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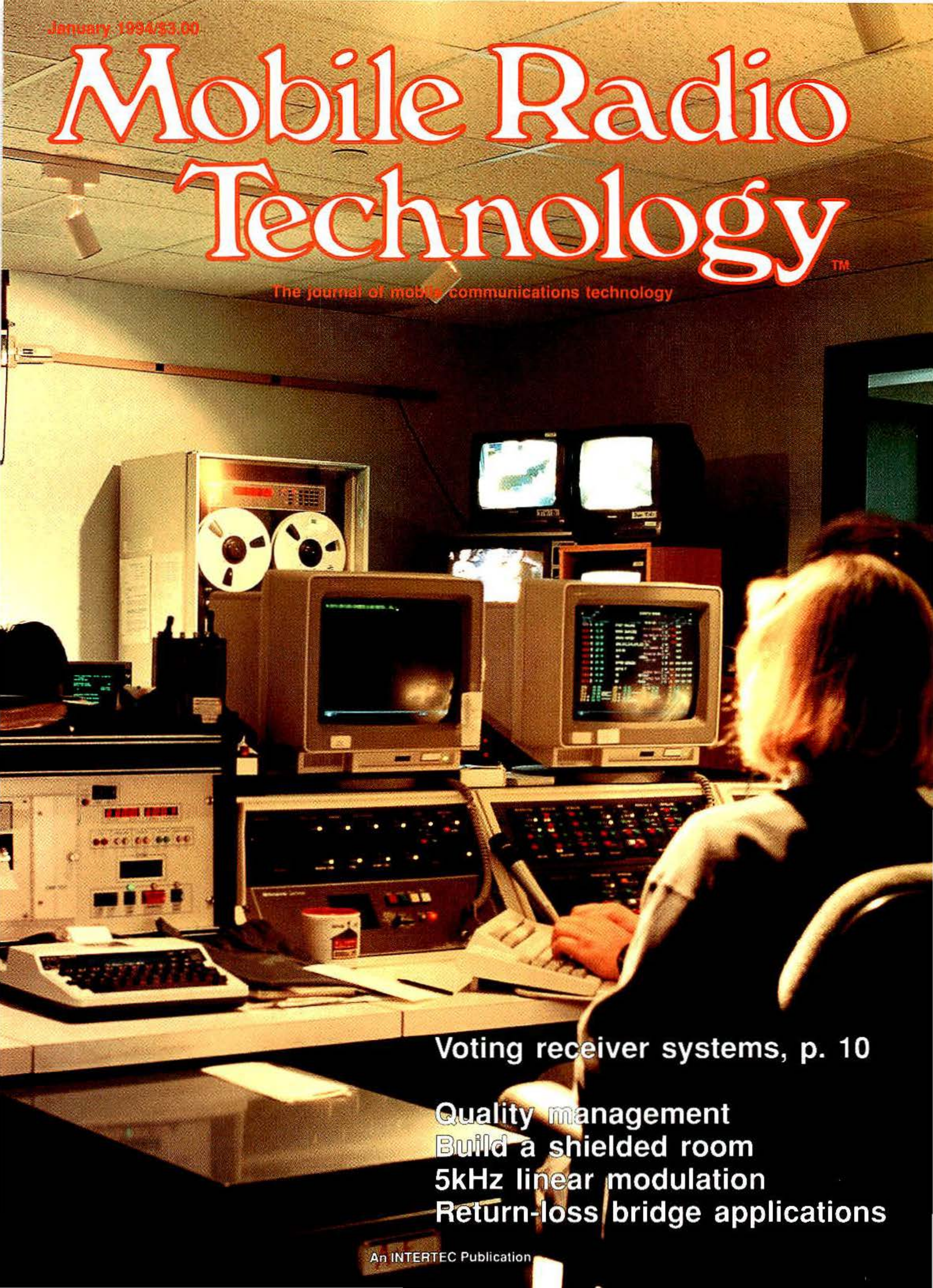

Voting receiver systems, p. 10

Quality management
Build a shielded room
5kHz linear modulation
Return-loss bridge applications

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Servicing pagers: Build a shielded room

Part 1—A do-it-yourself shielded room helps to isolate a signal generator from nearby paging transmitter signals while troubleshooting pagers. Here are some suggestions for building your own.

By David Ludvigson

When servicing any type of pagers, certain requirements must be met to guarantee good-quality results.

In large metropolitan areas, such as Houston, many paging transmitters *always* are operating; therefore, pager alignment usually is difficult because the signal generator's output may be "swamped" by an on-frequency paging transmitter.

To date, the only effective means of isolating these signal sources has been to enclose the test equipment and the operator within a copper shield.

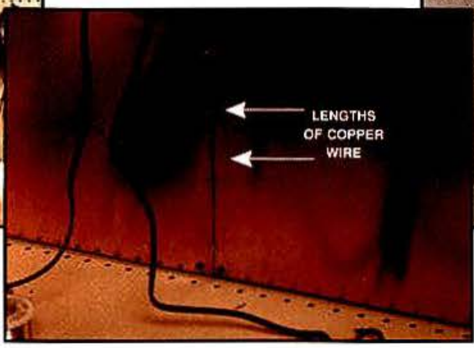
Manufactured shielded rooms that are big enough *are* expensive; nevertheless, after setting up the signal generator and trying to align a pager without any shielding, I soon realized that patience and sainthood await the technician working under those conditions!

In the corner of an electronics outlet

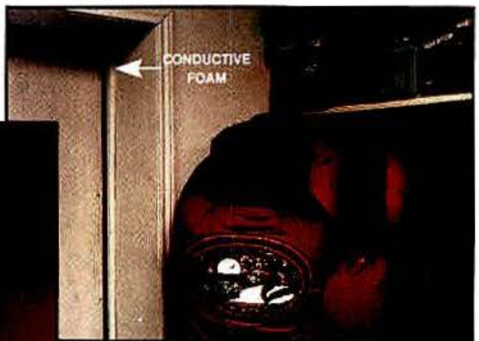
Ludvigson is a technician in Houston.

Four pieces of double-sided printed circuit board material make up the back wall of the test bench.

Raymond, my co-worker, cuts the aperture for the ac power lines.



Lengths of 12-gauge tensilized solid copper wire are soldered along the length of each seam.



Raymond checks the wall-ceiling seam. Earlier construction of the shielded room has been sheetrocked and finished. The black door strip is made of conductive foam.

Centrally located, the ac outlet strip is connected to an electromagnetic interference (EMI) filter behind the panel.

store I found some double-sided printed circuit board material at a reasonable price. Enough of these could tile a small room, so my employer, JJ Sounds, purchased several dozen 1.5-foot × 2-foot sheets.

With boards of these dimensions, about 78 sheets are required to cover the walls, floor and ceiling in a room measuring 4 feet × 8 feet × 6 feet. Additional pieces of circuit board are needed to finish the door, and special attention is required around air conditioning vents, lighting fixtures and ac power outlets.

The framework is a curious mixture of 2" × 4" and 2" × 2" materials. Sheetrock screws secure the circuit board material to the frame, with lengths of 12-gauge, tensilized, solid copper wire soldered every four inches to adjoining tiles on the top, sides and bottom.

Small holes were drilled to pass ac power lines, and electromagnetic interference (EMI) filters were placed between the power source and the outlet strips located inside the room.

The door presented an interesting problem because it had to present a sealed plane in common with the walls and floor. A length of conductive foam was used as a pressure seal against the closed door.

Accompanying photographs show the crew of JJ Sounds building the test bench for the homemade shielded room.

Although the idea of using circuit board material may be innovative, the construction is a large undertaking. No matter what, the room is never perfectly square. Gloves and masks should be worn when cutting tiles to size for protection from copper chips and fiberglass dust.

The walls may be finished in anything from sheetrock to carpeting, but the floor requires plywood over the copper-clad fiberglass to distribute the technician's weight without cracking the circuit board material. It might be fair to equate the care and construction of the shielded room to that taken in building the pyramids of Egypt—if labor may be provided in place of currency, the shielded room is relatively inexpensive.

The do-it-yourself shielded room's over-

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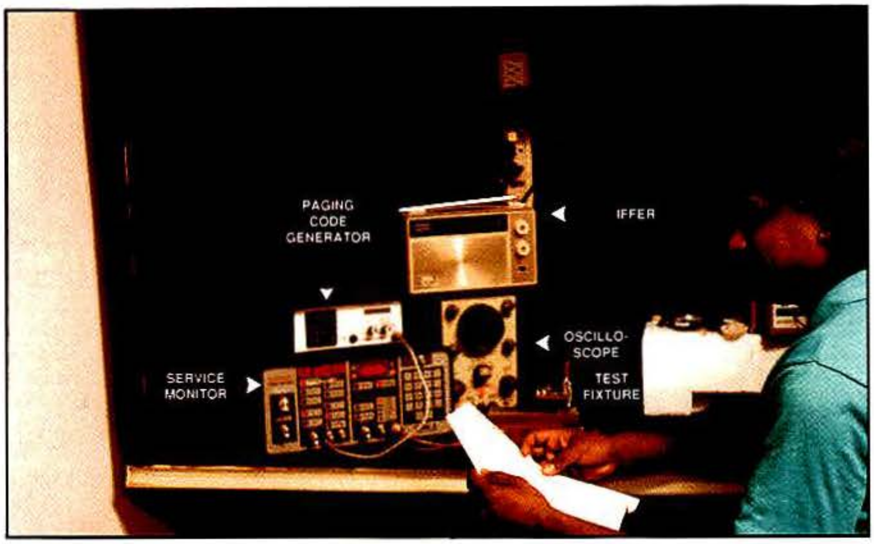


Once it is covered with dark speaker-box carpeting, the shielded room becomes as dark as a tomb! The Ramsey Com 3 service monitor serves as a test monitor. Above the monitor is a Cushman POCSAG and Golay paging code generator. The Motorola RTL-1005 radiation test fixture is in front of an old RCA oscilloscope. Above the scope rests the IFFER, a piece of test equipment built by the author. Pete, another co-worker, consults a frequency and format chart.

all performance has been good.

Reception on transistor radios and TV sets dies when they are placed in the room. Pagers at 931MHz are almost deaf to paging transmitters located three miles away, reducing their interference by more than 50dB.

To hear any of the paging transmitters on the Ramsey Com 3 service monitor requires an external antenna fed through coax; otherwise, the paging transmitters are just background noise.

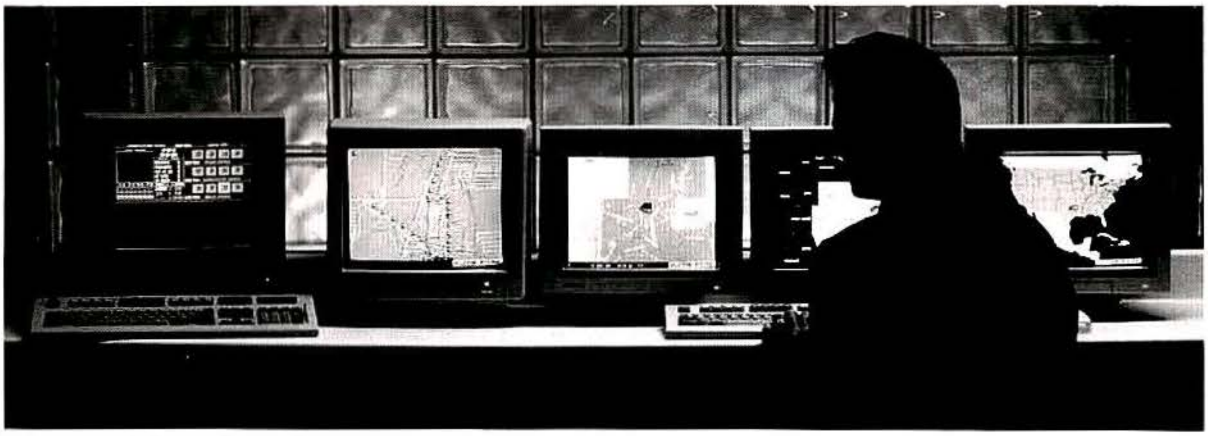
Justification for building a shielded room is a matter of individual test locations relative to nearby paging transmitters. If a repair location is within several miles of many transmitters, the quality of pager alignments will improve drastically when using a shielded room.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and my co-workers Raymond, Tim and Pete, for their help with this project.

Postscript

"Copper coffin" is my nickname for the do-it-yourself shielded room because receivers "die" when they are brought inside of it. The editor thinks it is too morbid a name to use in the article title, but I like it. I'm experimenting with using aluminum foil to build a shielded room called the "tin foil tomb."



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Servicing pagers: Build an 'IFFER'

Part 2—The IF section from a transistor radio makes an ideal accessory for the test fixture designed for Bravo pagers. Whether you use a shielded room or not, the accessory improves alignment results.

By David Ludvigson

One day, a heavy brass object arrived at JJ Sounds, where I work.

The company owner, J.H. Kim, looked completely baffled. "How do you use?" he asked.

I took a look and chuckled. It was the Motorola RTL-1005 test fixture: nearly $500 worth of enclosed antenna planes and shielding with a cantilevered set of springs for test probes. To the uninitiated, it must closely resemble the Wouff Hong!* (See Photo 1 and Figure 1 below.)

Following the directions for modifying the test fixture for use with Bravo series pagers requires a few minutes of work, and then a bit more time is required to get the assembly to drop the test probes across test point M1 and ground on a Bravo. (See Photo 2 on page 38.) Unfortunately, after finally adjusting everything, problems just seemed to follow.

First, the pager has to be put into the *monitor* mode. It seems that these units spend a good deal of their time turned *off* until they receive the appropriate preamble paging code. Turning the Bravo into a full-time receiver involves turning the pager off and depressing both the black and gray buttons simultaneously while turning the pager back on to the *beep* mode.

A steady 3.2kHz tone follows. You now have two seconds to release both push-buttons; quickly depress the gray button and release it. The word PAGING with an optional suffix will appear. Now you can troubleshoot the pager reliably.

While the window displays the word PAGING, insert the Bravo (with the back cover removed) into the test fixture. Close the clamp to connect the decoupling network to M1 and ground.

According to Motorola, alignment of the Bravo can be achieved with an ac millivoltmeter when subjected to an "on-frequency" signal. As I adjusted the output level of the Ramsey Com 3, there were times when the millivoltmeter responded

*The Wouff Hong, from an amateur radio legend, is a ficticious device said to be used for punishing radio operators who misbehave.

Ludvigson is a technician in Houston.

Pager servicing series

"Servicing Pagers: Build a Shielded Room," January 1994.
"Servicing Pagers: Build An 'IFFER'," February 1994.

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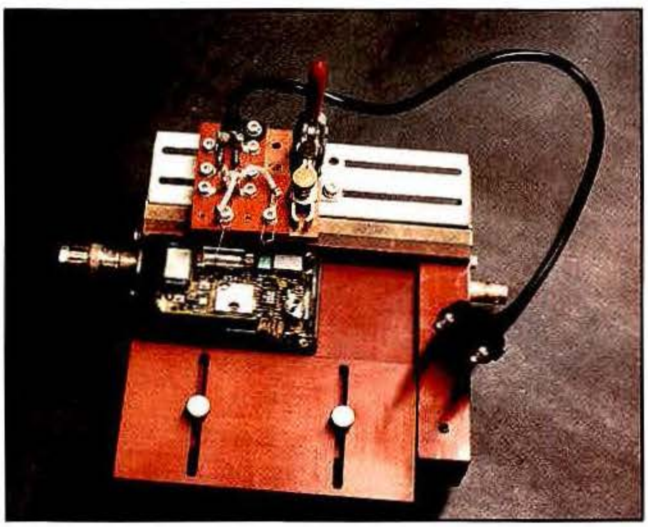

Photo 1. The Motorola RTL-1005 is nearly $500 worth of enclosed antenna planes and shielding with a cantilevered set of springs for test probes.

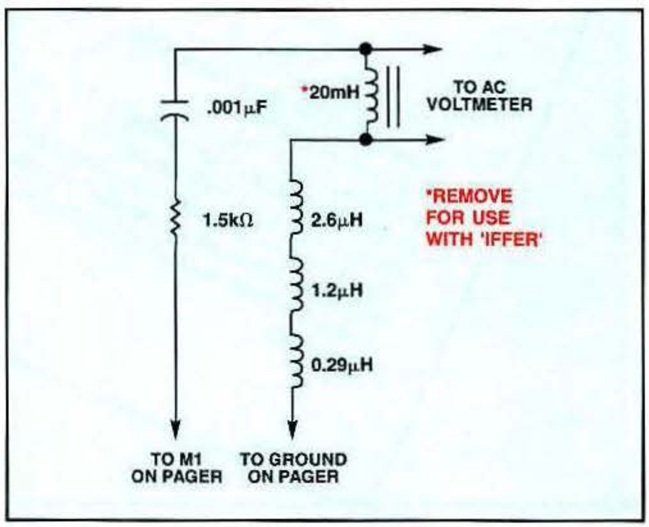

Figure 1. To use the IFFER with the RTL-1005 test fixture, remove the 20mH choke across the output. Otherwise, the inductor swamps the IFFER's input.

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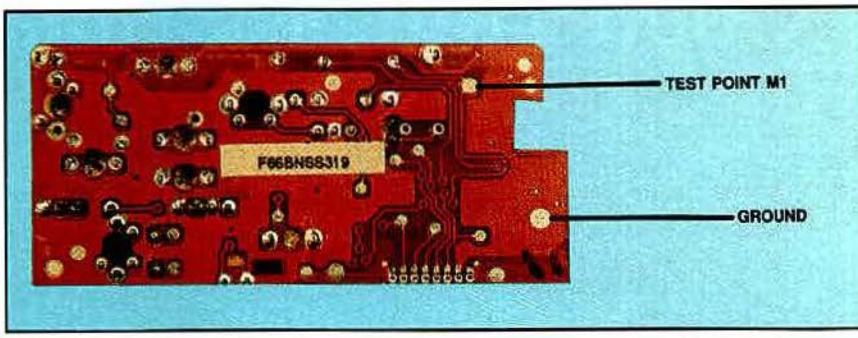

Photo 2. Adjust the RTL-1005 test fixture's probes across test point M1 and ground on a Bravo pager.

smoothly, and other times when it jumped all over the place.

We had not built the shielded room yet, and I was certain that signals from nearby paging transmitters were interfering with the pager test measurements. (See Part 1 in the January issue for information about building the do-it-yourself shielded room.)

Test point M1 is at the input of a 455kHz intermediate frequency (IF) amplifier, and it is isolated by a ceramic filter. To be able to differentiate between the signal from the signal generator and signals from the on-frequency paging transmitters, I use an external 455kHz IF strip followed by an audio detector and audio frequency (AF) power amplifier. By connecting an oscilloscope across the loudspeaker, I can see and hear when the pager is properly tuned.

To find a suitable IF strip, I experimented with a transistor AM radio. These radios are plentiful, and the part with a 455kHz IF amplifier, an audio detector and an AF amplifier forms about 4/5 of the radio.

Standard transistor radios have a converter that feeds two IF stages at 455kHz. Coupling from M1 on the pager through the radiation test fixture to a point in the IF of an external radio provides several

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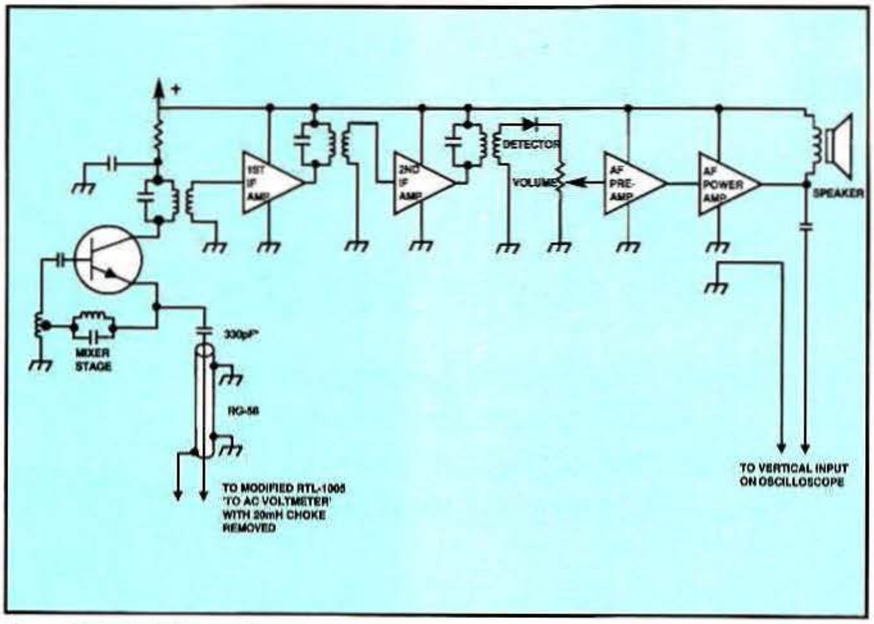

Figure 2. The IFFER is an AM transistor radio's intermediate frequency (IF) strip. A 330pF capacitor (marked with an asterisk) is tied to the primary side of the AM radio's converter, and the radio is tuned to any unused frequency.

advantages.

First, the AM radio continues to operate as an AM radio.

Second, the signal at M1 is sufficiently strong to be transported easily over three feet of RG-58 coaxial cable and translated at the external IF strip. (See Figure 2 to the left.)

With the IFFER in place, the 20mH choke across the output of the RTL-1005 is removed. This inductor swamps the input to the IFFER and just gets in the way. A 330pF capacitor is tied to the primary side of the converter in the AM radio, and the radio is tuned to any unused frequency in the broadcast band.

With the IFFER, pager alignment is vastly improved. Standard Sinadder techniques of using a 3.5kHz-deviated 1kHz tone on the selected frequency are sufficient. Unless you have a shielded room such as the one described in Part 1 of this series, on-frequency "rattling" by nearby paging transmitters will upset any alignment attempt. There is no uncertainty as to the cause of erratic meter readings when using the IFFER; you can both see and hear the interference.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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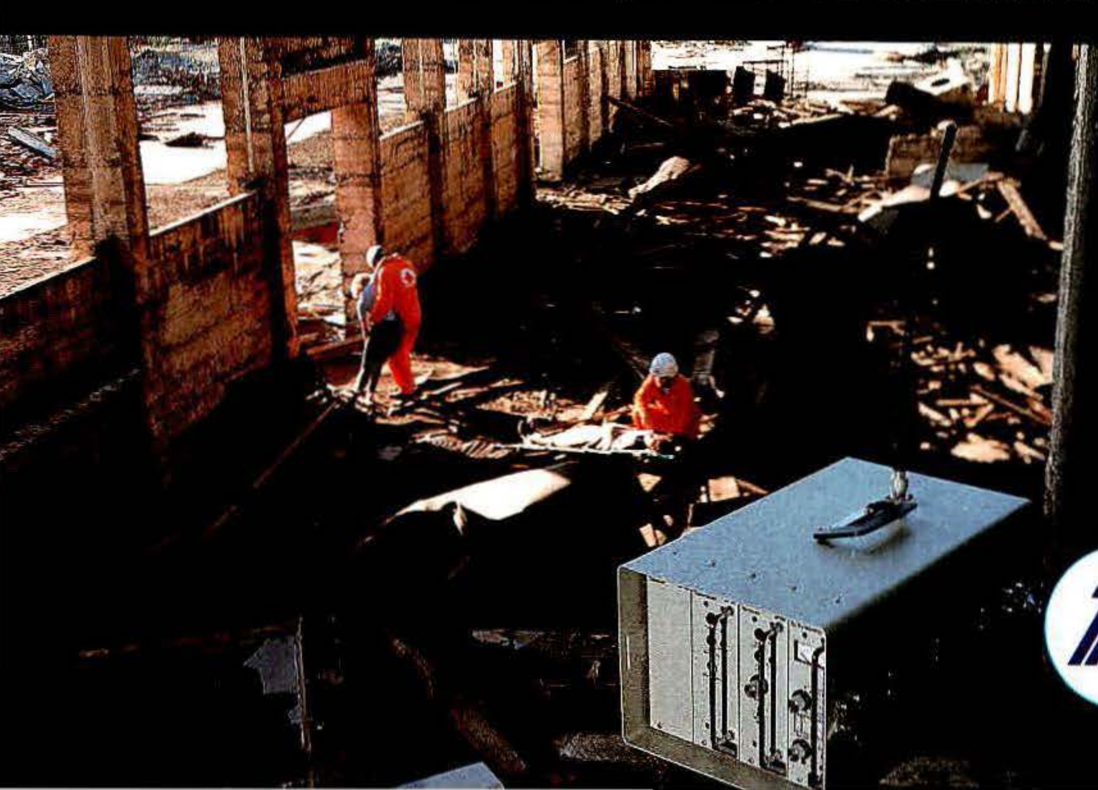

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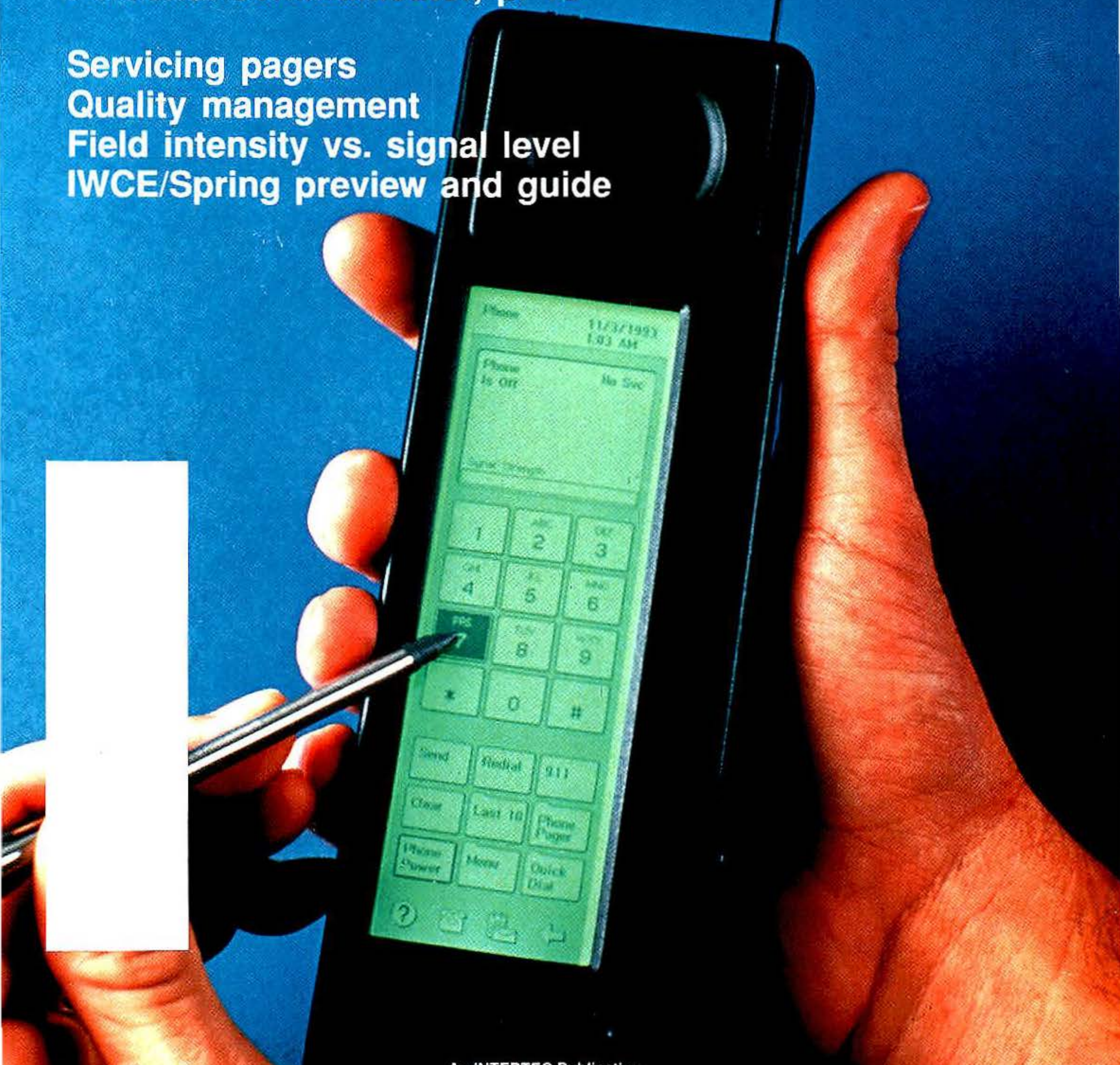

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Servicing pagers: Frequencies, coding formats

Part 3—'Hooking up' customers so their pagers work on one of the various paging services in a given area is simple with the right equipment and information about crystal frequencies, receiver boards and decoder boards.

By David Ludvigson

Bravo pagers are built to receive paging messages sent in two types of digital code, POCSAG and Golay.

With the POCSAG code, some of the pager's silicon chips decode the slow drawl of 512 bits per second (bps). Other chips can decode at 1,200bps, and yet another version races along at 2,400bps.

Golay, on the other hand, operates at a single rate of speed, forcing all the needed data into a well-defined timeframe.

From the retailer's point of view, this description summarizes all he needs to know about Bravo pager decoder boards. With this information and a 10-power magnifying lens, he has just about mastered the Bravo decoder. At the end of this article, we will hand him his degree.

Previous articles in this series have shown how a modest investment provides a signal generator, a POCSAG-Golay code generator, the radiation test fixture, the IFFER IF strip testing device and a do-it-yourself shielded room—everything necessary to handle service and repairs. An air-time supplier such as Pagenet or Pagemart can provide pagers, capcodes, beeper numbers and, often, the necessary crystals to put Bravo pagers on their frequencies. Programmers for Bravo, Bravo Plus, and Bravo Express are available from Motorola.

Ludvigson is a technician in Houston.

Capcodes and pager telephone numbers usually come in pairs. The pager telephone number is the usual seven-digit number that the caller dials from a Touch-Tone telephone. Capcodes usually contain either six digits or seven digits: six digits for Golay codes (sometimes followed by the letter "F"), or seven digits for POCSAG.

Golay codes often are used on paging systems using radio frequencies below 450MHz, and POCSAG generally is used (at varying speeds) above 150MHz.

The frequencies and formats chosen by a retailer must reflect both what pagers he sells and what pagers come in for a "hookup." If a customer wants a hookup for a pager crystalled to 152.24 MHz (with a POCSAG 512 decoder), the retailer probably will want to re-crystal the pager to "his" frequency of, say, 152.84MHz, for example, where the POCSAG 512 format is used, too.

In Houston, three paging carriers served by JJ Sounds operate POCSAG systems between 929MHz and 932MHz. All of them provide 1,200bps service. In addition, one provides 512bps service and another provides 2,400bps service, and they *all* want me to "hookup" customers!

The Bravo pager is well-designed. It is modular—it has two circuit boards: One is a receiver, and the other is the decoder. The modular construction allows the retailer to remove the receiver from the decoder to customize the entire unit to the retailer's frequency and format.

Several tables are provided on page 18 for those using the 930MHz Bravo. These tables are used to determine the operating frequency of Bravo pagers merely by looking at the first conversion oscillator and second conversion oscillator crystal frequencies.

The first intermediate frequencies are either 17.9MHz or 45.00MHz. Determining the first conversion oscillator frequency is a matter of simple math:

[(receiver frequency) − (first IF frequency)] / 12 = first conversion crystal frequency.

Up to this point, you are dealing with a fairly common radio receiver. The big difference is in the triple-conversion superheterodyne circuit that provides a narrow-bandwidth receiver capable of "ignoring" other transmitters operating close to the same frequency.

The detector used in the Bravo provides several useful outputs, each of which is metered easily by the "flap" of the RTL-1005 test fixture. Astute technicians will note an audio output pin (TP6) and question the use of the IFFER for alignment rather than this test point.

The IFFER simply provides greater gain at 455kHz, thus allowing a pager to be drastically mis-tuned and still have enough signal to perform "brute-force" alignments.

Data out and *data in* lines go to and from

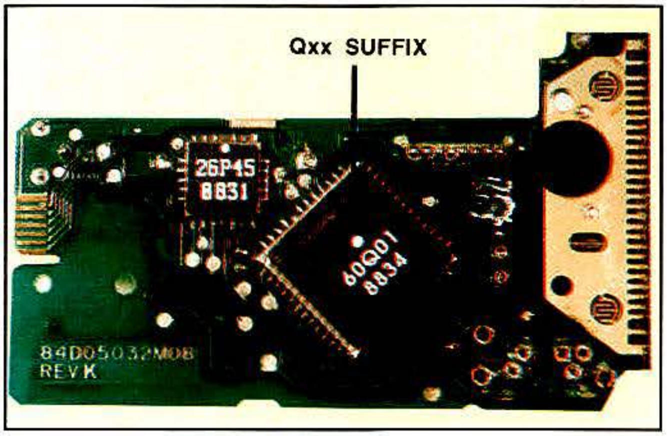

Photo 1. The suffix of the identification number printed on the decoder microprocessor is known as the *Qxx* suffix because it includes the letter *Q* and two digits. The suffix indicates the microprocessor's paging 'language' (POCSAG or Golay) and speed. A table in the text gives the language and speed that go with each suffix.

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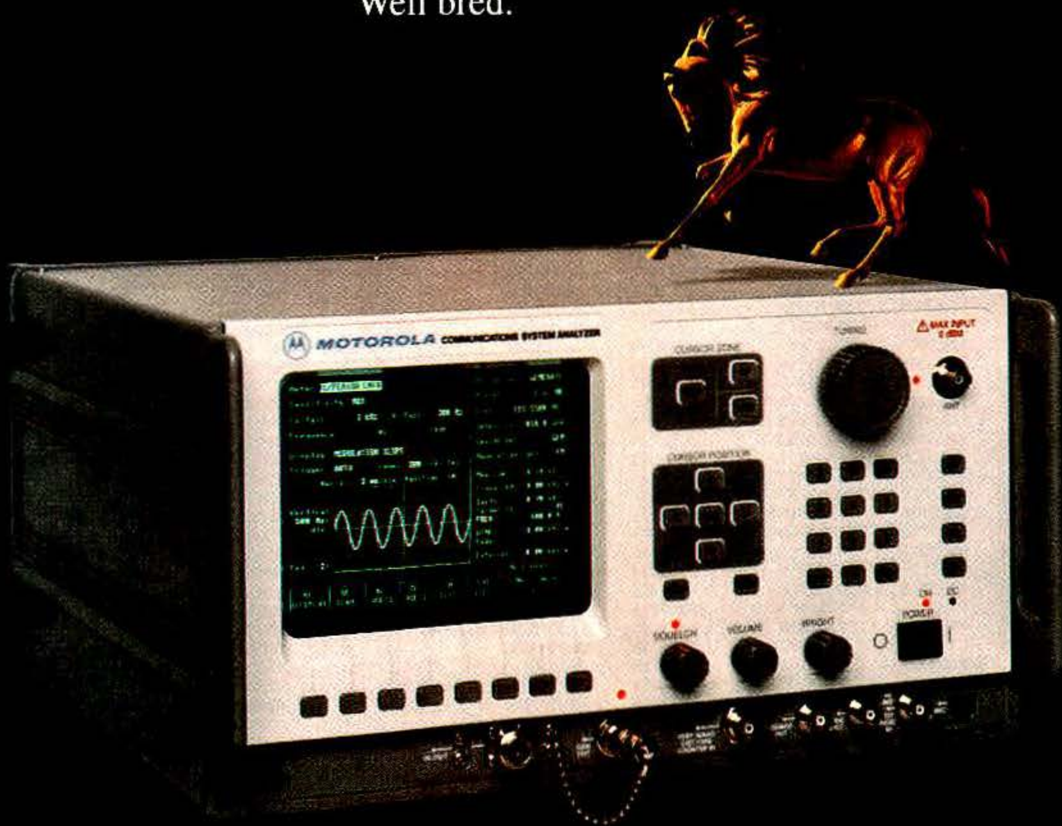

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The sculptured horse, "Magnificent Beast", is the work of George-Ann Tognoni, Phx., AZ.

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Table 1—KXN6370A (Y501) Oscillator Frequencies

Carrier Freq. (MHz)	1st Osc. Freq. (MHz)	Carrier Freq. (MHz)	1st Osc. Freq. (MHz)
929.0125	75.926042	930.5125	76.051042
929.0375	75.928125	930.5375	76.053125
929.0625	75.930208	930.5625	76.055208
929.0875	75.932292	930.5875	76.057292
929.1125	75.934375	930.6125	76.059375
929.1375	75.936458	930.6375	76.061458
929.1625	75.938542	930.6625	76.063542
929.1875	75.940625	930.6875	76.065625
929.2125	75.942708	930.7125	76.067708
929.2375	75.944792	930.7375	76.069792
929.2625	75.946875	930.7625	76.071875
929.2875	75.948958	930.7875	76.073958
929.3125	75.951042	930.8125	76.076042
929.3375	75.953125	930.8375	76.078125
929.3625	75.955208	930.8625	76.080208
929.3875	75.957292	930.8875	76.082292
929.4125	75.959375	930.9125	76.084375
929.4375	75.961458	930.9375	76.086458
929.4625	75.963542	930.9625	76.088542
929.4875	75.965625	930.9875	76.090625
929.5125	75.967708	931.0125	76.092708
929.5375	75.969792	931.0375	76.094792
929.5625	75.971875	931.0625	76.096875
929.5875	75.973958	931.0875	76.098958
929.6125	75.976042	931.1125	76.101042
929.6375	75.978125	931.1375	76.103125
929.6625	75.980208	931.1625	76.105208
929.6875	75.982292	931.1875	76.107292
929.7125	75.984375	931.2125	76.109375
929.7375	75.986458	931.2375	76.111458
929.7625	75.988542	931.2625	76.113542
929.7875	75.990625	931.2875	76.115625
929.8125	75.992708	931.3125	76.117708
929.8375	75.994792	931.3375	76.119792
929.8625	75.996875	931.3625	76.121875
929.8875	75.998958	931.3875	76.123958
929.9125	76.001042	931.4125	76.126042
929.9375	76.003125	931.4375	76.128125
929.9625	76.005208	931.4625	76.130208
929.9875	76.007292	931.4875	76.132292
930.0125	76.009375	931.5125	76.134375
930.0375	76.011458	931.5375	76.136458
930.0625	76.013542	931.5625	76.138542
930.0875	76.015625	931.5875	76.140625
930.1125	76.017708	931.6125	76.142708
930.1375	76.019792	931.6375	76.144792
930.1625	76.021875	931.6625	76.146875
930.1875	76.023958	931.6875	76.148958
930.2125	76.026042	931.7125	76.151042
930.2375	76.028125	931.7375	76.153125
930.2625	76.030208	931.7625	76.155208
930.2875	76.032292	931.7875	76.157292
930.3125	76.034375	931.8125	76.159375
930.3375	76.036458	931.8375	76.161458
930.3625	76.038542	931.8625	76.163542
930.3875	76.040625	931.8875	76.165625
930.4125	76.042708	931.9125	76.167708
930.4375	76.044792	931.9375	76.169792
930.4625	76.046875	931.9625	76.171875
930.4875	76.048958	931.9875	76.173958

$F_c = 12F_o + 17.9\text{MHz}$
2nd Osc. Freq. = 17.445MHz

NOTE

This table applies to KXN6370A crystals (Y501) which are used in Bravo pagers with receiver board kit number NRF4071A-D *ONLY*. Bravo pagers with receiver board kit number NRF4071E use NKN3000A crystals.

IMPORTANT: Y501 1st Oscillator Crystal and C517 must be replaced as a pair per this table:

Grp.	Crystal Marking Color Code: 1st Dot	Crystal Marking Color Code: 2nd Dot	C517 Markings: EIA Marking Code		C517 Markings: Color Code 1st Dot	C517 Markings: Color Code 2nd Dot	C517 Part Number
1	Black	None	COG	O	Black	None	2182358G41
2	Violet	None	U2J	R	Violet	None	2182358G46
3	Orange	Orange	P3K		Orange	Orange	2182358G48
4	Yellow	Orange	R3A		Yellow	Orange	2182358G49
5	No Markings		P3K		Orange	Orange	2182358G48

NOTE: Failure to replace Y501 and C517 as a pair could result in radio sensitivity at the temperature extremes of operation.

Table 2—NXN3000A (Y551) Oscillator Frequencies

Carrier Freq. (MHz)	1st Osc. Freq. (MHz)	Carrier Freq. (MHz)	1st Osc. Freq. (MHz)
929.0125	73.66770	930.5125	73.79270
929.0375	73.66979	930.5375	73.79479
929.0625	73.67187	930.5625	73.79687
929.0875	73.67395	930.5875	73.79895
929.1125	73.67604	930.6125	73.80104
929.1375	73.67812	930.6375	73.80312
929.1625	73.68020	930.6625	73.80520
929.1875	73.68229	930.6875	73.80729
929.2125	73.68437	930.7125	73.80937
929.2375	73.68645	930.7375	73.81145
929.2625	73.68854	930.7625	73.81354
929.2875	73.69062	930.7875	73.81562
929.3125	73.69270	930.8125	73.81770
929.3375	73.69479	930.8375	73.81979
929.3625	73.69687	930.8625	73.82187
929.3875	73.69895	930.8875	73.82395
929.4125	73.70104	930.9125	73.82604
929.4375	73.70312	930.9375	73.82812
929.4625	73.70520	930.9625	73.83020
929.4875	73.70729	930.9875	73.83229
929.5125	73.70937	931.0125	73.83437
929.5375	73.71145	931.0375	73.83645
929.5625	73.71354	931.0625	73.83854
929.5875	73.71562	931.0875	73.84062
929.6125	73.71770	931.1125	73.84270
929.6375	73.71979	931.1375	73.84479
929.6625	73.72187	931.1625	73.84687
929.6875	73.72395	931.1875	73.84895
929.7125	73.72604	931.2125	73.85104
929.7375	73.72812	931.2375	73.85312
929.7625	73.73020	931.2625	73.85520
929.7875	73.73229	931.2875	73.85729
929.8125	73.73437	931.3125	73.85937
929.8375	73.73645	931.3375	73.86145
929.8625	73.73854	931.3625	73.86354
929.8875	73.74062	931.3875	73.86562
929.9125	73.74270	931.4125	73.86770
929.9375	73.74479	931.4375	73.86979
929.9625	73.74687	931.4625	73.87187
929.9875	73.74895	931.4875	73.87395
930.0125	73.75104	931.5125	73.87604
930.0375	73.75312	931.5375	73.87812
930.0625	73.75520	931.5625	73.88020
930.0875	73.75729	931.5875	73.88229
930.1125	73.75937	931.6125	73.88437
930.1375	73.76145	931.6375	73.88645
930.1625	73.76354	931.6625	73.88854
930.1875	73.76562	931.6875	73.89062
930.2125	73.76770	931.7125	73.89270
930.2375	73.76979	931.7375	73.89479
930.2625	73.77187	931.7625	73.89687
930.2875	73.77395	931.7875	73.89895
930.3125	73.77604	931.8125	73.90104
930.3375	73.77812	931.8375	73.90312
930.3625	73.78020	931.8625	73.90520
930.3875	73.78229	931.8875	73.90729
930.4125	73.78437	931.9125	73.90937
930.4375	73.78645	931.9375	73.91145
930.4625	73.78854	931.9625	73.91354
930.4875	73.79062	931.9875	73.91562

$F_c = 12F_o + 45\text{MHz}$
2nd Osc. Freq. = 44.545MHz

NOTE

This table applies to NXN3000A crystals (Y551) which are used in Bravo pagers with receiver board kit number NRF4071E *ONLY*. Bravo pagers with receiver board kit number NRF4071A-D use KXN6370A crystals.

IMPORTANT: Y551 1st Oscillator Crystal and C567 must be replaced as a pair per this table:

Grp.	Crystal Marking Color Code: 1st Dot	Crystal Marking Color Code: 2nd Dot	C567 Markings: EIA Marking Code		C567 Markings: Color Code 1st Dot	C567 Markings: Color Code 2nd Dot	C567 Part Number
1	Black	None	COG	O	Black	None	2182358G41
2	Violet	None	U2J	R	Violet	None	2182358G46
3	Orange	Orange	P3K		Orange	Orange	2182358G48
4	Yellow	Orange	R3A		Yellow	Orange	2182358G49
5	No Markings		P3K		Orange	Orange	2182358G48

NOTE: Failure to replace Y551 and C567 as a pair could result in radio sensitivity at the temperature extremes of operation.

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an 8-pin connector. At this point, the receiver circuitry ends, and the next step is to look at filters and decoders, which are on the second board.

Decoders

Motorola Bravo pagers use dedicated silicon chips to decode either POCSAG or Golay formats.

These same chips provide output signals to the liquid crystal display (LCD) and control signals to make the pager beep or vibrate. They also have been programmed to respond to various portions of an encoded signal train.

A review of these decoders' schematic diagrams will convince a technician quickly that everything here is only a matter of time—or *timing*. Again, Motorola has simplified this technical wonderland by marking each microprocessor with an easily converted code number. It starts with *5105860* and has a suffix of *Qxx*, where *xx* is a number between 01 and 16. (See Photo 1 on page 16.)

The following table indicates the "language" and speed of the various processors.

PROCESSOR	LANGUAGE	SPEED
Q01	Golay	
Q04	POCSAG	512bps
Q06	POCSAG	512bps
Q07	POCSAG	1,200bps
Q08	Golay	
Q10	POCSAG	512bps
Q11	POCSAG	1,200bps
Q12	Golay	
Q14	POCSAG	512bps
Q15	POCSAG	1,200bps
Q16	Golay	

This table, along with a list of frequencies and formats supplied by the airtime vendor, is indispensable for determining rapidly the feasibility of hooking up Bravo pagers.

In Houston, JJ Sounds has signed on with three big airtime suppliers. They operate on the following frequencies and formats:

152.24MHz	Golay	
152.84MHz	POCSAG	512bps
454.10MHz	Golay	
929.6625MHz	POCSAG	1,200, 512bps
929.7125MHz	POCSAG	1,200bps
931.2875MHz	POCSAG	2,400, 1,200bps
931.4875MHz	POCSAG	1,200, 512bps
931.6875MHz	POCSAG	1,200bps

With a *frequency and format chart*, programming Bravo pagers becomes a process of matching crystals to the operating frequency needed, matching a receiver board to a decoder board and then heading to the Bravo Programmer.

Pager servicing series

"Servicing Pagers: Build a Shielded Room," January 1994.

"Servicing Pagers: Build An 'IFFER'," February 1994.

"Servicing Pagers: Frequencies, Coding Formats," March 1994.

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Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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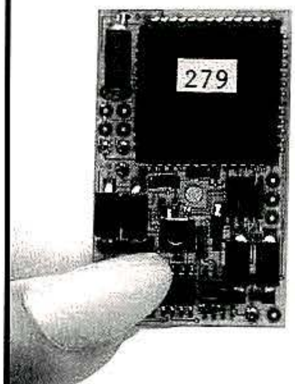

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Servicing pagers: From bench to programmer

Part 4—Follow these steps to choose an appropriate pager frequency, install the right crystal, verify proper receiver and decoder operation, and program the pager to work with a customer's pager telephone number.

By David Ludvigson

With a customer's Bravo pager in hand, turn the slide switch all the way up to the *beep mode*.

A rapid series of continuous beeps indicates a weak battery; replace it if necessary.

With a good battery, the pager should emit four sets of "beep-beep" noises, and the display lamps should flash before the pager settles down to "lights out" and a broken horizontal bar across the display.

Up to this point, the microprocessor has gone through its "wake-up" sequence. Failure at any point of this wake-up sequence usually indicates a failure of the decoder board.

Turn the pager off, and then turn the pager's slide switch all the way up (to beep mode) while depressing both the gray and black push-buttons beneath the liquid crystal display (LCD). Quickly release both push-buttons and rapidly depress the gray button. Upon release, the word *paging* (with an optional suffix) will appear in the LCD.

Another depression of the gray button will reveal a set of 1s and 0s. These are the options (in binary format) that have been programmed into the unit. Another depression will reveal the capcode (in decimal format). This condition, in which all the internal data may be read, is called the *service mode*.

While the Bravo is in service mode and *paging* is displayed on the LCD, use a jeweler's hexdriver to remove the two screws holding the case together. Remove the back cover.

At this point, insert the pager into the radiation test fixture with the IFFER attached to test point M1. Using the presets of the Ramsey Com 3 service monitor, generate an RF signal modulated with a 1kHz tone at 4.5kHz deviation and scan through the available frequencies to locate the pager's operating frequency.

The IFFER will show (on an external oscilloscope) how well the first local oscillator has been adjusted. Failure to locate the signal will require disassembly of the pager.

Turn the pager off. Remove the battery clip at the bottom of the case, and remove the battery. Remove the diffuser lens behind the LCD.

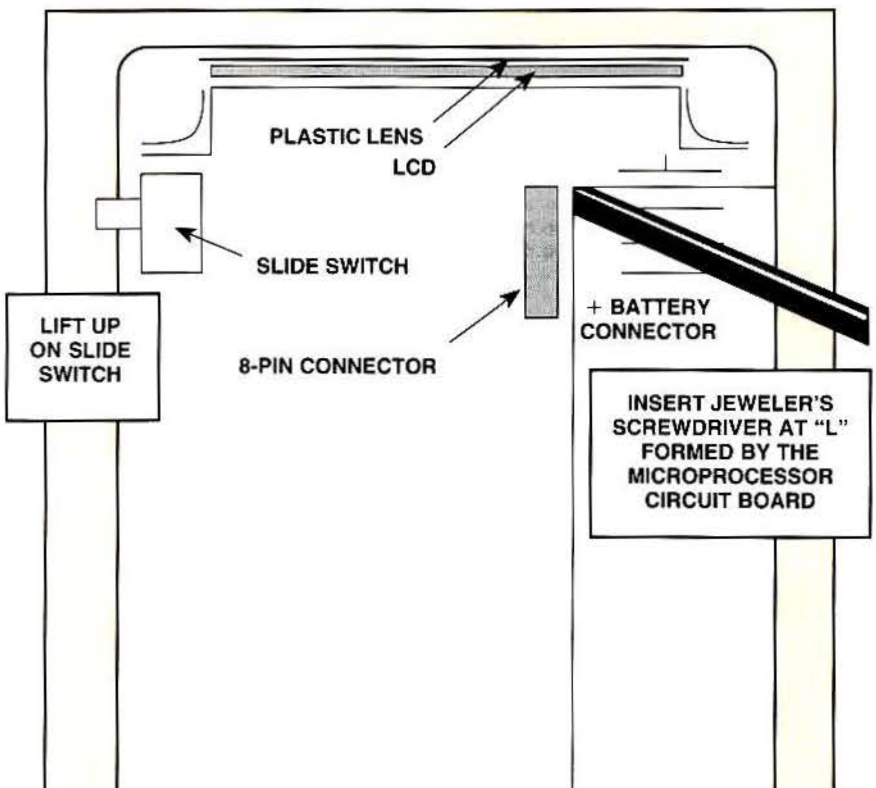

Figure 1. Use a jeweler's screwdriver to remove the decoder and receiver circuit boards from the Bravo pager housing.

Ludvigson is a technician in Houston.

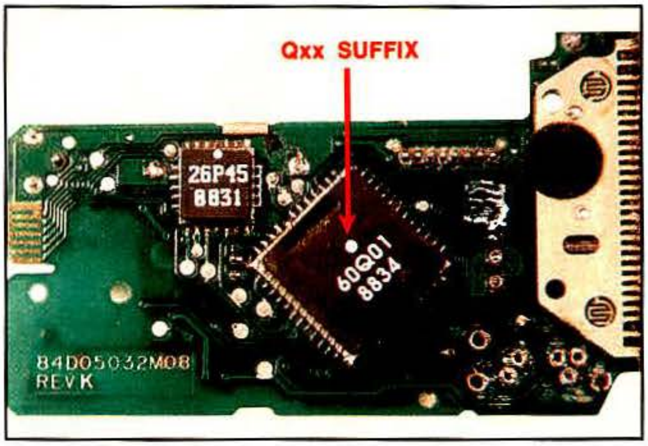

Photo 1. The suffix of the identification number printed on the decoder microprocessor is known as the *Qxx* suffix because it includes the letter *Q* and two digits. The suffix indicates the microprocessor's paging 'language' (POCSAG or Golay) and speed.

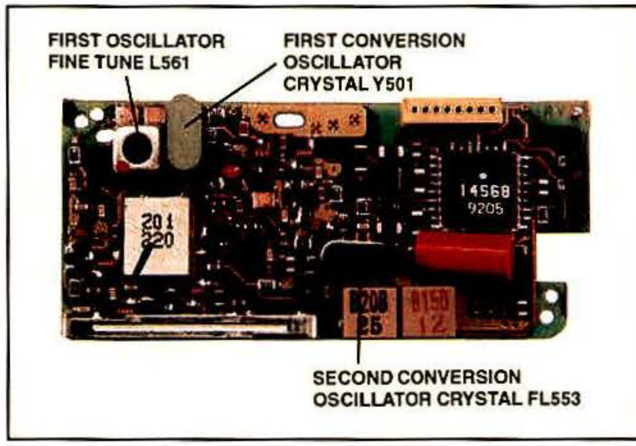

Photo 2. A view of the NRF4071E 928MHz–932MHz receiver board with a 17.9MHz IF shows the locations of the first conversion oscillator crystal, second conversion oscillator crystal and fine-tuning inductor L561.

With a small screwdriver placed at the "L" formed by the circuit board (to the left of the positive battery spring) and while lifting the lever of the side-mounted *on-vibrate-beep* switch, gently wedge the entire unit from the case. (See Figure 1 on page 22.)

Turn the circuit boards over to read the *Qxx* number on the microprocessor. (See Photo 1 above.) Let's call it *Q07* for our discussion, so (from our *frequency and format chart* in Part 3) the pager should operate with POCSAG at a rate of 1,200bps.

Gently rock the 8-pin junction, separating the two boards. With a small screwdriver, move the boot around the first conversion oscillator crystal. (See Photo 2 above.) Unless your eyes are good, I suggest the use of a 10-power (10X) loupe (magnifying lens) as an aid in reading the frequency information from the crystal.

Often, the crystal is installed backward, with the frequency information facing the fine-tuning inductor housing. In this case, note the characteristics of the antenna and the preselector tuning networks.

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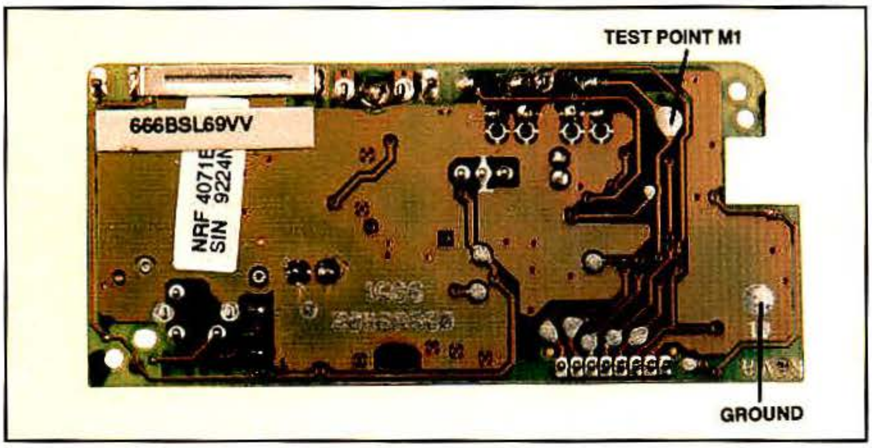

Photo 3. Adjust the RTL-1005 test fixture's probes across the receiver board's test point M1 and ground.

Having determined the range of receiver frequencies, change the crystal to match the desired frequency provided by the airtime carrier. The *frequency and format chart* for your own area will tell whether the capcode can be programmed to operate on POCSAG at 1,200bps for any given radio frequency.

From the *F&F* chart given as an example in Part 3 and assuming a 930MHz pager, paging systems on 929.6625 MHz, 929.7125MHz, 931.2875MHz, 931.4875MHz, and 931.6875MHz all use POCSAG at 1,200bps. Experience in Houston has shown transmitter problems with 929.7125MHz and transmitter loading on 931.6875MHz. I might choose 931.2875MHz because the frequency is not heavily loaded—*yet.*

Determining the first conversion oscillator frequency requires a knowledge of the first intermediate frequency. Subtract either 17.9MHz or 45.0MHz from the operating frequency.

Let's say the first IF frequency is 17.9MHz; therefore

$$931.2875 - 17.9 = 913.3875$$

This value (913.3875) is divided by 12 to obtain the first conversion oscillator frequency:

$$913.3875 \div 12 = 76.115625$$

Remove the original first conversion crystal and install a 76.115625MHz crystal in its place. Trim the crystal leads and reassemble the pager, leaving the back cover off.

Place the pager in the *service mode* with the word *paging* displayed on the LCD. Place the unit in the RTL-1005 test fixture (with the IFFER attached), and bring down the probes to M1 and ground. (See Photo 3 above.)

Radiate a fairly strong (>500μV) signal at 931.2875MHz with a 4.5kHz-deviated 1kHz tone. Adjust the fine tuning inductor slug with a ceramic tuning tool until the

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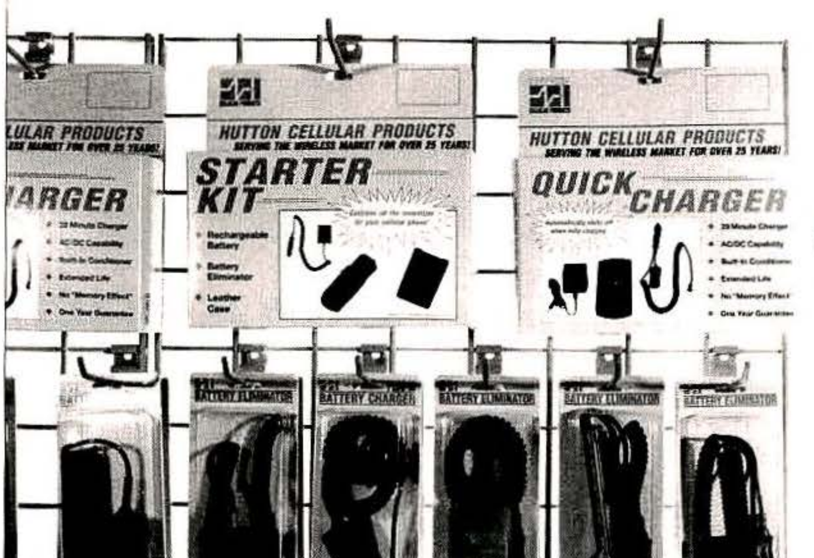

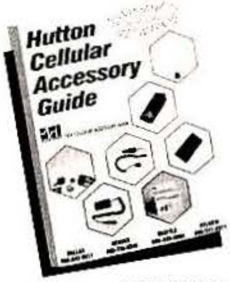

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Circle (23) on Fast Fact Card

signal from IFFER approximates a sine wave.

If you are in shielded room, such as the one described in Part 1 of this series, you can adjust the pager for maximum sensitivity. As a final check, use the oscilloscope attached to the IFFER and the IFFER's loudspeaker to watch and listen to the activity on 931.2875MHz. While the paging transmitter is active, the difference between the strength of its signal and the signal generator's signal may be on the order of only 10dB.

To this point, you have a working receiver at 931.2875MHz, but the decoder is still untested.

Remove the pager from the radiation test fixture. Depress the gray button to reveal the current capcode in the pager. Set the POCSAG-Golay generator to match the original capcode.

Depress the gray button on the Bravo to show *paging* on the LCD and set the pager back into the radiation test fixture. First defeat the 1kHz tone on the RF signal generator. Then modulate a strong RF signal with the code generator. A single *beep* and a flash of the back-light lamp indicate a working decoder.

Continue to decrease the RF signal while activating the code generator. At a certain point, the pager no longer will respond. In an unshielded room (with pager transmitters active) the pager will have a lot of junk data with which to contend.

Only with a shielded room will an accurate measure of overall sensitivity be obtained.

Okay, the pager understands the old capcode, and the receiver is working. It's time to go to the programmer.

Bravo programmer

Place the pager into the programmer.

When the programmer is turned on, it plays about 10 seconds worth of commercial messages. Then, it asks the operator to select:

1 GSC (Golay sequential code) or
2 POCSAG

Because you want POCSAG for this pager, select *2*. The screen now displays:

1 JRB/JRC
2 BAB

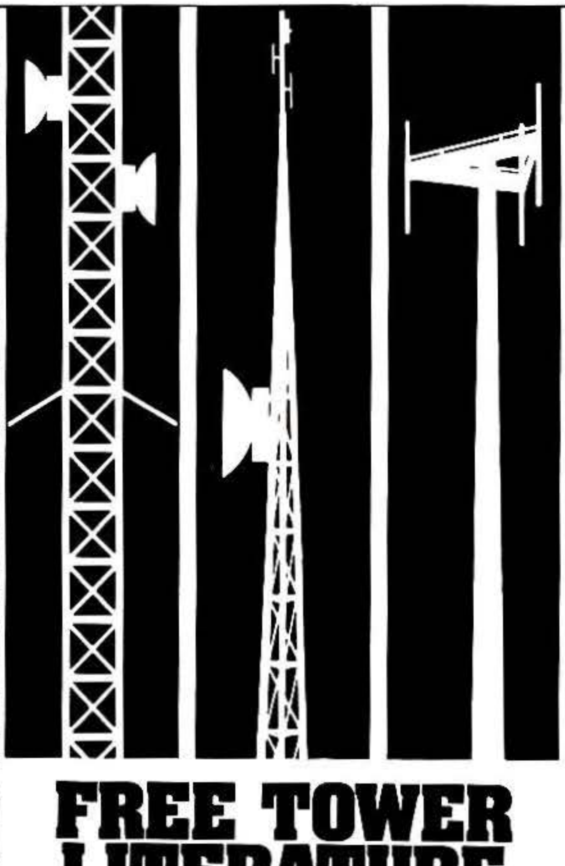
BAB, JRB and JRC were parts of the original model numbers, and probably have been lost as labels were replaced.

Placing the Bravo pager in *Test Mode 1*

1. With the pager off, depress both push-buttons beneath the display and bring slide-switch fully up (to *beep position*).
2. A steady tone at 3kHz or higher will be heard.
3. Release both buttons and momentarily depress the gray (*read*) button. The word *paging* (with an optional suffix in some cases) will appear.
4. At this point, the Bravo pager is configured as a full-time receiver. If it should receive its capcode, one lamp will flash and a single beep will be heard from the internal speaker.

Reading the capcode

1. Perform steps 1 through 3 above.
2. Depress the gray (*read*) button several times until the capcode is displayed on the LCD.



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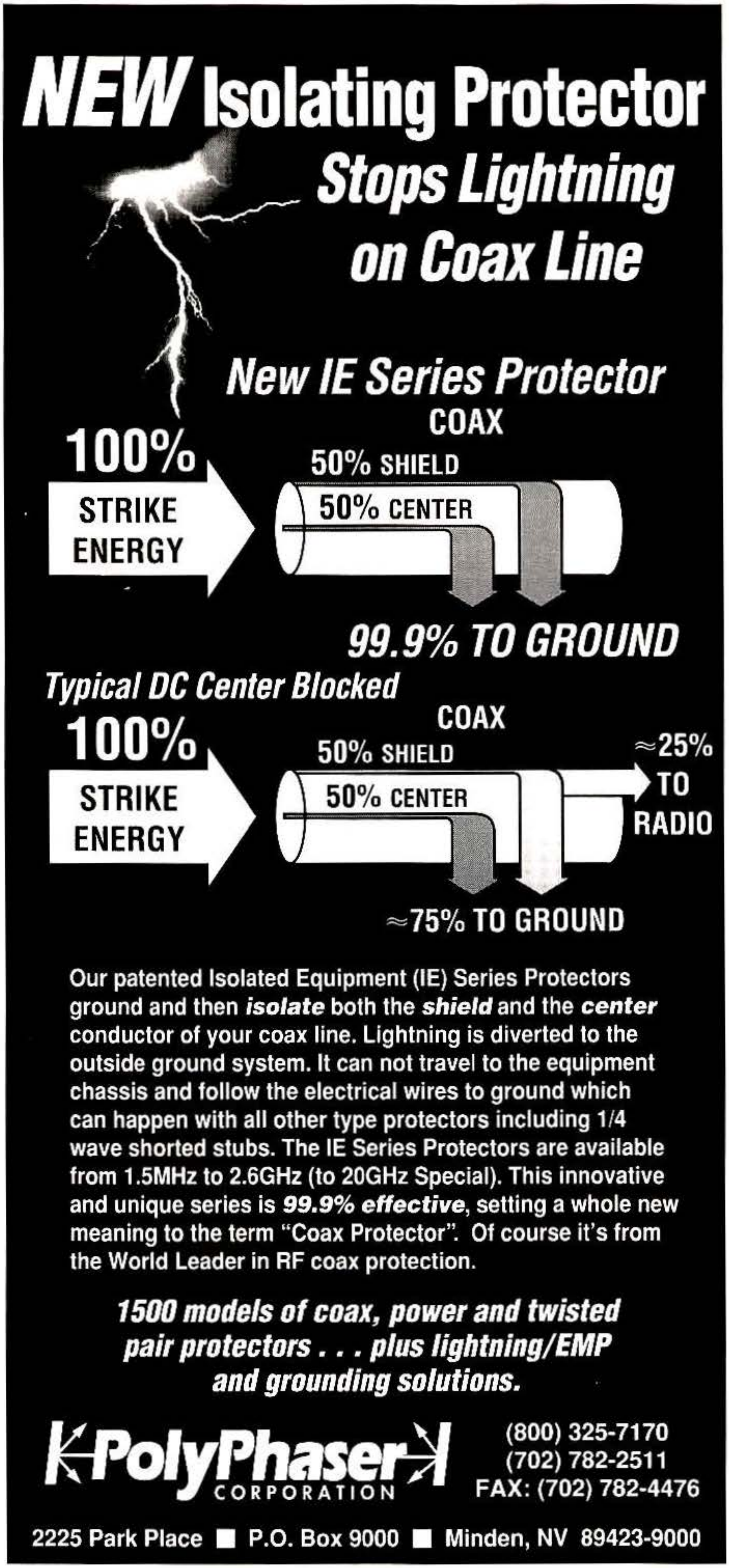

Circle (27) on Fast Fact Card

Pager servicing series

Part 1: "Build a Shielded Room," January 1994.
Part 2: "Build An 'IFFER'," February 1994.
Part 3: "Frequencies, Coding Formats," March 1994.
Part 4: "From Bench To Programmer," April 1994.

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Simply put, JRB/JRC is normal POCSAG code, whereas BAB responds to inverted POCSAG code. Select *1*.

The screen now presents several options. Because we want to program the Bravo, we select option *2*.

The screen now displays ENTER 7 DIGIT CAPCODE.

Select one of the capcodes for 931.2875MHz POCSAG at 1,200bps and enter the capcode. Hit the ENTER key.

The following screens allow a Bravo pager to perform numerous functions and are found in the programming manual which comes with the Bravo Programmer.

After the customizing, the programmer prompts, READY TO PROGRAM? Punch YES.

Any erratic connection between the pager and programmer halts the programming and prompts INSERT PAGER. Some wiggling and wedging might be needed to make proper connection.

The programmer will report PROGRAMMING PAGER and PROGRAMMING FINISHED. Remove the pager, grab your notes, and head for a telephone.

On a Touch-Tone telephone, dial the phone number associated with the capcode you have programmed. Depending on the activity on 931.2875MHz, the pager should sound off in a few minutes. Assuming success, strike out the capcode from your list. This step prevents duplicated pagers and upset customers.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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Servicing pagers: The receivers

Part 5—Here are some tips for identifying which frequency bands correspond with which receiver boards in Bravo pagers to help you install the right boards for hooking up new customers.

By David Ludvigson

Motorola Bravo receivers have been designed for several frequency ranges.

Although these ranges include the range from 33MHz to 50MHz, this discussion covers pagers used at frequencies above 150MHz.

Quick identification

From the backside, there are few visible differences between most of the Bravo receiver boards—they are all the same size, they all fit the 8-pin connector, and they all do basically the same job.

Our task is to identify which receiver will work in any given portion of the spectrum allowed by our *frequency and function chart*. (See Part 3, March issue.) Again, Motorola has simplified the task.

Located on a sticker on the back side of the receiver module is a number. Refer to the following chart for frequency range.

FREQUENCY RANGE (MHz)	RECEIVER MODULE No.
929 – 932	NRF4071A-F
406 – 420	NRE6421A,B
450 – 465	NRE6423A,B
465 – 480	NRE6424A,B
480 – 495	NRE6425A,B
495 – 512	NRE6426A,B
450 – 465	AARE4001A-0
450 – 465	AARE4001A-1
465 – 480	AARE4002A-0
465 – 480	AARE4002A-1
138 – 143	NRD7211A,B
143 – 148.6	NRD7212A,B
148.6 – 152	NRD7213A,B
152 – 159	NRD7214A,B
159 – 164	NRD7215A,B
164 – 169	NRD7216A,B
169 – 174	NRD7217A,B

These receiver boards are interchangeable; thus, by merely replacing a 932MHz board with a 454MHz board, the pager is capable of operating in a different frequency band. *Certain caveats must be noted when trying to interchange Bravo Plus or Bravo Express boards in the simple Bravo. Specifically, they will not work. Pinouts on the 8-pin connector are incompatible.*

In passing, the second conversion oscillator in these receivers determines the *polarity* of the received POCSAG or Golay code. Depending on *high-side* or *low-side* signal injection (at the second mixer), the detector *flips* the output polarity of either code format in the same manner as detecting *one side* of a single-sideband signal.

This factor might require attention during the Bravo programming stage (SELECT JRB/C or BAB), but it is confirmed easily by the NORMAL/INVERTED position of a POCSAG-Golay generator.

Quick identification of the band of operating frequencies requires a look at the component side of the receiver board.

Ludvigson is a technician in Houston.

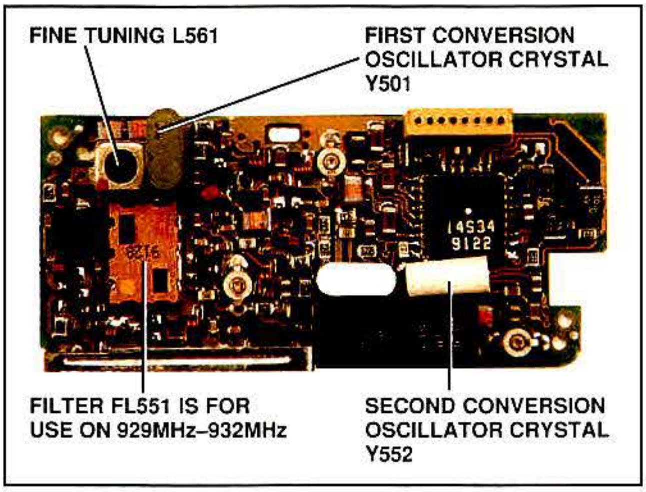

Photo 1. NRF series 929MHz–932MHz receiver circuit boards are easily identified by the small rectangular filter (FL551) used at the output of the RF pre-amplifier. Fine tuning is available by adjusting L561.

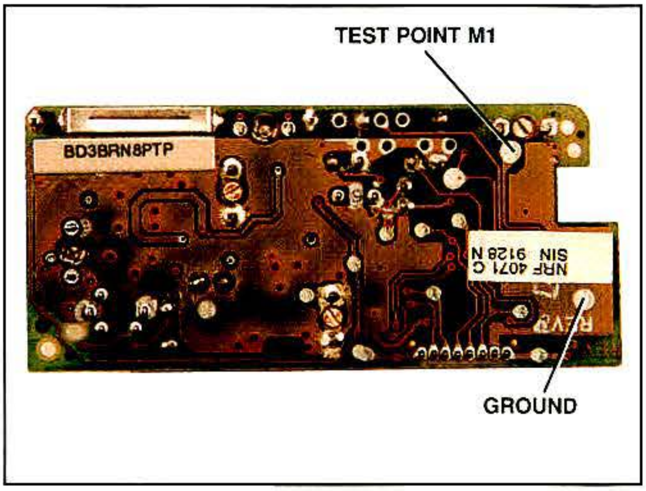

Photo 2. These are the M1 test point and ground locations on the NRF series 929MHz–932MHz receiver circuit boards.

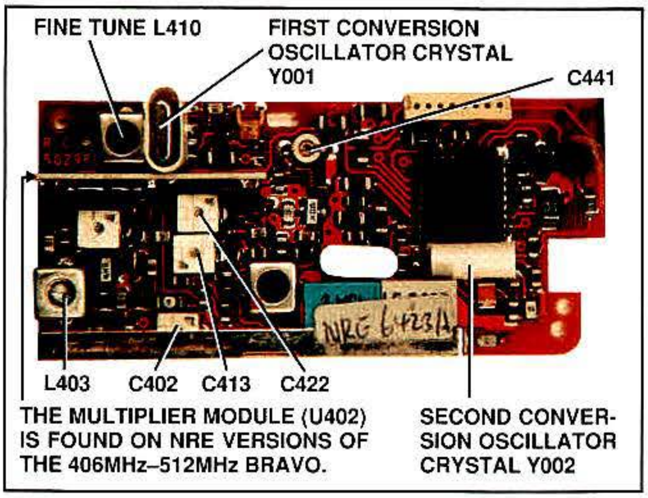

Photo 3. NRE series 406MHz–512MHz receiver circuit boards are identified simply by the ceramic module for the first conversion oscillator stage. Changing crystals requires adjusting both L410 and C441, and 'touch-ups' on C422, C413, L403, and C402. For small frequency changes, try adjusting only L403 and C402.

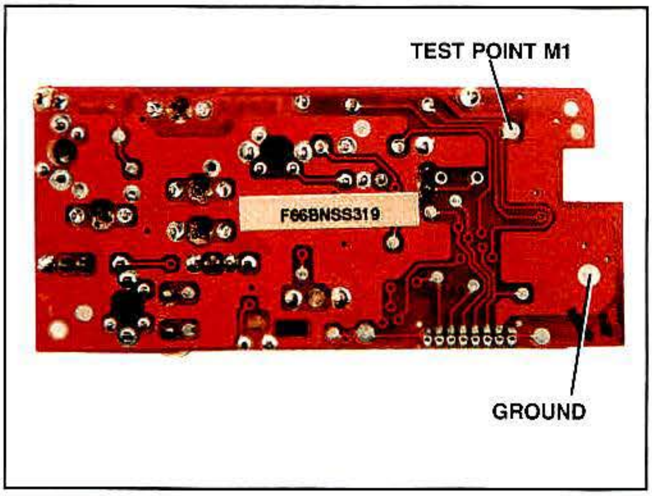

Photo 4. These are the M1 test point and ground locations on the NRE series 929MHz–932MHz receiver circuit boards.

Antenna and RF pre-amplifier filters tell the whole story.

The 928MHz–933MHz receiver usually has a single band of strapping for an antenna and a small square subassembly for a pre-amplifier filter.

For 406MHz–512MHz, the antenna may be either a single strap or a dual-strap (inductively coupled) assembly. When the dual-strap antenna is present, look for a ceramic sub-strated first conversion oscillator. This is a modular multiplier for the first conversion frequency.

Another version of the 406MHz–512MHz band receivers uses three tuning inductors as a helical filter between the RF pre-amplifier and the mixer. Wide frequency changes require both

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a re-alignment and a shielded room, such as the one described in Part 1, January issue, to optimize these inductors effectively.

Receivers equipped to run on 138MHz–174MHz are denoted by the use of a ferrite core surrounded by a single band of metal for an antenna loop. Beneath an identifying sticker are several capacitors placed in a notch across the metal band. The resonant circuit for this band is formed by the distributed capacitance, the values of these capacitors and the amount of inductance provided by the core.

Another significant clue to the frequency band is the placement of the first conversion oscillator crystal. It is placed parallel to, and at the edge of, the circuit board.

Receivers with a ferrite core with several windings of ribbon metal operate below 50MHz and will not be treated in these discussions.

Please note that tuning of these receivers will *require* a ceramic tuning tool. *Severe de-tuning results from the use of metal tools, such as jeweler's tools.*

NRF (929MHz–932MHz) receivers

The 929MHz–932MHz NRF series receiver circuit boards are identified easily by the small rectangular filter (FL551) used at the output of the RF pre-amplifier. (See Photo 1 on page 16.)

Located at one corner of the filter is the first oscillator crystal (Y501). Depending on the frequency of the first intermediate frequency, this crystal's frequency ranges between 73.666MHz and 76.175MHz. Fine tuning is available by adjusting L561.

The alignment of these receivers is straightforward. Radiate a signal into the RTL-1005 (You are in your shielded room, aren't you?) and test receiver sensitivity using M1 and ground. (See Photo 2 on page 16.) If necessary, adjust L561 to center the signal, and adjust the multiplier stage, the RF pre-amp and the second conversion oscillator frequency for optimum performance.

NRE (406MHz–512MHz) receivers

The 406MHz–512MHz NRE series receiver circuit boards are identified simply by the ceramic module for the first conversion oscillator stage. (See Photo 3 on page 18.)

Alignment can be really difficult without a shielded room because there are several LC networks in the RF pre-amp that interact. Changing crystals requires adjusting both L410 and C441, and "touch-ups" on C422, C413, L403 and C402. For small frequency changes, I suggest adjusting only L403 and C402.

Photo 4 on page 18 shows the M1 test point and ground locations.

AARE (406MHz–512MHz) receivers

AARE4001A receiver circuit boards cover the range of 450MHz–465MHz and

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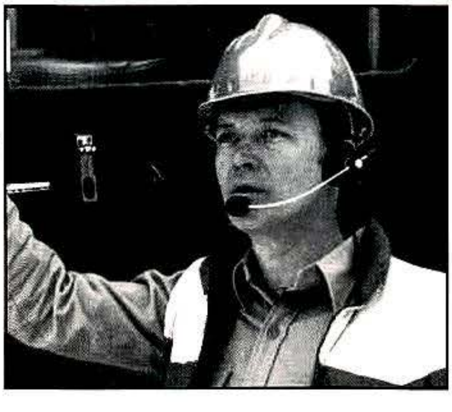

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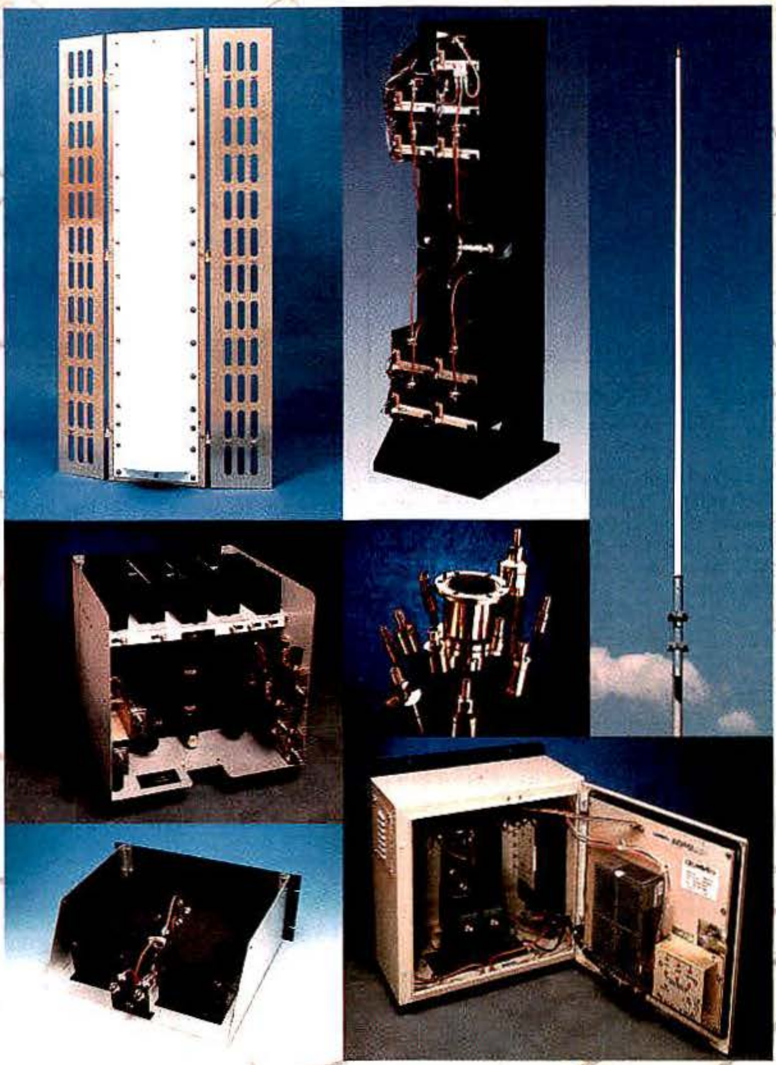

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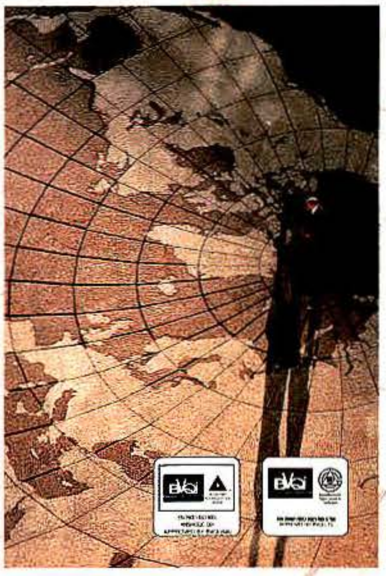

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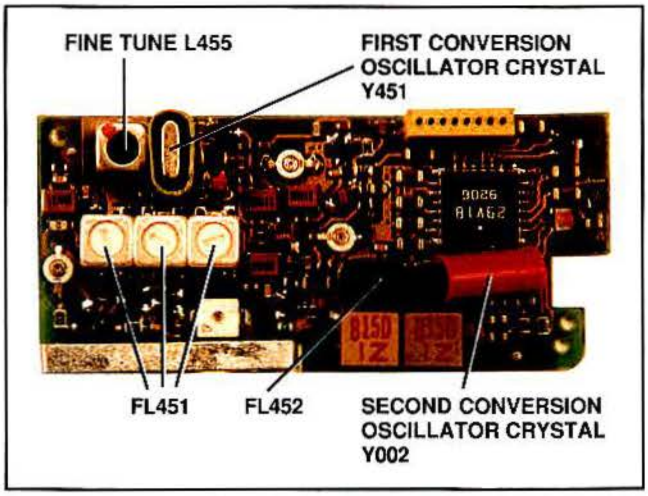

Photo 5. AARE series 406MHz–512MHz receiver circuit boards are virtually identical, with the exception of the tuning range. The AARE4001A board (pictured) covers 450MHz–465MHz and contains a 3-bay helical filter (FL451). Note that Y002 is the second conversion oscillator crystal. FL452 serves as a band-pass filter.

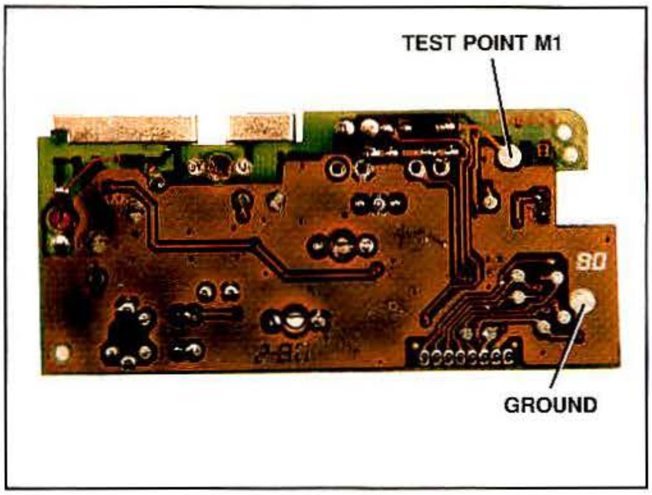

Photo 6. These are the M1 test point and ground locations on the AARE series 406MHz–512MHz receiver circuit boards.

contain a three-bay helical filter (FL451). (See Photo 5 above left.)

The AARE series pagers virtually are identical, with the exception of the tuning range. Further, note that Y002 is the second conversion oscillator crystal. FL452 serves as a band-pass filter.

Photo 6 above right shows the M1 test point and ground locations.

NRD (138MHz–174MHz) receivers

As shown in Photo 7 on page 26, NRD series receiver circuit boards use a ferrite bar in the antenna circuit.

The first conversion oscillator crystal, Y001, is in the range of 40.00MHz to 65.3MHz, followed by a frequency multiplier. The second conversion oscillator

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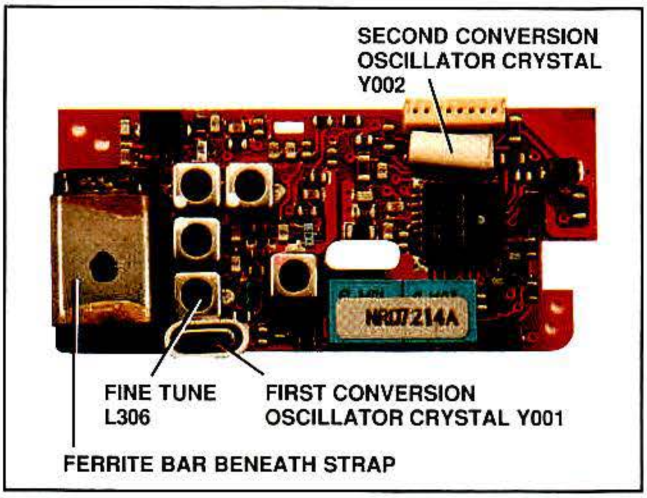

Photo 7. NRD series 138MHz–174MHz receiver circuit boards use a ferrite bar in the antenna circuit.

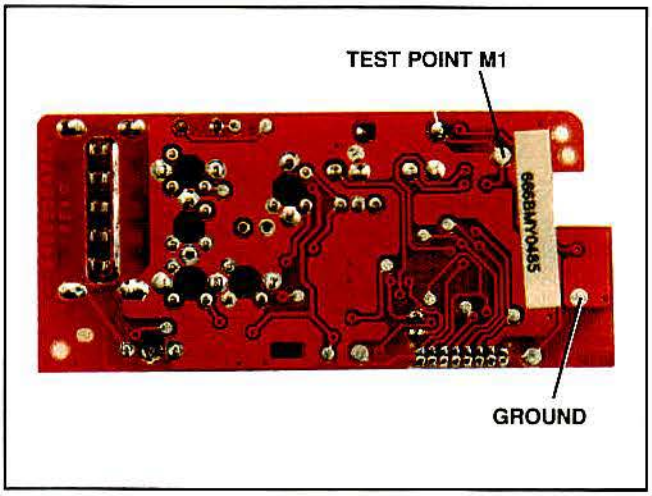

Photo 8. These are the M1 test point and ground locations on the NRD series 138MHz–174MHz receiver circuit boards.

(Y002) is set either +455kHz or −455kHz from 17.9MHz. As mentioned earlier, this frequency choice affects the polarity of the decoded signal.

L305 varies the signal input from the multiplier into the first mixer. L306 tunes the crystal (Y001) to frequency. L302 and L303 adjust the RF pre-amplifier to resonance while L304 is broadly resonant at 17.9MHz. A future article describes these circuits in detail.

Photo 8 above right shows the M1 test point and ground locations.

Motorola, from the start, has designed the Bravo receivers around triple-conversion superhets. Although the costs and complications of this conversion scheme have their drawbacks, the unrivaled sensitivity and selectivity this circuit affords cannot be denied.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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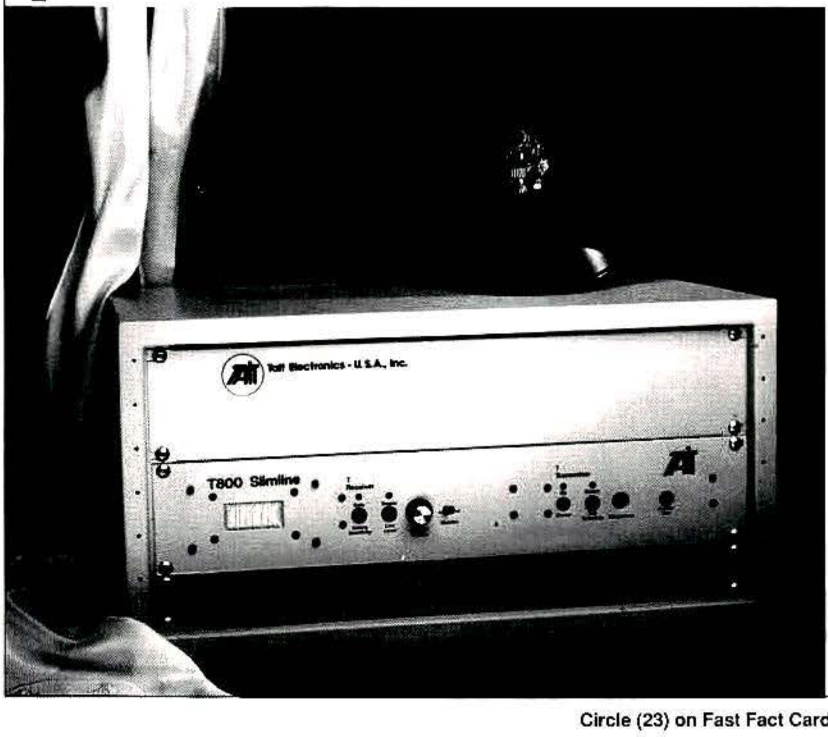

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Servicing pagers: Elegant simplicity

Part 6—Here are some details about the Bravo receiver circuitry. Surprisingly, the Bravo does not include one particular circuit that is common to most FM receivers. Alignment information is included.

By David Ludvigson

In engineering terms, the Bravo receivers share *elegant simplicity*.

To manufacture a receiver with the frequency stability, sensitivity, selectivity and features found on just the 930MHz Bravo—and to do it with only five transistors and a silicon chip—well, that (for me) defines *elegant simplicity*.

Let's take a look at the Bravo receivers, starting with the NRF series (929MHz–932MHz).

Figure 1 below is a block diagram of one of the NRF series receivers.

Ludvigson is a technician in Houston.

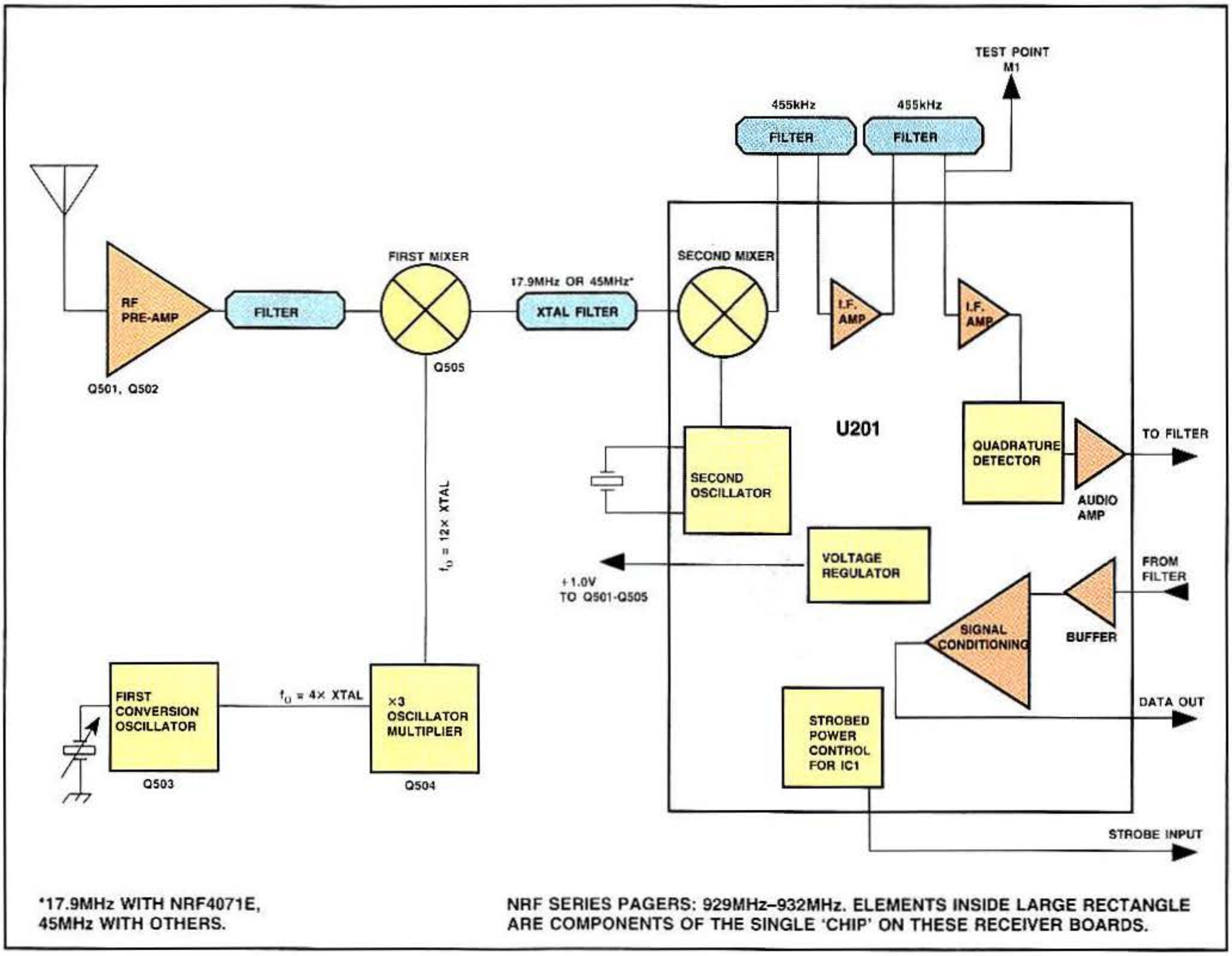


Figure 1. A block diagram of the NRF4071A receiver.

Alignment procedure: Bravo NRF series (45MHz IF)

The following procedure deviates somewhat from the suggested Motorola technique and assumes the use of a shielded room (See Part 1) and the IFFER (See Part 2).

1. Set signal generator to exact frequency of receiver: $F_{oper} = (12 \times \text{1st conv. xtal}) + 45\text{MHz}$.
2. Frequency-modulate the signal with a 4.5kHz-deviated 1kHz tone.
3. Meter M1 using the IFFER and an oscilloscope.
4. Adjust L511 for a close approximation of a sine wave (as viewed on scope). This should be the first peak as L511 is adjusted clockwise as viewed from the foil side of the circuit board.
5. Trim C521 to slightly distort the signal viewed in step 4. This adjustment affects the multiplier stage and causes "pulling" of the crystal oscillator.
6. Reduce the signal generator's output level. Adjust C521 (multiplier), C532 (45MHz filter response), C513 (930MHz bandpass filter input) and C502 (antenna trimmer)—in that order—to achieve maximum sensitivity.
7. Repeat step 6 as needed for maximum sensitivity. Output from the signal generator should read −90.2dBm (<7μV) for 1,200 baud POCSAG or −92.5dBm (<5.5μV) for 512 baud POCSAG. Measurements are signal generator output level readings applied through a 6dB attenuator to the RTL-1005 fixture.

(Additional detail is available from the schematic printed in the pager manual.) The antenna loop circuit (L501 and L502) is coupled via L503 and L504 into the emitter of Q501. C502 provides antenna tuning for the frequency of interest. Between the loop antenna and the emitter of Q501 is a matching network that effectively transforms the high-impedance antenna to about 50Ω. Q501 and Q502 provide roughly 12dB–15dB of signal gain.

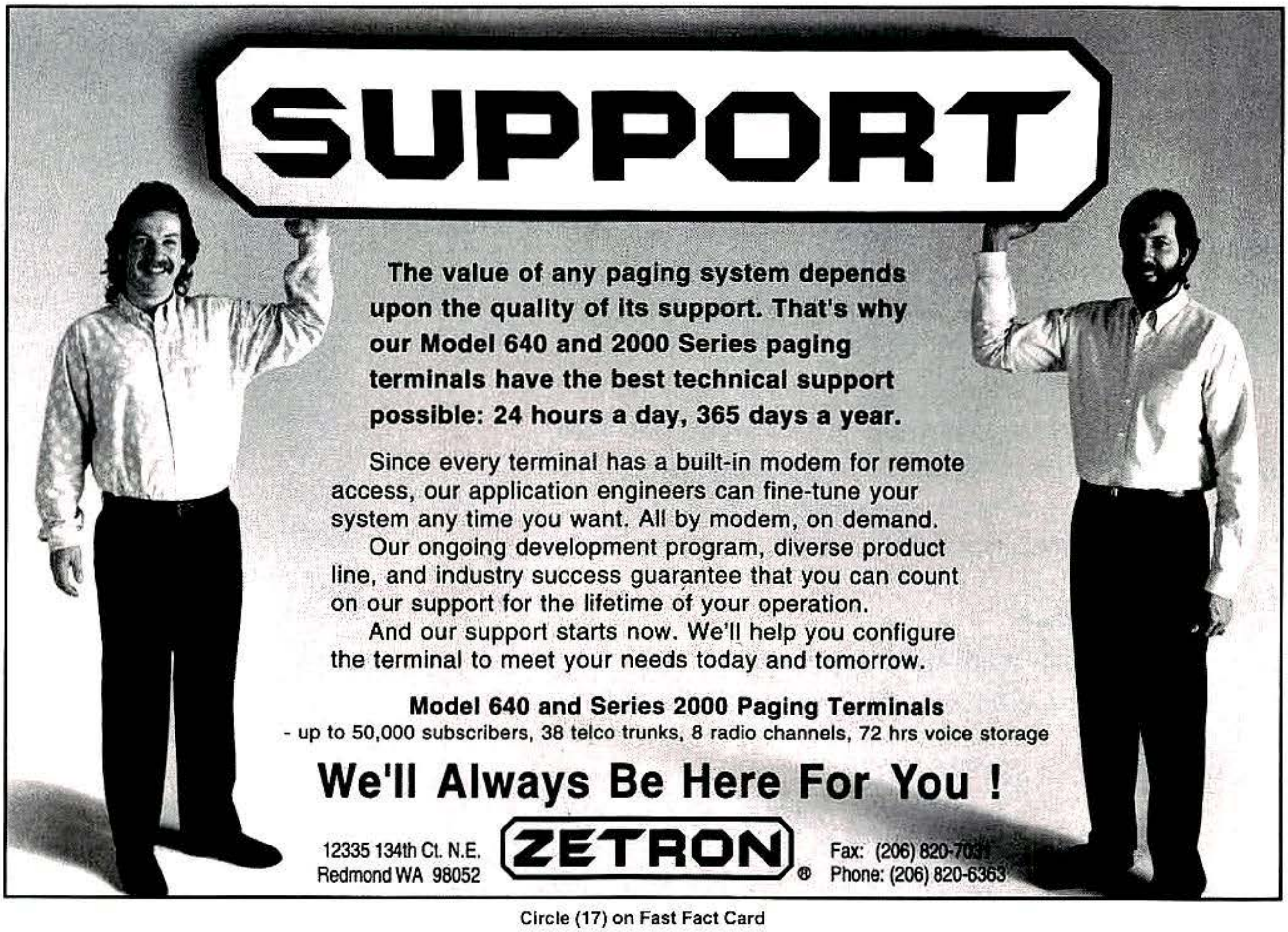
Configured in *common base*, these transistors' input and output signals remain *in phase* with each other, making neutralization virtually unnecessary. Output from Q502 (L508, C512 and C513) is tuned to the input frequency, reducing adjacent channel signals and images by about 15dB.

Lightly coupled by C514, this stage easily matches the 50Ω stripline filter (FL501).

FL501 is the "postage-stamp" near the first-conversion oscillator crystal on these boards. This dual-pole stripline filter has been pre-assembled and pre-tuned to provide image signal rejection at around 840MHz, while passing the 929MHz–932MHz antenna signal.

In the meantime, a signal is being generated at the first conversion oscillator. Q503 is a basic Colpitts oscillator operating from a nominal 73.8MHz crystal. The collector circuit of Q503 is roughly resonant at a frequency four times that of the original 73.8MHz, thus providing a frequency of 295.2MHz—along with the strong presence of 73MHz—to the base of Q504.

Between the collector of Q503 and the



Circle (17) on Fast Fact Card

base of Q504 is a network (L514, C521 and C520) that is tuned to the 4th harmonic of 73.8MHz (295.2MHz). Having cleaned up the input, Q504 is used as a frequency tripler to provide an output of 12 × 73.8 = 885.6MHz.

Q504's collector is broadly tuned to 880MHz by the combination of C524 and L515. Note the use of resistor R508, though. This resistor lessens the effective "Q" of the tuned circuit, allowing a fair amount of multiplier bandwidth.

L516 and C526 may seem redundant, but actually they provide another filter that keeps the output signal sinusoidal. (Multiplier stages get messy around the edges of their transition from F_{in} to F_{out}).

So, at one end of the bandpass filter (FL501) there is an amplified off-the-air signal, and at the other end of the filter the first conversion oscillator signal is injected. Mixer Q505 helps to sort them out.

At the base of Q505 is a parallel resonant circuit (C529 and L517) that closely matches the frequency response of the bandpass filter FL501. It also provides image rejection by selectively reducing the first conversion oscillator signal and passing the antenna signal.

Q505 mixes the incoming antenna signal at 930.6MHz with the signal frequency of the first conversion oscillator (at 885.6MHz) to provide an output of 45MHz.

The incoming FM signal should be deviated from 4kHz to 5kHz by the data stream. (Years ago, 5kHz deviation was the norm, but today the maximum deviation seems to vary.) As such, the second conversion mixer output should be able to pass at least ±5kHz from the center frequency. Bravo pagers' second conversion mixers pass signals with deviation from ±3.5kHz to ±5kHz, depending on the crystal filter's frequency.

The 45MHz intermediate signal then is mixed at the "crossed circle" located in IC U201. Onboard U201 is the "second oscillator," with C026 coupling either the 44.545MHz or 45.455MHz signal back to the second mixer.

Mixer output goes directly to a narrow-bandwidth external 455kHz filter, back into the chip for amplification, and into another filter. The second filter's output is test point M1 and the input to a second IF amplifier.

Up to this point, old-timers will have noted something *strange* about the entire receiver. *There is no limiter circuitry in it,* nothing to prevent it from responding to an AM signal, a dead carrier or a single-sideband signal. In short, it "pays attention" to anything it hears.

It is only after the second 455kHz amplifier that the "whatever it hears" is demodulated by an active quadrature demodulator, and we have an actual FM receiver. Demodulator output is sent to low-pass filter and audio buffer stages, and subsequent RC filtering networks on the decoder board.

Once filtered, the audio signal is processed further by the peak and valley detectors, limited, and then returned to the decoder board as *data.*

Further refinements in U201 include a battery-check comparator with a *1* or *0* output at TP9, and a voltage regulator with 1V output for all five transistors on the receiver board. The *main current reference* is toggled later by the *battery saver signal,* but it may be defeated by forward-biasing TP10 with a 10K resistor fed from TP4.

Elegantly simple, or simply elegant. A 930MHz receiver that fits in the palm of the hand, and is run by a 1.5V battery.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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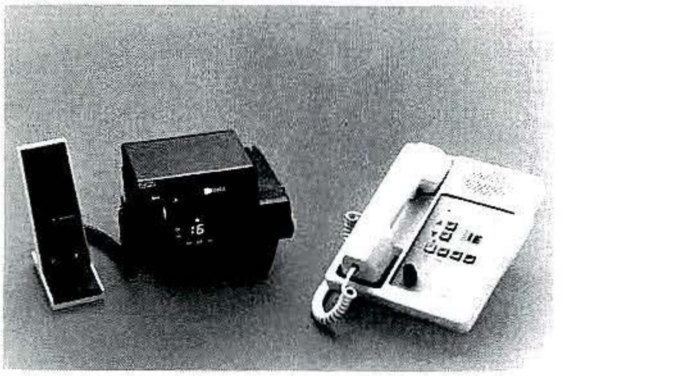

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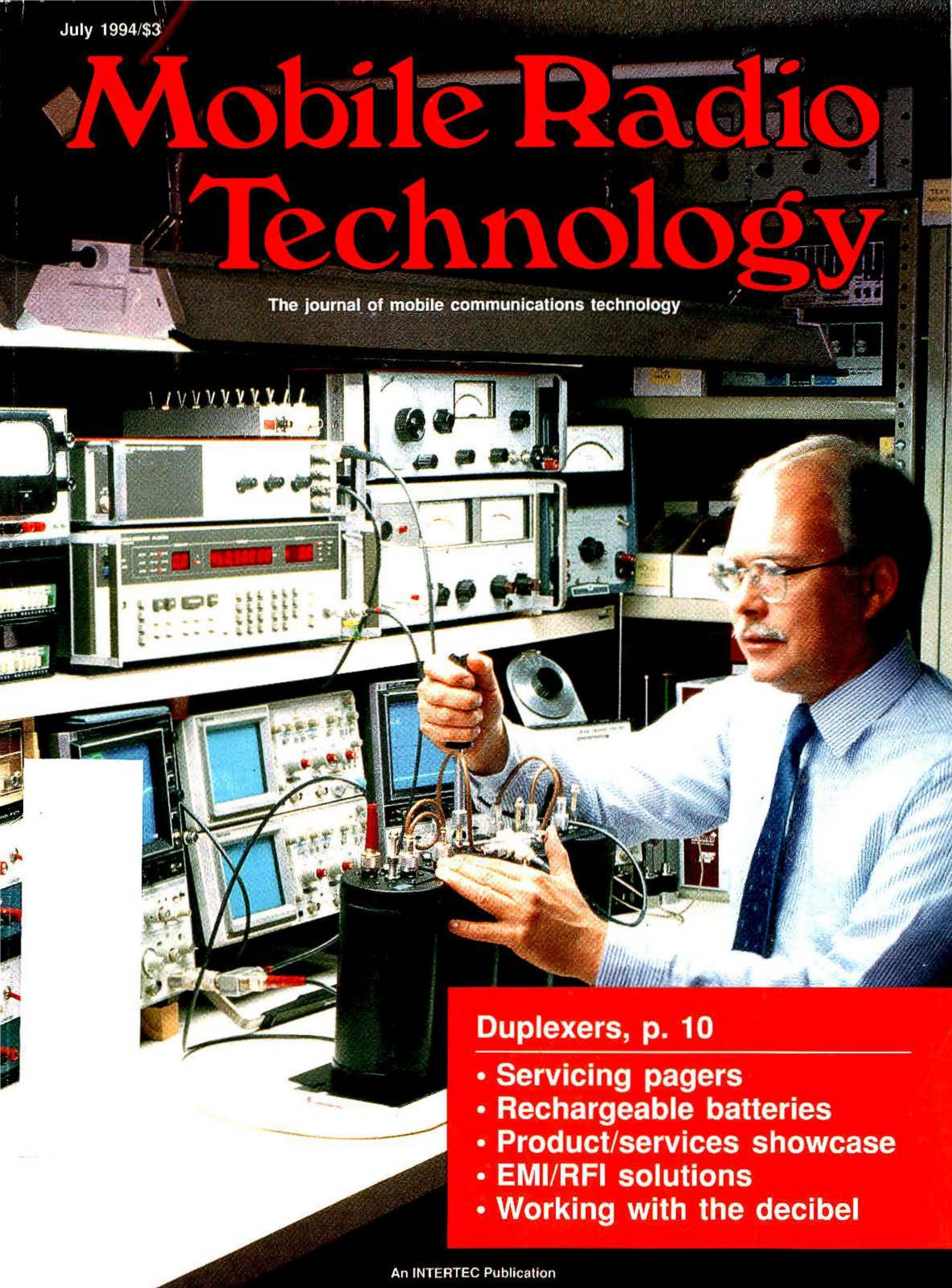

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Servicing pagers: Problems in paradise

Part 7—The hot sun is no friend of electronic equipment, and the Bravo pager is no exception. The 17.9kHz IF receiver board is the most susceptible to drift, especially in aftermarket cases. Here are some alignment tips.

By David Ludvigson

As was mentioned in last month's installment, making a five-transistor, one-chip radio receiver work reliably at 930MHz is quite a feat. When it comes to *paging* receivers, there is more to it than first meets the eye.

A side-by-side comparison of the NRF 4017A and NRF 4017E boards reveals many differences. (See photos 1 and 2 below.) The 45MHz IF "A" board has a gold-colored RF filter. The RF filter on the "E" board is slightly taller and silver-colored. The "E" board uses a 17.9MHz IF and has fewer components than the "A." There is also a glaring lack of "tech-tweakable" adjustments on the "E" boards; all that can be tuned is the antenna matching circuit (C552) and the oscillator frequency (L561).

Ludvigson is a technician in Houston.

Electronically, the two versions of this receiver are quite similar. The oscillator frequency first is quadrupled, then tripled, to provide an overall multiple of 12 times the crystal frequency. Although the 4017A and 4017B provide multiplier tuning, the 4017E does not have this feature. L564 and C570 are fixed-value components, generally resonant at around 304MHz.

Next, the 45MHz IF filter of the NRF 4017A is changed to 17.9MHz in the 4017E. This narrows the bandpass "window" for the incoming signal, making the oscillator tuning more critical.

After several months of working with the 4017E, I started noticing several customers having problems receiving their pages. In each case, they complained about a string of "Es" in their messages. (Displaying an E is the Bravo's way of reporting an error in data.) Every customer was using a pager with the NRE 4071 for a receiver. A few minutes spent aligning the oscillator was all that was required to bring back solid message reports.

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Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)
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Part 4: "From Bench To Programmer," April 1994. (Bravo.)
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Of utmost importance in any receiver design is the stability of the local

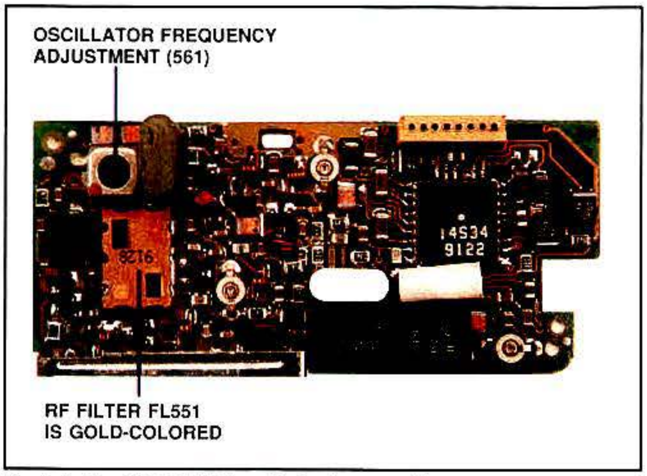

Photo 1. The NRF 4071C board closely resembles the NRF 4071A board referred to in the text. NRF 4071A, NRF 4071B and NRF 4071C boards have gold-colored RF filters (FL551) and a 45MHz IF.

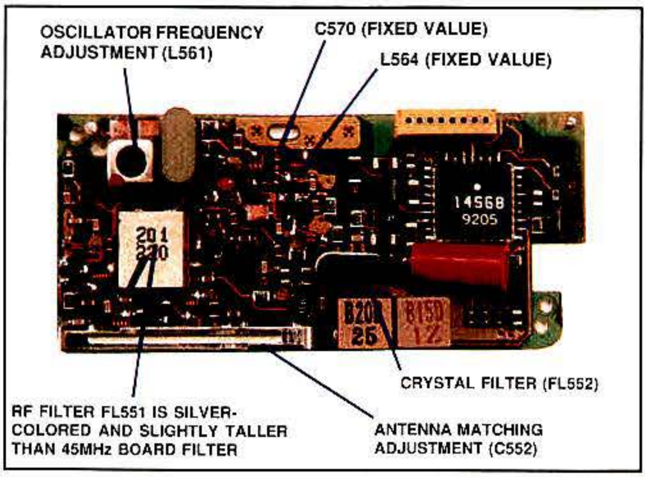

Photo 2. The NRF 4071E board has a 17.9MHz IF and a silver-colored RF filter (FL551) that is slightly taller than the filter on the A, B and C series boards.

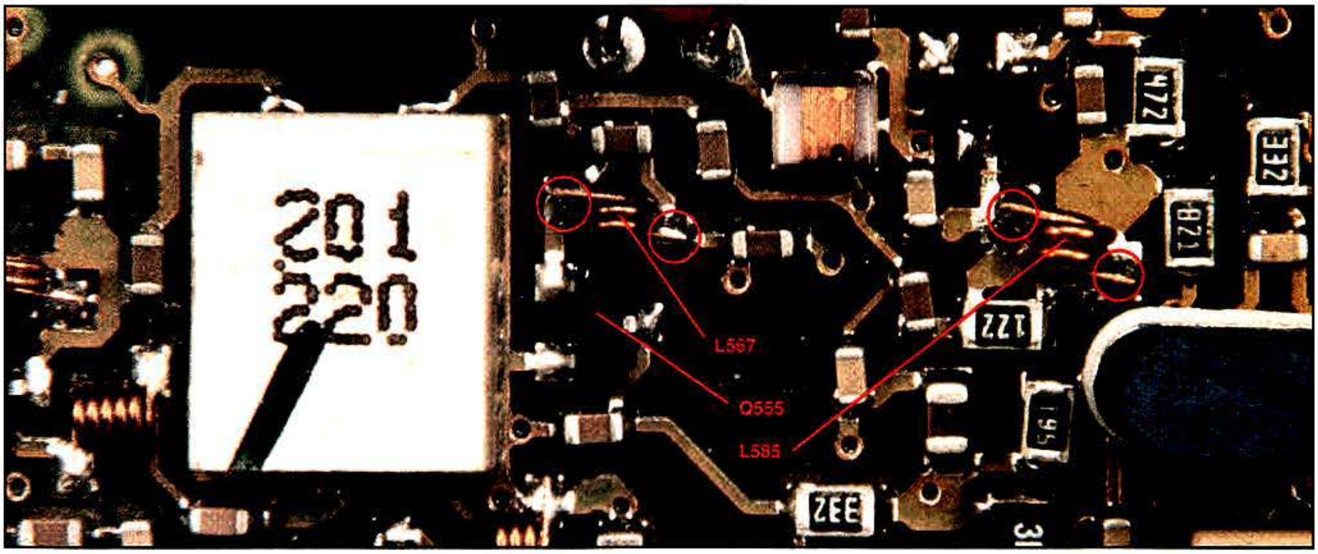

Photo 3. Poor performance of the NRF 4071E Q555 mixer stage often may be traced to poor soldering joints at either the base inductor (L567) or the collector inductor (L585).

oscillators and the bandpass characteristics of the IF. Should the oscillator drift beyond the bandpass window provided by the IF filter, the detected signal is going to be either above or below the range the decoder can handle. In short, the letter E will become common in displayed messages.

Summer came, and outdoor temperatures rose higher and higher. Beach activity followed. Again the NRF 4071E began plaguing my bench. In some cases, the first conversion oscillator was off by as much as 22kHz to 49kHz, and always on the high side. In each case, the customer had replaced the original black pager case with a semi-transparent after-market unit.

Any first-year electronics student can

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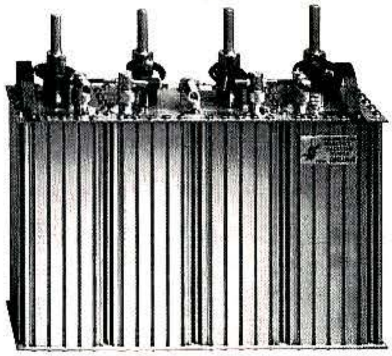

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Alignment procedure: Bravo NRF series (17.9MHz IF)

The following procedure deviates somewhat from the suggested Motorola technique and assumes the use of the shielded room (Part 1, January 1994 issue) and the IFFER (Part 2, February 1994 issue).

1. Set the signal generator to the exact frequency of receiver [(F_{oper} = (12 × 1st conv. xtal) + 17.9MHz].

2. Frequency-modulate the signal with a 134Hz tone at 3kHz deviation.

3. Meter M1 using the IFFER and an oscilloscope. (See photo A below.)

4. Adjust L561 for the maximum peak-to-peak scope display with the 134.0Hz tone. (See photo B below.) This should be the first peak as L561 is adjusted clockwise as viewed from the foil side of the circuit board.

5. Reduce the signal generator's output level, and adjust C552 for maximum sensitivity.

6. Repeat steps 4 and 5 as necessary for maximum sensitivity and 134.0Hz reception. Output from the signal generator should read −90.2dBm (<7µV) for 1,200bps POCSAG and −92.5dBm (<5.5µV) for 512bps POCSAG. Measurements are signal generator output level readings applied through a 6dB attenuator to the RTL-1005 fixture.

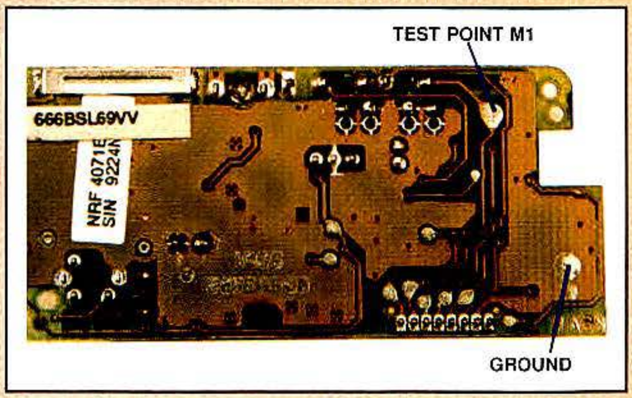

Photo A. Adjust the RTL-1005 test fixture's probes across the NRF 4071E receiver circuit board's test point M1 and ground.

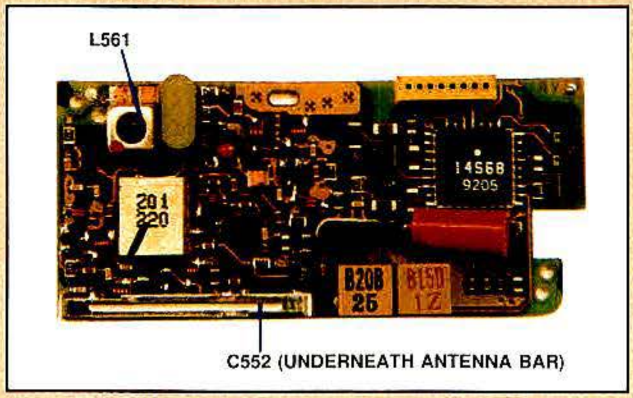

Photo B. These are the circuit adjustment locations for aligning the NRF 4071E receiver circuit board.

tell you that temperature changes cause frequency drift. At 76MHz, a ×12 frequency multiplier converts a 4kHz oscillator drift to a 48kHz drift at the output. This drift is exacerbated further by users who clip their pastel pagers to the sun visors of their cars in 100°F+ temperatures.

What effect does high temperature have on that fixed-tuned ×4 multiplier stage? L564 and C570 are getting the heat treatment as well as the oscillator. These surface-mounted components have been chosen to resonate around 304MHz—under ordinary circumstances. As the temperature increases, the components expand slightly, decreasing the actual amount of capacitance of C570, while also decreasing the inductance of L564. In short, the

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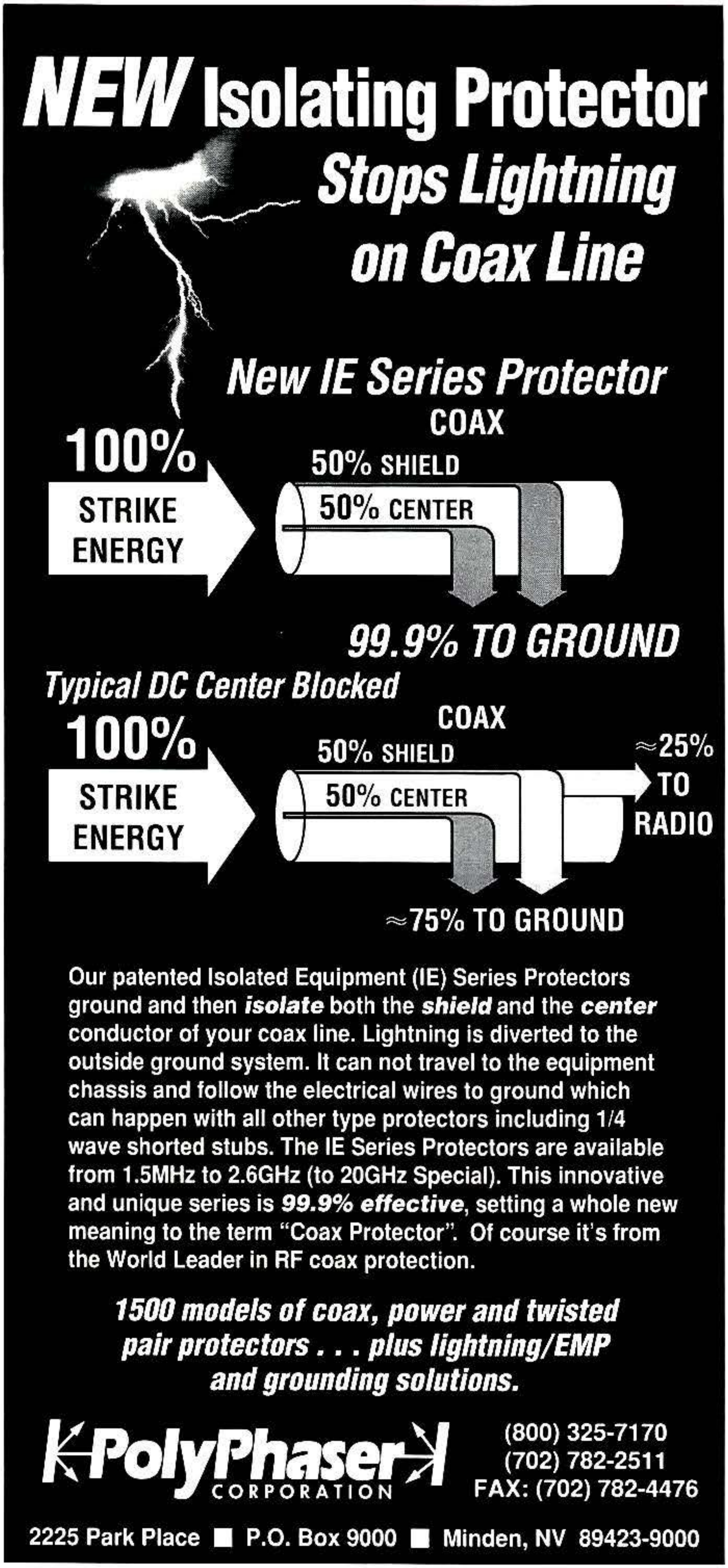

Circle (17) on Fast Fact Card

LC combination is changing its resonant frequency upward as well. This decreases the drive signal level to Q554, the ×3 frequency multiplier. Output from the overall ×12 oscillator-multiplier chain suffers, and the receiver sensitivity falls off. As the frequency drifts, the RF signal at the collector of Q555 moves closer and closer to the edges of the passband of the crystal filter (FL552) until the window is essentially shut, and the pager no longer receives pages.

Receiver boards NRF 4017A and NRF 4017B also tend to drift as temperatures rise. To its credit, Motorola selected components with decent temperature coefficients to minimize this tendency. Furthermore, the ×4 multiplier tuned circuit is capable of being optimized—literally, tuned to resonance—by the use of a variable capacitor in the 4017A and 4017B series. As another feature of these boards, the 45MHz IF is generally broad enough to tolerate a wandering oscillator.

Poor performance of the Q555 mixer stage often may be traced to poor soldering joints at either the base or collector inductors.

Other caveats on the NRF 4017E must include the problems encountered with some components. Poor performance of the Q555 mixer stage often may be traced to poor soldering joints at either the base or collector inductors. (See photo 3 on page 16.) It seems as though little time may have been spent tinning these inductors before assembly, because they are notoriously difficult to solder.

Tuning the first conversion oscillator is fast. A single turn of the L561 inductor brings the oscillator to frequency—and several kilohertz beyond—with only a fraction of a turn. There simply is too much inductance here, and adjustment of this coil is critical. The permeability of the core or the number of turns of the inductor needs to be changed. Whatever, it is too touchy for the east Texas climate.

August 1994/$3

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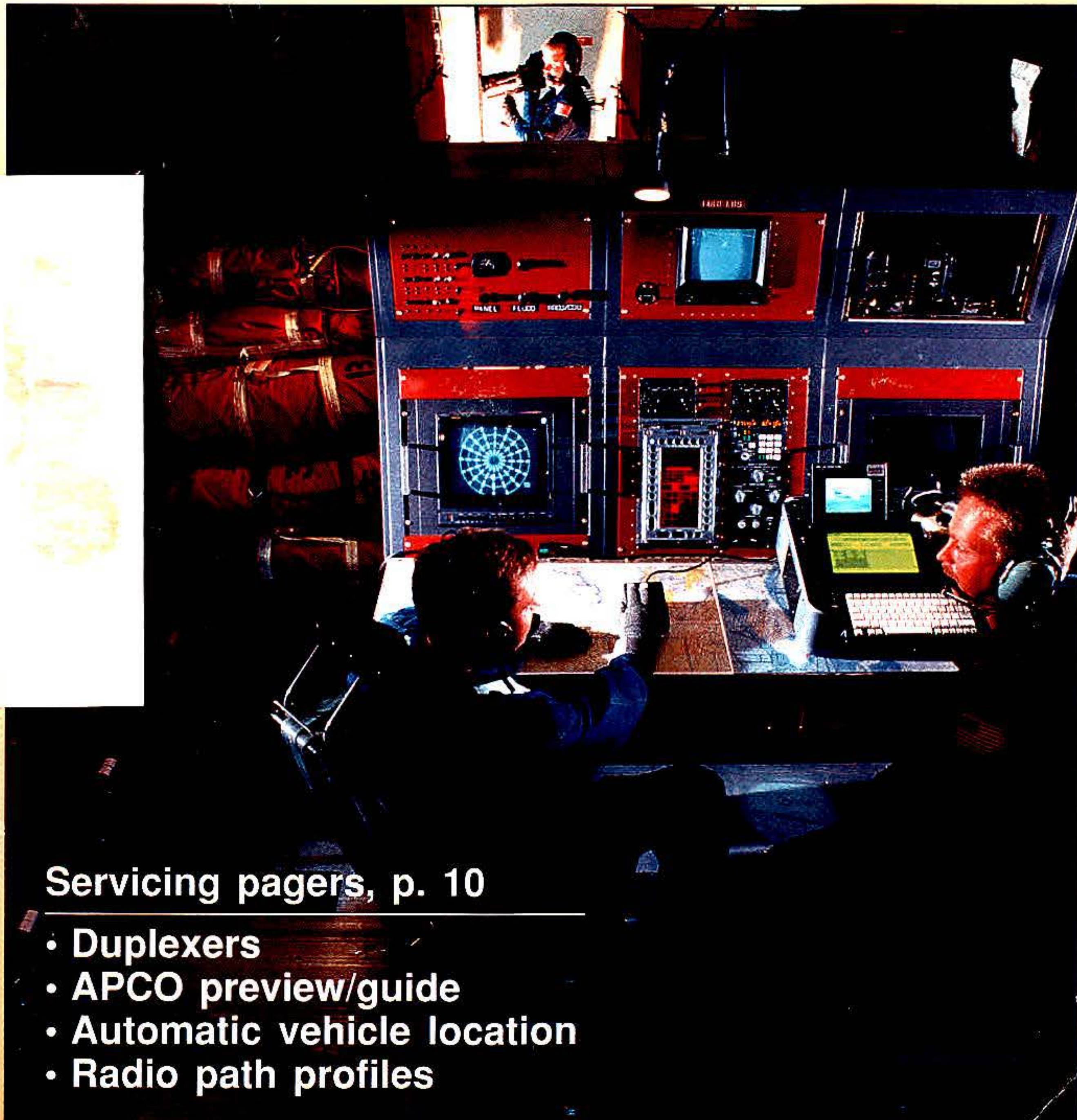

Servicing pagers, p. 10

- Duplexers
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Servicing pagers: 406MHz–512MHz receivers

Part 8—Here are some details about the inner workings of UHF Bravo receiver circuitry. Alignment information that makes use of some special equipment and techniques is included.

By David Ludvigson

As outlined in Part 5, the Bravo pager has been well-equipped to handle the 450MHz spectrum. Let's take a closer look at the NRE and AARE 406MHz–512MHz receivers.

The NRE series covers:

FREQUENCY BAND	MODEL NO.
406 – 420	NRE6421A,B
450 – 465	NRE6423A,B
465 – 480	NRE6424A,B
480 – 495	NRE6425A,B
495 – 512	NRE6426A,B

Figure 1 below is a block diagram of the NRE series receivers. (For additional detail, refer to the schematic diagram in the pager manual.)

An *outer loop antenna* is tuned by C402 and C403 to resonance at the operating

Ludvigson is a technician in Houston.

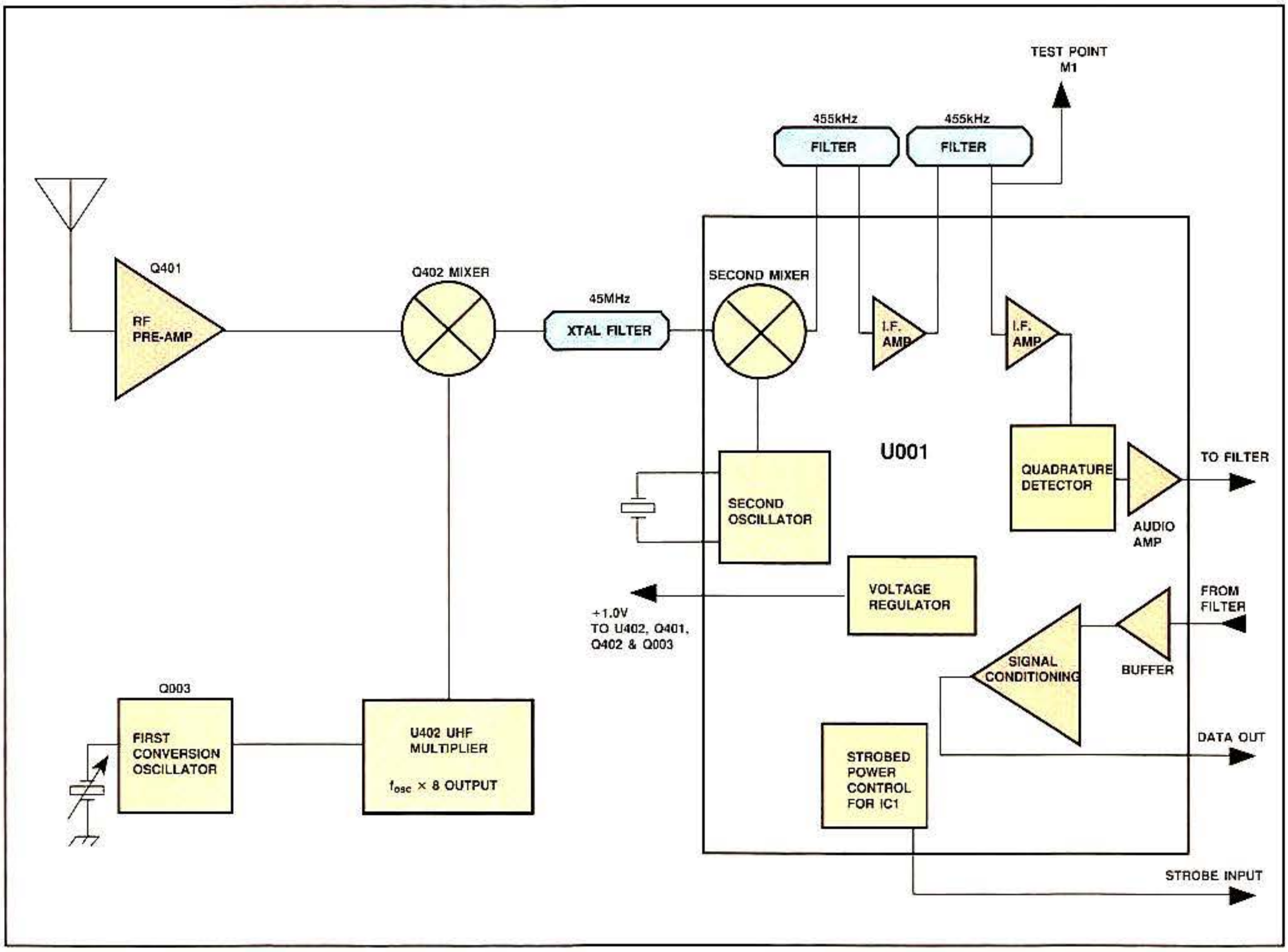
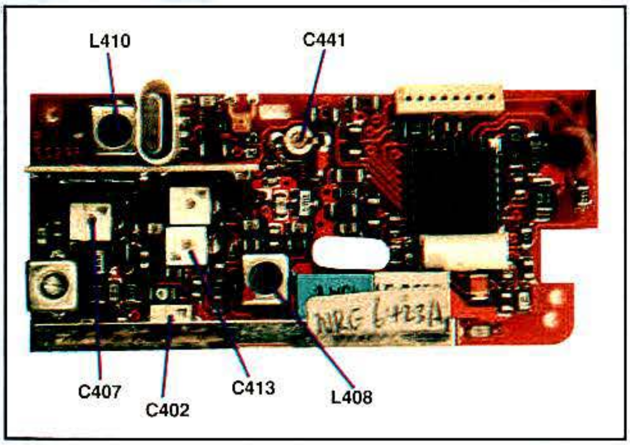


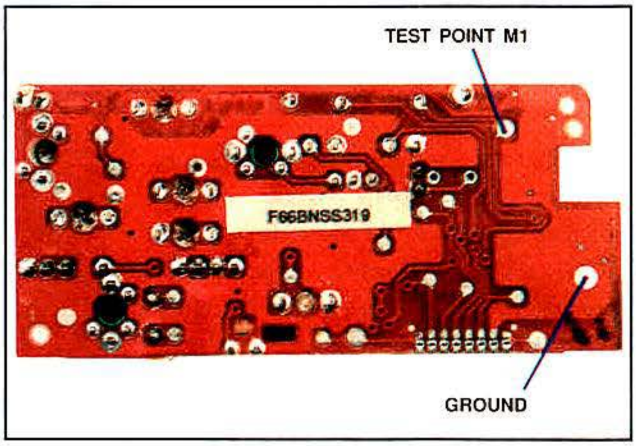
Figure 1. A block diagram of the NRE series 450MHz–512MHz receiver.

Alignment procedure: Bravo NRE series (45MHz IF)

The following procedure deviates somewhat from the suggested Motorola technique, and assumes the use of a shielded room (See Part 1) and the IFFER (See Part 2).

1. Set the signal generator to the exact frequency of receiver: $F_{oper} = (8 \times \text{1st conv. crystal}) + 45MHz$.
2. Frequency-modulate the signal with a 4.5kHz-deviated 1kHz tone.
3. Meter M1 using the IFFER and an oscilloscope.
4. Adjust L410 for close approximation of a sine wave (as viewed on scope). This should be the first peak as L410 is adjusted clockwise as viewed from the foil side of the circuit board.
5. Trim C441 to slightly distort the signal viewed in step 4. This adjustment affects the multiplier stage and causes "pulling" of the crystal oscillator.
6. Reduce the signal generator's output level. Adjust C441 (multiplier); L408 (45MHz filter response); C413 and C407 (antenna filter response); and C402 (antenna resonance)—in that order—to achieve maximum sensitivity.
7. Repeat step 6 as needed for maximum sensitivity. Output from signal generator should read −93dBm (5μV) for Golay or −90dBm (7μV) for POCSAG 1,200. Measurements are signal generator output level readings applied through a 6dB attenuator to the RTL-1005 fixture.





frequency. The *inner loop* transforms the incoming signal to a low impedance, matching the antenna to the RF pre-amplifier.

L403, R402, C404 and C405 provide negative feedback to Q401, stabilizing the common-emitter amplifier. Should the receiver be subjected to static discharges, CR001 will forward-bias with a negative voltage and clamp the discharge to ground.

Output from Q401 is coupled via C406 to C408, C407 and L405, which combine to form one portion of the bandpass filter. The rest of the filter consists of C412, C410, C413 and L406. This two-port filter provides attenuation of unwanted signals amplified by Q401.

Meanwhile, Q003 operates as a Colpitts oscillator at about 51MHz. U402 contains a parallel resonant circuit tuned to the 4th harmonic, across pins 2 and 3. The U402 module amplifies the resulting 204MHz signal, and then doubles it to produce an output at 408MHz (*Note:* Some versions use a tripler, followed by a doubler, for an overall ×6 multiplier stage.)

The resulting 408MHz signal from the first conversion oscillator is injected (along with the amplified antenna signal) at the base of Q402. The L409-and-C414 combination serves to bypass much of the 408MHz signal, while the antenna signal is virtually unaffected. Output from Q402, at 45MHz, may be adjusted by L408 to center the IF filter.

Once through the filter (FL401), the 45MHz signal mixes (at pin 12, U001) with the second oscillator signal at either

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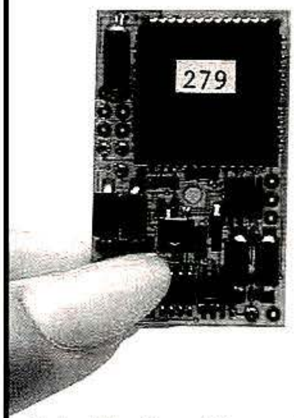

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45.455MHz or 44.545MHz to produce a 455kHz output at U01, pin 13. External filters at 455kHz are matched with on-chip amplifier stages before being detected by the active quadrature demodulator.

As mentioned in Part 6, the signal at test point MI is not FM! Until the received signal is demodulated, the input may be anything from AM to a dead carrier. There are *no limiters* in the Bravo receivers.

AARE series receivers

Figure 2 below is a block diagram of the AARE series receivers. (For additional detail, refer to the schematic diagram in the pager manual.)

These receivers are identified easily as having a triple set of tuning adjustments for the RF pre-amplifier stage, and as lacking the frequency multiplying module found in the other 406MHz–512MHz receivers (NRE series).

To begin with, a loop antenna network (E401, C451) is matched via C452 and C453 to the base of Q451. Diode CR451 performs as a static discharge device to prevent damage to Q451.

Q451 and Q452 are configured as *common emitter/common base* or *cascode*. The need for neutralization has been minimized by use of R453 across the resonant circuit L452, C455 and C456.

The helical filter (FL451) is adjusted to pass the RF signal at the antenna. AARE4001 receivers tune from 450MHz to 465MHz, and AARE4002 series receivers tune from 465MHz to 480MHz. As such, these helical filters tune the receiver accordingly.

As an example, in an AARE4001, the first conversion oscillator Q454 is in a Colpitts circuit operating at 51.12MHz. Output from Q454 is tuned to the 4th harmonic (204.48MHz) with tuned circuit L458 and C471. This signal drives multiplier Q455 (a frequency doubler) across L460 and C477 at 408.96MHz. L460 and C477 provide post-multiplier filtering at 408.96MHz.

Mixer Q453 combines the signals coming through the filter (FL451) and the signal from the oscillator-multiplier chain.

Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)
Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)
Part 3: "Frequencies, Coding Formats," March 1994. (Bravo.)
Part 4: "From Bench To Programmer," April 1994. (Bravo.)
Part 5: "The Receivers," May 1994. (Bravo.)
Part 6: "Elegant Simplicity," June 1994. (Bravo.)
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Part 8: "406MHz–512MHz Receivers," August 1994. (Bravo.)

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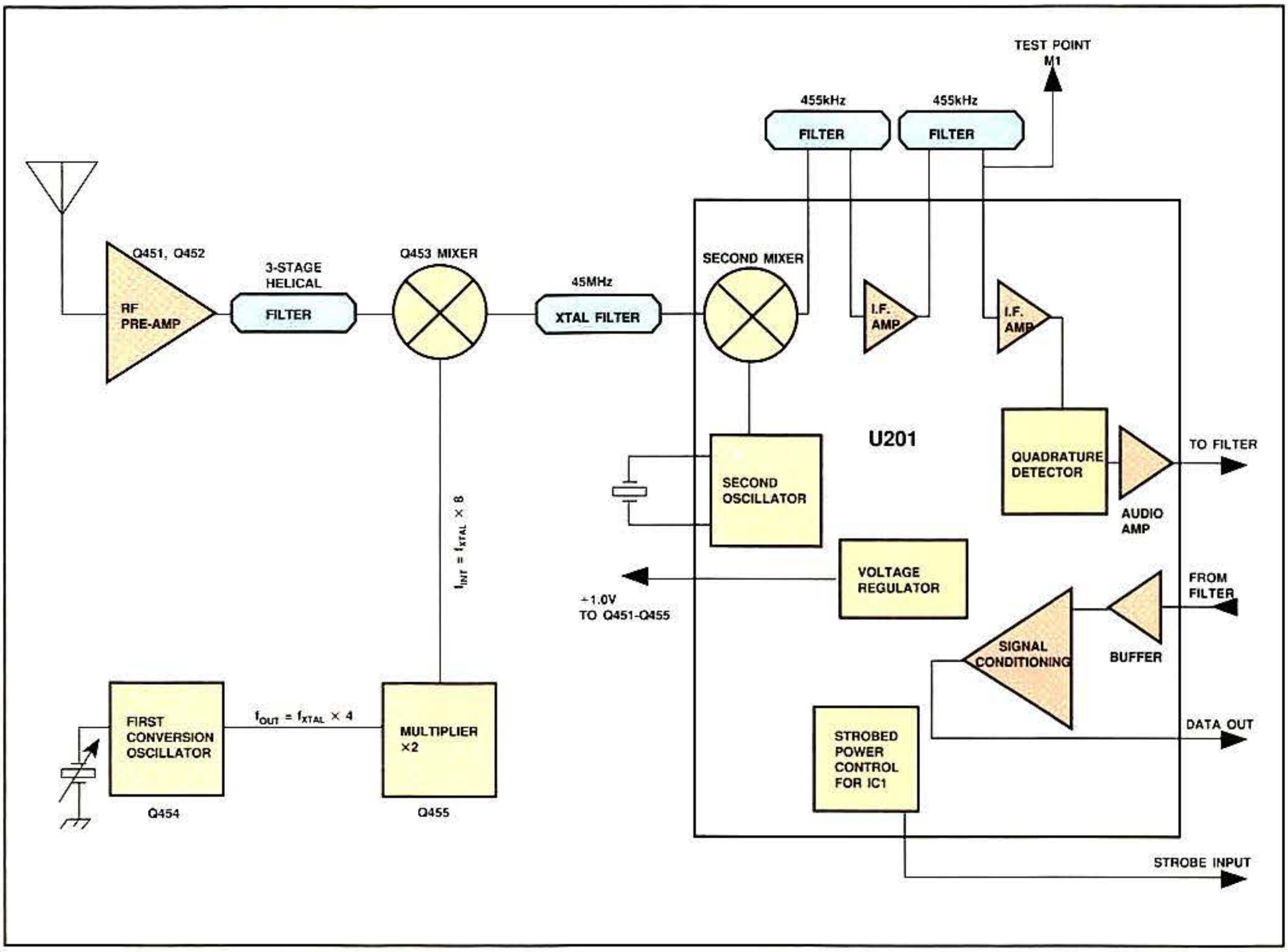


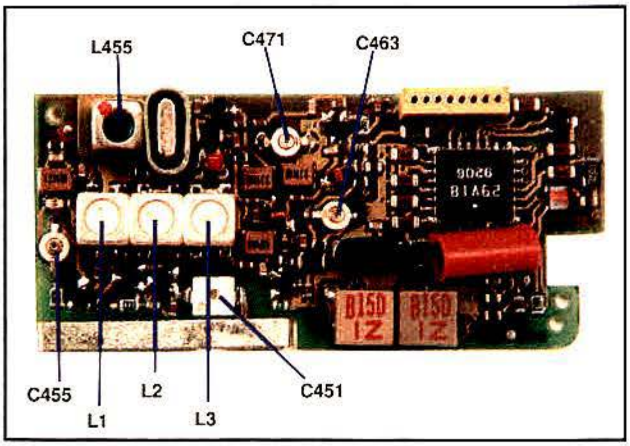
Figure 2. A block diagram of the AARE series 450MHz–480MHz receiver.

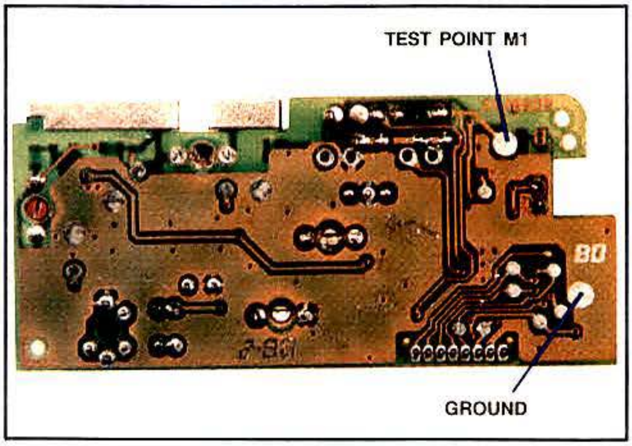
Alignment procedure: Bravo AARE series (45MHz IF)

Note: FL451 has three sections. These will be noted as L1 (antenna side), L2 (intermediate section) and L3 (mixer side) in this procedure.

The following procedure deviates somewhat from the suggested Motorola technique and assumes the use of a shielded room (See Part 1) and the IFFER (See Part 2).

1. Set the signal generator to the exact frequency of the receiver (F_{oper} = (8 × 1st conv. crystal) + 45MHz.
2. Frequency-modulate the signal with a 4.5kHz-deviated 1kHz tone.
3. Meter M1 using the IFFER and an oscilloscope.
4. Adjust L455 for a close approximation of a sine wave (as viewed on scope). This should be the first peak as L455 is adjusted clockwise as viewed from the foil side of the circuit board.
5. Trim C471 to slightly distort the signal viewed in step 4. This adjustment affects the multiplier stage and causes "pulling" of the crystal oscillator.
6. Reduce the signal generator's output level. Adjust C471 (multiplier), C463 (45MHz filter response), L3 (mixer side), L2 (intermediate), L1 (antenna side), C455 (RF preamp output) and C451 (antenna)—in that order—to achieve maximum sensitivity.
7. Repeat step 6 as needed for maximum sensitivity. Output from the signal generator should read –93dBm (5μV) for Golay or –90dBm (7μV) for POCSAG 1,200. Measurements are signal generator output level readings applied through a 6dB attenuator to the RTL-1005 fixture.





The filter composed of C459, C460 and L453 effectively reduces the oscillator-side signal while allowing the antenna signal to pass. These values may be critical to mixer operation because antenna-side signal level and local oscillator injection levels determine both sensitivity and selectivity of the receiver.

The 45MHz output from Q453 is filtered by FL452, and then sent to the U001 "second mixer," along with the signal from the internal crystal oscillator (at either 45.435MHz or 44.545MHz). The resulting 455kHz signal then is filtered, amplified, filtered and amplified before it reaches the quadrature detector. Further processing of the signal delivers audio to TP8. External filters (on the decoder board) route back to the Data Fil I/P (TP10) where the retrieved audio is converted into a data stream and subsequently decoded.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and co-workers Raymond, Tim and Pete, for their help with this project.

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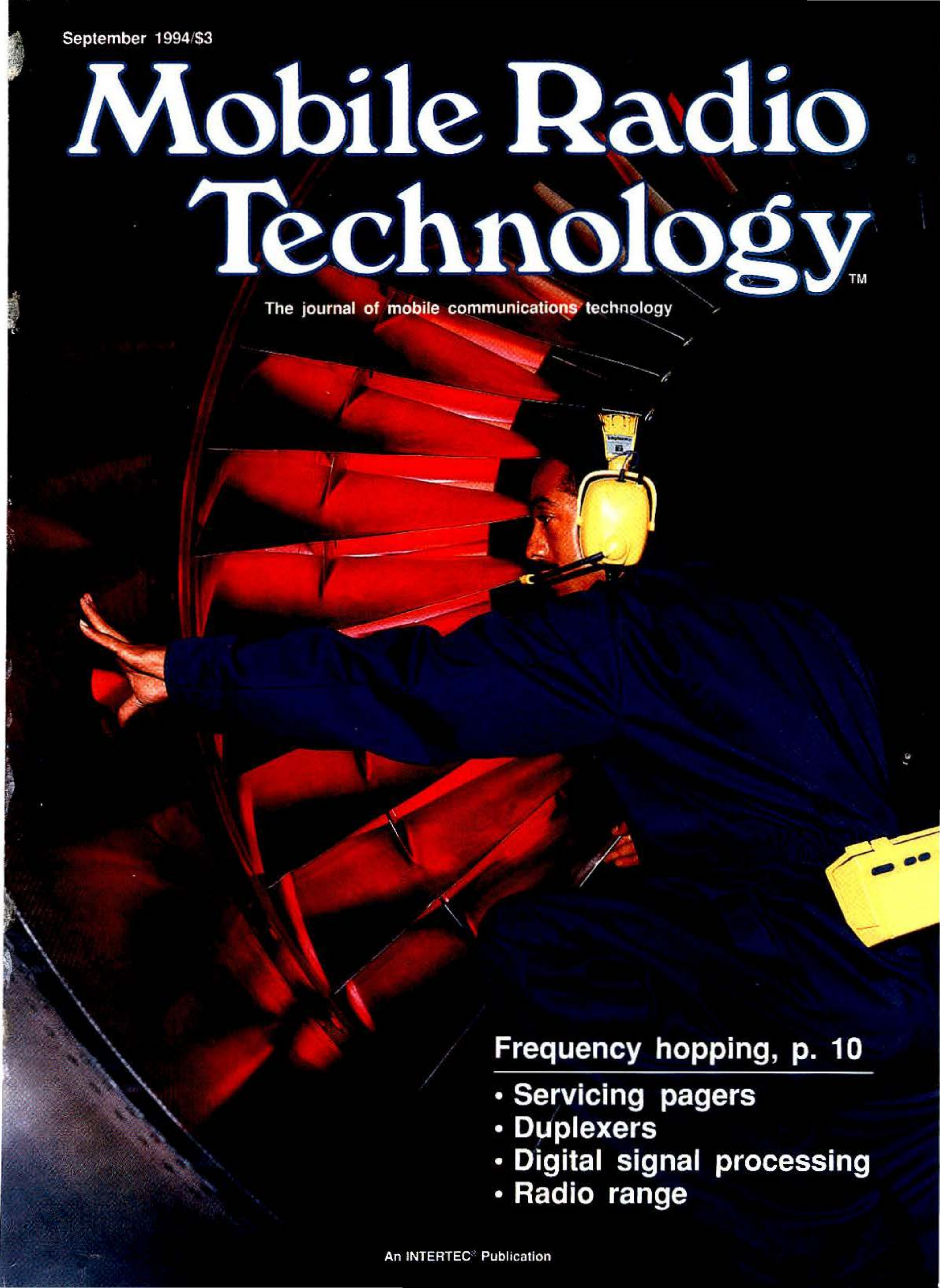

Frequency hopping, p. 10

- Servicing pagers
- Duplexers
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Servicing pagers: 150MHz receivers

Part 9—Here are some details about the inner workings of VHF Bravo receiver circuitry. Tips are included for changing pager frequencies for alignment purposes and other applications.

By David Ludvigson

To this point we have discussed Motorola Bravo receiver boards for the 929MHz–932MHz and 406MHz–512MHz frequency ranges.

The following information applies to the NRD7211–NRD7217 150MHz receivers that cover 138MHz–174MHz.

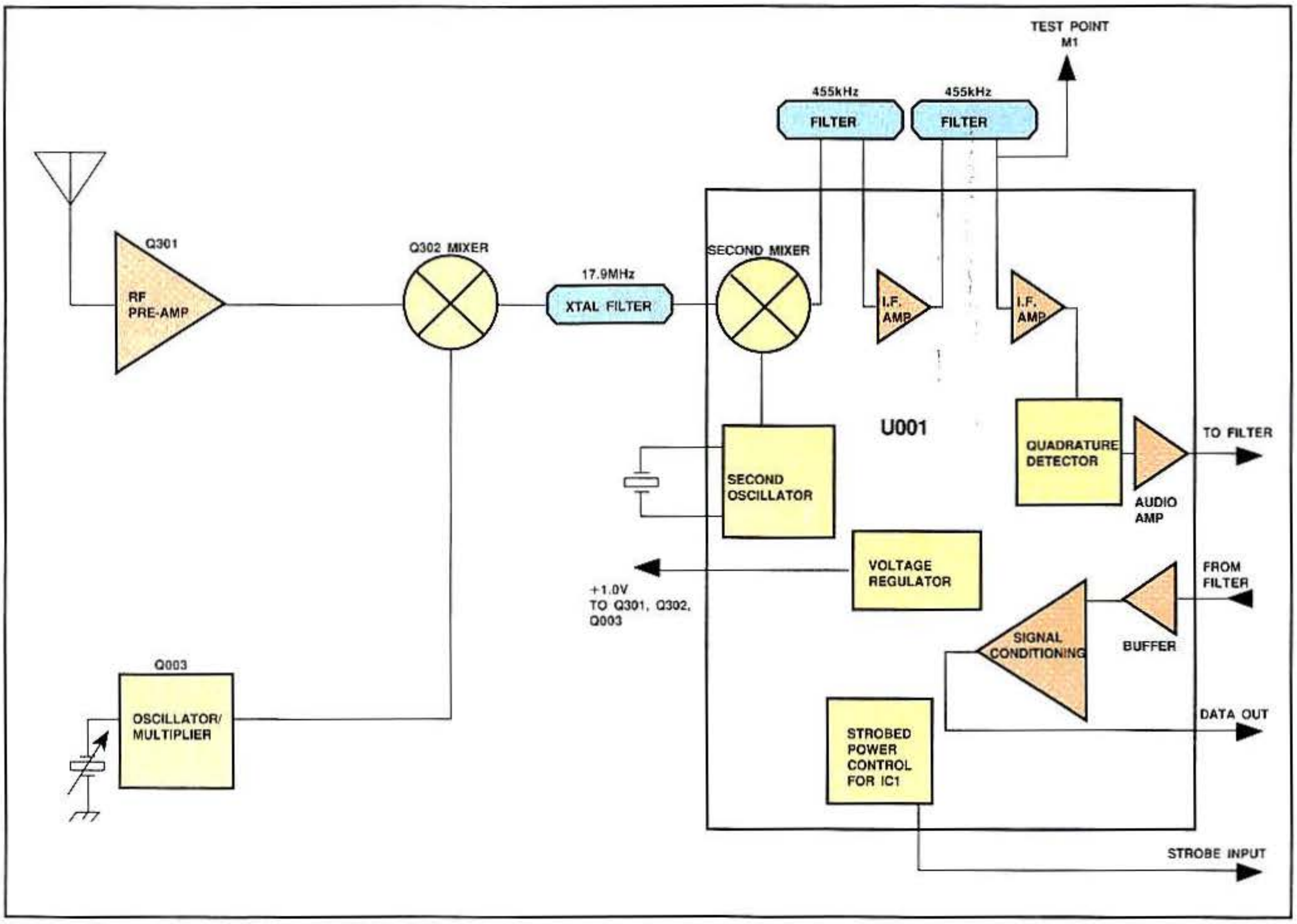
NRD receiver boards cover:

FREQUENCY RANGE (MHz)	MODEL NO.
138 – 143	NRD7211A,B
143 – 148.6	NRD7212A,B
148.6 – 152	NRD7213A,B
152 – 159	NRD7214A,B
159 – 164	NRD7215A,B
164 – 169	NRD7216A,B
169 – 174	NRD7217A,B

This particular series of boards is a mixed bag of tricks.

Figure 1 below is a block diagram of the NRD series receivers. (For additional detail, refer to the schematic diagram in the pager manual.) The first IF is 17.9MHz, and the second conversion oscillator may be either 17.445MHz or 18.355MHz. To

Ludvigson is a technician in Houston.



A block diagram of the NRD series 138MHz–174MHz receiver. See text for oscillator/multiplier details.

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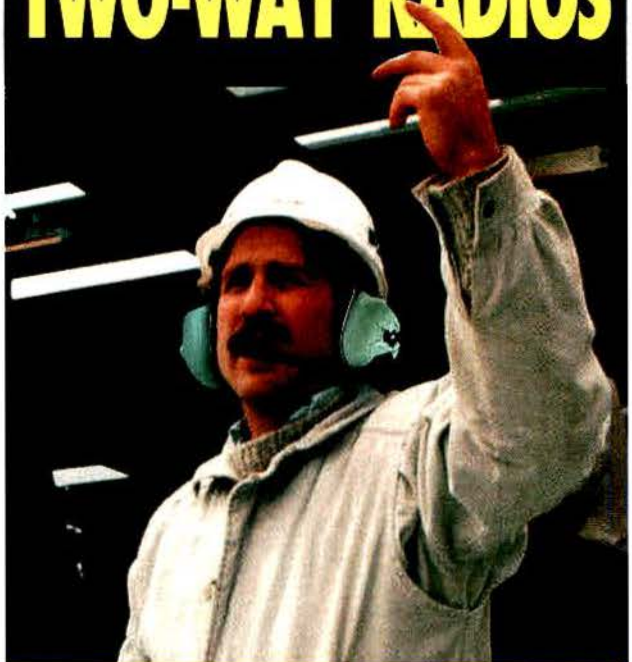

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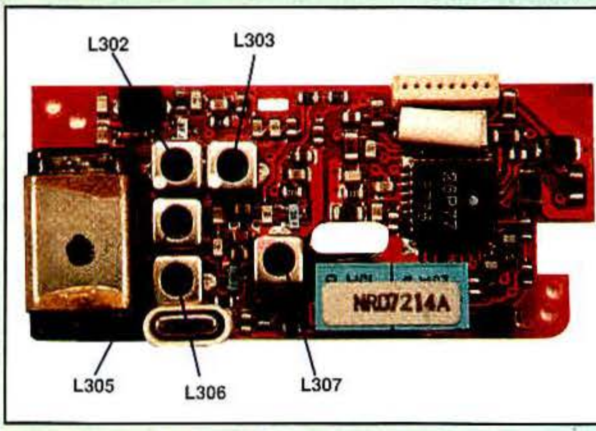
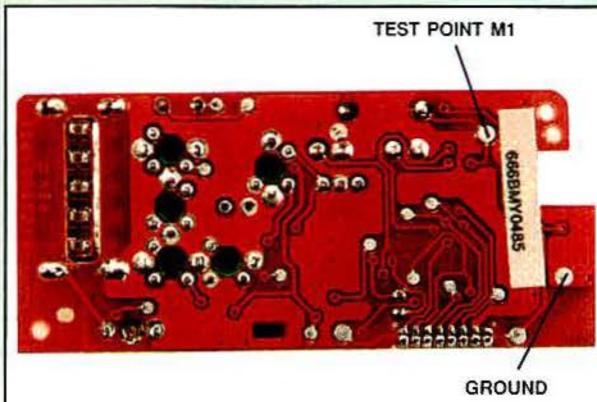
Alignment procedure: Bravo NRD series (17.9MHz IF)

The following procedure deviates somewhat from the suggested Motorola technique, and assumes the use of a shielded room (See Part 1) and the IFFER (See Part 2).

1. Set the signal generator to the exact frequency of the receiver. See text for a discussion of how to determine the receiver frequency.
2. Frequency-modulate the signal with a 4.5kHz-deviated 1kHz tone.
3. Meter M1 using the IFFER and an oscilloscope.
4. Adjust L306 for a close approximation of a sine wave (as viewed on scope). This should be the first peak as L306 is advanced clockwise into the core as viewed from the foil side of the circuit board.
5. Trim L305 to slightly distort the signal viewed in step 4. This adjustment affects the multiplier stage and causes "pulling" of the crystal oscillator.
6. Reduce the signal generator's output level. Adjust L305 (multiplier), C301F (antenna), L302 (RF preamp output), L303 (RF preamp filter) and L304 (17.9MHz filter response)—in that order—to achieve maximum sensitivity.
7. Repeat step 6 as needed for maximum sensitivity. Output from signal generator should read –88.8dBm (7μV) or less for Golay and POCSAG 512. For POCSAG 1,200, the output should read –86.5dBm (10.9μV) or better. Output level is measured at the input to the 6dB attenuator at the RTL-1005 fixture.





keep the second conversion oscillator's multiple harmonics out of the bandpass of other tuned circuits, 18.355MHz is used as the second conversion oscillator frequency for some receiver frequencies.

Conversely, to keep the second conversion oscillator's multiple harmonics out of the bandpass of the same tuned circuits, 17.445MHz is used as the second conversion oscillator frequency for other receiver frequencies. A chart is included to sort them out.

Next, the first conversion oscillator multiplier stage is either a doubler or tripler, again depending on the receiver operating frequency. The 138MHz–148.599MHz receiver boards (NRD7211A,B and NRD7212A,B) use a frequency *doubler* after the first conversion oscillator. NRD7213 through NRD7217 use a frequency *tripler* after the first conversion oscillator.

A receiver board missing the identifying sticker is no big problem. After having determined that it operates in the 138MHz-174MHz range, look at the first conversion oscillator crystal. If its frequency is between 60.8MHz and 65.32MHz, the oscillator is followed by a doubler stage. If the crystal frequency is between 43.6MHz and 52.03MHz, the oscillator is followed by a tripler stage.

The second conversion oscillator crystal (the smallest crystal on the board) is supposed to be color-coded, either yellow or green. Yellow indicates a frequency of 17.445MHz and means that data inversion is *not* required. Green indicates a frequency of 18.355MHz and means that data inversion *is* required. Selecting inversion is part of the programming function (DI = Y/N under Functions).

Now that we have waded the muddied waters, let's look at the block diagram.

The antenna assembly consists of a single band of metal surrounding a ferrite bar, a variable capacitor and several fixed capacitors forming a parallel resonant circuit at the operating frequency. C303 couples the antenna signal to the *diode clamped* RF preamplifier, Q301.

A neutralizing circuit, consisting of C304 and C305, helps to stabilize the common emitter circuit. The tuned circuit formed by L302 and C306 is tuned to the operating frequency. L303 and C309 provide impedance matching to the mixer, Q302, while providing image rejection.

C310 serves as a dc isolation capacitor and has negligible bearing on the tuned circuits.

A Colpitts crystal oscillator (Q003) feeds either a tripler or doubler (depending on the board; see above) tank circuit, L305 and C317. Fine-tuning of the crystal frequency is accomplished by L306.

Mixer output at 17.9MHz is applied to the crystal filter (FL301) and routed to the *second mixer* in U001. The internal *second oscillator* operates at either 17.445MHz or 18.355MHz (see above) and mixes with the 17.9MHz first IF to develop the 455kHz second IF. Further filtering and amplification of the 455kHz signal is then FM-demodulated by the U001's *quadrature detector*.

Passed through an external RC filter (on the decoder board), the audio is converted into a data stream by peak-and-valley detectors, limited, and sent back to the decoder board for translation.

As with all the receiver boards discussed so far, this one may be turned into a full-time receiver by connecting a 10K resistor between TP10 and TP12, defeating the strobed *battery saver signal* generated by the decoder board.

Acknowledgement

I would like to thank the management and staff of JJ Sounds & Communications, South Houston, TX, for their help with this project. Tel: 713-944-1813.

'Leftovers'

The NRF series (929MHz–932MHz) pagers includes the 4017E, which has a 17.9MHz IF and a first conversion oscillator operating around 76MHz.

Use the following equation to calculate the frequency for these pagers:

$$F_{oper} = (12 \times \text{1st conv. crystal}) + 17.9\text{MHz}$$

Although I have not tried it, modifying these units to operate on other frequencies probably would be easy. Converting the first conversion oscillator into a variable crystal oscillator would require replacing the fine-tuning inductor with an external permeability-tuned inductance. Although the range of frequencies that could be tuned in this manner might be relatively small, a bank of crystals might be switched in and out of the circuit.

M1 provides a starting point for an AM detector stage, and any old LM386 will provide adequate output to feed a small speaker (when powered by a 3V–6V supply). Tap into TP6 for demodulated FM.

Here is another idea. If your facility is set up to make changing pager frequencies easy, it might be helpful to offset the first conversion oscillator to a quiet frequency before starting the alignment procedure. If the purchase of a screen room or the construction of a do-it-yourself shielded room as described in Part 1 is out of the question, shifting the frequencies of both the receiver module and the signal generator to a relatively quiet frequency would help with the alignment procedures.

In short, the Bravo receivers might just find other applications than simply beeping!

Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)

Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)

Part 3: "Frequencies, Coding Formats," March 1994. (Bravo.)

Part 4: "From Bench To Programmer," April 1994. (Bravo.)

Part 5: "The Receivers," May 1994. (Bravo.)

Part 6: "Elegant Simplicity," June 1994. (Bravo.)

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Part 9: "150MHz Receivers," September 1994. (Bravo.)

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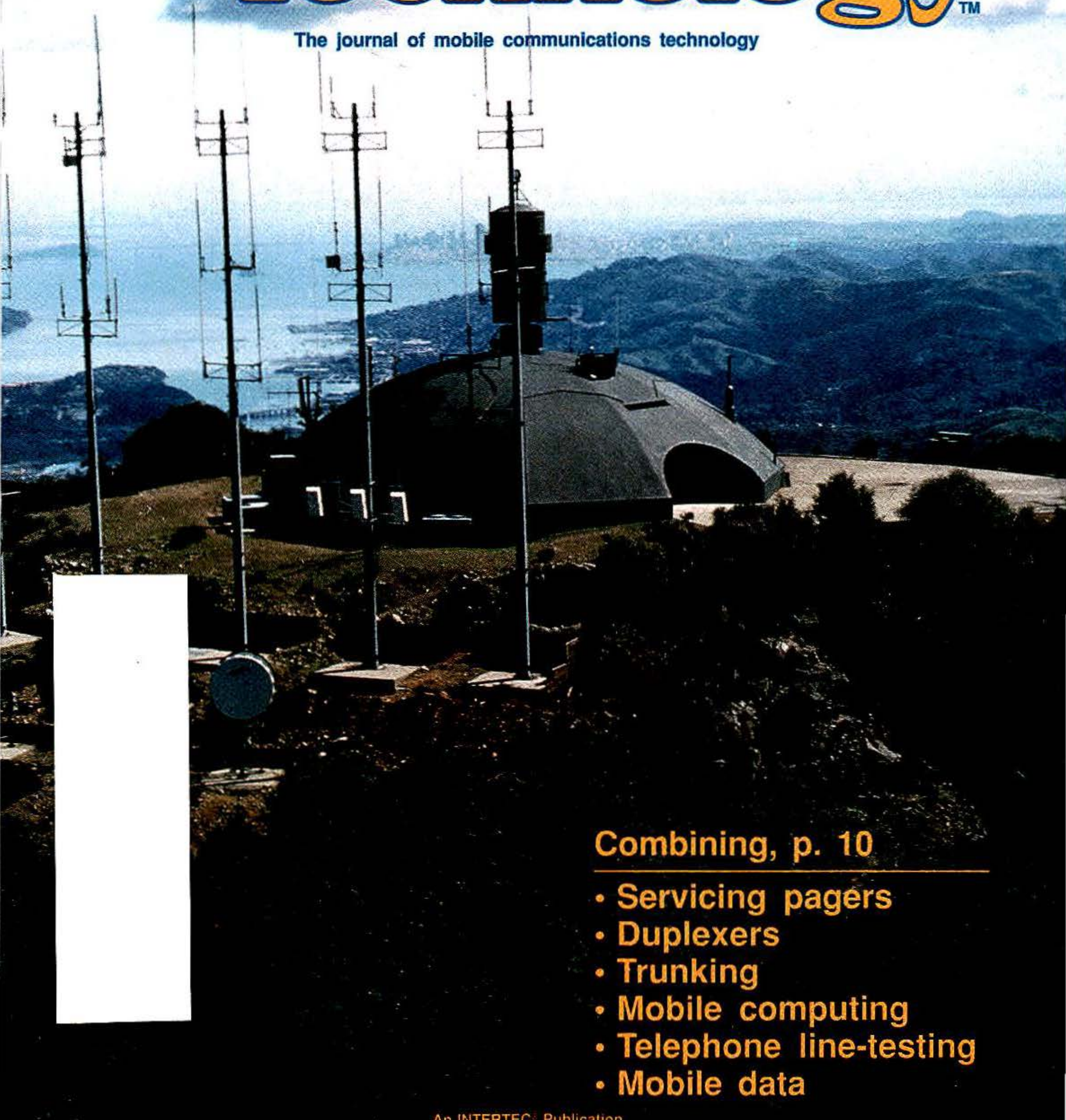

Combining, p. 10

- Servicing pagers
- Duplexers
- Trunking
- Mobile computing
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Servicing pagers: Tales crystal filters tell . . .

Part 10—Tuning Bravo pager crystal filters to the high side of the first injection oscillator frequency results in proper operation. Here's why, plus some tips for making and verifying the adjustment.

By David Ludvigson

Crystal filters long have been used to reduce a received signal's bandwidth. As a rule, filters usually are adjusted to approximate a rectangular passband characteristic at the receiver's intermediate frequency to restrict detection to only that portion of the signal containing the desired intelligence.

Perhaps the best demonstration is the tuning of an AM broadcast radio with an analog dial. With the receiver tuned to the low side of the carrier frequency, a decent audio signal is heard. As the radio is tuned upward in frequency, a point is reached at which the fidelity of the recovered audio drops off. This point is the carrier frequency. The carrier does not contain any audio information. Continuing to tune upward, once again a point of maximum fidelity is reached. This effect is especially noticeable if a narrow IF filter is used in the circuit ahead of the detector and amplifier.

Ludvigson is a technician in Houston.

An FM receiver's bandwidth (and the recovered information) may be restricted by use of an IF filter, with similar effects.

When placed in the path of a low-level signal, a properly terminated crystal filter passes only the fundamental frequency and a small portion of frequencies on either side of the fundamental. Depending on the construction and type of crystal geometry used to cut it, a crystal's bandwidth usually falls between 0.02% and 0.05% of the crystal frequency.

Several crystals of the same frequency may be configured to provide a narrower bandpass, but for the sake of discussion, we will limit the options to the 0.02% figures with respect to the Bravo receivers.

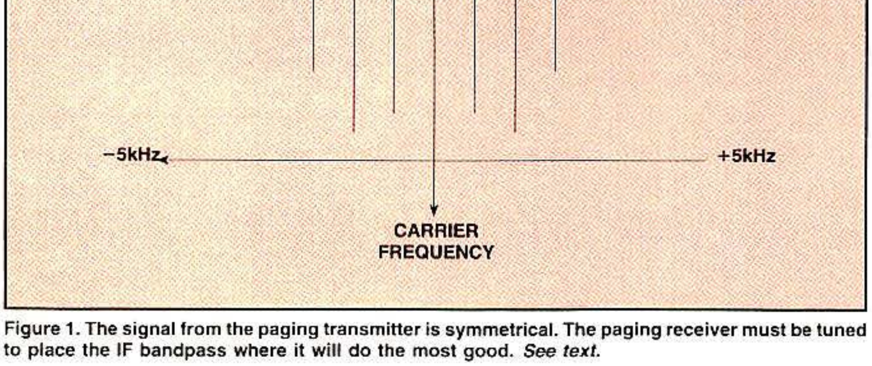

Figure 1. The signal from the paging transmitter is symmetrical. The paging receiver must be tuned to place the IF bandpass where it will do the most good. ***See text.***

The mathematics

$F_{xtal} \times 0.02\% = \text{bandwidth}$

$17.9\text{MHz} \times 0.02\% = 3{,}580\text{Hz}$

$45.0\text{MHz} \times 0.02\% = 9{,}000\text{Hz}$

These figures determine the "window" or bandwidth available through the associated 17.9MHz IF and 45.0MHz IF filters and agree quite closely with measured performance of the Bravo IF filters.

The signal radiated from paging transmitters is symmetrical. (See Figure 1 to the left.) On either side of the carrier frequency, the same intelligence is transmitted. "Normal" POCSAG is normal on both sides of the center frequency; "inverted" POCSAG remains inverted on both sides.

The crystal filter imposes a bandwidth factor that allows the quadrature detector to "see" that portion of the signal to which it has been tuned. This bandwidth factor may be adjusted by means of the first injection oscillator.

With a 9kHz window, the 45MHz IF boards are the easiest to tune, and they maintain their tuning for quite a long time. The narrower 3.58kHz window of the 17.9MHz IF filter is more critical of adjustment, and oscillator frequency drift causes reception of erroneous messages. Recalling that the maximum rate of data is 2,400bps and that the POCSAG signal preamble calls for a large portion of the overall "batch" to contain the "alternate 1 and 0" sequence, we are left with an IF window that must pass 2,400Hz to be of any value.

Next, consider the FM detector. Regardless of its design, an FM demodulator responds with an output voltage polarity determined by whether an input signal is higher or lower than the center frequency.

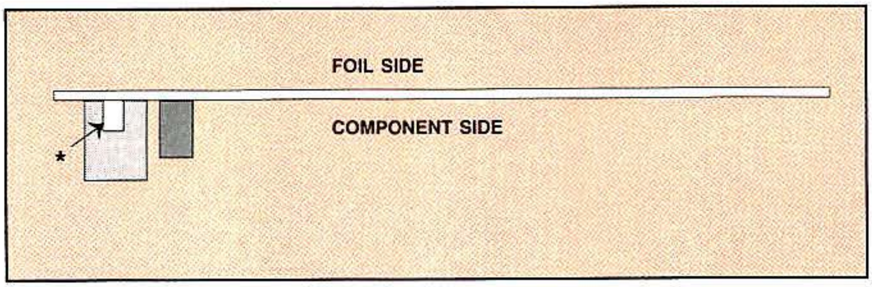

Figure 2. A side view of the Bravo receiver board. Start with the oscillator core fully up (at circuit board level) when adjusting it to frequency.

In short, careful adjustment of the first injection oscillator frequency might result in failure to decode a received message! Placing the Bravo pagers (all of them) on the high side of the first injection oscillator frequency results in proper operation. This fact means that the core of the oscillator coil should be set to the first peak as you adjust the core from the circuit board plane to the top of the coil form. (See Figure 2 above.)

Further advancing the core (downward, as viewed by the operator) causes the IF window to move lower in frequency, toward the carrier frequency, and if advanced further, toward the "unwanted side" of the FM signal.

When testing my tuning, I usually use a 134Hz tone that modulates the signal generator to 3.5kHz deviation. Using the IFFER, I can quickly determine proper tuning by noting symmetrical response above and below the oscilloscope's horizontal line. (See Part 2: "Build An 'IFFER,'" February 1994 issue.) At 134Hz, I am testing the low-frequency response of my filter, and by setting it symmetrically, I am moving the bandpass completely off the "unwanted" side. Audible output from the IFFER also reveals a more resonant response to the 134Hz signal when tuned in this fashion.

Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)

Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)

Part 3: "Frequencies, Coding Formats, March 1994. (Bravo.)

Part 4: "From Bench To Programmer," April 1994. (Bravo.)

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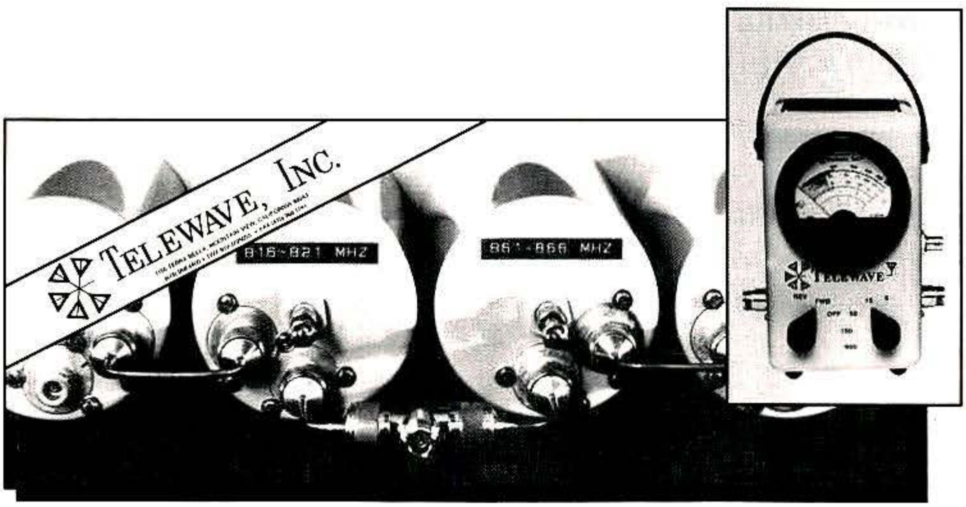

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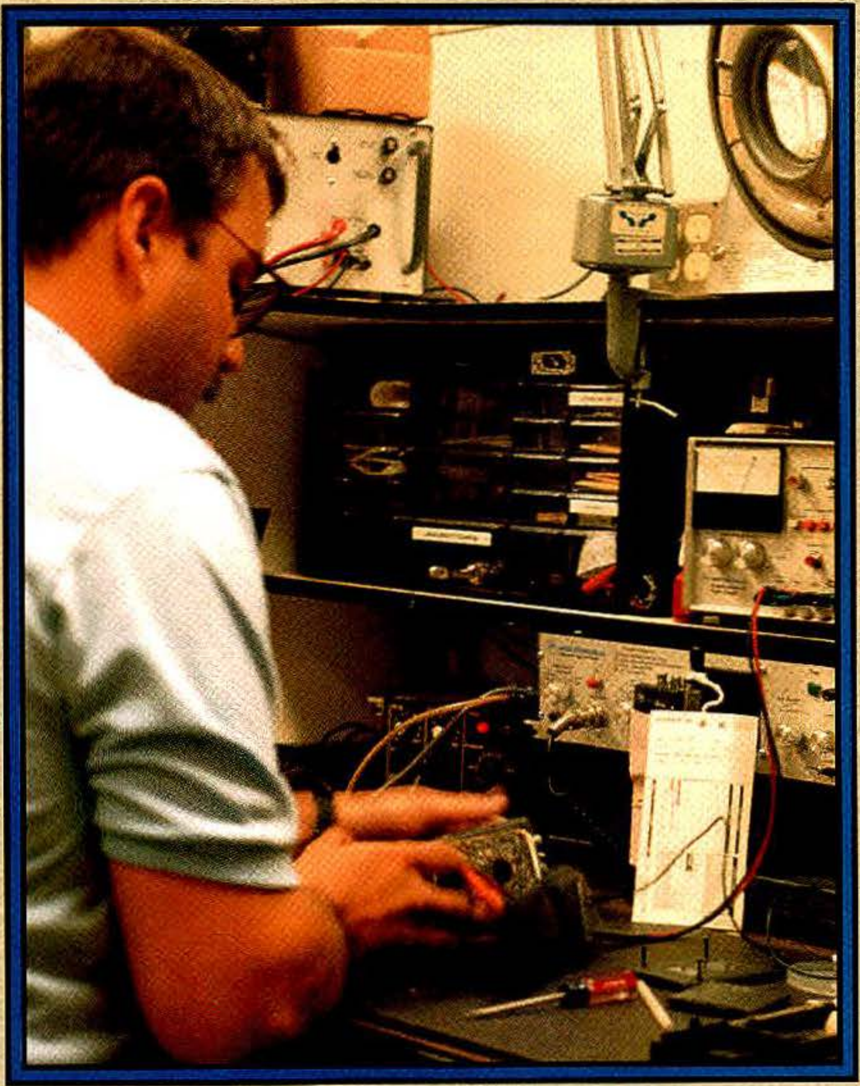

Duplexers, p. 10

- Antenna testing
- Servicing pagers
- RF power amplifiers
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- New Part 22 rules

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Servicing pagers: Microprocessor board

Part 11—Here's how the versatile Bravo pager microprocessor board performs its tasks in shifting the pager from standby to receive, verifying address reception and displaying messages from electronic memory.

By David Ludvigson

To this point, we have discussed the various receiver boards for the Motorola Bravo pager. Now we will take a closer look at just how the decoder board operates.

Motorola has made use of "dedicated" microprocessors to handle the decoding functions found in the Bravo. A list printed in Part 3 (March 1994 issue) identifies which chips handle Golay, POCSAG 512 and POCSAG 1,200. Although the formats may differ, programming each subset of chips uses the same microprocessor.

The most obvious difference to the technician is found in the values of RC filters (R101/R201, R102/R202/R302, C101/C201/C301, and C104/C204/C304) and the *clock* speed (Y101, Y201, and Y301). The RC filter values have been chosen to optimize the frequency response at *rec. audio* (pin 4, J001). The *peak* and *valley* detectors (on the receiver board) detect the level transitions of the audio signal and apply it to the *limiter*. The resulting output is a stream of rectangular pulses.

□ *NRN5155A-2 and NRN5156A-2 decoder boards:*

Numerous revisions have occurred with the decoder boards.

The NRN5155A-2 and NRN5156A-2 are capable of Golay and POCSAG 512 operation only, and use the 5105860Q01 or 510586Q04 microprocessors ('Q01 or 'Q04 in these discussions). Should you ever find a 'Q02 or a 'Q20 for a microprocessor (I never have), these processors serve as a POCSAG 512 chip when installed in these boards.

□ *NRN5155A-4, NRN5156A-4, NRN7459A, NRN7463A, and NRN7549A decoder boards:*

We will be discussing this series of decoder boards at length.

They are capable of operating Golay, POCSAG 512 and POCSAG 1,200 formats, with the previously noted modifications to the board (i.e., RC filter, clock speed and microprocessor). Our discussion will cover the three basic modes in which this board operates: the "Wake-up!" mode, the "I'm looking for it!" mode and the "Look what I found!" mode.

The 'Wake up!' mode

Placing a battery in the Bravo and switching it to "on" is just the beginning of its day. (See Figure 1 on page 24, or see Motorola manual 68P81006B85-C, page 15, for more detail.)

Switch S001 is shown in its *full up* (beep) position. B+ (from the nominal 1.5 volt battery) is applied to pin 2 of the switch, one side of L001 and the emitters of Q001-Q004. Power for the *support-interface* chip (U001) is provided through pin 21.

At the far side of L001 is a voltage multiplier that produces 3.2Vdc. This boosted dc is applied to pin 48 of U102 and pin 13 of the codeplug (U004) for operating voltage.

Pin 10 of U001 is fed a *high* voltage by means of the slide switch. This *flag* informs the chip that we expect it to *beep*. If this *high* is missing, the pager will go into the *vibrate* mode.

With the signal output devices having been determined and with the chips having been provided with the required operating voltages, the crystal oscillator (Y001 and associated circuitry) is enabled. The *reset* line (pin 2, U102) is held low until C006 charges. This momentary *low* forces the CPU (U102) and the codeplug (U004) to restart to its lowest address and begin execution of the program stored in the *6K BYTE ROM*. From ROM, the program begins.

The oscillator/timer counter advances by increments, starting the process of reading information stored in the codeplug. Line A0 (pin 11, U102) is tested. If it is *high*, peripheral interface adapter (PIA) *Port C* controls the flow of information *out* of the codeplug (U004) into PIA *Port A*. PIA Port A strobes the codeplug via A0 (pin 11, U102), reading the stored data via the I/O (pin 10, U102) into A1. These data contain the capcode and the options programmed into the codeplug. This information is stored in internal RAM.

If, for any reason, the program fails to execute properly, the *deadman timer* performs a *reset*. This failure is detected when a *low* is sensed on pin 11 of U102 and

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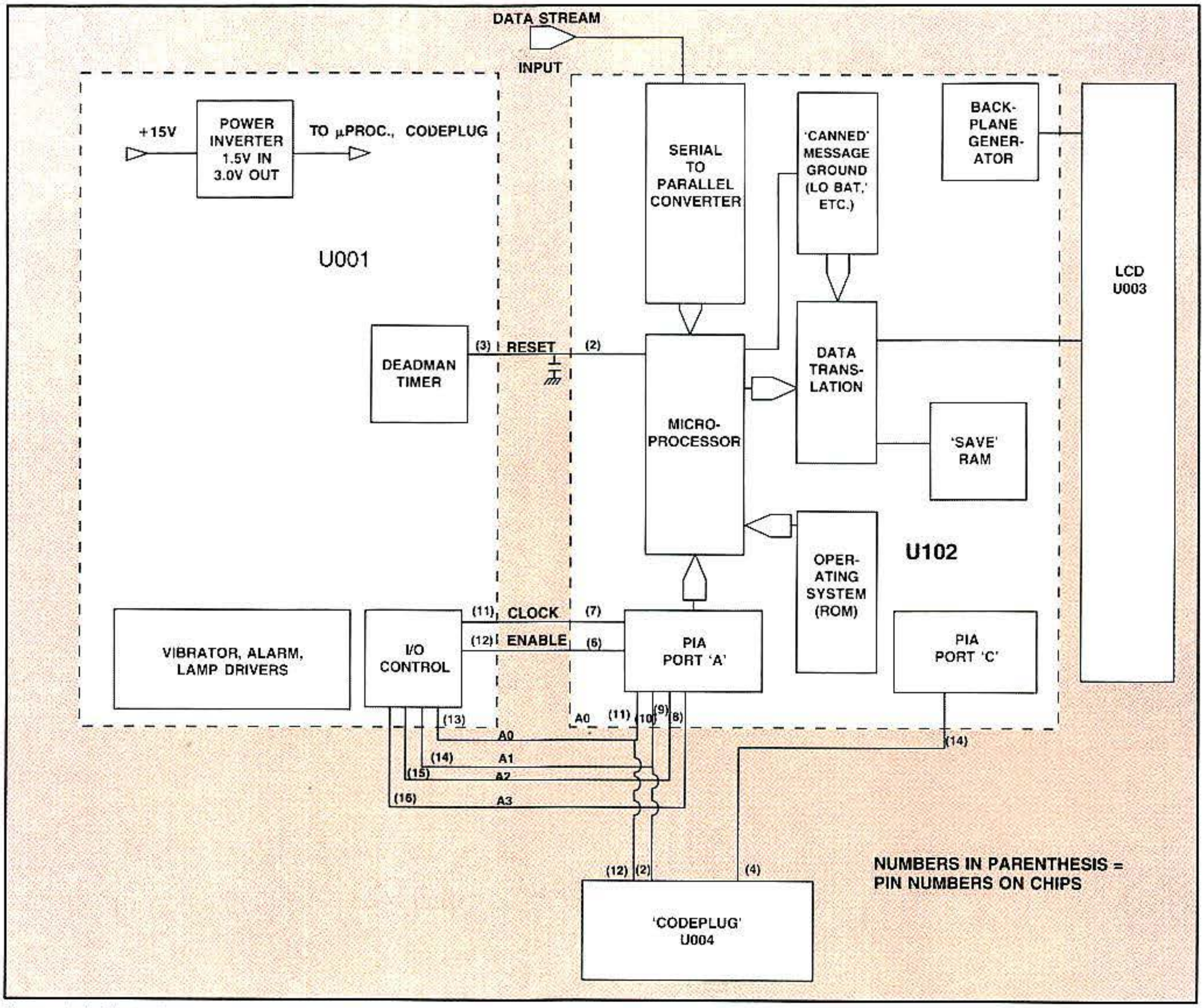

Figure 1. A block diagram of the Bravo decoder boards.

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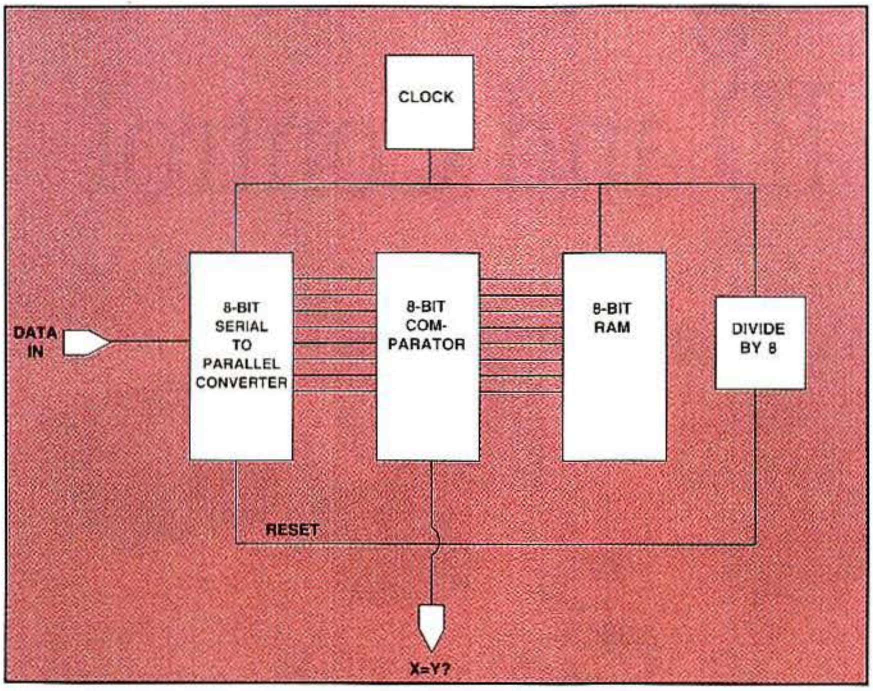

Figure 2. A block diagram of one method of comparing serial data. The Bravo uses a similar method of comparing 18 bits while looking for the capcode. It takes 32 bits to identify the proper pager, to determine the source and to perform parity checks at a rate of 512bps or 1,200bps for POCSAG. Assuming everything matches (X = Y), the alarm sounds and the following 32 bits are decoded as a message to be seen on the liquid crystal display.

generates a *warm reset* of the operation outlined to this point.

A warm reset is performed without any external signaling and will be unnoticed by the user unless the pager fails to either beep or buzz when turned on.

Once data from the codeplug have been transferred to RAM, the Bravo begins to beep, flash, enable the display generator (BP1–BP4) and provide a broken horizontal bar to the display.

'I'm looking for it!': format, results

Motorola has prominently displayed copyright notices throughout its literature to deter the unauthorized use of its techniques by competitors. We can, nevertheless, make an educated guess as to the coding structure, and here we concentrate on the POCSAG format.

The POCSAG format (regardless of speed) consists of a *preamble* and one or two *batches* of codewords. A 32-bit *frame sync code* precedes the *frame/codeword*. Each *batch* transmits signals to a maximum of eight pagers (16 for double-batch). Each *frame* contains a pager number and a message, with a total of eight *frames* (one for double-batch) being sent in a single *batch*. If the *batch* is occupied in only

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frames 1, 3 and 5, an *idle codeword* occupies *frames* 2, 4, 6, 7 and 8 (plus *frames* 9-16 for double-batch).

First, the *preamble* is 576 bits of alternating "101010...". The decoder in the Bravo uses this preamble to determine whether it is "hearing" POCSAG signals, and it determines synchronization with the transmitted signal. Note that if the *preamble* is transmitted at 1,200 baud, a 512-baud Bravo on the same frequency would "hear" a continuous string of either *1s* or *0s*.

Similarly, a 512-baud signal would produce an alternating "11001100" in a 1,200-baud Bravo on the same frequency. Such invalid code response is what allows several formats to share a single frequency.

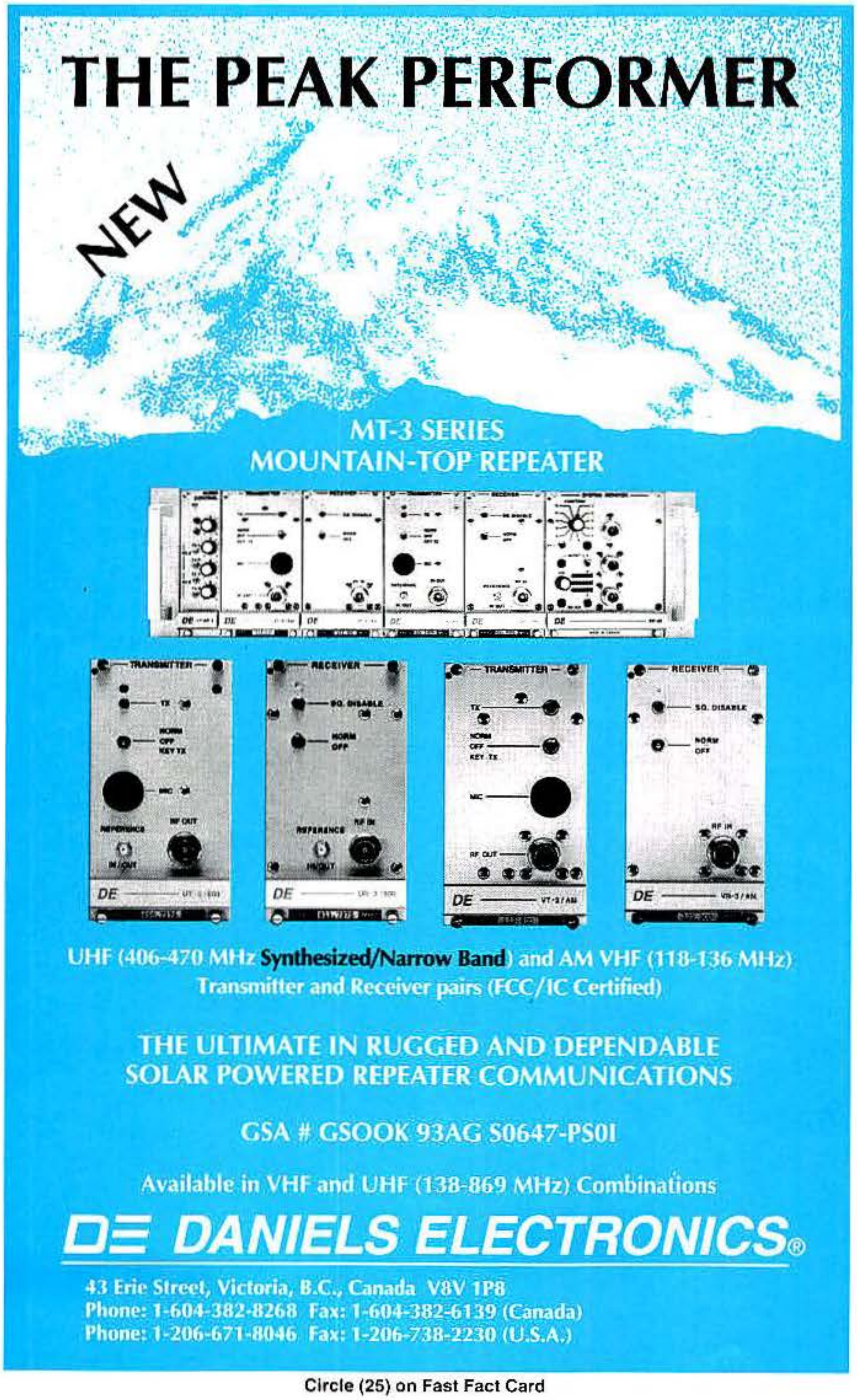
Next, the *batch*. Within each batch are eight (or 16) *frames*. Each *frame* is 64 bits long. The first 32 bits are the capcode programmed into the Bravo. The following 32 bits contain the calling party's phone number or message.

Frame synchronization is a unique 32-bit code (01111100110100100000101011101111000) that signals the beginning of each *batch*. The Bravo receiver board is activated each time this *frame sync* code is transmitted.

Within the Bravo codeplug, three bits have been programmed (by the capcode) to identify which *frame* in each *batch* is its own. (A double-batch pager would have four bits to identify which of 16 *frames* is its own). As the *batch* is sent, the Bravo turns on the receiver board only at the time its *frame* is being sent.

Up to this point, the information stored in RAM has been sitting there. Now, a comparison is made between the capcode information and the incoming data stream. (See Figure 2 on page 26.) If a match is found, the Bravo either beeps or vibrates. Further incoming data are then stored in RAM for display. This is the calling party's phone number or other information. Failing to match the capcode results in going back to looking for the *preamble*.

All this takes some split-second timing and a lot of coordination.



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Meanwhile, back at the programmer...

From the preceding information, we can learn much about the programming of Bravo pagers.

When turned on, the Bravo Programmer asks, *GSC or POCSAG?* Your response to this question sets a bit in the Bravo that determines the *preamble* format. With POCSAG, the *preamble* consists of 576 alternating *1s* and *0s*. Golay has 14 alternating *1s* and *0s* sent at a rate of 600bps.

Next, the Bravo Programmer requests JRB/C or BAB. The JRB/C is used for two-board Bravos, one receiver and one decoder board. The BAB is used for single-board Bravo receivers not discussed in this series. JRB/C will place the POCSAG or Golay format in *normal*. BAB will place the format in *inverted*. *These formats require the proper signal injection frequency in the receiver boards. "Normal" POCSAG or Golay usually is transmitted by paging systems. Most often, it is the receiver that is "inverted."*

Selection of an *inverted* format also sets a bit to signal the need to *logically AND* the incoming data stream with a *1*. This step produces a reversed image of the incoming signal (e.g., 10010 transmitted becomes 01101 received).

The capcode comes next. Hidden within the POCSAG capcode is the *frame* number it is assigned. Let's see where a capcode of 1034067 would be *framed*.

Divide 1034067 by 8. The quotient

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equals 129258.375. Multiply the decimal portion of the answer by 8. The product of $0.375 \times 8 = 3$. Recall that this is actually the *4th frame* because the *frames* start at *true* 0 and count to either 7 or 15. *We* just don't start counting at zero!

The heart-beat: synchronization

Acquiring and synchronizing with an incoming data stream takes some sophistication, but it is nicely done in the Bravo pagers by generating impulses at a regular rate of speed.

At 512bps, there are 576 bits (preamble) + 32 bits (frame sync) + ($8 \times 64 = 512$ bits) (eight frames), for a total of 1,120 bits per message. Because these 1,120 bits take 2.187472 seconds for transmission, divide 2.187472 by 1,120 to determine the duration of each bit; $2.187472 \div 1{,}120 = 0.0019531$ seconds or 1.9531 milliseconds.

> *Acquiring and synchronizing with an incoming data stream takes some sophistication, but it is nicely done in the Bravo pagers by generating impulses at a regular rate of speed.*

By reciprocation, we find that the clock is operating at $1/0.0019531 = 512$Hz. This value is easily achieved by dividing the 1.048576MHz timebase crystal frequency by 2,048 (a 10-bit shift).

Similarly, dividing the 2.457600MHz crystal frequency (used at 1,200bps) by 2,048 results in a clock frequency of 1,200Hz. By reciprocation, $1/1{,}200 = 833.3$ microseconds, the duration of each bit in 0.933296 seconds (the message time at 1,200bps).

Somewhere in this chip is a stage with the single function of counting these impulses and signaling when the count reaches 32. For want of a better term, call 32 impulses a *click*.

Everything in the POCSAG signal format is divisible by a number of clicks. There are 18 clicks in the *preamble* ($576/32 = 18$); there is one click in the *frame sync* and two clicks per *frame*.

For the duration of each click, a comparison is made. Does the information in the data stream during one click match the *preamble* (101010...)? If so, the receiver is turned on to receive the *frame sync*. If the click window matches the first half of a *frame* (the capcode), then the alert is signaled while the receiver stays on to get the next click of information (the calling party's number). These go into RAM.

Failing to match the capcode in its assigned *frame*, the Bravo starts looking for the 576-bit *preamble* and the 32-bit *frame sync code*.

Lacking a *preamble*, the Bravo drops into *POCSAG battery-saver mode*. The receiver is turned on for 217 milliseconds out of every 1.047 seconds (for POCSAG 512) and 93 milliseconds out of every 1.047 seconds (for POCSAG 1,200).

'Look what I found!': memory display

Once the Bravo "sounds off," it is free to display the converted data on the liquid crystal display (LCD).

Recalling the data stream "snapshot" from RAM (by depressing the gray *read* button at pin 9 of U001) involves two operations. The first depression of the *read* button silences the tone (if it is on). The second depression causes the microprocessor to transfer RAM contents into a decoder, and then to the display.

U102 contains 12 8-bit registers. These may hold as many as three 32-bit *words* — incoming phone numbers — and are enabled by use of the *protect* switch at pin 45 of U102. As long as power is available from pin 4 U001, these numbers remain in *memory*.

Electronically, the display section consists of the LCD driver, the LCD and a light switch. Another portion of the microprocessor is used to drive the multiplexed display and to provide backplane ac signals.

There is still more: Several *canned* messages are available when needed, as is a 3.2kHz audio generator to feed the *beep* speaker.

In all, there is a lot of technology to be found in the Bravo pager.

Acknowledgement

I would like to thank the management and staff of JJ Sounds & Communications, South Houston, TX, for their help with this project. Tel: 713-944-1813.

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Cellular data road tests, p. 10

- Servicing pagers
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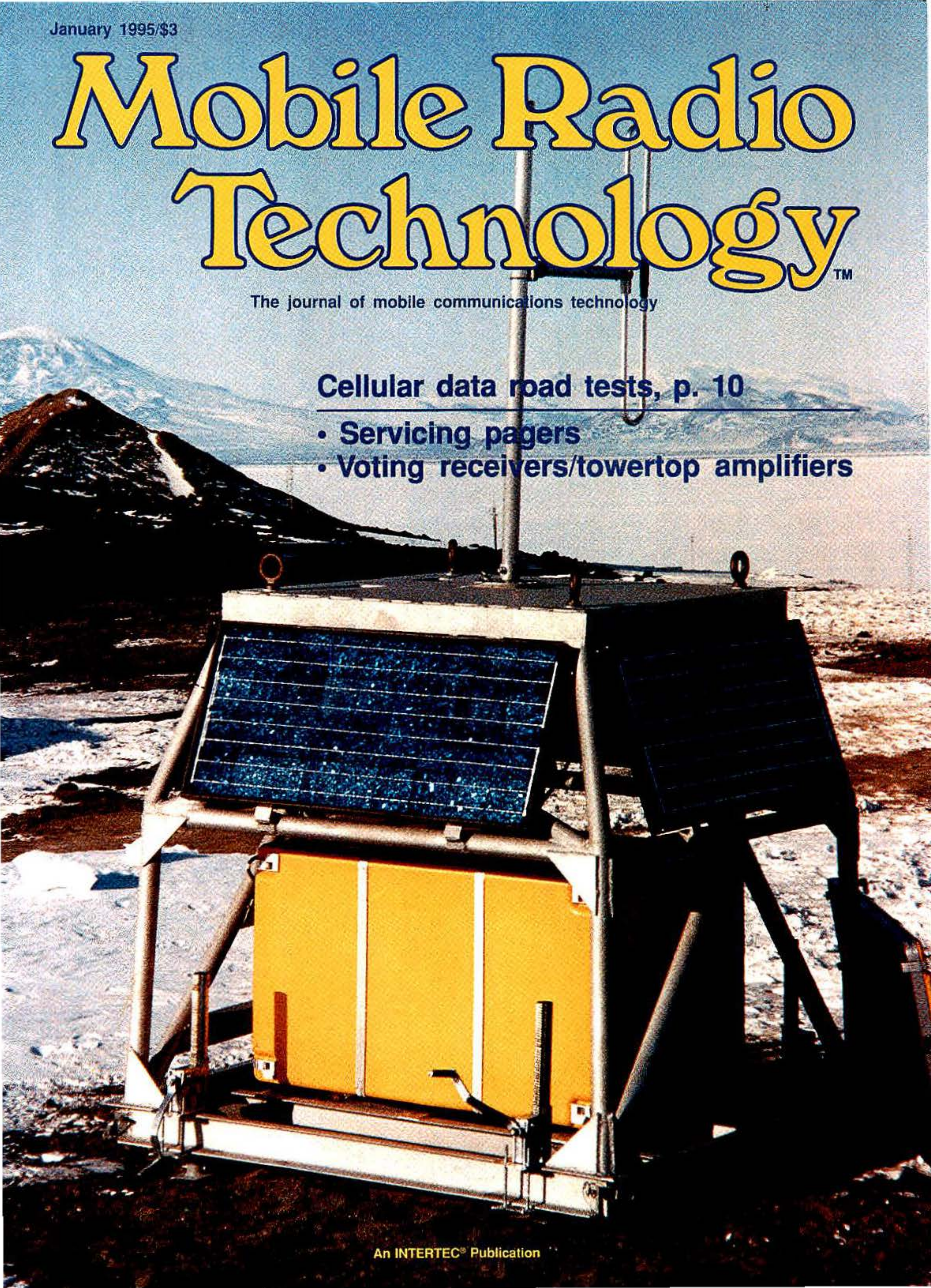

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Servicing pagers: Headaches (and some aspirin)

Part 12—Here are some tips for solving little quirks and problems that come up from time to time with Motorola Bravo pagers. A computer program you can use to track your customers is included.

By David Ludvigson

You have just finished replacing a crystal and aligning a Motorola Bravo pager. The frequency and format problems have been solved. You go to the programmer and confidently enter the new capcode and answer the appropriate prompts with "yes." Then you page it.

"123A456B789C" shows in the display. Whaaat?

This problem is one of several poorly documented problems that occur with different versions and programming methods of and for the Bravo pagers.

Certain "hidden" programming options can remove those interfering letters, as well as the annoying chirp that sounds when the Bravo is "reminding" you to read an unread message.

When trying to program a series of pagers simultaneously, the letters "PRC" may appear on the programmer display. To fix that error, from the selection page just preceding the *READY TO PROGRAM?* prompt, depress *0* and *9* on the programmer simultaneously. This step places you in another page of programming options. (See the operator's section of the manual for a full description of what the initials mean.) It is important that the *BSVR* (battery-saver) option be enabled, so enter *Y* in response to that prompt.

The page of options that follows contains the single entry *PRC*. Entering *N* (no) here removes those interfering letters from the display. The next page again prompts for *READY TO PROGRAM?*

Customers often complain of the momentary *chirp* that precedes vibration when the pager is in its vibration-alert mode. Use the Bravo Programmer to read the pager's programming. Under OPTIONS, the SMC prompt is followed by Y, which means that the *silent mode chirp* (SMC) has been enabled. Change the *Y* to *N*, and the problem is solved.

Recall what has been written about *normal* and *inverted* code formats. It is a good idea to test the pager with your code-box just to make sure the code format is correct. If you have to switch signal polarity to cause the pager to respond, then reverse your DI selection.

Sometimes, the output signal at M1 will look dead, even when you are belting it with 10V of RF signal. Recheck the first conversion crystal frequency. It is possible that you are using a 45MHz offset crystal in a 17.9MHz receiver board (or vice-versa). The oscillator cannot work so far from its intended frequency.

Several crystal manufacturers support the Bravo. I was doing fairly well in finding crystals, and then my supply improved when I found Crystronics' "rocks." Figure 1 on page 32 lists the company's codes for VHF through 900MHz crystals. Call the company at 305-566-6949 for further information.

Ludvigson is a technician in Houston.

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Tracking customers

When a merchant begins to deal in pagers, he may discover rapidly that he needs a means of keeping track of his customer base. Generally, as long as he does not exceed 200 customers, he can handle customer records with a Rolodex file. With more than 200 customers, though, it is time to look for a decent bookkeeping program.

After looking around for several months, I finally decided there was no software available that was designed for pager information filing. Several programs merely laid information down on the disk, and the user had to define whether his input was in the "Pager Number" or "Capcode" field. Then you could twiddle your thumbs while the disk found a match. The occasional "double number" problem (where two customers have the same capcode and pager number) was frustrating with some software because it would find the first match and just stay there! It was not possible to get beyond the first collision of matching data to find out what was on the other side.

Then, there was the issue of how ornate the software had to be. Were alternating color bars really necessary, or just a screen with information? How much of a hard disk drive would be occupied with actual data, and how much would be used to crunch color and location information as it printed the data to a particular spot on the screen?

I decided to write my own software in a (Beginner's All-purpose Symbolic Instruction Code) programming language called BASICA to see which would do the best. The results were surprising.

Heavy-duty databases use a separate data file where the information lies in wait to be displayed on the screen. Whenever you search for some data, this file is interrogated until a match is found, starting at your first file and marching through each file, one at a time. As your database increases, this search can become a huge task. One version of this sort of program uses nearly 3 million bytes of storage for the nearly 2,000 customers at JJ Sounds and Communications, South Houston, TX.

My own method is more conservative. No flashing colors, no neon, just basic business. The same 2,000 customer files *and* the program occupy *only 650K* of disk space.

The grinding of the hard drive is broken into 12 nearly identical programs that have been "chained" together, each calling the next in sequence. Information is presented in an easy-to-edit fashion, and a 12-year-old could easily update the program.

When entering data, eight fields are used in each file: *AZ$* is the pager phone number; *N* is the line number in which the data have been entered for this pager; *CC$* is the capcode for the pager; *NM$* is the customer name; *AD$* is the rate and month rental charge; *CT$* tracks special features such as voice mail or statewide coverage; *ST$* is the month-to-month payment due date; and *NT$* is used to keep track of various notes, such as our own registration number, price paid and when the last payment was received.

Often, we receive payment by check, with no more information than a name and address. Perhaps the most powerful portion of this program is found in the MID$ (midstring) function, which allows names (first, last and whole name) to be found by the program.

Pagerfiles

The Pagerfile program uses a universal entry format to allow the user merely to type in whatever information he has—without specifying the field—and the program finds the match(es).

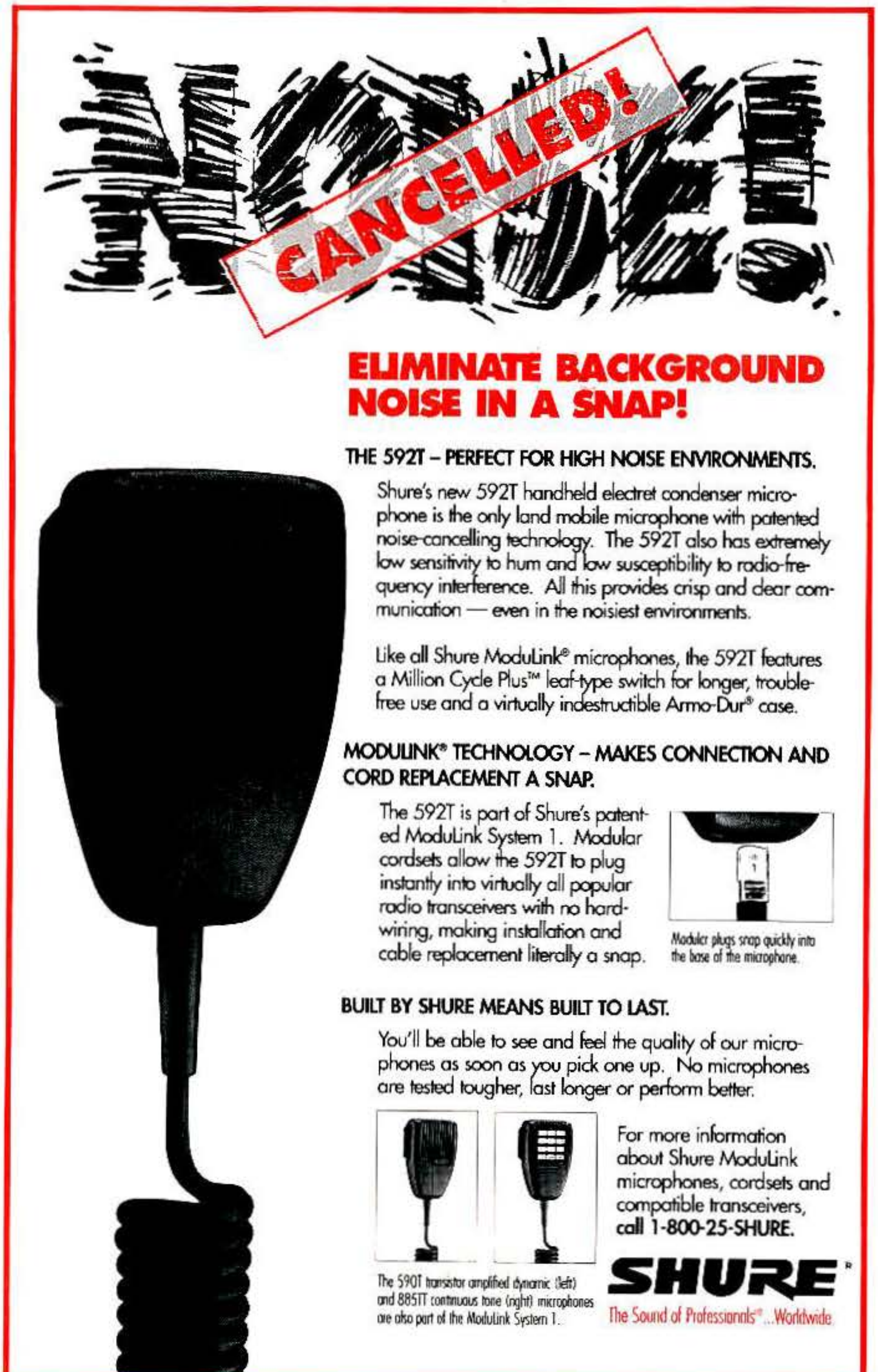
Pagerfiles contain—within themselves—the DATA statements that pertain to your customers. These statements are edited by the screen editor, and doubly resaved so there is a backup copy of the files. Each Pagerfile starts out about 5.5K long, but it can grow rapidly, so it is a good idea to install the program on a hard disk drive.

Hard copy receipts may be generated with Pagerfiles. Automatic "next payment due" mathematics are performed within the program and printed on the receipt. Embedded commands allow the user to print files for customers with past-due payments.

Current versions of Pagerfiles are "chained" through 12 programs, each capable of 200-250 customer fields. This capacity represents 2,400 to 3,000 customers. With slight modifications to the program, Pagerfiles could be extended to several hundred programs, each capable of handling 200-250 customers.

Written in BASICA, the essential program is adapted easily to any IBM-compatible computer offering a version of BASIC, which is usually bundled with the disk operating system (DOS).

It is important to note the presence of the "echo" copy, thus doubling the memory requirements of the floppy disk or hard disk drive. Ten full copies (and "echoes") of Pagerfiles fit nicely on a



Circle (26) on Fast Fact Card

1.44Mb floppy diskette and take care of 2,000 to 2,500 customers.

Depending on the microprocessor speed and hard drive access time, Pagerfiles sorts through 2,000 customers in about 4.5 seconds on a '486, 33MHz computer on the hard disk drive. Using a 5.25-inch diskette, the same machine takes 12 seconds. Speed is a question of machine and storage media.

Data entry consists of structuring your files around the format given (i.e., pager number, line number from the program, capcode, name, rate per month, features, monthly due date and miscellaneous and search information). Once this information is entered, begin entering data at line 500. (See program on page 36.)

Other special features may be embedded in Pagerfiles. Various portions of the NT$ may be used to indicate unassigned or inactivated pagers. A bit of imagination with Pagerfiles goes a long way toward achieving a better Rolodex index file.

Also included in Pagerfiles is a labor-saving routine that determines from the data exactly when payment is due and dials the pager number. The program downloads into any Hayes-compatible modem to leave a "get back to me" phone number that is programmed by the user. (See lines 92-116 in the program listing.)

When using BASICA, it is necessary to reset the date and time calendar-clock to print an accurate receipt. With BASICA running, type PRINT DATE$ and hit RETURN. The value of DATE$ is printed. To change it, type DATE$="mm/dd/yyyy" (with mm, dd and yyyy standing for month, date and year) and hit RETURN. To change the time, type PRINT TIME$ and hit RETURN. The value of TIME$ will appear. To change it, type TIME$="hh/mm/ss (with hh, mm and ss standing for hours, minutes and seconds in a 24-hour clock format) and hit RETURN. This step sets the internal calendar and clock, and the information will be printed on each receipt.

A documented copy of PGRFILE 1 is included with this article, and anyone is free to adapt, modify or use it. Copies of PGRFILES are available for a $15 check or money order. A program called PGF0 contains documentation of the program, and an INFO file provides an overview.

The following lines *must* be written carefully to allow the programs to chain properly: lines 12, 14, 20, 24, 66, 74, 78 and 100. Line 14 informs the user which Pagerfile is being used. The remaining lines handle the chaining operations.

Pagerfiles are provided on 5.25-inch diskettes (formatted for 360K) and 3.5-inch diskettes (formatted for 1.44mB) for IBM-compatible computers. Indicate which version you need. Send to: David Ludvigson, 318 Avenue B, South Houston, TX 77587.

For readers interested in a Windows-style bookkeeping and billing method, I recommend a program called PAGEKEEP, available from Electronic Information eXchange (EIX). This particular software generates reports and has numerous options such as multi-user capability, auto-page, over-call management and automatic data exchange, which provides an instant comparison between your records and those of the billing company. For further information, call 713-765-7400.

Acknowledgement

I would like to the management and staff of JJ Sounds and Communications, South Houston, TX, for their help with this project. Tel.: 713-944-1813.

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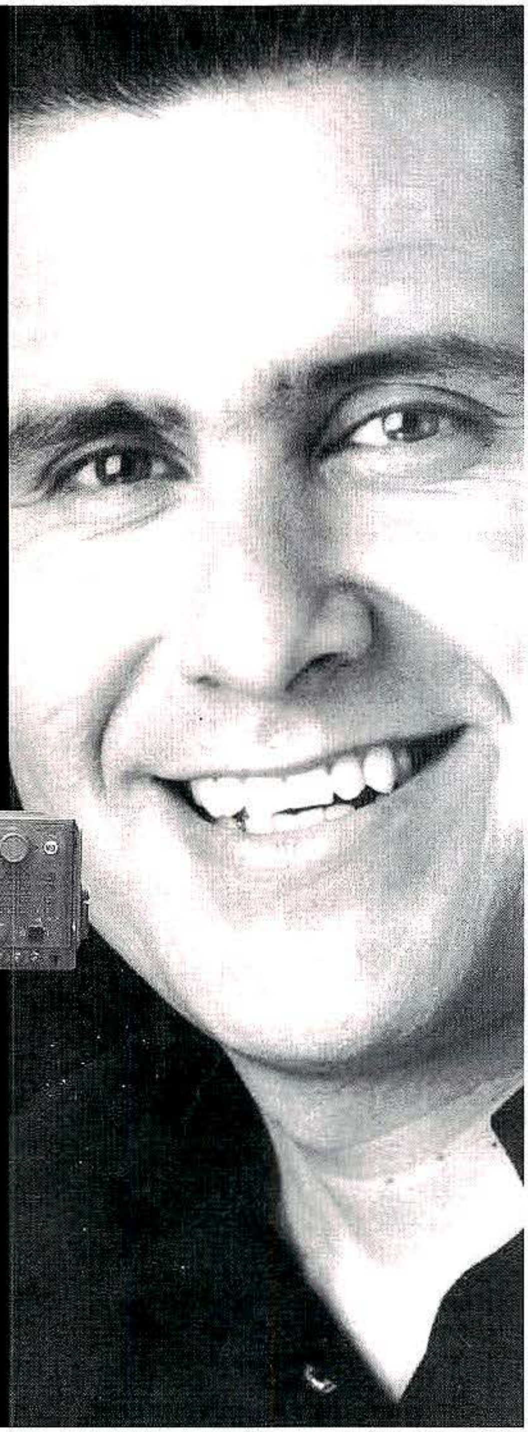

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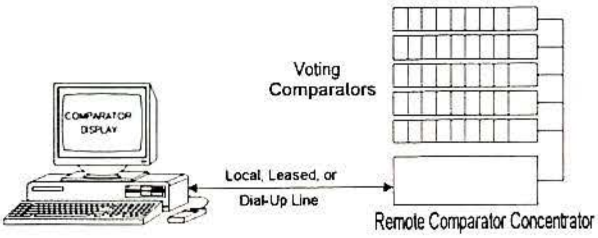

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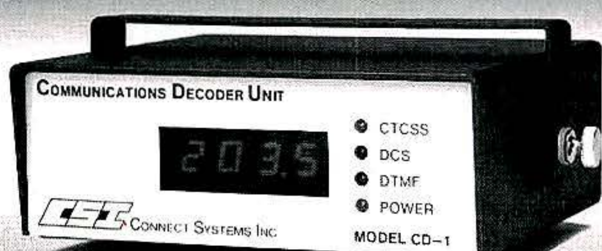

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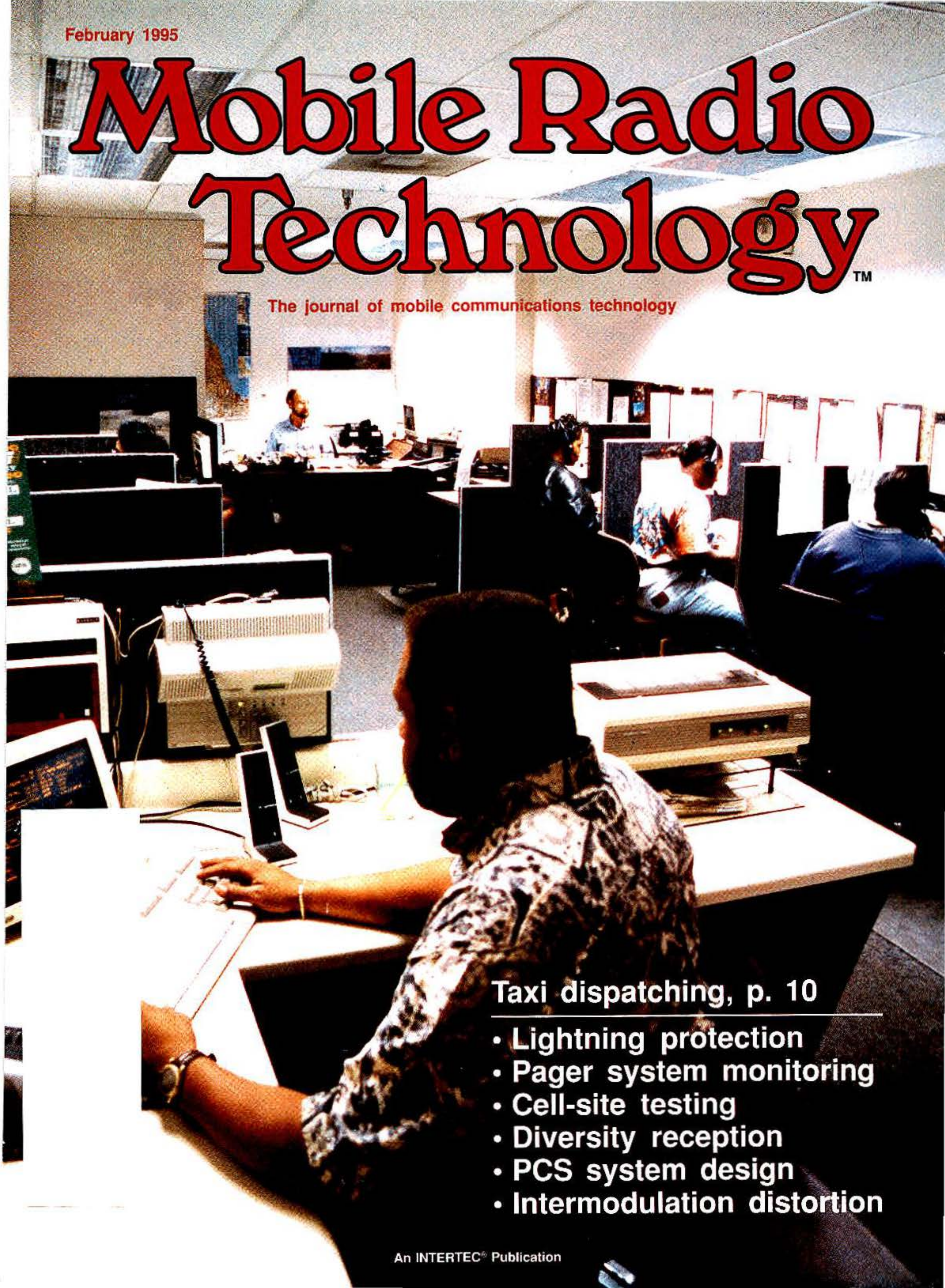
BR110003–35.240/L	BR310003–454.075	BR410003–929.4125
BR110010–35.500/L	BR310004–454.100	BR410004–929.4375
BR110011–35.540/L	BR310005–454.125	BR410005–929.4625
BR120011–35.540/H	BR310006–454.150	BR410006–929.5625
BR110012–35.560/L	BR310007–454.175	BR410007–929.6375
BR110013–35.580/L	BR310008–454.200	BR410008–929.6625
BR120013–35.580/H	BR310009–454.225	BR410009–929.6875
BR110014–35.600/L	BR310010–454.250	BR410010–929.7125
BR120017–43.200/H	BR310011–454.275	BR410011–929.7375
BR110019–43.240/L	BR310012–454.300	BR410012–929.7625
BR120019–43.240/H	BR310013–454.325	BR410013–929.7875
BR120022–43.340/H	BR310014–454.350	BR410014–929.8125
BR120024–43.420/H	BR310015–454.375	BR410015–929.8375
BR110028–43.560/L	BR310016–454.400	BR410016–929.8625
BR120028–43.560/H	BR310017–454.425	BR410017–929.8875
BR120029–43.580/H	BR310018–454.450	BR410018–929.9125
BR120031–43.620/H	BR310019–454.475	BR410019–929.9375
BR120033–43.680/H	BR310020–454.500	BR410020–929.9625
	BR310021–454.525	BR410021–929.9875
VHF	BR310022–454.455	BR410022–931.0125
	BR310023–454.575	BR410023–931.0375
	BR310024–454.600	BR410024–931.0625
BR210001–152.030	BR310025–454.625	BR410025–931.0875
BR210002–152.060	BR310026–454.650	BR410026–931.1125
BR210003–152.090	BR310027–462.750	BR410027–931.1375
BR210004–152.120	BR310028–462.775	BR410028–931.1625
BR210005–152.150	BR310029–462.800	BR410029–931.1875
BR210006–152.180	BR310030–462.825	BR410030–931.2125
BR210007–152.210	BR310031–462.850	BR410031–931.2375
BR210008–152.240	BR310032–462.875	BR410032–931.2625
BR210009–152.480	BR310033–462.900	BR410033–931.2875
BR210010–152.510	BR310034–462.925	BR410034–931.3125
BR210011–152.540	BR310035–465.000	BR410035–931.3375
BR210012–152.570	BR310036–464.975	BR410036–931.3625
BR210013–152.600	BR310037–457.575	BR410037–931.3875
BR210014–152.630	BR310038–452.130	BR410038–931.4125
BR210015–152.660	BR310039–455.500	BR410039–931.4375
BR210016–152.690	BR310040–452.650	BR410040–931.4625
BR210017–152.720	BR310041–457.975	BR410041–931.4875
BR210018–152.750	BR310042–454.550	BR410042–931.5125
BR210019–152.780	BR310043–464.700	BR410043–931.5375
BR210020–152.810	BR310044–456.375	BR410044–931.5625
BR210021–152.840	BR310045–464.375	BR410045–931.5875
BR210022–154.625	BR310046–452.750	BR410046–931.6125
BR210023–157.740	BR310047–453.125	BR410047–931.6375
BR210024–158.100	BR310048–456.680	BR410048–931.6625
BR210025–158.460	BR310049–463.200	BR410049–931.6875
BR210026–158.700	BR310050–463.250	BR410050–931.7125
BR210027–152.420	BR310051–449.675	BR410051–931.7375
BR210028–159.855	BR310052–464.350	BR410052–931.7625
BR210029–152.0075	BR310053–454.6125	BR410053–931.7875
BR210030–153.710	BR310054–445.600	BR410054–931.8125
BR210032–155.280	BR310055–445.675	BR410055–931.8375
BR210042–152.650	BR310056–445.825	BR410056–931.8625
BR210046–153.605	BR310057–445.950	BR410057–931.8875
BR210053–152.500	BR310058–462.625	BR410058–931.9125
BR210056–150.635	BR310059–462.200	BR410059–931.9375
BR210059–151.190	BR310060–462.350	BR410060–931.9625

The first two characters of the model number BR = Bravo; BE = Bravo 17.9IF (900 band). The last two digits represent a specific frequency and is common for all models.

February 1995

Mobile Radio Technology™

The journal of mobile communications technology



Taxi dispatching, p. 10

- Lightning protection
- Pager system monitoring
- Cell-site testing
- Diversity reception
- PCS system design
- Intermodulation distortion

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Servicing pagers: Mixed signals

Part 13—Check pager alignment after a customer has used a new pager for a week and listen to the paging system regularly for signs of trouble to make yourself extra valuable to the airtime supplier.

By David Ludvigson

To this point in the pager servicing article series, various pitfalls and problems that occur with Bravo pagers have been discussed. The following information describes some other "disturbances" not previously covered.

After changing a crystal in a Bravo pager, it is wise to have the customer bring the unit back after about a week to check the alignment. There is a natural tendency of a crystal to age, which may cause it to wander from its original frequency. This phenomenon is especially noticeable with Bravo pagers that use 17.9MHz IF receivers operating in the 930MHz range. The operating frequency also is adversely affected by changes in ambient temperatures, so as the seasons change, expect a sudden influx of alignment work orders.

Beyond local control

Frequent "hookups" (setting up new customers to receive messages) require a paging network to maintain vast quantities of capcodes and associated telephone lines. Having these, the supplier also must deliver a radio signal to geographic areas that suit the customers' needs. Theoretically, all the equipment and data will provide reliable service—but there may be other problems.

As the reseller's customer base grows, confusion may result: capcodes may suffer from "dyslexia;" pager telephone numbers may be confused or duplicated; and transmitters may fail. More unusual problems may arise, too.

As a paging service grows, the need to expand current services may conflict with the existing structure. Thus, in spite of a technician's loud insistence that "this capcode *has* to be working" (and the network representative asserting that "it should be"), it usually is discovered that expansion (or some other work) has caused inadvertent shut-downs of several capcodes—at the *network's* end. A capcode generator and an alignment of the pager have produced reliable operation, but the switchboard required attention to make the proper connection.

Technicians who are always listening to their airtime suppliers' frequencies usually are quick to notice impending problems. In September 1993, a noticeable "pinging" was heard in a signal from one of Houston's largest airtime suppliers. I suggested that the transmitter's voltage-controlled oscillator (VCO) was introducing distortion. Tests conducted with the transmitter circuitry off-line and under ideal conditions revealed proper waveforms. When the transmitter was placed back on the air, though, the waveform distortion returned. A new VCO assembly was required to tame the problem.

Unfortunately, not all problems are consistent. Tracking the source of countless "error" messages in pagers caused one Houston airtime supplier to lose many of its resellers. Intermodulation distortion was entering the data stream at the satellite receiver and cutting data to ribbons. With the intermittent nature of the problem, tracking the source was extremely difficult. The solution was expensive because it involved new sites and accompanying transmitters.

Sometimes, the problem might be localized. A paging transmitter sometimes will fail, leaving a large territory without service. Listening to the monitor revealed that the distant paging transmitters were operating, but the local one seemed to be dead. A thunderstorm had flooded a transmitter location in south Houston.

Service technicians who take time to listen to their supplier's frequencies can be helpful when they contact service employees at the paging company to report unusual system operation. Remote transmitter monitors may report a system is working fine, but they cannot report the presence of intermodulation distortion. Furthermore, varying weather conditions may also cause signal fading.

Ludvigson is a technician in Houston.

Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)
Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)
Part 3: "Frequencies, Coding Formats, March 1994. (Bravo.)
Part 4: "From Bench To Programmer," April 1994. (Bravo.)
Part 5: "The Receivers," May 1994. (Bravo.)
Part 6: "Elegant Simplicity," June 1994. (Bravo.)
Part 7: "Problems In Paradise," July 1994. (Bravo.)
Part 8: "406MHz–512MHz Receivers," August 1994. (Bravo.)
Part 9: "150MHz Receivers," September 1994. (Bravo.)
Part 10: "Tales Crystal Filters Tell . . .," October 1994. (Bravo, Bravo Plus, Bravo Express.)
Part 11: "Microprocessor Board," November 1994. (Bravo.)
Part 12: "Headaches (and Some Aspirin)," January 1995. (Bravo.)
Part 13: "Mixed Signals," February 1995. (Bravo.)

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Circle (35) on Fast Fact Card

With the proliferation of 930MHz assignments has come the considerable problem of transmitter noise. In heavily populated areas, transmitted signals tend to overlap one another, causing desensitization at the receiving pager. (See "Technically Speaking—Transmitter Noise" by Harold Kinley, C.E.T., in the September 1993 issue, p. 8, for an indication of the headaches that may occur at transmitter sites.) In Houston, where many pager users are often directly *beneath* paging transmitters, channel spacing vs. pager sensitivity may become a critical issue. Receiver designers will attempt to narrow the pager's bandwidth (at the IF) to allow reception in the presence of a strong adjacent-channel signal, but this places stringent requirements on receiver local oscillators for frequency stability.

Another issue often found in synchronous or simulcast paging systems is the problem of synchronizing the very start of the message at the preamble or comma.

Another issue often found in synchronous or simulcast paging systems is the problem of synchronizing the very start of the message at the preamble or comma. The alternating 1-0 pattern of POCSAG coding could easily become confusing to a pager located mid-way between two out-of-sync transmitters. At 512bps, this condition could occur in as little as $^1/_{512}$ of a second. It gets worse as the bps rate is increased! Various proposals have been suggested (such as specific codewords) to minimize this problem, although implementation would require a totally new approach, as well as new pagers.

Acknowledgement

I would like to thank the management and staff of JJ Sounds & Communications, South Houston, TX, for their help with this project. Tel: 713-944-1813.

April 1995

Mobile Radio Technology™

The journal of mobile communications technology

Coaxial connectors, p. 10

- CDMA cellular
- Servicing pagers
- Lightning protection theory
- Pulling cable

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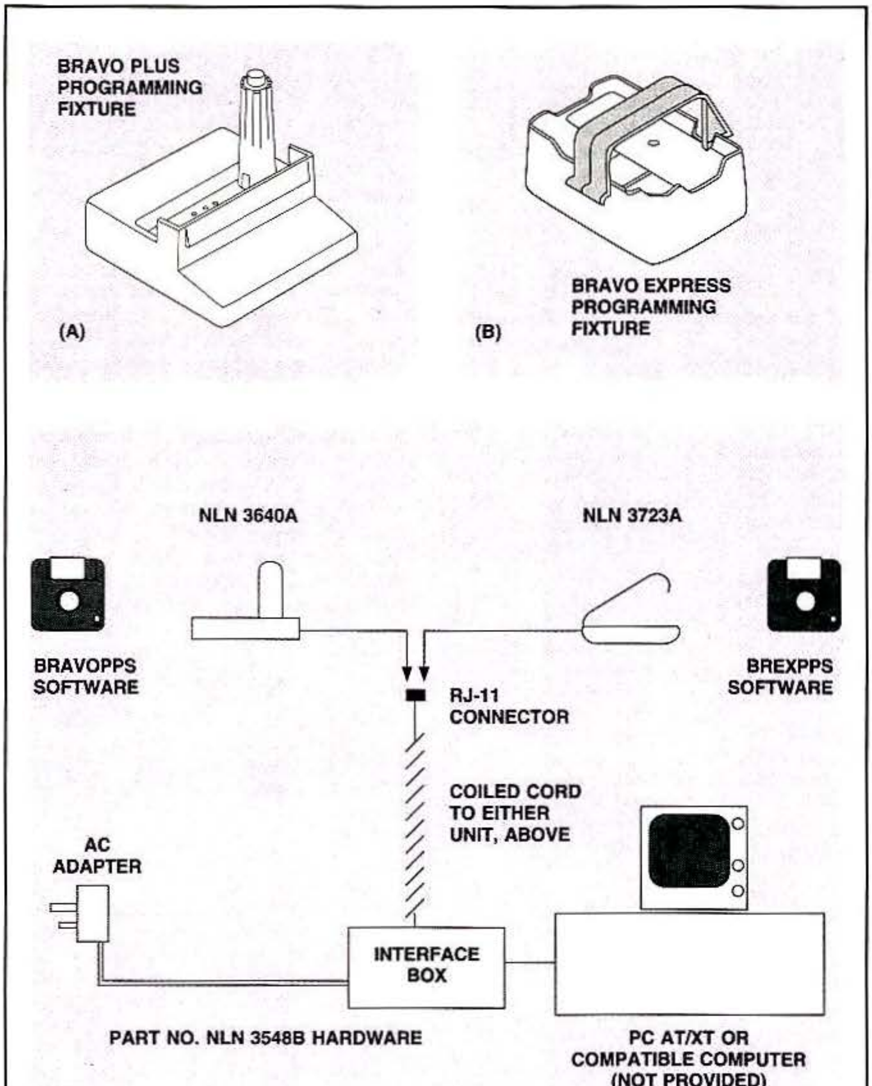
Servicing pagers: Essential differences

Part 14—Here are some tips for programming Bravo Plus and Bravo Express pagers, including computer and storage media selection, hardware connections and software installation.



The NLN 3548 series hardware connects between the computer and the appropriate hardware and software for either the Bravo Plus or the Express. All three items (both fixtures with their software, and the interface) are available from Motorola for about $300.

Figure 1: Programming fixtures are used to hold the Bravo Plus (A) and Bravo Express (B) pagers. The equipment configuration is shown at (C).

By David Ludvigson

Unlike the Bravo pager, the Bravo Plus and Bravo Express pagers are capable of more than merely receiving pages and displaying basic information in the window. One big difference is a 12/24-hour clock with a time stamp. The clock and time stamp features (although not essential to pager operation) provide something for the microprocessor to do while waiting for a paging message.

View from the programmer

Plus and Express programming requires more sophistication than the Bravo. In this case, the user will need an IBM-compatible computer with at least 360K of resident RAM (user supplied) and the programming interface and software (provided by Motorola). The necessary hardware and software are packaged under Motorola part number NLN 3548B. The NLN 3640A includes diskettes for the Bravo Plus and the necessary interfacing hardware to match the pager to be programmed. Similarly, the NLN 3723A package contains software and a test fixture to mate with the Bravo Express.

The NLN 3548B requires the use of one of the RS-232 serial ports found at the rear of the computer, defined by the user in the SETUP program when saved to hard disk or diskette. It is suggested that the default names be used to access the program, i.e., BRAVOPPS for Bravo Plus, and BREXPPPS for the Bravo Express.

Depending on what is connected to your computer, it may be convenient to use COM PORT 1 for a printer and COM PORT 2 for the programmer. In this manner, PGRFILES (or any other bookkeeping utility program) will not collide on

Ludvigson is a technician in Houston.

the RS-232 lines. (PGRFILES was covered in Part 12 in the January 1995 issue.)

There is one quirk with the Bravo Plus and Bravo Express software. The Bravo Plus software runs well at 33MHz; both reading FROM and writing TO the Bravo Plus may be done at Turbo speed. Programming the Express, though, requires defeating the Turbo feature of most high-speed computers. The software can READ the pager fine at Turbo speeds, but WRITING to the Express requires a slower speed. Motorola has a software remedy for this problem, available for the asking.

Software protection is an option in these programs. Passwords can be placed in front of the main body of the program, preventing unauthorized use. Similarly, a password may be embedded in either the Plus or Express to prevent others from reading or overwriting the data you have entered. As you will discover, there are 10 spaces in the ENTER PAGER PASSWORD frame. Each space may be filled with any letter, number or some punctuation marks. Because there are 26 letters, 10 digits and numerous punctuation marks, the possibility of exactly matching an unknown string is exceedingly remote—and you only get six or seven attempts to do so! Unofficial (non-Motorola) hardware and software adaptations have been developed that allow the user to defeat the password protection. Password-removal equipment may be purchased from Viamtel, 2909 Fannin, Houston, TX 77002, 713-750-0007.

Hardware connections

An ac adapter provides the required operating voltages for the interface unit. Attached by means of RJ-11 connectors, a mechanical interface consisting of a 3-pin electrical connector and a form-fitting pager nest provides the terminals for communicating data to and from the pager. (See Figure 1 on page 66.) The mechanical interface is changed to match either the Bravo Plus or the Express.

Software installation: Bravo Plus

Provided with the NLN 3640A are the necessary diskettes (both 5¼-inch and 3½-inch) that turn the computer into a programmer.

Bring up the drive-prompt (A>). Insert the proper diskette into the A drive. Verify the drive by typing *A:* and hit *ENTER*. Behind the A prompt, type *SETUP* and hit *ENTER*. Copyright and version number will be displayed along with a "hit any key to continue" message. Doing so will bring up a selection screen where you decide whether you will be using backup floppy copies of the software or installing it on a hard drive.

. . . a password may be embedded in either the Plus or Express to prevent others from reading or overwriting the data you have entered.

Assuming use of the hard drive, merely hit *ENTER* or *RETURN* after reading the first page of the SETUP program. Page two asks for verification of the destination drive for the program. Is it the hard drive?

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If you answer YES, the program will prompt for PATHS and PATHNAMES for your program. Because the program is on the A drive and you wish to place it on the hard drive (usually "C"), your source drive is A and the destination drive is the C drive.

The BRAVOPPS.EXE file will start on the C drive, so the program path will originate on C: . The archive files (BPLUSARK) and help files (BPLUSHLP) are "child" files called by BRAVOPPS.EXE. Unless you know how to use paths and pathnames, I suggest simply hitting *ENTER* when the default names are highlighted—it is easier that way, and the names are odd enough to avoid accidental over-writes.

Next, the COM PORT is selected. As mentioned earlier, I use COM PORT 1 for my printer, so COM PORT 2 is assigned for the interface. It should be noted that resident software for fax or modems might occupy various COM PORTS, so someone who *knows* might be helpful in determining what is available and how to get to it.

Ok, password time . . . (sigh!) If you are paranoid, enter your magic password in the blank. If not, leave it blank. (Mega-sigh!) The password will prevent unauthorized use of your computer as a means of programming Bravo Plus pagers.

No hard drive?

If you have no hard drive, get into your DOS version of DISKCOPY and make copies of both disk 1 and disk 2, labeling them appropriately.

Enter the SETUP program by answering *N* to the "Is this setup correct?" question at the bottom of the screen. Place your *copy* of disk 1 in the B drive and your *copy* of disk 2 in the A drive.

At the DISK #1 DRIVE prompt, enter *B*. At the DISK #2 DRIVE prompt, enter *A*. Hit the *ENTER* key as the default paths are highlighted, and select your COM PORT and PASSWORD as outlined above. If you have followed these directions, or if you are content with your choices, answer *Y* to the query at the bottom of the screen. The drives will grind for a few seconds as the appropriate files are marked and transferred from one to the other.

Starting the diskette version of BRAVOPPS will require placing the *copy* of disk 2 in drive A and the *copy* of disk 1 in drive B. At the A> prompt, enter *BRAVOPPS*. Unless you have protected your program with a password, the Motorola copyright notice and "hit any key. . ." message will appear. If the program has been password-protected, you

Crystal suppliers

David Ludvigson's January 1995 article included a reference to a supplier for crystals that can be used in the Motorola Bravo pager. In response to a request, here is a list of additional suppliers for such pager crystals. Circle the corresponding number on the Fast Fact Card on page 117 to receive information from any supplier. Addresses, telephone numbers and fax numbers for these suppliers are printed in the December 1994 edition's buyers' guide section.

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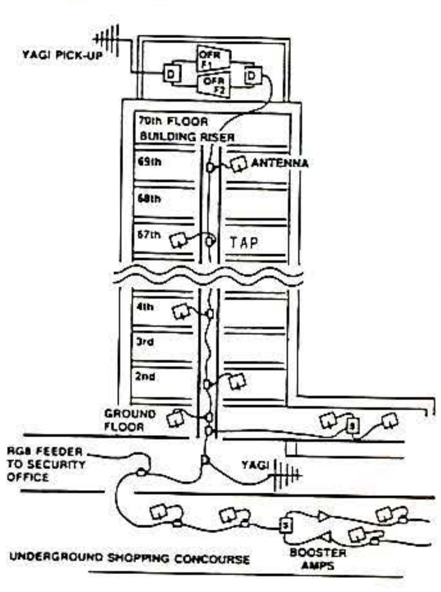

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Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)

Part 2: "Build An 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)

Part 3: "Frequencies, Coding Formats, March 1994. (Bravo.)

Part 4: "From Bench To Programmer," April 1994. (Bravo.)

Part 5: "The Receivers," May 1994. (Bravo.)

Part 6: "Elegant Simplicity," June 1994. (Bravo.)

Part 7: "Problems In Paradise," July 1994. (Bravo.)

Part 8: "406MHz-512MHz Receivers," August 1994. (Bravo.)

Part 9: "150MHz Receivers," September 1994. (Bravo.)

Part 10: "Tales Crystal Filters Tell . . .," October 1994. (Bravo, Bravo Plus, Bravo Express.)

Part 11: "Microprocessor Board," November 1994. (Bravo.)

Part 12: "Headaches (and some aspirin)," January 1995. (Bravo.)

Part 13: "Mixed Signals," February 1995. (Bravo.)

Part 14: "Essential Differences," April 1995. (Bravo Plus, Bravo Express.)

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will *have* to enter your password before the program will let you in.

Similarly, starting BRAVOPPS from the hard drive will require entering *BRAVOPPS* at the C> prompt. Enter your password, if required, and you will be at the copyright notice.

Software installation: Bravo Express

In general, installation of the Bravo Express software is identical to that of the Plus.

With the SETUP diskette in drive A, type *SETUP* behind the A> prompt. The same options as presented above will appear on the screen, allowing you to exit and make copies using DOS DISKCOPY or proceed to install the programs on your hard drive. You will be prompted for your COM PORTS and PASSWORD. If the Bravo Plus software works well, enter the same COM PORT as you used previously. As noted earlier, diskette working copies will end up with diskette copy 1 in drive B and diskette copy 2 in drive A. The use of default paths and pathnames is encouraged.

Having successfully installed the software, type *BREXPPPS* at the drive prompt and hit *ENTER*. Enter your password (if used) and begin programming the Bravo Express.

Acknowledgement

I would like to thank the management and staff of JJ Sounds & Communications, South Houston, TX, for their help with this project. Tel: 713-944-1813.

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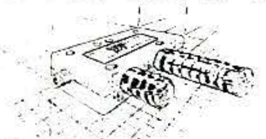

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Mobile Radio Technology™

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Flex paging setup, p. 10

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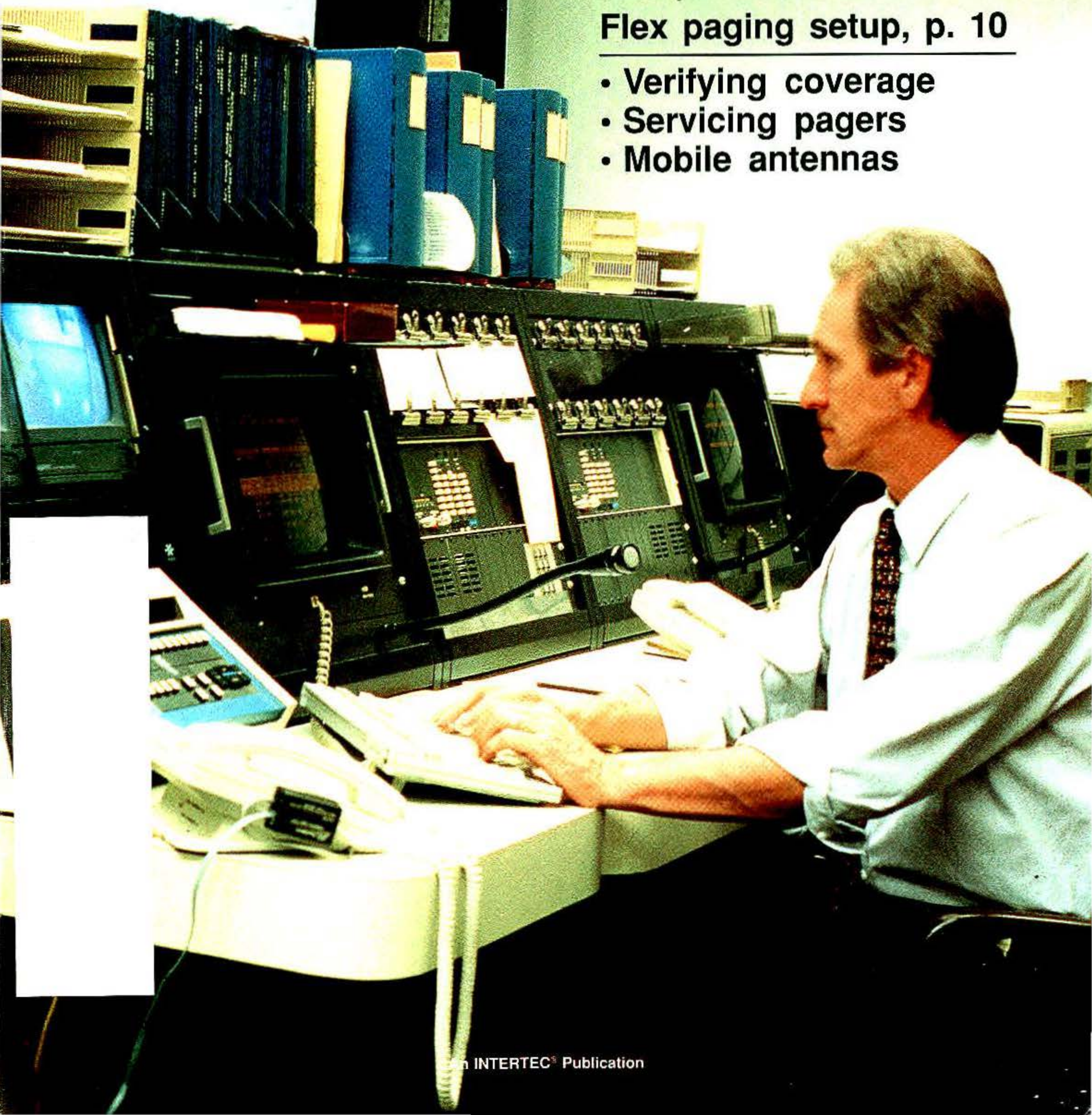

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Servicing pagers: And you shall receiver knowledge . . .

Part 15—Details about the Bravo Plus and Bravo Express 928MHz–932MHz NRF4101 receiver boards include some tips to make testing easier and faster. As with the Bravo, the 17.9MHz IF units have critical adjustments.

By David Ludvigson

The NRF 4104 receiver board for 928MHz–932MHz Bravo Plus and Bravo Express pagers comes in two basic flavors—17.9MHz IF and 45MHz IF versions. Past articles on the Bravo have dealt extensively with the frequency stability and other characteristics of these two IF blocks. (See Part 7, "Problems In Paradise," July 1994 issue.)

Basically, the 45MHz IF board is less critical of adjustment than the 17.9MHz board. This difference stems from:

Ludvigson is a technician in Houston.

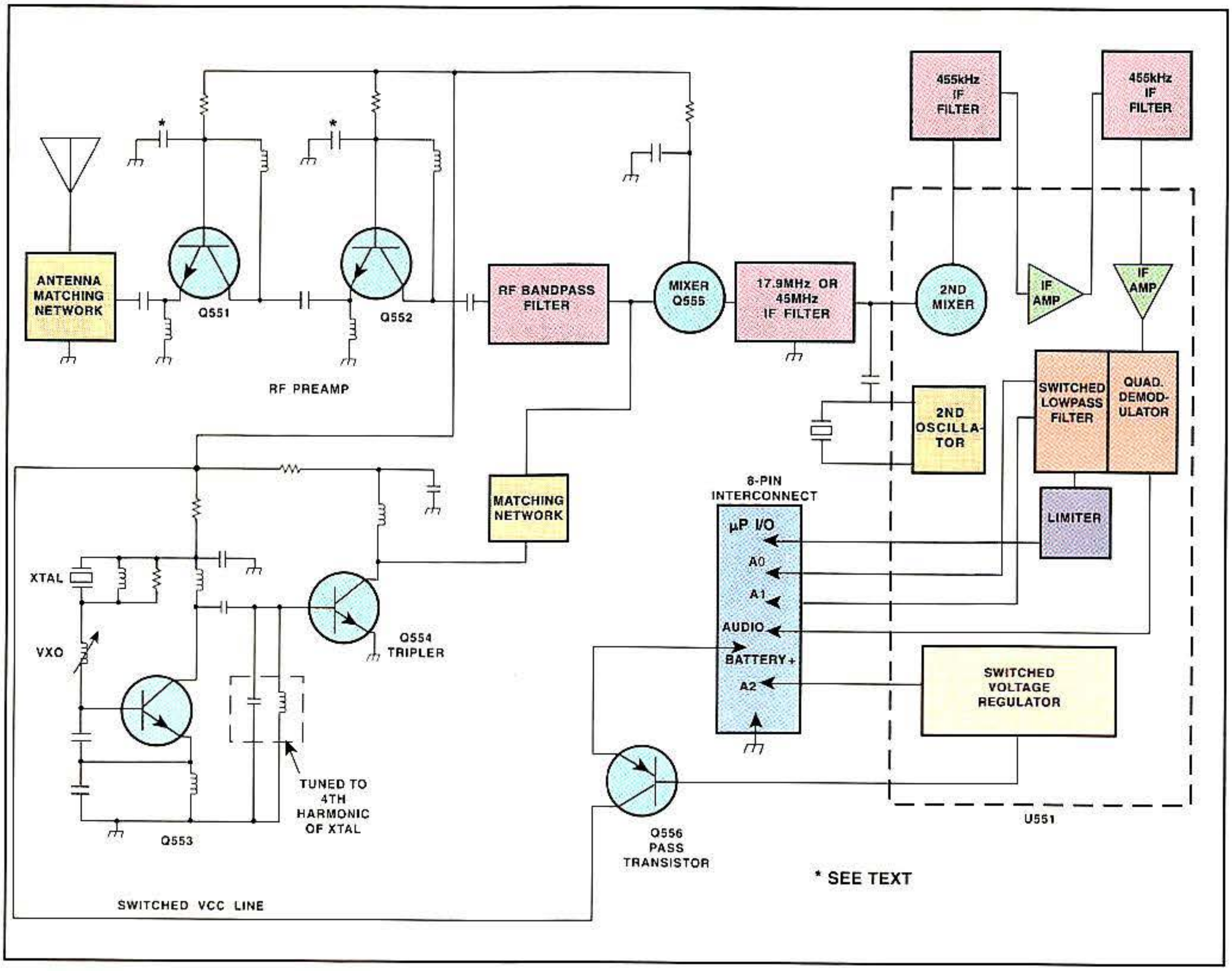

Figure 1. This block diagram represents the circuitry used in the Bravo Plus and Bravo Express receivers.

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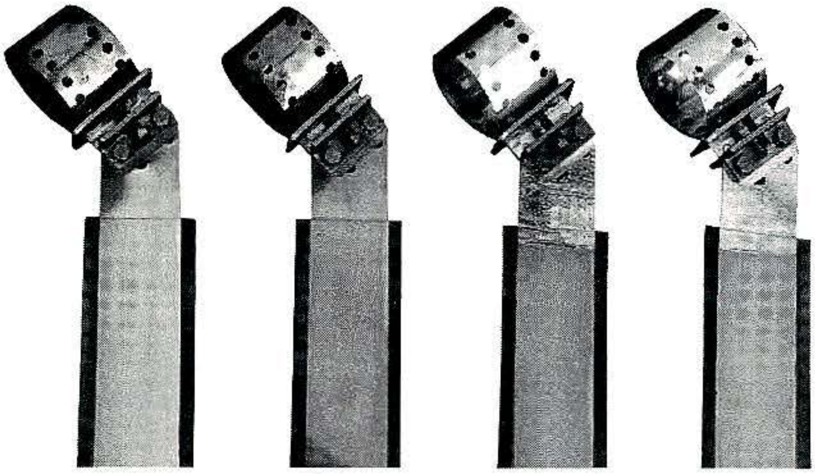

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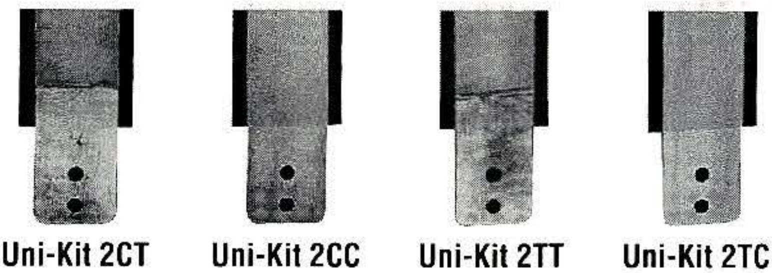

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(1) the stability of the first conversion oscillator.

(2) the bandwidth of the signal getting through the IF stage.

The service technician can expect problems with the 17.9MHz IF boards from another perspective—the only controls accessible to the technician are the first conversion oscillator tuning and the antenna matching network. The rest of the tuned circuits are either thin-film encapsulated or surface-mounted, pre-tuned networks that only a soul bent on sainthood would care to adjust!

One block diagram is sufficient to fully appreciate these receivers. (See Figure 1 on page 34.)

RF preselection is provided by a pair of transistors in common-base configuration. These two stages have been configured to provide about 12dB of gain without requiring a neutralizing network. Either of these stages, though, can get "wild" if the base bypass capacitors should open—in which case sensitivity drops off severely, or adjustment of the antenna network causes the stages to oscillate—so watch for poor solder joints!

The first conversion crystal oscillator is a Colpitts circuit with oscillation taking place between the base and emitter of Q553. Output from the collector is tuned to roughly four times the crystal frequency by means of a surface-mounted coil and capacitor. This same LC network feeds Q554, which is configured as a frequency tripler. This tripler yields an output of nearly 900MHz to the base of mixer Q555.

At Q555, a combination of the RF signal (at 931MHz, roughly) and the signal from the oscillator-multiplier stages is coupled into the base. The collector circuit contains the crystal filter, either 17.9MHz or 45MHz, and a matching network directly feeding the second mixer.

Within, U551 has a multitude of capabilities. Not only does it include a mixer, it has another crystal oscillator, a pair of 455kHz IF amplifiers, a quadrature FM detector, a switching low-pass filter, a limiter and at least two voltage regulators. It's a jungle in there!

In the Bravo, low-pass filtering is a function of a separate RC network on the logic boards. In the Bravo Plus and Bravo Express, the 4101 series receiver boards have audio filtering functions controlled by signals from the logic board that are fed into the "jungle-chip" on the receiver board. More about this later.

Getting into test mode

As with their little brother, the Bravo, the Bravo Plus and Bravo Express spend much of their time turned off. The battery

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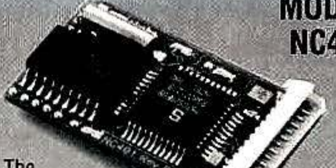

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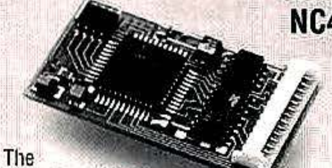

The Model NC409 is a DTMF ANI/Alarm status encoder and companion product to the Model NC401 DTMF Decoder designed to automatically or manually generate any of the 16 DTMF characters. The NC409 features 15 memory locations of up to 30 digits each plus last number redial and multiple user-configurable functions. Programming is easily performed by means of a 12 or 16 button "X-Y" keypad with common ground or the Model NC500 Universal/P.C. programmer. The NC409 measures .85"W x 1.36"L x .165"H and comes complete with micro-miniature 14 pin header and 12" color coded cable assembly. For FREE detailed information ask for the NC409 user's manual.

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saver literally gates the entire 1V line to the RF preamp, first injection oscillator-multiplier and mixer stages simultaneously. At first glance, one would expect this gating to cause frequency instability as the oscillator is being turned from *off* to *on*. The single saving grace for this method lies in the fact that the switched voltage is well-regulated, and the dc decoupling networks to each stage have very short RC time constants.

Placing the Bravo Plus into full-time receive mode requires depressing the two buttons beneath the display simultaneously while bringing the *off-mem-beep* power switch from *off* all the way to the *beep* position. Quickly release the buttons beneath the display, and depress the gray (READ) button momentarily. This procedure sets the pager into sound pressure level (SPL) mode, and the internal speaker will emit a steady tone. Depress the gray button again to advance the pager to MODE 1. In this mode, the pager is serviceable as far as the receiver alignment is concerned.

Another depression of the gray button sets the pager to MODE 2. In this mode, the decoder gives a single chirp when the proper capcode has been transmitted.

Another depression of the gray button reveals hexadecimal information as to how the pager has been programmed. None of this information reveals the capcode, by the way. The capcode must be read with the BRAVOPPS software discussed in Part 13, "Essential Differences," in the February 1995 issue.

When placing the Bravo Express into test mode, a different approach must be taken. Turn the Express off, then, sequentially, from right to left, depress each button beneath the display, and wait. The word POCSAG with a numeral will appear in the window. If you want an SPL test, depress the center switch; otherwise the pager is set only to the test mode. To get out of test mode, turn the Express on by depressing the left button.

There are other ways of turning these pagers into full-time receivers without constantly lifting them out of the RTL 1005 radiation test fixture. For the Bravo, you could solder a 10K resistor across pins 1 and 8 of the interconnection block. For the Bravo Plus and Express, simply ground line A2 (this is easily traced to a test point) coming from the interconnecting block between the circuit boards.

It was mentioned earlier that the Bravo Plus and Express use a switched filter to define the bandpass of the POCSAG signal. The filter connects to lines A0 and A1, again available at the interconnecting block. A bit of experimenting shows that when the pager is in normal operating mode (capable of decoding an on-the-air signal), programming different POCSAG rates into the pager (at the computer) cause lines A0 and A1 to respond differently.

POCSAG 512 A0 goes low, A1 goes high
POCSAG 1200 A0 goes high, A1 goes low

These changes occur in response to the strobed battery-saver signal at Line A2 and the received data stream. It will help greatly if you use the IFFER ("Build An 'IFFER,'" February 1994 issue) when trying this for yourself, because you can actually hear the voltage transitions while moving an oscilloscope probe from test point to test point.

Acknowledgement

I would like to thank the management and staff of JJ Sounds & Communications, South Houston, TX, for their help with this project. Tel: 713-944-1813.

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Part 15: "And You Shall Receiver Knowledge . . .," June 1995. (Bravo Plus, Bravo Express.)

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Servicing pagers: The information highway

Part 16—Some tips for programming Bravo Plus and Bravo Express pagers help you to bypass possibly unnecessary bells and whistles. It may be better to have the pager 'beep on bad data' than to risk undelivered messages.

By David Ludvigson

The interface between the pager and its programming device is relatively simple. Serial information is read sequentially from the pager into the program or, conversely, from the program into the pager. Although the presentation of this data "looks" different than the Bravo programmer presentation, actual differences between the IBM-compatible computer hookup and the Bravo programmer are minor, as far as data handling is concerned.

```
Motorola Radio Service Software                      Enter characters      PG Up/Dn for Menus
BRAVO Plus        Ver. R02.00.01
Page 1 of 2
Main, Read

Inventory Control #          BP4BUL2R2C              Serial #BP4BUL2R2C
Synthesized Pager            No
Frequency                    931.2875MHz
Phone Number Screen
Coding Format                POCSAG 2400
                             Code A     Code B
                             1802572    None

                             1234       1234
Active        Y,N            YYYY
Functions     T,N,O          NNNN
Priority      Y,N            NNNN

Code Type                    Indiv      Indiv
Code Alerts                  Indiv      Indiv

F1     F2     F3     F4     F5     F6        F7     F8     F9     F10
HELP   KEY                         CLEAR TO                        EXIT
       HELP                        EMPTY                           TO MAIN
```

Figure 1.The first programming screen for the Bravo Plus includes some superfluous information that has little to do with the operation of the pagers.

```
Motorola Radio Service Software                Spacebar to select      PG Up/Dn for Menus
BRAVO Plus        Ver. R02.00.01
Page 2 of 2
Main, Read

                                               Menu Erase All              Yes
                                               Vibrator                    Yes
Sequential Lockout        None                 Reminder Vib                Yes
Duplicate Detection       Yes                  Reminder Chirp While On     Yes
Alert Level               Full                 Chirp in Mem                No
Alert Length              8 secs               Reminder Chirp in Mem       No
Time Format               12 Hour              Beep On Bad Data            Yes
Display Time              Yes                  Low Battery Alert in Mem    No
Display Time Stamp        Yes                  Download Password Req'd     No
Display Slot Number       Yes                  Pager Password              Bravo Two
Display Source            No                   Cust. Req. Inv. Data        No
Service Screen First      No
Non Volatile Memory       Yes
Memory Cleanup            No                   Out of Range                6 Mins
Memory Full               Yes                  International Symbols       No

F1     F2     F3     F4     F5     F6        F7     F8     F9     F10
HELP   KEY                         CLEAR TO                        EXIT
       HELP                        EMPTY                           TO MAIN
```

Figure 2. The second programming screen offers a 'beep on bad data' option. More on this in the text. Additional clock options are not vital.

As described in "Servicing Pagers: Microprocessor Board" in the November 1994 issue, there is a definite pattern to the Bravo programmer. First, you define whether to program POCSAG or Golay information; then you look for NORMAL or INVERTED data handling, and so forth.

With the Bravo Plus and Bravo Express, this "fill in the blanks" form of programming gets muddled. Suddenly, there is room for serial numbers, passwords, meaningless frequency information, clock options and cadenced tone alerts—none of which has anything to do with the operation of the pager! Bells and whistles!

As you fill in the various pieces of information, a "string" of information is created for downloading into the pager's codeplug. Pieces of this "string" will be placed into specific program locations where they will be used to perform individual tasks.

I mentioned that much of the information filled in at the computer is just so much junk as far as the paging operation is concerned. With a crystal-controlled pager, there is no point in identifying operating frequency—it is nice to have but not necessary. Clock options are other "nice to have" features, but they are not terribly vital—but I have made my point.

Once programmed, the pager operation resolves itself to performing specific tasks at certain well-defined times. When initially turned on, the whole system performs a reset, clearing the memory, performing self-testing functions and resetting the clock display. Capcode information is downloaded from the codeplug into

Ludvigson is a technician in Houston.

the proper memory location, the receiver "on-time" cadence is determined by the POCSAG data rate information, and the audio filter is activated to pass the data stream information at the selected speed.

The receiver is enabled for a specific period during each BATCH transmission. This is a function of the CAPCODE. If, during the BATCH, the CAPCODE is matched, the information contained in the following 32 bits transfers to the microprocessor. Decoded, these bits form the numerals that are passed to the display.

When the data matches the CAPCODE, several operations occur. First, the cadenced tone generator sounds (while the phone number is being decoded). Clock information is stored to indicate the hour at which the page arrived at the pager. In this manner, two memory locations are occupied and sequentially accessed via the gray (READ) push-button.

If the user wishes to LOCK the information in the pager, a form of "scratch-pad" memory stores the number and time in the next available scratch-pad slot. The LOCK key serves to latch or to unlatch this data, and a padlock symbol appears in the display to indicate saved data. Unlike the Bravo, the Bravo Plus and Bravo Express do not necessarily drop memory contents when the power is turned off. Instead, they offer a CLEAR function to erase those numbers that are UNLOCKED.

The majority of functions found in the Plus and Express are virtually identical to those of the Bravo. (See "Servicing Pagers: "The Receivers," May 1994 issue.) The receiver boards differ in that the

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Part 16: "The Information Highway," July 1995. (Bravo Plus, Bravo Express.)

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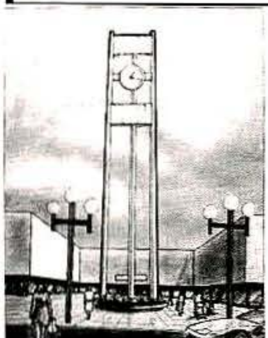
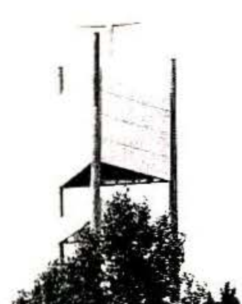

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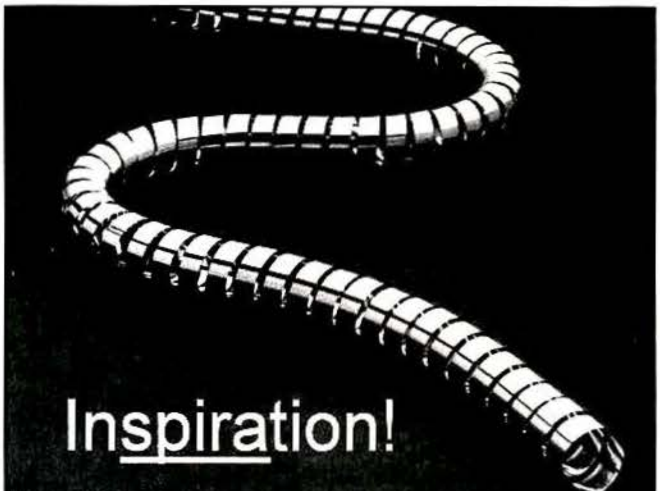

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```
Motorola Radio Service Software          Enter characters.     PG Up/Dn for Menus
Bravo Express      Ver. R03.00.00
Page 1 of 3
Read pager's codes and Functions

Inventory Control #                      Serial #234EUC3WWX
Synthesized Pager          No

Frequency                  931.2875MHz
Phone Number Screen        - - - - - - - - - -
Coding Format              POCSAG 1200
                           Code A     Code B
                           0408196    None

                           1234       1234
Active       Y,N           YYYY
Functions    T,N,O         NNNN
Priority     Y,N           NNNN

F1     F2     F3   F4   F5   F6         F7   F8   F9   F10
HELP   KEY                   CLEAR TO                  EXIT
       HELP                  EMPTY                     TO MAIN
```

Figure 3. The first programming screen for the Bravo Express specifies the operating frequency—nice, but not necessary for a crystal-controlled pager.

```
Motorola Radio Service Software          Spacebar to select.     PG Up/Dn for Menus
BRAVO Express    Ver. R03.00.00
Page 2 of 3
Read Pager's Options

Alert Type              Pleasing          Out of Range                 None
Alert Length            8 secs            MEM Page Alert               Vib
Escalert                No                Reminder Alert               Yes
Code B Type             Individual        MEM Reminder Alert           Vib
Time Stamp              Yes               Sequential Lockout           None
Time Stamp Oldest       No                Beep on Bad Data             Yes
Show Source             No                RF Programming Allowed       No
Auto On/Off             Yes               RF Programming Password
Silent Auto On/Off      No                Download Password Req'd      No
                                          PAGER Password

F1     F2     F3   F4   F5   F6         F7   F8   F9   F10
HELP   KEY                   CLEAR TO                  EXIT
       HELP                  EMPTY                     TO MAIN
```

Figure 4. 'Beep on bad data: yes' helps to reveal reception problems. 'RF programming' is available on the Bravo Express; see text about 'RF downloading.'

```
Motorola Radio Service Software          Spacebar to select. PG Up/Dn for Menus
BRAVO Express    Ver. R03.00.00
Page 3 of 3
Read Pager's Pleasing Alerts

ALERT 1  :  RING                         You have chosen the pleasing alert type option.
ALERT 2  :  RING                         This menu allows you to choose a pleasing alert for
VOLUME   :  LOUD                         ALERT 2 and then assign the two alerts to the
                                         addresses. ALERT 2 is the power-up alert. You may
CODE A   :  Address 1    ALERT 2         also choose a 'LOUD' or 'NORMAL' alert level for
            Address 2    ALERT 2         some select ALERT 2 pleasing alerts.
            Address 3    ALERT 2
            Address 4    ALERT 2

CODE B   :  Address 1    ALERT 2
            Address 2    ALERT 2
            Address 3    ALERT 2
            Address 4    ALERT 2

F1     F2     F3   F4   F5   F6         F7   F8   F9   F10
HELP   KEY                   CLEAR TO                  EXIT
       HELP                  EMPTY                     TO MAIN
```

Figure 5. The third programming screen for the Bravo Express allows a selection of loud or normal alert levels.

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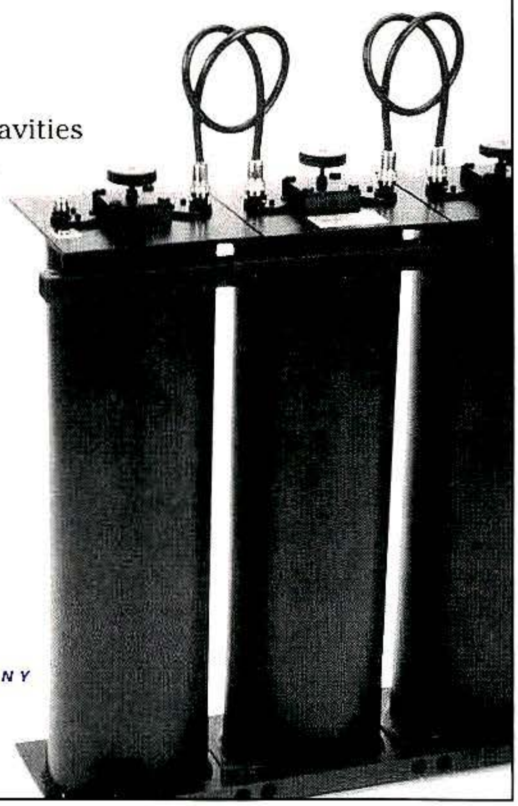

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Bravo uses an external resistor-capacitor (RC) data filter, whereas the Plus and Express use a two-port, selectable-bandpass active filter within the detector integrated circuit (IC). Attempts to use the Bravo and Plus/Express receiver boards interchangeably will result in frustration. They are not compatible.

Express programming features

The Express program has several options that may be confusing to the first-time user. "RF downloading" is a feature that has found favor in the alphanumeric pager business because it allows the same transmitter that has been transmitting stock price information from Dow Jones to turn off any selected customer's capcode by sending the proper preamble and text. It controls service delivered to a late-paying user. Similarly, the RF-downloading feature may be used to select any of a number of datastreams (e.g., paging, stock prices or sports scores) to be decoded at the pager.

Current technology could easily provide paging companies with such ability. Such service is not supported in the Express, though, so any selections made in the "RF downloading" option are ignored by the pager. It is just as easy for the paging company to enable or disable an individual capcode at the switchboard.

Another feature of the program is the "beep on bad data." In areas where simulcast signals overlap, the possibility of phasing differences causing an imperfect match of the capcode exists. When the signal strength is relatively weak, the Bravo family of pagers often is willing to decode "bad" data. Received pages are solid when signal strength and phasing are favorable, but the letter "E" creeps into messages under unfavorable conditions—also when the receiver is out of alignment.

If the "beep on bad data" is left off (BBD=N on the Bravo), count on customers complaining of missed pages. I would rather have customers tell me they are getting "E's" in their messages than to have them miss them entirely. A few minutes on the alignment bench might be all that is required to restore proper operation.

Acknowledgement

I would like to thank the management and staff of JJ Sounds and Communications, South Houston, TX, for their help with this project. Tel.: 713-944-1813.

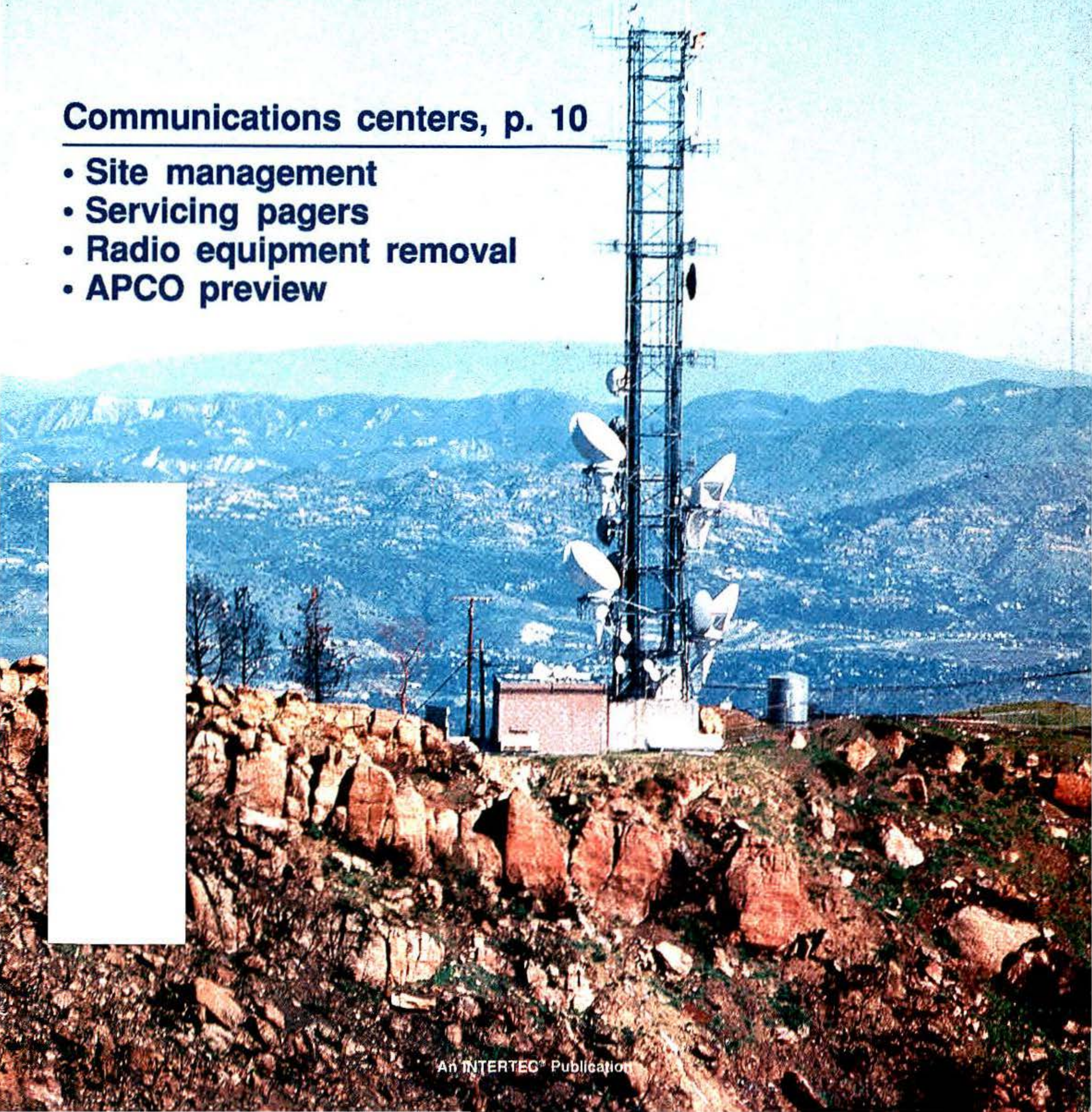
August 1995

Mobile Radio Technology™

The journal of mobile communications technology

Communications centers, p. 10

- Site management
- Servicing pagers
- Radio equipment removal
- APCO preview



An INTERTEC® Publication

Servicing pagers: 450MHz receiver boards

Part 17—Here are some details about the inner workings of UHF Bravo Plus and Bravo Express receiver circuitry. Use an 'unknown' feature during extensive troubleshooting of the circuit boards.

By David Ludvigson

The lady came up to me quietly with a furtive look. "Can you fix this?" she whispered.

I looked at the pager in her hand. It was a Bravo Plus, or at least the circuit boards that make up the Bravo Plus. Neatly sandwiched between the front lens and the light diffuser were the remains of the liquid crystal display (LCD), its flex-strip curling lazily at the bottom of the case.

Ludvigson is a technician in Houston.

Rule 1. When disassembling a Bravo Plus to make any repairs, remove the diffuser lens by placing a jeweler's screwdriver between the screw retaining post and the edge of the diffuser lens, and gently "rock" the screwdriver to release the friction-fit part. Forcing the circuit boards out of the case without performing this step results in much unneeded cost and frustration!

Logic and receiver board removal then may be accomplished by the same technique used for the Bravo pagers. (See Figures 1 and 2 below.)

The NRE series of Motorola Bravo Plus and Bravo Express receiver boards for 406MHz–512MHz includes:

NRE6550B	45MHz IF	406MHz–423MHz
NRE6551B	45MHz IF	435MHz–450MHz
NRE6552B	45MHz IF	450MHz–465MHz
NRE6553B	45MHz IF	465MHz–480MHz
NRE6552A	45MHz IF	450MHz–465MHz
NRE6553A	45MHz IF	465MHz–480MHz

Figure 3 on page 22 illustrates the parts and functions of the receiver boards. See the appropriate Motorola technical manual for a complete schematic.

Q451 and Q452 are configured as a cascode amplifier, capacitively coupled to

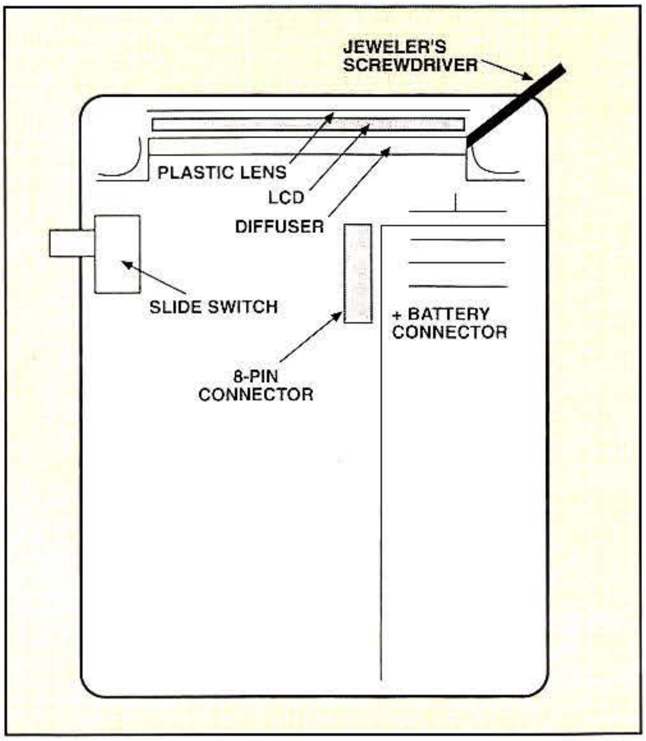


Figure 1. Step 1: Turn the pager off. Remove the battery clip at the bottom of the case, and remove the battery. Insert a jeweler's screwdriver at the edge of the diffuser lens to remove it.

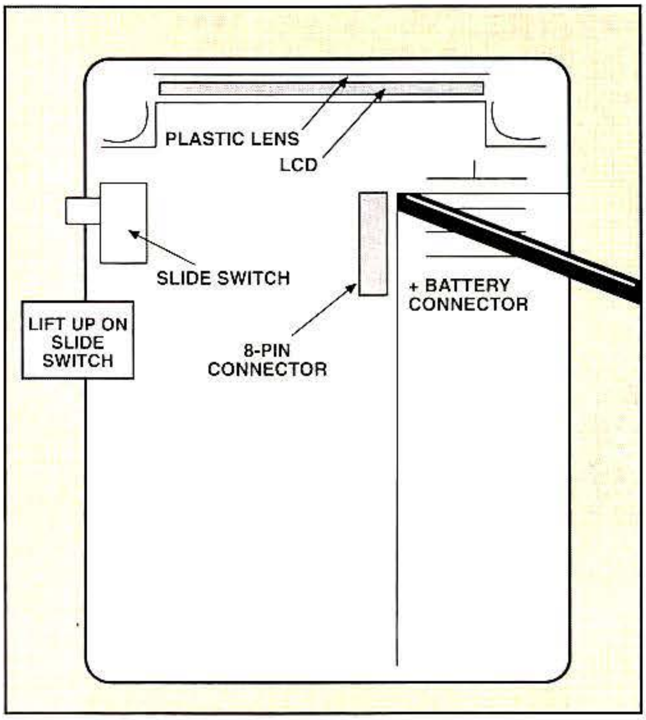


Figure 2. Step 2: With a small screwdriver placed at the "L" formed by the circuit board (to the left of the positive battery spring) and while lifting the lever of the side-mounted *on-vibrate-beep* switch, gently wedge the entire unit from the case.

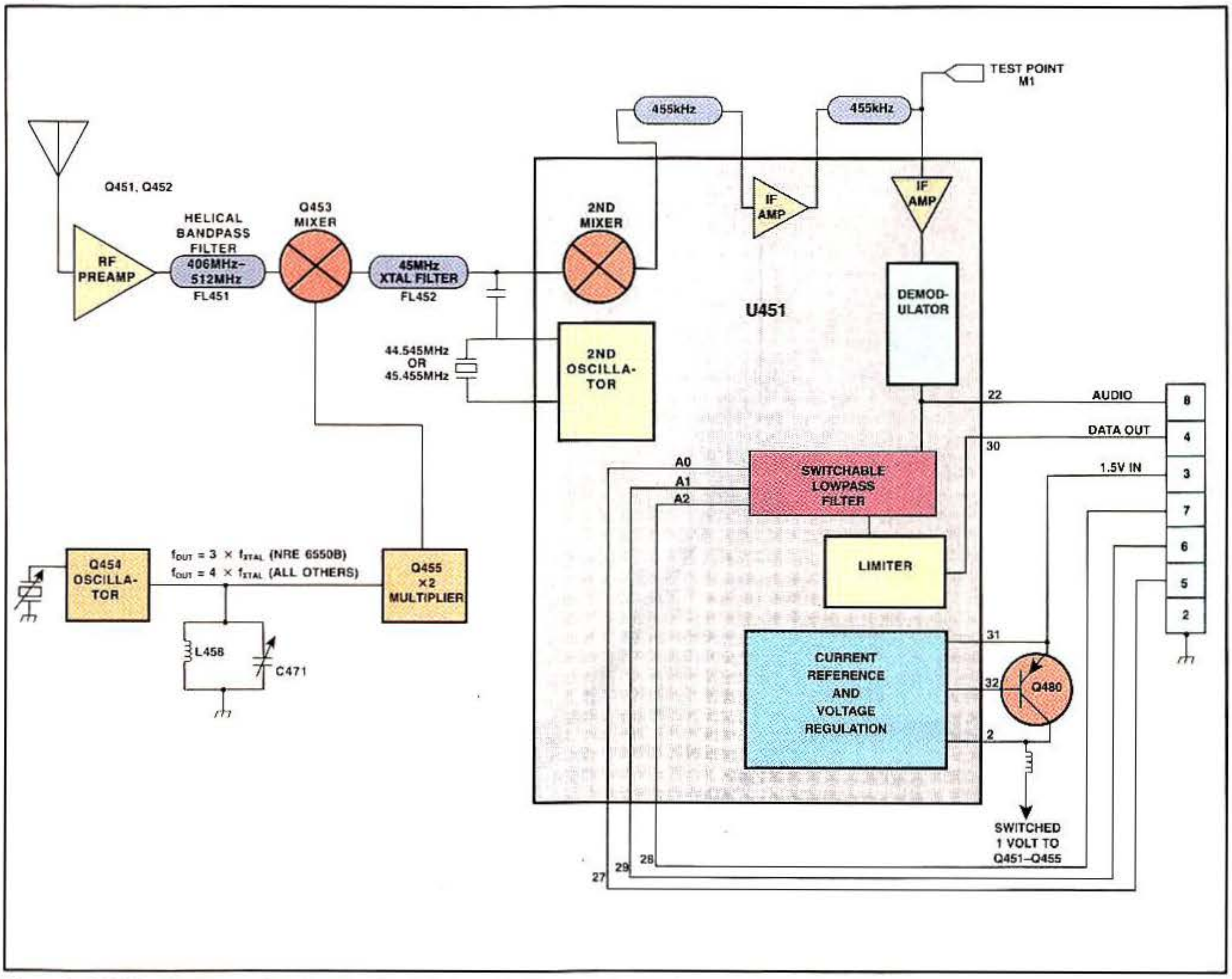


Figure 3. 406MHz–512MHz receiver boards. See text for multiplier operation details.

the loop antenna. Diode CR451 prevents damage by clamping any excessive signal levels to ground. The resulting amplified 406MHz–512MHz signal is injected through FL451, a helical filter generally broad enough to pass a 15MHz range without significant band-edge attenuation. The preamplified and filtered signal is then presented to the base of Q453, the first mixer.

At the same time, Q454 operates as a Colpitts crystal oscillator with a bit of L455 slug-tuning applied. This tuning allows the crystal oscillator to be centered at the required frequency to decode the paging signal properly. (See "Tales Crystal Filters Tell ..." in the October 1994 issue.) The Q454 output is actually either three or four times the crystal frequency. In the NRE6550B, the values chosen for Q454's collector resonate at

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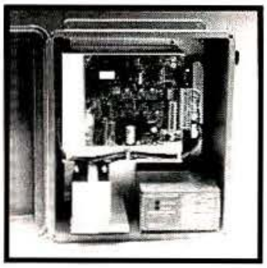

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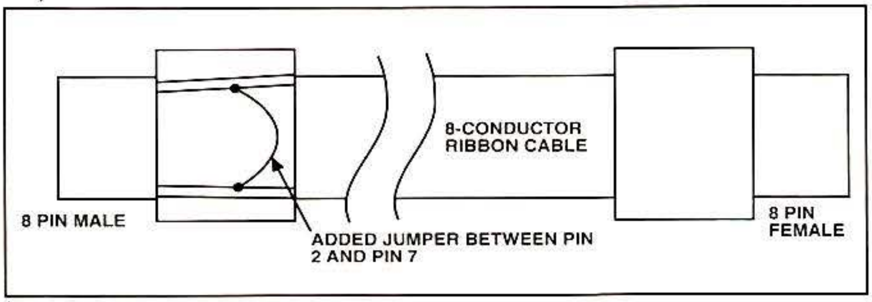
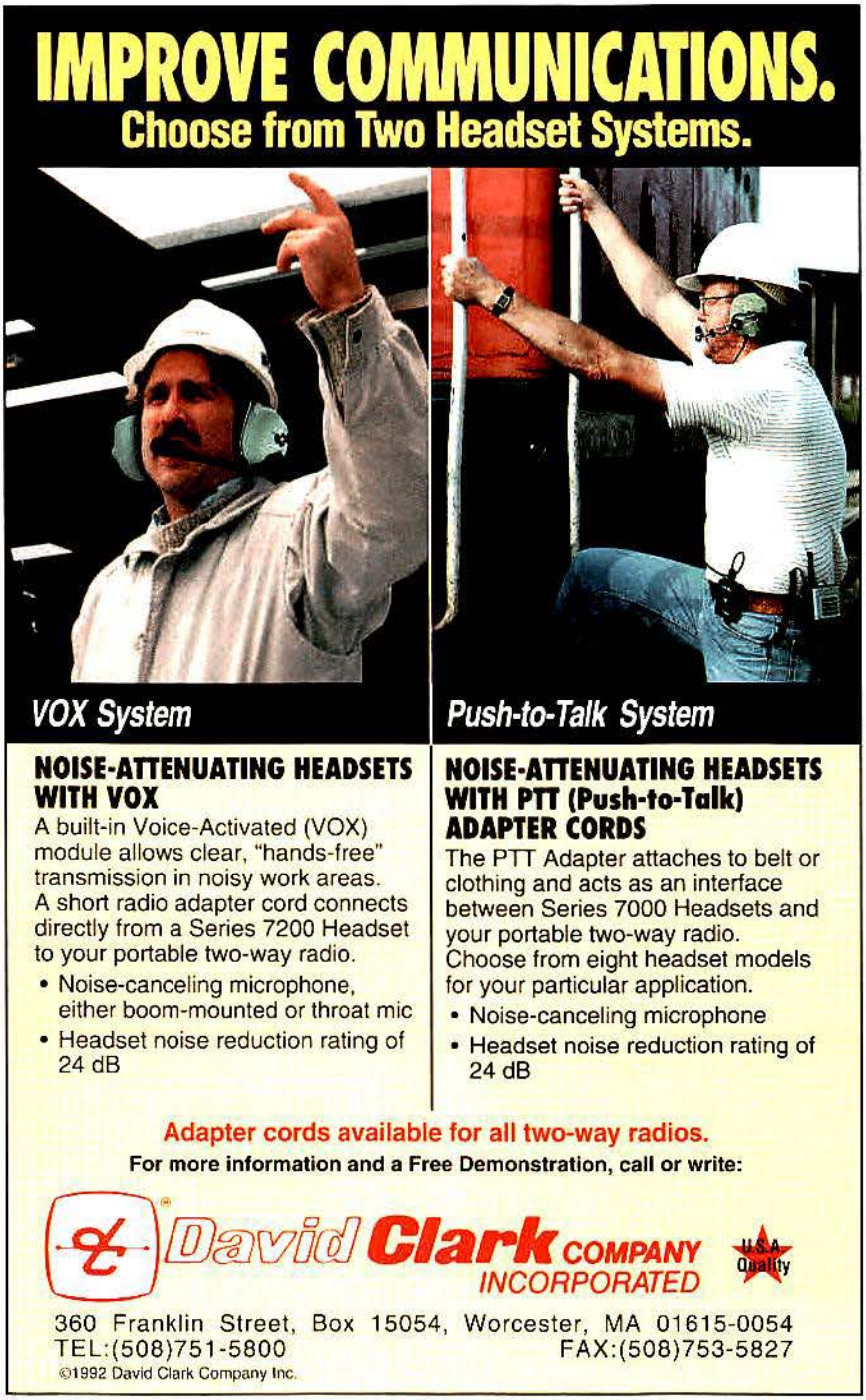


Figure 4. Modification to extender cable for Bravo Plus and Express pagers (*not* for Bravo). See text for details.



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roughly three times the crystal frequency. All other NRE-series receivers are tuned to four times the crystal frequency.

Capacitively coupled, this three-or-four times crystal-frequency signal is applied to another filter (L458 and C471) that removes virtually all other frequencies besides the multiplied signal output. Q455 operates as a frequency doubler, yielding an overall output frequency of either six or eight times the crystal frequency. This signal is also applied to the base of mixer Q453.

Q453 (in the case of a NRE6552B) receives an oscillator frequency of eight times 50.6363MHz (405.09MHz) and an incoming range of frequencies that is determined by the bandwidth of the 450MHz–465MHz helical filter. Limited to a crystal frequency of 45.0MHz for the center of its response, signals around 405.09MHz + 45.000MHz = 450.09MHz are passed for further processing and decoding.

The crystal used for the second oscillator *should* be color coded brown for 45.455MHz and violet for 44.545MHz. The 45.455MHz version probably will require *data inversion*. (Respond YES to the programmer when the CUSTOMER REQUIRES DATA INVERSION prompt appears.) The 44.545MHz version probably will *not* require data inversion. *In either case, tune the crystal frequency for the first strong peak on the IFFER as the slug is tuned clockwise into the core.* (Again, see "Tales Crystal Filters Tell ..." in the October 1994 issue.)

Capacitive coupling is used to feed the second oscillator output into the second mixer within "jungle chip" U451, so called because of its complexity. At this point, the signal passing through FL452 is mixed with the second oscillator output to produce an output of 455kHz. This 455kHz signal is amplified through a pair of intermediate frequency (IF) amplifiers, and then demodulated by a quadrature detector. Audio output is brought out through the chip's pin 22 and also presented to the switchable lowpass filter. Line A2 (pin 28) is enabled by the battery-save strobe. Lines A0 and A1 (pins 27 and 29, respectively) control the bandpass characteristics of the signal that reaches the limiter. The signal is subsequently processed as output data.

There is an undocumented (and virtually unknown) feature of the Plus and the Express that may help you if you conduct extensive troubleshooting on either circuit board. On the jumper-cable used to interconnect these boards, place a jumper between pins 2 (ground) and 7 (A2) as shown in Figure 4 on page 24. This jumper allows the receiver to operate "full-time" while the microprocessor continues to perform all of its "housekeeping" and "decoding" chores. An on-frequency POCSAG signal with a matching capcode and baud-rate will cause a "full-response" (alarm active for length of time determined when programmed). When troubleshooting, this utility should be of considerable value.

To this point ...

Many telephone calls have been received regarding some of the pagers that have been troublesome. One complaint is that there is a strong signal at test point M1 but no subsequent decoding. Test point M1 is far removed from the actual demodulating stage (as shown in Figure 2). It is certainly possible to have a perfectly working "receiver" at 455kHz but nothing coming from the demodulator or audio stages. I use a dual-trace scope to look at what is available for both audio and data (pins 8 and 4 on the Plus and Express receiver boards' interconnect block). That "jungle-chip" does not stop at the IF! Keep a few test receiver and decoder boards around and try replacing suspected faulty boards with known good boards. If the signal at M1 looks good but decoding does not take place until the receiver board is replaced, then the demodulator or signal-processing section of the jungle-chip is falling down. Often, this failure may be traced to a loose chip capacitor or resistor.

Another problem is locating the operations frequency of some pager with its crystal-frequency marking positioned away from a viewing plane. The Ramsey Com 3 service monitor provides a programmable offset frequency, which I have set to 0.0250MHz for all pager frequencies. Merely putting the Ramsey into *generate* mode with a 1kHz tone allows me to sequentially move the frequency up or down in 0.0250MHz steps. This single feature of the Com 3 has saved countless hours of removing crystals and performing the math to calculate the operating frequency! On the Com 3, press *CLR*, enter .0250, press *STO* and *OFFSET* +. The same offset is useful on 450MHz. A tip of my hat to Ramsey!

There also has been mention of the "single-board Motorola pagers." These pagers basically are early versions of the two-board Bravo units and *may or may not* be worth the time to explain. To program them, select "BAB" on the programmer. To get them to work properly usually requires setting them for data inversion (DI=Y). The operating frequency is marked on the voltage-controlled oscillator (VCO) module on the rear side of the board. The chart provided in "Servicing Pagers: Frequencies, Coding Formats" (March 1994 issue) indicates the coding language and speed of the various decoder chips. I have not spent enough time to decide the various test points or what they signify in these "old-timers."

Motorola has introduced a conversion for the Bravo programmer that everyone will find valuable. This conversion consists of a new "ground" pin that physically connects to the logic board's negative battery tab and some new software to program the POCSAG "blob-chip." Newer versions of the decoder chip are no

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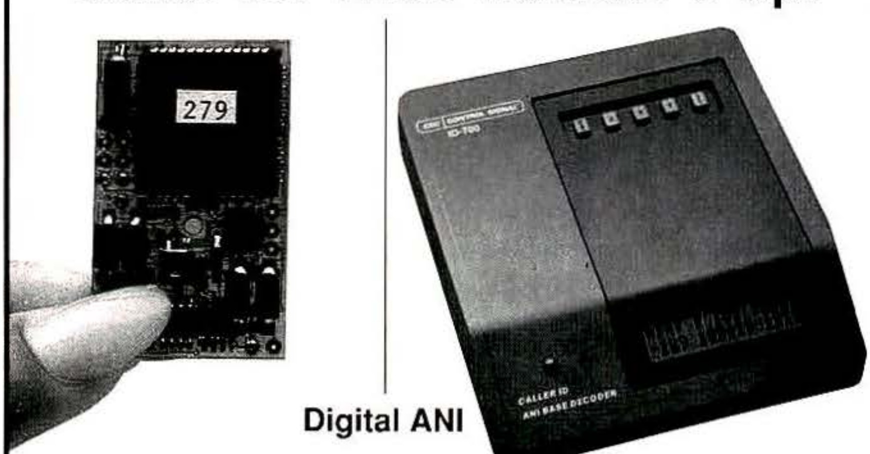

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longer covered with a ceramic "lid"; instead, they are covered with an epoxy-filled "blob." These chips *may or may not* be programmable using the unmodified programmer. Different voltage levels are used to program the codeplugs. Modifications are performed at all Motorola pager service centers.

One further note regarding the "missing page" problem. Everything in the Bravo family of pagers allows a choice for a function known as "beep on bad data" (BBD on the Bravo). Invariably, I set this function to YES because it defeats the need for a perfect checksum before displaying a message. This is enough to compensate for bad reception associated with signal overlap and weak signals. More on this next edition.

When the pager is set this way, the message display degenerates to a string of Es when the receiver board drifts off frequency or becomes nearly deaf to the transmitters. At the service bench, we either realign the oscillator and check the antenna tuning or replace the entire receiver board with a good one.

Acknowledgement

I would like to thank the management and staff of Toltec Communications Resources, Pasadena, TX, for their help with this project.

Pager servicing series

Part 1: "Build a Shielded Room," January 1994. (All pagers.)
Part 2: "Build an 'IFFER,'" February 1994. (Bravo, Bravo Plus, Bravo Express.)
Part 3: "Frequencies, Coding Formats, March 1994. (Bravo.)
Part 4: "From Bench to Programmer," April 1994. (Bravo.)
Part 5: "The Receivers," May 1994. (Bravo.)
Part 6: "Elegant Simplicity," June 1994. (Bravo.)
Part 7: "Problems in Paradise," July 1994. (Bravo.)
Part 8: "406MHz–512MHz Receivers," August 1994. (Bravo.)
Part 9: "150MHz Receivers," September 1994. (Bravo.)
Part 10: "Tales Crystal Filters Tell ...," October 1994. (Bravo, Bravo Plus, Bravo Express.)
Part 11: "Microprocessor Board," November 1994. (Bravo.)
Part 12: "Headaches (and Some Aspirin)," January 1995. (Bravo.)
Part 13: "Mixed Signals," February 1995. (Bravo.)
Part 14: "Essential Differences," April 1995. (Bravo Plus, Bravo Express.)
Part 15: "And You Shall Receiver Knowledge...," June 1995. (Bravo Plus, Bravo Express.)
Part 16: "The Information Highway," July 1995. (Bravo Plus, Bravo Express.)
Part 17: "450MHz Receiver Boards," August 1995. (Bravo Plus, Bravo Express.)

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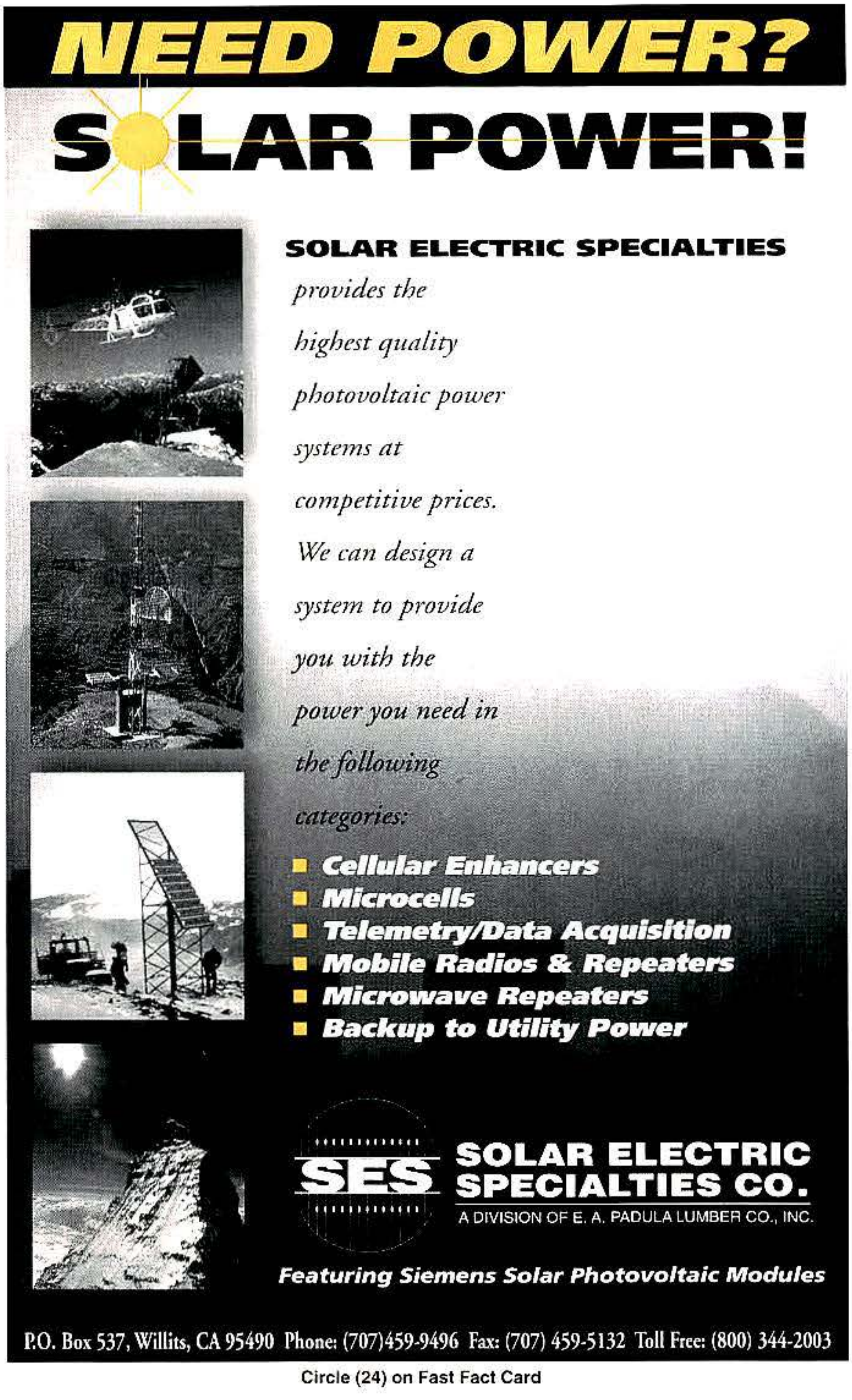

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November 1995

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Cable test equipment, p. 12

- Servicing pagers
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Servicing pagers: Logic/decoder boards for Bravo Plus, Bravo Express

Part 18—Circuit descriptions unlock some of the mysteries about Bravo Plus and Bravo Express pagers. Miniaturization may defeat some repair attempts, but other faults can be remedied in a well-equipped service shop.

By David Ludvigson

The November 1994 article "Servicing Pagers: Microprocessor Board" introduced you to the Motorola Bravo pager's logic board. With that information as a background, this article covers the Bravo Plus version of the same board. Part number references can be found in the appropriate Motorola technical manuals.

The 'wake-up call'

As the Bravo Plus is first activated, a RESET is performed at pin 78 of the microprocessor (U025). This pin is held "low" for the time it takes to charge capacitor C5, and this "master RESET" causes the entire pager to perform the following operations:

(1) The power supply and voltage doubler circuitry is enabled. This action provides the 3V power to operate the entire microprocessor and logic functions.

(2) Once the 3V supply is operating smoothly and verified by proper operation at U023, the clock oscillator should be churning out a signal at 38.4kHz (pin 71, U025).

(3) With the 38.4kHz clock signal operating and the RESET invoked, the microprocessor address counter is reset to the lowest register. Each subsequent clock cycle (coming through an appropriate divider network) moves the operating system up, one notch at a time, through a copyrighted Motorola program. Although no portion of that program is divulged here, it is possible to observe several functions and to identify "what occurs when" to help with troubleshooting this remarkable board.

As the wake-up call proceeds, information stored in the codeplug (U024) is transferred from pin 2 of U024 to pin 2 of the microprocessor (U025), where the data are stored in various registers located in U025. This information includes everything that was programmed using the software, along with some mathematically derived information. More on this in a bit (or is it "byte"?).

Once the information transfers from the codeplug, the clock moves through each succeeding register, performing each software instruction located at each register. These instructions include testing the current position of various switches, testing battery status, testing 3V level status, resetting the "wake-up" for the liquid crystal display (LCD) to display a full-segment load of 12 digits, and then settling down to a time display in the window. The characteristic "four sets of two chirps" and the flash of DS021 round out the light-and-trumpet show, and the Bravo Plus is ready to begin its day.

Ludvigson is a technician in Houston.

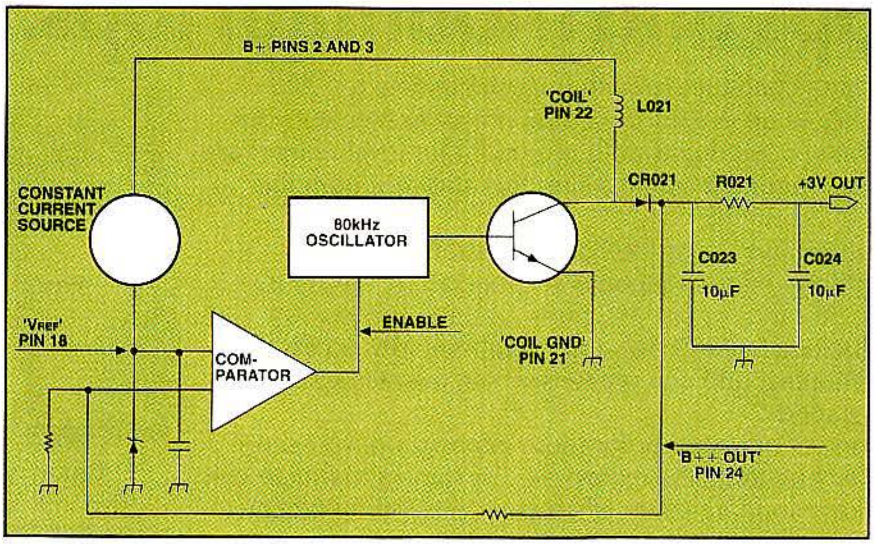

Figure 1. Few portions of the Bravo pager family are as important as the U023 3V power supply shown in this block-and-equivalent circuit diagram. This supply maintains the operating voltage for the microprocessor and logic circuitry. Without it, the pager would be nothing more than a radio receiver.

The 3V power supply

Few portions of the Bravo pager family are as important as the 3V power supply. (See Figure 1 to the left.) This supply maintains the operating voltage for the microprocessor and logic circuitry, and without it the pager would be nothing more than a radio receiver.

References cited in the pager servicing series

Bravo pagers

Service Manual (138MHz–174MHz) 68P81047C75-C
Service Manual (406MHz–512MHz) 68P81047C80-C
Service Manual (929MHz–932MHz) 68P81006B85-C

Bravo Plus pagers

Service Manual (138MHz–174MHz) 68P81012B20-A
Service Manual (406MHz–512MHz) 68P81012B25-A
Service Manual (929MHz–932MHz) 68P81012B30-A

Bravo Express Series:

Service Manual (929MHz–932MHz) 6881013B15-B
Service Manual (450MHz–480MHz) 6881013B10-0
Service Manual (138MHz–174MHz) 6881013B05-A

Programming equipment:

Bravo Portable Programmer NLN-3163A
Bravo Plus/Express Interface NLN-3548B
Bravo Plus Fixture/Program NLN-3640A
Bravo Express Fixture/Program NLN-3723A

For technical assistance:

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The "internals" of U023 contain a switchmode power supply. Essentially, a switchmode power supply is an energy transfer method. The flux energy stored in an inductor is added to energy already present on a dc power rail, using a technique called *step-up mode*.

In the case of the Bravo Plus, an oscillator operating at about 80kHz is gated to provide driving current to an output transistor. As configured, energy stored in the external inductor (L021) is momentarily placed in *series-aiding* mode with the source voltage of 1.5V. As the transistor is toggled, energy is alternately stored in L021 as the transistor saturates, and then placed in *series-aiding* mode with the source voltage as the transistor comes out of saturation. The toggled 80kHz square wave is rectified by CR021, filtered by a 10µF capacitor (C023), and decoupled by R021 and C024, providing a little more than 3V output.

The B++ output is deceptive—this is *not* the actual output of the supply, but a means of resistive tapping to provide a reference feedback voltage to be compared at the voltage reference (V_{REF}), pin 18, U023. An internal comparator is constantly checked and toggled to cause the 80kHz oscillator

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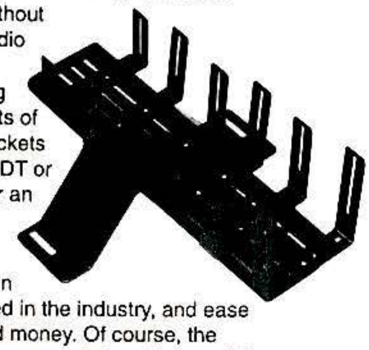

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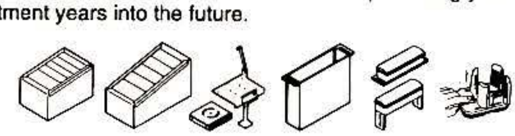

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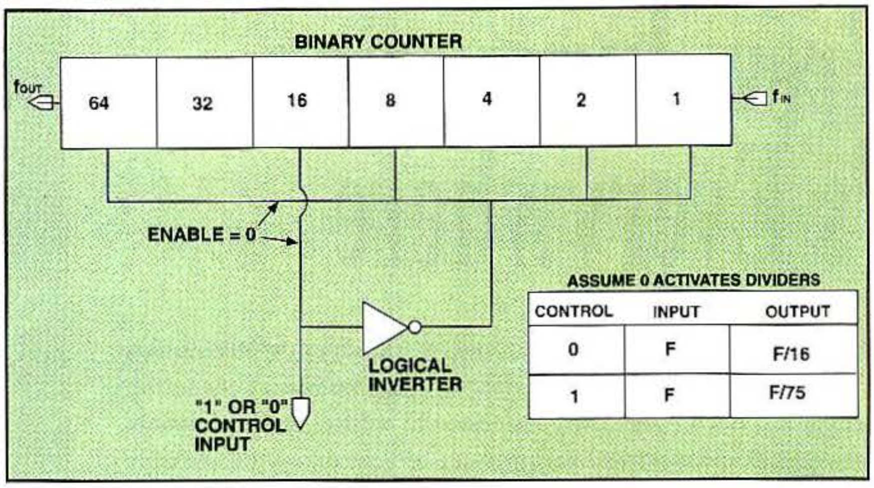

Figure 2. One method of control for the binary counter and divider stages of the Bravo Plus pager.

to provide adequate signal to keep the charge-discharge cycle across L021 operative and to maintain the required output voltage. Overall, this is a sophisticated supply, but it cannot handle much output current.

Meanwhile, back at the microprocessor . . .

Remember the information loaded from the codeplug contains both *instructional* and *mathematically derived* data. The instructional data contain responses programmed to such prompts as BEEP ON BAD DATA Y/N or SILENT MODE CHIRP Y/N. These instructional data represent bit patterns that are simple yes/no instructions.

The mathematically derived information is dependent on the capcode entered and (to some extent) by the baud (actually, bits per second [bps]) rate selected in the first screen of the programming session. As described in the November 1994 article, the capcode *mathematically* determines which *frame* will be used to seek the capcode.

In the case of the Bravo Plus and Bravo Express pagers, the baud (bps) rate also determines a division ratio that places the pager in a synchronous mode compatible with the selected POCSAG data rate.

The choice of 38.4kHz for the clock oscillator was *not* arbitrary. When divided by 75, the resulting frequency is 512Hz; when divided by 32, the resulting frequency is 1,200Hz; and when divided by 16, the resulting frequency is 2,400Hz. In any of these cases, a simple binary divider would suffice nicely to provide an accurate time base to match the baud rate of a POCSAG signal. (See Figure 2 above left.)

Those familiar with programming the Plus and the Express have long been familiar with the fact that some versions program to 512 baud or 2,400 baud, but not to both, and all of them program to 1,200 baud.

This difference is because one version of the microprocessor has both a divide-

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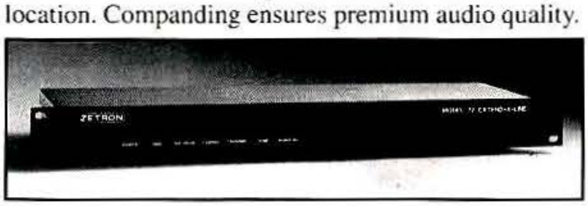

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by-75 and a divide-by-32 binary counter, although another version contains the divide-by-32 and the divide-by-16 binary counter. In both cases, the division ratio may be set with either a *1* or a *0* controlling the clock's output frequency. (See Figure 2.)

Further housekeeping chores (e.g., 12/24-hour time displays and vibrator on-off functions) are directed to specific addresses within the processor's memory map to be performed at the appropriate times.

The 'I'm looking for it' mode

Once past the wake-up mode, the pager goes into an alternating on-off mode, turning the receiver board on briefly and then turning it off. The length of on-off timing is governed by the bps (baud) rate determined at the programmer and is directly controlled by the division ratio just discussed.

The pager is looking for two basic signals, either the alternating "*1010 ...*," 576-bit repetition signaling the beginning of a POCSAG transmission or the unique, 32-bit "word" that contains the *frame sync code*. If the "*1010 ...*" sequence is found, the pager responds by lengthening the receiver's *on* time. If the *frame sync word* is found, the pager immediately resets the *frame counter* to zero and turns *on* at the *frame* appropriate to the capcode programmed to that pager.

Each *frame* (1 through 8) contains 64 bits organized as 32 bits for *capcode* and *parity*, and the following 32 bits contain the remaining information that will be displayed as a message, plus the same check sum.

The *capcode/parity* portion starts out with the first bit always being a zero. Bits 2 through 19 contain the capcode, and bits 20 and 21 identify the "source" of the pager call (a throwback to the day when pager calls were identified by the letters *A* through *D* to identify who was calling). It is the remaining bits' function (bits 22 through 32) to report parity tests performed on the message. These tests are used at the pager to verify accurate message reception.

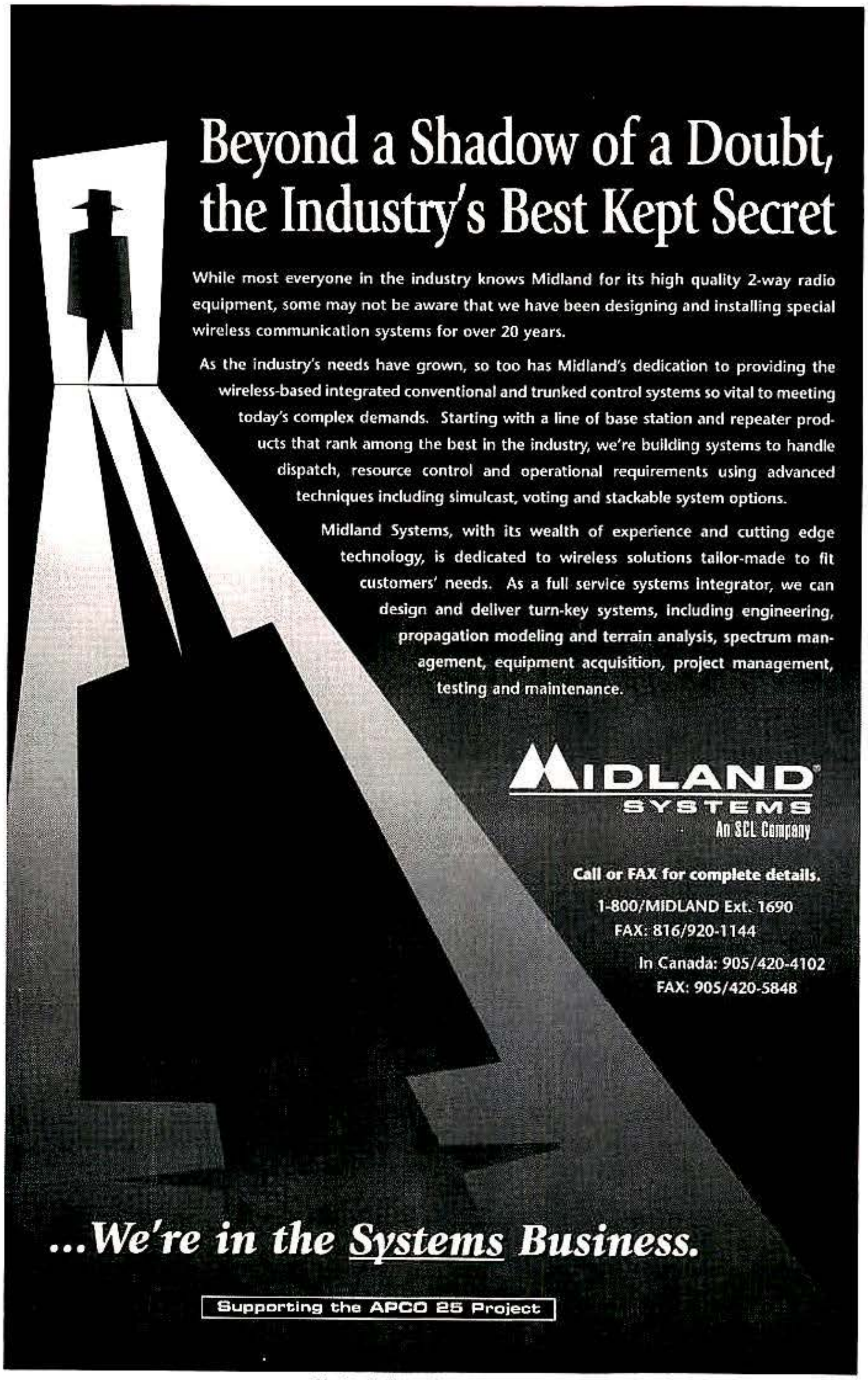
If the values in these last 10 bits are not matched by the parity values received at the pager, the message is then turned over to a decision made at the programmer. BEEP ON BAD DATA = N prevents any response from the pager. BEEP ON BAD DATA = Y allows the message to be displayed with the letter *E* filling whatever portion of the message that did not match the calculated parity values.

It was mentioned earlier that the "*1010 ...*," 576-bit alternating *preamble sequence* of the POCSAG signal is monitored by the receiver. The speed at which this sequence is sent *must* be matched by the receiver to provide synchronous detection. Unless the receiver "sees" the alternating "*1010 ...*" *preamble sequence*, it remains in its "relaxed" on-off cycle, waiting for something to happen.

Similarly, if the *frame sync* happens to be sent at the same time the pager receiver is on, a proper decoding of the frame sync signal immediately resets the *frame counter* to zero and turns the pager receiver on again at the appropriate frame. Unmatched baud rates prevent the pager from responding to any portion of the frame sync or preamble signals.

The 'Storing it away!" mode

Upon receiving and properly acknowledging a page, the pager transfers



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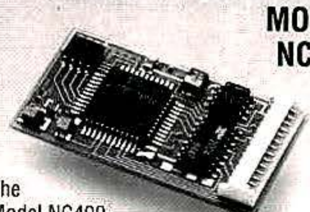

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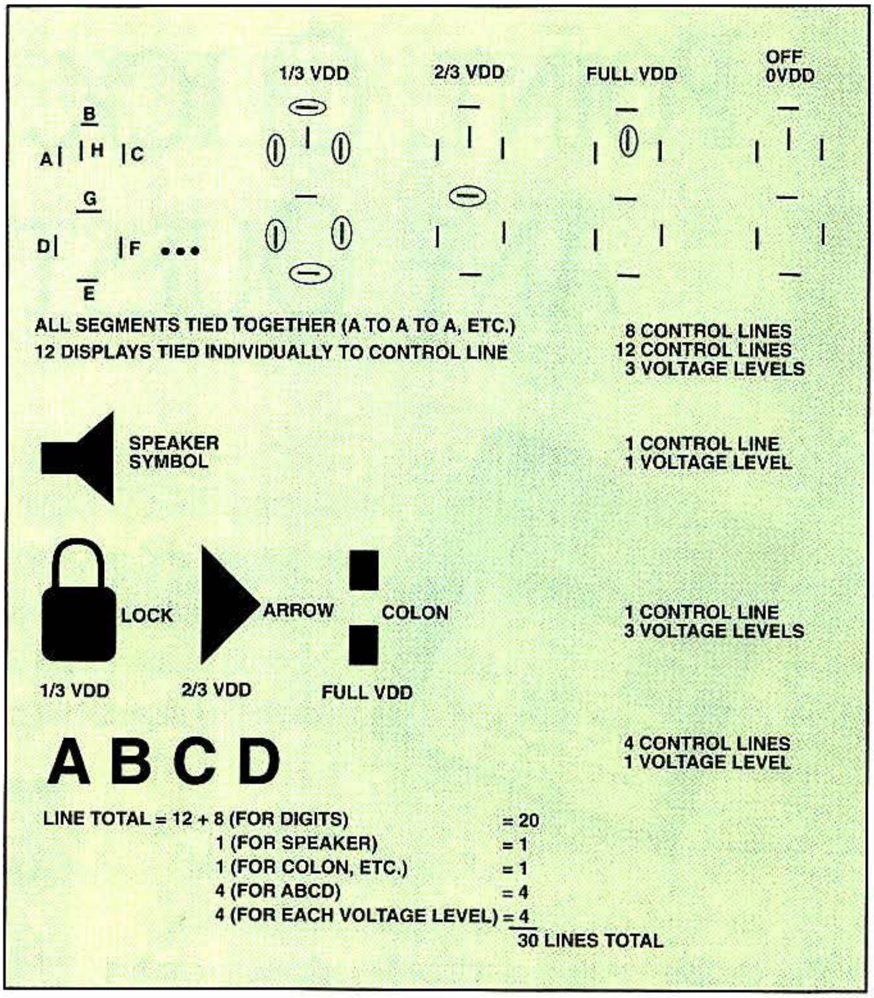


Figure 3. The liquid crystal display (LCD) consists of 12 eight-segment displays, eight special-function displays (arrow, speaker, lock, colon, A, B, C and D) and the "wake-up" display (all segments, all displays). These displays are controlled by 30 active connections between the output of the microprocessor and the display.

the 32-bit message to electronic memory, where it is stored in RAM (random access memory). The RAM has enough capacity to store 16 numbers plus the arrival time of the page. If it may be assumed that 32 bits are used for the message, and 32 bits are used for the time-clock, then a 64 bits would be used for each message-clock combination. With 16 message-clock combinations, 1,024 bits would be needed in RAM to contain all of the messages. When the memory is full, an *overflow* message is generated.

Using the *lock/unlock* feature, several messages may be "locked" into memory. This action means that the remaining "unlocked" memory is used to handle incoming messages, preventing overwrites. Associated with each locked message is a padlock icon, indicating the locked condition. Removing the locked condition involves displaying the locked number or locked time display and pressing the black selector switch to remove the padlock symbol. RAM performs its own housekeeping by shifting memory contents up to the newly opened space and opening the bottom of RAM memory to allow a new message to occupy the newly opened 64-bit area.

New messages arrive at the Bravo Plus in an unlocked condition but may be maintained in RAM (depending upon how the pager is programmed), in which case the Bravo Plus may be turned off with no loss of messages. It is not until the *clear all* message is enacted (by pushing the gray push-button) that all unlocked messages are cleared from RAM. All locked messages must be unlocked before they become erasable.

Translating and displaying

The display consists of 12 eight-segment displays, eight special-function displays

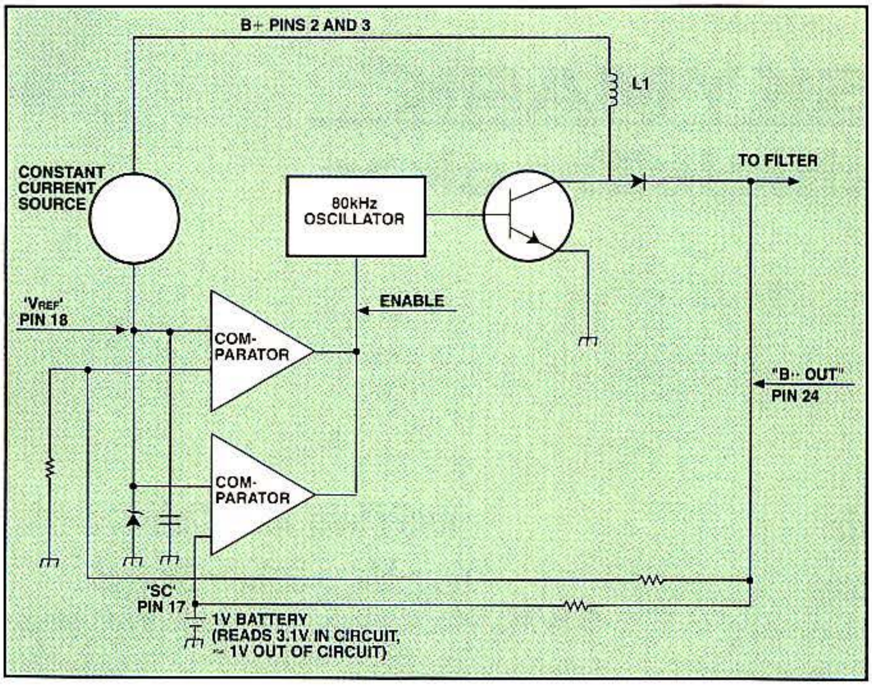
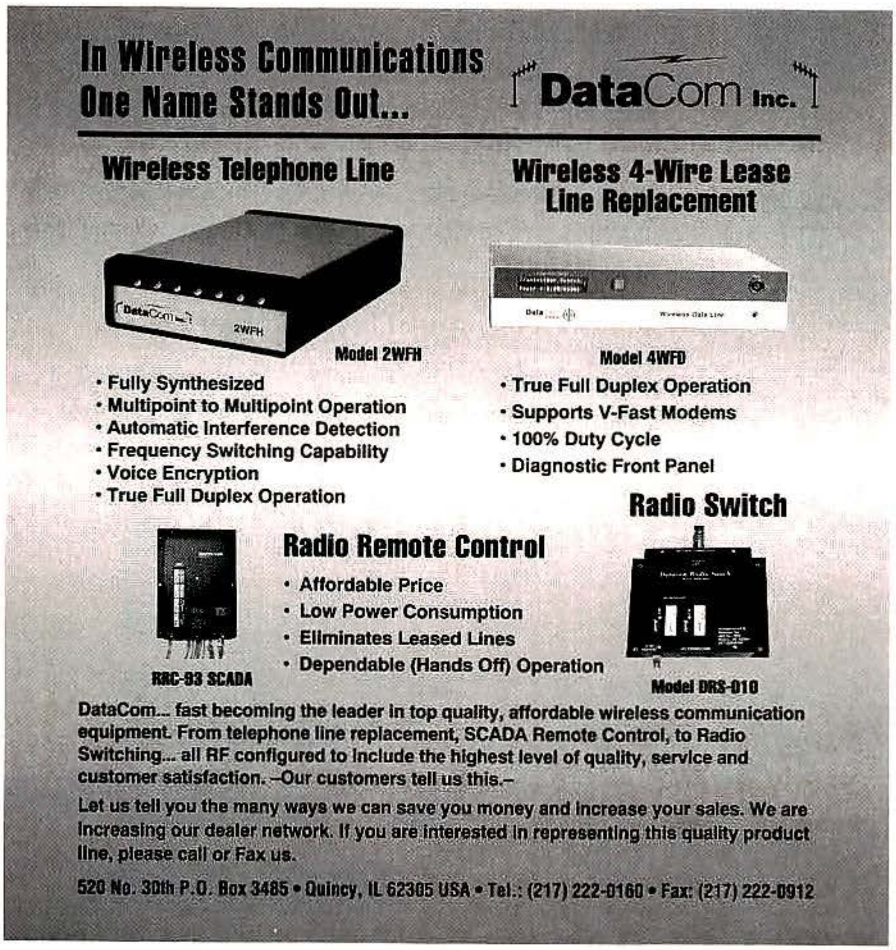


Figure 4.The Bravo Express U2 power supply chip uses an onboard battery to maintain the VCC voltage to the real-time clock when the power has been shut down, as shown in this block-and-equivalent circuit diagram. This single feature allows an internal timer to compare *master on* and *master off* times (set by the user) and to transfer control to or from the AAA-size battery as a source of main power.



Circle (19) on Fast Fact Card

(arrow, speaker, lock, colon, A, B, C and D), and the "wake-up" display (all segments, all displays). These displays are controlled by 30 active connections between the output of the microprocessor and the display.

There are four "backplane" voltage levels and control lines. Individual voltage steps of 0, 1/3, 2/3 and full VDD are applied to these four lines, which activate separate LCD planes within the crystal display. *Zero* equals *off*.

There are 12 eight-segment displays. Assuming that a typical multiplex arrangement is used, these 12 displays would be controlled by 8 + 12 = 20 lines. These lines are used in conjunction with the four backplane voltages to provide numeric data. (See Figure 3 on page 24.)

The *speaker* display uses a single control line and a voltage level to display the symbol to the screen.

Lock, arrow and *colon* share a single control line and use the available three levels of display planes to darken the appropriate symbol. Otherwise, the set of displays remains inactive (VDD = 0).

Letters *A, B, C* and *D* are controlled by four control lines and a single display plane/voltage level.

The line total equals the following:

12 + 8 (for digits) =	20
1 (for *speaker*) =	1
1 (for *colon, etc.*) =	1
4 (for *A, B, C* and *D*) =	4
4 (for voltage levels) =	4
	30

At best, the schematics are ambiguous ...

These are multiplexed displays, which means the average service shop is not going to be able to see (let alone fully diagnose) potential problems with the output from the microprocessor chip. If the display shows "stray" portions of some other voltage level's segments, replacing the contact strip and display often cures the problem. (The conductive ribbon might be touching an adjacent contact next to its own.) LCD replacement requires the proper set of tools and a bit of patience, but being able to do it is often worth the investment.

Notes on the Bravo Express

Refer to the appropriate Motorola schematics.

The previous information largely applies to the Bravo Express logic boards with the following exceptions:

First, the power supply chip uses an onboard battery (see pin SC of U2) to maintain the VCC voltage to the real-time clock when the power has been shut down. (See Figure 4 on page 26.) This single feature allows an internal timer to compare *master on* and *master off* times (set by the user) and to transfer control to or from the AAA-size battery as a source of main power. Compare the pinouts of U025 in the Bravo Plus with the pinouts of U1 in the Bravo Express. U025 and U1 are the same chip, just loaded with different software. U023 equals U2, and U024 equals U3 but the same programming software does not work on both pagers.

Second, the *Port A* register is configured differently, but this difference is largely just a matter of switch placement and the addition of *mode* and *select* switches to step the user through various features available in the Express.

Third, geographical territory on the logic board is limited. Only someone with a pair of eagle eyes and nerves of steel should attempt repairs to this board!

Acknowledgement

I would like to thank the management and staff of Toltec Communications Resources, Pasadena, TX, for their help with this project. Tel.: 713-947-7660.

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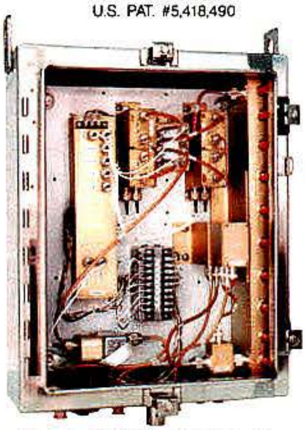

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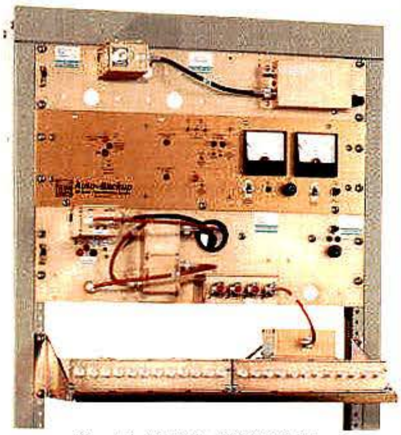

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Editor's note: The final installment in this article series will appear in the January 1996 issue. David Ludvigson has made an arrangement with the publisher such that, when the series is complete, he will offer a compilation of all the articles for purchase. Ludvigson also is preparing a videotape with pager servicing information based on his articles.

January 1996

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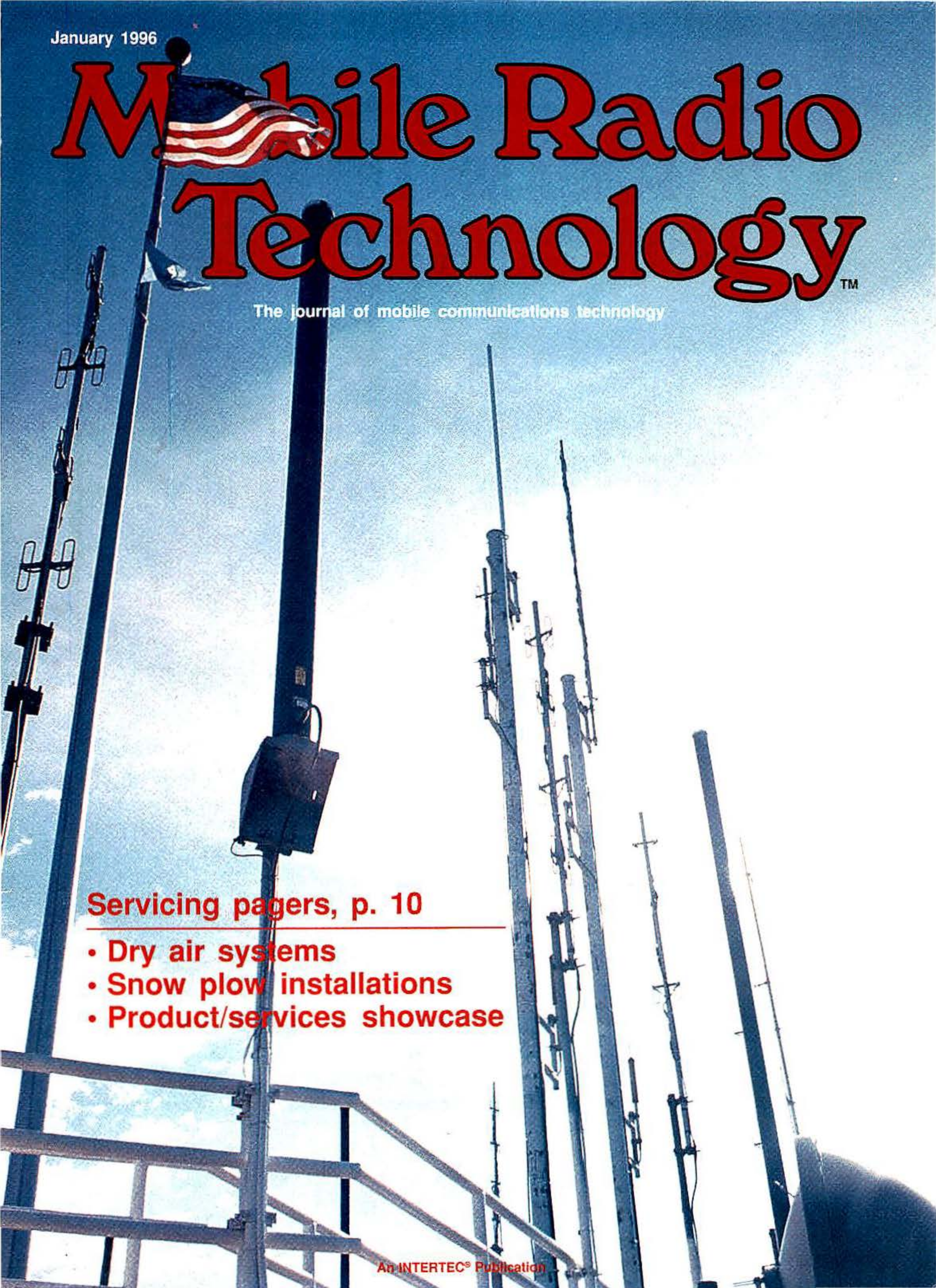

Servicing pagers, p. 10

- Dry air systems
- Snow plow installations
- Product/services showcase

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Servicing pagers: The 'tinfoil tomb'

Part 19—Use aluminum foil to build a do-it-yourself shielded room and overcome oxidation and breakage problems associated with rooms made of copper circuit-board material. Proper earth grounding plays a key role.

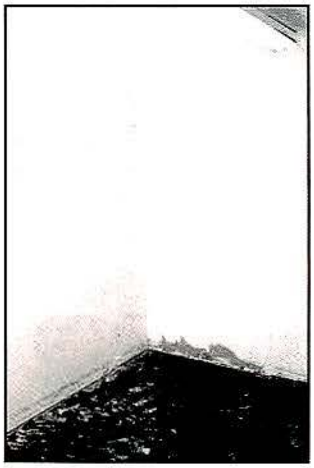

Photo 1. This is the northeast corner of an 8' × 9' × 7' room with a fluorescent light fixture near the center of the ceiling. The walls and ceiling are gypsum-board; the floor is 8-inch concrete.

Photo 2. Applying the shielding began by hanging 8-foot lengths of 15-inch aluminum foil directly on the wall. Overlapping pieces are stapled directly to the wall with office paper staples.

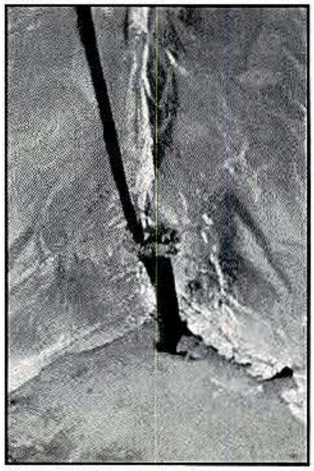

Photo 3. A hole is drilled through the concrete floor at the northeast junction, and a 4-foot-long, $^5/_8$-inch-diameter copper ground rod is driven into the underlying soil for an earth ground connection.

Photo 4. The No. 4 ground wire is bonded mechanically and electrically to the foil at the juncture of both walls and the floor. Foil-backed tape is applied to the entire length of each section's seam.

By David Ludvigson

"Servicing Pagers: Build a Shielded Room," the first article in this series (January 1994), described a do-it-yourself shielded room made of copper-clad, circuit-board material. I like to call it the "copper coffin," because receivers "die" when they are brought into the room.

Although the original design works well, it is difficult to build. Moreover, extended use has revealed the need for several modifications, and sometimes individual "tiles" of circuit-board material must be replaced for the room to retain effective shielding. Corrosion and the inevitable cracked circuit board require a "minesweeping" exercise with a transistor radio to locate RF leaks.

Ludvigson is a technician in Houston.

The copper coffin's costs were largely absorbed in the acquisition of several pieces of test equipment, but 70 tiles at $6 per tile (not including the intensive labor) added up to an expensive project. There had to be another way.

Some tests conducted at home used a 4-foot cube covered with aluminum foil sold for home use. The cube was connected to an earth ground, and a transistor radio placed within it could not receive a 1kW AM broadcast station three miles away.

The combination of a remodeling project at JJ Sounds and the maintenance problems with the copper coffin led us to try aluminum foil for RF shielding.

Photo 1 above left shows the northeast corner of a room measuring about 8' × 9' with an overall height of about seven feet. A single fluorescent fixture mounts in the center of the ceiling. The walls and ceiling are constructed of standard two-by-fours with gypsum-board walls and ceiling placed on an 8-inch concrete floor.

Construction began by hanging 8-foot lengths of 15-inch aluminum foil directly on the wall. Overlapping pieces were stapled with office paper staples directly to the wall. (See Photo 2 above.)

At the northeast junction of walls and floor, a single hole was drilled through the concrete and a 4-foot-long, $^5/_8$-inch-diameter copper ground rod was driven into the underlying soil. Without a connection to this ground, the surrounding foil has virtually no effect on receiver sensitivity to AM or FM broadcast stations. *If the room is not fully and completely earth grounded, it will not work.*

By the way, just because an electrician says a connection to a ground rod is good does not necessarily mean that it is. Photo 3 above shows oxidation around the clamp. Despite an electrician's opinion, the connection was not grounded. The clamp had to be removed, the rod cleaned and the clamp reset to make a truly effective ground. Perhaps the path of the copper rod abraded the oxidation on its way into the earth.

At this point, bringing a transistor radio near a grounded section of foil revealed some attenuation of broadcast band signals, but overlapping joints were leaking RF badly. Passing the broadcast band receiver next to a joint while applying enough pressure to seal the junction caused further signal reduction.

"Ground" is one thing to a radio communications technician. To an electrician, "ground" is *neutral*, and neutral may or may not have anything to do with an earth ground.

With respect to the "tinfoil tomb," the electrical service's earth ground is nearly 70 feet from the junction box used for power distribution to the shielded room. This earth ground consists of a ½-inch rod driven into the earth and clamped to the conduit that extends to the junction box. Several mechanical junctions of the conduit were physically separated from each other, and a few showed a dc short-circuit when an ohmmeter was connected

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Construction expenses for the shielded room included:

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Five rolls 2-inch × 50-yard aluminum tape	$14
Twelve 2 × 2-inch, 8-foot lengths of construction pine	$20
Four sheets 4 × 8-foot, ¾-inch plywood	$48
Five 2 × 4-inch, 8-foot lengths of construction pine	$14.50
Total cost of major building materials	$126.50
Two 4-foot copper ground rods	$60
Electrical work and materials	$400
Total cost of electrical labor and materials	$460

on either side of the mechanical junction.

To improve the grounding, another 5/8-inch copper rod was driven into the earth a few inches from the "grounded" conduit. An 8-foot length of No. 4 gauge stranded copper wire was run to the junction box, and *neutral*, whatever its electrical potential might have been, was *grounded*.

Electrical service to the "tinfoil tomb" consists of two independent branches, each on a separate 20A breaker. Four double outlets were used with sets 1 and 3 on one branch and sets 2 and 4 on the other.

Aluminum conduit and junctions were abraded to maintain "interruption-proof" dc integrity at each end before being joined mechanically. It is not enough merely to pass a green-coated wire through the conduit back to the earth ground, but that had better be done, too.

On each side of the ac line, in the outlet boxes, a 0.1μF, 600V bypass capacitor effectively reroutes to ground any RF coming down the power lines. Without these bypass capacitors, the transistor radio would "come alive" when passed near the outlets. These same capacitors render wireless intercoms nearly worthless as a means of room-to-room communications.

Photo 4 on page 10 shows the placement of a foil wrap around the No. 4 ground wire. This wire is grounded mechanically and electrically to the foil at the juncture of both walls and the floor.

Foil-backed tape is applied to the entire length of each section's seam. The seams could be taped with virtually any type of tape, but foil-backed tape maintains the visual monotony! Taping each seam prevents RF leakage through each junction.

The floor

Photo 5 on page 16 shows how a double-

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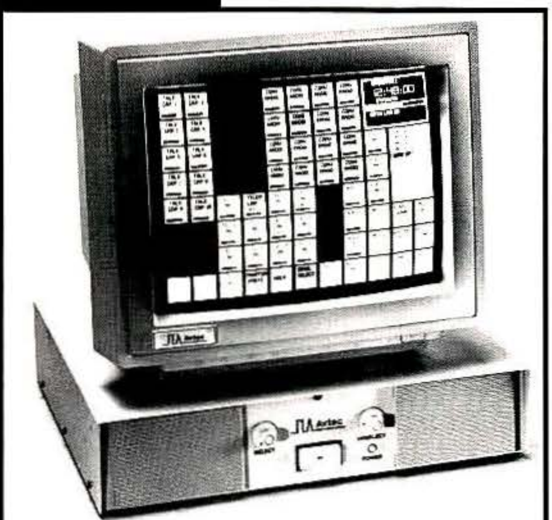

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Photo 5. A double-layer of foil on the floor is taped and bonded to the wall foil. Crosspieces will support the floor deck.

Photo 6. Foil-backed tape covers the bottom of the 2"×2" floor frame of interlocking crosspieces to maintain bonding even if the underlying foil becomes abraded.

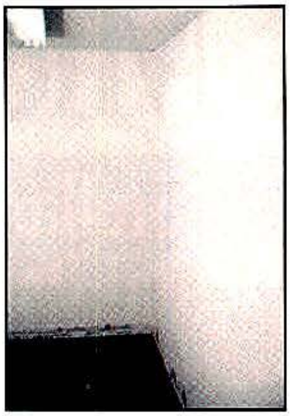


Photo 7. The southeast corner *before* shielding. The fluorescent light fixture requires bypassing and bonding to the foil.

Photo 8. The southeast corner *after* shielding. The foil, floor support lattice and electrical service boxes are put in place.

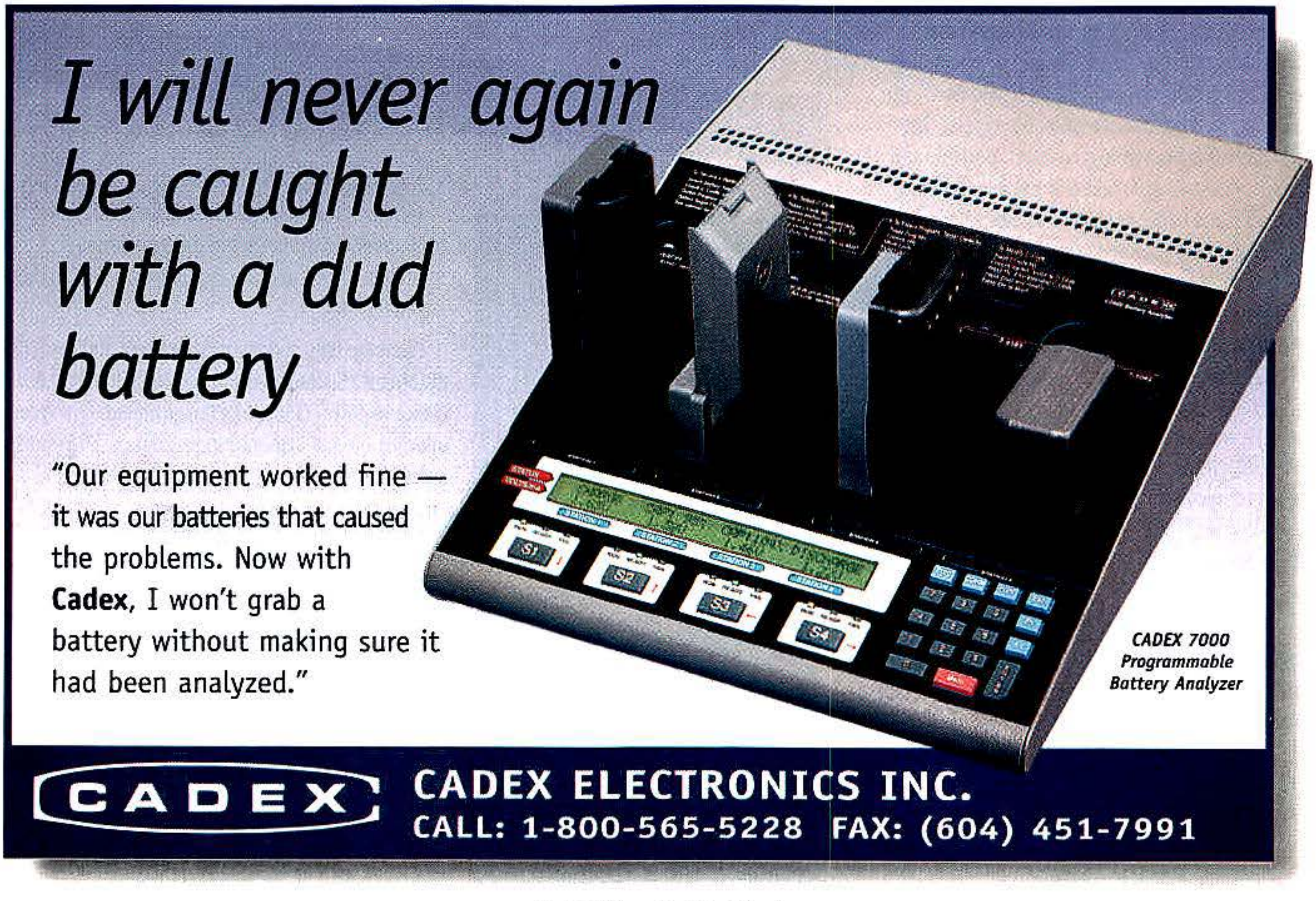
layer of foil is laid, taped and bonded to the protruding wall foil shown in Photo 2. Liberal use of foil-backed tape virtually hermetically seals the flooring to the walls.

John Espinoza's custom woodworking provided an interlocking 2" × 2" frame and filler crosspieces to support the ¾-inch plywood floor. Foil-backed tape covers the bottom of this frame to maintain bonding should the underlying foil be abraded. (See Photo 6 above.)

Photos 7 and 8 above right are *before* and *after* views of the southeast corner during construction.

Applying spray-on adhesive, Irving Johnson and John Espinoza covered the exposed ceiling (Photos 9 and 10 on page 18) and then placed the foil. (See Photos 11 and 12 on page 18.) Again, these overlapping junctions were stapled and taped to prevent RF leakage.

The dangling fluorescent light fixture was bypassed with capacitors (using the method described earlier) and bonded to the ceiling foil. A receiver picks up some residual hum near the fixture, but



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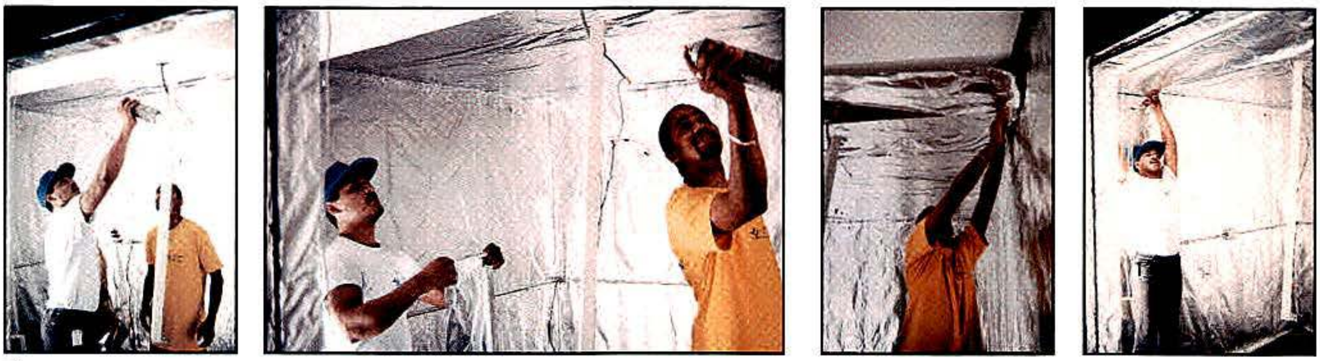

Photos 9-12. John Espinoza (on the left in the first two photos) and Irving Johnson cover the exposed ceiling with spray adhesive and then place the foil. The overlapping junctions are stapled and taped to prevent RF leakage.

RF signals are virtually eliminated.

Unlike the copper coffin, the door to the "tinfoil" tomb was simple to construct. Photo 13 on page 20 shows that a single layer of aluminum foil was simply stapled directly to the door, folded around the door thickness, and then taped to secure the gaps. The door jamb was treated similarly, becoming in essence an external laminate to the existing woodwork.

Flooring inside the "tinfoil tomb" is about two inches above the concrete floor at the entrance, so foil from the floor was form-fitted around a two-by-four used as a threshold. This configuration provides metal-to-metal contact between the threshold and the door when the door is closed. The elevated floor was covered with carpeting.

Next, a table was constructed along the north wall. This, too, was covered with aluminum foil and bonded to the walls. Over the tabletop, a layer of gray carpeting provides a bit of insulation from the foil. There is not much value in building a table that "shorts out" the circuitry being worked on.

Photos 14 and 15 on page 20 show the equipment setup. From left to right are a Panavise's mount used to secure various boards for servicing, a Ramsey COM 3 service monitor and a KNS Enterprises Cushman multifunction POCSAG/Golay generator.

The large black unit with the blue screen is a Tenma 72-920 40MHz dual-trace oscilloscope. Atop this unit is the modified AM radio described in the February 1994

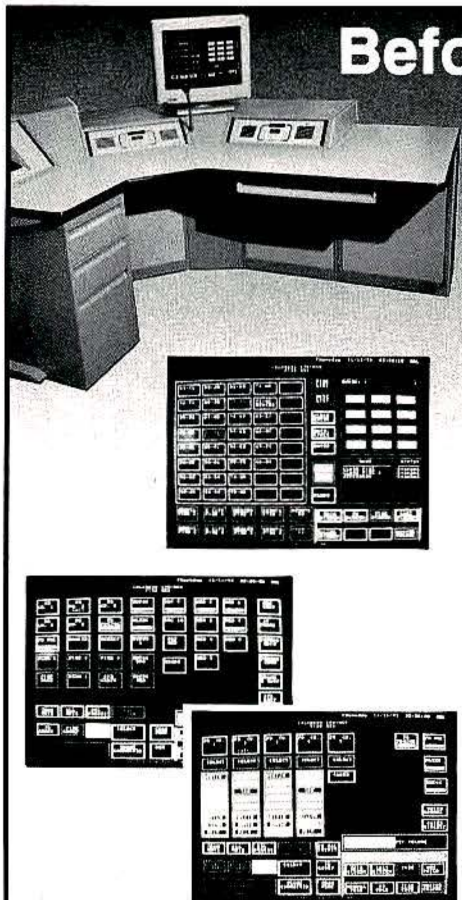

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Photo 13. Aluminum foil is stapled directly to the door, folded around it, and then taped to secure the gaps. The door jamb is treated similarly.

Photo 14. The table for equipment used to service pagers has been built in the northeast corner of the shielded room, close to the earth ground connection.

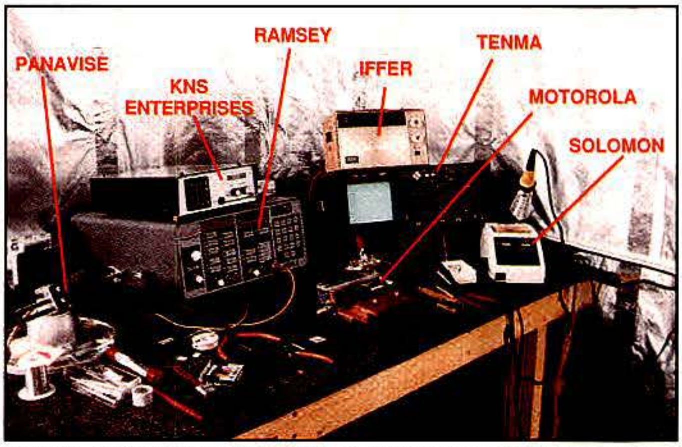

Photo 15. Equipment used for pager servicing includes a PanaVise mount, a Ramsey COM 3 service monitor, a KNS Enterprises Cushman multifunction POCSAG/Golay generator and a Tenma 72-920 40MHz dual-trace oscilloscope. Additional equipment includes an 'IFFER,' a Solomon Brothers SL-10 soldering station and a Motorola RTL 1005 radiation test fixture.

article "Servicing Pagers: Build an 'IFFER.'" A Solomon Brothers SL-10 soldering station (available from Micro Alarm Systems, 800-736-2999) provides temperature-controlled soldering convenience. For $42.50, it is a surprising value, and it includes a grounding post (guess where that is connected?) and multiple replacement tips.

At front and center is the Motorola RTL-1005 radiation test fixture, surrounded by hand tools and repair aids. In the white box next to the soldering station is a jeweler's loupe, a 10-power monocle that attaches to the eyeglass bow.

Project expenses are detailed in the box on page 14.

How does it work?

Preliminary testing shows little difference between the copper-circuit-board- and the aluminum-foil-shielded rooms. Both require excellent grounding, and both provide about 50dB of attenuation to 930MHz signals. With the aluminum version, copper oxidation is a thing of the past, and any RF leaks can be fixed with a patch of aluminum foil and aluminum tape.

With both rooms, RF has to be piped in by coax connectors to bring in enough signal for a pager to receive on-the-air signals. Received signal strength on a pager is roughly equivalent to that generated by the Ramsey Com 3 when the attenuator is at full minimum (X1 scale with variable attenuator set at minimum). The room *is* effective.

Acknowledgement

My thanks to Raymond Duran, Irving Johnson, John Espinoza and Leo Rodriguez at JJ Sounds and Communications, South Houston, TX, for their help with this project. Additional thanks go to the management and staff of Toltec Communications Resources, Pasadena, TX, for their help with this project. Tel. 713-947-7660. My thanks as well to readers who have called with thought-provoking questions and kind words about this article series.

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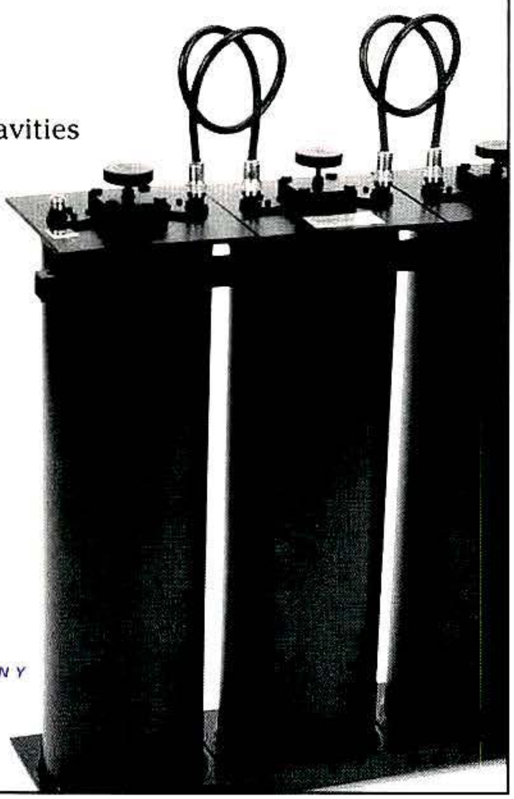

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