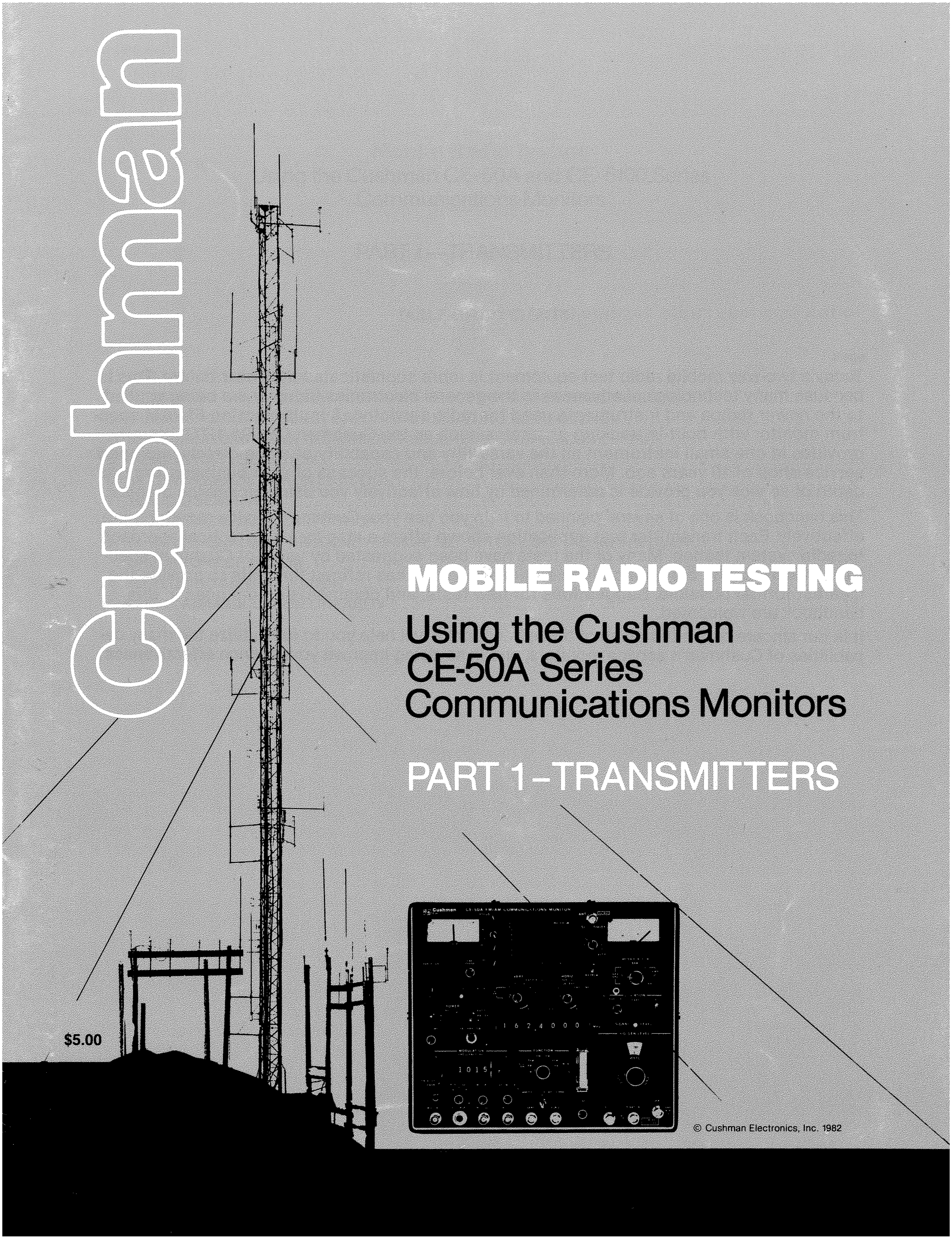

Cushman

MOBILE RADIO TESTING

Using the Cushman CE-50A Series Communications Monitors

PART 1–TRANSMITTERS

$5.00

To the two-way radio service technician . . .

Today's two-way mobile radio test equipment is more sophisticated than ever before. This is because many technological advances in the general electronics industry are being applied to the newer radios and instruments used for radio servicing. A multifunction FM/AM spectrum monitor with built-in tracking generator, such as the Cushman CE-50A-1/TG, literally provides in one small instrument all the versatility and capability of a completely equipped service shop of 10 years ago. More than ever before, the success of your business and the depth of service you provide is determined by how effectively you use your service monitor.

This handbook is one of several planned to help you use your Cushman service monitor more effectively. Each transmitter test application shown offers a step-by-step practical approach to radio system testing. Many of the tests have been suggested by users of Cushman spectrum monitors, and our applications engineering staff has refined the tests to provide the clearest format possible. Suggestions for new tests, and comments on the ones in this handbook are welcomed.

It is our sincere desire that each of these handbooks will help you to fully utilize the many capabilities of Cushman's service monitors, and in so doing improve your service effectiveness.

Mobile Radio Testing
Using the Cushman CE-50A and CE-5100 Series Communications Monitors

PART I—TRANSMITTERS

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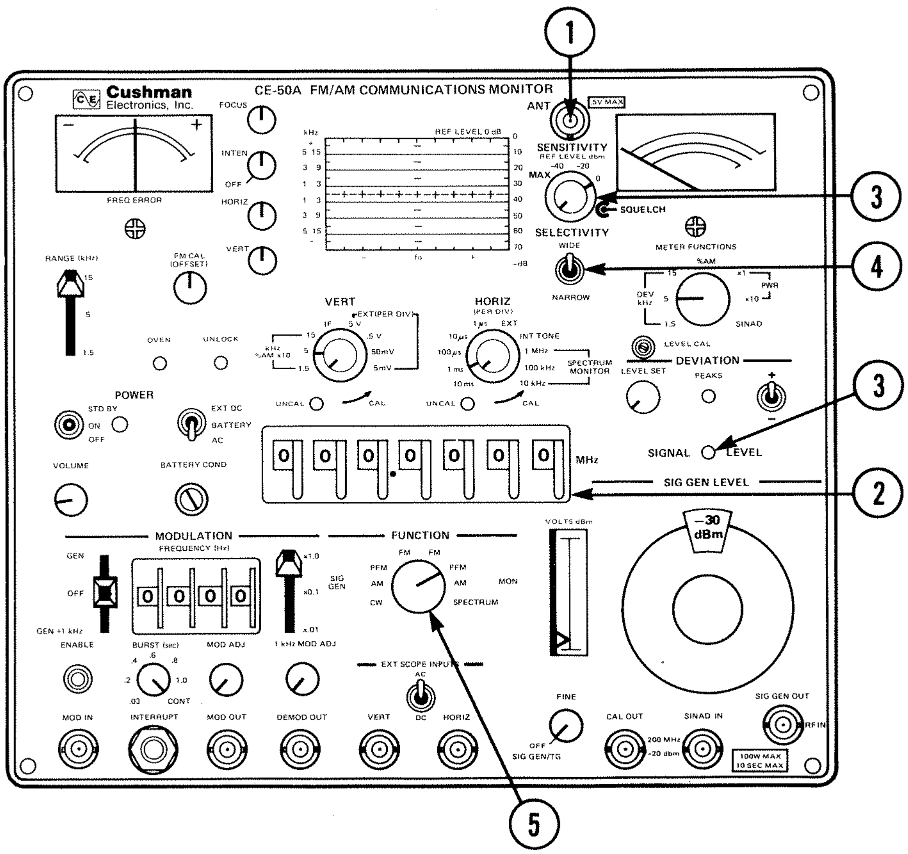
TRANSMITTER TEST TX-1

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series



TEST PROCEDURES:

1. Attach the antenna to the ANT IN connector.
2. Set the FREQUENCY SELECT switch to the frequency to be monitored.
3. Set the SENSITIVITY switch to REF LEVEL 0 dBm. Adjust the SQUELCH control until the SIGNAL LEVEL light turns on. Increase SENSITIVITY to -20 or -40 as needed to turn on the light.
4. SELECTIVITY switch. Use NARROW band filter for adjacent channel selectivity and use the WIDE band filter for deviation measurements.
5. Set the FUNCTION switch to MON; FM position for wide band FM, PFM position for narrow band FM (<5 kHz deviation) or to AM position for amplitude modulation.
6. Measure frequency error, deviation, % AM, Tx spurious signals, and tone signaling frequency as described in application notes; TX-2, 3, 5, 8, 9.

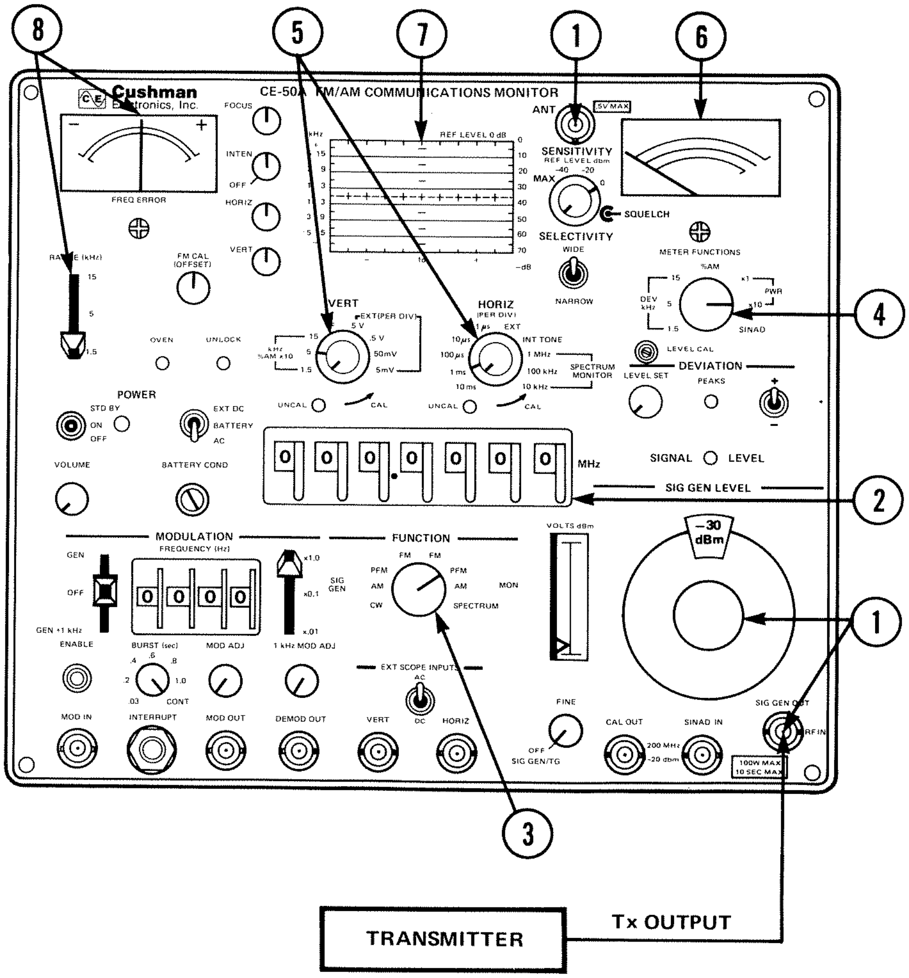
2μV sensitivity allows remote measurements of basic transmitter characteristics.

Reception of an image frequency can be a real problem in most service monitors that use low frequency local oscillators in the first IF of the receiver. The image frequency will be 2 times the first IF plus or minus the frequency dialed up on the front panel, depending on the conversion scheme. If the image signal is strong enough, it will override the "on channel" frequency being monitored. The Cushman 50A Series uses a first IF of 2100 MHz. The image frequency of the IF would be 4200 MHz away and, therefore, never seen or heard because this is outside the tuning range of the instrument.

TRANSMITTER TEST TX-2

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series

Measuring Tx Power, Deviation and Frequency Error Simultaneously



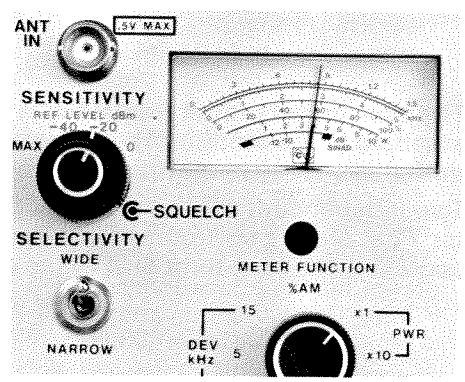
When the rated value of power is measured at the output of the transmitter then every stage in the RF chain, from the oscillator up through the final power amplifier, can be considered functioning properly. No power or low power measurement indicates something is wrong and may require any repair from a simple adjustment to in-depth troubleshooting. Higher than rated power out is also an indication of a problem (causing heat-related failures). Excess current drain on batteries and spurious output are things to consider if this problem should appear. Remember to carefully construct and inspect all connectors and cables in your test setup to minimize power loss and VSWR.

TEST PROCEDURES:

1. Connect the transmitter output to the SIG GEN OUT/RF IN. Connect and attach the monitors antennas to the ANT IN connector. Set the SIG GEN LEVEL to -30 dBm.
2. Set the FREQUENCY SELECT switches to the frequency of the transmitter.
3. Set the FUNCTION switch to MON PFM.
4. Set the METER FUNCTION switch to PWR x 10 or x 1 as needed.
5. Set the VERT switch to 5 kHz; set the HORIZ switch to 1 ms/div.
6. Key the transmitter and read the FUNCTION meter.

   (CAUTION: When making power measurements, do not key for over 10 sec. if Tx power is over 3 watts, and allow 90 sec. between measurements.)
7. Read the deviation on the CRT.
8. Set the RANGE switch to 1.5 kHz and read the frequency error on the FREQ ERROR meter.

   (CAUTION: Do not connect the output of a transmitter to the ANT IN connector.)



Built-in 2 range, 1 watt to 100 watt power meter makes peaking of output power quick and easy whether you're in the shop or on the site.

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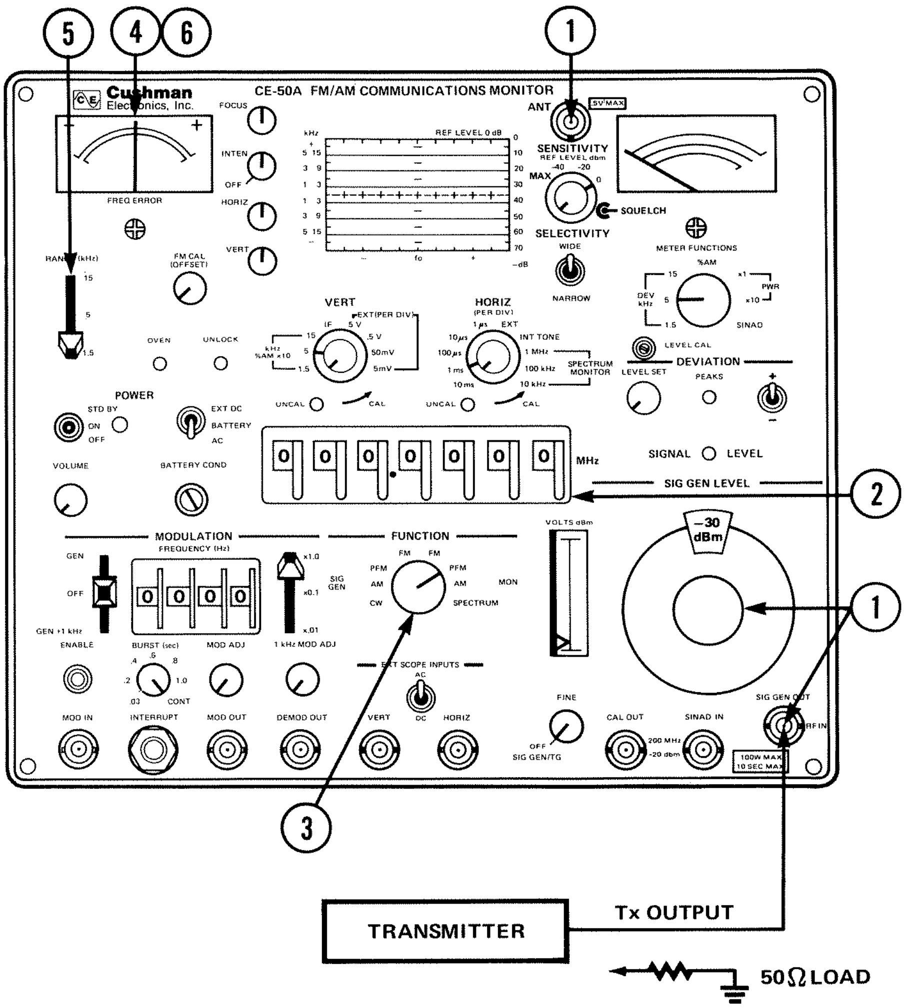
TRANSMITTER TEST TX-3

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series

Measuring Tx Frequency Error
Adjusting Tx Frequency

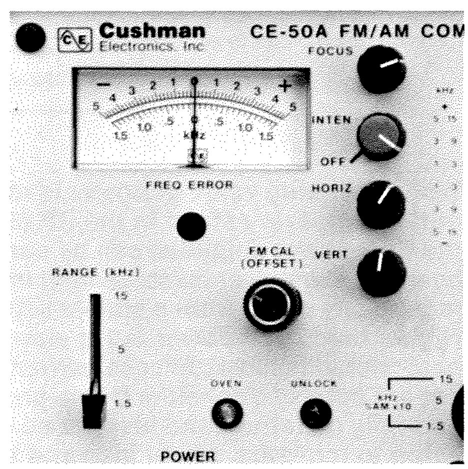


The transmitter output frequency is compared to an accurate reference standard in the monitor. The difference reading is the amount the transmitter frequency is off from the assigned frequency.

Two independent causes can affect the frequency error of the transmitter. First are the environmental effects of temperature and humidity. The second is the long-term drift of the channel element.

TEST PROCEDURES:

1. Connect the transmitter output to the SIG GEN OUT/RF IN connector or to an external 50Ω load and attach the monitor antenna to the ANT IN connector.
   (CAUTION: If you're keying into the SIG GEN OUT/RF IN connector, do not key for more than 10 sec. If Tx power is over 3 watts. Be sure the SIG GEN LEVEL switch is set to -30 dBm.)
2. Set the FREQUENCY SELECT switches to the transmitter frequency.
3. Set the FUNCTION switch to MON: PFM or AM as needed.
4. Key the transmitter and read the ± frequency error from the frequency selected in step 2 on the FREQ ERROR meter.
5. Set the RANGE switch to 1.5 kHz for the best resolution.
6. Adjust the transmitter channel element for zero error on the FREQ ERROR meter.



3 ranges, zero centered meter and CRT display, and a TCXO time base stability of 1 x 10-⁶ allow easy and accurate frequency measurements across the entire 2-way mobile spectrum.

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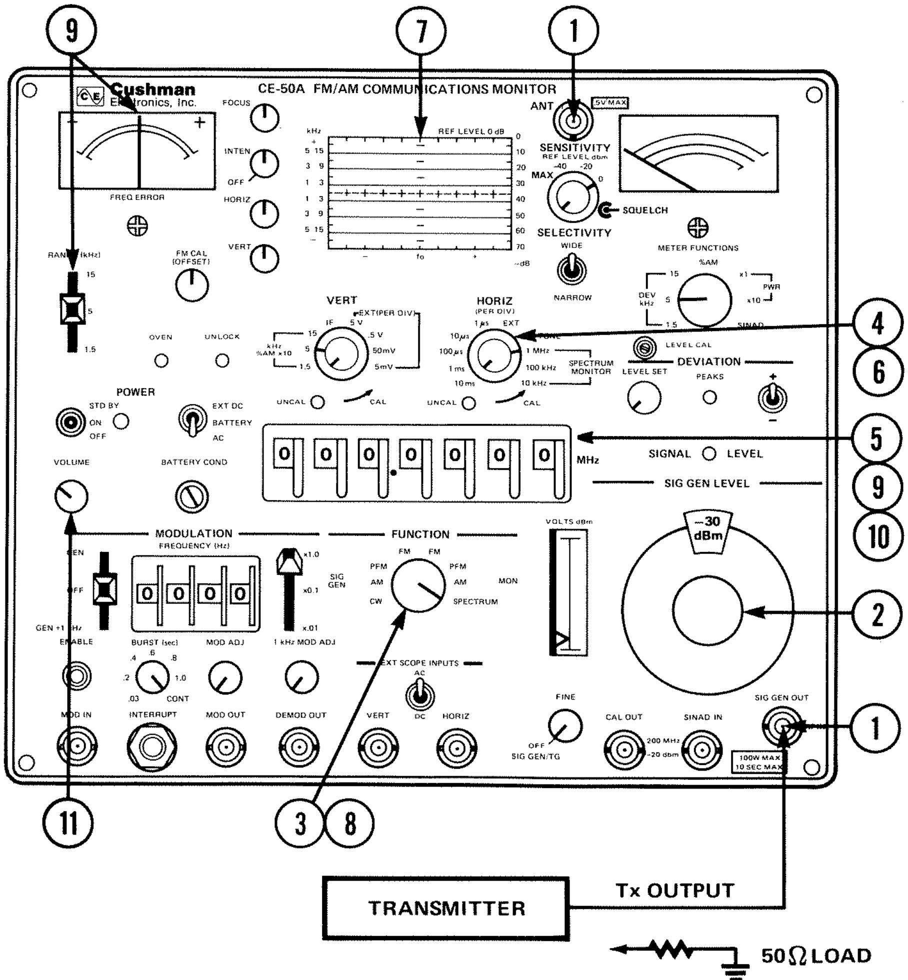
TRANSMITTER TEST TX-4
Recommended Test Equipment:
CE-50A-1, CE-50A-1/TG
CE-46A
CE-5110

Measuring Unknown Tx Carrier Frequencies or Spurious Output



3 calibrated sweep dispersions on the spectrum analyzer and lever operated frequency select switches make unknown signal identification quick, easy and accurate.

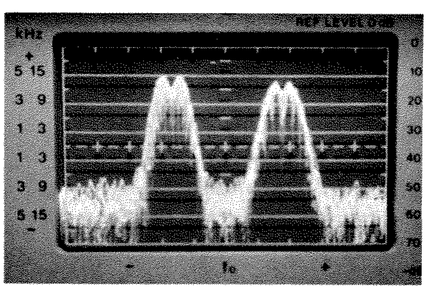


Photo A

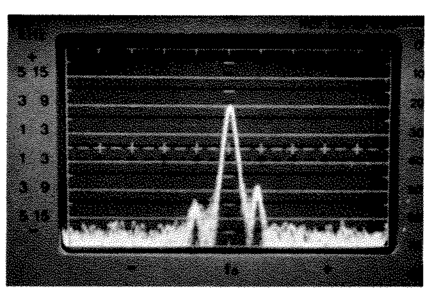


Photo B

Spectrum monitor CRT displays. Photo A: Two adjacent channels with 5 kHz peak deviation are easily resolved by the CRT's 10 kHz/division scan width. Note the FM modulation and its effect on channel band width. Photo B: 10 kHz/division scan width readily identifies RF interference. Note the resolution of two signals 10 kHz in frequency, 30 dB apart in level.

TEST PROCEDURES:

1. Connect the transmitter output to the SIG GEN OUT/RF IN connector, or connect the output to an external 50 Ω load and attach the monitor antenna to the ANT IN connector.

   (CAUTION: If your keying into the SIG GEN OUT/RF IN connector, do not key for over 10 sec. if the Tx power is more than 3 watts).
2. Set the SIG GEN LEVEL to -30 dBm.
3. Set the FUNCTION switch to SPECTRUM.
4. Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/div.
5. Set the unknown signal to the center of the CRT with the FREQUENCY SELECT switches. (Note: The signal must be within ± a half of a division of f_0 before the dispertion can be reduced to the 100 kHz position).
6. Set the HORIZ switch to 100 kHz/div and center the display to within ± a half a division. Set the HORIZ switch to 10 kHz and again center the signal on the CRT.
7. Observe CRT display for spurious signals compared to the carrier. Also note effects on FM modulation channel band width as shown below:
8. Set the FUNCTION switch to MON: PFM or AM.
9. Adjust the FREQUENCY SELECT switch until the FREQ ERROR meter reads zero. Set the RANGE switch 1.5 kHz for best resolution.
10. Read the frequency of the unknown signal on the FREQUENCY SELECT switch.
11. Adjust VOLUME control up to hear detected audio.

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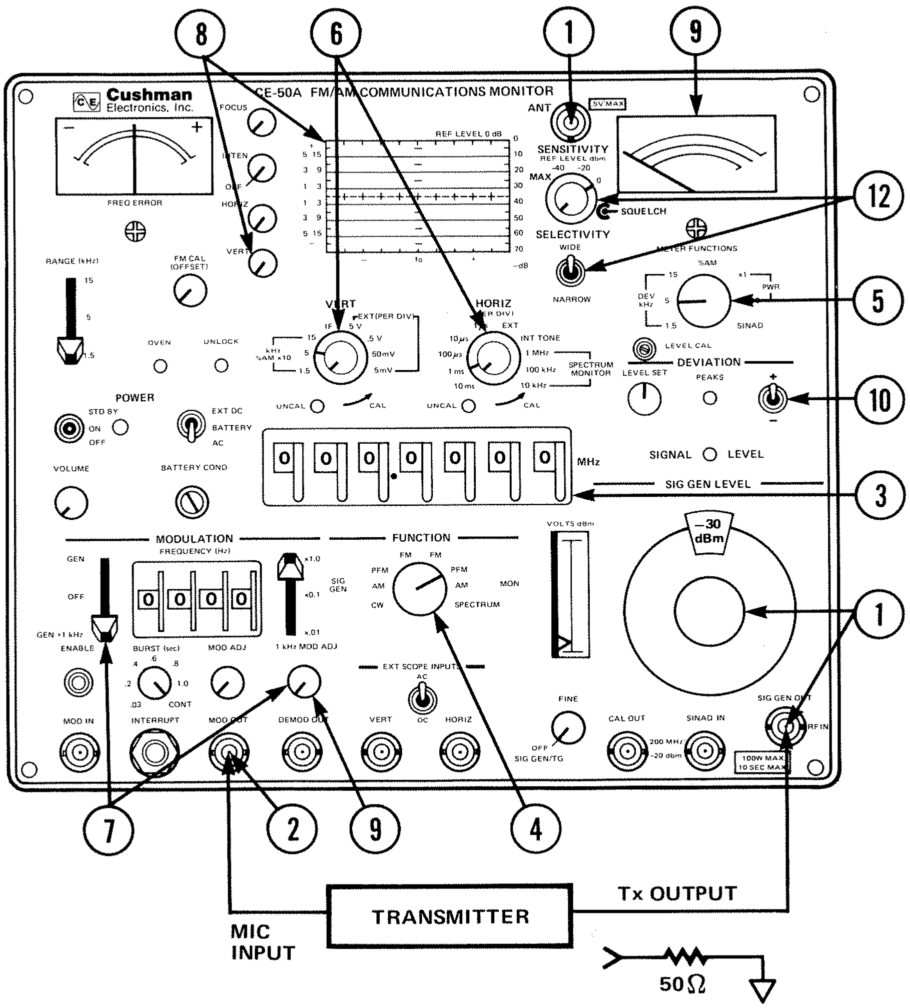
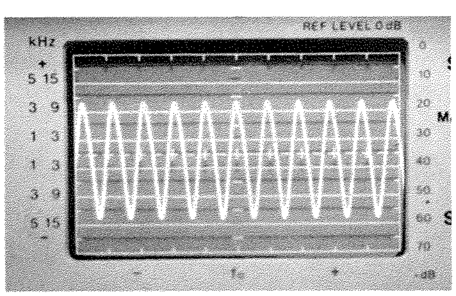
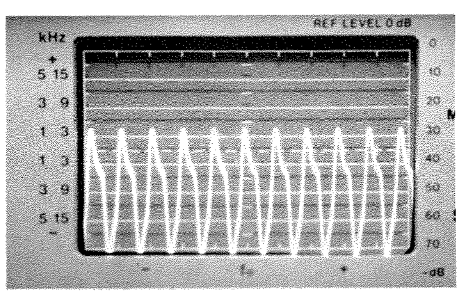
TRANSMITTER TEST TX-5
Recommended Test Equipment:
CE-50A Series

Measuring Tx Deviation Measuring Deviation Symmetry



Simultaneous meter and CRT displays as well as ± peak detection of the deviation gives accurate analysis of transmitter modulation performance.





A well-performing modulator will have good symmetry as the left CRT display shows. The large excursion of the demodulated signal up or down on the CRT display at the right is an indication of an average carrier frequency shift due to gross dissymmetry of the modulation circuits or distortion of the modulation signal.

TEST PROCEDURES:

(1) Connect the transmitter output to the SIG GEN OUT/RF IN connector, or to an external 50 Ω load, and attach the monitor antenna to the ANT IN connector. (Set the SIG GEN LEVEL to -30 dBm).

(2) Connect the MOD OUT to the MIC input on the transmiter. (Disable tone encoder).

(3) Set the FREQUENCY SELECT switches to the frequency of the transmitter.

(4) Set the FUNCTION switch to MON: PFM.

(5) Set the METER FUNCTION switch to 5 kHz.

(6) Set the VERT switch to 5 kHz; Set the HORIZ to 1 ms/div.

(7) Set the GEN + 1 kHz switch to GEN + 1 kHz; Set the 1 kHz MOD ADJ to full counter clockwise.

(8) Key the transmitter with no modulation and center the trace vertically on the CRT, with the scope controls.

(9) Key the transmitter and increase to 1 kHz MOD ADJ until the deviation reads 60% of maximum system deviation on the meter or CRT displays.

(10) Set Deviation ± switch to measure positive and negative peak deviation on meter.

11 Calculate transmitter dissymmetry.

$$\frac{\text{Deviation (higher)} - \text{Deviation (lower)}}{\text{Deviation (higher)}} \times 100 =$$

Deviation Dissymmetry (in percent)

Example:

$$\frac{5.0\text{ kHz} - 4.75\text{ kHz}}{5.0\text{ kHz}} \times 100 = 5.0\%$$

(12) **SELECTIVITY Switch:** Use WIDE band filter with making deviation measurements with the SENSITIVITY switch in the least sensitive position (0 dBm critical squelch). When making off-the-air measurements, use NARROW band filter for adjacent channel selectivity.

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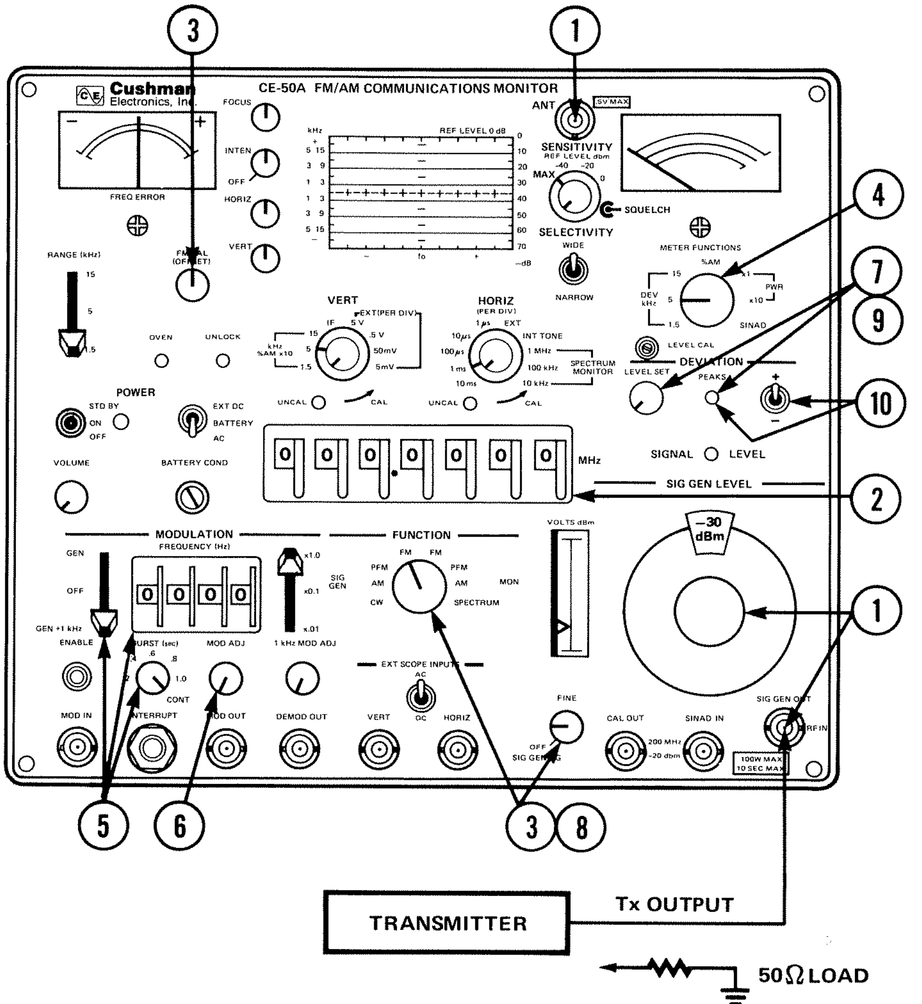
TRANSMITTER TEST TX-6
Recommended Test Equipment:
CE-50A Series

Setting Peak Deviation Limit Light



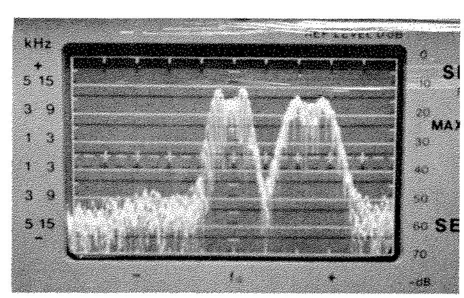
Detecting peak deviation is an important test because it verifies that the transmitter is not exceeding the maximum legal deviation. The test verifies that the audio limiter stages are working properly. If maximum system deviation is unobtainable, suspect low gain in the audio stages. If the system exceeds deviation limits and will not adjust downward, troubleshoot the deviation control circuitry. A transmitter that is exceeding deviation limits may spill R.F. energy over to adjacent channels causing interference problems, as shown in the photo at the right.

The Spectrum analyzer gives a clear picture of whether two transmitters only 25 kHz apart are interfering with each other. Both signals are tone modulated. The signal on the left is deviating 5 kHz, while the one on the right is overmodulated to 6 kHz deviation.

TEST PROCEDURES:

1. Connect the transmitter output to the SIG GEN OUT/RF IN connector. Or connect to an external 50 Ω load, and attach the monitor antenna to ANT IN connector. (Set the SIG GEN LEVEL to -30 dBm).
2. Set the FREQUENCY SELECT switches to the frequency of the transmitter.
3. Set the FUNCTION switch to SIG GEN: FM, turn the SIG GEN LEVEL on with the FINE control, and zero the FREQ ERROR meter with the OFF SET control.
4. Set the METER FUNCTION switch to 5 kHz.
5. Set the GEN + 1 kHz switch to GEN + 1 kHz, BURST to CONT, and the MODULATION thumbwheel switches to the desired audio frequency.
6. Adjust the MOD ADJ for the maximum allowable peak deviation as read on meter.
7. Adjust the LEVEL SET control until the PEAKS light turns on; then back off until the light just turns off.
8. Set the FUNCTION switch to MON: PFM.
9. Key the transmitter and modulate. When PEAKS light turns on, deviation is over preset limit.
10. Set deviation ± switch to observe the instaneous ± peaks on the PEAKS L.E.D.

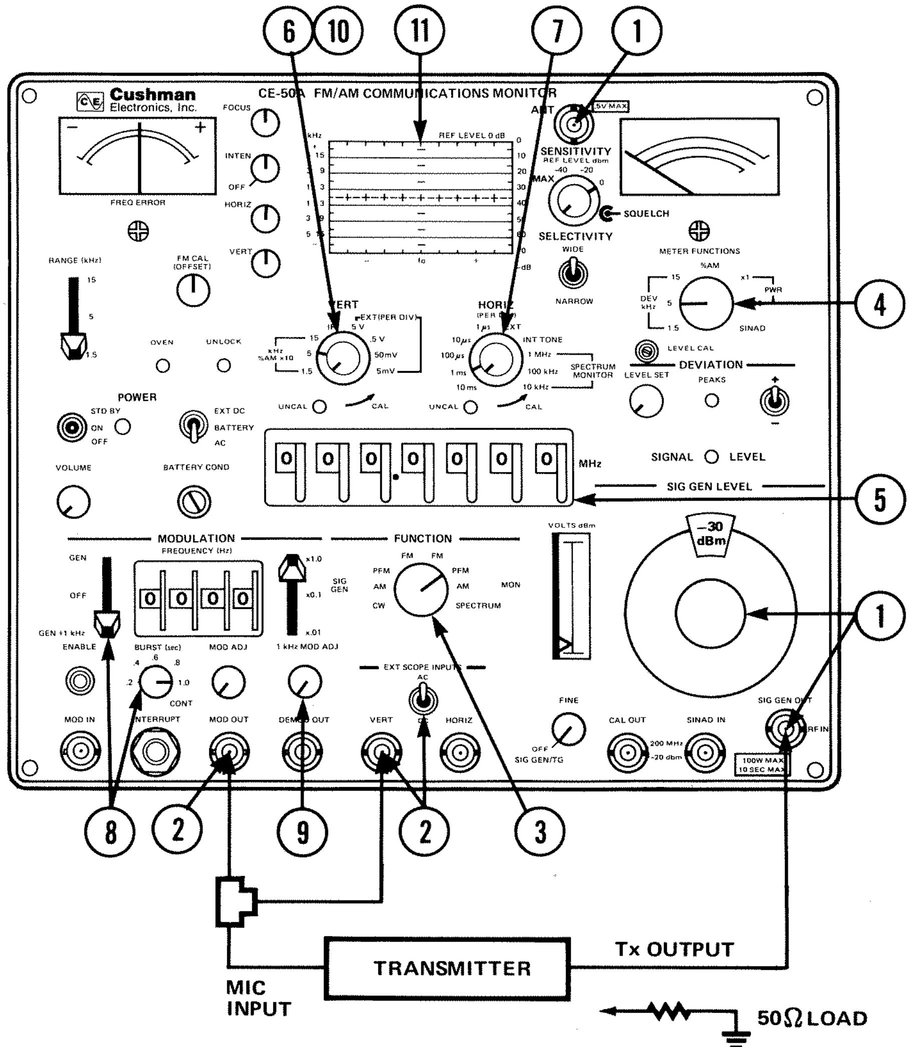
Adjustable ± peak level set with L.E.D. indication allows easy detection of peak voice deviation of the transmitter over preset level.



TRANSMITTER TEST TX-7

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series

Tx Audio Sensitivity



When the manufacturer's specification for audio sensitivity for a given transmitter is met, then the audio gain circuit is amplifying the microphone input to a level that can drive the modulation limiter. Too low a gain results in low average deviation while too high a gain increases audio background noise and distortion.

TEST PROCEDURES:

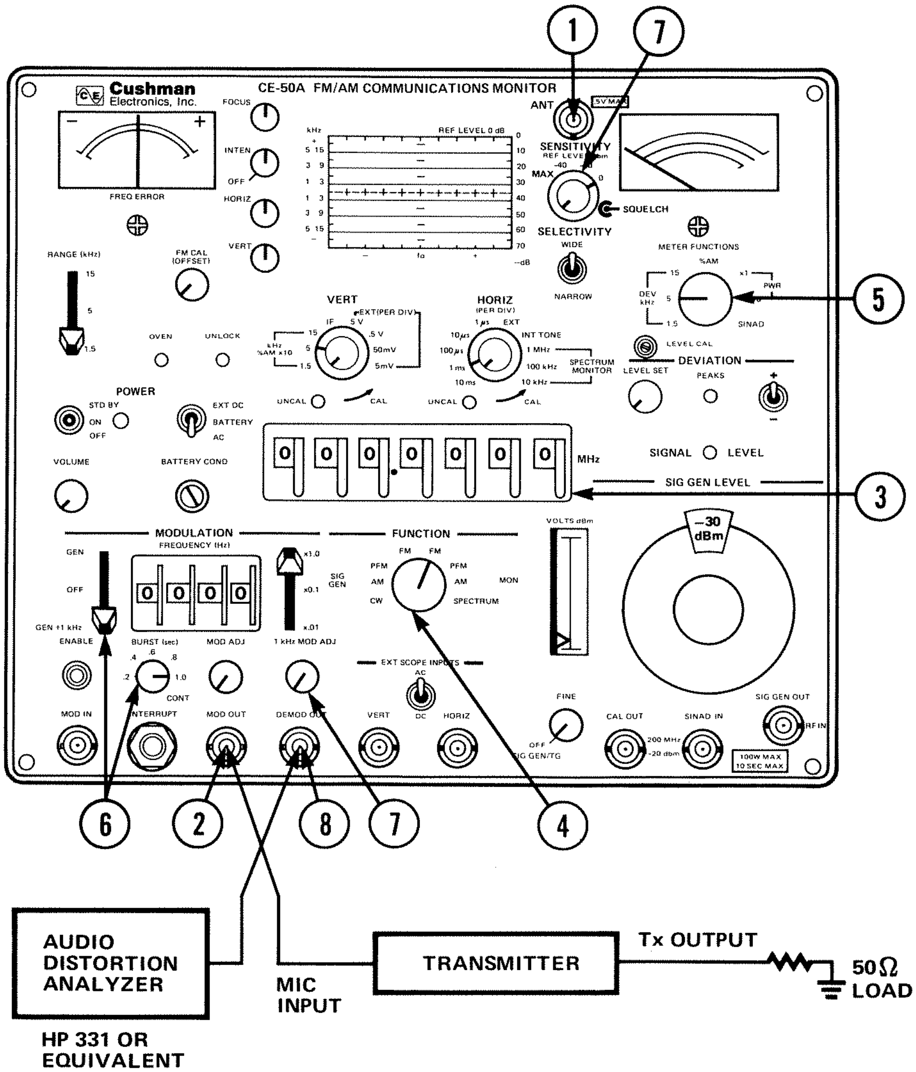
1. Connect the transmitter output to the SIG GEN OUT/RF IN connector or connect the output to an external 50 Ω load, and attach the monitor antenna to the ANT IN connector (Set the SIG GEN LEVEL to -30 dBm).
2. Connect the MOD OUT through a "tee" to the mic input of the transmitter. Connect the third port on the "tee" to the EXT VERT input. Set the AC/DC switch to AC.
3. Set the FUNCTION switch to MON, PFM or AM.
4. Set the METER FUNCTION switch to 5 kHz.
5. Set the FREQUENCY SELECT switch to the frequency of the transmitter.
6. Set the VERT switch to 5 kHz.
7. Set the HORIZ switch to 1 ms/Div.
8. Set the GEN + 1 kHz switch to GEN + 1 kHz, BURST to 1.0 sec position. (Disable the tone encoder on the transmitter).
9. Key the transmitter and increase the 1 kHz MOD ADJ until the transmitter is deviating 60% of maximum system deviation.
10. Set the VERT switch to EXT; 50 mv/div. or as needed.
11. Read the transmitter audio sensitivity on the CRT.

5 mV sensitivity of built-in oscilloscope detects low audio levels.

TRANSMITTER TEST TX-8

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series

Measuring Tx Audio Distortion



The transmitter audio distortion test measures the amount of harmonic distortion added to the input audio signal by the transmitter audio stages. Test measurement should range from 3-10 percent as read on the audio distortion analyzer. Failure to meet the manufacturer's specification would indicate trouble in the audio stages since evaluation of the modulator and modulation limiter has been done with the Deviation Dissymmetry test. Remember to perform the audio distortion test at 60% of maximum deviation which is below the level at which limiting occurs. High level distortion can be detected with the monitor oscilloscope while low level distortion can be detected by using the Distortion Analyzer and isolating probe or resistor to minimize loading on the audio circuitry.

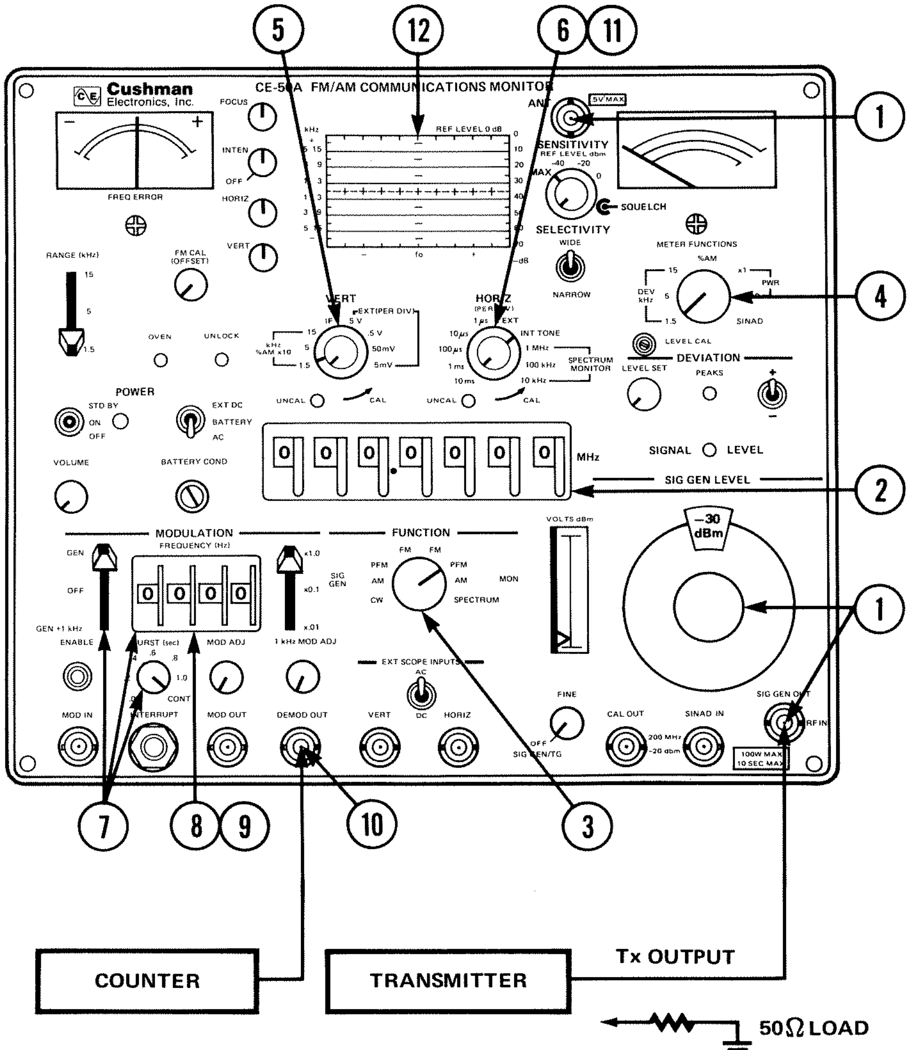
TEST PROCEDURES:

1. Connect Tx output to external 50 Ω load and attach the monitor antenna to ANT IN connector.
2. Connect the MOD OUT to the transmitter mic input.
3. Set the FREQUENCY SELECT switches to the transmitter frequency.
4. Set the FUNCTION switch to MON, FM or AM as needed.
5. Set the METER FUNCTION switch to 5 kHz DEV.
6. Set the MODULATION switch to GEN + 1 kHz and the BURST (sec.) to 1.0 sec. position. (Disable tone encoder.)
7. Key the transmitter and adjust the 1 kHz MOD ADJ to produce 60% of the maximum system deviation as read on the meter or CRT. Adjust the SENSITIVITY switch to fully quiet the monitor's receiver.
8. Connect the DEMOD OUT to the input of the audio distortion analyzer.
9. Key the transmitter and set the audio distortion analyzer to 100% scale.
10. Set the Filter to 1000 Hz and tune for a minimum reading.
11. Reduce the Distortion Analyzer percentage control and null the meter until the lowest possible meter reading is obtained.
12. Compare the distortion level measured to the manufacturer's specification.

TRANSMITTER TEST TX-9

Recommended Test Equipment:
CE-50A Series
CE-45A, CE-46A
CE-5100 Series

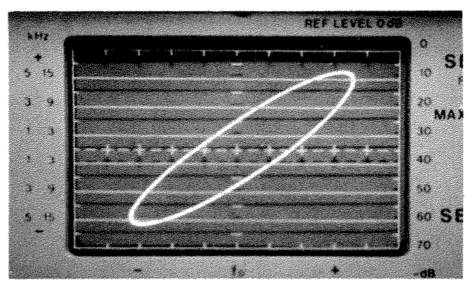
Tx Tone Signaling Frequency Error
Set Tx Tone Signaling Frequency
Check Tone Deviation



10.00 to 9999 Hz audio synthesizer with .005% ± 20 ppm/year stability allows precise measurements and settings of subaudible and audible tone coded squelch systems.

TEST PROCEDURES:

1. Connect Tx RF output to RF IN/SIG GEN OUT connector. Or connect it to 50 Ω load and attach monitor antenna to ANT connector. Set SIG GEN LEVEL to -30 dBm.
2. Set the FREQUENCY SELECT switches to the frequency of the transmitter.
3. Set the FUNCTION switch to MON: PFM or AM.
4. Set the METER FUNCTION switch to 1.5 kHz.
5. Set the VERT switch to INT TONE.
7. Set thet GEN + 1 kHz switch to GEN; BURST to CONT; and set the MODULATION thumbwheel switches to the frequency of the tone encoder.
8. Key the transmitter and adjust the MODULATION frequency until the lissajous pattern is a stationary ellipse. Read the encoder frequency equal to the frequency dialed on the MODULATION thumbwheels.



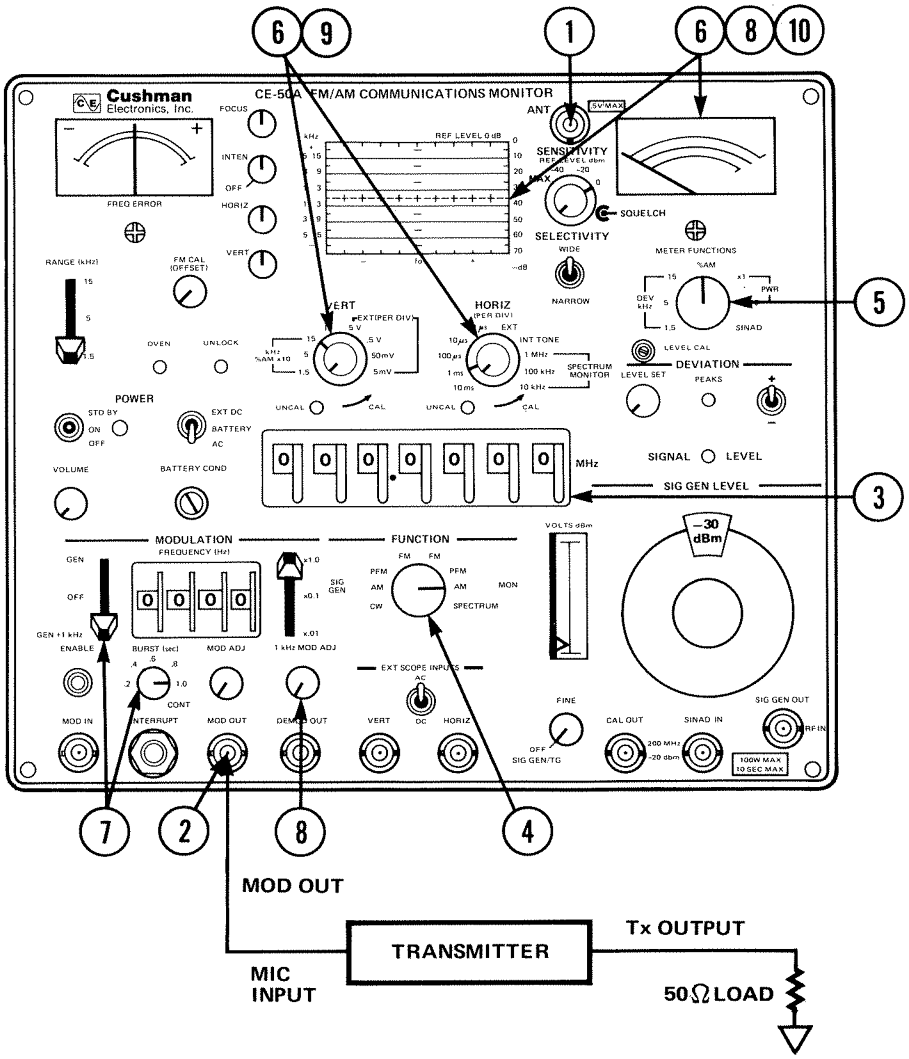
9. Set the MODULATION to the proper encoder frequency. Key the transmitter and adjust the encoder frequency until the lissajous pattern is stationary.
10. (Optional) Connect counter to DEMOD OUT and read frequency.
11. Set the HORIZ switch to 1 ms/Div.
12. Key the transmitter and check the tone deviation for the proper setting on the CRT.

NOTE: You can adjust the CAL of the HORIZ control to see more cycles of the tone.

TRANSMITTER TEST TX-10

Recommended Test Equipment:
CE-50A Series (IF Envelope Method)
CE-46A
CE-5100 Series

Measuring AM Modulation



TEST PROCEDURES:

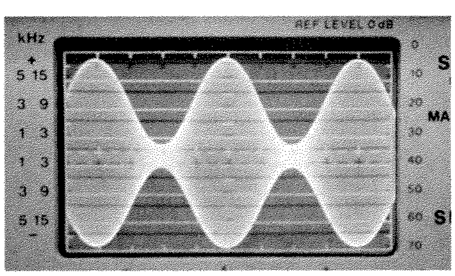
1. Connect the transmitter output to an external 50 Ω load and attach the monitor antenna to the ANT IN connector.
2. Connect the MOD OUT to the mic input of the transmitter.
3. Set the FREQUENCY SELECT switches to the frequency of the transmitter.
4. Set the FUNCTION switch to MON: AM.
5. Set the METER FUNCTION switch to % AM.
6. Set the VERT switch to 15 - % AM x 10.; set the HORIZ switch to 1 ms.
7. Set the GEN + 1 kHz switch to GEN + 1 kHz, BURST to the 1.0 sec position.
8. Key the transmitter and modulate by increasing the 1 kHz MOD ADJ or by talking into the mic. Measure the % AM on the meter or CRT.

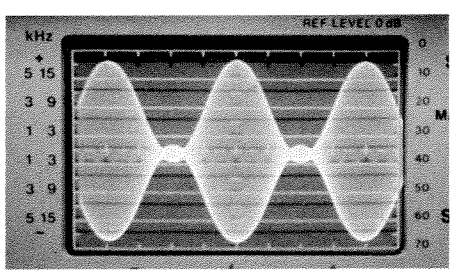
   IF ENVELOPE METHOD

9. Set the VERT switch to the IF position; Set the HORIZ switch to 100 μs/Div. (NOTE: adjust the CAL knob if the peaks of the envelope go off the CRT.)
10. View the modulation envelope on the CRT.
11. Calculate the % AM.

$$B \quad A = 100 \times \frac{A-B}{A+B} = \%\ AM.$$

Simultaneous display of the IF envelope and the meter indication of the percent of modulation gives a quick analysis of modulator performance.



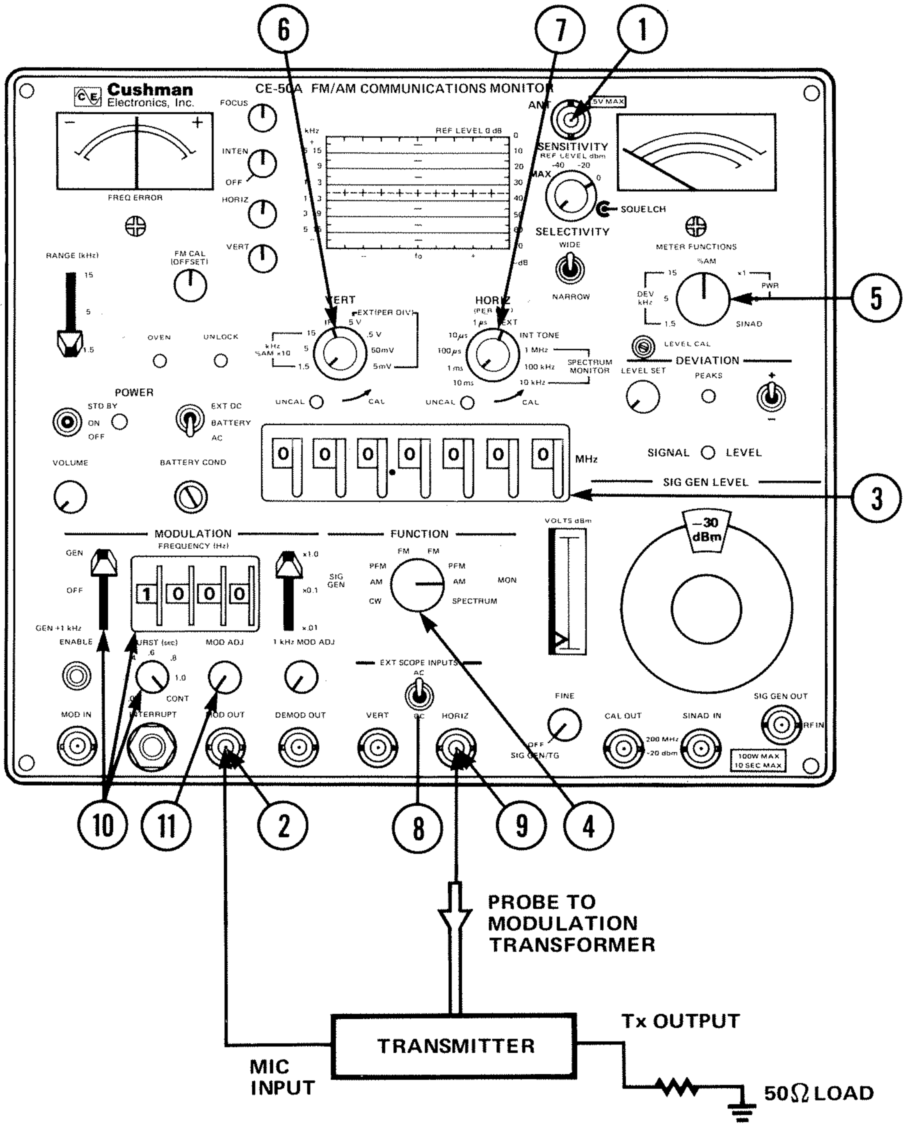


The IF envelope on the left-hand photo shows a correctly performing modulator with a 1 kHz tone at 80% modulation. The right-hand CRT shows an IF envelope with over 100% modulation. Over modulation will cause spurious output of the transmitter. A modulation of 80% is a normal setting to prevent the voice peaks from causing this condition.

TRANSMITTER TEST TX-11

Recommended Test Equipment:
CE-50A Series
CE-5100 Series

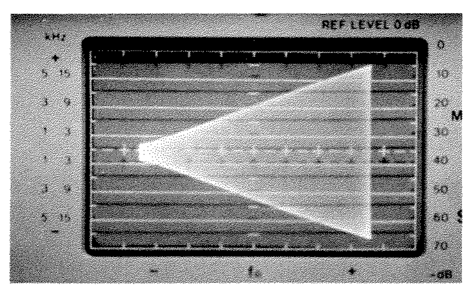
AM Modulation Linearity



The trapezoid display will check the linearity of the modulation circuits. If this linearity is good, the trapezoid sides will be straight. Poor linearity will produce curvature of the sides. Concave sides indicate improper neutralization or stray coupling from a previous stage. A convex curvature of the sides at the large end of the trapezoid is usually an indication of excessive bias or insufficient excitation of the P.A.

TEST PROCEDURES:

1. Connect the output of the transmitter to an external 50 Ω load and attach the monitor antenna to the ANT IN connector.
2. Connect the MOD OUT connector to the mic input.
3. Set the FREQUENCY SELECT switches to the frequency of the transmitter.
4. Set the FUNCTION switch to MON: AM.
5. Set the METER FUNCTION switch to % AM.
6. Set the VERT switch to IF.
7. Set the HORIZ switch to EXT.
8. Set the EXT SCOPE INPUT switch to AC.
9. Connect a scope probe to the HORIZ input connector and attach the probe to the secondary of the modulation transformer of the radio.
10. Set the GEN + 1 kHz switch to GEN; BURST to CONT; and set the MODULATION thumbwheel switches to 1 kHz.
11. Key the transmitter and increase the MOD ADJ until the trapezoidal pattern appears. An extended tip of the trapezoidal pattern is an indication of modulation over 100%.



The IF position of the Vertical switch enables the scope to display the 700 kHz IF of the service monitor's receiver. A variety of A.M. transmitter tests can be made with this feature.

Cushman

Notes:

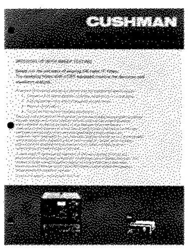
Product Application Notes

The following applications notes are available upon request.

A Portable Test Set for Microwave Radio Installation and Maintenance

Shows how to utilize the combination of test instruments in the Cushman Communications Monitor to maintain and verify the proper operation of microwave radio systems to 1000 MHz.

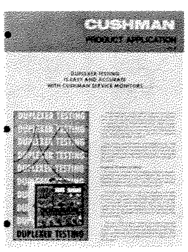
Application Note 1



Speeding Up With Sweep Testing

Describes how to use swept frequency tuning techniques with a Communications Monitor having a CRT display to easily and quickly align receiver IFs and other tuned circuits.

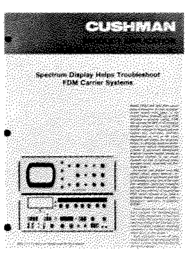
Application Note 2



Duplexer Testing is Easy and Accurate With All Cushman Service Monitors

The test set-up and methods of testing transceiver duplexers using the Cushman Communications Monitor.

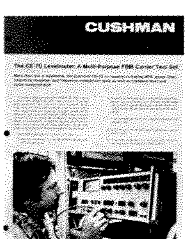
Application Note 5



Spectrum Display Helps Troubleshoot FDM Carrier Systems

Rapidly changing conditions on a carrier system are impossible to follow using only a Frequency Select Levelmeter (FSLM). This Product Application shows how to utilize a suitable spectrum display system to track these conditions in FDM systems.

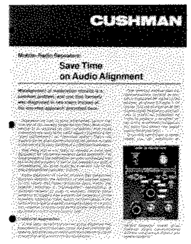
Application Note 6



The CE-70 Levelmeter: A Multi-Purpose FDM Carrier Test Set

Explains the procedures for using the CE-70 Frequency Select Levelmeter to make NPR, phase jitter, frequency response and frequency comparison tests as well as standard level and noise measurements.

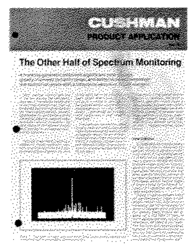
Application Note 7



Mobile-Radio Repeaters: Save Time on Audio Alignment

Describes a method of diagnosing misalignment of modulation circuits in one step instead of the normal two-step approach, and then aligning them for a total elapsed on-site time of five minutes or less.

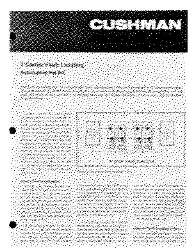
Application Note 10



The Other Half of Spectrum Monitoring

Tells how tracking generators (TG) work, and their use with a spectrum monitor as an exceptionally useful troubleshooting aid for frequency-sensitive circuit elements such as duplexers, receiver RF and IF circuits, transmitter output filters and combiners.

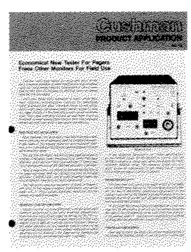
Application Note 11



T-Carrier Fault Locating: Automating the Art

To understand why the fault-locating scheme has remained virtually unchanged through 17 years of system hardware evolution, and to find out what can be done to improve the situation.

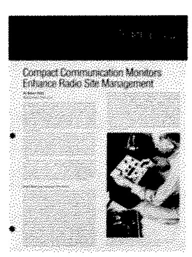
Application Note 12



Economical New Tester for Pagers Frees Other Monitors for Field Use

Shows a simplified test set-up for pager repair and describes how to use the CE-31A FM Radio Test Set to measure basic pager parameters.

Application Note 13



Using the Synthesized Offset Generator to Save Time On Audio Alignment

Misalignment of modulation circuits is a common problem, and one that formerly was diagnosed in two steps instead of the one-step approach using the CE-5110 Communications Monitor.

Application Note 14

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