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Pager Testing using the HP 8648A with an Internal Pager Encoder, Option 1EP



Product Note 8648A-1



Introduction

There are over 60 million subscribers of paging services throughout the world. By the year 2000, the number of subscribers is expected to grow to over 140 million. To meet this demand, pager manufacturers will need to produce over 30 million pagers per year.

Competition among pager manufacturers is strong. Improvements in manufacturing processes and techniques provide competitive advantages. This product note will focus on testing pagers during manufacturing.

This product note will cover three topics:

1. Paging theory overview
2. Paging tests
3. Recommended test equipment

The topics examined extend beyond testing and provide a general overview of paging. The goal of this paper is to assist you in improving pager manufacturing.

Paging Overview

Network Structure

A paging network connects to the public switched network or telephone lines. Callers access voice mail, a paging operator, or enter a message via the keypad of a touch-tone phone. Pages are assembled in the paging terminal and sent to the network controller where they are combined into batches, based on their final destination. The network controller specifies which site controllers receive the batched messages and sends them out. Each site, covering a particular geographical location, contains one or more paging transmitters. Once a site controller receives a batch of pages, it uplinks them to the paging transmitters. Each paging transmitter then transmits the batch of pages at the same time on the same frequency. Simultaneous broadcasting of identical information from two or more transmitters at the same time allows the system to provide seamless coverage.

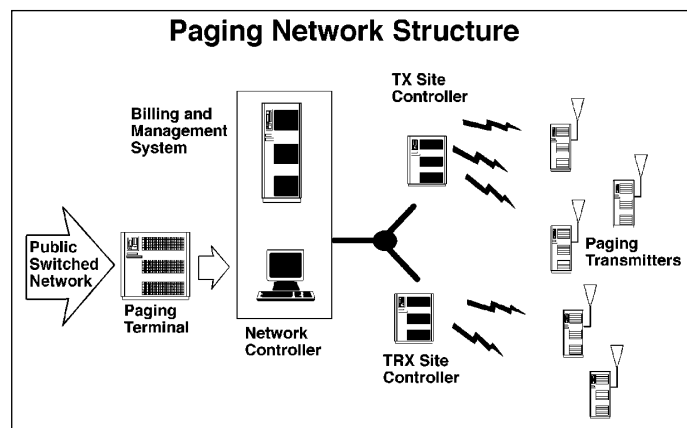


Figure 1. A paging network.

Types of Pager Services

Paging services come in several forms: tone-only, tone-voice, numeric, and alphanumeric.

The simplest type of paging service emits a tone when the subscriber is paged. This service is most useful when the subscriber only needs to call one place, such as his/her home or office. Tone-only service is the least expensive signaling option.

Tone-voice allows the subscriber to receive a voice message without calling a central location. Initially, tone-voice pagers could not store voice messages; therefore, a message could be missed if the subscriber was in a noisy environment when the page was received or was out of range of the transmitter. Newer systems are now available in some locations, where the pager can actually record messages up to 10 seconds long and play them back later.

Numeric pagers are the most popular on the market today. Callers dial the phone number assigned to the pager, then enter a numeric message using a touch-tone phone.

An alphanumeric pager requires the caller to have access to an alphanumeric terminal, or a message center, that can send alphanumeric messages to the pager. This type of service is the most expensive; however, it is valuable if the pager subscriber requires immediate information.

Pager Formats

There are many different types of paging formats in use today. By far the most popular are the new digital formats which offer tone, numeric, or alphanumeric messaging, and in some cases voice messaging. Digital formats offer significant advantages over analog systems, including increased subscriber capacity, addressing flexibility, messaging capability, faster signaling speeds, and improved battery life.

The most common digital format is POCSAG (the most popular worldwide standard, also known as RPC1). The newer digital formats are FLEX (a Motorola trademark), FLEX-TD, and ERMES. FLEX systems are being deployed throughout the world. FLEX-TD systems are being installed in Japan. ERMES systems are intended primarily for Europe and are currently being tested.

The following table compares four digital paging formats: POCSAG, FLEX, FLEX-TD and ERMES.

	POCSAG	FLEX, FLEX-TD	ERMES
Subscriber channel capacity	two million	up to one billion	up to one billion
Data rates (bps)	512, 1200, 2400	1600, 3200, 6400	6250
Modulation type	2 level FSK	2 level FSK (at 1600 or 3200), 4 level FSK (at 3200 or 6400)	4 level FSK
Timing	synchronous with preamble	synchronous	synchronous
Battery saving option	yes	yes	yes

Table 1. Digital Paging Format Comparison.

The HP 8648A with option 1EP, the internal pager encoder, provides the signaling required to meet POCSAG, FLEX and FLEX-TD specifications. The addition of option 1E5, the high stability timebase, enables the 8648A to meet the stringent requirements imposed on FLEX and FLEX-TD signals.

POCSAG

POCSAG, Post Office Code Standardization Advisory Group, is a digital paging scheme that was developed by British Telecom to provide a standard signaling format for the United Kingdom. In February 1981, it was accepted by the Consultative Committee for International Radio (CCIR) as the recommended Radiopaging Code No. 1 (RPC1). POCSAG is the most popular paging format in the world. POCSAG has three signaling speeds: 512, 1200, or 2400 bits per second (bps).

POCSAG has a synchronous framework. Messages are always sent in batches and each pager address is located in a specific frame within a batch. A preamble precedes the first batch to wake up any active POCSAG pagers in the system and synchronize them with the transmission. A batch consists of a frame sync code, which identifies the beginning of a batch, and eight frames containing address, message, or idle codewords. Refer to the figure for a diagram of POCSAG's structure.

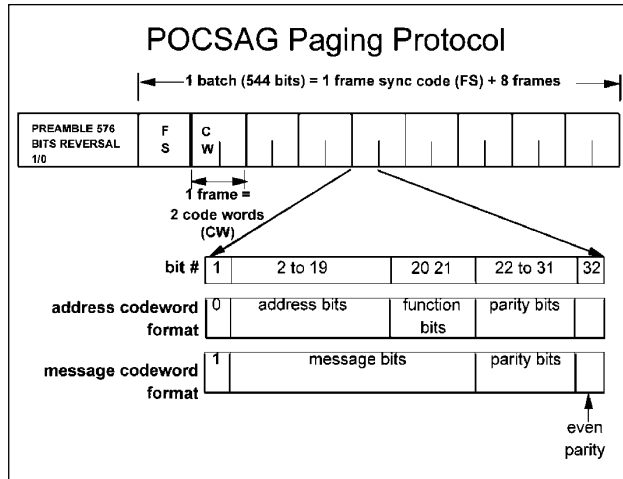


Figure 2. POCSAG paging protocol.

After detecting the preamble and synchronizing to the frame sync word, the pager will turn off its receiver circuitry and conserve the battery until the assigned frame appears. When it reactivates, it will either find its address in the assigned frame, or one of two other codewords: an idle codeword (if there is no page), or a message codeword from another subscriber's page. In the latter case, if there is a page, it will be deferred to the next batch.

Each POCSAG address codeword is capable of providing address information for four different paging sources, addresses one through four in the pager. These addresses are determined by the values of bits 20 and 21, the source identifier bits.

A message codeword can contain up to 5 numeric or 2.8 alpha characters. For a numeric pager to receive a 10 digit phone number, two message codewords must be sent. Since message codewords directly follow an address codeword, the second message codeword will take over the first 32 bits of the next frame, overriding any address codewords for the pagers assigned to that frame.

FLEX

The growing volume of pager subscribers requires an increase in system capacity. In addition, as pager users become more sophisticated, there is a desire for more messaging capability and services. Motorola's new "flexible" paging protocol, FLEX (a Motorola trademark), was designed to respond to the needs of this evolving pager market.

The FLEX protocol offers several benefits to users. First, battery life has improved significantly. FLEX pagers have ten times more battery efficiency than existing POCSAG 1200 pagers. More effective battery use provides new opportunities to reduce the size and change the shape of pagers. FLEX error correction capabilities have improved message integrity. In addition, users will benefit from enhanced services, such as: nationwide paging, missed message indication, efficient dynamic group calling, information services, and computer file transfers.

Since FLEX is optimized for throughput, efficiency, and flexibility, there are also significant advantages for service providers. The FLEX protocol can support more subscribers than any existing paging protocol - four times the number of pagers on an RF channel. FLEX, with 1600, 3200, or 6400 bits per second signaling speeds, is compatible with existing paging protocols. Service providers with an existing system (such as POCSAG 1200) may add FLEX 1600 with a minimal investment, and then upgrade to 3200 and 6400 bps as their capacity requirements increase. Fade protection has been enhanced. By interleaving address and message bits, FLEX can overcome a 10 ms fade independent of signaling speed. In addition, the FLEX design offers new opportunities to expand messaging capabilities and services.

FLEX pagers can operate at any of the three speeds and will automatically adjust to the speed of the transmitted signal. A 2-level FSK modulation is used for 1600 bps and 3200 bps transmissions. A 4-level FSK modulation is used for 3200 bps and 6400 bps transmissions. The figure shows the differences between 2-level and 4-level FSK. For 4-level FSK each level represents a 2-bit sequence, known as a symbol. Therefore, for the same rate of transmission, 4-level FSK transmits double the information of 2-level FSK.

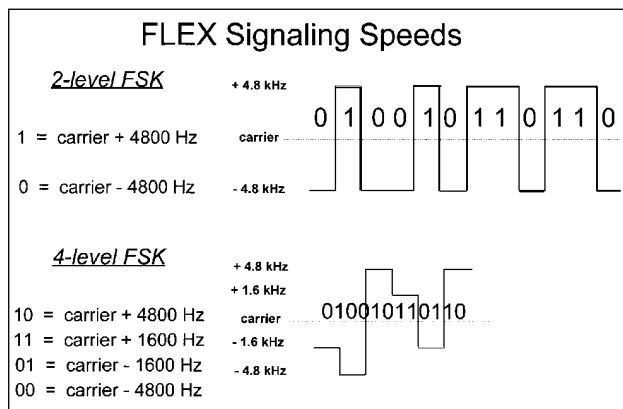


Figure 3. 2-level versus 4-level FSK.

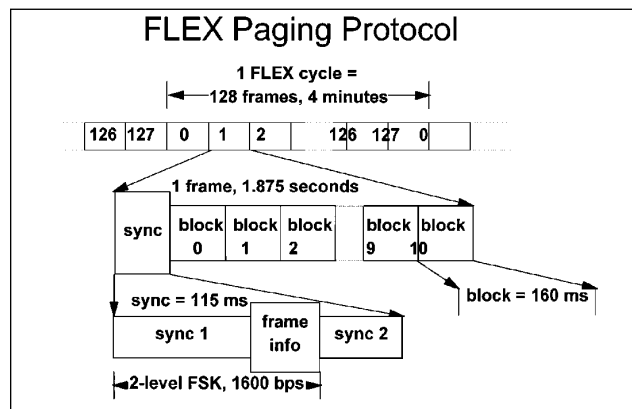


Figure 4. FLEX frame organization.

FLEX Protocol Structure

FLEX has a synchronous format that assigns a pager to a frame. The frames are numbered 0 to 127. These frames occur at a rate of 128 every 4 minutes and represent one FLEX cycle. There are 15 FLEX cycles per hour, numbered from 0 to 14.

Each pager is assigned a particular frame (or frames) within a FLEX cycle. When turned on, the pager will synchronize with the local transmitter, and then turn on the receiver circuitry for its assigned frame(s). This feature significantly improves battery life. The pager no longer needs to detect a preamble as with POCSAG.

Each frame consists of a sync field and 11 blocks. The sync information is composed of three parts: sync 1, frame information, and sync 2. The first two parts are always transmitted at 1600 bps using 2-level FSK. Sync 1 provides timing information and defines the speed of the rest of the frame (the block speed). The frame information word contains the frame number, the cycle number, and other information. Sync 2, which is transmitted at the speed defined in sync 1, provides block synchronization so that the data can be properly decoded.

The information that is transmitted within a FLEX frame is shown in figure 5. The 11 blocks contain up to five fields of information. They include a block information field, an address field, a vector field, a message field, and an idle code field. These fields are not constrained by block boundaries. The block information field is typically one word long and contains information that indicates where in the frame the address and vector fields start, and how many priority addresses are placed at the beginning of the field. Priority addresses are assigned to pages with an urgent priority. The address field contains addresses of the pagers that are being paged. The vector field, which has a one-to-one relationship with the address field, points to the start of and indicates the length of the message. The message field contains the message. Any unused blocks in a frame are filled with idle code - alternating 1's and 0's at 1600 bps. At higher speeds, the symbol pattern must produce the same binary waveform as the bit pattern of a 1600 bps idle signal.

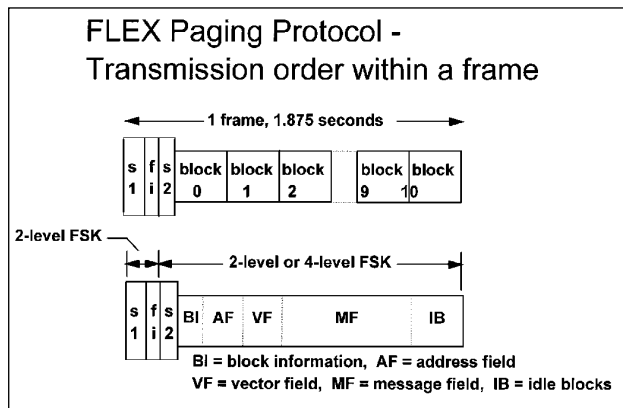


Figure 5. FLEX block organization.

CAPCODE structure

Within a standard CAPCODE (pager's address) several parameters are defined: address, phase, and frame number. At a minimum, a standard CAPCODE will contain an alpha character followed by seven digits (short address) or nine digits (long address), such as 'A1234567' or 'A123456789', respectively. An additional one or four digits may also be added in front of the alpha character to specify a different battery saving cycle (called collapse cycle) and a frame number for a non-standard CAPCODE.

Collapse cycle

FLEX has defined the concept of collapsing the frame number to less than the seven binary bits normally required to convey a number from 0 to 127. Specific bits are masked to enable the pager to check more than one frame per cycle; this trades battery life for more immediate message delivery. The first frame a pager will check is determined by the CAPCODE; how frequently a pager will turn on afterwards is a function of $2C$, where C is the collapse cycle. Each pager has an assigned collapse cycle that can be adjusted to meet the needs of the user. The transmission system also assigns a collapse cycle in the block information word of each frame. The service provider may choose to adjust the collapse cycle to force concentrations of FLEX paging traffic into very small periods of time to facilitate mixing with other codes. If the pager and the network specify different collapse cycles, the pager will be set to the smaller collapse cycle.

Figure 6 illustrates the affect of the collapse cycle on message delivery. For a collapse cycle of seven, a pager that is assigned frame 126 (binary 1111110) will check for messages every four minutes. If the collapse cycle is set to one, all but the first bit will be masked. The pager will then check for messages every other frame. If the collapse cycle is set to two, all but the first two bits will be masked. The pager will then check for a message every fourth frame.

1 FLEX cycle =								
← 128 frames, 4 minutes →								
Collapse Cycle	Decimal	126	127	0	1	2	3	4
7	2^7	1111110	1111111	0000000	0000001	0000010	0000011	0000100
1	2^1	XXXXXX0	XXXXXX1	XXXXXX0	XXXXXX1	XXXXXX0	XXXXXX1	XXXXXX0
2	2^2	XXXXX10	XXXXX11	XXXXX00	XXXXX01	XXXXX10	XXXXX11	XXXXX00

- Pager decodes only unmasked bits for frame assignment.
- Frame assignments are in bold.

Figure 6. Collapse cycle vs frequency of pager activation.

FLEX-TD (time diversity)

FLEX-TD, also known as RCR-43, is based on FLEX and adds a time diversity feature. This feature improves messaging reliability by repeating the transmission of a message up to four times.

The standard frame is divided into subframes whose number of words is fixed by the transmission number. One frame is divided into two subframes for two transmissions (one repeat), three subframes for three transmissions (two repeats), or four subframes for four transmissions (three repeats).

Pager tests

Most pager manufacturers test similar aspects of a pager although many of the specifics vary from one manufacturer to another. The following tests are frequently done and will be reviewed in this product note:

1. Preselector alignment
2. Oscillator tuning
3. Sensitivity
4. Functional

For proper testing, the pager receiver must be in an RF isolation enclosure. Shielding the pager from any external RF signals ensures that the pager is responding only to the test signal.

Figure 7 is a typical block diagram for a pager receiver. This receiver has a two-stage downconverter; other designs use only a single-stage downconverter. Often, the preselector, the first-stage mixer, and the first-stage local oscillator (LO), contain variable components that must be adjusted during production. Components used after the first stage mixer are generally fixed and do not require adjustment. Most manufacturing test is done to adjust the variable components in the pager receiver section. We will refer to this block diagram as we review each test.

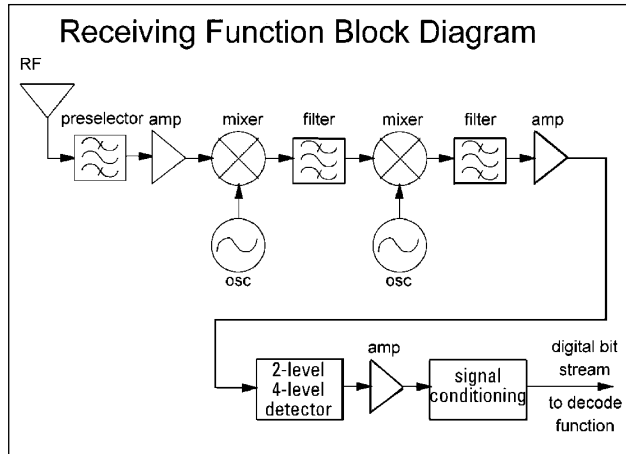


Figure 7. Typical pager receiver block diagram.

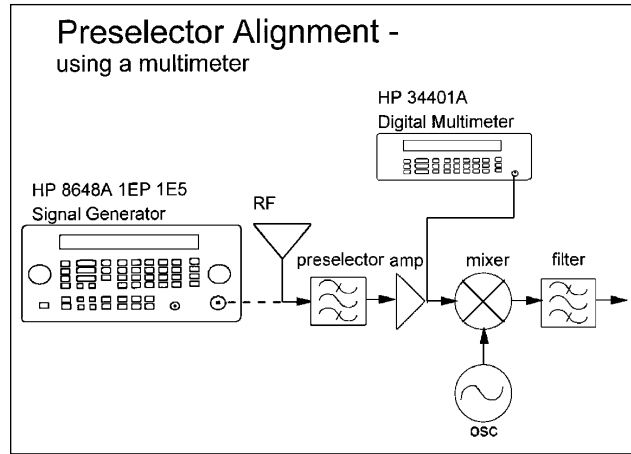


Figure 8. Preselector alignment using an HP 8648A signal generator with option 1EP and a digital multimeter (DMM).

Preselector alignment

Many pager designs use adjustable components in the preselector section of the receiver. These components are adjusted during manufacturing. For example, if the pager is designed to operate at 929.1125 MHz with a 25 kHz channel width, the components in the preselector will be adjusted to filter out frequencies outside of this channel.

Figure 8 shows a typical setup used to align the preselector. The signal generator outputs a paging signal (for example a 4-level FSK for a FLEX pager) at the channel frequency (for example at 929.1125 MHz). The adjustable components, variable capacitors, and inductors are adjusted until the received signal strength after the amplifier is maximized. Many pager designs have a test point where a voltage level that is proportional to the received signal strength can be measured. For these designs a voltmeter can be used to verify that the preselector has been properly aligned.

For pager designs that do not have a voltage test point, a spectrum analyzer may be used to monitor the output of the preselector. Again, variable components are adjusted until the received signal strength reaches the required level. The received signal strength can be viewed directly on the spectrum analyzer by adjusting the center frequency of the spectrum analyzer to the desired channel (for example, 929.1125 MHz) and setting the span to the channel width (for example, 25 kHz). The spectrum analyzer also displays any asymmetry in the preselector filter shape. The amplitude levels of the FSK sidelobes should be of equal height. Sidelobes that are of unequal height indicate that the preselector filter shape needs to be adjusted.

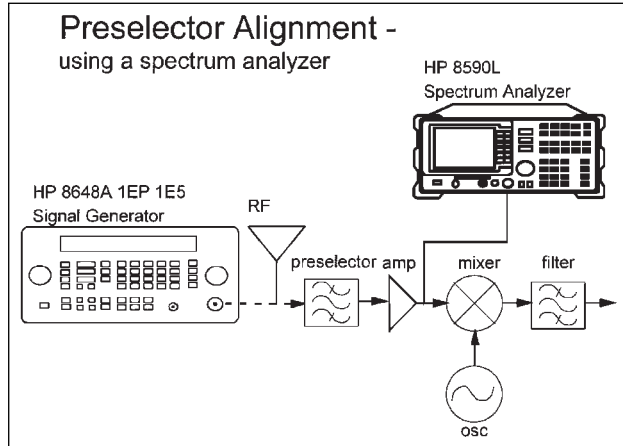


Figure 9. Preselector alignment using an HP 8648A signal generator with option 1EP and a spectrum analyzer.

Operating the pager encoder, option 1EP:

1. Before entering the pager encoder menu, check that the correct carrier frequency and FM deviation for the pager under test are set.
2. Enter the pager encoder menu by pressing the [FM] (ENCODER) key. The screen should display FORMAT in the upper left corner.
3. To select a parameter, use the [PREV] and [NEXT] keys.
4. To move between options for each parameter, rotate the AMPLITUDE/ENCODER knob until the desired option is displayed.
5. When all parameter options have been selected, press the [INCR SET] (START/STOP) key to initiate a page.
6. To exit the pager encoder menu, press the [FM] (ENCODER) key again.

Setting up the HP 8648A option 1EP to output continuous pages:

1. Press [FREQUENCY] and enter the paging frequency.
2. Press [FM] and enter the FM (FSK) deviation (4.5 kHz for POCSAG, 4.8 kHz for FLEX and FLEX-TD).
3. Press [AMPLITUDE] and enter the desired output power. Press [RF ON/OFF] to turn on the RF output.
4. Press [FM] a second time to enter the encoder menu. You should see FORMAT displayed in the upper left corner.
5. Rotate the AMPLITUDE/ENCODER knob to select the proper paging format.
6. Press the [NEXT] key to move to the DATA RATE parameter and select the desired data rate.
7. Press the [NEXT] key to move to the PAGER TYPE parameter and select the desired pager type.
8. Press the [NEXT] key to move to the MESSAGE parameter and select a message.
9. Press the [NEXT] key to move to the MODE parameter and select continuous.
10. Press the [NEXT] key to move to the PAGER CODE parameter and use the alphanumeric keys to enter the pager code.
11. For FLEX pagers, press the [NEXT] key to move to the COLLAPSE CYCLE parameter. Adjust the COLLAPSE CYCLE value to 1. This ensures that the pager searches every other frame for a message.
12. Press the [START/STOP] button to begin paging.

Oscillator tuning

After adjusting the preselector to the appropriate channel, the local oscillator (LO) needs to be adjusted to downconvert the RF signal to the correct intermediate frequency (IF). Many pager designs incorporate a variable inductor into the oscillator design. This inductor is tuned until the proper IF value is measured. Some designs incorporate laser-trimmable or air-trimmable components.

A simple method of tuning is to connect a frequency counter at the IF output of the mixer and adjust the oscillator value until the counter reads the proper IF frequency. The output of the signal generator must be a sine wave at the required channel frequency (for example, 929.1125 MHz).

This is an inexpensive tuning solution. However, the counter requires a filter to remove unwanted mixing products and generally requires a preamplifier to raise the signal level to the detection threshold. For designs that use a fixed IF filter, the measurement can be made at the IF filter output. This eliminates the need for an external filter at the counter input.

A spectrum analyzer can be used instead of a frequency counter. The spectrum analyzer is frequency selective and has greater sensitivity. This eliminates the need for an external filter and a preamplifier.

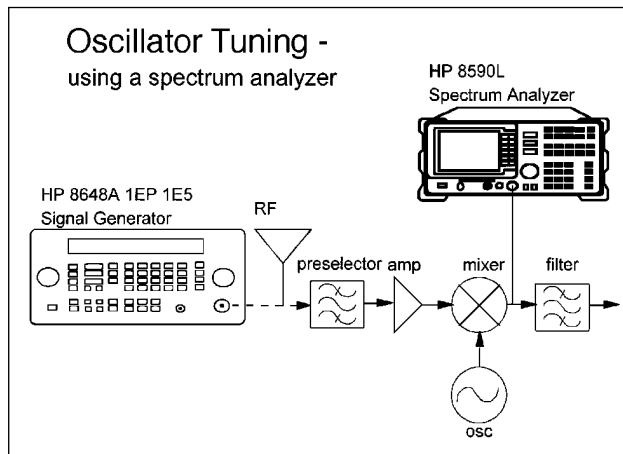


Figure 10. Manual oscillator tuning using a spectrum analyzer.

Configuring the HP 8648A for oscillator tuning:

1. Press [FREQUENCY] and enter the paging frequency. Do not turn on any modulation!
2. Press [AMPLITUDE] and enter the required output power. Press [RF ON/OFF] to turn on the output power.

Some manufacturers use laser trimming to adjust the LO frequency. In laser trimming, a YAG laser is aimed at a laser-trimmable component (usually a capacitor). The capacitor is generally a multilayer ceramic capacitor. The energy from the YAG laser removes metal and ceramic material from the capacitor. The removal of material changes the value of the capacitor and thus changes the LO frequency.

Laser-trimming systems require an automated test system that shuts off the laser at the proper time. In many automated test systems, the spectrum analyzer is set to zero span with a resolution bandwidth (RBW) equal to the width of the paging channel (for example, 25 kHz). The center frequency is set to the IF frequency (for example, 17.9 MHz). The **video out** connector from the spectrum analyzer is connected to the input of the DMM. During tuning of the LO, increasing received signal strength from the IF results in an increase in the RMS voltage read by the DMM. In an automated system, the DMM can update a computer every 20 ms. Thus, when the specified signal strength is received, the computer can quickly shut down the YAG laser.

The spectrum analyzer/DMM measures a product parameter. However, this same system can measure a process parameter. The YAG laser trims a capacitor for a period of time. In addition to measuring the IF signal strength, the test system can measure the laser-trimming time. A statistical analysis of the laser-trimming times will produce an average value and acceptable process limits. This information can be used to improve the production process.

A YAG laser-trimming system is very expensive. For most manufacturers, this type of system does not provide a financial return over manual tuning and testing. Air-trimming systems, typically ten times less expensive, offer a low-cost alternative to laser trimming.

An air-trimming system focuses a particle stream onto a trimmable component. The particle stream removes metal and ceramic material from the capacitor to adjust the capacitor value and, consequently, the LO value. Air trimming requires the same test equipment to monitor the IF signal and measure the process characteristics. As with laser trimming, the trimming time is a process parameter. Figure 11 shows the equipment configuration for a laser- or air-trimming measurement.

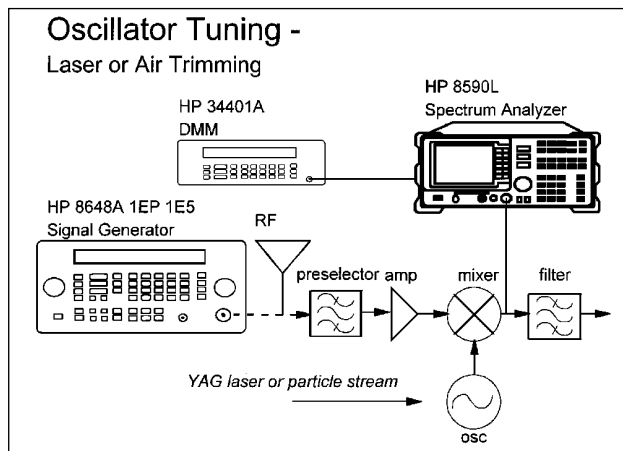


Figure 11. Tuning the LO using laser or air trimming.

Sensitivity

Perhaps the most important specification for a pager is the receiver sensitivity. The receiver sensitivity determines the ability of the pager to properly receive low-level signals. A pager with poor sensitivity will not reliably detect messages. This results in unhappy customers!

Sensitivity specifications are usually in microvolts per meter ($\mu\text{V}/\text{m}$). A sensitivity measurement must be made with a calibrated, known field strength. To achieve this, the pager is placed in an RF isolation enclosure (typically a TEM cell, screen room, or isolation chamber). A signal generator is attached to the enclosure. The power from the signal generator is radiated into the enclosure and generates a uniform field strength. When using the HP 8648A with option 1EP, the output power will need to be converted to field strength using the following formulas¹:

$$E \text{ (volts/meter)} = \text{SQRT} (P \text{ (watts)} * \Omega \text{ (ohms)}) / d \text{ (meters)}$$

$$E \text{ (dBmV/m)} = 20\log (E \text{ (\mu V/m)} / 1\mu\text{V/m})$$

Where:

P = power output from the signal generator

Ω = impedance of the RF isolation enclosure

d = distance from upper wall to septum of TEM cell

An optional TEM cell is available with the HP 8648A (option K17). The following table converts the output power from the signal generator to the field strength inside the TEM cell.

Signal Generator Power (dBm)	TEM Cell Field Strength ($\mu\text{V}/\text{m}$)	TEM Cell Field Strength (dB $\mu\text{V}/\text{m}$)
-120	2.91	9.29
-115	5.18	14.29
-110	9.21	19.29
-105	16.38	24.29
-100	29.14	29.29

Table 2. Power to Field Strength Conversion.

There are many methods for measuring sensitivity. The 9 of 10 method is a common technique for measuring sensitivity. In this method, the signal generator output is set to the sensitivity of the pager. Ten pages are sent. To pass, at least nine of the ten pages should be received. For this technique, when using the HP 8648A option K17 TEM cell, the pager should be oriented to achieve the maximum sensitivity reading. Other techniques involve varying the orientation of the pager with respect to the incoming paging signal. A second technique, known as the 3/20 method is more involved.

In the 3/20 method, the pager is placed inside the HP 8648A option K17 TEM cell. The measurement begins with the pager placed in the upright position inside the TEM cell. A total of eight measurements are made with the pager being rotated 45 degrees for each measurement. The sensitivity of the pager, in $\mu\text{V}/\text{m}$, is recorded at each orientation.

1. Myron L. Crawford, "Generation of Standard EM fields using TEM trans-mission cells", IEEE Transactions on Electromagnetic Compatibility, November 1974

To obtain the pager sensitivity at each orientation, send three consecutive pages. If the pager responds to all three, reduce the output power by 1dB and send three more pages. Reduce the output power to the lowest level that triggers a response on each of the three successive pages. Record the output field strength as E_{3p} .

Reduce the output power by 1dB. Send twenty pages. If three successive pages are received, the output power is reduced by 1dB. If no pages are received, the output power is increased by 1dB, otherwise, the output power remains the same. Record the output field strength as E_{20p} .

The pager sensitivity at each orientation is the average of E_{3p} and E_{20p} : $E_n = (E_{3p} + E_{20p}) / 2$. The overall pager sensitivity is calculated as:

$$E_{\text{SENS}} = \sqrt{\frac{8}{1/E_1^2 + 1/E_2^2 + 1/E_3^2 + 1/E_4^2 + 1/E_5^2 + 1/E_6^2 + 1/E_7^2 + 1/E_8^2}}$$

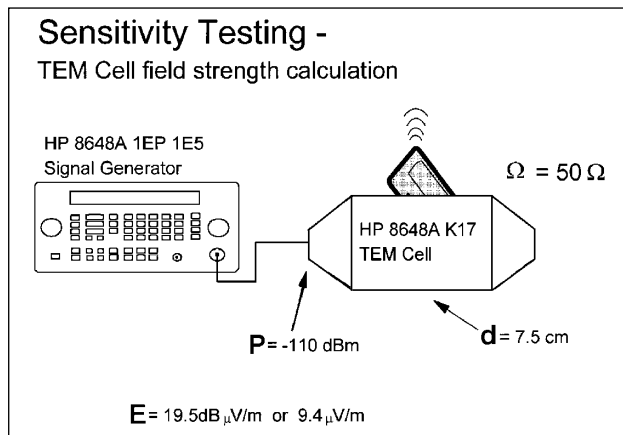


Figure 12. Pager sensitivity example.

Configuring the HP 8648A with 1EP for making a sensitivity measurement:

1. Press [FREQUENCY] and enter the paging frequency.
2. Press [FM] and enter the FM (FSK) deviation (4.5 kHz for POCSAG, 4.8 kHz for FLEX and FLEX-TD).
3. Press [AMPLITUDE] and enter an output power equal to the sensitivity of the pager (see table 2).
4. Press [FM] a second time to enter the encoder menu. You should see FORMAT displayed in the upper left corner.
5. Rotate the AMPLITUDE/ENCODER knob to select the proper paging format.
6. Press the [NEXT] key to move to the DATA RATE parameter and enter the desired data rate.
7. Press the [NEXT] key to move to the PAGER TYPE parameter and select the desired pager type.
8. Press the [NEXT] key to move to the MESSAGE parameter and select a message.
9. Press the [NEXT] key to move to the MODE parameter and select BURST. Enter a value of ten for the number of bursts.
10. Press the [NEXT] key to move to the PAGER CODE parameter and use the alphanumeric keys to enter the pager code.
11. For FLEX pagers, press the [NEXT] key to move to the COLLAPSE CYCLE parameter. Adjust the COLLAPSE CYCLE value to 1. This ensures that the pager searches every frame for a message.
12. Press the [START/STOP] button to begin paging.
13. If the pager responds to nine of the ten pages, then the pager meets its sensitivity specification.

Functional testing

In final testing, before the pager is shipped, all of its basic functions should be tested. Does it beep? Does it vibrate? Does the light flash? Does it display the message correctly?

Recommended test equipment

For POCSAG pagers, most manufacturing tests can be made with: an HP 8648A with options 1EP and K17, a frequency counter, and a DMM. In addition, a spectrum analyzer and an oscilloscope are often used in production testing.

For FLEX and FLEX-TD, the same test equipment may be used. However, when testing FLEX and FLEX-TD, a high stability timebase for the HP 8648A is required. FLEX and FLEX-TD both require that the FSK deviation of the output signal be within 60 Hz of the specified deviation. The high stability timebase option for the HP 8648A, option 1E5, with an accuracy specification of 0.15 ppm, enables the HP 8648A to meet this requirement. In addition, an external reference may be used if the performance specifications of the reference signal are superior to those of the high stability timebase, option 1E5.

HP 8648A	Synthesized Signal Generator
Option 1EP	Pager Signaling Option (FLEX, FLEX-TD and POCSAG)
Option 1E5	High Stability Timebase (needed to meet FLEX requirements)
Option K17	TEM Cell for RF Isolation (includes test fixture)
HP 34401A	(A digital DMM multimeter used in pager tuning and alignment procedures)
HP 53181A²	RF Counter (used in pager tuning and alignment procedures)

Alternate test equipment

HP 8590L	RF Spectrum Analyzer (may be used in place of a frequency counter)
HP 54600 Series²	General Purpose Oscilloscope (may be used in place of DMM and frequency counter)

2. A filter and preamplifier may be required.

For more information on Hewlett-Packard Test and Measurement products, applications, or services, please call your local Hewlett-Packard sales office. A current listing is available via the World-wide Web through AccessHP at <http://www.hp.com>. If you do not have access to the internet please contact one of the HP centers listed below and they will direct you to your nearest HP representative.

United States:

Hewlett-Packard Company
Test and Measurement Organization
5301 Stevens Creek Blvd.
Bldg. 51L-SC
Santa Clara, CA 95052-8059
1 800 452 4844

Canada:

Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(905) 206 4725

Europe:

Hewlett-Packard
European Marketing Centre
P.O. Box 999
1180 AZ Amstelveen
The Netherlands

Japan:

Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192, Japan
Tel: (81-426) 48-0722
Fax: (81-426) 48-1073

Latin America:

Hewlett-Packard
Latin American Region Headquarters
5200 Blue Lagoon Drive, 9th Floor
Miami, Florida 33126, U.S.A.
(305) 267 4245/4220

Australia/New Zealand:

Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130, Australia
131 347 Ext. 2902

Asia Pacific:

Hewlett-Packard Asia Pacific Ltd.
17-21/F Shell Tower, Times Square,
1 Matheson Street, Causeway Bay,
Hong Kong
(852) 2599 7070