antenna produce characteristic variations in signal strength for small base subscriber separations.

An envelope of the peaks close to the base site reveals path loss values in some cases less than free space, as found by Whitteker [1] and Harley [2] indicative of near lossless two path conditions with rates of fall of 20 dB per decade. For non-ideal reflections, the higher angles of incidence close-in result in higher losses giving lower rates of fall, i.e.: 15 dB per decade [3]. As separations increase, but still in sight of the base antenna, and beyond the last signal peak the signal strength becomes asymptotic to a 40 dB per decade law (plane earth case) [4]. These line of sight cases or LOS models are illustrated in Fig. 1. The break point between the tangent region and the two path asymptote is given approximately by the expression:

$$Dbp = 4 * Hb * Hs / \lambda$$

where: Hb = base antenna height
Hs = subscriber antenna height
λ = wavelength in meters

The LOS mode is sustained down streets by ground reflection and by building reflections. As shown in Bertoni [5] the smooth peaks expected in the two path model are broken up by the building reflections to the extent that this case becomes a 4-ray model. By including the two additional rays one can add credence to the so-called out-of-sight mode (OOS) as named by Schilling et al [6]. Here illumination is provided along orthogonal streets by the building reflections propagating down the street containing the base site. Since only a cone of rays limited by the width of the orthogonal street can enter that street it is logical that there is a transition loss as shown in Fig. 2. In addition the number of reflections per unit length encountered by these rays will always be greater than in the originating street. Therefore the rate of attenuation in the orthogonal street is always greater than in the originating street and highly dependent on the width of the orthogonal street [6].

The third, and the most common, propagation mode found in urban areas is due to diffraction over the roof tops with characteristic loss curves as shown in Fig. 3. An empirical model, derived from measurements made in Tokyo, reported by Okumura [7] has long been a standard for this mode. Hata [8] has reduced the Okumura curves to a form suitable for a programmable hand calculator. Adjustments for broad changes in environment are made simply by subtracting a fixed loss from the urban curve for suburban, quasi-open and open area cases.

Further refinements correcting for variations in environment were made by Kozono and Watanabe [9] who used building density as a key to choosing an additive factor. However the process still depends on only a single correction. Ray paths with mixed environments are difficult to cope with by this method.

A theoretical model using multiple diffraction over a series of thin opaque screens has been developed by Bertoni and Walfisch [10]. Propagation slopes with distance similar to those measured by Okumura are predicted by this method. Further refinement by Bertoni, Maciel, and Xia [11] shows a correspondence between propagation slope and base antenna height relative to the building roof line. A recent paper by Löw [12] illustrates the development and testing of an approach combining Walfisch/Bertoni and Ikegami [13]. This new method, a result of work by the European research committee COST 231, combines the ray-theoretic work of Ikegami for effects around the mobile with the multiple diffraction analysis of Bertoni/Walfisch for the effects along the path from the base site. Empirically derived adjustments correct for base antenna height relative to the roof line. Löw suggests that this method offers a viable interim solution prior to the use of specific deterministic models utilizing more sophisticated building and street data.

Löw is certainly correct in that more complete data bases providing three dimensional descriptions of terrain and man-made structures are needed. No inroads can be made on improved solutions to the problem of machine aided propagation coverage prediction without such a data base. In the following section some of the Trenton data is used to show examples of LOS and diffraction models. No attempt is made to localize results to the extent that more explicit models can be applied. Instead, sites are selected to minimize environment variations and all valid data is used to derive a model. The final section shows an attempt to generate a building data base for Trenton and how it might be used in a machine driven propagation analysis program.

TRENTON MODELS

LOS

A number of test runs in the Trenton area were made on streets fully illuminated by the base site antenna. Distances less than the break-point Dbp show between 15 to 20 dB per decade slope for the upper limit but in some cases deep nulls were found. The composite plot of Fig. 4 clearly shows this as well as the high slope indicating a two ray mode beyond Dbp. The deep nulls may be effects due to side reflections from buildings as they did not appear in a very extended run taken in a parking lot as seen in Fig. 5.

DIFFRACTION

The majority of the test samples were measured under conditions of diffraction first and then building reflections before reaching the test receiver antenna. The data from two similar sites, site "A" and site "B" (taken at 900 mHz) were combined, then purged of data below Dbp and data that showed overload or thresholding. A regression analysis resulted in a linear-log representation of the path loss of signals from the 36 ft and the 18 ft antennas. The representations are shown in Fig. 6. The data, consisting of 3466 samples for each antenna, was not shown as the regression lines would have been obscured. The regression parameters for the curves of Fig. 6 are given below:

PL (36 ft ant) = 136.6 + 46.0 * Log (Dmi) {in dB between dipoles}
with std. dev. of residuals = 6.3 dB

PL (18 ft ant) = 145.6 + 48.7 * Log (Dmi) {in dB between dipoles}
with std. dev. of residuals = 6.1 dB

The loss difference between the two antennas averaged to 9.0 dB at 1 mile and changed by 2.7 dB for each decade above or below 1 mile. The environment for these two sites consisted mainly of two to three story residences.

MIXED ENVIRONMENT SITES

Terrain and environmental variations within the coverage of many of the other sites negated their use as models. This points out the need for a methodology to categorize and define microcell propagation based on building and terrain characteristics. Work toward categorizing differences in environment is hampered by lack of a data base of sufficient detail. Digitized terrain maps available from the USGS at present do not include details of man-made structures. Line drawings of street and building details are available, for instance, from the Sanborn Map Company [14]. However the format of machine readable files suitable for this type of data is open to question. In an attempt to explore possible avenues a readily available CAD program called MiniCad+ has been utilized to transfer building data from scanned Sanborn maps. A profile of the first 1000 ft of the 160 degree radial from site "B" ,as shown in Fig. 7, was extracted manually. Work is continuing on the process of machine extraction of data of this type.

The 160 degree radial propagation data was selected from the near data runs of site "B". Selection was based on measuring vehicle bearings from north lying between 150 and 170 degrees and distances greater than 0.1 mile and less than 1.0 miles with received carrier powers below overload and above threshold. Fifty measured samples were found with results as shown in Fig. 8. The regression equation becomes:

$$\text{PL (between dipoles)} = 142 + 58 * \text{Log (Dmi)}$$
$$\text{with std. dev. of residuals} = 3.75 \text{ dB}$$

At the present time there is insufficient data to determine if the slope and intercept given above can be satisfactorily explained by the multiple diffraction theory of Bertoni and Walfisch. Building height data beyond 1000 ft may throw more light on the fact that the slope above is greater than that obtained for the total runs from site "B" as given in a previous section. Initial work on computing the functions given in Bertoni using mean values of separation distances and building heights have only been marginally successful.

CONCLUSIONS

It has been shown that the Trenton data presents valid representations of some of the accepted theories of propagation in a microcellular environment. Further work is needed if better inroads are to be made in correlating measured data to very localized terrain and structure characteristics already available in man-readable form. The mechanization of this process presents another challenge since the amount of data needed is quite large and detailed.

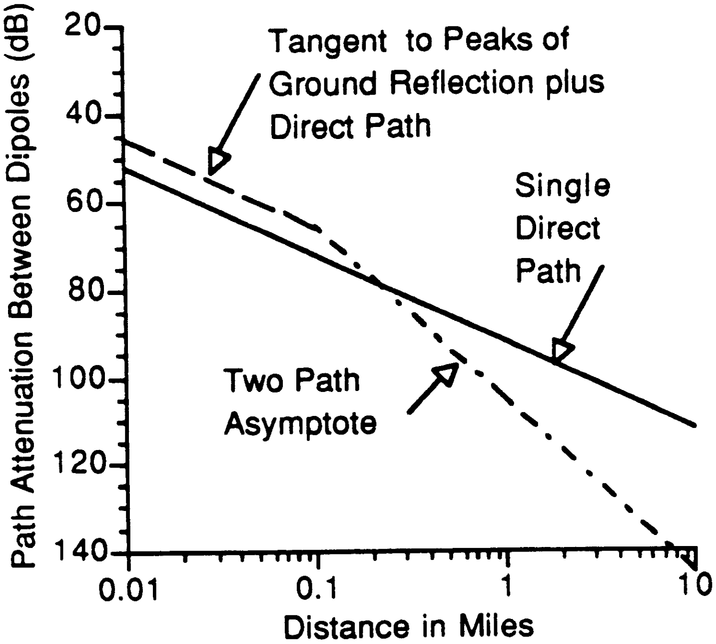
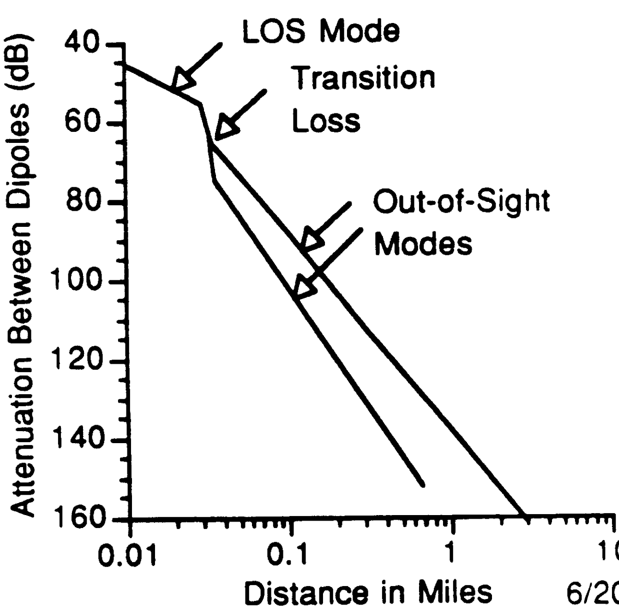


Fig. 1
LINE-of-SIGHT
(LOS)
MODELS

6/20/92-VG



6/20/92-VG

FIG. 2

OUT-of-SIGHT
(OOS)
MODEL

FIG. 3

DIFFRACTION MODELS

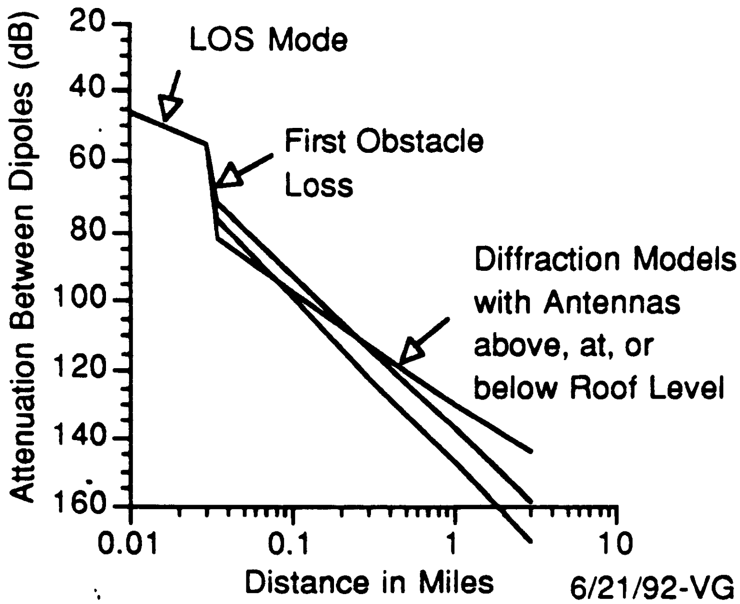


FIG 4 LOS STREET RUNS
Sites E,F,G,J,L,O,P
36 ft Antenna - 900 mHz

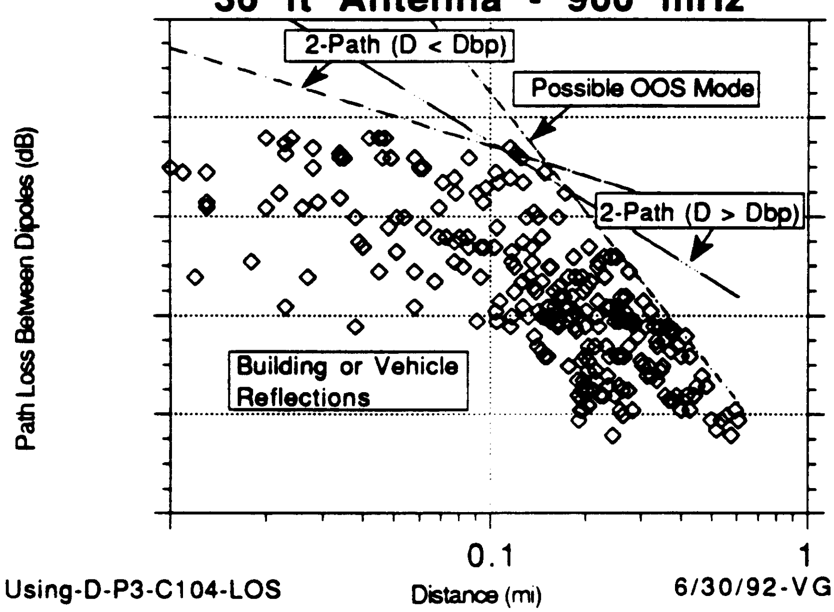


FIG. 5 LOS PROPAGATION MODEL TRENTON PARKING LOT 900 MHZ

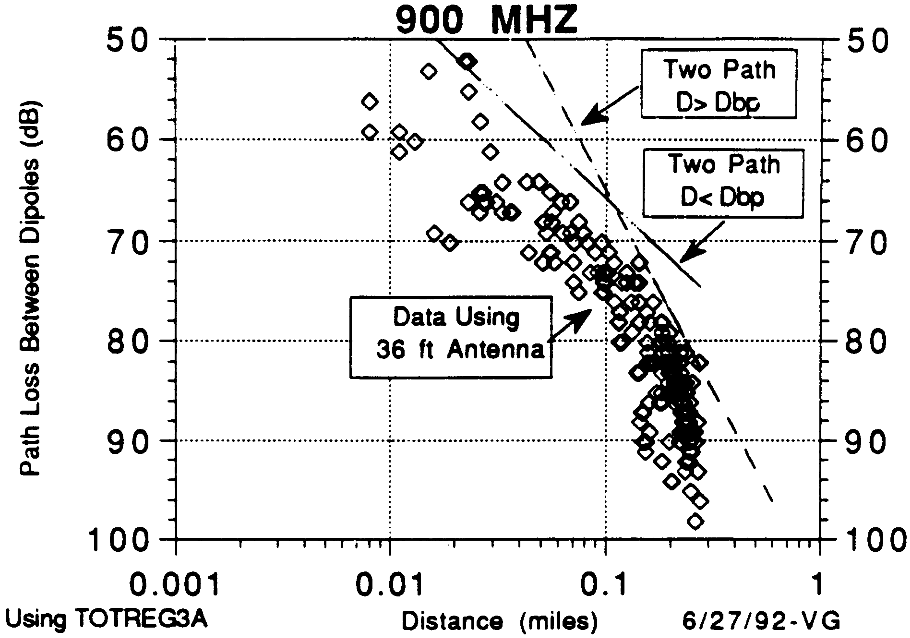
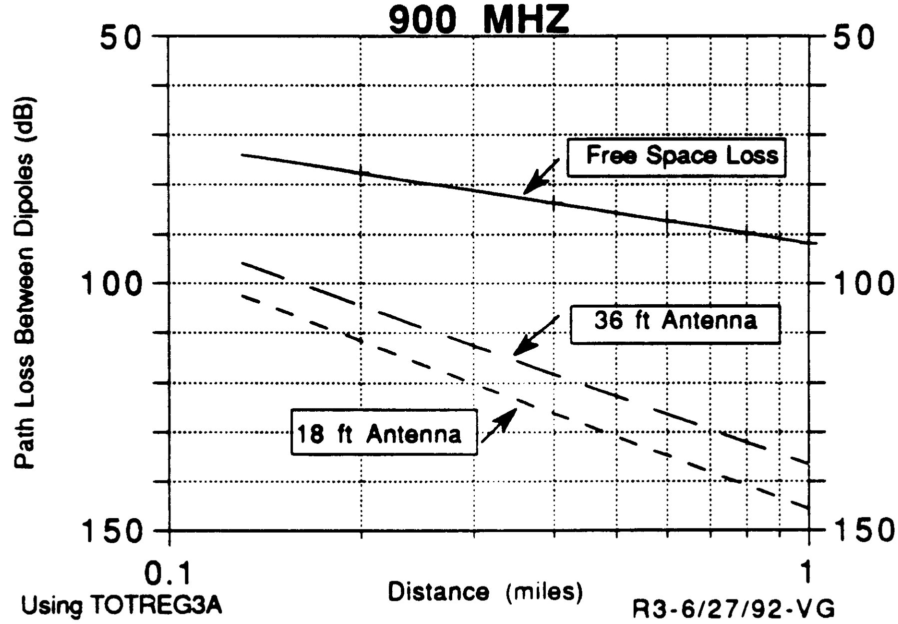


FIG. 6 DIFFRACTION PATH MODELS TRENTON SITES A and B 900 MHZ



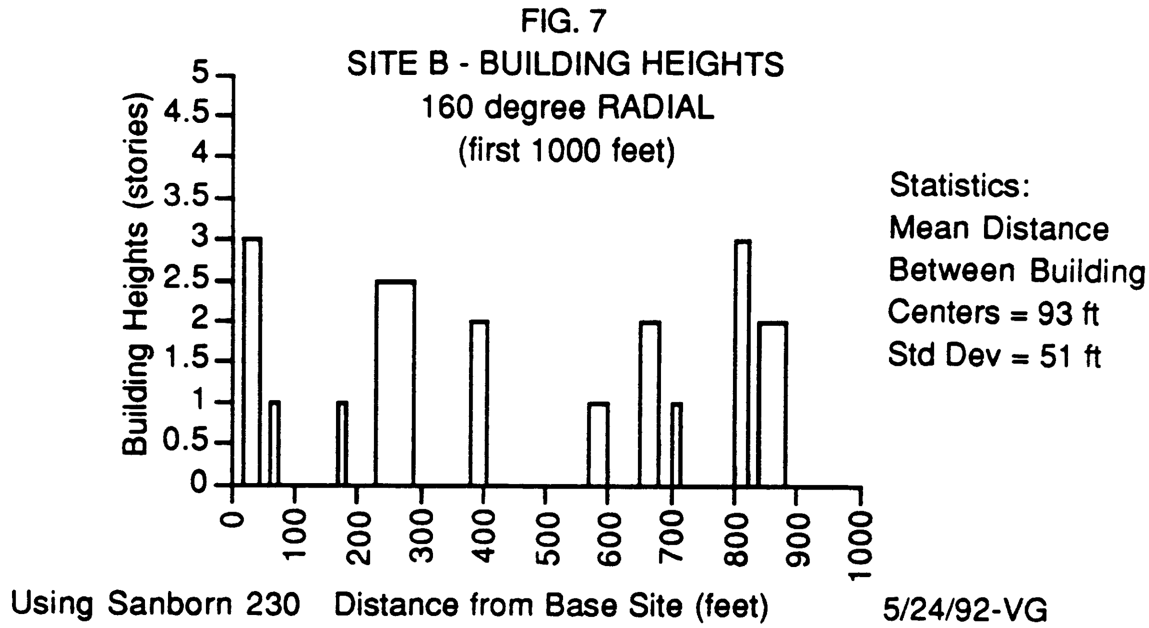


FIG. 7
SITE B - BUILDING HEIGHTS
160 degree RADIAL
(first 1000 feet)
Building Heights (stories)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
900
1000
Statistics:
Mean Distance
Between Building
Centers = 93 ft
Std Dev = 51 ft
Using Sanborn 230
Distance from Base Site (feet)
5/24/92-VG

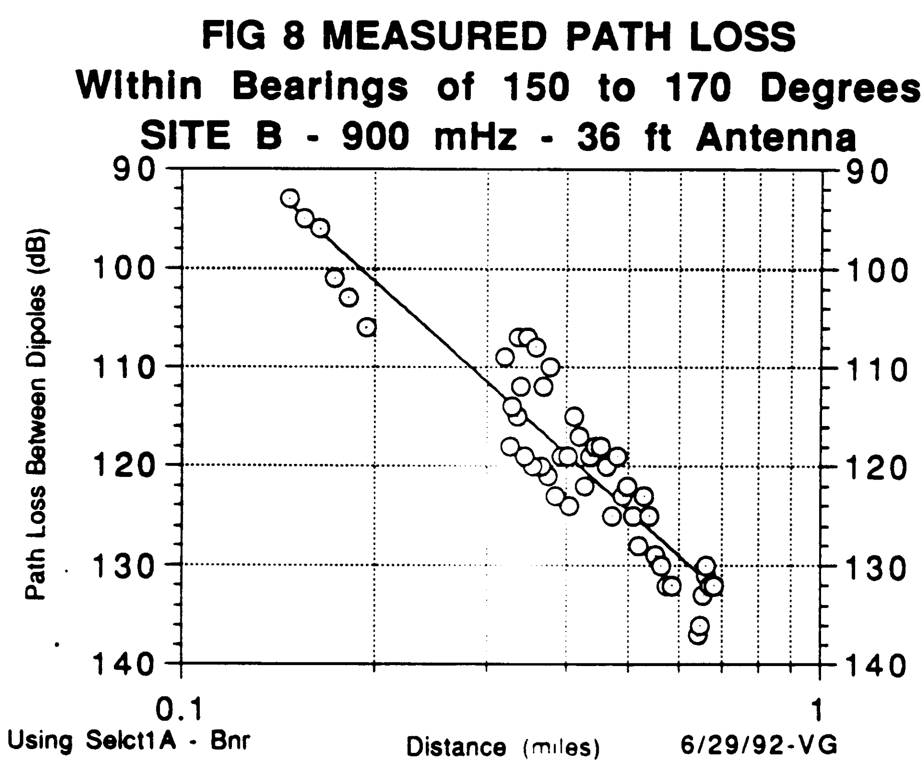


FIG 8 MEASURED PATH LOSS
Within Bearings of 150 to 170 Degrees
SITE B - 900 mHz - 36 ft Antenna
Path Loss Between Dipoles (dB)
90
100
110
120
130
140
0.1
1
Using Selct1A - Bnr
Distance (miles)
6/29/92-VG

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