MOTOROLA

A GUIDE TO THE GOLAY SEQUENTIAL CODE (GSC)

DIMENSION 1000

OPTRX Alpha-Numeric and Numeric

BPR Display

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PREFACE

• CODING FOR PAGING SYSTEMS

A paging system consists of a base station, a terminal or encoder, and a number of pagers sharing a common RF frequency. Coded signals are used to selectively alert one pager in the system, and each pager has a unique code traditionally determined by plug-in reeds, active filters, or a code plug.

Radio group call is a variation of the individual selective alerting in that several people are alerted and paged simultaneously on a common code. Terminal group call enables the formation of groups at the terminal by special programming of the terminal to signal two or more individually assigned codes. Group call will be explained in more detail in subsequent sections.

The principles listed above pertain to all types of coding. Since the Golay Sequential Code (GSC) is new to most Motorola personnel, this booklet was prepared to help you understand it enough to answer the questions your customers are most likely to ask. The Golay Sequential Code is used in the DIMENSION 1000 Radio Pager, the BPR 2000 Display Pager, and the OPTRX Display Pager.

• INTRODUCTION

Metro Pageboy and Metrx pagers have been available for a number of years with binary digital coding; hundreds of thousands of such pagers are presently in use. The Motorola binary coding used in these systems has been improved to enable more flexibility in systems design.[1] This new binary format is called Golay Sequential Code (GSC). GSC (named after the inventor of the word structure, Marcel Golay) provides the following improvements and features over conventional coding schemes.

1. Larger number of codes with multiple address capability
2. Expanded group call size and flexibility
3. Multi-function capability; tone alert, tone and voice, and data paging
4. Efficient battery saver operation
5. Fast signalling speed
6. Code Word Automatic Reset for voice paging
7. Excellent falsing protection

Before continuing with a further explanation of the points listed above, it will be helpful to define some terminology used in the Golay Sequential Code.

• GSC TERMINOLOGY

GSC BINARY WORD—A GSC binary word is a group of 23 binary bits where each bit, or segment of information, can have a value of 0 or 1. A string of 0's and 1's and their respective position define a particular GSC binary word.

[1]Consult Subscriber Marketing when using GSC and previously used binary digital coding in the same system

GSC CODE—A GSC code is a unique GSC binary word 1 (W1) and GSC binary word 2 (W2) combination that can be assigned to a pager. Some GSC pagers may be assigned two codes (see Appendix III).

CODE DESIGNATION—Each GSC code is designated by a five-digit decimal number (preceded by N) for non-battery saver operation or a six-digit decimal number for battery saver operation.

(N) $G_1\,G_0\,A_2\,A_1\,A_0$—For Non-Battery Saver
$I\,G_1\,G_0\,A_2\,A_1\,A_0$—For Battery Saver

e.g. Non-Battery Saver = N01360
Battery Saver = 001360

I = Preamble Index (only used for battery saver)
$G_1\,G_0$ = Group Digits
$A_2\,A_1\,A_0$ = Address Digits

ADDRESS—Each GSC code is capable of providing four different addresses. The pager decoder can detect two binary words, and it can also detect inverse words or complements. Inverse binary words are created by substituting 1's for 0's and 0's for 1's within the binary string. The first of the four addresses is defined by W1 W2 designated by the five- or six-digit GSC code. Three more addresses are created by inverting one or both of the binary words. ($\overline{W1}$ = inverse word 1; $\overline{W2}$ = inverse word 2).

Address 1	W1	W2
Address 2	W1	$\overline{W2}$
Address 3	$\overline{W1}$	W2
Address 4	$\overline{W1}$	$\overline{W2}$

FUNCTION—Function describes how a pager responds. Each address listed above may be assigned a function at the time of ordering a pager. The function for GSC pagers may be:

1. Tone
2. Tone and Voice
3. Data (numeric or alphanumeric)

FUNCTIONAL ADDRESS—A functional address is the complete definition of how the radio responds, or the description of a function assigned to a specific address. For example, address 2 above might be assigned a function of tone and voice for a particular pager, thus the functional address is address 2 (word 1, inverse word 2), function; tone and voice. The pager signalled in this instance would "beep" and be ready for a voice message to follow.

FUNCTION PLAN "A"— Since one GSC code may have four addresses, it is important that we select a systematic way of describing each of the four addresses and their accompanying functions (functional addresses). Each functional address is described by the GSC code ($I\,G_1\,G_0\,A_2\,A_1\,A_0$) and a function digit (f) from Function Plan "A". The suffix digit (f) defines the function and which of the four possible GSC addresses the function corresponds to.

Figure 2-1

Function Plan "A" Suffix

			Function Plan "A" Suffix (f)		
	Address	Binary Word Format	If Function is Tone & Voice, f =	If Function is Data, f =	If Function is Tone Only, f =
ONE GSC CODE (I G_1 G_0 A_2 A_1 A_0)	1	W1 W2	1	5	9
	2	W1 $\overline{\text{W2}}$	2	6	0
	3	$\overline{\text{W1}}$ W2	3	7	N/A
	4	$\overline{\text{W1}}$ $\overline{\text{W2}}$	4	8	N/A

The preceding table (see Figure 2-1) lists the (f) digits and shows how they are suffixed to a GSC code to describe one of the four addresses and its accompanying function.

The following charts (see Figure 2-2) exemplifies the assignment of tone and voice, tone only, tone and voice, and data respectively to the four addresses related to one GSC code (010362). As you will learn when using the ordering guides and price pages for pagers that use the GSC code, the assignment of functional addresses for your customers' pagers is accomplished by using "R---" options.

NOTE: Future paging products may use alternate function plans (B, C, D, etc.); however, these are not yet available.

ACTIVATION CODE—The activation code is transmitted after a GSC address to initiate the alert tone in voice pagers. It is also used to squelch the pager's audio after completion of the voice message (see Code Word Automatic Reset, p. 6).

START CODE—The start code is a GSC binary word that is used to delimit the end of a preamble (for battery saver) and supply timing information for batch mode decoding (see Batch Mode Transmission, p. 5).

PREAMBLE — A preamble consists of a repeated GSC word which precedes the transmission of an address for a particular radio. The preamble provides battery saver information for a particular GSC code.

CAP CODE — A cap code is the number on the outside of the radio, usually related to the number entered into the encoder or terminal to call a particular radio. Depending upon the specific encoder or terminal used in the system, the cap code may or may not bear any resemblance to the actual GSC code or functional address.

For systems which utilize the automatic terminals, "working" cap codes depend on how the terminal is programmed. Ideally, the pager (user) code represents a "working" cap code which can be entered into a terminal to access a particular GSC code or address. Pager (user) codes can only be determined after your customer determines how he will program his terminal. Cap codes can be ordered as "blank" and filled in after your customer receives his pagers and programs his terminal (see Appendix IV, Terminal Inputs).

After gaining an understanding of the terminology associated with GSC, let's now consider some of the unique features and benefits this coding/signalling format provides.

1. LARGER NUMBER OF CODES

The Golay Sequential Code (GSC) provides 100,000 different codes for non-battery saver systems. Since each code provides four different addresses, total address capacity for non-battery saver systems is 400,000 addresses.

Battery saver systems utilize ten different preambles, and this expands the total number of available codes to 1,000,000 or (10 x 100,000). With four addresses per code, the total number of available battery saver addresses is 4,000,000.

Type of System	# Of Codes	# Of Addresses
Battery Saver	1,000,000	4,000,000
Non-Battery Saver	100,000	400,000

With GSC code capacity, co-channel users will be able to add many, many pagers before code duplication becomes

Figure 2-2

				Functional Address							Function Plan "A" Suffix (f)			
ONE GSC CODE	Address	Function Assigned	GSC Code w/o Function Plan "A" Suffix	I	G_1	G_0	A_2	A_1	A_0	(f)	Address	If Function is Tone & Voice, f =	If Function is Data, f =	If Function is Tone Only, f =
010362	1	Tone& Voice	010362	0	1	0	3	6	2	1	1	1	5	9
	2	Tone Only	010362	0	1	0	3	6	2	0	2	2	6	0
	3	Tone& Voice	010362	0	1	0	3	6	2	3	3	3	7	
	4	Data	010362	0	1	0	3	6	2	8	4	4	8	

a problem. Also, the development of nationwide paging systems without code duplication is now possible.

Although GSC provides code and address capacity as described above, the type of pager used in the system will have an impact on how many codes and addresses can be used (see Appendix III).

2. GROUP CALL FLEXIBILITY AND EXPANDED GROUP CALL SIZE

Terminal group call and radio group call are both possible with GSC. Common code assignments are used to create radio group call while terminal group call is achieved by programming the terminal to signal a group of pagers with individually assigned codes.

Pagers that utilize the Golay Sequential Code radio group call use two codes, the first GSC code (AA) for individual addresses and a second common GSC code (AB) for group call addresses.

Code AA (First Code)	Code AB (Second Code)
Individual Address 1	Group Call Address 1
Individual Address 2	Group Call Address 2
Individual Address 3	Group Call Address 3
Individual Address 4	Group Call Address 4

NOTE:

1. GSC pagers that utilize a second code (AB) can also use the second code for additional individual addresses. Instead of assigning one common code to a group of pagers, a unique second code is assigned to each pager.

2. Designation of code (AA) and code (AB) are also used to configure functions and addresses for OPTRX Display Pagers (see OPTRX Ordering Guide R8-1-65).

3. See Appendix III for GSC code and address capabilities of the different GSC pagers.

GROUP CALL SIZE—Actual radio group call size will depend upon the terminal(s) and/or encoder(s) used in the system. The Golay Sequential Code provides capability for up to 1,970 individuals in one group. If G_1 G_0 is held constant for both codes assigned to a pager, group call size is limited to 980 individuals in one group. To expand the group call size to 1,970 members, 5 must be added to the G_1 digit of the second GSC code assigned to pagers in the expanded group set. (Maximum size changes if more than one group is used. See Figure 7-1, Page 7.)

Radio group call is created by following three steps.

1. Radio group call is achieved by assigning a common second GSC code (AB) to all pagers in a group.

2. In a battery saver system, all pagers in a group must use the same preamble.

3. In all systems (battery saver and non-battery saver), G_1 G_0 digits must be the same for the two codes assigned to the pager. Also, for expanded group call size (over 980), 5 can be added to G_1 for group call codes (AB) in the group expansion (e.g. G_1 G_0 = 01, G_1 G_0 = 51) (see example below).

EXAMPLE FOR EXPANDED GROUP CALL CODE ASSIGNMENTS

Standard Group Call (980 individuals)	Expanded Group Call (1970 individuals)
G_1 G_0 = 01 for all pagers with common group call code (code AB)	G_1 G_0 = 51 for group call codes AB of pagers added to the original group
G_1 = 0	0 + 5 = G_1 used for expansion

NOTE: In order to have the expanded group call size, the terminal or encoder must be capable of two independent G_1 G_0 settings.

MULTI-GROUP CALL—The Golay Sequential Code also provides capability for improved group call flexibility compared to existing coding schemes. Multi-address group call (up to four different group calls in one pager) is also possible with GSC. This may include overlapping groups or sub-groups within groups.

Again, although GSC provides multi-group call capability, not all GSC pagers use two codes and/or all the available addresses per code. The chart below shows the group call capabilities for DIMENSION 1000 Radio, BPR 2000 Display, and OPTRX Display pagers.

Pager	# Of Available Group Call Addresses
OPTRX Display	4
DIMENSION 1000	1
BPR 2000 Display	No Group Call

Once a common second GSC code is assigned to a group of OPTRX pagers, the four addresses related to the second code are also common, and each address is used for a different group call. With GSC's multi-addressing/multi-group call capability, four distinct groups can be created (for one OPTRX Display pager), or three different groups can be created with an additional all call group. OPTRX pagers are configured into particular groups by activating one, two, three, or four of the addresses related to the common GSC code which is used for a group call. At time of an OPTRX Display pager order, the four possible addresses are specified as active or inactive by option number (RXXX). For example, if an OPTRX Display pager is to be a member of group 1 and 2, then address 1 and 2 must be activated for that pager. If another pager is to be only a member of group 1, only address 1 should be activated. Below, address 4 has been designated as the all call address. (For further details, consult the OPTRX Order guide, R8-1-65.)

One GSC Code (common second code assigned to all OPTRX Display pagers in group(s))			
Address 1	Address 2	Address 3	Address 4
Group 1	Group 2	Group 3	Group 4
		-or-	
Group 1	Group 2	Group 3	Groups 1, 2, & 3 collectively (all call)

TERMINAL GROUP CALL — With the GSC binary signalling format, formation of groups at the terminal is possible, regardless of individual code assignments. Terminal group call capacity is shown below.

Terminal or Encoder	Group Size (up to)	No. of Groups
MODEN Plus	15	5
MODAX 500A	Not available	N/A
MODAX Plus*	20	50
METRO-PAGE*	20	50

*Requires THE Subscriber List for terminal group call.

3. MULTI-FUNCTION CAPABILITY

Tone only, tone and voice, and data paging are all possible with GSC. Again, actual capability depends upon the type of pager or pagers used in the system (see Figure 4-1).

NOTE: Pager functions must be assigned at time of radio order, and these functions cannot be altered without changing code plugs. On OPTRX Display pagers, different model numbers exist for the tone alert and tone and voice pagers, as well as numeric and alphanumeric pagers (see OPTRX Order Guide (R8-1-65).

Figure 4-1

	Available Pager Functions			
Type of Pager	Tone Only	Tone & Voice	Data (Numeric)	Data (Alphanumeric)
BPR 2000 Display Pager	Yes	No	Yes	No
DIMENSION 1000 Radio Pager	Yes	Yes	No	No
OPTRX Display Radio Pager	Yes	Yes	Yes	Yes

4. EFFICIENT BATTERY SAVER OPERATION

Battery saver operation extends battery life by approximately a 3:1 ratio over non-battery saver operation. Basically, GSC pagers strobe "on" and "off" searching for their correct preamble. If the pager decoder does not see its correct preamble, the pager returns to the battery saver mode in which current consumption is at a minimum level. If the correct preamble is detected by the decoder, the pager then remains "powered up" and looks for the proper GSC binary address words. For voice pagers, if the proper address words are detected, the decoder will then look for an activation code which activates the audio circuit in the pager and initiates the alert tone sequence for tone and voice pages.

If the proper address words are not detected after the correct preamble, the pager once again returns to the battery saver mode.

5. FAST SIGNALLING SPEED

The Golay Sequential Code provides fast and efficient binary signalling. Signalling and paging time varies, depending upon the function (tone, voice, or data) used and the amount of data or the length of voice message that follows the actual signalling of the pager. The following chart provides a general reference and compares GSC to other conventional signalling schemes.

The times listed are relevant for systems which are approaching the point of full loading. The times (for tone only and data) represent averages based on groupings of similar preambles taking place before transmission of addresses from the terminal (Batch Mode Transmission).

Battery Saver System Signalling Times

Type of Signalling	Signalling Time	Additional Airtime Reserved for Alert Tone or Interpage Gap
GSC (Tone & Voice)	2.03 seconds	2 seconds (alert tone)
5/6 (Tone & Voice)	0.92 seconds	1 second (alert tone)
2-Tone Sequential (Tone & Voice)	N/A	N/A
Echo Binary (Tone & Voice)	N/A	N/A
GSC (Tone Only)	0.24 seconds	N/A
Echo Binary (Tone Only)	0.219 seconds	N/A
2-Tone Sequential (Tone Only)	3.5 seconds	1.3 seconds (Interpage Gap)
5/6 Tone (Tone Only)	0.23 seconds	N/A
GSC (Data)	0.24 seconds	N/A

Non-Battery Saver Systems Signalling Times

Type of Signalling	Signalling Time	Additional Airtime Reserved for Alert Tone or Interpage Gap
GSC (Tone & Voice)	0.4 seconds	2 seconds
2-Tone Sequential (Tone & Voice)	4.0 seconds	None (alert tone occurs during signalling)
5/6 Tone (Tone & Voice)	0.217 seconds	1 second (alert tone)
GSC (Tone Only)	0.2 seconds	N/A
Echo Binary (Tone Only)	0.2 seconds	N/A
2-Tone Sequential (Tone Only)	1.2 seconds	1.3 seconds (Interpage Gap)
5/6 Tone (Tone Only)	0.217 seconds	N/A
GSC (Data) (See note)	0.2 seconds	N/A

NOTES:

1. Signalling time for GSC listed above does not include the "Paging Universal Remote Control" (PURC) base station sequence which varies, depending upon the system. For details, see the PURC systems planner or consult your ASE.
2. The data and tone only times are averages based on batch mode transmission, and these averages differ from individual response times (see batch mode transmission format below).
3. Total air time for the various functions is determined by the following summations.

   Tone and Voice = Signalling Time + Alert Tone Time + Voice Message Time

   Tone Only = Signalling Time + Interpage Gap Time

   Data = Signalling Time + Data Message Time*

   *Each 12 digits of a numeric data message or eight characters of an alphanumeric message consumes .202 seconds of air time.
4. Alert tone time for *GSC* voice functions may be used to send tone only addresses (see interleaving).
5. Additional air time reserved for alert tone can be used for other signalling in 5/6 tone and GSC formats.

Interleaving — Interleaving increases systems throughput by enabling the transmission of tone only addresses during the alert tone time for **tone and voice pages.** The figure below shows how tone only addresses are sent during the voice page alert tone time (see Figure 6-1).

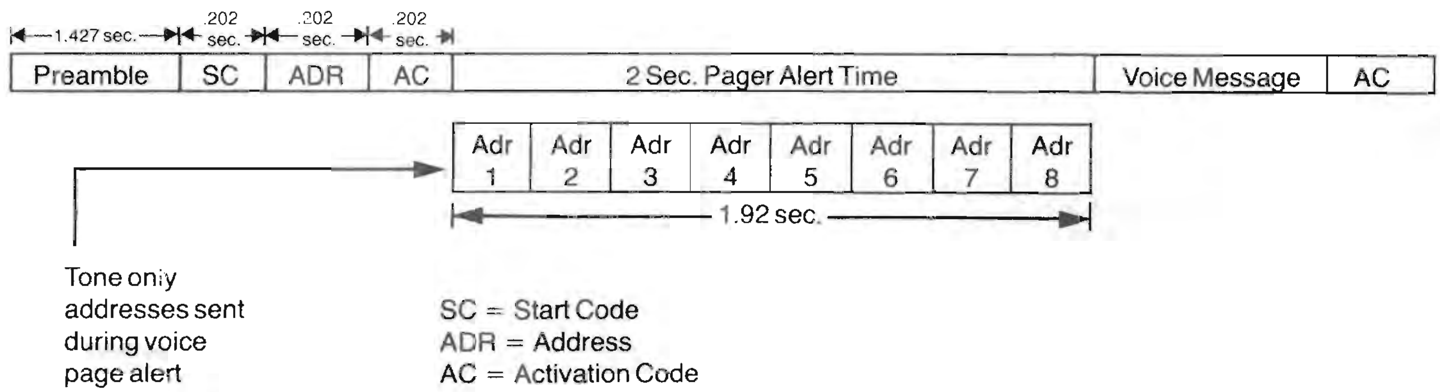
Batch Mode Transmission Format

The batch mode transmission format provides increased throughput (more efficient air time utilization) for tone only and data addresses which use the same preamble. In the individual mode, *each* battery saver address must be preceded by a preamble. In contrast, the batch mode transmission format begins with *one* inverted preamble followed by a start code and up to 16 addresses without repeating the preamble before each address (see Figure 6-2).

Extended Batch Mode Format

In situations where more than 16 addresses are required in the batch mode, an *extended batch mode* can be used by inserting the start code in the 17th address block. Using the start code in the 17th address block precludes the retransmission of the preamble, thus saving additional air time.

The following timing diagrams show a comparison of the different transmission formats and the air time saved by using batch and extended batch operation (see Figure 6-2).



NOTE: 1. For battery saver systems, all addresses must have the same preamble.
2. The MODAX 500A, MODAX PLUS, and METRO-PAGE TERMINALS are all capable of interleaving.

Figure 6-1
Interleaving

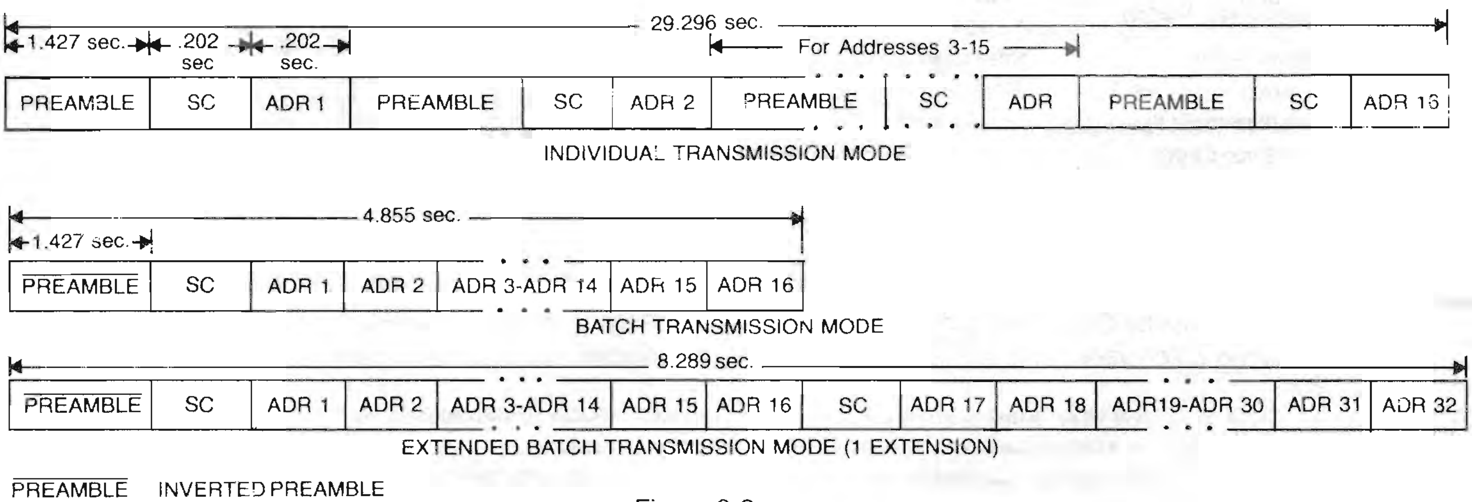


Figure 6-2
Batch and Extended Batch Operation

6. CODE WORD AUTOMATIC RESET (for voice function)

This innovative and exclusive automatic reset operation is accomplished by the receipt of a binary "turn-off" word transmitted by the encoder or terminal at the end of the voice message. Availability of code word automatic reset depends upon the encoder or terminal used in the paging system.

Comparison to previous reset schemes shows the advantage of code word automatic reset. Carrier squelch reset in busy systems is ineffective because the carrier may never cease, and in fringe areas, the carrier may be lost in a "null", causing the pager to reset before a voice message is completed. Timeout reset also has limitations. Messages may get "cut-off" when the timeout occurs before the end of the message, or messages which are shorter than the timeout require manual reset.

Variable voice message length (within a 20-second timeout for DIMENSION 1000 and 50-second timeout for OPTRX) is possible with code word automatic reset, and the user is spared the annoyance of listening to extraneous channel noise.

APPENDIX I

INVALID GSC CODES

Certain GSC codes are invalid and must be skipped when assigning codes. The following combinations listed below represent invalid GSC codes, but any other combinations of six digits for battery saver or "N" plus five digits for non-battery saver represent valid GSC codes.

If G_1 G_0 Equals	Then Do Not Allow A_2 A_1 A_0 To Equal
00-49	000, 025, 051, 103, 206, 340, 363, 412, 445, 530, 642, 726, 782, 810, 825, 877
50-99	000, 292, 425, 584, 631, 841, 851

For "N" Codes — Non-Battery Saver Systems G_1 G_0 should never equal 40 or 90 regardless of value assigned to A_2 A_1 A_0.

APPENDIX II-A

CODE ASSIGNMENT PLANS FOR GSC PAGERS

Most GSC codes are plant assigned, but if you must assign codes at time of order, Appendix II-A and II-B provide relevant background information. Also, refer to Appendix VI for additional reference material (ordering and coding information). A multiplicity of pager code assignment plans are possible, depending on the system size, the pager types to be serviced, and the customer needs. For example, a customer who anticipates the need for a maximum of 1000 codes can select an assignment plan in which two digits of the pager code are fixed in the terminal. Selection of the fixed digits will affect the battery life and determine the maximum group call size. A number of these code assignment plans are listed in Figure 7.1 and discussed below.

Multiple preambles are generally used in large systems to improve battery life. The preamble index (I) plus group digit G_0 (of the GSC code) indicates the specific battery saver preamble that is used in the pager. If G_0 is fixed in the terminal, only one preamble will be used. The group digit G_0 is nominally incremented every 1000 codes.

The maximum group call size is affected by the number of address digits (A_2 A_1 A_0) used in the system. Fixing any of these digits in the terminal reduces the maximum group call size (see Appendix II-B).

In tone and voice systems using 100 codes or less, the use of multiple preamble does not provide a significant improvement in battery life. Therefore, assignment plan 1 of Figure 6-1 should be used for this case.

In tone and voice systems that require up to 1000 codes, plan 2 will maximize battery life by rotating the preamble every 100 codes, but the group call size will be limited to 96 individuals. If larger group call sizes are needed, plan 3 can be used; this plan allows groups up to 980 individuals, but only one preamble is used, thus compromising battery life.

For large tone and voice systems and small tone only and data systems, code assignment plans 4 and 5 from Figure 6-1 can be used. Code plan 4 rotates preambles every 1000 codes while code plan 5 utilizes a single preamble, (if I is fixed). The maximum group size is 980 for both plans. The single preamble plan is acceptable for tone only and data systems, and it can also be used for tone and voice systems and systems with split function (mixed voice and tone only).

Code plan 5 is useful in tone only or data systems where pagers from several manufacturers with different code formats are mixed.

For large tone only and data systems, assignment plan 6 should be used. The number of codes can be further expanded to 1,000,000 using the I digit; however, this digit must not be incremented until the first 100,000 codes have been exhausted.

Figure 7.1 Pager Code Assignment Plans

Code Plan #	Digits Fixed in Terminal	Variable Address Digits	System Size	Maximum Individ. Per Group	No. of Word 1's	Group Examples
1	$G_1G_0A_2$	A_1A_0	50: 2 Code Pagers or 100: 1 Code Pagers	96 Ind.	1	1 Group of 96 2 Groups of 48 4 Groups of 22, etc.
2	G_1A_2	$G_0A_1A_0$	500: 2 Code Pagers or 1000: 1 Code Pagers	96 Ind.	10	10 Groups of 96 20 Groups of 48 40 Groups of 22, etc.
3	G_1A_2	$A_2A_1A_0$	500: 2 Code Pagers or 1000: 1 Code Pagers	980 Ind.	1	1 Group of 980 4 Groups of 245 8 Groups of 122, etc.
4	G_1	$G_0A_2A_1A_0$	5000:2 Code Pagers 10,000: 1 Code Pagers	980 Ind.	10	10 Groups of 980 100 Groups of 96, etc.
5	G_0	$G_1A_2A_1A_0$	5000: 2 Code Pagers 10,000: 1 Code pagers	980 Ind.	10	10 Groups of 980 20 Groups of 490 100 Groups of 96, etc.
6	—	$G_1G_0A_2A_1A_0$	50,000: 2 Code Pagers 100,000: 1 Code pagers	1970 Ind.	50	50 Groups of 1970 100 Groups of 980 800 Groups of 122, etc.

APPENDIX II-B

• PROCEDURE FOR ASSIGNING CODES

Once a code plan is determined, you should follow these rules.

1. Codes used for individual addresses are assigned in ascending order starting at 000001, and the invalid codes listed in Appendix I are skipped.

2. Codes used for group call addresses are assigned in descending order, starting at a point determined by the number of address digits (A_2 A_1 A_0) used in the system. Fixing any of these address digits (in the terminal) reduces the maximum group call size.

Digits Used	Digits Fixed	Max. Group Call Size	Group Call Starting Point
$A_2 A_1 A_0$	None	980	999
$A_2 A_1$	A_0	96	99
A_1	$A_2 A_0$	9	9

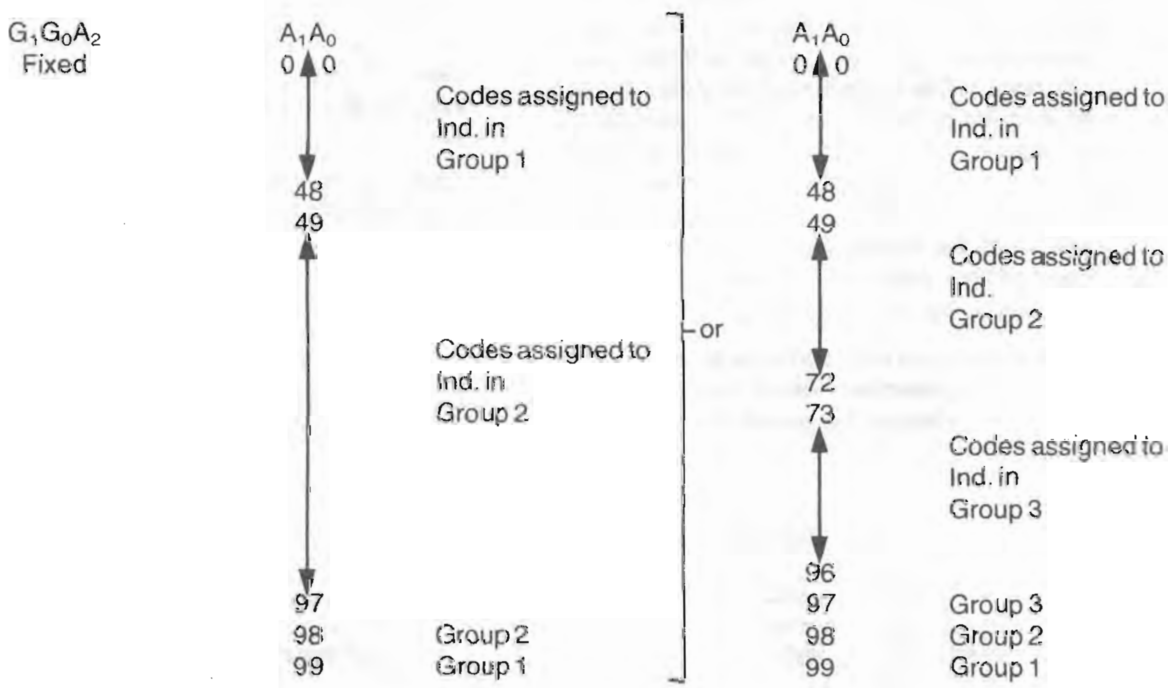
NOTE: Group call size can be expanded to 1,970, and if you require group size that large, refer to page 3.

All pagers in the same group must have the same I G_1 G_0 digits in the six digit GSC code (I G_1 G_0 A_2 A_1 A_0). For non-battery saver systems, the I digit will not be used. For example, if the I G_1 G_0 digits equal 010 and all three address digits are used, the group call code assignments for three groups would be as follows. If more groups are required in the future, the appropriate number of codes should be reserved.

	I	G_1	G_0	A_2	A_1	A_0	
Starting Point (Group Call Codes)	0	1	0	9	9	9	Group 1
	0	1	0	9	9	8	Group 2
	0	1	0	9	9	7	Group 3
	0	1	0	9	9	6	Individual Code Assignments
Starting Point (Individual Call Codes)	0	1	0	0	0	1	

(a) Example of Group Assignments For DIMENSION 1000 (900 MHz) Pagers

For the case:



(b) Example of Group Assignments for OPTRIX Display Pagers

(b) Example of Group Assignments for OPTRX Display Pagers

For the case:

$G_1\,G_0\,A_2$	$A_1\,A_0$			$A_1\,A_0$	
Fixed	0 0 – 20	Codes assigned to individuals in Group 1		01 – 25	Codes assigned to individuals in Group 1
	21 – 36	Codes assigned to individuals in Group 2		26 – 51	Codes assigned to Individuals in Group 2
	37 – 49	Codes assigned to Individuals in Group 3	or	52 – 98	Codes assigned to Individuals in Group 3
	50 – 98	Codes assigned to Individuals in Group 4		99	(One GSC code for group call—capable of 4 group call addresses. This code can provide addresses for group 1, 2, and 3, plus an all call (1, 2, and 3 collectively). If all call is not used, group (#4) can be created as a distinct group.
	99	Groups 1-4			

Figure 9.1
Group Call Pager Code Assignment

NOTE:
1. Only pagers that are capable of two GSC codes can provide both individual call and radio group call.
2. Each GSC code (for OPTRX pagers) is capable of four addresses.

(See Appendix VI for additional reference material)

APPENDIX III

• AVAILABLE CODES AND ADDRESSES FOR GSC PAGERS

The number of available GSC codes and addresses vary, depending upon the pager. The chart above provides a reference for the code, address, and function capabilities of the different GSC pagers.

Also, terminal or encoder capabilities may constrain the number and type of functions per radio in a given system.

Pager	GSC Code	Address	Available Pager Functions	Call Mode
DIMENSION 1000	1st	(1) W1 W2	T&V, T.O.*	Indiv. Call
(capable of 2 GSC	1st	(2) W1 $\overline{\text{W2}}$	T&V, T.O.*	Indiv. Call
codes per unit)	2nd	(1) W1 W2**	T&V, T.O.*	Third Indiv. Call or Group Call
BPR 2000 Display	1st	(1) W1 W2	T.O.	Indiv. Call
capable of 1 GSC	1st	(2) W1 $\overline{\text{W2}}$	T.O.	Indiv. Call
code per unit)	1st	(3) $\overline{\text{W1}}$ W2	Data	Indiv. Call
	1st	(4) $\overline{\text{W1}}$ $\overline{\text{W2}}$	Data	Indiv. Call
OPTRX Display	1st	(1) W1 W2	T.O., T&V, or Data*	Indiv. Call
(capable of 2 GSC	1st	(2) W1 $\overline{\text{W2}}$	T.O., T&V, or Data*	Indiv. Call
codes per unit)	1st	(3) $\overline{\text{W1}}$ W2	T.O., T&V, or Data*	Indiv. Call
	1st	(4) $\overline{\text{W1}}$ $\overline{\text{W2}}$	T.O., T&V, or Data*	Indiv. Call
OPTRX Display	2nd	(1) W1 W2**	T.O., T&V, or Data*	Indiv. or Group
	2nd	(2) W1 $\overline{\text{W2}}$**	T.O., T&V, or Data*	Indiv. or Group
	2nd	(3) $\overline{\text{W1}}$ W2**	T.O., T&V, or Data*	Indiv. or Group
	2nd	(4) $\overline{\text{W1}}$ $\overline{\text{W2}}$**	T.O., T&V, or Data*	Indiv. or Group

*Actual functions per code determined by available call options.
**W2 used in second GSC code must be a different W2 than the one used in first GSC code.

NOTE: Only one of the pager functions can be assigned to each address.

APPENDIX IV

TERMINAL/ENCODER CODE CAPACITY

Terminal Encoder	Code Capacity	Address Capacity
MODEN Plus Encoder	2,000	8,000
MODAX 500A Terminal**	1,000	4,000
MODAX Plus Terminal (Standard)	10,000	40,000*
With UNI Option**	1,000	4,000
METRO-PAGE Terminal (Standard)	10,000	40,000*
With UNI Option**	1,000	4,000

* A system is set up using either the post entry digit or an input number per address. Address capacity listed reflects the use of post digit entry (Function Plan "A" suffix digit). Input numbers are assigned to codes and remain the same for all addresses related to the code. Only the post entry digit from Function Plan "A" changes (per address). If separate input numbers are assigned to each address without using the post entry digit, the total number of addresses becomes equal to the code capacities shown. Using number per address permits individual address validation and call counting per address. In the post digit configuration, calls per pager (code) are counted.

** With the MODAX 500A or UNI configuration, only the post digit entry (function digit) plan is used for multi-function radio pagers.

TERMINAL INPUTS

In a typical selector level (direct inward dialing) paging system, the number dialed to access the GSC address in a pager is similar to a normal phone number.

NNX-PPPP

Telephone Exchange # — accesses the terminal

Pager (User) Code (P) — accesses a particular GSC address in a pager

Above, the pager (user) code identifies a GSC address in the terminal; that is, one of the four possible addresses derived from one GSC code.

POST ENTRY DIGIT

The term "post entry digit" implies entering digit(s) after the complete pager (user) code. If post entry digit is used, the pager (user) code identifies a GSC code and an additional digit (f) (from function plan "A") must be entered to identify one of the four possible addresses that can be derived from one GSC code (see page 3).

With touch code (DTMF), additional digits (post entry digit) may be entered to identify a function plan "A" digit (f) of the radio pager functional address and/or convey numeric data (D) to the terminal.

NNX-PPPP-f-DDDD

Telephone Exchange # — accesses terminal

Pager (User) Code (P) — For post digit entry, identifies GSC code in terminal

Post Entry Digit (f) — Function plan "A" digit which is used to identify one of the four possible GSC addresses and its function

Data Entry (D) — Data entered for numeric display— OPTRX and BPR 2000 Display pagers

The following chart shows the flow of various inputs and terminal transformations for post entry digit.

1. Pager (User) Code (P) (input to terminal through phone; e.g. 5026)
2. Terminal References GSC Code ($IG_1G_0A_2A_1A_0$) e.g. 010362 which is stored in terminal and cross references 5026 through UNI or THE Subscriber List
3. Post Digit Entry Function plan "A" digit entered into phone and passed to terminal; e.g. 1
4. Terminal "reads" post digit entry (from function plan "A") as address 1 of GSC code and identifies that address as voice (see Function Plan "A", page 2).
5. Terminal passes complete Functional address (in binary form) to station for transmission to appropriate pager

In end-to-end (line level) touch code (DTMF) systems, a complete phone number is dialed to access the paging terminal input. This is followed by input of the pager (user) code (P), function digit (f), and numeric data, if required.

NNX-XXXX-PPPP-f-DDDD

Telephone Number — accesses terminal

Pager (User) Code

Post Entry Digit (f) — (Function plan "A" digit)

Numeric Data Input

NOTE: Generally, rotary dial telephone will not allow post digit entry, precluding dial-in of function (f) or data digits (D).

• ENTRY WITHOUT POST ENTRY DIGIT

The MODAX Plus or METRO-PAGE terminals may be set up to operate in a pager (user) number per address mode without post digit entry. The address with its corresponding function (functional address) is identified by a unique pager (user) code. This functional address would be programmed into THE Subscriber List and a pager (user) code also assigned. An example is shown below.

Pager (User) Code (PPPP)	GSC Functional Address ($IG_1G_0A_2A_1A_0(f)$)	Function
5026	010362(1)	Voice
5027	010362(2)	Voice
5028	010362(7)	Data
5029	010362(8)	Data

Post Entry Digit Vs. No Post Digit

	Address	Pager User Code (PPPP)	Post Digit Entry Function Plan "A" (f)	GSC Functional Address	Function
Post Entry Digit	1	5026	1	010362(1)	Voice
	2	5026	2	010362(2)	Voice
	3	5026	7	010362(7)	Data
	4	5026	8	010362(8)	Data
No Post Entry Digit	1	5026	None	010362(1)	Voice
	2	5027	None	010362(2)	Voice
	3	5028	None	010362(7)	Data
	4	5029	None	010362(8)	Data

APPENDIX V
GSC VS. POCSAG

What's a POCSAG?

POCSAG is simply an acronym for Post Office Code Standardization Advisory Group. This group was formed at the behest of the British Post Office (now British Telecom) in an effort to formulate a single paging code that would meet the defined requirements of the United Kingdom's paging system. The advisory group was put together with representatives from manufacturers, including Multitone, Philips, Pye, Storno, Standard Telephones and Cables, and Motorola; and representatives from British Telecom and the British Home Office.

The principle requirement put before the advisory group was for speed, which translates to throughput. Both GSC and POCSAG have a total number of available codes which reach beyond the physical constraints of throughput due to the signalling speed of each code format. Based on traditional pager usage rates, the resulting POCSAG code has a tone only throughput capacity of approximately 300,000. The Golay Sequential Code has a tone only throughput capacity of about 100,000 since the call rate for GSC addressing is one third that of POCSAG.* This may be a reasonable requirement for a system covering all of the U.K., but for localized, highly competitive systems as in the U.S., 100,000 should be adequate. In this case, performance, not capacity, is the key requirement. (See article on following page.)

Although Motorola participated in the advisory group and has developed a POCSAG coded METRX pager for the U.K. system, we do not believe that the tradeoffs made to achieve the speed of the POCSAG code are warranted in other marketplaces. Consequently, our future paging development focuses on the Golay Sequential Code, not just for tone only, but for tone and voice, numeric, and alphanumeric paging as well. Our extensive laboratory testing has shown that the GSC has significant sensitivity advantages over POCSAG in fading and multi-path environments.

The GSC is an extremely robust code offering signalling speed combined with versatility, sensitivity, and resistance to falsing. We believe that it has the best combination of these important features available in the competitive paging marketplace today.

*Throughput is based on non-battery saver systems.

THE BASIC DIFFERENCES BETWEEN GSC AND POCSAG ARE CITED IN THE FOLLOWING ARTICLE WHICH IS A REPRINT FROM "COMMUNICATIONS" MAGAZINE (OCTOBER, 1981).

Subscriber Paging Performance Considerations for Future Planning

By Brad Davis

The subscriber paging industry has reached an important crossroads in its evolution. Even as RCCs, telephone companies, PTTs, telecommunication authorities, and manufacturers gear up for the changes in product and service offerings only recently unveiled, we can all see beyond this first flush of enthusiasm to the enhancements awaiting us all in the mid and late 1980s.

Transmission of data to pagers is an idea that has been awaiting implementation ever since the first RCC realized that he could not fit any more tone-and-voice pagers on his existing channels. The industry finally has a number of implementations to choose from, each with varying strength in regard to speed, sensitivity, resistance to falsing, number of possible codes, flexibility, and battery saving. Before selecting a data paging format, it is appropriate to consider the relative business impact of each of these various strengths. This comparison is best done with the thought in mind that we are just on the threshold of new subscriber service offerings, a sentiment that is echoed in the FCC proceedings on Docket 80-183 where it is recommended that a megahertz be held in reserve for advanced technologies in paging.

Presented here is a comparison, from a business as well as technical viewpoint, of just two high-capacity, data-capable paging codes, POCSAG, which should be in subscriber service in mid-1981, and the Golay Sequential Code, in service since 1973. Neither code format is believed to be proprietary.

The Golay Sequential Code (GSC) is patterned after the proven two-tone sequential signaling system in that it makes use of two sequential binary (23.12 Golay) words per address. The POCSAG code, being promulgated by the British Telecom, is a synchronous format requiring bit and word synchronization and is based on the 31:21 BCH code. The features of the two codes are as follows:

Table I

	GSC	POCSAG
Number of Codes	1 million, 4 address 500,000, 8 address	2 million, 4 address
Call rate (Addresses) (Data)	5 calls/sec 2.5 calls/sec (12 characters) .45 calls/sec (80 characters)	15 calls/sec 5.0 calls/sec (10 characters) .52 calls/sec (80 characters)
Decoder Type	Asynchornous	Bit synchronization and word framing required
Address Format	2 word (23:12 Golay)	1 word (31:21 BCH)
Data Format	Block of 8 15:7 words 12 numeric characters per block	31:21 words 5 numeric characters per word
Battery Saver Grouping	Selective Batching	Time Division
Fade Protection		
Address		
Bits Corrected	3/23 (300 BPS)	2/32 (512 BPS)
Fade Percentage	13%	6.3%
Fade Length*	10 ms	4 ms
Data		
Bits Corrected	16/120 (600 BPS)	1/32 (512 BPS)
Fade Percentage	13%	3.1%
Fade Length	27 ms	2ms

*For reference, existing 5-tone sequential paging systems provide 10 ms fade length protection.

It is evident that the POCSAG format achieves greater speed and code capacity. However, certain important trade-offs were accepted to achieve these features in the POCSAG code. The extent of these trade-offs was examined via a series of computer controlled tests.

Speed

Obviously speed is a desirable attribute of a data paging code format. But is it free? How fast is fast enough?

To achieve its signaling speed improvement, POCSAG reduces the redundancy employed in binary formats for detection and correction of burst errors in the received transmission. Specifically, POCSAG allows 2 bits to be corrected out of a 32-bit address and only 1 bit to be corrected out of 32 bits for data messages. This corresponds to 4 ms and 2 ms fade protection for address and data respectively. This compares to the significantly greater GSC fade protection of 10 ms for address and 27 ms for data. Therefore, one should expect the POCSAG code to provide less reliable performance in the real world of fading and impulse noise. This difference has been manifested in both computer simulations and actual field testing.

It should also be noted that, unlike the POCSAG code, the GSC is designed to give longer fade protection to data than to address. What this means in practical terms is that when a paging user receives his page, there is a greater probability that he will also correctly receive his data message. This results in less frustration for the user and fewer administrative headaches and complaints for the system operator.

As alphanumeric pagers appear on the scene, the length of data messages will increase. Here is where the difference between POCSAG and GSC will become more pronounced. For an 80-character alphanumeric message in a fading environment, the GSC has a 12.2 dB advantage in the relative signal strength required for 99 percent success rate. Thus the GSC provides four times the reliable coverage area per transmitter. In addition, POCSAG's speed advantage lessens as data messages grow longer.

In today's metropolitan radio signal environment, characterized by multipath interference, impulsive noise, and simulcast beats, the GSC format's greater ability to accommodate long burst errors will translate directly into user satisfaction.

To substantiate the impact of fading on paging reliability, which translates to sensitivity, computer-controlled tests were carried out on the recovered binary signals from an actual receiver which was being driven by a fading simulator designed to emulate the same type of RF signal received while in a moving vehicle in an urban environment. In order to compare only code formats and not a specific implementation, bit synchronization and bit decisions were made in an identical optimum manner. The results of these tests are presented in Table II.

In a Gaussian noise environment, the two codes perform essentially the same for address and 10-character numeric paging. GSC offers a slight advantage for 80-character alphanumeric paging. The Gaussian noise environment is that experienced in a test fixture, antenna range, or rural areas. Although it is often the basis on which code comparisons are made, real world urban environments are seldom Gaussian.

However, as the length and proportion of data paging messages of the future is a moot point, let's evaluate speed on a purely tone only basis, where POCSAG enjoys the greatest advantage. At traditional pager usage rates, the GSC supports a system of 100,000 pagers. POCSAG, at three times the speed would therefore support 300,000 pagers per channel, or about one fifth the total number of pagers in subscriber service in the U.S. today. There are some 600 RCC's in the U.S. and about 40 telephone companies providing subscriber paging service. With eight channels currently allocated to carrier paging only service, 40 900 MHz channels pending, 40 more held in reserve, and 20 more low band channels soon to be made available (albeit on a restricted basis), few system operators are likely to feel a compelling need for this degree of single channel capacity before alternative codes with enhanced performance and features are made available. In supporting these new services and opportunities, it would seem important that excess capital not be applied to less than optimal systems.

Flexibility

Granted there are systems operating with high capacity tone only paging formats that can see a day in the not-too-distant future when no more pagers of the current type can be accommodated. The operators of these systems are understandably excited with the apparent possibilities of the POCSAG format. However, here they are apt to encounter another of the format's trade-offs. Central to what makes the POCSAG code a high capacity, high speed format is its synchronous nature. In brief, this means that every POCSAG pager on a system must periodically attain bit synchronization as well as word synchronization. Groups of POCSAG pagers are assigned to specific time slots. This allows the pagers to go into a low current drain "standby" mode during periods of transmission not meant for them. Thus receiver and decoder are only fully on about 14 percent of the time. This, along with the search sequence used, results in good battery economy, but, since it requires rigid time controls in the paging system, it sacrifices to a large degree the flexibiity to permit multiple code formats and voice on the same channel.

This is not to say that POCSAG cannot co-exist on the same channel with other code formats or voice. However, the system would have to resend the POCSAG 1/0 preamble after each such transmission to resynchronize all the POCSAG pagers in the system, which would have lost sync during a voice message or batch of non-POCSAG code. This is of no real consequence unless one is expecting a quantum leap in capacity by adding POCSAG to an already 60 percent to 70 percent loaded system.

The GSC, on the other hand, is asynchronous in nature requiring neither bit synchronization nor word framing that must be recognized before correct address decoding can be guaranteed. Consequently GSC pages can be interspersed quite randomly among voice messages and transmissions of other code formats without regard to special system protocol. The approach taken to implement a battery saver achieves battery economy commensurate with that of POCSAG, preserves maximum system flexibility, and does not destroy the asynchronous nature of the basic coding format. Such flexibility ought to be a major concern in system implementation. Today's leading paging carriers may not be competitive tomorrow if their systems are unable to assimilate new, attractive product and service offerings. Such a situation could be a company's undoing in a highly competitive largely lease market.

Code Capacity and Resistance to Falsing

The POCSAG code has twice the number of codes available as the GSC, but in either case the code capacity is so much higher than system capacity as to make this difference irrelevant. The GSC has a greater resistance to falsing than does POCSAG (1 in 100 years vs. 1 in 10 years). However, both are so much better than the false dialing rate as to make this difference irrelevant also. Should a real market requirement arise for two million address capacity, the GSC code set could be readily expanded at the expense of some of its falsing resistance.

Table II

Test results showing the performance differences in a fading environment between the Golay Sequential Code and the POSCAG code:

	Relative Signal Strength* for 99% Success Rate		GSC Performance Advantage
	GSC	POCSAG	
Address Paging	Ref.*	+ 4.5 dB	4.5 dB
10-character numeric	+ 1.5 dB	+ 10.5 dB	9.0 dB
80-character alphanumeric	+ 3.8 dB	+ 16.0 dB	12.2 dB

*Reference is GSC address performance IF signal to noise ratio = 15 dB for 99 percent success rate.

thereby putting it on a parity with the POCSAG code.

Economics

Perhaps the most widely touted aspect of the POCSAG code is that a standard code will bring many new suppliers into the market, and the resultant competition will drive the price of pagers down. This may indeed be true in the short term as new entrants vie for enough volume to realize their forecasted product costs. However, total market growth is a function of the carriers, not of the manufacturers. Figure 1 shows that tone alert pager prices have been following a classic experience curve since 1972. Unless an unforeseen redoubling of the market growth rate occurs, there is little to support an acceleration down this curve[1].

The point is that invention and manufacturing experience are the cornerstones of cost reduction and therefore of price reduction. Unnecessary standardization can effectively stifle invention. Likewise, artificially inducing a market price reduction by dangling the carrot of inflated forecasts before potential suppliers does no one any good in the long term.

Conclusion

The RCC's and telephone companies in highly competitive markets like the U.S., Canada, and Hong Kong do not have the luxury of dictating the quality of paging service to their customers. Neither can they delay the adoption of products, features, and services of true benefit and appeal to the user. Performance standards have been set and will continue to be set by the progressive, meticulous, and competitive engineers and businessmen in these markets. Their best designs, implementations, and decisions have matured into de facto standards that serve as the minimum ante to play in the subscriber paging game. There are nearly a quarter of a million pagers in service around the world utilizing the Golay based format, while there is no current quantitative performance data on the POCSAG code other than that presented here. The Golay Sequential Code is the optimum choice for the smart businessman, who sees data messages and high speed and voice paging as the likely evolution of his business. Its performance advantages apply to user satisfaction, system cost, and future flexibility.

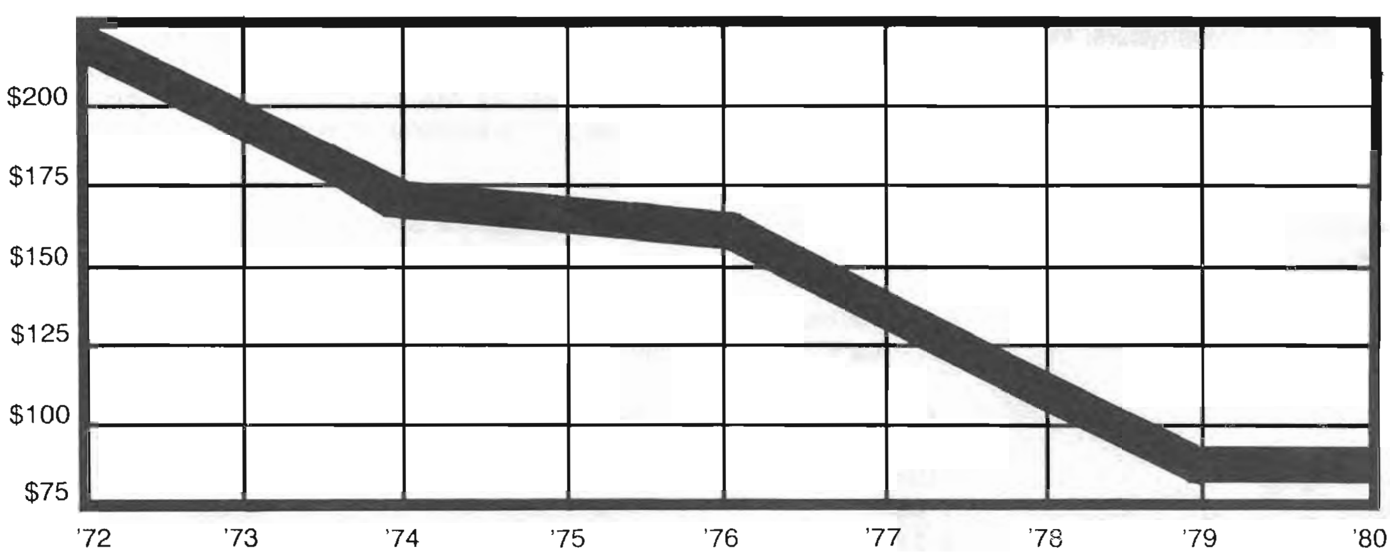
About the Author

Brad Davis is product planning manager, Subscriber Paging Operations for Motorola, Inc. Davis has held his present position for one and one-half years, and previously held various positions with the company in the area of subscriber paging marketing. He is a graduate of the University of Pennsylvania, with a BA in English Literature.

Footnote

[1]For more on the experience curve, see *Perspectives on Experience,* by the Boston Consulting Group. The concept is based on accumulated volume. Figure 1 represents the accumulated market volume curve on a linear yearly scale. Prices are in constant 1972 dollars (i.e., the effect of inflation is removed).

Figure 16-1 Average Price of Tone Alert Pager in the U.S. Carrier Market
(Constant 1972 $'s)



APPENDIX VI

ADDITIONAL REFERENCES FOR GSC PAGERS

Ordering and Coding Information	
OPTRX Ordering Guide	R8-1-65
DIMENSION 1000 Ordering Guide	R8-1-64A
BPR 2000 Display Ordering Guide	R8-1-66
Paging Systems Planner (Coding Information)	Section IV
Product Information (Pagers)	
DIMENSION 1000	
Catalog Sheet	R3-5-90A
RB Sheet	RB-06-14A
BPR 2000 Display	
Catalog Sheet	R3-5-91
RB Sheet	RB-05-05
OPTRX Display	
Catalog Sheet (all models)	R3-5-93
RB Sheet (numeric)	RB-05-08
RB Sheet (alphanumeric)	RB-05-07
Product Information (Terminals/Encoders)	
MODEN Plus (Encoder)	
Catalog Sheet	R3-5-96
Systems Planner	68P81026C35-
MODAX 500A (Terminal)	
Catalog Sheet	R3-5-97
Systems Planner	68P81026C30-
MODAX Plus (Terminal)	
Catalog Sheet	R3-5-101
Systems Planner	68P81026C30-
METRO-PAGE (Terminal)	
Catalog Sheet	R3-5-100
Systems Planner	68P81026C30-

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