a negotiated basis with the specific device. This requires some form of response system.

The system can manage and keep track of r-f transmissions on the forward channels. However, users can respond to messages either digitally or with push button responses. Consequently, the reverse channel will see random r-f responses which, on a conventional channel, would be mutally destructive. The Freeman paging system anticipates utilizing code division multiple access (CDMA) techniques on the reverse channel which allow simultaneous access by large numbers of pagers without interference on the reverse channel. This complex technique is easily handled by DSPs. Since the pagers are already intended to utilize DSPs, no penalty is extracted by using CDMA techniques on the reverse channel because the pager DSP has enough spare capacity to process CDMA responses along with its normal decoding of the subchannels and the processing of Vocoder or digitized voice messages.

Reverse channel receivers will be located throughout the system service area so that the low energy (approximately 1 joule) transmissions from the pager may be sent back to the system. It is anticipated that these receivers will be located every two to three miles depending upon topography, building characteristics and attainable receiver antenna heights.

Unassociated with the technical facets of the transmission system are certain operational features which may be readily employed without affecting transmissions. For example, while voice responses are not anticipated in the system, a code sent from the pager to the terminal may be converted into a synthesized voice message with any number of meanings. This could be

accomplished on a per user basis with voice and pager response definitions customized by the user. Button number one, for instance, could consist of the message "Don't do anything about this now. Wait until I return to the office". When the user presses button number one, that voice message can be played back to the calling party or, upon previous arrangement, can be forwarded to a voice mail box with or without the original message accompanying the response. Encoded responses are virtually unlimited; however, in most instances, Freeman anticipates that the responses will be simple and fast and be returned directly to the calling party without delay. In the event that the system gets backed up or delayed, which is highly unlikely, responses may be either printed or sent to an operator's console or any number of different locations. A user responsive paging system opens a whole new world of communications strategies.

SYSTEM CAPACITY

A natural question to be asked by spectrum administrators is "Why should wideband channels be allocated under any circumstances?" There is some opposition to allocating wideband channels which include such issues as the restriction of competition. Freeman anticipates that more than one wideband channel will ultimately be allocated by the FCC for competitive purposes. Furthermore, current paging device limitations are mentioned in most discussions about wideband spectrum allocation. With a wideband channel, new innovative services could provide new forms of communications which are currently not

available and not attainable using conventional 25 KHz wide channels. The concept of sending large amounts of data to a terminal or even to a group of terminals cannot be done efficiently in the 25 KHz structure. The Freeman system has the capability of sending a great deal of data very quickly and will permit new uses of the one-way technology. This, along with the response mechanism to invoke retransmissions, will make the system fast and highly accurate.

Freeman is requesting allocation of the equivalent of eight conventional 25 KHz paging channels. In those channels, if we assume that two would be used for response channels, then it is more likely that six forward channels and two reverse channels must be compared against the one 150 KHz forward channel and one 56 KHz reverse channel of the Freeman proposal. Since for the Freeman system the ultimate capacity relies on the capacity of the forward channel we will not consider the reverse channels in our comparisons. Freeman is proposing to use 30 of its 32 subchannels for data at 9600 bps. This raw data capacity is five times the information rate of six conventional channels operating at the same speed. Currently, most paging channels do not operate at this speed. However, any new 25 KHz allocations could probably use 9600 bps. Freeman's system has the capability of utilizing two or more data channels simultaneously. This could not be simply done with conventional channels. The efficiency obtained by utilizing a calling/working channel configuration also cannot be reached using 25 KHz channels in the conventional sense. Even if some sophisticated scheme were adopted to expand the number of subchannels used on a conventional channel, with resulting greater capacity for tone-only, alpha-numeric and numeric paging, there would still be very little capacity for conventional voice messaging. The

Freeman system is considerably more versatile than would be the reconfiguring of conventional channels. In short, the use of wideband channels should not be ignored in allocations for advanced paging systems.

Capacity of any paging system is very difficult to quantify because one must make assumptions concerning the mix of various paging services. These assumptions would also necessarily include devices and processes which are not yet available. Rather than attempt any form of mixture, each of the various conventional paging types will be analyzed and compared against conventional channels to illustrate the enormous capacity and innovation of the proposed Freeman paging system.

Subchannel 1 encodes the pager addresses and designates a data channel for message delivery. This information is contained within a single 32-bit word for which 18 bits are used as a pager address with 3 address bits assumed, based on the group to which the pager is associated. Thus, an effective 21 bit address is obtained which has the capability of uniquely addressing approximately two million pagers. Two bits in the codeword are reserved for future expansion and could be used to expand the address field which would bring the unique addressing capability to something over 8.3 million subscribers. Since it is unlikely that the system will ever reach its full addressing capacity, only 2 million unique addresses have been specifically designated. The reason 8 million subscribers are unanticipated is that the mix of pagers will likely limit the capacity of the system to something less than 8 million users. As will be shown, if most of the users are voice subscribers, the system will achieve a considerably lower capacity than if the system were to be composed of mainly tone-only or numeric customers. In the

latter case, the system would be limited by Channel 1's ability to process pager addresses. In the former case, the system would be limited by the capacity of the data channels. None of these should be viewed as limitations since the system capacity is enormous.

By far and away the most versatile form of paging is, and always has been, the voice message. Words convey meaning, but the voice also conveys emphasis by its intonation. The simple words "call me now" can have various meanings depending on the inflections given each of the words. Moreover, for complex messaging, the voice message, particularly with pager recording capability (which can be instituted from any telephone) can be much more versatile and user friendly than any digital form of messaging. For many current users of paging systems, voice messaging could be a very satisfactory paging method. System operators have discouraged the use of voice paging because, in the past, voice paging has not been efficient and did not permit service to as many customers on a channel as do other paging methods. Paging systems did not drift away from the voice format simply because of customer desires. It was purely an economic consideration.

Freeman anticipates allowing average length voice messages of approximately 15 seconds. If one visualizes a typical one minute commercial, there is a great amount of information that can be conveyed in a 15-second message. Compression techniques are to be used in the system which will permit a 15-second message to be transmitted in about 11 seconds.

The conventional way to determine system capacity is to compute the number of calls that may be processed during a busy hour. This is an old

telephone convention which is used by the paging industry. The industry average for paging rates is approximately 0.1 calls per busy hour per paging subscriber. This means that the system can usually obtain a subscriber capacity of ten times the number of calls it can process in the busiest hour of a day. With 15-second voice messages, the proposed Freeman system can process 9,863 calls per hour. This corresponds to a system capacity of 98,630 voice subscribers. In a conventional voice system it is common that a voice paging channel have a maximum capacity of approximately 1500 subscribers. If we assume six channels available for voice messaging (reserving two for responses), the equivalent conventional system capacity would be 9000 subscribers. The Freeman system represents an expansion of more than ten times over the conventional voice paging channels.

Equally impressive and innovative is the capacity of the Freeman paging system to process alpha-numeric messages. These are digital messages which utilize letters and numerals and which are displayed on a screen or readout. Assuming an average message length of 60 characters encoded as ASCII characters with eight bits per character, the Freeman system can process, including subchannel acquisition times, 952,066 calls in a busy hour. If the number of bits representing a character were reduced to seven, the processing rate would be proportionately higher. This calling rate would support over nine million subscribers which exceeds the system addressing capacity of about eight million. (This is the limitation imposed by the bit-length of the available address.) If some pagers received two or more calls during the busy hour, the system will be capable of processing the full 952,066 calls in the busy hour. On a typical

conventional alpha-numeric channel, it is unlikely that a channel would sustain 40,000 alpha-numeric subscribers assuming a 60-character message. That would yield a six channel capacity of 240,000 subscribers compared to Freeman's 9.5 million, an improvement factor of about 40 times. Even if the conventional channels were operated with a bit rate similar to the Freeman proposal, there would still be a four times benefit with the Freeman system based simply on the number of channels achieved.

The Freeman system has such a large capacity that the number of numeric pages (each comprising a 10-digit, BCD encoded, numeric message with a tone alert) that can be carried by the system, far exceeds the number of possible address codes. That is, the Freeman system has the ability to process calls to support over ten million tone-only/numeric paging subscribers, but its available address space is only capable of addressing some eight million.

Because the numeric and tone-only messages are so short, the number of messages which can be processed will be limited by the rate at which addresses can be sent over Channel 1. This rate is 282 calls per second which equates to slightly more than one million calls per hour. The system is thus able to support up to ten million subscribers on its calling channel of which eight million are uniquely addressable. Thus, if all users on the system were tone-only or numeric subscribers, the system could process and support the maximum number of callers which it can uniquely address.

A typical paging channel, of which there are few purely numeric/tone-only in existence, could probably attain a subscriber capacity of 75,000. Even if the

number were 100,000 (with a six-channel capacity of 600,000 subscribers) the Freeman system would represent greater than ten-times expansion over conventional systems.

If we study the issues of mixing the different paging types and introducing hypothetical large volume processing, we can hypothesize virtually any position desired. The important issue is that the Freeman proposal represents an order of magnitude increase over present systems and a substantial increase over the capacity of the equivalent number of narrowband paging channels.

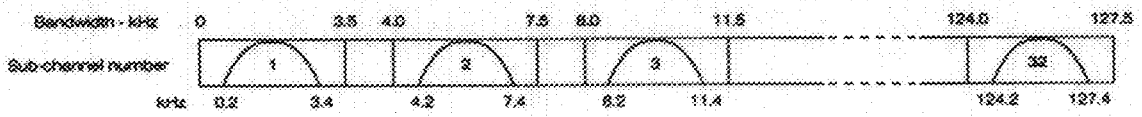
There is evidence that when pager volumes reach the million range, pager prices will likely be less costly than pagers currently available in conventional services. This includes the cost of some perceptually higher priced digital chips such as the DSP.

Other issues involve infrastructure. Eight conventional 25 KHz channels require eight times as many transmitters, transmission lines, antennas, etc. to achieve an equivalent system. Moreover, the institution of 25 KHz response channels makes random access transmissions nearly impossible without having a discrete response channel available for each conventional 25 KHz forward channel. Thus, the assumptions made in the capacity comparisons above show a further advantage of the Freeman system. A conventional system requires a discrete response channel for each forward channel. Therefore, the two Freeman channels would be equivalent to four forward and four response conventional channels. Even with very high data rates, the narrowband 25 KHz channels could not match the capacity of the proposed Freeman system.

The Freeman system, which proposes a 9600 bps data rate, has selected that data rate because it is easily achievable, can be provided quickly and has already been accomplished using DSP technology. It is anticipated that 19,200 bps could be accomplished without much additional effort. This would virtually double the capacity of the Freeman system but would also require the use of Channel 2 as an additional, simultaneous calling channel along with Channel 1. This would complicate the simultaneous transmission equalization techniques to be used with the Freeman system. That same data rate, on a conventional 25 KHz channel, would be virtually impossible to equalize except in a few rare locations where topographic and geographic conditions are ideal. In the caverns of New York City and the Grand Canyon, simultaneous transmitters would be virtually impossible to employ at the higher data rates. Freeman's method of equalization will be explained in a subsequent section.

R-F CHANNEL STRUCTURE

Forward Channel



The Forward channel will have 32 sub-channels, each capable of 9600 bps data. Sub-channel 1 is the baseband and carries unaltered signals from 200-3400 Hz. Sub-channels 2-32 are similar to sub-channel 1 except they have been shifted in frequency to be centered in their respective sub-bands.

Figure 1 - Forward Channel Modulation

The forward channel has an effective r-f bandwidth of 150 KHz in the 930 MHz frequency band. The channel will employ narrow-band FM transmission modulated by a system of subcarriers which has an upper frequency of 127.5 KHz. Each subcarrier will have a voice-grade bandwidth which is approximately C-Message weighted with modulation frequencies from 200 Hz to 3400 Hz. The address or calling channel will occupy the base band on subchannel number 1. Subchannels 2 through 32 will each be derived utilizing widely available modern technology. The 32 channels will then be pre-emphasized and used to modulate an FM carrier to approximately ±75 KHz deviation. Each subcarrier will be given an insertion level to achieve the same modulation index. Similar techniques have been utilized for many years in other radio services and represent relatively common equipment and processes.

Reverse Channel

As indicated, the proposed reverse channel utilizes a 56 KHz bandwidth which is used for pager responses. If the reverse message rate is approximately 600 bps, the 56 KHz band achieves about 20 dB processing gain utilizing spread spectrum CDMA modulation. In fact, the Freeman system anticipates using a direct sequence, pseudo noise, spread spectrum, code division multiple access modulation process for all transmissions on the reverse channel. Some experimentation will be required to select the R-F channel carrier type (FSK, BPSK, etc.) for maximum battery power conservation. The CDMA response system will be operated using asynchronous techniques.

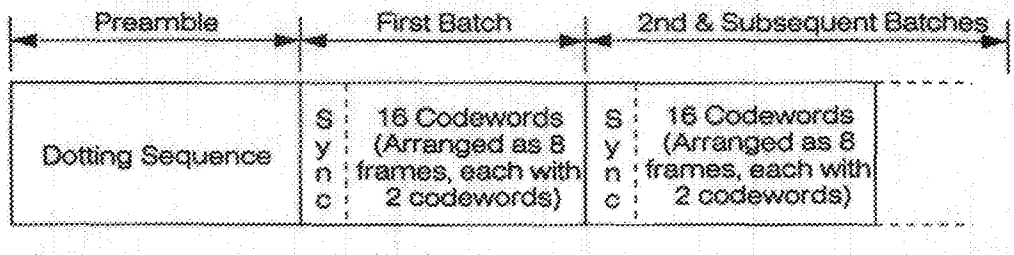
Due to the relatively low data rate of 600 bps, the proposed Freeman system will be robust in the presence of multiple interferors. However, the data rate will not permit large volumes of data to be returned to the system over the reverse channel.

CODE FORMAT AND PROTOCOL

Figure 2 illustrates the code structure of the proposed Freeman system. It is based on the POCSAG format which has been used world-wide for many years. The calling channel, Channel 1, is a synchronous channel in which one "Sync" word is sent for every 16 addresses. Pagers are assigned to one of eight frames based on some algorithm which is typically the last character in their access code.

Modeled after the widely used POCSAG format

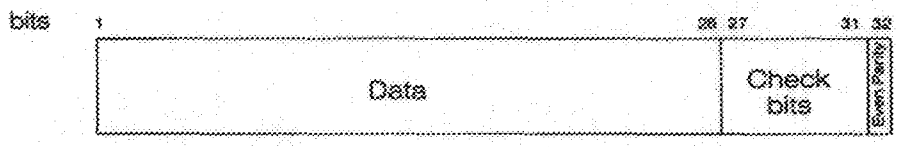
Channel Structure



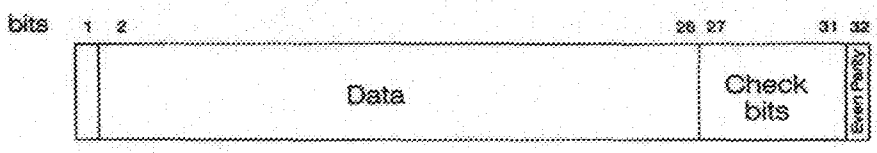
The channel is synchronous and the preamble will be necessary only on rare occasions. Sync is a special word synchronization codeword.

Codeword Structure

One Codeword consists of 32-bits. Most configurations of codewords use an error correcting BCH (31,26,1) structure plus one fill-bit which is used as a parity bit. Some message codewords do not conform to this convention.



Codeword Types



Notes:

Bit 1 is always either 0 = address codeword or 1 = other

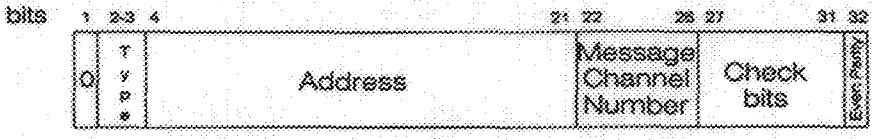
Synchronization codeword assigned a hex value of 7CD215D8. Used for word sync.

Address fill codeword assigned hex value of 7A89C197. Used as fill on synchronous address channel when no paging messages are pending.

Figure 2 - Code Format

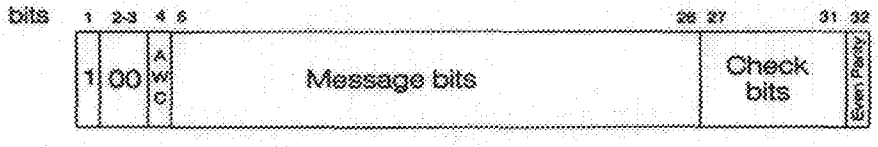
Codeword Types - continued

Address Codeword



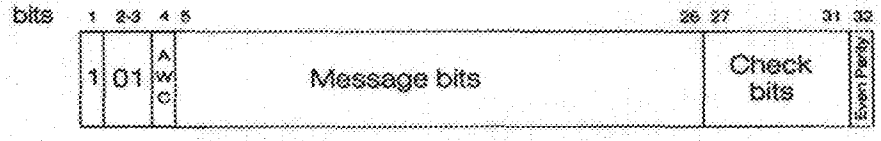
bits 2-3 Reserved, set to 00 for address message type
22-26 Message channel number 2 to 32 if message pending.
If = 0, no message pending.
If = 1, no message pending, transpond on response channel.
if > 1, move to designated sub-channel for message
Note: sub-channel number = message number

Message Codeword - Type 1 - Alpha and numeric



bits 2-3 are message type designators - 00 for Message Type 1
bit 4 is 1 if more message words are coming,
0 if this is the last message word

Message Codeword - Type 2 - Binary and Voice



bits 2-3 are message type designators - 01 for Message Type 2
bit 4 is 1 if more message words are coming,
0 if this is the last message word

Message Codeword Type 3 (10) and Type 4 (11) are reserved

Figure 2 - Code Format

For example, a pager which has an address ending in zero or one might be assigned to frame one; one with a last digit of two may be assigned to frame two and so on. In this manner, pagers are placed in one of eight frames which represents three binary address bits. The frame arrangement is required to employ battery saving techniques by which a pager literally shuts down during frames other than its own. This is shown on Figure 2, labelled as Channel Structure.

Each codeword has a structurally similar appearance irrespective of its purpose. Typically, a codeword is 32-bits long in which the first 26 bits are used for data and the remaining bits are used for error detection and correction. All data in the system is encapsulated in an error-correcting block code referred to as a BCH(31, 26,1) code which has the ability to correct one bit. This is illustrated in Figure 2 under Codeword Structure. Note that in future definitions, some codewords can be defined which do not conform to the convention indicated in the codeword structure. This is because different types of transmission may be required and will be indicated by the codeword types which may be dynamically negotiated. For example, a Type 3 message code may result in the pager switching to a message channel and then setting up the protocol and format for the remainder of the message. The new protocol may or may not have the same structure as that indicated in the codeword structure of Figure 2. This will permit the future use of variable length binary data, with or without error correction, and any other of a variety of messages that can be formulated digitally. Under these circumstances the system would service the various message types based upon

the type of pager being paged. Recall that pager is a generic term and can take on many forms.

Normally, in the proposed Freeman system, codeword types will conform to the convention described in Figure 2. Once the address has been decoded and the pager has moved to the working channel, its messages will have the form shown for Type 1 and Type 2 message codewords. The distinction between the two codeword types occurs in bits two and three of each word. As indicated, types three and four are reserved for future purposes. Message codewords will continue to be sent sequentially until the message is completed. Bit four in the message codewords has been assigned as an "another word coming" bit which indicates that the current word is or is not the last word of the message. Each message codeword nets 22 bits out of 32 for the message which is reasonably efficient considering the error correction capability. If greater efficiency is necessary, message codeword types three and four could be defined to utilize up to 100% efficiency. However, this is not a recommended practice. Typically, when the parity fails or the check bits fail, the pager will not return a message receipt response which will then force the system to resend the message as many times as required to get it correct. But, even this does not have to be a hard, fast rule. Different levels of reliability could be utilized by the system operator to provide different levels of performance to different subscribers on the same system for different prices. These matters will be incorporated into the operational considerations of the system and do not require any changes to the technical characteristics of the paging system.

The calling channel, Channel 1, is synchronous and all pagers continuously decode this channel unless they are operating on a subchannel. Occasionally, during idle periods, the system will not have an active address to put in every codeword. In that case, an address codeword, which may not be assigned to a pager, is used as a fill word. In this case, we have selected the same codeword that is used in the POCSAG format. Between each group of 16 codewords, the system will send a word synchronization so that pagers which are just joining the bit stream can synchronize to the first frame. The pager thus knows when to sleep and when to wake up to look at its frame for an address match.

EQUALIZATION OF SIMULTANEOUS SYSTEM

Existing simultaneous transmission systems operating at 900 MHz do not require complex, high accuracy equalization. However, when bandwidths become large (with faster bit rates or higher modulating frequencies) then the equalization of the systems becomes critical. In any simultaneous transmission system, a number of requirements must be fulfilled for the system to work properly to ensure signals from two or more transmitters add coherently without total destruction and chaos. One of the requirements is that all transmitters start transmitting at precisely the same time. This means that each transmitter in a simultaneous system which is within range of a receiving pager must be time-delayed so that signals arriving at the pager are in step with each other. Two signals arriving at a pager delayed in time by one-half cycle of the highest modulating frequency will

cause that frequency to cancel. Once this happens, the pager can no longer accurately decode a message. The fundamental reason for simultaneous systems is to provide elevated signal levels in areas where signals are lowered by penetration of buildings or behind obstacles or for various other reasons. Illumination of a difficult area from a nearby transmitter often allows paging where none would otherwise exist.

In high-speed digital or analog systems, higher and higher modulating frequencies require equalization of transmitting times to smaller and smaller values. For example, a system which uses 19,200 bps will be cancelled if two signals arrive at the receiver with equal strength and displaced in time by about 26 microseconds. Can this happen in a real system? The answer is yes. Since r-f signals move about one mile in 5.3 microseconds, transmitters within five miles of the receive location can interfere. A pager which is located one mile from one transmitter and six miles from another transmitter will be interfered with if signals from the closer transmitter are very slightly attenuated relative to the signals coming from the more distant transmitter. This is true even with equalized transmitters. As the distance between transmitters increases, the probability of the more distant transmitter having the same signal level as the closer transmitter diminishes. Because modern receivers are designed to reject co-channel interference, once the signals differ by about 6 dB, the receivers will have a tendency to reject the signal from the weaker transmitter in deference to that from the stronger transmitter. This is comparable to the capture effect which is prevalent in wideband FM transmission. Systems which utilize conventional analog paging typically have a high modulating frequency of about 3000 Hz and will be equalized

for transmitter differential distances of some 15 miles. This will generally provide a ratio of signal levels which is adequate to provide excellent reliability. In designing simultaneous systems, the firm of Arthur K. Peters specifies that the equalization of the system shall be within 90° or 1/4 period of the highest modulating frequency for reliable results.

The proposed Freeman system has an upper modulating frequency of about 127.5 Kbps, which would result in a maximum transmitter differential distance of less than one mile before cancellation would occur. This is clearly unacceptable since no transmission system will place transmitters within two miles of each other so as not to exceed the maximum differential distance. Freeman's paging system utilizes special considerations and special signal processing to circumvent the untenable equalization requirements and still provide reliable paging using high frequency signals. Appendix A is a diagram which shows an arbitrary dashed circle which represents the desired service area of a simultaneous system. Within that circle and centrally located is a circle representing a centrally located base station of arbitrary size but chosen to keep a single tier of transmitters serving the area. In any such configuration with practical area coverages, the area between stations where signals from each of the transmitters are within 6 dB of each other represents about 30% of the area of the desired service area (dashed). This is essentially independent of the radius of the circles. In this zone, shown shaded in Appendix A, the signals from any two or three transmitters are within ±3 dB of each other. This is the zone where the receiver co-channel rejection feature will not function optimally. Interestingly, in the areas between any two or three circles, a properly equalized system will provide coherent signals which will not be mutually

destructive. The only places where mutual destruction may be expected, would be areas that are outside the ring of transmitters.

We then have a situation where, in a properly equalized system, signal levels and equalizations would be expected to achieve reliable coverage. In such situations transmitters are located in places where they are needed such as central downtown districts, hospitals with heavily constructed buildings and other such difficult-to-serve areas. Once these areas have been served, the randomness of signal variations will be the only factors producing unreliable results. In general, a simultaneous system which employs enough transmitters to keep the average signal level high will have very few full cancellation of signals due to the summation of out-of-phase signals. It is much more likely that a pager will be in a location where the signal penetration into a building is low or might be shielded from some nearby object. In general, when the average signal levels are high, the simultaneous system excels in reliability. When average signal levels drop to levels where cancellations due to multipath or reflections cause levels to drop below the receiver threshold, then the simultaneous systems tend to behave badly. Typical transmitter spacings of five miles would keep signal levels very high and produce excellent results. As transmitter separation distances increase, signal levels between transmitters tend to decrease until the reliability of the system diminishes below acceptable levels.

In the Freeman system, the base stations will always be equalized so that the first two subchannels are fully equalized throughout the system. Subchannels above 2 will not be equalized and will have a slightly elevated probability of error associated with them. There are two factors which come into play in this scheme.

One concerns the areas where the signals might be of approximately equal magnitude as illustrated in Appendix A. This represents approximately 30% of the total service area in a fully implemented simultaneous system. The second factor involves the ability to equalize only the first two subchannels. Appendix B has been prepared to illustrate the r-f energy appearing in the band. As shown in Appendix B, most of the energy in the FM signal associated with the first two subchannels will be contained in the spectrum between the carrier and approximately 7.4 KHz above and below the carrier. In narrowband FM, the signals approximate those of AM spectra with the exception that one side-band is 90° out of phase. It is demonstrated in Appendix B that each of the subchannels is a narrow band modulator even at the lowest frequencies. Therefore, the spectra will cluster around the carrier. Even though there may be r-f energy in higher frequencies, if the entire signal is equalized to 7.5 KHz, then at least the first two subchannels will receive coherent sums and be fully equalized throughout the system.

Outside of the area where signal levels are within 6 dB of each other, the probability for cancellation of signals at any modulating frequency or for any spectra within the FM signal diminishes rapidly. This is commonly observed in existing simultaneous systems, albeit with lower frequency equalization. As the average signal levels increase, the depth of cancellation must be greater which means that the signals have to be more nearly identical to provide complete cancellation. The probability falls dramatically as the requirement for exactness increases. This is precisely why higher signal levels do better in a simultaneous system.

In spite of all the rhetoric concerning the low probability of cancellation, there will be errors occuring in the system for many reasons including unanticipated signal cancellations. With the calling channel and the first subchannel fully equalized throughout the system the errors on those channels will be lower. In fact, errors on those channels will be on the same order as conventional simultaneous systems today which provide very good reliability. The upper subchannels, 3 through 32, will incur, we believe, only slightly elevated errors. However, when an error occurs, the Freeman system will attempt to resend the message. It will do this by first determining that a pager is in the system and available by requesting a pager to transpond on the response channel. Once the pager transponds, the system will resend its message on Channel 2 which is a known high-reliability channel. If the pager still does not receive its message the system will initiate a maintenance report concerning that pager and its approximate location, because it knows which receiver received the transponded pager code. Multiple fault reports in a specific area could point to a need for an additional base station in that area. However, it must be kept in mind that in most cases the base stations will have already been placed at optimum locations for the most reliable service. Builders of simultaneous transmission systems already search for difficult areas of coverage and try to locate base stations nearby for greatest reliability. This further decreases the probability of error because most of the pager traffic will be directed in areas covered by strong, single base station facilities. Typically the areas between base stations are populated by fewer pagers than areas immediately adjacent to serving base stations.

The channel capacity for subchannel 2 is totally independent and left available for error recovery and other functions. The capacity figures given above were calculated for channels 3 through 32. Capacity reductions due to resending signals on Channel 2 would only occur if the number of pages due to retries or errors diminished the capacity of the calling channel, Channel 1. We can identify only one time when this would occur and that would be when the system is comprised of all tone-only and/or numeric pagers and the call rate was over a million in the busy hour, which already implies more than the industry average number of calls per paging subscriber in the busy hour. This is a relatively improbable event since the addressing capability of the system is some 20% below the point at which capacity would be affected by repeats on Channel 2. Another factor would be if Channel 2 reached saturation due to a high rate of error somewhere in the system. It is expected that this condition would be temporary and could be fixed by the proper placement of additional base stations.

If Channel 2 does become totally occupied by retransmitting messages received with errors, any of the remaining subchannels could be used for "retries" as frequently as required. There is a good deal of backup capability in the proposed system. It is unlikely that the condition will ever develop whereby a paging message will not get through due to subchannel cancellations due to errors. The nature of the cancellation process is that if phase delays cancel on one subchannel at some specific frequency, they cannot simultaneously cancel on another subchannel unless it is harmonically related by an odd multiple frequency of the first subchannel. i.e., if you get cancellation in Channel 3, Channel 4 will be available. Therefore, the only reason to send "retries" on Channel 2 is to take advantage of the channel which has been fully equalized throughout the system.

CONCLUSIONS

The following is a list of new, unique or innovative system features and concepts, each of which would qualify as pioneering:

1. Up to 8.3 million subscribers for one system;
2. Up to 40 times greater capacity than current systems;
3. High-quality voice services in addition to all other paging services;
4. Responses which can be delivered as E-mail, voice, character strings, mailbox and TDD information;
5. Variable paging formats which will not obsolete existing pagers;
6. Paging format changes selected by pagers themselves. Accomplished by interactive negotiations between a pager and the system;
7. Simultaneous equalization of wideband system;
8. Special features for the deaf and other disabled persons;
9. One-eighth of the infrastructure costs of equivalent conventional systems;
10. Interference-free response system;
11. Capability of high-speed data delivery using selectable bandwidth techniques;

12. System costs equivalent to conventional systems. Thus, even areas with smaller populations can economically use the system and receive the benefits of greater compatibility.

The summary which Freeman included in its Request for a Pioneer's Preference has been expanded upon in this presentation. A new and innovative system which can be built from available components at costs equivalent to current paging systems has been evaluated and shown to be 4 to 40 times more efficient than equivalent 25 KHz bandwidth conventional channel systems, even when using elevated data rates. The system will function reliably and have a useful life because its coding structure is not fixed and may be expanded in the future without obsoleting existing users. Since the configuration of the system and its costs are comparable with conventional 900 MHz paging system, there is no reason to restrict its use to any particular area or any particular paging format. The definition of the pager to be utilized in the system has been purposely left sufficiently broad to allow generic use of the term "pager". It is anticipated that future paging efforts will utilize high volumes of data over these channels at rates that would not otherwise be available on 25 KHz channels. Moreover, because of the ability to combine two or more data channels the Freeman paging system has the ability to go even beyond its massive capacity and throughput as presently envisioned.

Arthur K. Peters, P.E.

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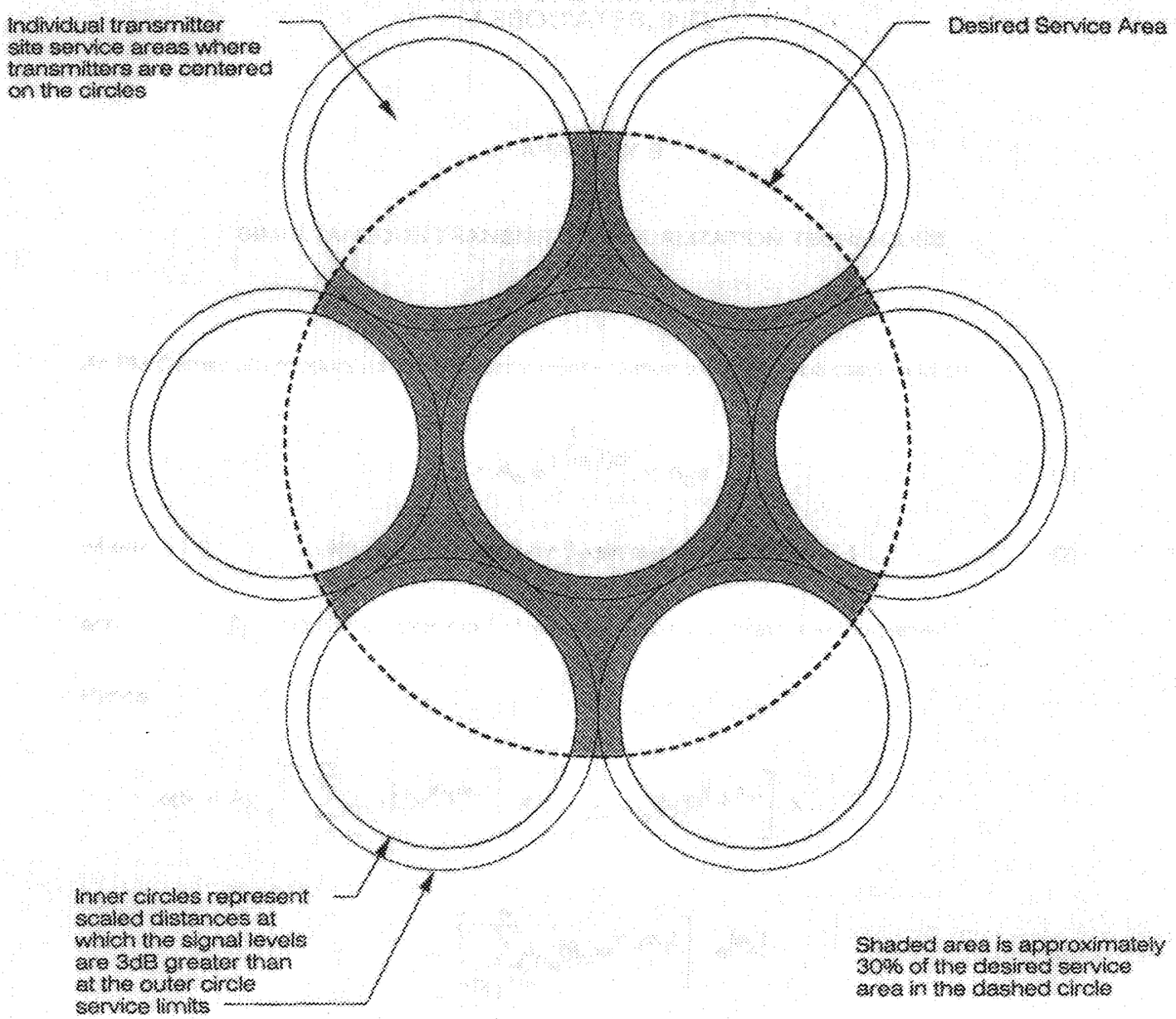

The shaded area shows the area in which signal levels from two or more transmitters are within ±3dB of each other. This is the area which has the greatest probability for signal cancellation. However, since all transmitters have been made to be precisely in step (time equalized), the modulation will not differ by the requisite 180° for any modulating frequency contained in the first two subchannels. Therefore, with respect to those subchannels, the Freeman system behaves as a familiar 900 MHz sumultaneous transmitter system. Furthermore, the equipment and techniques used for such equalization are available and familiar.