7150 Campus Drive, Suite 155, Colorado Springs, CO 80920

United States of America
FEDERAL COMMUNICATIONS COMMISSION
EXPERIMENTAL
SPECIAL TEMPORARY AUTHORIZATION

EXPERIMENTAL
(Nature of Service)

KK2XCV
(Call Sign)

XD FX & MO
(Class of station)

S-1223-EX-93
(File number)

NAME OMNIPOINT CORPORATION

Vicinity of Colorado Spring, CO
(Location of station)

Special Temporary Authority is hereby granted to operate the radio transmitting apparatus described below:

Frequency MHz	Authorized Power (watts)	Emission Designator
1850-2200	5 (ERP)	1

1. Licensee is authorized to use various modes of modulation, bandwidth, and data rates. None of these modes of transmission shall extend beyond the band band limits set forth above.

This special temporary authorization is granted upon the express condition that it may be terminated by the Commission at any time without advance notice or hearing if in its discretion the need for such action arises. Nothing contained herein shall be construed as a finding by the Commission that the authority herein granted is or will be in the public interest beyond the express terms hereof.

This special temporary authorization shall not vest in the grantee any right to operate the station nor any right in the use of the frequencies designated in the authorization beyond the term hereof, nor in any other manner than authorized herein. Neither the authorization nor the right granted hereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934. This authorization is subject to the right of use of control by the Government of the United States conferred by Section 706 of the Communications Act of 1934.

This authorization effective August 5, 1993 and will expire 3:00 A.M. EST. December 31, 1993

FEDERAL COMMUNICATIONS COMMISSION

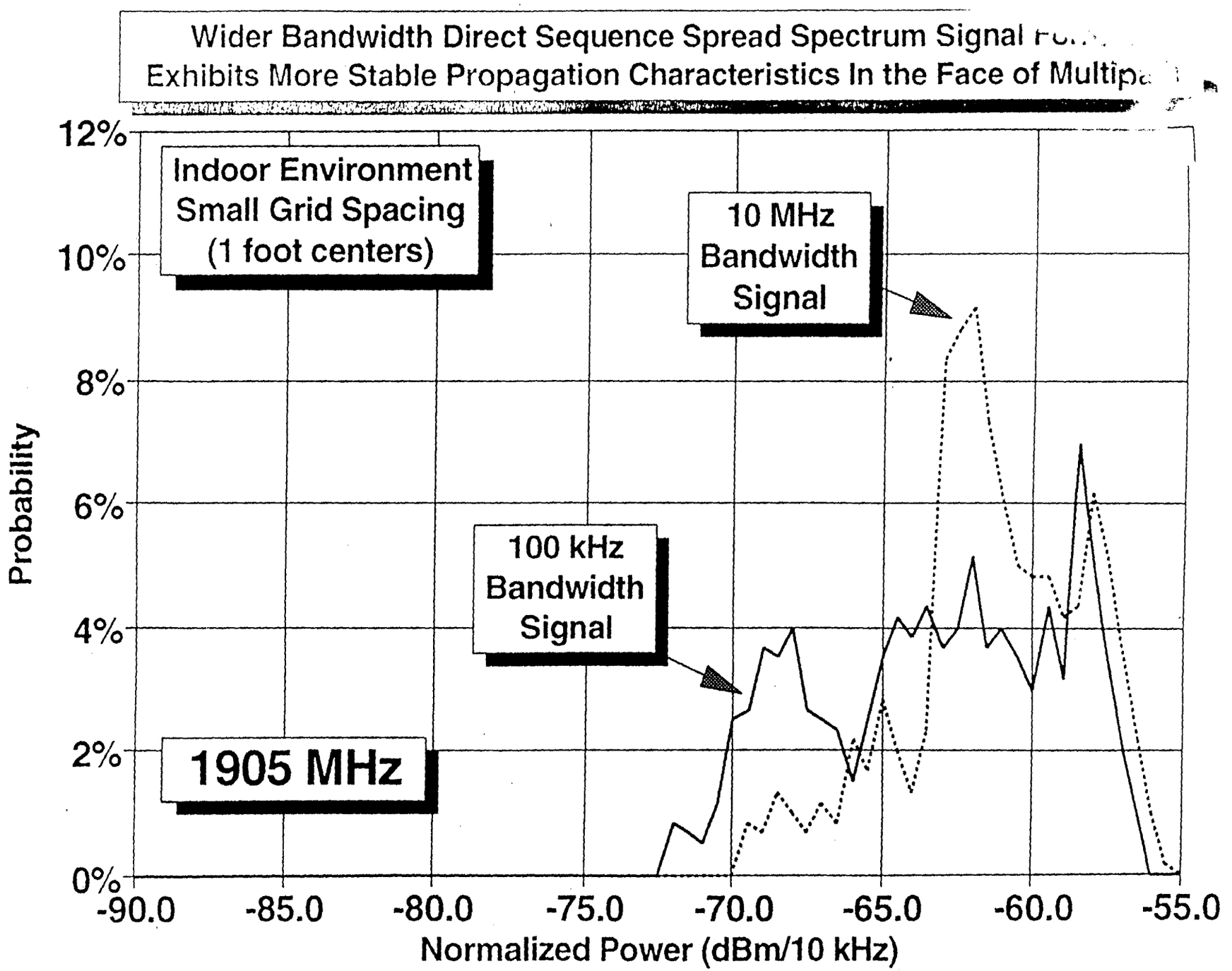

Wider Bandwidth Direct Sequence Spread Spectrum Signal
Exhibits More Stable Propagation Characteristics In the Face of
Indoor Environment
Small Grid Spacing
(1 foot centers)
10 MHz
Bandwidth
Signal
100 kHz
Bandwidth
Signal
1905 MHz
Probability
12%
10%
8%
6%
4%
2%
0%
-90.0
-85.0
-80.0
-75.0
-70.0
-65.0
-60.0
-55.0
Normalized Power (dBm/10 kHz)

Figure 3-1

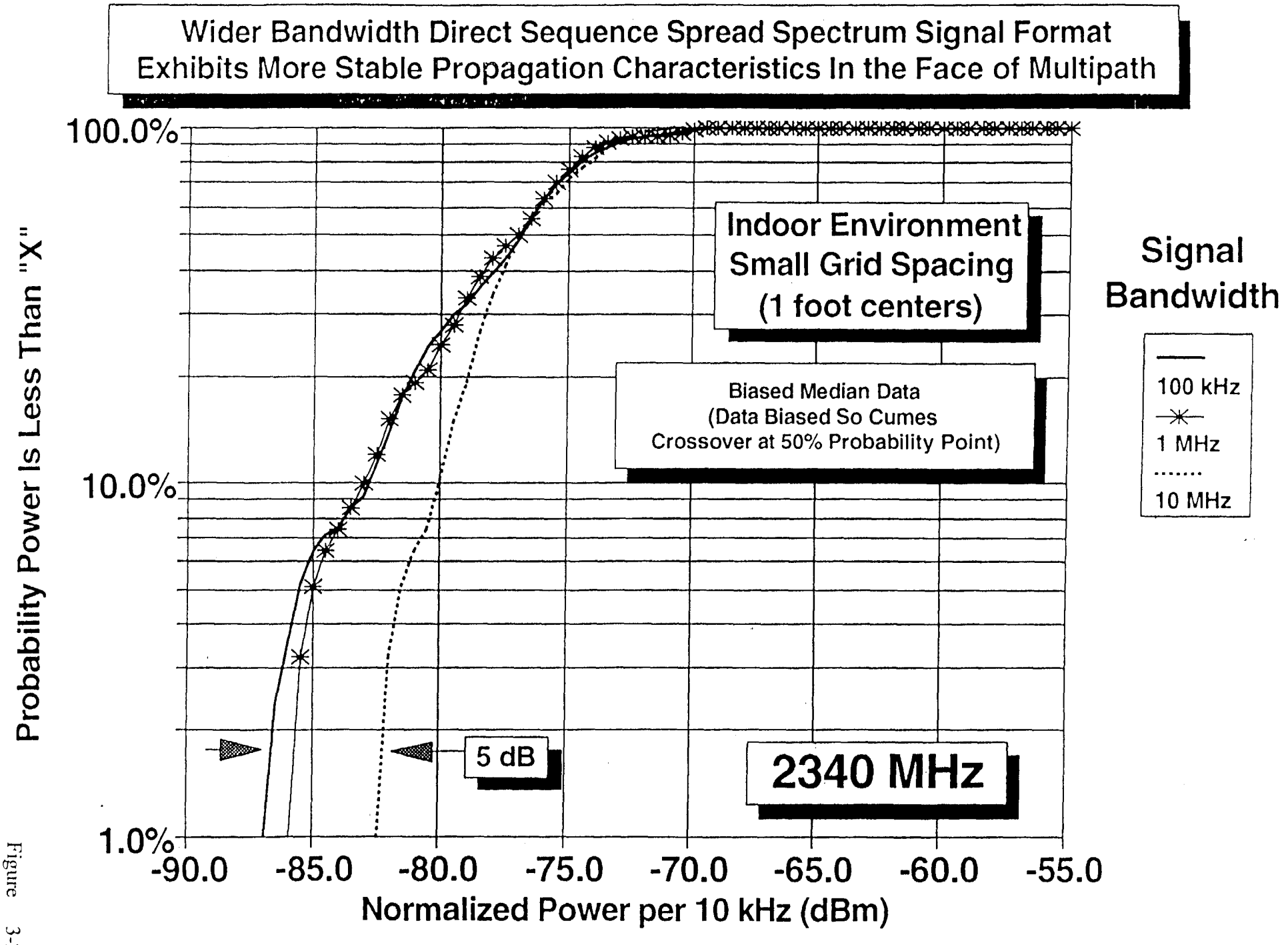
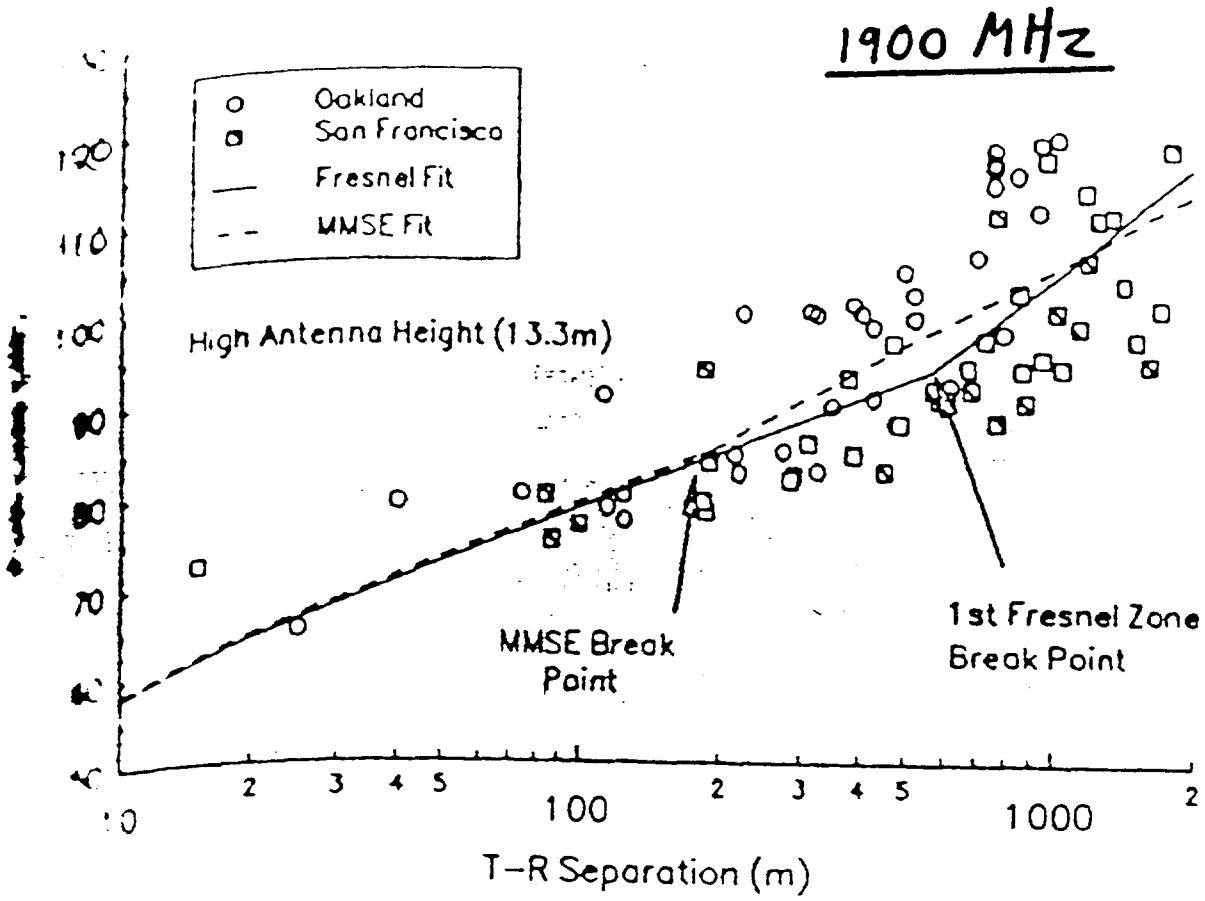

Wider Bandwidth Direct Sequence Spread Spectrum Signal Format
Exhibits More Stable Propagation Characteristics In the Face of Multipath
Indoor Environment
Small Grid Spacing
(1 foot centers)
Biased Median Data
(Data Biased So Cumes
Crossover at 50% Probability Point)
5 dB
2340 MHz
Signal
Bandwidth
100 kHz
1 MHz
10 MHz
100.0%
10.0%
1.0%
-90.0
-85.0
-80.0
-75.0
-70.0
-65.0
-60.0
-55.0
Normalized Power per 10 kHz (dBm)
Probability Power Is Less Than "X"

Figure 3-2



Path loss vs. T-R separation for high antenna height.

	Fresnel Best-Fit				MMSE Best-Fit				
	n_1	n_2	σ (dB)	d_f (m)	n_1	n_2	σ (dB)	d_b (m)	h_b (m)
Low	2.18	3.29	8.76	159	2.20	9.36	8.64	884	3.7
Med	2.17	3.36	7.88	366	2.14	6.87	7.23	884	8.5
High	2.07	4.16	8.77	573	2.03	2.79	8.34	190	13.3

Table 1: Path loss exponents, standard deviations, and break points for 1st Fresnel zone and MMSE break point curve fits for each antenna height.

5. Blackard et. al., *Path Loss & Delay Spread Models as a Function of Antenna Height for Microcell System Design*, IEEE 1992 Vehicular Technology Conference Proceedings.

Figure 3-3

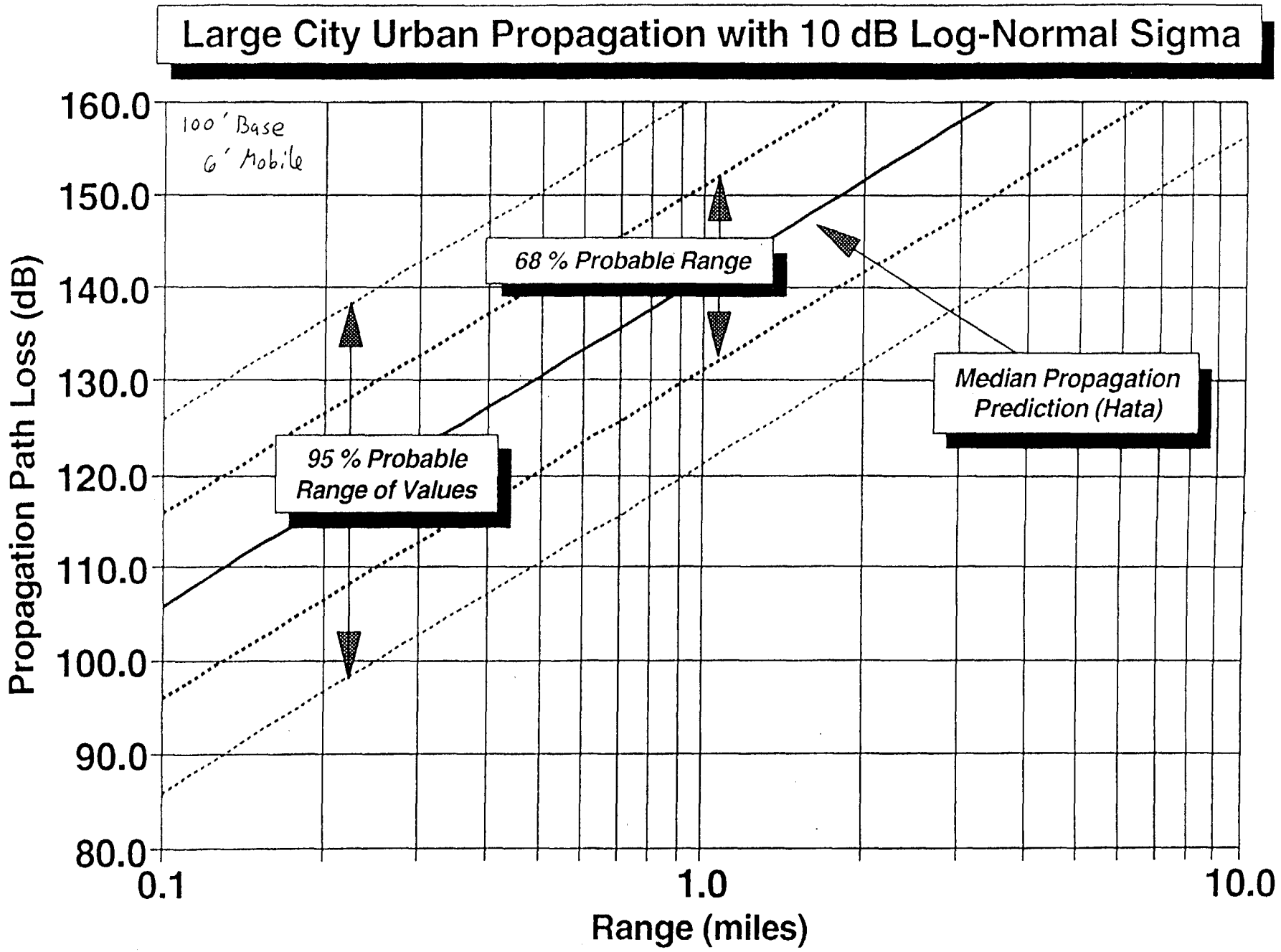

Large City Urban Propagation with 10 dB Log-Normal Sigma
100' Base
6' Mobile
68 % Probable Range
95 % Probable Range of Values
Median Propagation Prediction (Hata)
Propagation Path Loss (dB)
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0.1
1.0
10.0
Range (miles)

Figure 3-4

PCS Cell Radius Will Be Much Smaller Because of Differences In Propagation and Expected Lower Handset Transmit Power

Hata Large City Urban with Log-Normal Sigma of 10.0 dB, 9.0 dBd Base Ant.
Mobile at 6.0', -100.0 dBm Sens., 0.0 dBd Antenna, 0.0 dB Penetration Loss

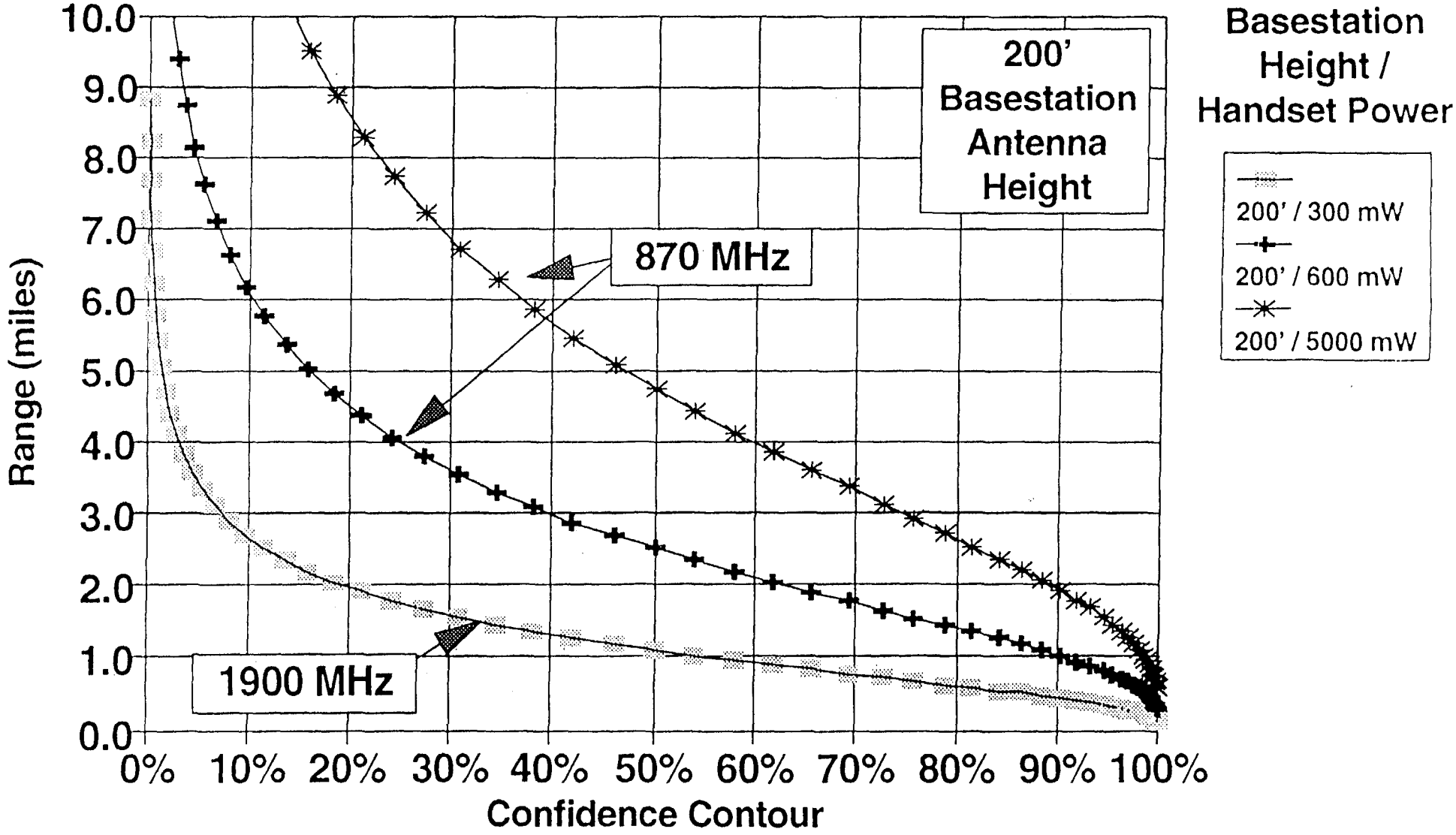


Figure 3-5

PCS Cell Radius Will Be Much Smaller Because of Differences In Propagation and Expected Lower Handset Transmit Power

Hata Large City Urban with Log-Normal Sigma of 10.0 dB, 9.0 dBd Base Ant.
Mobile at 6.0', -100.0 dBm Sens., 0.0 dBd Antenna, 0.0 dB Penetration Loss

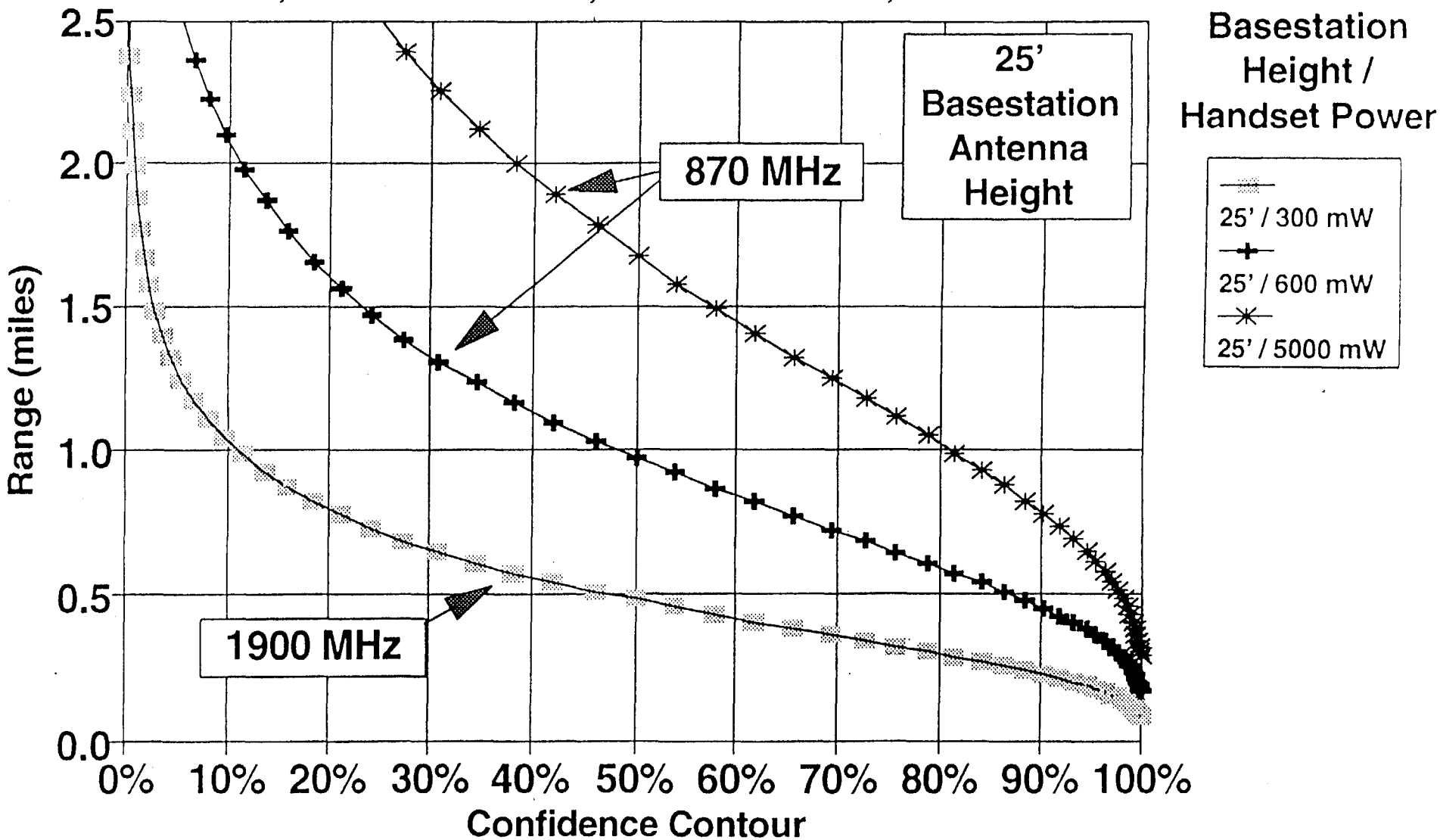
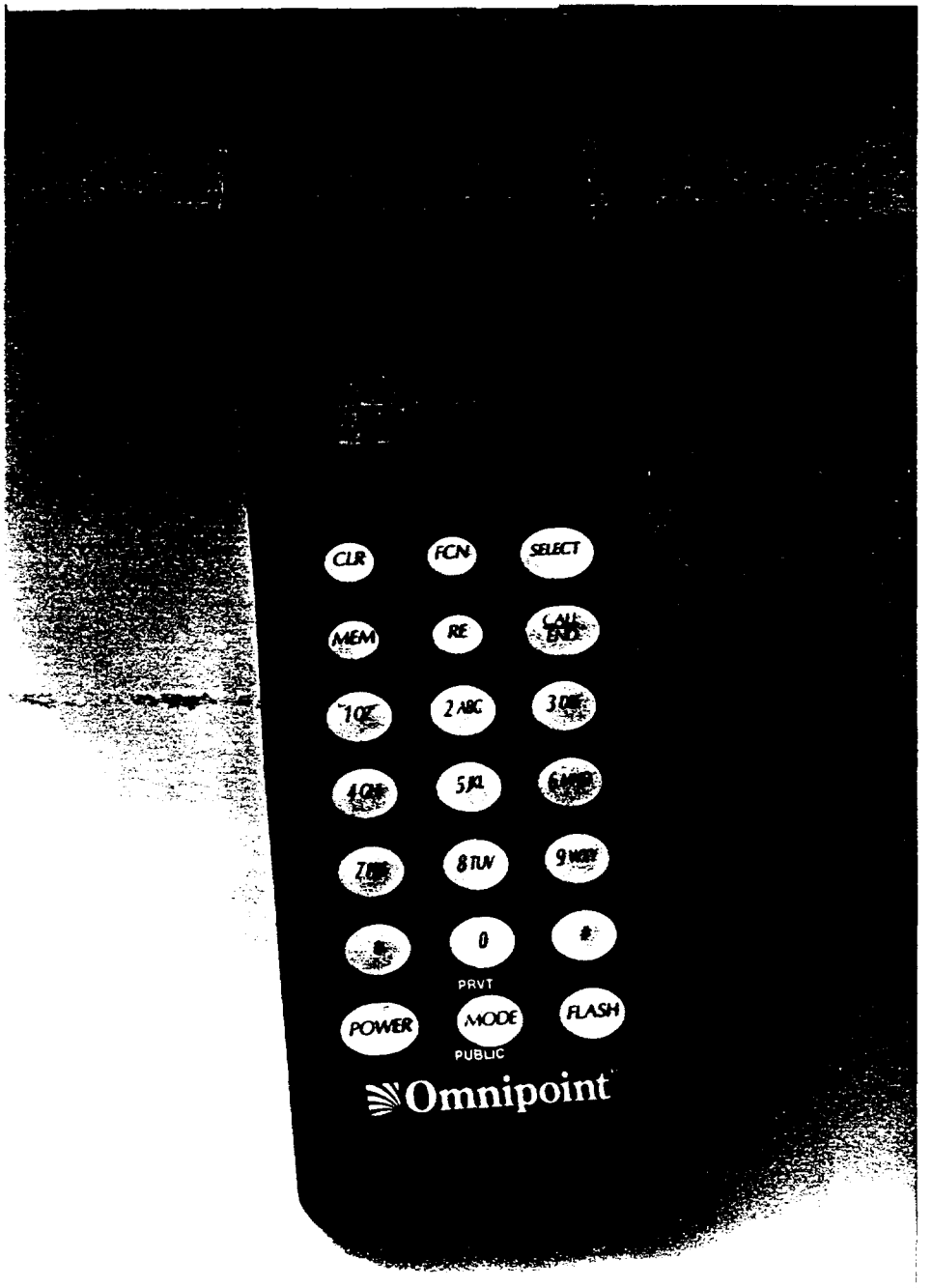
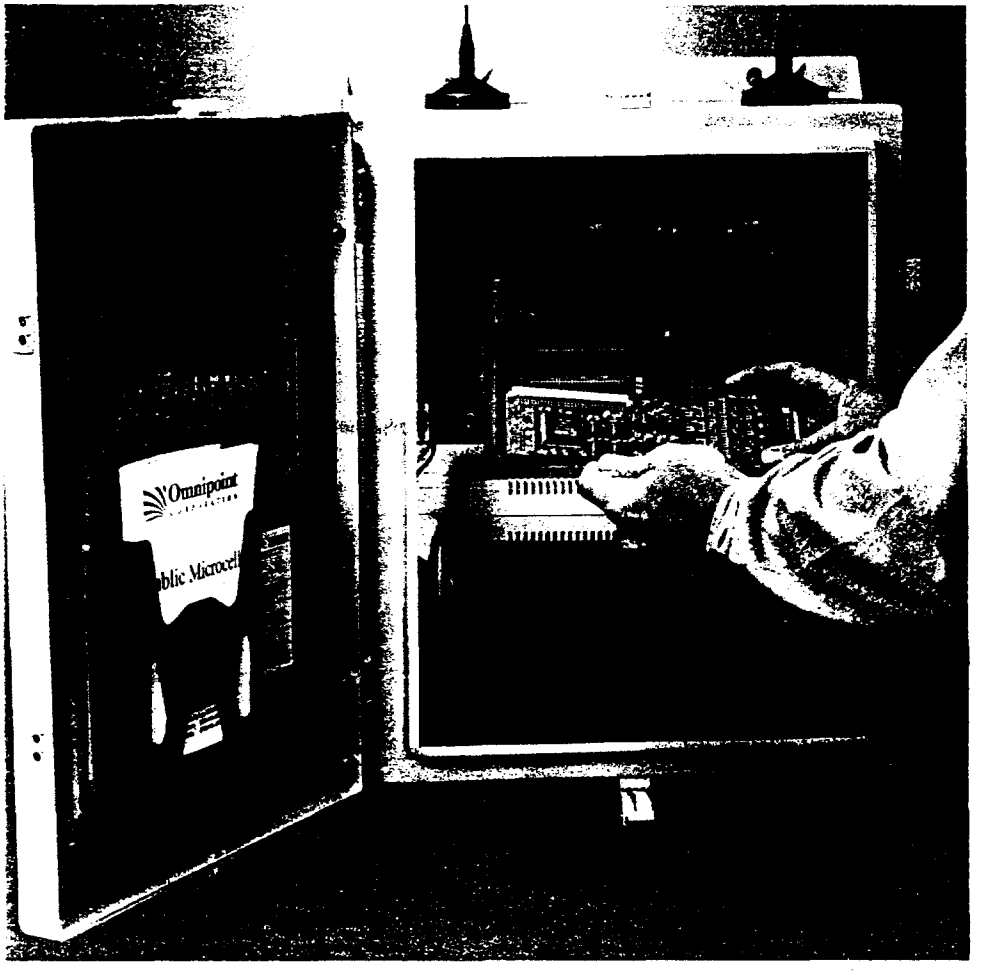


Figure 3-6


CLR
FCN
SELECT
MEM
RE
2 ABC
5 JKL
8 TUV
0
PRVT
POWER
MODE
PUBLIC
FLASH
Omnipoint

Omnipoint
Power
Master
Sync
CUSTOM
DISPLAY


Omnipoint
blic Microcell

LCC Incorporated

August 17, 1993

To whom it may concern:

LCC has participated in tests with Omnipoint over the last several months including tests for New York City and Colorado Springs. The purpose of the tests is to verify various design assumptions and create valid design rules for constructing a personal communications network using the Omnipoint system. The tests involved set up of test transmitters, extensive data collection on streets and in buildings, and data processing and analysis to allow support of test conclusions. The data collected, analysis, and conclusions are contained in this report. Further, LCC personnel verified and replicated the performance of the Omnipoint system in Manhattan with respect to the coverage plots and drive tests. I validate that all data, analysis, and conclusions are correct and accurately reflect the characteristics found for personal communications.

Louis Olsen

Louis Olsen
Director of Engineering

Arlington Courthouse Plaza II 2300 Clarendon Boulevard, Suite 800 Arlington, Va. 22201 (703) 351-6666 Fax (703) 516-4950

Attachment
OFS Sharing Revisited (Again)

Five months after the Reply deadline, Qualcomm requested a "Motion for Leave to File Supplemental Comments", in which they attached an 8 page Appendix A presenting their views on the OFS sharing problem. However, in Qualcomm's comparison of interference potential between Omnipoint's system and theirs, Qualcomm loads their cells with only one user, ignores disparities between FDD and TDD systems regarding frequency availability, and demonstrates an insensitivity to how a FDM-FM OFS receiver actually operates. At the same time, they make inaccurate claims about the architecture and performance of Omnipoints system. Further, they portray Omnipoint as distorting the American Personal Communications (APC) results,[1] denying the validity of Omnipoint's analysis by simply saying it isn't so while offering no corroborating experimental evidence.

Qualcomm's OFS Sharing Analysis is Severely Flawed in Several Ways

> *"Of course, because the narrowband signal occupies one one hundredth the bandwidth of the Omnipoint signal, it will cause interference to far fewer OFS users."* Qualcomm, Page 4 of Appendix A

Such a statement shows a lack of knowledge of the typical FDM-FM radio's signal structure and basic OFS operational characteristics. As an example, analog FDM-FM OFS transmissions universally use different but specific OFS narrowband frequencies for:

[1]Re: American Personal Communications KC2XDM, FCC File No. 2056-EX-ML-91, Tenth Progress Report. dated January 26,1993.

- AGC functions
- Space diversity combiner control
- Squelch control
- Link continuity monitoring
- Baseband SSB demodulation

Interference with any of these functions generally causes catastrophic OFS link failure. Even a single narrowband interferer can concentrate essentially all of it's energy in the spectral region of one of these control frequencies and thus drop the link with substantially less radiated power than a wideband system. A narrowband CDMA-only PCS system has the further problem that it layers the power of each user on top of the same OFS frequencies. **These control frequencies vary from vender to vender andequipment type to equipment type and are also dependent on FDM baseband groupings.** Qualcomm's statement that narrowband interferers harm a relative few channels, is quite simply, wrong and is just the type of assumption that will lead to damaging interference to incumbent OFS users.

As another example of how wrong Qualcomm is, many OFS users employ fixed FDM channel allocations and group routings to support required functions. For example, FDM channel 22 for one OFS link might be allocated to modem modulated data for control and monitoring of a particular pipeline valve, FDM channel 912 to another, and so on. Undetected disruption of any channel could lead to obvious problems. OFS provisioning doctrine is very different from common carrier doctrine because of the large number of "semi-permanent" connections and relative few alternate routings.

Qualcomm's Comparison of Omnipoint's System with CT-2 is Invalid

In their original January 29, 1993 comments on Omnipoint's system Qualcomm argues that:

> *"there is no significant difference in exclusion zone radius between Omnipoint's system and the generic narrowband system"*[2]

They base this on the following statement

> *"If Omnipoint's system transmits the same number of speech bits over the same RF channel using the same antenna as the CT-2 system, its average power would be comparable to that of the CT-2 system. Thus for example, an Omnipoint mobile transmitting 1 watt peak power is equivalent to the CT-2 system transmitting 40 milliwatts (50%/2% x 40 mW = 1 Watt)"*[3]

In their most recent attack they repeat this argument almost verbatim saying

> *"Clearly, both a narrowband system (say, the 100 kHz bandwidth) and a wideband system (Omnipoint's 10 MHz bandwidth) must transmit the same energy per bit to achieve the same link performance..."*[4]

There are several fundamental flaws in Qualcomm's argument. First, the notion that Omnipoint uses average power in our interference calculations is wrong; we do not and never have.

---

[2]Page 20, Qualcomm 29 January 1993 filing

[3]ibid.

[4]page 1, Appendix A

Qualcomm then makes a rather lengthy argument about "temporal concentration" but the fact is, from the OFS user's perspective peak power is the important parameter. Qualcomm agrees with this statement:

> *"victim microwave receivers are sensitive to the peak power of the interfering waveform, not the average power."*[5]

Note that Qualcomm's temporal concentration arguments based on range and bits per PCS channel of different PCS systems are irrelevant to the OFS user concerned about interference. The factor that is very relevant to the OFS user is aggregate peak PCS power, ie what is the peak power of each PCS transmitter and how many PCS transmitters are active simultaneously, regardless of the efficiency of the PCS system or the PCS operator's service goals with respect to range, data raate, or contiguous coverage. Qualcomm's starting premise that PCS systems must be equal is actually only relevant to PCS debates on the performance characteristics of different PCS systems. Whether a PCS system uses small cells, efficient modulation formats, or even islands of coverage is a function of the PCS operators service definition.

However, let us consider Qualcomm's assumption that the PCS services should be identical in performance, as based on range and bits, and then consider the sharing problem. First, a narrowband PCS signal experiences more propagation impairments than a wideband PCS system. Narrowband systems are subject to deep, "notch like" fading and consequently must transmit at much higher powers to overcome these fades. A typical narrowband system requires a 5 - 13.5 dB higher transmit power relative to a wideband system to obtain the same bit rate in Rayleigh fading (depending on delay spread). Qualcomm recognizes this effect[6] and even notes that we take advantage of it (although they give us no credit for it in their sharing analysis).

---

[5]page 2, Appendix A.

[6] Price&Green also recognized this in their 1958 paper: "A Communication Technique for Multipath Channels", Proc. IRE vol.46, pp 555-570, March

Second, regarding sharing, a major difference is that multiple CT-2 transmitters will be active simultaneously in a cell whereas in the Omnipoint system, only one transmitter is active at a given time, thus less interference is seen by the OFS receiver.

In actuality, the disparity is even greater since Omnipoint uses a much more efficient modulation format than CT-2. Among the many advantages associated with Omnipoint's direct sequence spread spectrum format is an ability to employ higher order orthogonal[7] spreading functions thereby allowing an Omnipoint system to increase the data rate without increasing the symbol rate and without having to increase RF carrier bandwidth. By providing for operation at significantly lower Eb/No than a CT-2 like modulation, transmit powers can be further reduced relative to other PCS systems with the same data rate. At the same time, the lower symbol rates improves resistance to intersymbol interference effects caused by multipath.

The use of Omnipoint's higher order modulation format can improve Omnipoint's performance an additional 5 - 6.5 dB at a BER of 10^{-3} relative to the CT-2 format. Thus, from the above two factors alone, to obtain the same data rate as a CT-2 type modulated system, the Omnipoint system could operate with well over 10 dB less transmitted power. Indeed Omnipoint systems are currently operating over distances far in excess of 1.9 GHz CT2 systems while transmitting seven times the data rate with only 2 - 2.5 times the transmit power.[8].

As we have repeatedly demonstrated[9], in a one transmitter to one transmitter comparison of different PCS technologies with respect to interference potential, direct sequence spread spectrum modulation helps greatly by spreading the energy over the OFS receive bandwidth.

---

[7]In the context of this discussion, we actually mean "sufficiently orthogonal". Perfectly orthogonal code exist only in a mathematical sense; after modulator and channel impairments, complete orthogonality ceases to exist.

[8]Note also that differences in transmission data rates per user, such as those due to different vocoder requirements, will also result in different transmit energies per user.

[9]Omnipoint May 4, 1992, June 25, 1992, and March 1 , 1993 filings

However, in comparison with a Qualcomm style spread spectrum CDMA-only system, we must consider the many transmitters versus one transmitter interference scenario.

In summary, Qualcomm's comparison of Omnipoint's system to CT2 is based only on duty factor and bit rate and is grossly incomplete when calculating interference to an OFS user. The wider bandwidth waveforms that Omnipoint uses exploits environmental features and technical design options in ways that are simply not available to the narrowband waveform designer. Major reductions in transmitter power requirements are made possible through the use of implicit diversity structures within the waveform design itself. Omnipoint's spread spectrum TDMA implementation employs a higher order modulation technique and couples this with lower spectral density. This means that Omnipoint's system truly causes less interference to OFS incumbents at high data rates, and this is what has been tested in the field by multiple parties. The overly simplistic analysis that Qualcomm uses does not consider these aspects of the design process, choosing instead to simply ignore the above benefits of the Omnipoint techniques.

Qualcomm's Sharing Comparison Claims are Also Flawed

In their requested Supplemental Comment's appendix A, Qualcomm claims *"the Qualcomm system has an advantage of 42 dB in interference potential over the Omnipoint system ..."*[10] Taken at face value, Qualcomm is saying they can broadcast with an effective radiated power of 1.585 kilowatts without causing interference to an OPS receiver from the same location that an Omnipoint system transmitting at 100mW will cause interference.

To start with, Qualcomm ignores a key distinction between Omnipoint's TDMA system and their CDMA-only system. CDMA-only systems have multiple transmitters active simultaneously within a cell that contribute to the overall interference picture. Omnipoint's system only has one transmitter on at a time.

[10] page 7 of Appendix A

Next, Qualcomm makes a major issue of the so called "temporal concentration of energy" associated with other TDMA systems and proceeds to give themselves 17 dB of credit because they operate with 100% duty cycle. However, they did not consider the benefits which Omnipoint has from employing the higher order modulation as noted above, and they neglect to mention the radically different interference environments the two systems operate in. In a single cell environment, Omnipoint's TDMA system must only transmit enough energy to overcome thermal noise power since only one transmitter is on at a given time even when fully loaded. In a fully loaded Qualcomm CDMA single cell, there are the equivalent of 18 other transmitters on at the same time, on the same frequency. This has the effect of increasing interference potential into an OFS receiver since the CDMA transmission powers sum up in the OFS receiver.

In the multiple cell environment, the situation becomes even more complex since competing cochannel cells now contribute to the interference picture within the cellular system. In Omnipoint's TDMA system, an allocation must be made for collisions between transmissions from other cochannel cells. However, one of the reasons Omnipoint uses direct sequence spread spectrum is to permit operation at lower C/I ratios (more interference). The exact allocations necessary depend on exact spreading ratios employed, reuse patterns, and most especially, propagation characteristics. Interestingly, the capacity of N=1, pure CDMA systems such as Qualcomm's are extremely sensitive to transitions in propagation characteristic.

Qualcomm's general capacity claims[11] are based on the assumption that signal strength falls off as $1/R^4$. However, at shorter ranges, signals tend to fall off with a $1/R^2$ characteristic. This has

[11]K.S.Gilhousen,"On the Capacity of a Cellular CDMA System", IEEE Transactions on Vehicular Technology, May 1991

been confirmed by a myriad of researchers[12 13 14 15] as well as Omnipoint's own experimental data. In a sense, there is a breakpoint in propagation coefficient. Rappaport and Milstein[16] have conducted theoretical studies to establish the impact of propagation variations on pure CDMA only systems using a two-ray model. Of particular interest, they found that **by changing CDMA cell radius from 10 km to 2 km, CDMA capacity drops by a factor of 6**. Discussing a 2 km cell radius case, Rappaport and Milstein observe:

> *"This is more than six times (8 dB) lower than the frequency reuse obtained using the exact same channel model except with d = 10 km"*

Interference from nearby cells leaks into adjacent cells much more readily in an N=1 system such as Qualcomm's and effectively reduces capacity. Compared with an N=3 reuse pattern, the nearest cochannel basestation neighbors are a factor of 1.73 closer and nearest cochannel handset neighbors are a factor of 2.31 closer[17]. Moreover, all of the CDMA-only transmitters and receivers are on the same frequency in every cell, whereas in Omnipoint's system in addition to

---

[12]Telesis Technologies Laboratory, "Experimental License Progress Report", August, 1991

[13]Henrik Borjeson, "Outdoor Microcell Measurements at 1700 MHz", IEEE VT-92 Proceedings pp. 927-931

[14]Bell Atlantic Mobile Systems, "Experimental Report", 1 Feb, 1993

[15]Vinko Erceg et al. "Urban/Suburban Out-of-Sight Propagation Modeling", IEEE Communications Magazine, June 1992

[16]T.S. Rappaport & L.B. Milstein, "Effects of Radio Propagation Path Loss on DS-CDMA Cellular Frequency Reuse Efficiency for the Reverse Channel", IEEE Transactions on Vehicular Technology, August 1992

[17]Ratios were obtained using idealized hexagonal cell structures. In actuality cell structure is controlled by specific environmental factors but the trend remains the same; N=1 systems have closer cochannel neighbors.

the N=3 advantage only one user in each cell is on at any instant in time. These effects will dominate performance in the 1.9GHz PCS environment where small cells are the norm.

Returning to the OFS interference question, Qualcomm argues *"a wideband system (Omnipoint's 10 MHz bandwidth) must transmit the same energy per bit to achieve the same link performance, all other things being equal..."* As we have just shown, all other things are not equal; e.g., higher order modulation, the fact that CDMA-only systems must deal with much greater interference, etc. all contribute to the overall picture. Additionally, one of the primary reasons for using spread spectrum is to avoid deep multipath fading and the consequent requirements for large fade margins (i.e. high transmit powers). Qualcomm certainly claims this benefit for their system while denying any gains to our system, even though our signal is of wider bandwidth and less subject to frequency selective fading.