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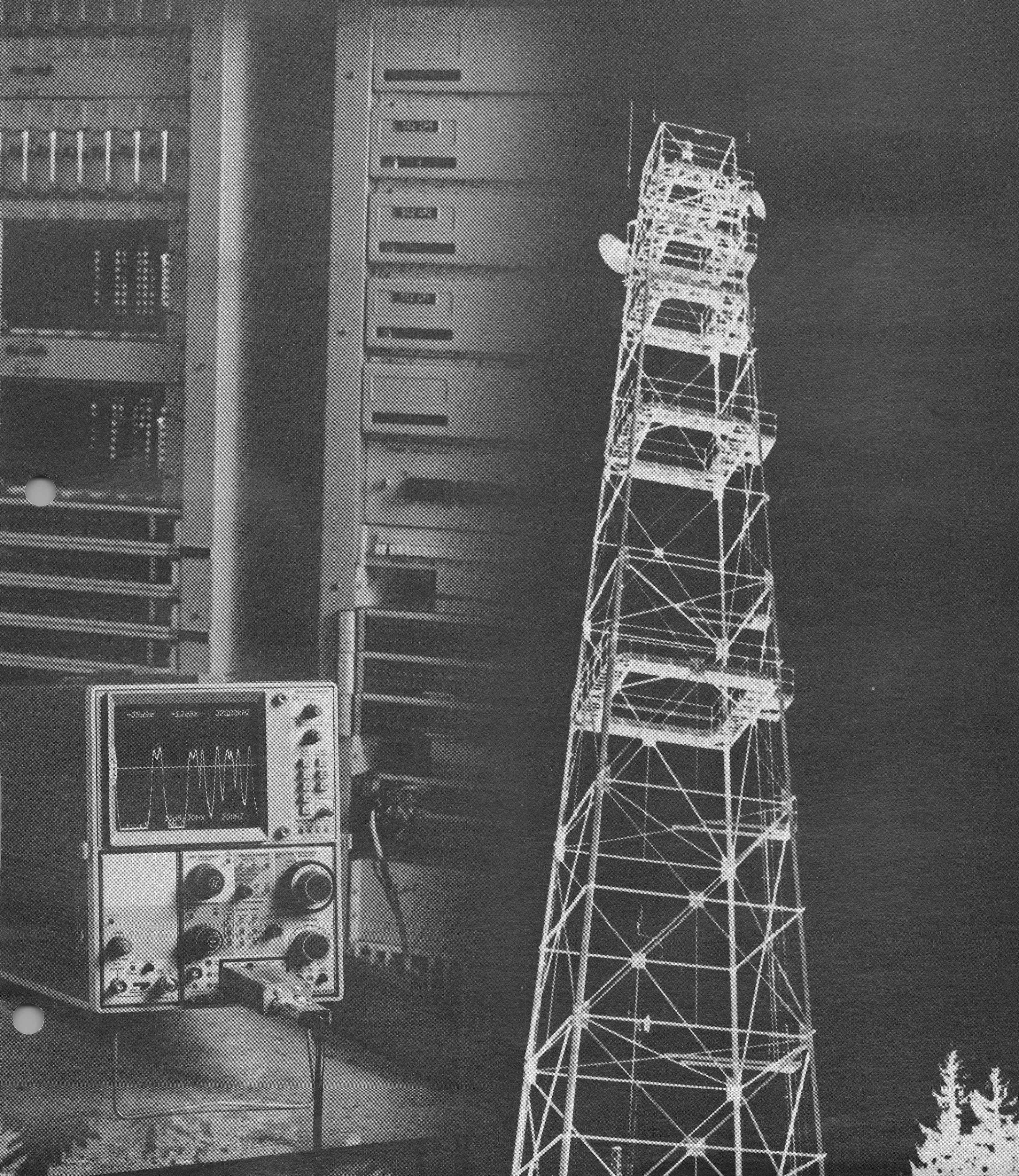
SWEPT SELECTIVE LEVEL MEASUREMENTS

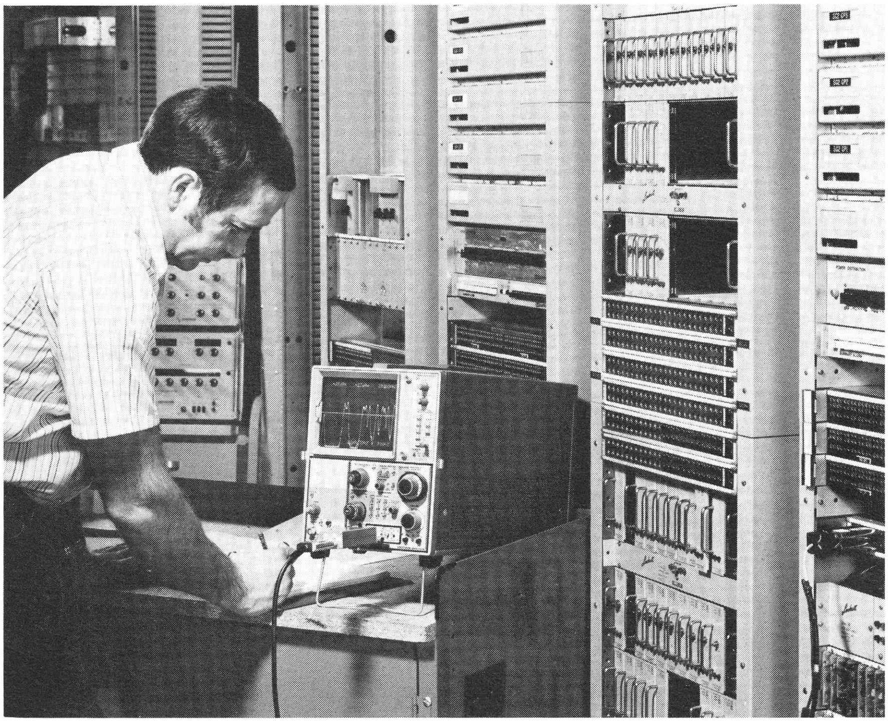


Swept Selective Level Measurements

By Morris Engelson

Introduction

This application note provides detailed information for using the TEKTRONIX 7L5 Spectrum Analyzer to make swept selective level measurements. It shows how to obtain level measurements to an accuracy of fractions of a dB. The instrument can be used to perform noise measurements including C-message weighting. In addition to swept selective level measurements, the 7L5 will perform the various specialized measurements, such as hunting for noise bursts or checking intermodulation, which are usually performed with a spectrum analyzer.* The tremendous flexibility afforded by rapidly switching from a super group to a single FSK tone makes this instrument a valuable addition for baseband measurements.



Acknowledgement
Swept selective level measurements are by courtesy of Communication Department, Portland General Electric Company.

**The reader may wish to refer to "Baseband Measurements Using the Spectrum Analyzer," TEKTRONIX AX-3433, and "The Spectrum Analyzer as a Frequency Selective Level Meter," TEKTRONIX AX-3682.*

I. Relative Measurements

Comparative carrier level, pilot tone, and signalling tone measurements are of interest in frequency division multiplex (FDM) baseband systems. These measurements are easily performed with the 7L5 Spectrum Analyzer. Gain step and attenuator accuracy is of no interest here. Only display flatness affects measurement accuracy. The 7L5 as a whole has a maximum flatness error of 0.5 dB peak-to-peak over a 5 MHz span. However, the flatness is substantially better over narrower ranges. The peak-to-peak error is less than 0.15 dB for any 50 kHz span. This will accommodate a 12-channel bank. A 60-channel supergroup can be checked within 0.25 dB peak-to-peak. In addition to spectrum analyzer flatness it is necessary to consider the flatness of signal modifying accessories such as a balanced input transformer. TEKTRONIX balanced transformer PN 013-0182-00 has less than 0.25 dB peak-to-peak unflatness from 50 kHz to 3 MHz with negligible error over any 50 kHz range.* Consequently, relative amplitude can be checked or adjusted to an accuracy of better than 0.3 dB peak-to-peak for channel distributions of up to a supergroup.

A. The Basic Measurement

Suppose one wishes to check or adjust the relative levels of the twelve carriers spaced at 4 kHz intervals bounded by 659 kHz and 615 kHz.

There might be other signals within the selected range such as a pilot tone, usually at 656.08 kHz. However, the simulated channel bank, shown in *Figure 1,* displays only the unmodulated carriers.

After normal calibration, the spectrum analyzer is set as follows:

Input Impedance and Scale Factors:
As needed to properly terminate the signal (See Appendix A for discussion). Set for 75Ω, dBm, terminated in *Figure 1.*

**The transformer is usable over the frequency range of 10 kHz to 20 MHz.*

Reference Level:
As needed for the signal level being measured. Set at −32 dBm for *Figure 1.*

Center Frequency:
The center of the range of interest; this is 637 kHz for *Figure 1.*

Frequency Span:
Narrowest setting in the calibrated 1, 2, 5 sequence that will accommodate the frequency range of interest. Since a 12-channel bank occupies 48 kHz, the setting in *Figure 1* is 5 kHz/div (50 kHz full screen).

Resolution:
Coupled will work most of the time. If especially narrow resolution bandwidth is needed, such as to separate a carrier from the modulation, set the position accordingly. The setting for *Figure 1* is coupled.

Time/Div:
Auto.

Log Display:
2 dB/div.

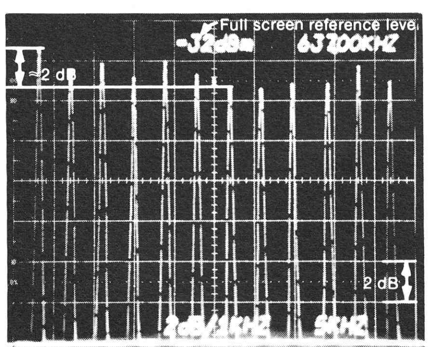


Figure 1. Spectrum Display of Unmodulated Carriers for 12 Channel Bank.

With the instrument operating normally with digital storage display, we observe the twelve channels of interest. The maximum amplitude variation is about 2 dB. The measurement limitation is set by system flatness and the ability to establish display amplitude position at 2 dB/div. For higher accuracy it is desirable to expand the vertical display to improve vertical deflection resolution as illustrated in *Figure 2.*

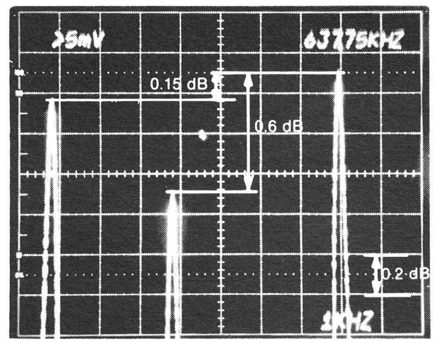


Figure 2. Expanded Amplitude Measurement at 0.2 dB/div.

B. Expanded Measurement

Figure 2 shows three channel carriers with the vertical scale expanded by a factor of ten to produce a display factor of 0.2 dB/div. The display was produced by connecting the detected vertical output at the 7L5 front panel to a 7A22 set at a sensitivity ten times the 50 mv/div output from the 7L5*. Accurate vertical calibration is obtained by changing the 7L5 reference level by 1 dB and adjusting the 7A22 variable gain to get the desired vertical deflection. (5 divisions in our example). Since the trace now occupies ten screen heights, it is necessary to use the 7A22 dc offset control to position the display on screen. Maximum amplitude difference is 0.6 dB and the minimum difference is 0.15 dB. Considering the close frequency spacing of the signals and the instrument flatness specifications, this measurement has an accuracy of better than 0.1 dB.

**Digital storage should be turned off to synchronize the 7A22 and 7L5 horizontal scales.*

II. Absolute Measurements

Absolute measurement accuracy depends on many factors as discussed in Appendix B. Measurement set up is illustrated by the following examples.

A. Overall Observation

Figure 3 shows all baseband activity for the system of interest. One can observe at a glance which groups are occupied, which are missing, and if anything is there that does not seem to belong, such as a suspicious tone subsequently identified as spurious at 1606.5 kHz.

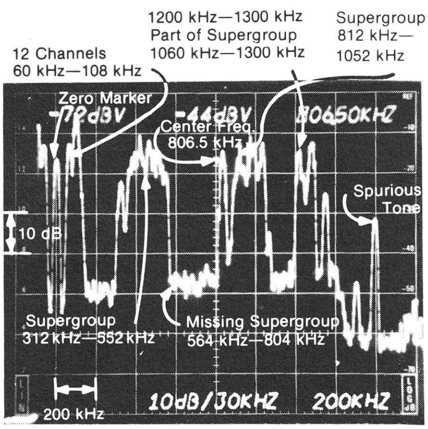


Figure 3. Full Baseband Spectrum Showing Several Supergroups.

The amplitude level will fluctuate as channel loading activity changes. An average amplitude level, however, can be established. The top of the screen is at −44 dBV and the vertical display is 10 dB/div as shown by the CRT readout. Most of the supergroups are running a bit more than one division from full screen reference for an amplitude level of about −55 dBV. The display was obtained through balanced transformer 013-0182-00 with the termination switch set to NONE for a bridging measurement. Since system impedance is 124Ω, we add 9.1 (see Appendix A) to get results in dBm. The result is a loaded amplitude level of −46 dBm. One can next proceed to examine selected sections of the baseband spectrum as shown in *Figures 4 & 5.*

Figure 4 shows a full supergroup covering the frequency range of 312 kHz to 552 kHz. Idle channel noise is about −80 dBm (−90 + 9.1) in a 10 kHz resolution bandwidth (see Appendix C for a discussion on bandwidth). The loaded channel signal level is at −42 dBm. Note that at a resolution bandwidth setting of 10 kHz it is not possible to separate the individual channel carriers spaced 4 kHz apart.

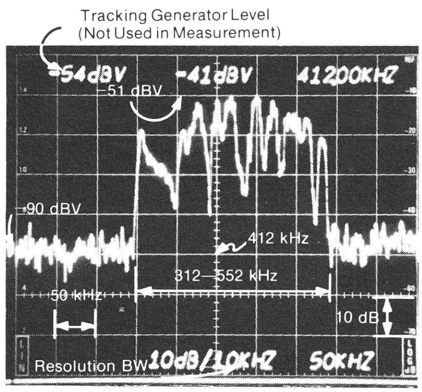


Figure 4. Spectrum of One Supergroup.

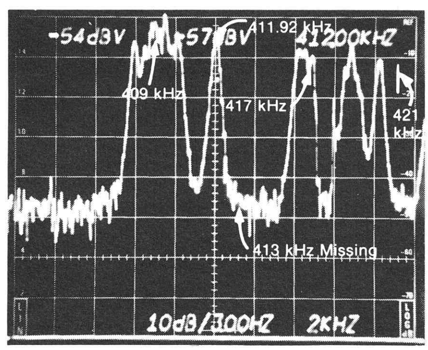


Figure 5. Spectral Display of Individual Channels.

The central portion of *Figure 4* is expanded for more detailed examination in *Figure 5.* The tone just below CRT center at 412 kHz is a group pilot at 411.92 kHz. Below the group pilot is the 409 kHz channel carrier modulated with FSK. Individual mark/space components which cannot be resolved with 300 Hz resolution setting are examined later. The 413 kHz channel is missing but 417 kHz and 421 kHz are in service. Signal level varies from −48 dBm (−57 + 9) to −58 dBm (−67 + 9.1). This is considerably different from *Figures 3 & 4* where individual channels (including missing channels) and modulation are combined into an average level.

B. Detailed Observation

For detailed observation it is necessary to reduce the resolution bandwidth to the point where individual tones can be resolved. With 10 Hz minimum resolution, the 7L5 can perform a detailed analysis even on FSK signals as illustrated in *Figure 6.*

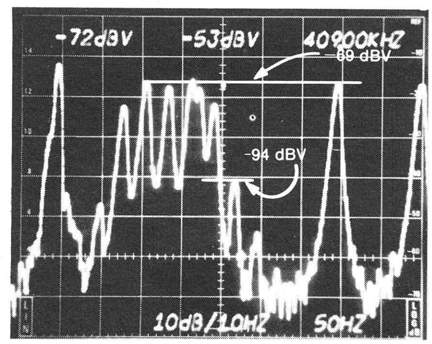


Figure 6. Spectrum of FSK Signal.

Figure 6 shows the spectral characteristics of the first channel (409 kHz) in group three of the basic supergroup (312-552 kHz). At 50 Hz/div we are only observing 500 Hz of the 4 kHz channel. Now that individual components are resolved, it is clear that this is an FSK signal. Tone amplitude level is −60 dBm (−69 + 9.1). At a vertical setting of 10 dB/div we can easily establish the level of the various tones, but the vertical resolution at this setting prevents high accuracy. For high accuracy, it is necessary to go to a vertical setting of 2 dB/div as illustrated in *Figures 7 and 8.*

Figure 7 shows an expansion about the center of *Figure 5.* Here, what was assumed to be a group pilot is shown to be two signals. One is the usual group pilot at 411.92 kHz, the other is a spurious tone (possibly a carrier leak) at 412 kHz. It is the combination of these two tones that gives the center component a ragged appearance in *Figure 5.* The group pilot is at an amplitude level of −63.5 dBV, bridging a balanced 124Ω line. The theoretical correction factor for 124Ω is 9.07 dB, and taking into account some balanced transformer losses, we get an amplitude level of −63.5 + 9.1 = −54.4 dBm.

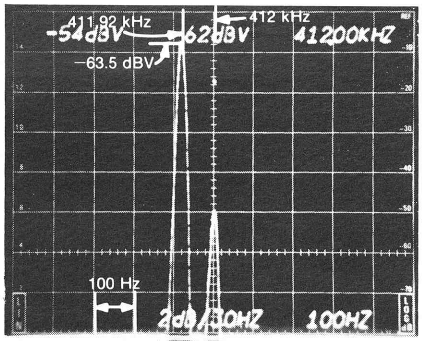


Figure 7. Detailed Analysis of Group Pilot and Spurious Leak.

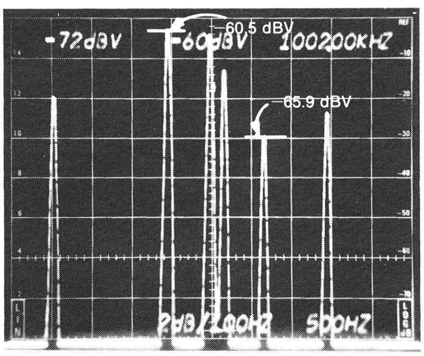


Figure 8. Detailed Analysis of Control Signals.

According to Appendix B, the worst case error for this measurement is 1.4 dB; a more likely error is 0.53 dB. Measurement with other equipment yields a most likely amplitude level of −54.3 dBm — within 0.1 dB of our measurement. The level of the spurious tone at 412 kHz is 4.25 divisions, or 8.5 dB, below the pilot.

Another detailed amplitude measurement is illustrated in *Figure 8,* showing a group of control signals. These vary in amplitude from −51.4 dBm (−60.5 dBV) to −56.8 dBm (−65.9 dBV). Expected measurement error as discussed in Appendix B is 0.66 dB. With a little care, accuracy can be improved even further as discussed in Appendix D.

Appendix

A. Impedance

The 7L5 uses interchangeable input modules to provide different input impedance and calibration factors. The following performance is available:

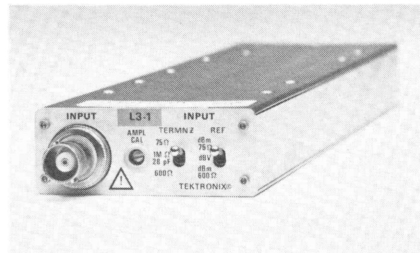


Figure A1. L3 Option 01 input Module.

Module Nomenclature	Input Impedance	Calibration Factors	Notes
L1	50Ω	dBm, dBV	Terminated Measurements only.
L2	75Ω	dBm, dBV	Terminated Measurements only.
L3	50Ω 600Ω 1 MΩ	dBm, dBV dBm, dBV dBV, dBm (50Ω), dBm (600Ω)	Terminated Terminated Bridging
L3 Option 01	75Ω 600Ω 1 MΩ	dBm, dBV dBm, dBV dBV, dBm (75Ω), dBm (600Ω)	Terminated Terminated Bridging

Baseband telephony systems frequently utilize balanced connections. This is accommodated by a balanced to single-ended transformer, part number 013-0182-00. The transformer has a three-position switch at the output to provide a 124Ω termination, a 135Ω termination, and no termination. Thus, an L3 Option 1 in conjunction with the accessory transformer provides all of the common baseband impedance levels (75Ω, 600Ω, 124Ω, 135Ω, 1MΩ for bridging).

Balanced connection at other than 124Ω or 135Ω uses the transformer in the unterminated position with the termination provided either by the L3 or by a feed-through termination connected between the transformer and 7L5 input. When the termination is outside the 7L5, it is necessary to set the 7L5 in the 1MΩ bridging position so as not to double terminate the connection. The reference level should be set to dBV. This accommodates any impedance. The relationship between dBV and dBm is: dBm = dBV − 10LogZ + 30, where Z equals the terminating impedance. For the two impedances provided on the balanced transformer, the theoretical relationship is: dBm (124Ω) = dBV + 9.07, dBm (135Ω) = dBV + 8.7. Since the transformer has an insertion loss of less than 0.1 dB, the theoretical correction factors offer sufficient accuracy.

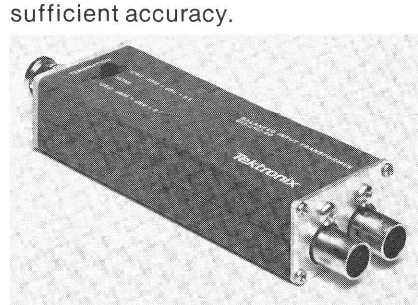


Figure A2. Balanced Transformer

B. Amplitude Accuracy

Absolute amplitude measurement accuracy depends on the following factors:

Calibrator accuracy:
−40 dBV ± 0.15 dB at 500 kHz.

Display flatness: 0.5 dB peak to peak maximum over 5 MHz.

Reference level steps: 0.2 dB/dB, to maximum of 0.25 dB/10 dB change in reference level.

In addition, one needs to consider the flatness and insertion loss of accessories such as the balanced transformer PN013-0182-00 which has a 0.1 dB ± 0.1 dB insertion loss and 0.25 dB maximum unflatness to 3 MHz (usable 10 kHz to 20 MHz).

The above is the worst case error situation. Actual measurement error is considerably less than this, depending on the measurement requirement and the measurement procedure used. The following provides a detailed error analysis followed by a table of cumulative measurement error as a function of measurement conditions.

The Calibrator

Calibrator output level is set at the factory against a secondary standard. The comparison uses the expanded measurement technique described in the body of this note. Total absolute error, including transfer accuracy, is 0.15 dB. There is little that the user can do to improve the calibrator accuracy, though a more accurate outside source can be substituted for the calibrator.*

Display Flatness

Total instrument display flatness is specified as 0.5 dB maximum peak to peak over 5 MHz. The amplitude variation is gradual so that flatness improves at narrower frequency span. Virtually every instrument meets a flatness specification of 0.15 dB/50 kHz and 0.25 dB/250 kHz.

Figure B1 shows a typical flatness response over a full 5 MHz. This particular instrument has an amplitude peak at the calibrator frequency of 500 kHz. Other instruments might have a different distribution. Consequently, the peak-to-peak unflatness needs to be counted as a possible plus/minus error with respect to the calibrator position when computing absolute amplitude measurement errors.

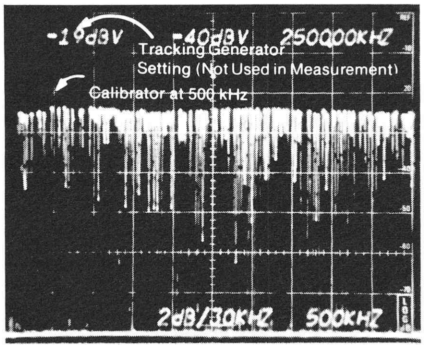


Figure B1. Flatness Measurement.

Reference Level Step Accuracy

Reference level gain step errors contribute the most to total measurement inaccuracy. The basic specification is ± 0.2 dB/dB to a maximum of ± 0.25 dB/10 dB. Thus, changing the reference level from the calibrator setting of −40 dBV to −80 dBV appears to introduce an error of

$$1 \text{ dB } \left(\frac{0.25 \times 40}{10}\right).$$

This is a worst case situation in two ways. First, the specification assumes maximum absolute gain error, a theoretical situation that has never been observed in practice. Secondly, the specification assumes that the highest error gain step is switched in. A complete analysis requires an understanding of L unit front-end module gain and attenuation switching, which is described below.

Gain, and attenuation, is switched in steps of 1 dB, 2 dB, 4 dB, 8 dB, and 16 dB. Adding a 1 dB gain step to increase the gain from 12 dB to 13 dB introduces considerably less potential error than switching out 15 dB (8 + 4 + 2 + 1) and switching in 16 dB. For the L3 option 01, zero gain and zero attenuation corresponds to −42 dBV. Thus, 15 dB gain gives −57 dBV and 16 dB gain gives −58 dBV.

This is a position to be avoided, as it represents a worst case error condition. The next 16 dB step yields −74 dBV reference level, etc. The maximum relative switching error for a 16 dB step is 0.15 dB, whereas it is only 0.05 dB for an 8 dB step. Consequently, sticking to −73 dBV instead of going to −74 dBV means a 0.1 dB reduction in potential measurement error.

Switching errors are of two types. The absolute gain error comes from op-amp gain variations (0.22 dB max for 16 dB step). This is a rare possibility since the op-amps come from the same chip so the absolute error tracks between steps and is mostly calibrated out in the front panel calibration procedure. Maximum relative error due to resistor tolerance is 0.15 dB for a 16 dB step, 0.05 dB for an 8 dB step, and lesser errors for smaller steps. Thus, the most likely maximum gain step error is 0.1 dB/dB, not 0.2 dB/dB. This is also the error for the attenuators which are switched in at reference levels greater than −40 dBV. Worst case maximum, most likely maximum, and rms cumulative error distribution are detailed in *Figure B2* below. Note that the worst most likely rms error is 1.1 dB and the best is 0.1 dB. Most measurements will fall between these two extremes.

**The 7L5 will exhibit some amplitude differences between resolution filter settings. To achieve a 0.15 dB calibration accuracy, the user should perform a front panel calibration at the resolution bandwidth used in the measurement.*

REFERENCE LEVEL		SOURCE OF ERROR	FREQUENCY			
			500 kHz	Within 50 kHz of 500 kHz	Within 250 kHz of 500 kHz	Full Range to 5 MHz
		Calibrator	0.15 dB	0.15 dB	0.15 dB	0.15 dB
−40 dBV	Maximum	7L5 Flatness	0 dB	0.15 dB	0.25 dB	0.50 dB
	Specified	Transformer Errors	0.1 dB	0.1 dB	0.1 dB	0.25 dB
	Error	Gain Steps	0 dB	0 dB	0 dB	0 dB
		Worst Maximum	0.15 dB	0.3 dB	0.4 dB	0.65 dB
Single Ended		Most Likely Maximum	0.10 dB	0.2 dB	0.25 dB	0.5 dB
		Most Likely RMS	0.10 dB	0.14 dB	0.18 dB	0.41 dB
		Worst Maximum	0.24 dB	0.4 dB	0.5 dB	0.9 dB
Balanced*		Most Likely Maximum	0.20 dB	0.3 dB	0.35 dB	0.65 dB
		Most Likely RMS	0.14 dB	0.17 dB	0.21 dB	0.44 dB
		Calibrator	0.15 dB	0.15 dB	0.15 dB	0.15 dB
−40 dBV	Maximum	7L5 Flatness	0 dB	0.15 dB	0.25 dB	0.50 dB
to	Specified	Transformer Error	0.1 dB	0.1 dB	0.1 dB	0.25 dB
+8 dBV	Error	Gain Steps	1.2 dB	1.2 dB	1.2 dB	1.2 dB
		Worst Maximum	1.35 dB	1.5 dB	1.6 dB	1.85 dB
Single Ended		Most Likely Maximum	0.60 dB	0.7 dB	0.75 dB	1.0 dB
		Most Likely RMS	0.51 dB	0.52 dB	0.53 dB	0.64 dB
		Worst Maximum	1.45 dB	1.6 dB	1.7 dB	2.1 dB
Balanced*		Most Likely Maximum	0.70 dB	0.8 dB	0.85 dB	1.15 dB
		Most Likely RMS	0.52 dB	0.53 dB	0.54 dB	0.66 dB
		Calibrator	0.15 dB	0.15 dB	0.15 dB	0.15 dB
−40 dBV	Maximum	7L5 Flatness	0 dB	0.15 dB	0.25 dB	0.50 dB
to	Specified	Transformer Error	0.1 dB	0.1 dB	0.1 dB	0.25 dB
−80 dBV	Error	Gain Steps	1.0 dB	1.0 dB	1.0 dB	1.0 dB
Single Ended		Worst Maximum	1.15 dB	1.3 dB	1.4 dB	1.65 dB
		Most Likely Maximum	0.60 dB	0.7 dB	0.75 dB	1.0 dB
		Most Likely RMS	0.51 dB	0.52 dB	0.53 dB	0.64 dB
		Worst Maximum	1.25 dB	1.4 dB	1.5 dB	1.9 dB
Balanced*		Most Likely Maximum	0.70 dB	0.8 dB	0.85 dB	1.15 dB
		Most Likely RMS	0.52 dB	0.53 dB	0.54 dB	0.66 dB
		Calibrator	0.15 dB	0.15 dB	0.15 dB	0.15 dB
Any Level	Maximum	7L5 Flatness	0 dB	0.15 dB	0.25 dB	0.50 dB
	Specified	Transformer Error	0.1 dB	0.1 dB	0.1 dB	0.25 dB
	Error	Gain Steps	2.5 dB	2.5 dB	2.5 dB	2.5 dB
Single Ended		Worst Maximum	2.65 dB	2.8 dB	2.9 dB	3.25 dB
		Most Likely Maximum	1.10 dB	1.2 dB	1.25 dB	1.5 dB
		Most Likely RMS	1.0 dB	1.0 dB	1.0 dB	1.1 dB
		Worst Maximum	2.75 dB	2.9 dB	3.0 dB	3.4 dB
Balanced*		Most Likely Maximum	1.25 dB	1.3 dB	1.35 dB	1.65 dB
		Most Likely RMS	1.0 dB	1.0 dB	1.0 dB	1.1 dB

dBm = dBV − 10 log Z +30
dBm (124 Ω) = dBV + 9.07 dBm (135 Ω) = dBV + 8.7, dBm (600 Ω) = dBV + 2.2

*These numbers are for 124 Ω and 135 Ω. Measurements at 600 Ω depend to a great extent on the interconnecting cable. A two-foot run of 75 Ω cable, for example, will cause an error at 5 MHz of more than 1 dB due to cable capacitance. For best accuracy, use short runs of low-capacitance cable.

Figure B2.

C. Resolution Bandwidth

Resolution bandwidth is usually set in the "coupled" position. In this setting, it is changed automatically as a function of frequency span. Thus, when examining an extensive range of frequencies, such as a super group, the resolution bandwidth is conveniently wide, but when examining a narrow spectral range, such as a single channel, the resolution bandwidth is reduced accordingly. All of the display photographs in this note were obtained with the resolution bandwidth set in the coupled mode. It is conceivable that one might want to reduce resolution bandwidth so as to display true carrier levels (rather than carrier and modulation combined) while checking a fairly wide spectrum such as a 12 channel bank. This is easily accomplished by setting the resolution bandwidth to the desired position manually. The sweep speed will automatically slow down to maintain vertical calibration so long as the Time/Div control is set in the automatic position. Should the sweep speed be set accidentally to an illegal position, a front panel "Uncal" indicator is activated to warn the operator.

Noise

The most important area for controlling resolution bandwidth is in the measurement of noise. This is a complicated subject that will not be discussed here in detail. The reader is referred to TEKTRONIX Application Note AX-3260 entitled "Noise Measurements Using the Spectrum Analyzer — Part One: Random Noise."

Random noise is measured on the basis of power per unit bandwidth. Therefore, for uniformly distributed (white) noise, the measured power is proportional to the product of noise power per unit bandwidth and measurement bandwidth. Thus, when measuring noise, it is important to know the noise bandwidth of the measuring instrument. For the 7L5, the noise bandwidth (B_N) is approximately three-quarters the resolution bandwidth (B_R), which is defined as the 6 dB bandwidth (B_6).

Thus, $B_n/B_R \cong 0.75$, or 2.25 kHz for 3 kHz resolution bandwidth, or 7.5 kHz for the 10 kHz resolution bandwidth.

A possible source of error in noise measurement is failure to consider the detector. Accurate noise measurement requires a true rms detector. Envelope detectors used in spectrum analyzers measure random noise as 1.05 dB lower in level than actual. In addition, logarithmic compression of the noise spectrum prior to detection also makes the noise power appear less than actual. The result is a total error of 2.5 dB. When measuring noise with a spectrum analyzer in the logarithmic mode, it is necessary to add 2.5 dB to the measurement to get the true power level.

An additional complication in measuring noise on telephone channels is that noise weighting, by shaping the measurement filter, is used to approximate the annoyance factor of the noise. The 7L5, like other spectrum analyzers, does not contain any of the specialized weighting filters. Accurate noise measurements are, however, possible in most cases.

White Noise

Noise measurements comparison using different filter shapes requires a correction factor equal to the ratio of filter noise bandwidth. The standard message channel reference is a 3.1 kHz wide filter. Measurements are computed on the basis of this bandwidth.

The CCITT specification calls for a "psophometric" filter shape which shows a 2.5 dB reduction in output when subjected to flat noise over the standard 3.1 kHz bandwidth. This is slightly more than the 1.7 dB reduction shown by the C-message filter used in the U.S.A. Wideband noise, covering more than a 3.1 kHz bandwidth, will show about 0.3 dB less reduction (0.3 dB more output) since some of it is intercepted on the skirts of the filter.

For the 7L5 3 kHz resolution position, the correction factors are −1.7 dB and −1.4 dB for flat 3.1 kHz noise and wideband noise respectively.*

Thus, the 7L5 will read 0.8 dB (2.5−1.7) more than a psophometric filter and the same level as a C-message weighted filter.

Remember, though, that a spectrum analyzer reads 2.5 dB low when measuring noise in the logarithmic mode and 1.05 dB low in the linear (voltage) mode. Total correction factors are: Add 1.7 dB (2.5-0.8) in log mode and 0.3 dB (1.05-0.8) in linear mode for psophometric weighting. Add 2.5 dB in log and 1.05 dB in linear mode for C-message weighting.

Non-Uniform Noise

Direct scaling of noise bandwidths is not possible when checking a non-uniform noise spectrum. One way to get the information is to set the 7L5 at a fairly narrow resolution bandwidth, such as 100 Hz (about 75 Hz noise bandwidth). The noise spectrum is then weighted (multiplied) by the response curve of the filter of interest (e.g., C-message) and the result integrated to get the final answer.

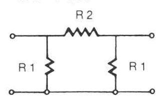
This is not a simple procedure, as it can take several hours. However, in the absence of equipment with an appropriate filter, it may be worth the trouble.

These correction factors are approximate since the bandwidth of the resolution filters is specified as ± 20%. See TEKTRONIX application note AX-3260, "Noise Measurements Using the Spectrum Analyzer — Part One: Random Noise," for details on how to measure actual noise bandwidth.

D. Improving Accuracy

There are two causes of amplitude measurement error: frequency flatness and reference level step error. The flatness error can be reduced by checking instrument flatness against a known-to-be-flat signal source. The result is a display such as shown in *Figure B1.* The flatness error can be further accentuated by making the measurement in an expanded mode as discussed in Section I of this note. The resulting correction factor will improve measurement accuracy by up to 0.5 dB.

The major cause of error, however, is reference level step uncertainty. This is eliminated by calibrating the instrument not at −40 dBV but at the reference level of interest. The easiest way to accomplish this is to insert an accurate external attenuator between the calibrator output and L unit input. The attenuator must have the same impedance as the L unit internal termination setting, 75Ω being the most convenient. If a high accuracy pad is not available, one can be constructed from 0.1% resistors. Pi pad values for 75Ω 6 dB, 10 dB, and 20 dB are given below.



	6 dB	10 dB	20 dB
R1(Ω)	225.8	144.4	91.7
R2(Ω)	56.0	106.7	371.3

Example of Use

You are measuring a signal whose level is expected to be about −54 dBm on a 124Ω balanced line. This is equivalent to −63 dBV (−54−9). Therefore, we set the L3 Option 01 to 75Ω termination and reference level units in dBV. Insert an accurate 75Ω 20 dB attenuator between the −40 dBV calibrator and L3 input and calibrate the instrument at a −60 dBV (−40 −20) setting. Now measure the signal in the usual fashion—connect the balanced transformer, switch out the 75Ω termination on the L3 Option 01 used for calibration, etc. The reference level will have to be changed by 3 or 4 dB instead of over 20 dB. The resulting measurement will have a likely error of less than 0.2 dB instead of more than 0.5 dB as discussed in relation to *Figure 7.*

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