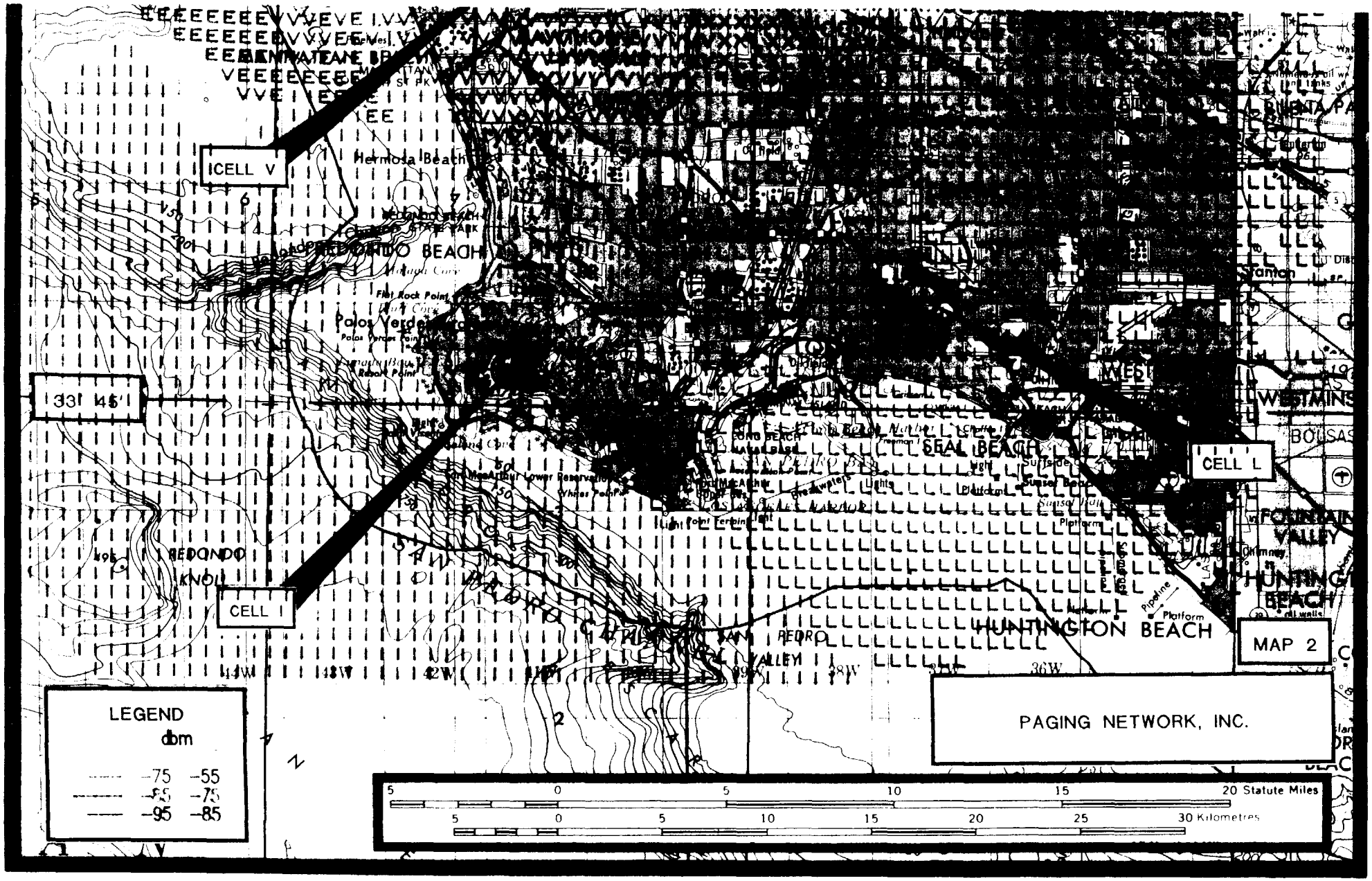
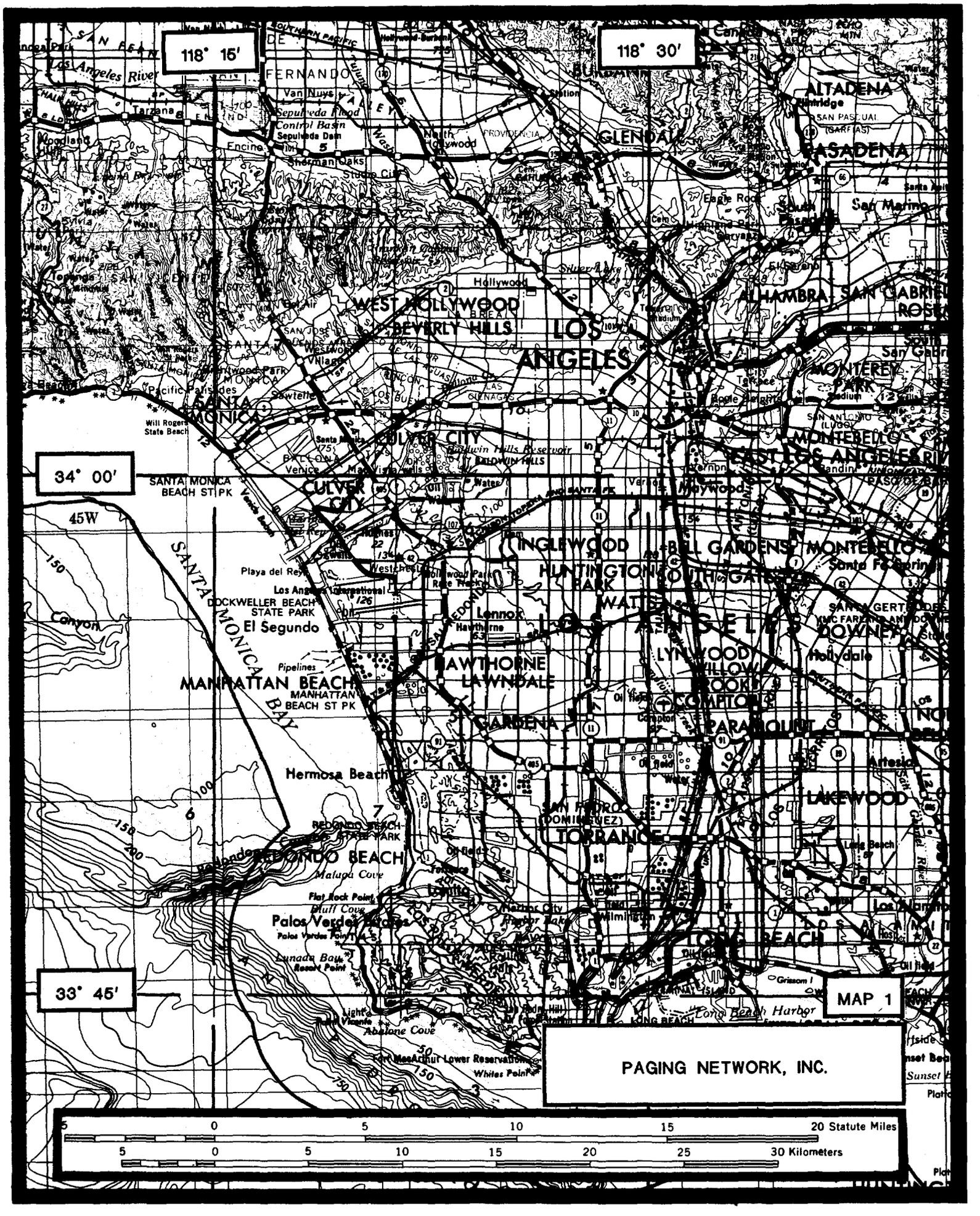

CELL V
CELL I
CELL L
MAP 2
PAGING NETWORK, INC.
LEGEND
dbm
-75 -55
-95 -85
Hermosa Beach
REDONDO BEACH
Palos Verdes
SEAL BEACH
HUNTINGTON BEACH
WESTMINS
BOLSAS
FOUNTAIN VALLEY
REDONDO KNOLL
5 0 5 10 15 20 Statute Miles
5 0 5 10 15 20 25 30 Kilometres


118° 15'
118° 30'
34° 00'
33° 45'
MAP 1
PAGING NETWORK, INC.
SANTA MONICA BAY
SANTA MONICA
CULVER CITY
WEST HOLLYWOOD
BEVERLY HILLS
LOS ANGELES
GLENDALE
ALTADENA
PASADENA
ALHAMBRA
MONTEREY PARK
MONTEBELLO
EAST LOS ANGELES
INGLEWOOD
HUNTINGTON PARK
BELL GARDENS
SOUTH GATE
WATTS
LYNWOOD
WILLOWBROOK
COMPTON
PARAMOUNT
DOWNEY
LAKEWOOD
HAWTHORNE
LAWNDALE
GARDENA
TORRANCE
LONG BEACH
MANHATTAN BEACH
MANHATTAN BEACH ST PK
Hermosa Beach
REDONDO BEACH
Palos Verdes Estates
El Segundo
Playa del Rey
Los Angeles International
DOCKWELLER BEACH STATE PARK
SANTA MONICA BEACH ST PK
Will Rogers State Beach
Pacific Palisades
Sawtelle
Venice
Hollywood
Lennox
Hawthorne
Wilmington
Long Beach Harbor
Abalone Cove
Whites Point
Fort MacArthur Lower Reservation
Malaga Cove
Flat Rock Point
Bluff Cove
Palos Verdes Point
Lunada Bay
Resort Point
Los Angeles River
Sepulveda Flood Control Basin
Sepulveda Dam
Van Nuys
Sherman Oaks
Studio City
North Hollywood
Eagle Rock
Highland Park
Garvanza
El Sereno
Boyle Heights
Maywood
Vernon
Bandini
Santa Fe Springs
Hollydale
Artesia
Long Beach
Grissom I
Oil field
Water
Pipelines
Canyon
45W
5 0 5 10 15 20 Statute Miles
5 0 5 10 15 20 25 30 Kilometers

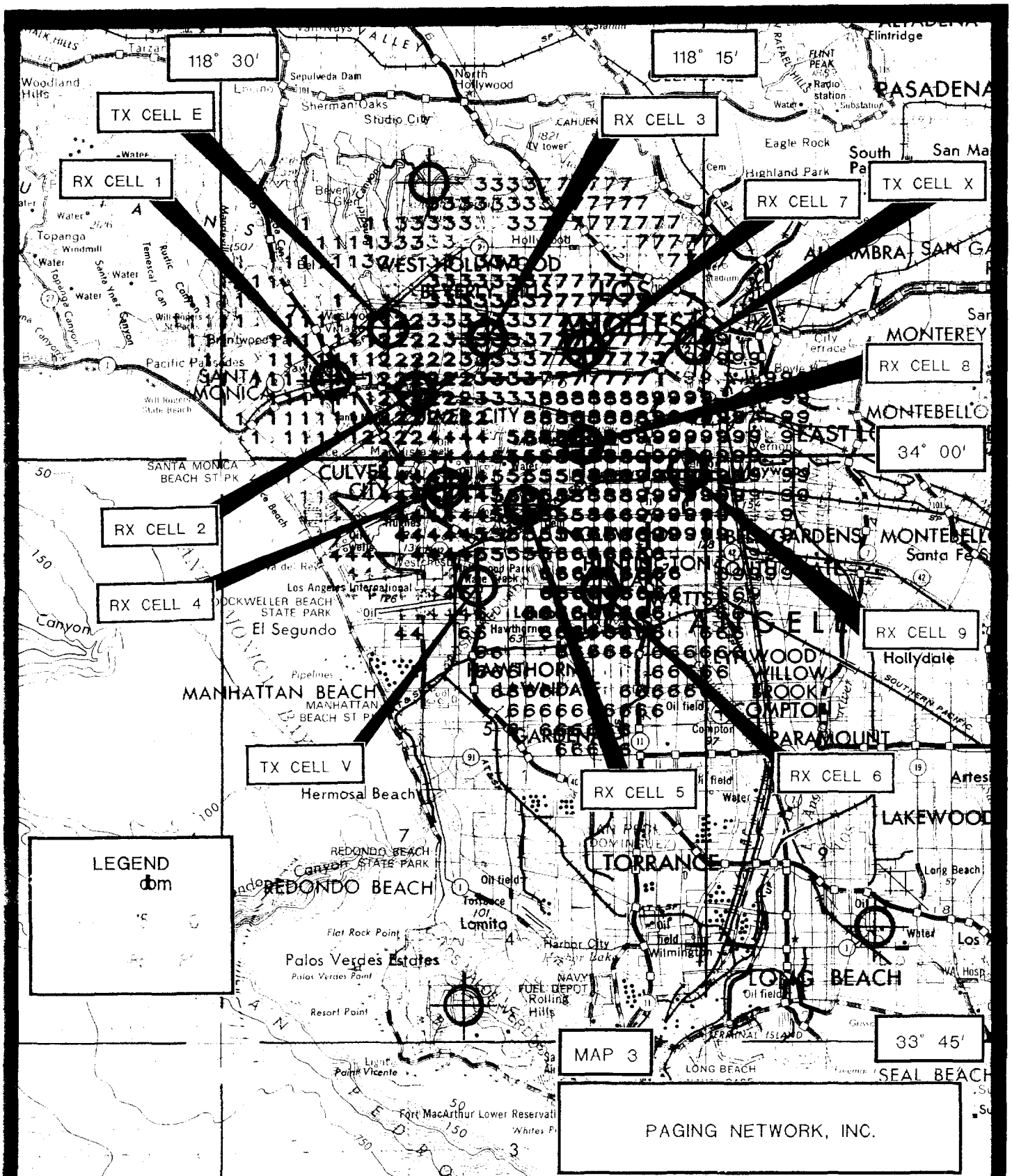
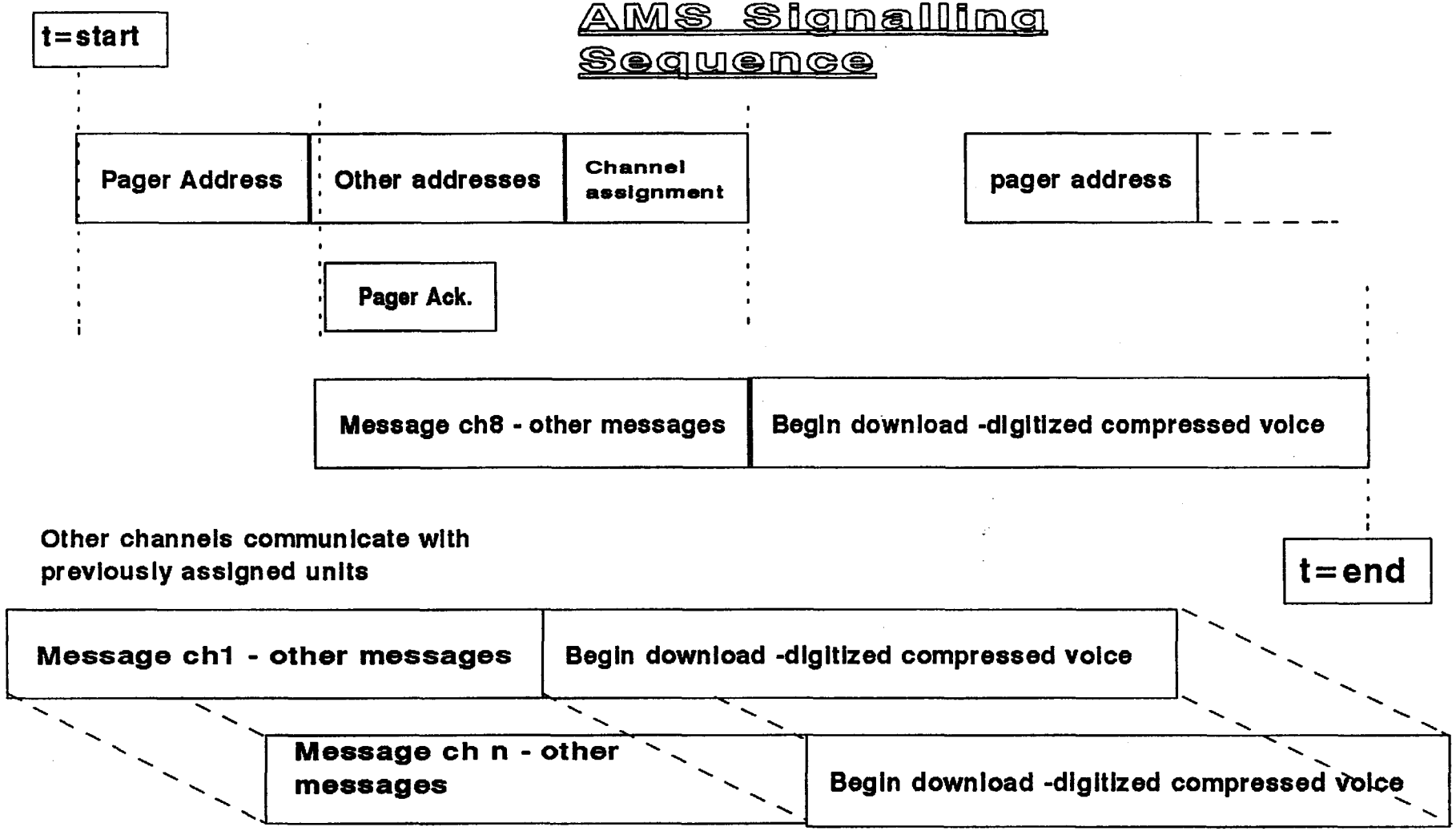

118° 30'
118° 15'
TX CELL E
RX CELL 3
RX CELL 1
RX CELL 7
TX CELL X
RX CELL 8
34° 00'
RX CELL 2
RX CELL 4
RX CELL 9
TX CELL V
RX CELL 5
RX CELL 6
LEGEND
dbm
MAP 3
33° 45'
PAGING NETWORK, INC.

EXHIBIT 4

AMS Signalling Sequence



Receiver operates on various channels under the direction of the network

PAGE NET

EXHIBIT 5

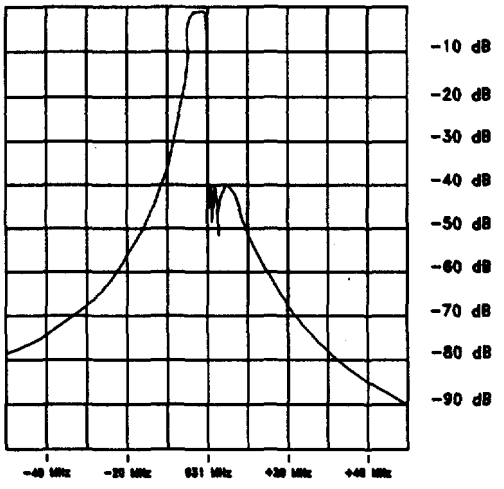
Report of Raymond C. Trott
Consulting Engineers, Inc.

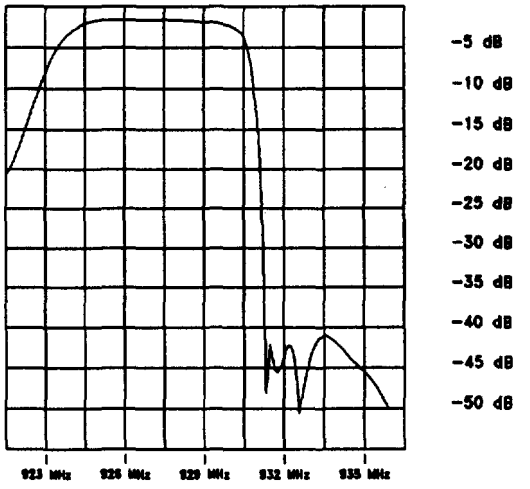
RCT

Raymond C. Trott Consulting Engineers, Inc., as part of a professional services agreement with Paging Network, Inc. has evaluated the feasibility of utilizing the 930 to 931 MHz band reserved spectrum for use as an uplink paging service (from pagers equipped with a low-power transmitter to a fixed-site receiver network). This report is intended to provide to Paging Network, Inc. the interim results of the analysis and investigation into such feasibility. The results stated herein are the outcome of extensive discussions with Paging Network, Inc. personnel and with many manufacturers of receivers and filter products. The final determination and recommendations are not complete and work is ongoing to develop the optimum system configuration and design process. The results of this continuing process will be provided as they become available.

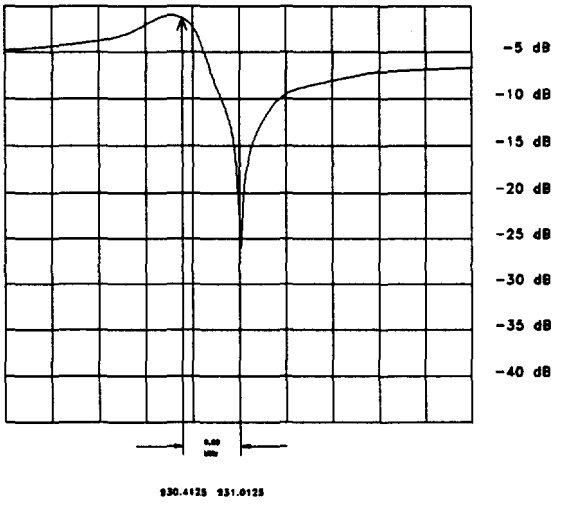
The problem associated with utilization of the 930 to 931 MHz band for inbound messages (from mobile/portable to fixed base site) is the relatively low power of the mobile/portable, in the range of 0.1 to 10 watts E.R.P., compared to the relatively high power, 100 to 3500 watts E.R.P., of the existing paging transmitters on the two adjacent bands (929 to 930 MHz and 931 to 932 MHz). This situation presents two separate and distinct problems to the design and implementation of receive stations in the new 930 to 931 MHz band. First is desensitization of the receiver by the strong signal emitted by the paging transmitter and second is the noise produced by the paging transmitter on the receive frequency.

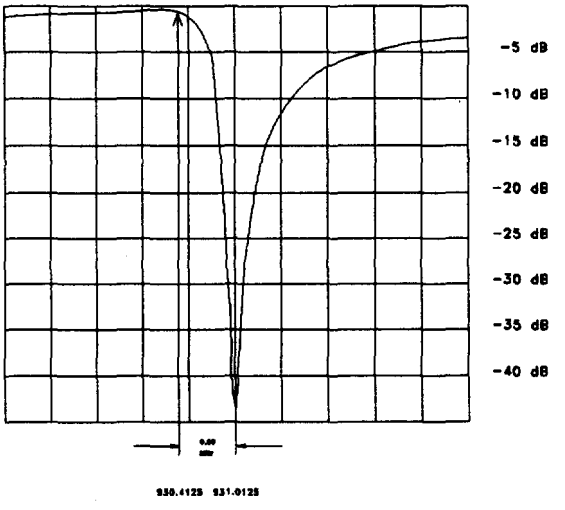
Modern filter technology (See typical filter curve below) will allow receivers in the 930 to 931 MHz band to be protected from receiver desensitization by as little as 0 dB (with paging transmitter 25 kHz removed from the receive frequency) and no more than 40 dB (with paging transmitter 1 MHz removed from the receive frequency). This filter is placed ahead of the receiver in the receive antenna system. Assuming a nearby transmitter emitting 3500 watts (+65.44 dBm) E.R.P., the signal level at a receiver located within 0.1 mile (528 feet) will be -10.52 dBm or 80.92 dB above the minimum on-frequency received signal (43 dBu). Since most good receivers will possess a 80 db or better adjacent channel selectivity, there should be no more than 1 dB received signal threshold degradation based upon 43 dBu (6μV) minimum received signal level. This mandates that any paging transmitter in either the 929 or 931 MHz band must not be co-located (within 528 feet) of any receive site in the 930 to 931 MHz band. However, this minimum separation distance could be reduced if the paging transmitter E.R.P. is substantially reduced from the 3500 watts or removed by substantially more than 25 kHz from the receive frequency.





The above two filter frequency response curves are based upon an interdigital bandpass filter with a bandreject cavity filter tuned to reject the band above the bandpass filter.





The frequency response curves above are one-cavity (left) and two-cavity (right) bandpass-bandreject cavity filters.

In order to protect the receiver from transmitter noise, a similar filter must be placed in each nearby transmitter to minimize the amount of transmitter power generated

within the channel bandwidth of the receiver. Likewise, this power can be reduced by as little as 0 dB and no more than 40 dB.

Assuming a nearby transmitter emitting 3500 watts (+65.44 dBm) E.R.P., the amount of transmitter noise 1 MHz removed (band center to band center) from the transmit frequency must, by F.C.C. R&R § 22.106, be no more than -14.56 dBm or 42,000 μV. Assuming the transmitter is located within 0.10 mile (528 feet) of the receiver site, the free space attenuation will be 75.96 dB, resulting in a received signal level of -90.52 dBm. Further assuming that a mobile is transmitting a 0.1 watt (+20 dBm) E.R.P., equal signal levels will be obtained from the mobile/portable and the interfering transmitter when the free space loss of the mobile/portable is 110.52 dB or at approximately 5.1 miles from the receive antenna site. This calculation is only valid when there is only one nearby paging transmitter. Should there be five such transmitters each at 0.1 mile, the composite interfering signal could be -83.52 dBm resulting in an allowable mobile/portable distance of 2.3 miles. In addition, should the interfering transmitter be removed from the receive frequency by up to 62.5 kHz, the power radiated at the receive frequency by the interfering transmitter could be 10 dB higher than that specified above or -4.56 dBm with no protection available through filtering. This would result in an allowable mobile/portable distance of 1.6 miles for a single interfering transmitter or 0.72 miles for five such transmitters.

In some cases, this transmitter noise effect can be minimized by additional filtering; however, this filter must be placed in the transmitter antenna line since the noise is generated on the receive frequency, and therefore, cannot be filtered at the receive site without also filtering out the desired mobile/portable signal. Since these filters do exhibit at least 3 dB insertion loss, it is doubtful that the licensees of the interfering paging transmitters will be willing to accept the additional filter loss since their stations are operating within emission guidelines per F.C.C. R&R § 22.106.

In order to verify that these issues could present problems when the 930 to 931 MHz band is utilized for fixed-site receivers, tests were made in the Los Angeles area at two sites, one where the incident adjacent band paging transmitter signals were received at minimal levels (-74 dBm), and the other site, with the paging transmitter co-located where signals were received at maximum levels (+30 dBm). The noise levels at the two sites were recorded at 930.0 MHz, 930.5 MHz and 931.0 MHz. The table below is the results of those measurements.

Site	Commerce	San Pedro Hill
Paging Tx Frequency	931.1875 MHz	931.3125 MHz
Rec'd Level from 931 MHz Tx	-74 dBm	+30 dBm
Noise Level at 930.0 MHz	-110 dBm	-35 dBm
Noise Level at 930.5 MHz	-110 dBm	-35 dBm
Noise level at 931.0 MHz	-110 dBm	-10 dBm

From the results of these measurements, it is obvious that filtering will not allow San Pedro Hill, or any other such site, to perform adequately as a 930 to 931 MHz receive site. Since the co-located transmitter is 325 kHz removed from the highest channel in the 930 MHz band, a filter placed in the 931.3125 MHz transmitter will reduce the transmitter noise at 930.9875 MHz by no more than 10 to 15 dB while reducing the transmitter E.R.P. by 4 to 6 dB. Likewise, a filter placed in the receiver will reduce the desensitization effects by only 6 to 8 dB while reducing the received signal level by 3 to 4 dB. The above filter frequency response curves were measured in an effort to determine the maximum amount of filtering and protection that could be provided to closely-spaced transmitter and receiver frequencies in the 900 MHz band. The filters were specifically tuned in an effort to maximize the rejection without seriously degrading the on-channel or passband transmission losses.

The utilization of the 930 to 931 MHz band may present a significant problem if implementation of fixed-site receive systems are to be considered. As indicated in the table below, there are no possible frequencies in the 930 to 931 MHz band that are more than 500 kHz removed from both high-power paging bands. In this case, the filter configuration identified above will provide no more than 10 dB protection to the center frequency of the 930 to 931 MHz band from either the highest 929 frequency or the lowest 931 frequency. This fact will severely limit the locations where receivers may be placed utilizing 930 to 931 MHz frequencies.

In order to design multiple site receive systems, a three step process will be necessary. First, the locations and E.R.P. of every transmitter in the band from 928.0 MHz to 933.0 MHz must be identified. A formula must be developed as a guideline for distance vs. E.R.P. vs. number of potential interferers, and then, all locations eliminated by this guideline identified. The second step is to identify potential sites in conformance with the guideline and predict their coverage performance utilizing existing techniques. The third step is to perform actual

measurements at each site to identify the level and number of interfering transmitters incident upon the potential receive antenna (at the receiver input) to verify conformance with the guideline.

At the present time, work is continuing to develop the detail parameters necessary to produce the guidelines for distance vs. E.R.P. vs. number of potential interferers. Investigations are ongoing into the availability and accuracy of propagation prediction tools that include the terrain and building structure database necessary to incorporate into an overall system design process. It is still the intention of the parties to continue field testing to develop the necessary parameters, and to expand that testing to include talk-back message transmission in the presence of nearby interfering transmitters, in-band, adjacent-band, and out-of-band. The test plan and procedures developed and utilized for these tests can also be used to test talk-back massaging from within building structures in the subsequent developmental phases.

FCC R&R § 90.494	Dist From 930.000	Dist From 931.000	FCC DOC 92-100	Dist From 929.9875	Dist From 931.0125	FCC R&R § 22.501	Dist From 930.000	Dist From 931.000
929.0125	.9875	1.9875	930.0125	.0250	1.0000	931.0125	1.0125	.0125
929.0375	.9625	1.9625	930.0375	.0500	.9750	931.0375	1.0375	.0375
929.0625	.9375	1.9375	930.0625	.0750	.9500	931.0625	1.0625	.0625
929.0875	.9125	1.9125	930.0875	.1000	.9250	931.0875	1.0875	.0875
929.1125	.8875	1.8875	930.1125	.1250	.9000	931.1125	1.1125	.1125
929.1375	.8625	1.8625	930.1375	.1500	.8750	931.1375	1.1375	.1375
929.1625	.8375	1.8375	930.1625	.1750	.8500	931.1625	1.1625	.1625
929.1875	.8125	1.8125	930.1875	.2000	.8250	931.1875	1.1875	.1875
...	...	...	...	...	...	...	...	...
929.3875	.6125	1.6125	930.3875	.4000	.6250	931.3875	1.3875	.3875
929.4125	.5875	1.5875	930.4125	.4250	.6000	931.4125	1.4125	.4125
929.4375	.5625	1.5625	930.4375	.4500	.5750	931.4375	1.4375	.4375
929.4625	.5375	1.5375	930.4625	.4750	.5500	931.4625	1.4625	.4625
929.4875	.5125	1.5125	930.4875	.5000	.5250	931.4875	1.4875	.4875
929.5125	.4875	1.4875	930.5125	.5250	.5000	931.5125	1.5125	.5125
929.5375	.4625	1.4625	930.5375	.5500	.4750	931.5375	1.5375	.5375
929.5625	.4375	1.4375	930.5625	.5750	.4500	931.5625	1.5625	.5625
929.5875	.4125	1.4125	930.5875	.6000	.4250	931.5875	1.5875	.5875
929.6125	.3875	1.3875	930.6125	.6250	.4000	931.6125	1.6125	.6125
...	...	...	...	...	...	...	...	...
929.8125	.1875	1.1875	930.8125	.8250	.2000	931.8125	1.8125	.8125
929.8375	.1625	1.1625	930.8375	.8500	.1750	931.8375	1.8375	.8375
929.8625	.1375	1.1375	930.8625	.8750	.1500	931.8625	1.8625	.8625
929.8875	.1125	1.1125	930.8875	.9000	.1250	931.8875	1.8875	.8875
929.9125	.0875	1.0875	930.9125	.9250	.1000	931.9125	1.9125	.9125
929.9375	.0625	1.0625	930.9375	.9500	.0750	931.9375	1.9375	.9375
929.9625	.0375	1.0375	930.9625	.9750	.0500	931.9625	1.9625	.9625
929.9875	.0125	1.0125	930.9875	1.0000	.0250	931.9875	1.9875	.9875

There are several other issues concerning the utilization of this new band which must also be addressed. Should this band be allocated for multiple services, some of the services proposed includes licensing up to 3500 watt transmitters in the 930 to 931 MHz band. The level of interference expected from the proposed 930 to 931 MHz transmitters are the same as that identified for adjacent band paging transmitters. The problem of destructive interference is reduced at the center of the new band (channels near 930.5 MHz); however, if transmitters are authorized in the new band, there may be no frequency void of this type of interference. The above discussion of interference only considers cases directly related to individual transmitters. Due to the adjacency of the bands and similarity of service provided in these adjacent bands, the likelihood of intermodulation interference is higher than would normally expected. Considering all 40 channels in each adjacent band as transmitters and the 40 channels in the 930 to 931 MHz band as receivers, there are over 33,000 potential 2 signal, 3rd and 5th order and 3 signal, 3rd order intermodulation products. Since all 120 channels will most probably not be located at the same site, not all of these potential intermodulation products are realistic.

This situation is not of major concern with the existing 929 and 931 MHz bands since these are used for one-way paging transmissions only with no receiver in the range of 929 to 932 MHz co-located with the transmitters. If only a few transmitters in the adjacent paging bands are co-located with the 930 to 931 MHz receivers, the intermodulation problems, if they exist at all, will be easily overcome.

EXHIBIT 6

Letter to Ron Turner, PageNet from Bernhard Keiser, Keiser Engineering, Inc.

KEISER ENGINEERING, INC.
2046 CARRHILL ROAD
VIENNA, VA. 22181-2917
(703) 281-9582

May 30, 1992

Mr. Ron Turner, Director
Systems Management
Paging Network, Inc.
4965 Preston Park Blvd., Suite 500
Plano, TX 75093

Dear Mr. Turner:

I have reviewed the PageNet Engineering Report at the request of Mr. Charles G. Perry of Moffet, Larson & Johnson, Inc. In my opinion, this system definitely is feasible using parameters approximating those of the Report. My understanding of this system is as follows:

A paging system is to be devised that will be capable of a maximum number of messages within a 25 kHz channel, with the requirement for good speaker recognition and intelligibility.

The 25 kHz channel allows a symbol rate on the order of 20 kBd. This rate permits filtering to be done for the proper meeting of the regulatory mask conditions.

Digital modulation using 16-QAM is feasible to paging units operating in what probably is a Rician fading environment (portable pagers operating under slowly moving conditions, often indoors). This conclusion is based on recently reported results.[1,2] The use of 16-QAM allows an overall bit rate of 80 kb/s at 20 kBd.

The speech coding technique should be one that operates at the lowest bit rate consistent with adequate intelligibility and speaker recognition. The lowest rate not only minimizes channel occupancy, but also minimizes storage requirements. LPC at 2400 b/s is felt to meet this requirement. However, LPC chips vary as to quality, and different ones should be tested in this application to assure satisfactory performance. An advantage of the 2.4 kb/s rate is that alternate data can also be sent at this popular rate. If a suitable LPC chip cannot be found, the next recourse is to CELP at 4800 b/s.

Assuming LPC is found to provide satisfactory speech quality, a rough estimate of the digital rate per channel can be obtained by noting that TIA plans for half rate VSELP at 4800 b/s call for an overall 8 kb/s channel. Accordingly, it is reasonable to postulate a 2400 b/s speech system occupying 4 kb/s, allowing for forward error correction (FEC) and overhead. On this basis, one can predict the availability of about 20 operating channels. Since this is a paging system using ACK replies, and not a full duplex telephone system, as is that of the TIA's half-rate VSELP, some further efficiencies may be found possible upon detailed system study.

The foregoing estimate assumes that the use of FEC is limited as it is in digital cellular telephony systems, where only the most significant bits get FEC. Occasional frames containing errors are deleted, with the previous frame being repeated.

The actual number of messages per hour that can be achieved by this system will be a function of the parameters discussed in the Report, as well as the system layout relative to the locations of the most active users. For example, a pager in a poor location probably will generate many retries in the process of getting the message correctly. The system throughput will be degraded accordingly. Additional suitably located transmitters will correct this problem.

Based on the use of current technology, it should be possible to build the pager using VLSI chips, as has been discussed in numerous recent papers, four of which were referenced in a recent Toshiba paper[3].

Very truly yours,

Bernhard E. Keiser

Bernhard E. Keiser

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1. W. Webb, et al, "Does 16-QAM Provide an Alternative to a Half-Rate GSM Speech Codec?", *41st VTS Conference*, (May 1991), pp. 511-516

2. J. K. Cavers, "An Analysis of Pilot Symbol Assisted 16 QAM for Digital Mobile Communications," *41st VTS Conference*, (May 1991), pp. 380-385.

3. H. Tsurumi and T. Maeda, "Design Study of a Direct Conversion Receiver Front-End for 280 MHz, 900 MHZ, and 2.6 GHz Band Radio Communication Systems," *41st VTS Conference*, (May 1991), pp. 457-462.

BERNHARD E. KEISER, D.Sc. E.E.

Bernhard E. Keiser is a consulting engineer in telecommunications and related fields.

Prior to establishing his consulting practice in February, 1975, he was Director, Systems Analysis, ATS-6 Satellite Program, Fairchild Space and Electronics Company, Germantown, MD. He also held the positions of Director, Advanced Engineering, Atlantic Research Corp.; Vice President and Technical Director, Page Communications Engineers; and Engineering Manager, RCA.

Dr. Keiser is the author of the book, *Broadband Coding, Modulation and Transmission Engineering*, and co-author of the book, *Digital Telephony and Network Integration*. He is a Fellow of the IEEE, The Washington Academy of Sciences and the Radio Club of America. He is listed in *Who's Who in America, Who's Who in Engineering*, and *American Men of Science*.

Dr. Keiser has served as Chairman of the Northern Virginia Section of the IEEE. He holds the D.Sc. degree in Electrical Engineering from Washington University, St. Louis, MO.

BERNHARD E. KEISER, DScEE

Experience in digital cellular telephony and related technologies:

* Developed the RF and speech coding portions of the Request for Proposal issued by BellSouth Mobility, Inc., Atlanta, GA, for a digital cellular system for Georgia.

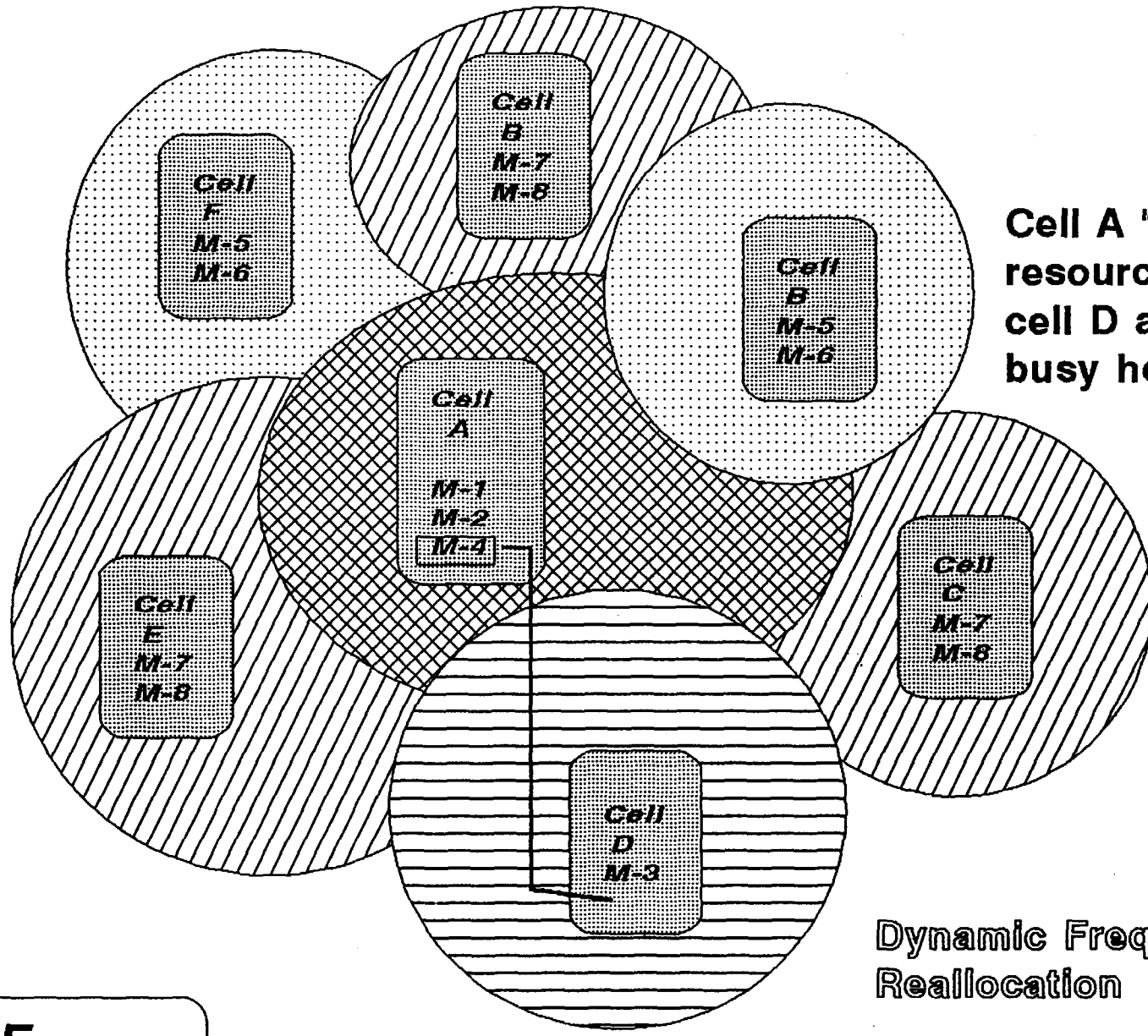
* Served as consulting engineer to IMM, Inc., Philadelphia, PA, in the development of Ultraphone, a digital telephone system for BETRS use in rural areas.

* Teaches course in Digital Cellular Telephony (US standards) for The George Washington University, Washington, DC.

* Teaches course in Digital Cellular Telephony (GSM standard) for Frost & Sullivan, Ltd., London, UK.

* Co-author of text *Digital Telephony and Network Integration*, VanNostrand, 1985. (Now under revision to include a full chapter on digital cellular telephony.)

EXHIBIT 7

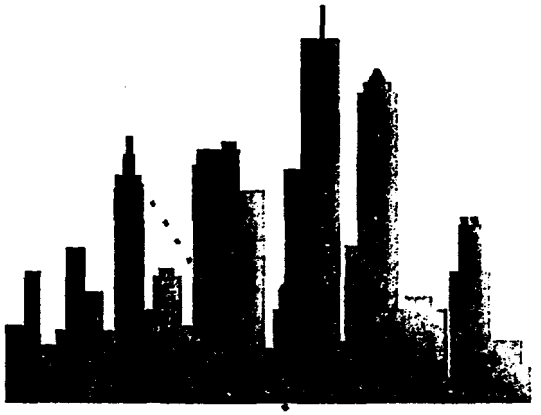


Cell A "borrows" a resource from cell D according to busy hour loading

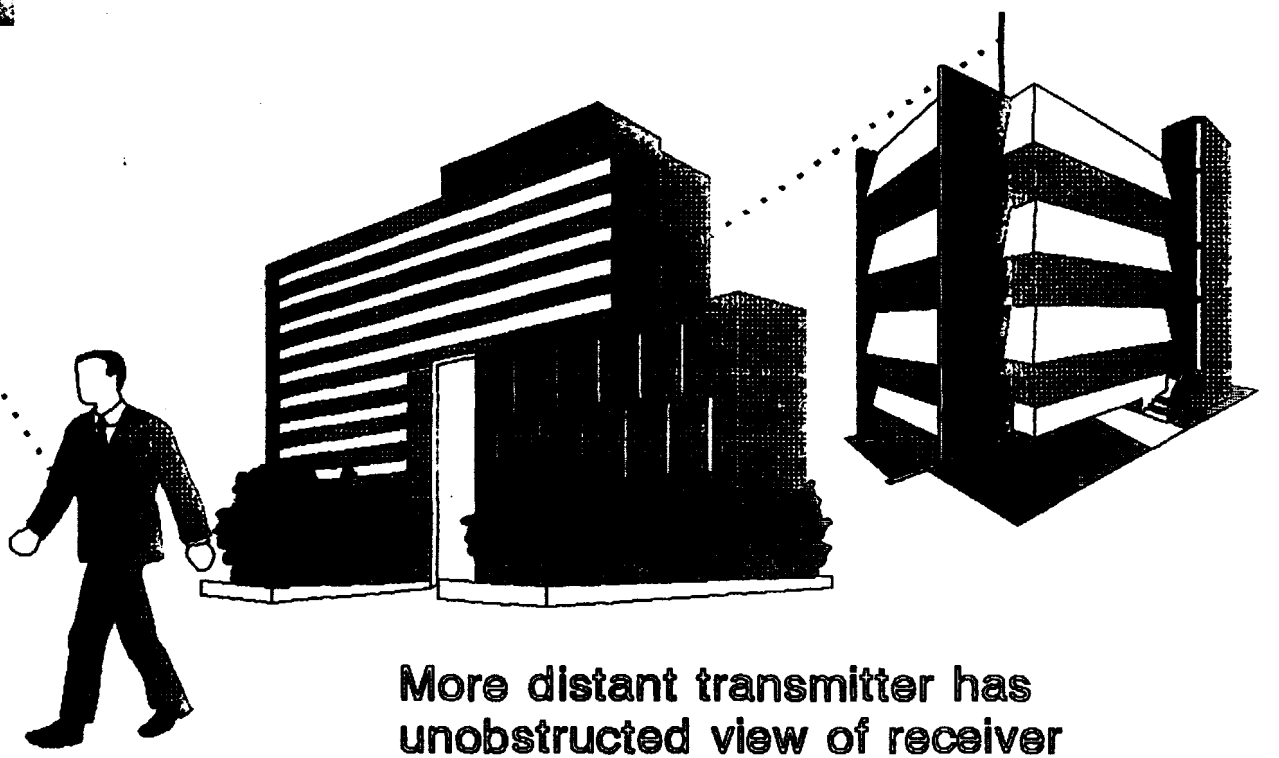
Dynamic Frequency Reallocation

PAGE NET

EXHIBIT 8



Optimum message transmitter not always the nearest to the subscriber



More distant transmitter has unobstructed view of receiver

PAGENET

EXHIBIT 9

Letter to Ron Turner, PageNet from Scott Greenwell, CNet

CNet

CNet, Inc. 4975 Preston Park Blvd., 8th Floor, Plano, Texas 75093 214/867-3333

May 29, 1992

Mr. Ron Turner
Director of Systems Management
Paging Network, Inc.
4965 Preston Park Boulevard, Suite 500
Plano, Texas 75093

Sent to: Washington D.C.
Via facsimile
202•457•6113

Dear Mr. Turner:

CNet is a multinational corporation dedicated to providing software tools and engineering services to the global personal communications industry. CNet's highly-automated software applications help mobile radio engineers stay abreast of the rapid growth of this industry. As our software tools have evolved to keep pace with rapidly changing technologies, our vision and our commitment have remained focused:

> "We are dedicated to providing state-of-the-art software and services that can help our customers become more competitive and more successful in their businesses. Further, we recognize that this may require us to go the extra mile to resolve problems and overcome challenges that we and our customers encounter along the way. We are committed to providing excellence in service —and look to our customers to help us redefine and reestablish this standard every day."

With the active support of our customers, we continue to provide innovative and timely tools to address emerging industry needs. With the introduction of our mobile radio planning tools, SOLUTIONS, CNet was first to develop and implement a grid-based, rather than radial-based, system modeling approach —greatly facilitating comprehensive system-wide studies. We were first to introduce a software system that could be implemented, without modification, on the desktop or in the computer room, sized to an operator's actual need. CNet was also first to develop and actively integrate field measured data (from any field measurement system) into predictive analyses.

True 3-dimensional modeling capabilities are required – from the base station antenna and along the radio path – to effectively study and manage complex mobile radio systems, and CNet was first here, as well. Taking this a step further, and to better depict the impact of terrain on mobile radio system performance, CNet recently introduced coverage analyses displayed in 3-dimensions, and is developing 3-dimensional interference analyses, and others. Each of these "firsts" are significant, but could not have been possible without the close working relationships we seek and have formed with our customers.

Yet another first for CNet is our ability to produce highly detailed urban/building attenuation databases to be used with our communications software tools. CNet's Digitizing Services Group can either digitize or scan detailed building information to create a database that enables the

personal communications system operator to effectively see what their system sees. (See enclosed brochure.) Coupled with integrated field measured data, CNet's SOLUTIONS software can accurately characterize virtually any mobile radio environment.

We understand that you propose to integrate our 3-dimensional modeling capabilities and detailed urban building attenuation databases with your own field measurements. While we are experienced in providing these services to engineers in the system design process, we are not aware of any existing or proposed system which uses these tools in the way which you propose.

As we understand PAGENET's proposal, you plan to install a network of receivers to determine, through the comparative signal strength at different sites, the location of the pager. Once the Network Controller has established this location, it would refer to our database to ascertain an optimum transmitter site for message delivery. This determination would be based not only on location, but would consider propagation, terrain, foliage, and buildings, as well as actual field measurements and experience.

While this application of technology is beyond CNet's specific experience, we are capable of modeling the predicted performance of a 930 MHz network of transmitters —taking into consideration terrain, foliage, buildings, and actual field measurements— to determine an optimum message transmitter for a given location.

Ron, we recognize that PAGENET is a leader in the personal communications industry and we appreciate the interest you have shown in CNet. We are ready to respond to your specific request for high density urban attenuation data to conform to PAGENET's high quality standards and look forward to working with you to address the industry's future needs.

Best regards,

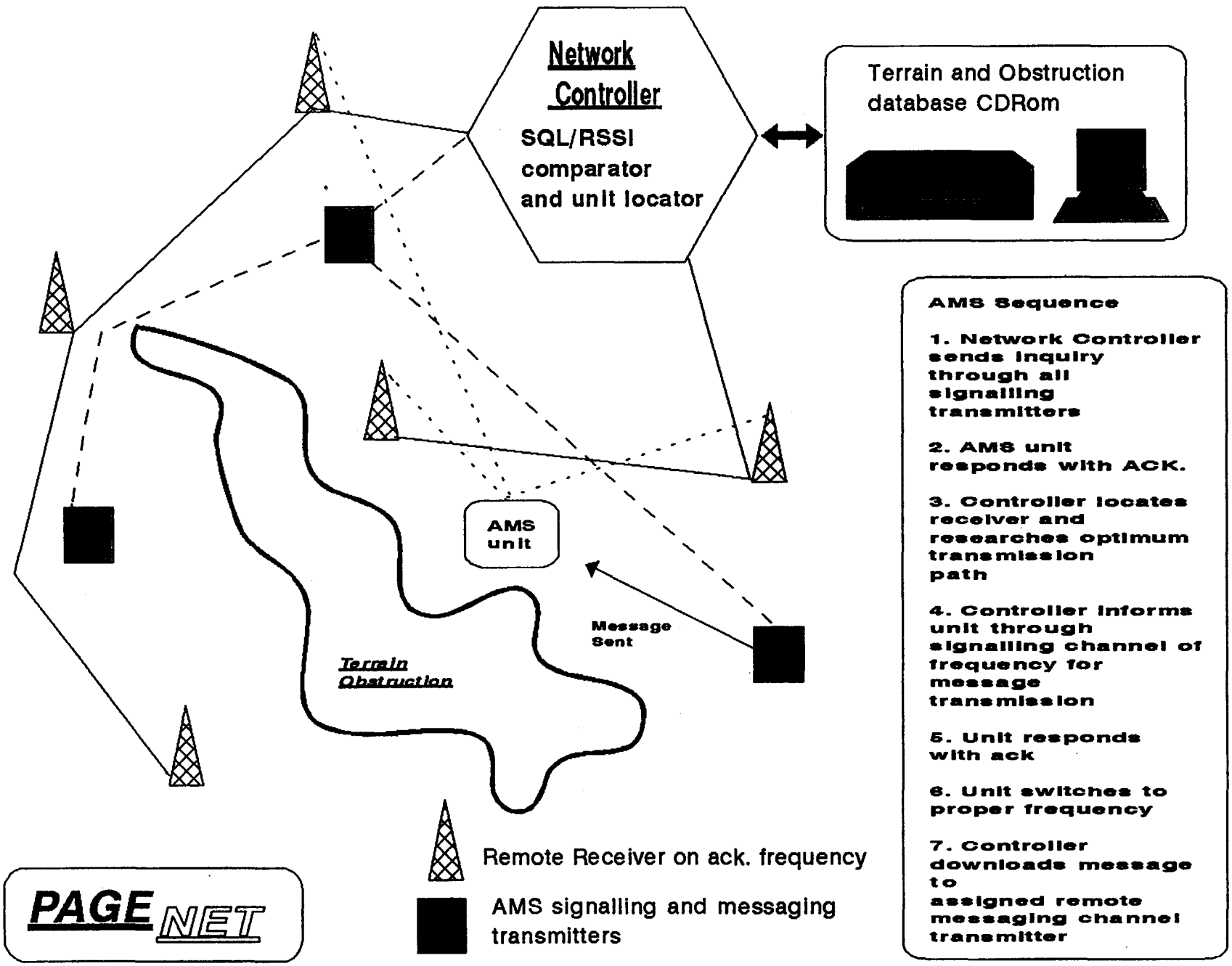
Scott R. Greenwell
Vice President

cc: Dale W. Carter
Director of Engineering
PAGENET

Mike Kampen
Account Manager
CNet, Inc.

enclosures

EXHIBIT 10


Network Controller
SQL/RSSI comparator and unit locator
Terrain and Obstruction database CDRom
AMS Sequence
1. Network Controller sends inquiry through all signalling transmitters
2. AMS unit responds with ACK.
3. Controller locates receiver and researches optimum transmission path
4. Controller informs unit through signalling channel of frequency for message transmission
5. Unit responds with ack
6. Unit switches to proper frequency
7. Controller downloads message to assigned remote messaging channel transmitter
AMS unit
Message Sent
Terrain Obstruction
Remote Receiver on ack. frequency
AMS signalling and messaging transmitters
PAGE NET