This same process is repeated each time a message is initiated, since the system must be able to accommodate movement of the subscriber transceiver to other locations better served by other base stations. Since each message is queued in a time slot for delivery, it is possible the location and the strongest base station would have changed prior to actual delivery of the message. This may be particularly likely in an office cell. In this event, no acknowledgement will be received as the message packets are sent, and the system controller will be notified by the serving cell, thereby re-initiating the polling channel request for the subscriber's new location.

To make the most efficient use of the spectrum, the "search" process is done in a hierarchial manner by the system. Each subscriber transceiver is registered as having a "home" MSA. First, the system controller attempts to contact the subscriber transceiver over its "home" MSA simulcast polling channel. If the user is not found in his "home" MSA, the system controller sends the page request to the remaining MSAs which, in turn, send out the page for location. If necessary, the MSA system controller can communicate over the Public Data Network (PDN) using TNPP link protocol, which is an existing industry standard for this application. Specifically, the system controllers send the page for location request over the PDN to the satellite uplink, where the requests are transmitted for satellite broadcast of the requests nationwide. The Ku-band satellite footprint is the continental U.S., and any Ku-band satellite receiver in this coverage area that is tuned to this channel will receive the request and page the subscriber unit on the polling channel in simulcast.

C. Subscriber Transceiver Unit

The subscriber transceiver unit is essentially a low-power, portable, wireless RF modem that interfaces personal data products to PIMS. A conceptual model of the subscriber unit, and its functions and specifications are shown in Exhibit XII. It is designed to be used, at the option of individual equipment manufacturers, as either a "card" type module that may be inserted and used in a range of compatible applications devices, or as an integrated element of individual equipment platforms.

The subscriber transceiver unit performs three distinct and important functions in the PIM service. First, it operates with the overall system to identify, or locate, the "best" transmitting station with which it should communicate for purposes of command/control and message transmission. Second, when an out-going message is being sent to the subscriber, the unit acts as a receiver, synchronizing with the system control stations and the transmit stations in order to receive the message. The unit also performs data flow control and acknowledgment and error control in conjunction with the rest of the system, and it provides a formatting and interface function vis-a-vis the particular applications device in which it is installed. In the receiver mode, the subscriber unit performs functions much as an alphanumeric pager today, except that it is frequency agile and has considerably more data storage capability (a minimum of 128K bytes).

Third, when the subscriber wants to originate a message, such as from a palm-top computer equipped with a subscriber transceiver, the unit acts as a transmitter, accepting the message, converting it into a transparent format for transmission, and providing for its transmission to the correct network receiver and, ultimately, to its destination. Here also

Personal Transceiver Subsystem

(Subscriber Transceiver Module + Power Module + End User Product)

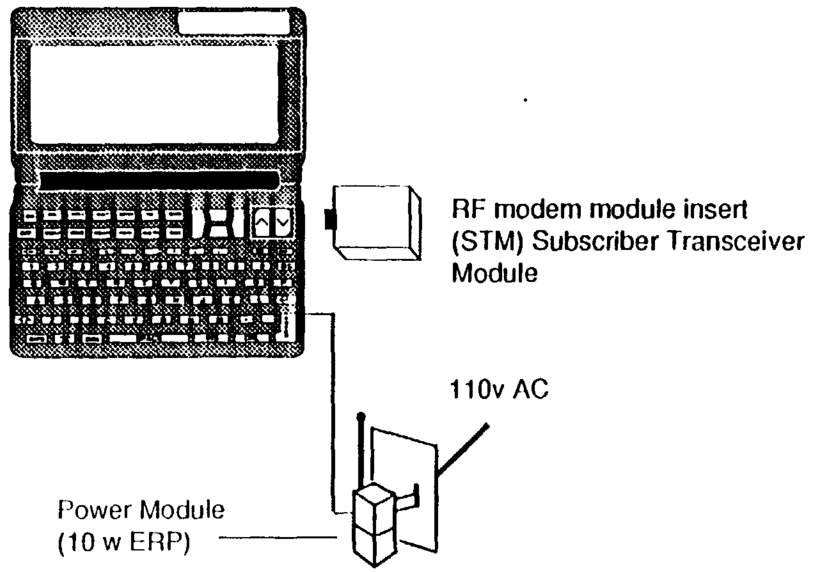
EXHIBIT XII

Operating Functions

- STM receives Polling and Data channel signals
- STM transmits Return Link channel plus Data channel signals
- Power Module unit boosts RF modem output to 10 watts ERP

Operational Sequence

When paged by the polling channel, the STM receives, decodes and then the Power Module outputs a 10-watt RF signal on the Return Link that tells its ID, best receiving station ID and instructions on delivery of that data. The STM then receives the data on a Data channel and sends back ARQ over the Return Link at 10w. To transmit data back, access is acquired through the Return Link, and data is transmitted over one of the assigned Data channels.



Product Specifications

- RF modem module
  - STM is "card size" - fixed or removable
  - Meet pager receiver specs.
  - 100 mw transmitter
- Power Module Unit
  - 10-watt ERP
  - 110 AC wall socket input
  - RF amplifier + power supply
  - Charger feedback option
  - Wireless option

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acknowledgement and error control are performed.

The subscriber unit is designed to be a small, low-cost, battery operated transceiver, with an effective radiated power of approximately 100 milliwatts. Its power supply would be independent of the applications device in which it may be installed or integrated. This is to enable it to remain in an "on" mode and capable of receiving signals on the polling channel, and responding on the return link, for the purpose of the radio location function, without requiring the host device to be "powered up." The 100 milliwatt power level is believed fully sufficient to support the proposed operation of the unit as a receiver.

To achieve two-way operation in a high insersion loss building, the unit would be coupled with a separate power module, as depicted in Exhibit XII, which would be capable of generating up to 10 watts as a transmitter. This module could be plugged into a standard 110 AC wall socket and connected to the subscriber unit, or it could even be made wireless. It would receive the transmission from the low-powered hand-held unit, amplify and repeat it, as shown in Exhibit XIII. In this configuration, a pocket organizer or notebook computer with an RF transceiver unit and could be expected to function reliably both in buildings and on the street (i.e., free space).

The subscriber unit is designed to be frequency agile so that, upon a command from the polling channel, it can move from one frequency to another to receive messages. The "home base" frequency for the unit would always be the polling channel, so that it would always be ready to receive signals for radiolocationing and message transmission set-up. Immediately after receiving an "end of transmission" (EOT), or after a pre-determined interval of time if no signal has been received, the unit would automatically return to the polling frequency.

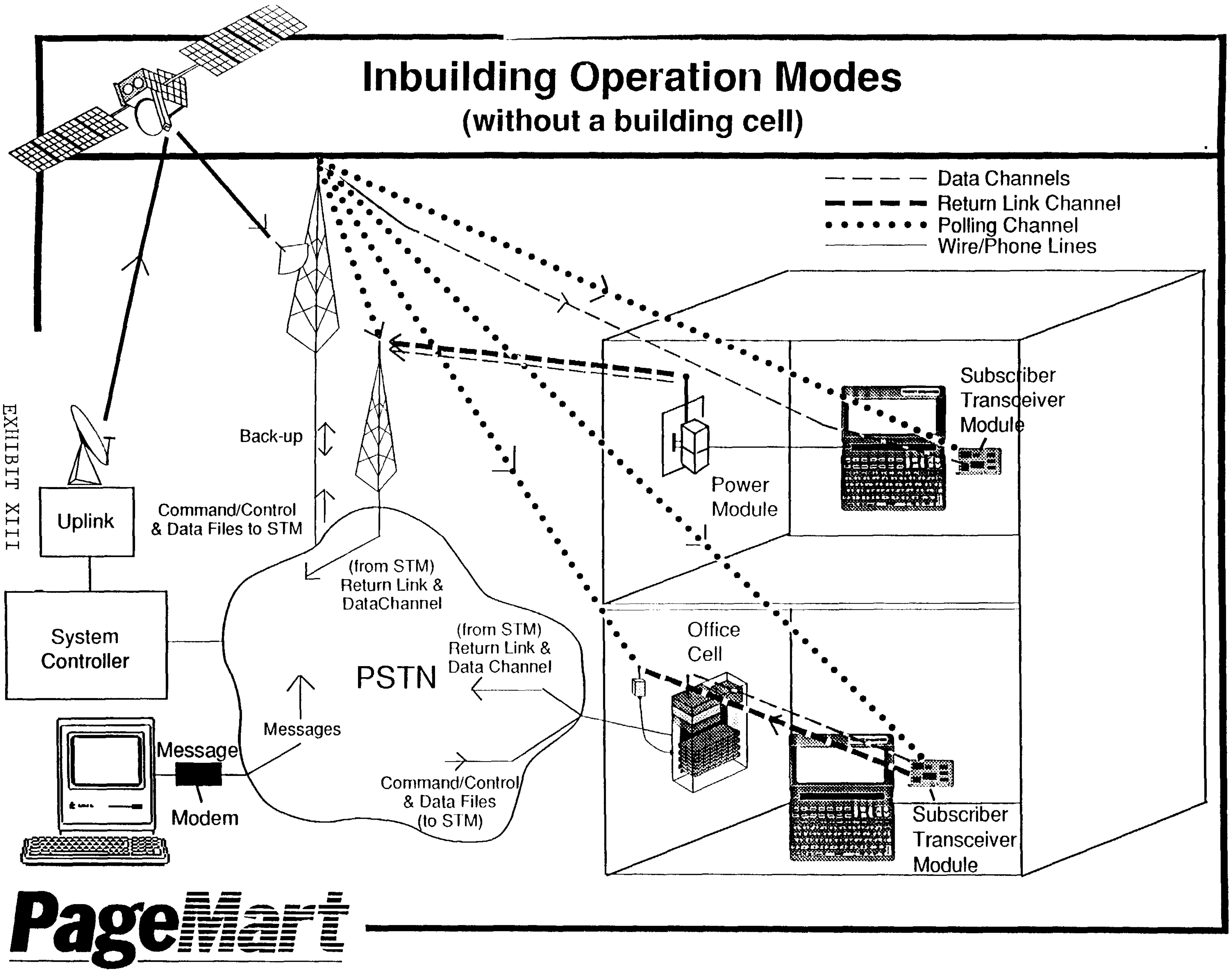


EXHIBIT XIII

An important aspect of PageMart's proposal is that the subscriber unit would be protocol transparent, so that it could be used with devices made by many different manufacturers, to serve numerous customized applications, without dictating the higher level protocols to be followed. The protocol conversion would take place between the unit itself and the host device. Thus, it is intended that a subscriber having a card-type unit would be able to use it in a variety of products produced by many different vendors. Moreover, the unit could be designed to operate with a range of RF interfaces (POCSAG, ERMES, CDLC, plus source coding, most likely at the session level) and with various channel coding and modulation schemes for level 1, 2, 3 of OSI.

D. Data Transmission and Acknowledgement

Data transmission and acknowledgement in PIMS is performed much like it is in most packet networks. Once the system controller has "located" the subscriber unit and identified the serving base station (along with the instruction to transmit the message), the controller creates a "file" for the message, assigning to it a time "marker," a duration (i.e., N batches), and a base station transmit frequency. This message "file" is then forwarded to the serving transmitter station where it is held in memory until the assigned transmission time. The forwarding of this message file is typically done via telephone or leased lines, in order to avoid unnecessary use of the spectrum for this purpose (see Exhibit XIV).

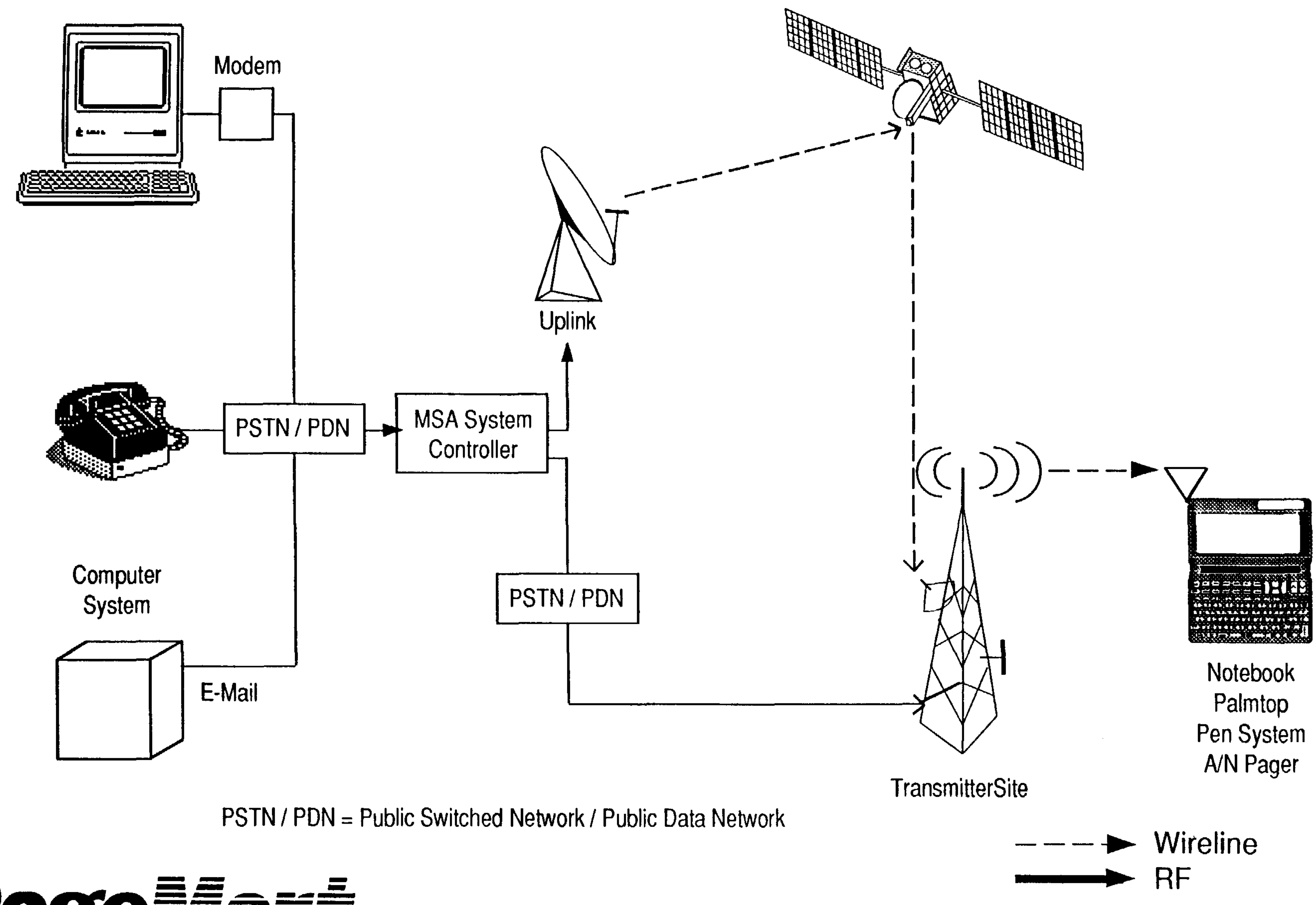
At the assigned transmission time, two events happen simultaneously:

- the subscriber unit is sent, via the polling channel, the "Go To" command telling it what channel to tune into and its time "marker"; and

- the message file is retrieved from memory, formatted for that time and transmitted by the serving cell transmitter to the subscriber unit using the assigned data channel. By using this system command/control technique, the subscriber unit does not need to

EXHIBIT XIV

Message Outbound to Subscriber



PSTN / PDN = Public Switched Network / Public Data Network

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remain continuously in a "receive" mode.

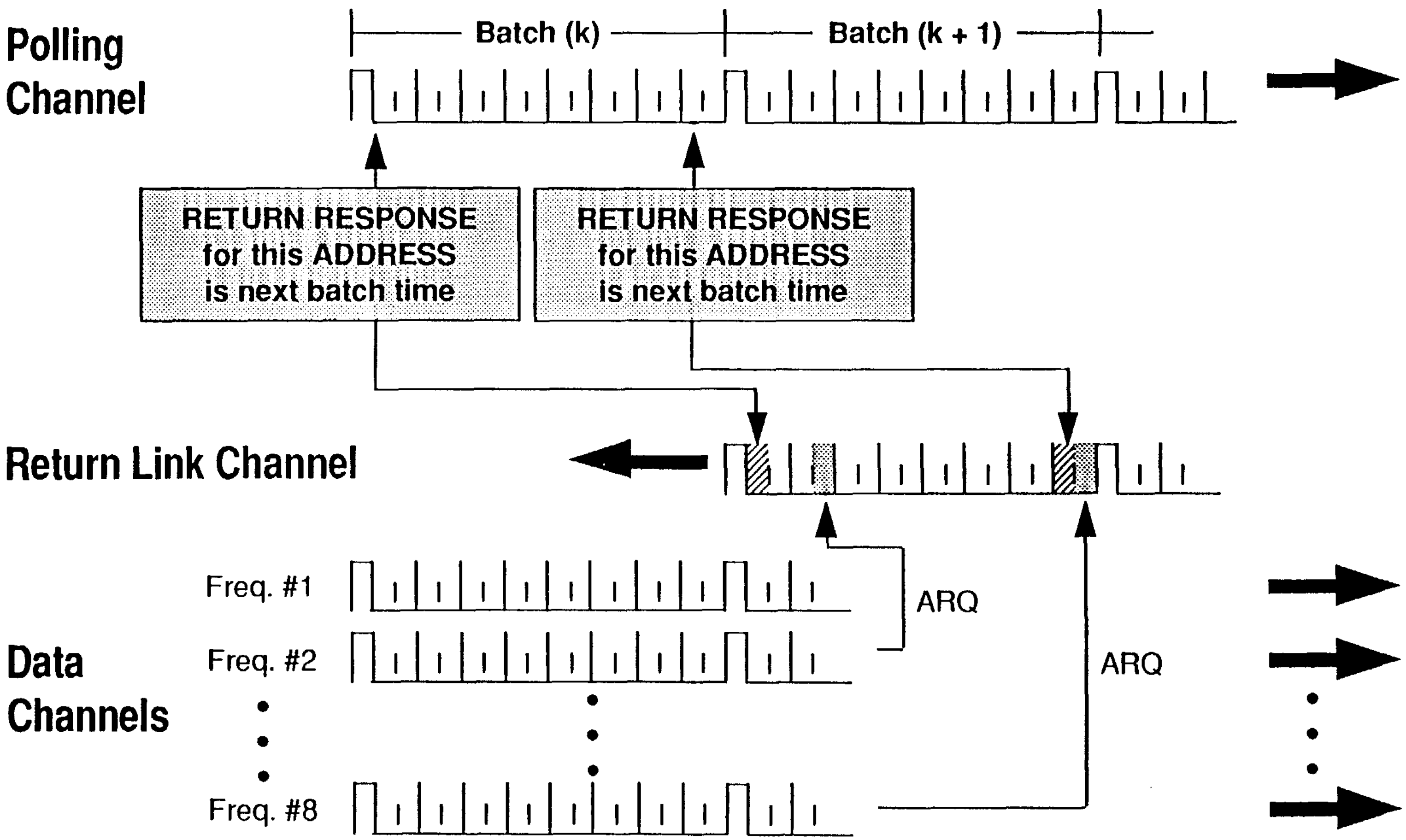
After a message packet has been successfully received by the subscriber unit, an acknowledgement (ACK) is sent back on the return link channel in its designated time frame. If the message received contains errors, a negative acknowledgement (NACK) is sent back made on the return link.

In the event of either type of ARQ response, no collision between subscribers can occur with the algorithm employed because it is based on frequency of the data channel, time of response corresponding to message receipt and spatial separation of subscriber units to ensure no co-channel interference on the return link. The algorithm employed by ARQ response is to respond one batch time later (similar to the "best" serving transmitter ID response) but in the second work position of the frame, to be determined by the data channel frequency which is transmitting the data in that cell (Exhibit XV). For example, an STM receiving data on channel 2 would respond in frame 2-second word. No other STM can cause a collision because, by rule, no other STM could be in a position to cause co-channel interference on the forward link and, therefore, no other STM is in a position to interfere on the return link channel either.

For this synchronization to work effectively, it is important for the subscriber unit to have good reception of the command/control signals. This is done by having these polling channels signals precisely timed and "simulcast" from multiple transmitters in the particular serving area, to ensure that the multiple signals reinforce, rather than interfere with, each other. This "simulcasting" is done by both geographic cell transmitters and building cell transmitters, but it is not done by in-building office cell transmitters, because it is unnecessary to increase the complexity of the office cell when system coverage patterns will be designed so that effective

Polling & Acknowledgement

- Response to Polling channel made one batch time later
- ARQ time assignment by Data channel frequency assignment



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coverage is provided independent of the extent to which office cells may be utilized.

One of the ways that system efficiency is achieved is through the use of multiple data channels and frequency agile subscriber transceivers. In the case of both geographic and building cells, the message may be assigned to one of eight different data channels, for the nationwide licensees, and one of four data channels, for the local licensees. The system controller tracks channel availability and assigns the next available channel to the next message in the queue. In the case of office cells, however, it is assumed that user needs can be met effectively, and more efficiently, by using a single programmable channel rather than a fully frequency agile transceiver.

The PIMS distributes and maintains time management of the RF channels through one RF channel, the polling channel. Within a given serving area, this polling channel continuously transmits a simulcast POCSAG protocol signal throughout the desired continuous coverage region. This omnipresent polling channel signal is the time base for the system's RF interface. Therefore, all polling channel transmitter sites are time-synchronous. These transmitter sites acquire and maintain time synchronization through the common satellite control link signal. Other system elements, such as office cells and subscriber transceiver units, are maintained in a time synchronous manner by using the Polling channel for reference.

E. Subscriber-Originated Messages

When a subscriber wishes to send a message from a portable subscriber transceiver unit, the data is entered into the host applications device, and then the request for transmission sequence can be initiated by simple key stroke. The unit's transceiver monitors the Return Link channel using an algorithm that denotes the batch time dedicated to random access requests by subscribers wishing to transmit data.

When a subscriber transceiver requests access to a data channel for transmission of data, it transmits an RF burst on the return link. This RF burst occurs at the second word in POCSAG Frame time of that units capcode (Exhibit XVI). Also, the Frame time is scheduled so that no ARQ or response bursts are being transmitted during that Frame.

The subscriber indicates the message length to be transmitted, the serving transmitter site identification, and the subscriber unit identification, or "call sign." There are eight frames per batch in POCSAG and subscribers are uniformally assigned to the frames. Thus, the probability of a collision between two different subscribers' messages requests for a data channel is reduced by a factor of eight. Since receivers are spatially located throughout the coverage area, the probability of jamming is further reduced. This spatial diversity is shown in Exhibit XVII, with each receiver that receives the signal forwarding it to the MSA system controller via the public switched or private data network.

The polling channel assigns a data channel to the subscriber unit to be used for data transmission, and transmits this information, along with a time "marker" for beginning and end of transmission, to the subscriber unit. During that interval, it also blocks out the use of the data channel from other subscriber units. If the message is received incomplete or with errors the system controller sends a transmission incomplete ARQ back to the subscriber unit with the defective packet assignments and the GoTo command for a data channel assignment for re-transmission over the polling channel at the end of transmission. Subsequently, the subscriber unit transmits the defective packets and completes the message, whereupon, it receives a

EXHIBIT XVI

Random Access Sequence For Two-Way Data

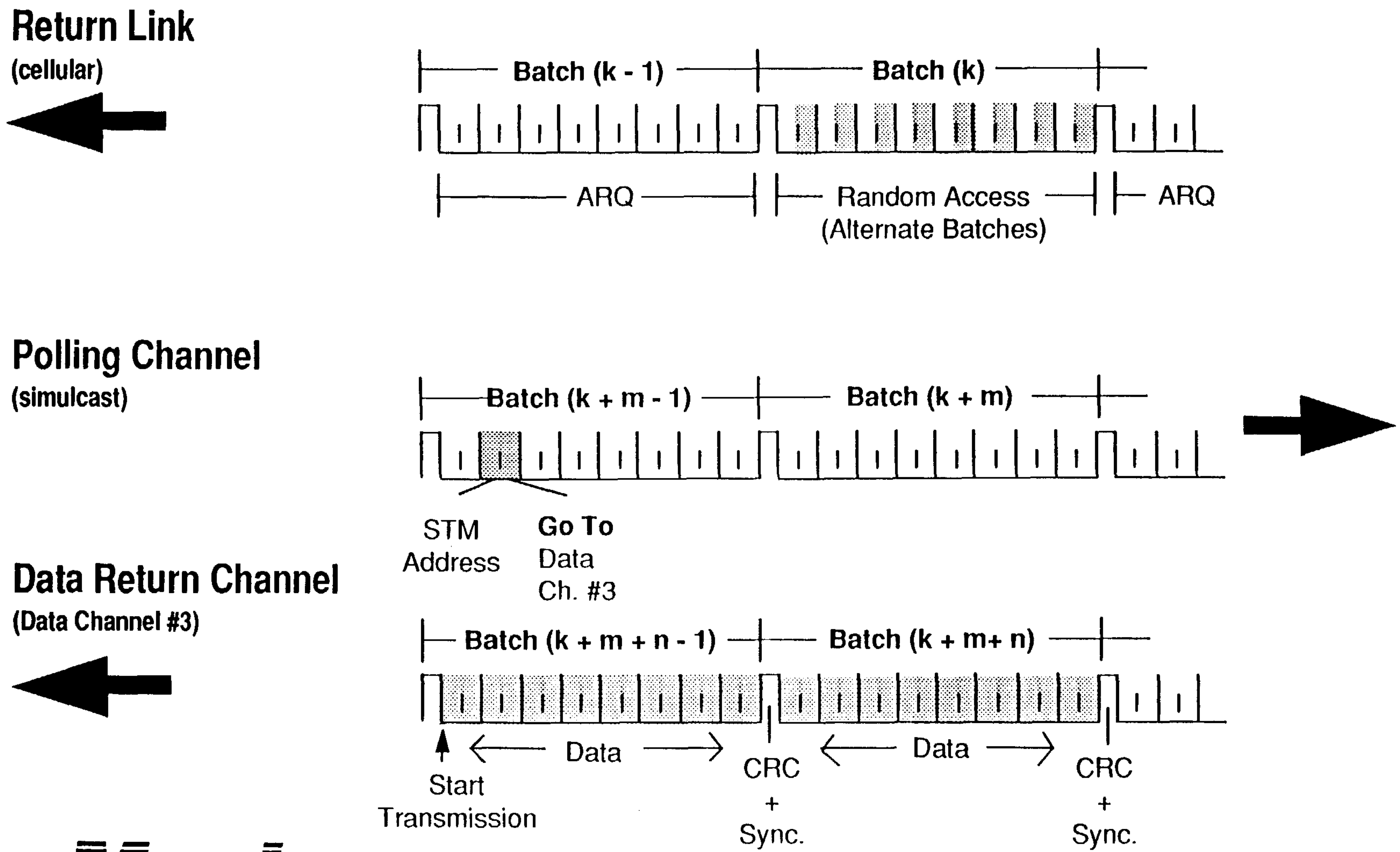

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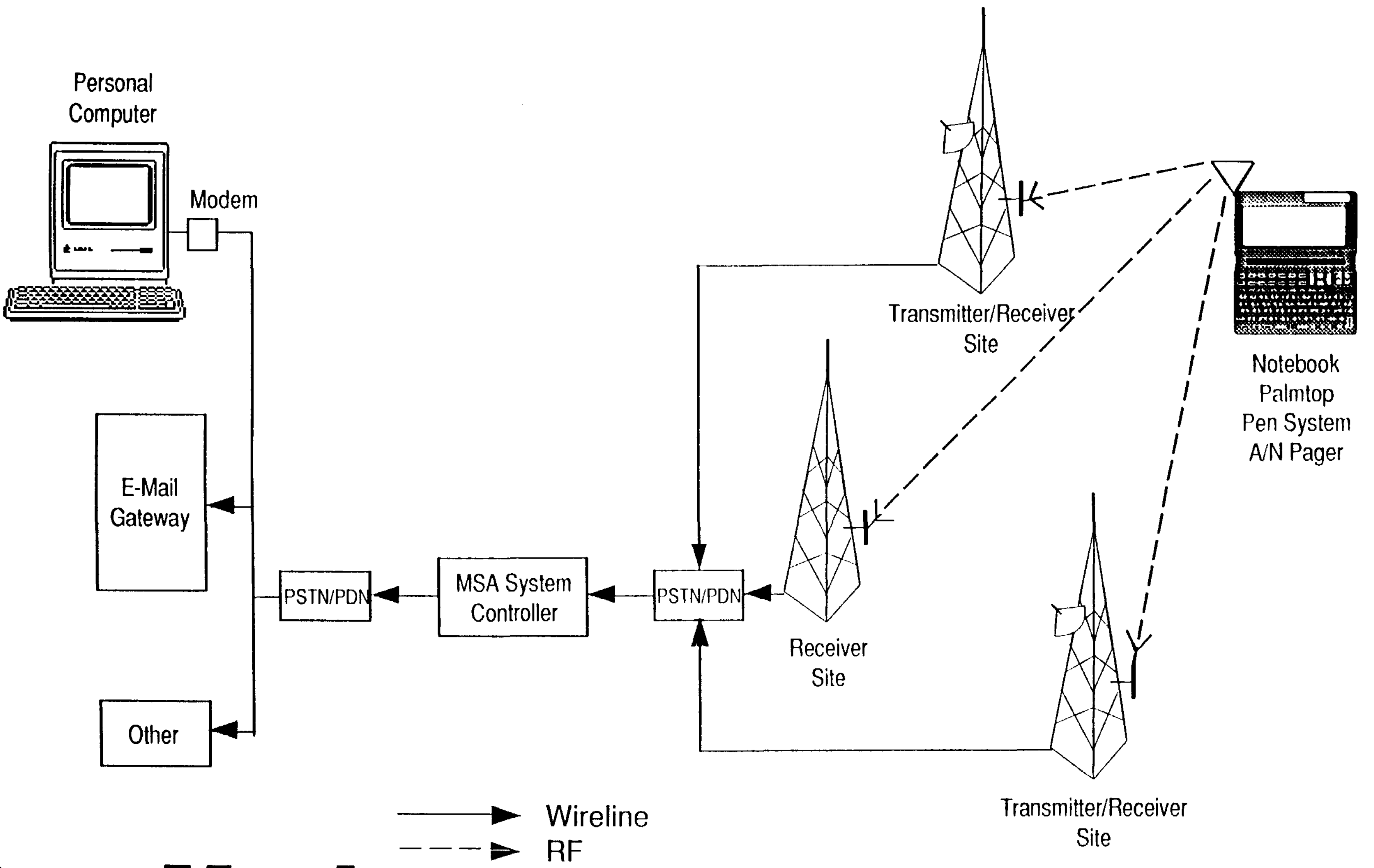
EXHIBIT XVII

Inbound Message/Acknowledgement



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transmission complete ARQ over the polling channel.

F. System Controller

The system controller serves as the central computer system for an MSA, which includes a paging terminal, PSTN/PSDN interface/control module, base station controller and bridge modules for the Billing and Diagnostic/Maintenance Monitoring systems. The System Controller contains the software module to link to the "paging terminal." The system controller performs the following key functions:

- Interfaces with the "paging terminal," which in turn interfaces with the PSTN and PDN networks;
- Queues messages for the geographic, building and office cells;
    - Sends data to appropriate cells with proper command and control functions;
    - Re-schedules re-transmission per request from cells;
    - Removes files from queues when EOT is obtained;
    - Returns to polling process when re-transmission exceeds threshold value;
    - Initiates ARQ response to subscribers transmitting data on the return link data channels;
- Interfaces with wireline communications networks;
    - Bridges E-mail, modems, information, utility services;
    - Links to cells;
    - Links to satellite uplink;
- Maintains the MSA cell configuration data base;
- Performs as the MSA system configuration controller; and
- Performs as MSA Diagnostic and Monitoring Center

Each system controller interfaces to other system controllers via high-speed digital lines in order to process polling requests to locate subscriber units either within its MSA or beyond its MSA, and to transmit messages between MSAs for delivery to subscribers.

Before the process of polling subscriber units for the best serving transmitter site, the system controller stores the message according to the unique capcode number assigned to each subscriber unit until the ID of the serving transmitter site is added. Once a subscriber unit is located, the message is queued according to the serving cell loading conditions.

If the subscriber unit cannot be located within the "home" MSA, then the system controller makes a polling request to all other MSA's system controllers within the subscriber's selected coverage area (including nationwide). The system controller will then transfer the message to the serving MSA system controller for message transmission. Once the serving transmitter is identified, the system controller optimizes the "message-ready" queues, by transmit frequency for each cell, and assigns a time to transmit, or time "marker," to each message. The message is then sent over phone lines to the selected "cell" transmitter to be broadcast at the specified time.[10]

The timing signals are delivered to cell transmitters either by the direct broadcast satellite control channel, in the case of geographical and building cells, or indirectly by synchronization to the polling channel in the case of an office cell. Since data transmission batches are themselves synchronized to the polling channel, the entire MSA system in effect uses the direct

[10] Note that the link protocol for data input to the system is one protocol and the link protocol to the cell site is another independent link protocol, which is also independent of the RF link protocol, to allow each link to optimize its protocol for error correction/detection.

broadcast satellite as a master clock. In special cases the clock can be a GPS receiver.

In order to ensure messages are completed with minimum re-transmission being required, the packet size should be short. However, to minimize the address and error correction overhead, the packet size should be as long as possible. Although packet size is variable, the typical size will be an integral number (N) of the POCSAG words or batches with N being 2 to 5 POCSAG batches at present. Also, check bits are processed for error corrections and CRC for batch error detection followed by ARQ return on return link.

Given that most cells will operate more than one data channel and, in many cases up to eight (8) different data channels along with the polling channel and the return link channel, the system controller unit optimizes the message queues for each frequency in order to ensure maximum throughput of messages. The queue optimization is done with respect to the earliest transmission initiation time available for each frequency in each cell. For building and office cells, where there is no practical co-channel interference present, since only building cells, office cells and non-interfering remote geographical cells broadcast at same time, the queues for each frequency can be loaded on a FIFO basis. However, in the primary geographical cell broadcast interval, adjacent cells must follow a practical, four-cell reuse pattern. Therefore, optimizing cell throughput for minimum message delivery time requires an optimizing algorithm to take into account available frequencies based on the cell reuse plan employed.

For example, a nationwide provider could use algorithms that permit all 8 data channels to broadcast in one out of each 4-cell reuse group, with all others inactive. Alternatively, if loading is more uniform between cells, each cell could broadcast simultaneously on two mutually exclusive channels in each 4-cell group.

III. Other System and Service Features

A. System Capacity

PageMart has estimated the total number of subscribers that could be supported on a MSA basis. Depending upon 1) the average number of cells utilized, 2) the mix of cells utilized (i.e. geographical versus building versus office cells), 3) the average message length, 4) the average number of messages per user, and 5) the number of users contending for service during busy hour, system capacity will ultimately be limited by either the number of data channels available or by the throughput capability of the polling and response command/control channel pair.

PageMart's planning model, based on conservative assumptions, indicates that the proposed service can support over 100,000 subscribers per major MSA, such as New York City and Los Angeles, if the system is operating at 4,800 bps. This is based on (i) an average message size of 6,000 characters, and (ii) an average of 2.5 messages per subscriber during a 10-hour busy period (15,000 characters per subscriber per day during busy hour).[11] If the data rate were increased to 9,600 bps, then over 200,000 subscribers could be accommodated in a major metropolitan area. This assumes a cell reuse configuration of 40 geographic cells, 40 building cells and 400 office cells, which is quite realistic for large cities.[12]

An effective way to view the spectrum efficiency and capacity of PIMS is relative to a typical simulcast network. For a well developed major MSA system, the following model

[11] This is roughly equivalent to one facsimile page per subscriber per day.

[12] This is a conservative sizing of the practical capacity of the service. The theoretical limit at 4800 bps is some 350,000 subscribers.

illustrates PIMS capability:

Assumptions

1) Average percentage of cells (geographic & building) containing messages per batch = 70%

2) Average message utilization of each batch (geographic & building) = 80%

3) Data channels per cell - Geographic - 8 channels

   - Building - 6 channels

   - Office - 1 channel

4) Average utilization of office cells = every third building cell batch or 1/3 per batch

5) Proportion of batches involving geographic cells versus building and office cells = 1:1

6) Percentage of geographic cells that can transmit on a non-interfering basis during building cell transmission cycle = 50%

7) POCSAG Code Efficiency = 0.58

8) Busy Hour Period Characteristics: a) 10 hours, b) 2.5 messages per subscriber, and c) 6,000 characters per message

9) Average re-transmission as a fraction of total batches =.95

10) Comparative simulcast system is 100% efficient or theoretical efficiency used for comparison.

Equivalent Throughput Calculation (Relative to Simulcast)

Geographical Cell Batch =

(40 cells/4 cell re-use) X 8 channels X .7 X .8 = 44.8 Effective Channels

Building Cell / Office Cell and Non-Interfering Geographical Cell Batch =

(40 building cells X 6 channels X .7 X .8) + (20 geographical cells/4 cell re-use X 8 X.7 X .8) + (400 office cells X 1 channel X .7 X .8 X 1/3) = 231.5 Effective Channels

Average Batch Throughput = (44.8 + 231.5) / 2 X .95 = 13 Effective Channels

Average Batch Throughput per all Channels used relative to theoretical simulcast channel = 131/10 = 13.1 multiplier

Subscriber Loading Calculation (Per Major MSA)

Character (byte) through-put during 10-hour busy period at 4,800 bps

= 131 X 4,800 / 8 X 0.58 X 36,00 [?] = 1.64 X 10^9 characters

Average Subscriber Capacity @ 4,800 bps

= 1.64 X 10^9 characters / (2.5)(6,000 characters)

= 109,000 subscribers

To illustrate the improvement of PIMS over conventional simulcast for spectrum efficiency, the following table indicates that the multiple of throughput as a function of the number cells can be as high as 30:1 on a projected bases, and as high as approximately 100:1 on a theoretical basis.

PIMS Multiple Over Conventional Simulcast (Single Channel Equivalent)

	Projected Case	Theoretical Limit
CASE (A) - Growth Phase	Multiplier=13.1X	Multiplier=42X
a) 40 Geographical cells;		
b) 40 Building cells;		
c) 400 Office cells		
CASE (B) - Mature Phase	Multiplier=29.6X	Multiplier=99X
a) 60 Geographical cells;		
b) 100 Building cells;		
c) 1,000 Office cells		

Further, the following table shows the impact of data rate on PIMS' overall system performance:

PIMS Subscriber Capacity by Major MSA (e.g. New York, Los Angeles)

	Data Rate (bps)		
	4,800	*9,600*	*12,000*
CASE (A)	109,000	219,000	273,000
CASE (B)	247,000	493,000	618,000

Clearly, as the ratio of facsimile transmissions increase relative to text or E-mail messages, the average "message" size increases and, consequently, the average subscriber capacity is reduced. When the number of subscribers approaches the 500,000 subscriber range per MSA, the capacity of the polling and return link could reach capacity and be the limiting system element. Therefore, the mature system is approximately "balanced" in CASE (B), with receivers operating at 9,600 bps, but can be fully functional with receivers operating at only 4,800 bps.

B. Coding Modulation Options

The aforementioned features of the PIMS system provide enormous flexibility in using a wide variety of channel bandwidth and modulation schemes. PIMS is fundamentally a novel signalling concept for one-way and two-way transmission of data utilizing frequency reuse to achieve spectrum efficiency. Design flexibility can be illustrated is several key areas.

The current approach is to utilize channel bandwidth of 25 KHz in conjunction with a conventional paging-type receiver design capable of 4,800 bps or higher. However, as PageMart's involvement with equipment manufacturers continues, other alternatives emerge, involving the use of coding modulation methods to increase data rate for a given bandwidth and bit error rate (BER), which may also meet the objective of low-cost receiver design. For example, options meriting consideration include:

- Set bandwidth at 25 KHz and optimize the modulation and coding to maximize data throughput at a given lower bound on bit error rate (BER) for this RF link (e.g., 9.600-12,000 bps)

- Set bandwidth at 5 KHz and use technology developed for 220 MHz band rulemaking (e.g., 2,400 plus bps)

- Set bandwidth at 50 KHz and optimize the modulation and coding for maximum data rate at a given lower bound on BER for this RF link (e.g., 19,200-24,000 bps)

In all three cases, the practical upper bound on data rate is about one-half the effective RF bandwidth. Because of the impulse response of the RF channel, or intersymbol interference (ISI), some form of channel equalization is required as the data rates increase. Also, as the data rate and bandwidth decrease, the cost of filtering plus frequency accuracy and stability become a major issue. Balancing these factors, PageMart currently believes that the optimal bandwidth is in the 15-30 KHz range, and this prototype system design is framed accordingly.

Moreover, PageMart's present approach is to use binary frequency modulation, but alternatives to binary frequency modulation have been and are being evaluated. PageMart has restricted its evaluation to constant amplitude phase and/or frequency modulation schemes and, in most cases, pre-coding and filtering of the data, to obtain spectrum shaping with good error rate performance. Below is a partial list of modulation alternatives that have been or are under consideration.

1) BPSK (Binary Phase Shift Key)
2) CPFM (Coded Phase/Frequency Modulation)
3) SQPSK (Staggered Quadrature Phase Modulation)
4) CPFM (Constant Phase Frequency Modulation)
5) TFM (Timed Frequency Modulation)
6) PFSK (Permutations Frequency Shift Key)
7) DS/SSM (Direct Sequence/Spread Spectrum Modulation)

C. Trunking

Another important feature of the PIMS design is that it is uniquely suited for utilizing multiple frequencies, or trunking, in the transmission of data to achieve high data throughput. The advantage of trunking multiple frequencies on data channels is to:

- maximize throughput per cell and improve busy hour service response time;
- maximize the shared electronics equipment overhead per site (e.g. cell controller, cable, antenna, etc.), and;
- minimize the command and control channel overhead per Data channel.

D. Frequency Plan

Given that at any one point in time at least one low-power return link channel will be operational, and more if subscribers are transmitting messages from their subscriber transceiver modules, a frequency plan must be determined that will minimize interference. This will be done after engineering development and thorough testing of the RF links and network receiver stations have been completed. Also, PageMart will utilize the abundance of RF data already collected and in the public record on co-channel and adjacent channel interference studies to verify its findings.

Conclusion

In sum, PIMS is a technologically advance combination of radiolocation, frequency reuse and state-of-the-art communications technologies. PIMS enables hand-held data communications transceivers to signal their location to a wide-area transmission network, and to be contacted on a selective, spectrally-efficient basis. Similar to cellular mobile phone service, PIMS architecture is based on the concept of "reusing" frequencies among cells in a given service area on a reuse pattern which assures that co-channel interference is kept to acceptable levels. This approach is essential to transmit text and other messages (i.e., alpha-numeric pages, graphics and facsimile) that consume large segments of transmission time. Existing "simulcast" paging technologies cannot economically deliver these types of messages to large numbers of users without high-speed and unacceptably high-cost receiving equipment.

PageMart's PIMS proposal promises to serve as the foundation for a new wireless messaging industry, enabling American consumers to receive and transmit full-text and graphic messages from palmtop and pocket sized personal organizers and computers, and their successors, which are increasingly becoming an integral part of modern business and personal information management. Unlike existing "simulcast" paging technologies and proposed enhancements for data delivery, PIMS achieves high throughput rates without necessitating proprietary or confining modulation schemes or substantially increased costs for high-speed receiving equipment. Unlike cellular and other packet network technologies, PIMS achieves instantaneous messaging, with reliability and portability, without the network control, battery consumption and size constraints dictated by these voice and document-based technologies.

PIMS architecture offers enormous flexibility of design while achieving the fundamental objectives of the service concept. In particular, alternative approaches in both bandwidth size and modulation can be used without sacrificing the basic service concept and the benefits of high spectrum efficiency, high throughput, and low cost operation and user equipment. PIMS is structured as a "protocol transparent" service, permitting equipment manufacturers or end users to devise and implement their preferred and efficient methods for formatting information. PIMS also permits adaptive development of system architecture, allowing service providers to deploy individual network cells of any size -- office, building or geographic-based -- and to easily alter system configuration as demand dictates.