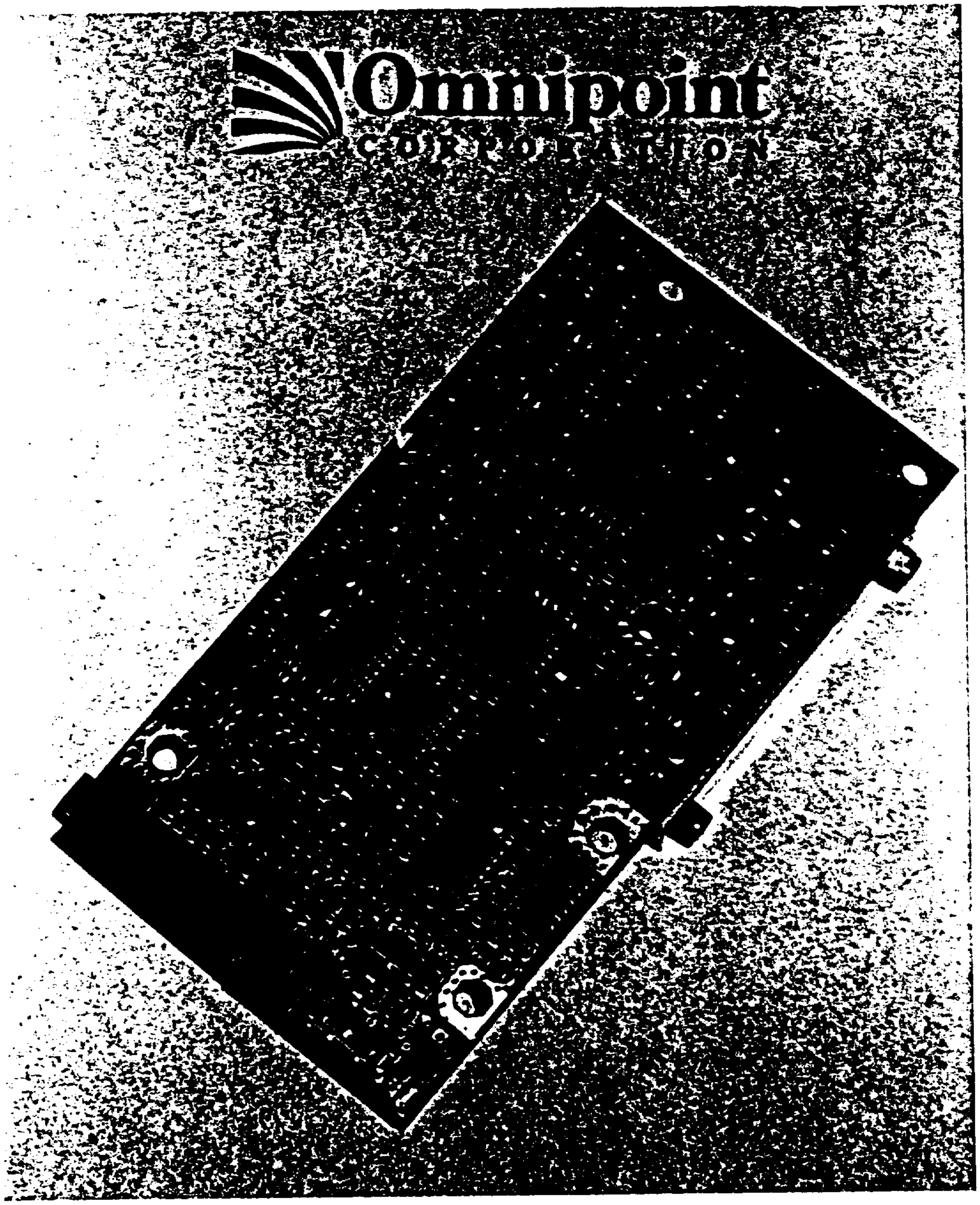
**This figure withheld from public disclosure.**

**Figure 3.4-1**

Omnipoint
CORPORATION




**Omnipoint Universal Data Module**
**Figure 3.4-2**

# 4 System Characteristics

## 4.1 MULTIPATH

Key to being able to operate any wireless service, especially one which requires radio coverage inside office structures, is the ability to withstand destructive multipath effects. It has been observed in Omnipoint's extensive tests that a number of different types of structures provide highly reflective environments and commonly cause fades on the order of 30 dB and more. In one particular building, delay spreads of up to 1.2 µsec in less than 400 feet were observed. Since multipath effects tend to be frequency selective in nature, wideband spread spectrum has proven to be an excellent choice for mitigating these destructive effects.

It should be noted, however, that wideband systems are not automatically robust in the presence of severe multipath signal fades just because they are wideband. The system must be specifically designed to overcome these effects, and the Omnipoint system was produced with this in mind. The Omnipoint spread spectrum system has been observed to perform with multiple frequency selective fades up to 35 dB with minimal degradation of bit error rates (BER), and no user discernible audible effects in the wireless phone hardware.

Typical multipath samples showing frequency selective fades from a number of different environments of up to 30 dB are detailed in Figures 4.1-1 through 4.1-4 along with a pure spectral plot in Figure 4.1-5.

### 4.1.1 Multipath Observations in Different Environments

Multipath effects in a highly diverse set of environments have been sampled and observed. Some of these environments include high, medium and low rise office buildings of varying construction, large open indoor atrium or

**This figure withheld from public disclosure.**

**Figure 4.1-1**

This figure withheld from public disclosure.

Figure 4.1-2

**This figure withheld from public disclosure.**

**Figure 4.1-3**

**This figure withheld from public disclosure.**

**Figure 4.1-4**

This figure withheld from public disclosure.

**Figure 4.1-5**

arena buildings, single level conference & hotel facilities, and open field line-of-site outdoor locations.

It has been observed that in typical indoor office structures, regardless of the height of the building, multipath fades on the order of 20 - 25 dB are common. These types of structures present typical highly reflective environments, with a combination of hollowcore/metal stud walls, temporary office cubicles (often of metal construction), and other reflective surfaces such as filing cabinets and desks, and in the case of the Omnipoint facility, metal enclosed RF shield rooms. Destructive signal recombination of several paths makes for a system design need that will continue to function in the presence of typical fades of 20-25 dB, with up to 35 dB fades not uncommon.

In open-air indoor facilities, such as atrium-type hotels or multi-purpose arenas, a different type of multipath phenomenon has been observed. Here, the problem appears to be not so much the combination of several reflected signals of varying strengths as it is additive signals of approximately the same strength but with varying time delays in their arrival at the reception point. This environment still poses significant frequency selective fading problems (up to 35 dB), but also measured delay spreads of up to 1.4 μsec, compared to delay spreads on the order of 400 nsec in typical office structures.

In open field line-of-site operations, multipath continues to be a factor, but initial measurements indicate that effects of signal reflections aren't as dramatic until the signal is transmitted in an area with multiple structures to provide additional multipath routes. In these situations fades on the order of 15 dB are typical, with maximum observed degradations of approximately 20 dB.

## 4.2 INTERFERENCE POTENTIAL

### 4.2.1 Omnipoint Spectral Density Characteristics

Omnipoint systems are designed to supply minimal interference to both primary and secondary users of shared frequencies. Although we have explored bandwidths of 5 MHz to 40 MHz, we have chosen to implement initial systems with either 9 MHz to 25 MHz depending on the application. With transmitted power from 10 mW to 1W, spectral densities range from 0.38μW/kHz to 0.11 mW/kHz, which will provide minimal interference to other systems operating in the band. For example, all systems adhering to the Part 15.247 rules and operating with minimal processing gains should function with no interference from Omnipoint systems.

### 4.2.2 Other Users of ISM bands

With continued and future scarcity of available bandwidth for new applications, the many present and myriad future users of these bands will have to design their systems with a high degree of interference rejection. Omnipoint systems have been designed with this future popularity of the ISM bands in mind, with minimum average true jamming margins on the order of 8 dB to 14 dB. Omnipoint recommends that future participants in these bands should plan on a minimum of 8 to 10 dB of interference rejection in order to operate with minimal degradations to bit error rates.

## 4.3 PROPAGATION

Omnipoint's success around the country has allowed for testing in various locations and environments, and has yielded a wealth of information on system performance and propagation effects in both the 900 MHz and 2.4 GHz ISM bands.

Test and Analysis Procedures

A least squares regression analysis was performed on each data set to form an estimate of propagation coefficient and standard deviation away from the regression curve. Propagation coefficient (Alpha) describes the rate at which signal strength falls off with range while sigma describes the variation in accordance with a log-normal distribution.

Short Range Indoors -

- In general, indoor measurements confirmed our expectation that propagation would be highly dependent on the specifics of the environment. In particular, we observed propagation coefficients ranging from 1.02 to as high as 5.93. This extreme variation in propagation coefficients precludes classic cellular frequency reuse patterns because of the high degree of variation. Large standard deviations were also observed, indicating substantial shadowing effects. Obtaining near universal coverage within a building will require more base stations in order to reduce shadowing effects. Alternatively, passive repeaters and reflectors may be used subject to aesthetic considerations.

- Measurements in a multi-story high rise office building demonstrated significant signal propagation between floors. This was especially true when users were located in exterior offices. Systems operating in this type of environment will have to be self-coordinating in terms of frequencies since different floors are likely to house different companies; a single network design regimen is unlikely. Our spread spectrum system accomplishes this by allowing for universal frequency reuse and/or dynamic channel allocation.

Short Range Outdoors -

- In the outdoor environment, at short ranges, we observed less variation in propagation coefficient but found it to be smaller than classical cellular values. Whereas typical cellular values are in the neighborhood of 3 to 4, we found that in most instances, at short ranges, outdoor propagation is more consistent with the free space value of 2. Because of this, spread spectrum systems will be increasingly favored from a capacity point of view; smaller propagation coefficients would force more infrequent frequency reuse.

- We found some evidence of ducting. In several instances, propagation coefficients of less than 2 were observed. Standard deviations were also smaller, reflecting a more homogeneous set of environments

Long Range Outdoors -

- We performed only one series of outdoors tests at 1925 MHz under what were essentially open field/undeveloped terrain conditions. Measured propagation coefficient was surprisingly low, about 1.49. Given the small amount of collected data this may be an anomaly and further testing is planned to provide a more complete picture.

The test setup for these tests was the same in all cases. A bandpass filtered BPSK IF transmit signal was upconverted to the desired output frequency using a mixer and LO source. The output was then passed through a second bandpass filter to remove the undesired mixer products and the LO leakage. This signal was then amplified by a series of amplifier stages to a power of 1,000 mW at 1880 MHz and 500 mW at 2430 MHz.

The only changes necessary to change frequency was to change the LO frequency and to change the tuning of the second bandpass filter. The discone antennas used in the test are described elsewhere in this report and have sufficient bandwidth to cover both frequencies. The transmitter remained at a fixed location. The spectrum analyzer and its preamp and antenna were rolled around on a small cart to take measurements at a number of locations. Indoors, twenty eight locations were measured on the transmitter's floor. Nine other locations were tested up one floor and 9 others up two floors.

Antennas used in the field tests were disc-cones, tested in pairs to determine the antenna loss or gain characteristics, compared to theoretical dipoles. FCC bulletin OET 55 was referenced for site measurements. Theoretical site attenuation above 80 MHz can be calculated from;

$$A = 20 \log_{10} D + 20 \log_{10} F_m - G_s - G_r - 27.6 - R$$

where:

$A$ = site attenuation in dB
$D$ = distance in meters between the source antenna and the receiving antenna.
$F_m$ = Frequency in MHz
$G_s$ = Gain in dB of the source antenna relative to isotropic
$G_r$ = Gain in dB in the receiving antenna relative to isotropic
$R$ = contribution to ground reflected radiation.

Changing the units of "D" to miles, the equation may be rewritten as :

$$A = 20 \log_{10} D + 20 \log_{10} F_m - G_s - G_r + 37 - R$$

In our antenna test, D = 10 ft. At a center frequency of 2430 MHz, the theoretical loss between two dipoles is:

$$A = 20 \log_{10} (10/5280) + 20 \log_{10} (2430) - 2.15 - 2.15 + 37 + 4.7 \text{ dB}$$
$$= 50.65 \text{ dB}$$

Cable loss was measured at 3.3 dB. Therefore total loss expected was 54 dB. Actual loss was measured at 52.5 dB, 1.5 dB less than expected. Assuming half of the error is from each antenna, the gain of each antenna is 2.9 dBi.

In our second antenna test, at a center frequency of 1930 MHz, the theoretical loss, between two dipoles is:

$$A = 20 \log_{10} (10/5280) + 20 \log_{10} (1930) - 2.15 - 2.15 + 37 + 4.7 \text{ dB}$$
$$= 48.66 \text{ dB}$$

Cable loss was measured at 2.5 dB. Therefore total loss expected was 51.2 dB. Actual loss was measured at 50.0 dB, 1.2 dB less than expected. Assuming half of the error is from each antenna, the gain of each antenna is 2.75 dBi.

A third antenna was measured at 1930 MHz, for comparison. This antenna was a 1/4 wave vertically polarized element fed by a bazooka balun. Its equivalence at this frequency, compared to the disc-cone antenna, was verified by substitution measurements. Its gain measured 2.6 dBi.

The gain measurements assume 4.7 dB ground reflection and may differ due to this assumption, however this error seems negligible.

Equipment used in this test procedure included:

HP8660C signal generator with 86632B and 86603A plug ins.
HP8595B spectrum analyzer.
RG223 double shielded coax cable with SMA terminations.
Narda Model 3022 bi-directional coupler was used to verify antenna match.

Most of the work detailed here was performed with Omnipoint's first generation telephone systems, which utilize up to four remote users per base station, and transmit in a time division duplexing mode, with dual antenna diversity at the base, transmitting at 100 mW. Figure 4.3-1 details in block diagram form the test fixtures detailed above, and Figures 4.3-2 through 4.3-6 are photos of these fixtures, including mobile and base station systems.

Coverage plots generated were based on subjective tests relative to a Grade of Service established by Omnipoint. This Grade of Service is similar to standard analog cellular circuit merits, but adapted for the digital voice that is employed in