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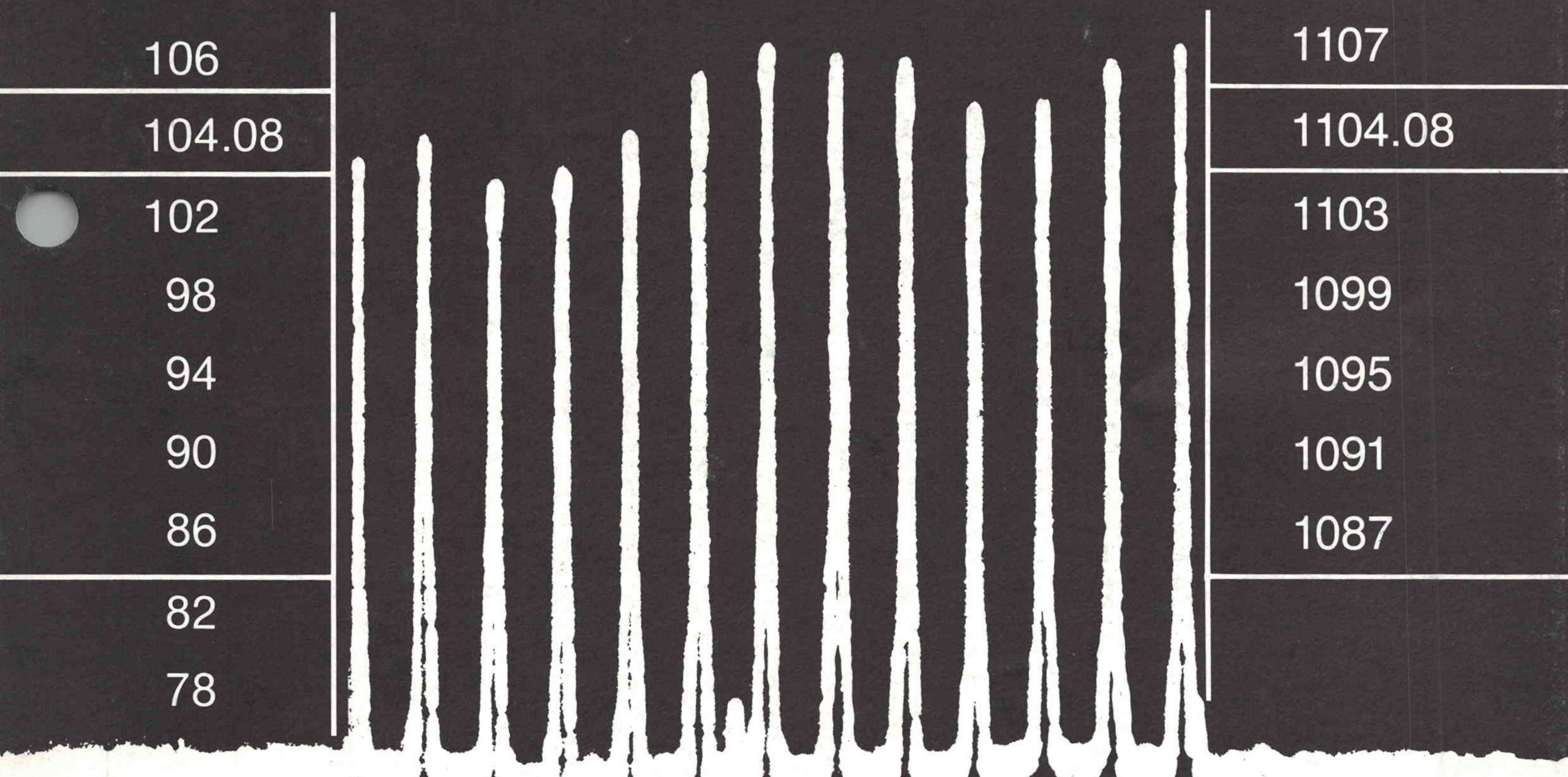
BASEBAND MEASUREMENTS USING THE SPECTRUM ANALYZER



BASEBAND MEASUREMENTS USING THE SPECTRUM ANALYZER

By Morris Engelson

I. The Baseband Signal

Baseband generally refers to a composite signal consisting of voice, teletype, data or other channels along with pilots and test tones. This signal is generated by frequency multiplexing the information channels and test tones onto several different subcarriers. The multiplexed composite baseband signal is then modulated onto a microwave carrier for final transmission. Several types of baseband generation schemes and equipment are presently in use. These may vary in respect to channel frequency, amplitude level, impedance, etc. The system described in the following paragraphs is a typical L Carrier configuration.

A channel bank consists of twelve channel carriers spaced 4 kHz apart from 64 kHz to 108 kHz. They may carry voice information from 300 Hz to 3,550 Hz, narrowband teletype signals, etc. A pilot tone is usually added, typically at 104.08 kHz.

Five channel banks make up a supergroup bank of 60 channels. Supergroup carriers are 420 kHz, 468 kHz, 516 kHz, 564 kHz, and 612 kHz. The group bank signal consists of a 60 channel group from 312 kHz to 552 kHz in addition to the carriers and pilot tones (common pilot frequencies are spaced 48 kHz apart starting at 315.92 kHz).

Ten groups make up a 600 channel mastergroup. Mastergroups, covering roughly 3 MHz of frequency spectrum, can be combined further in groups of two, three, or even more. Some installations contain additional test and signalling tones, which contribute to the complexity of the baseband signal.

While frequencies or signal levels may vary from one installation to another, the basic measurement requirements are quite similar. Basic parameters to be measured include:

A. Amplitude levels of carriers, test tones, signal tones, data, etc.

B. Spurious signal levels and frequencies due to harmonics and intermodulation.

C. Leakage at channel carrier, group carrier or other frequencies.

D. System noise levels.

E. Frequency shifts due to changes in degree of modulation or other causes.

F. Identification of random transient noise burst interference.

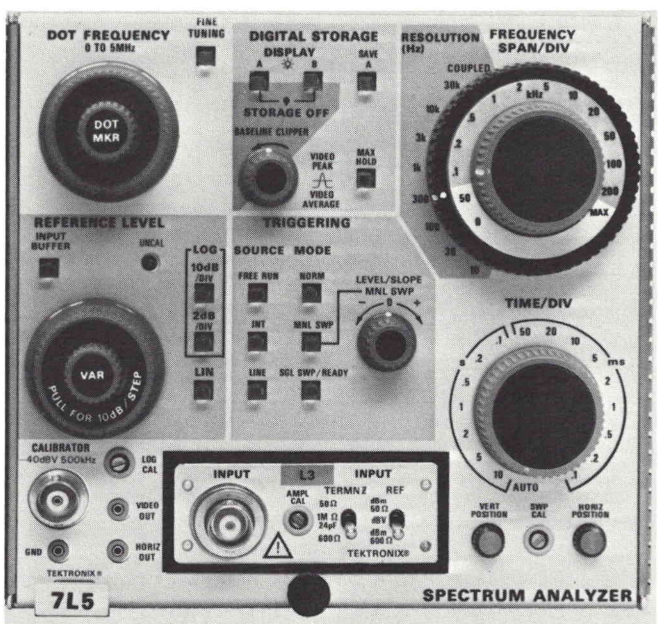
G. Determination of notch filter shape.

All these parameters can be measured with the TEKTRONIX 7L5 Spectrum Analyzer.

Measurement techniques are illustrated by specific examples in Section III. First, however, let us get acquainted with the capabilities of the 7L5.

II. The 7L5 Spectrum Analyzer

The 7L5 Spectrum Analyzer tunes over a frequency range from zero to 4999.75 kHz. Thus it meets all the frequency requirements of a 600 channel baseband system and most of the requirements of a 1,200 channel baseband system. Instrument frequency range is not adequate for more complex installations, such as those consisting of three mastergroups. Of course, one can use a separate mixer and local oscillator to convert a signal down to the



Acknowledgement: Baseband system measurements are by courtesy of the Dittmer Communications Group of Bonneville Power Administration.

Using "Save A"

The ability to save, and hence to freeze, a spectral display in the A digital storage section, while section B continues to update, permits some useful measurements. One application is shown in Figure 5. The modulated carrier at 1102 kHz is saved in Memory A while Memory B shows the unmodulated carrier at a later time. Note the frequency shift of 400 Hz between modulation on and modulation off. Note also that the supposedly unmodulated carrier has a 400 Hz sideband 25 dB below carrier level.

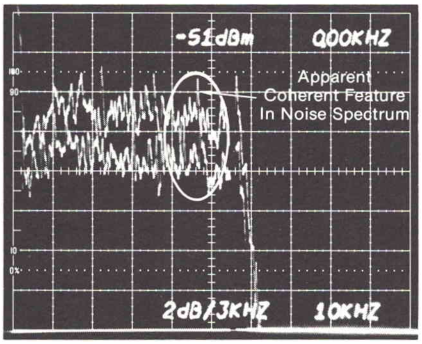


Figure 7—Using "Save A" for noise spectrum comparison.

Figure 7 shows another application of the "Save A" function. Here we observe the spectrum of a down converted noise test signal. The noise extends from virtually zero hertz at the left hand dot position to almost 60 kHz. A noise burst is held for comparison in the A Memory while the B Memory continues to update. The gain has been reduced 2 dB to move one division down and separate the traces for ease of viewing. A consistent match-up of a peak or notch between the A and B spectra indicates a non-random component in the noise. Such a coherent feature may indicate system non-linearities. The first peak to the left of screen center has a suspicious match-up between the A and B traces which should be more closely examined at a narrower frequency span.

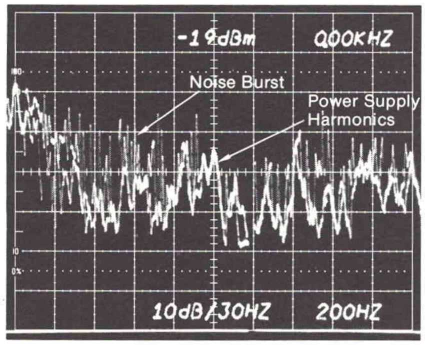


Figure 8—Observation of noise burst and power supply harmonics.

Figure 8 shows another low frequency noise display. Here a random noise burst is saved in A Memory, while the brighter trace of Memory B shows the noisy but coherent spectrum of power supply harmonics.

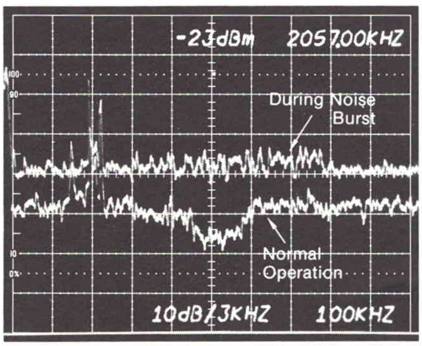


Figure 9—Showing interference level during noise burst.

The last illustration of the "Save A" feature is shown in *Figure 9*. The lower trace displays the shape of a notch filter at 2,057 kHz. There are also several spurious signals about 300 kHz below the notch frequency. The upper trace shows the update in Memory B with the MAX HOLD function activated. The MAX HOLD function will hold in memory and display the maximum amplitude level that occurs during observation time. Here a noise burst has increased the system noise about 10 dB while totally obliterating the effect of the notch filter. The MAX HOLD feature permits unattended monitoring of random noise burst interference, since the maximum amplitude will be held in memory.

Spurious Signal Analysis

The ability to set frequency with a high degree of accuracy makes it easy to intercept intermodulation and other spurious signals whose frequency can be predicted. The high degree of accuracy also means that the frequency of unexpected spurious responses can be pinpointed and the source identified.

If three tones at 57 kHz, 2600 kHz and 2714 kHz are fed to the system under test, the following second and third order intermodulation responses will occur:

A. $\begin{cases} 2\,(57) = 114 \text{ kHz} \\ 2714 - 2600 = 114 \text{ kHz} \end{cases}$

B. $\begin{cases} 2600 + 57 = 2657 \text{ kHz} \\ 2714 - 57 = 2657 \text{ kHz} \end{cases}$

C. $\begin{cases} 2714 + 2\,(57) = 2828 \text{ kHz} \\ 2\,(2714) - 2600 - 2828 \text{ kHz} \end{cases}$

Theoretically the pairs of responses fall at precisely the same frequency, but the actual tones will be displayed as pairs due to slight input signal deviations in frequency.

III. Making The Measurement

General Search

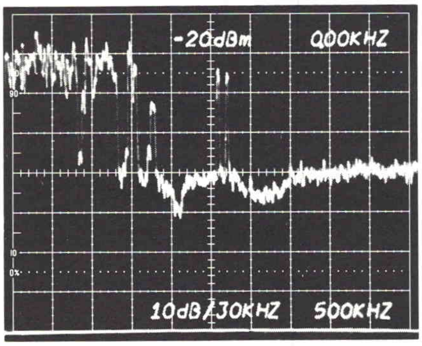


Figure 2—Zero to 5 MHz display of baseband spectrum.

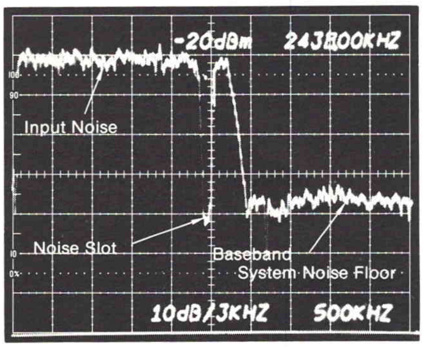


Figure 3—Noise loading test showing noise slot at 2,438 kHz.

Figures 2 and 3 show a search of the full 5 MHz spectrum. In Figure 2, a number of active channels below about 2 MHz are shown blending into each other. Two tones occur just above 2.5 MHz. The remainder of the spectrum display up to 5 MHz shows only system noise. Figure 3 displays a noise loading test. Input noise, at −30 dBm, is 35 dB above system noise, at −65 dBm. The noise slot at 2438.00 kHz goes all the way down to the system noise level, a depth of almost 40 dB.

Having performed a preliminary examination across the full frequency range, we proceed to a detailed examination of specific portions of the spectrum.

Leakage Measurements

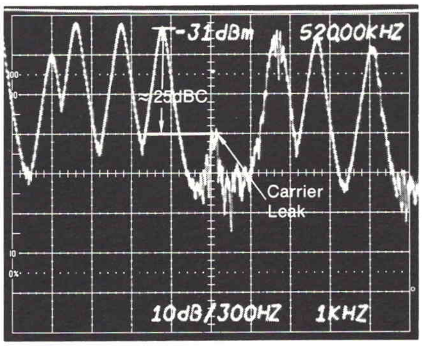


Figure 4—Carrier leak measurement.

Figure 4 shows a carrier leak at 520 kHz. Carrier leak is the carrier signal that remains after suppression in a suppressed-carrier system. Leakage amplitude is −60 dBm. This is almost 25 dB below the level of the adjacent signals.

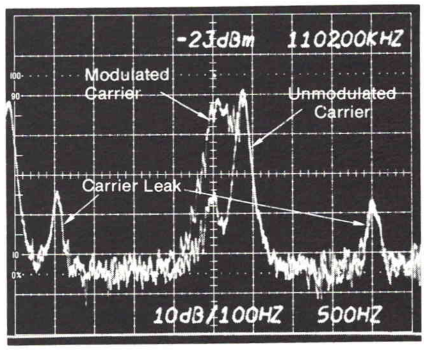


Figure 5—Illustrating frequency shift with modulation, and carrier leak.

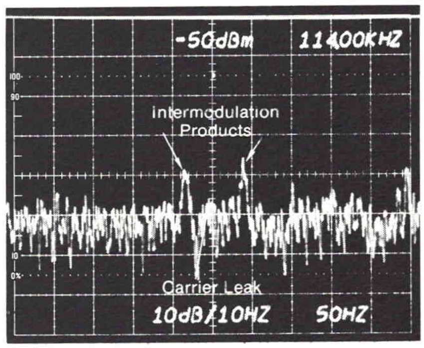


Figure 6—Illustrating three tone intermodulation products, and carrier leak.

Figures 5 and 6 show a combination of measurements including carrier leak. Figure 5 shows two leaking carriers 4 kHz apart, at amplitude levels of −65 dBm and −70 dBm respectively. The complex looking signal at 1102 kHz will be described later.

Figure 6 shows a carrier leak at 114 kHz which is barely discernible above the noise level at −98 dBm. (Note the setting of the peak/average cursor above the noise for best sensitivity.) The two tones at 40 Hz on either side of the carrier are intermodulation sidebands caused by a three-tone test signal. Three tone testing is discussed later.

7L5's frequency range. However, this process negates the 7L5's major advantage: ease of use. This application note is therefore addressed primarily to users of baseband systems which contain less than two mastergroups.

Frequency is synthesized in 250 Hz steps and indicated on a six digit frequency readout. The frequency sweeps across the screen, providing a full-screen indication from 500 Hz to 5 MHz, depending on the frequency span setting. In addition, resolution bandwidth can be set from 10 Hz to 30 kHz. This combination of frequency control capabilities means that the screen can be made to display either a single signal or a combination of carriers, channels, pilot tones, etc.

Signal amplitude differences can be displayed on a scale of 10 dB/div for spurious signal hunting or at 2 dB/div and volts/div for accurate amplitude measurement. The full-screen reference level can be varied from +21 dBm to −128 dBm for convenient display of all desired signal levels as well as idle channel noise.

The display system includes several features particularly useful for observing amplitude and frequency changes. Dual-memory digital storage allows a spectral display to be saved in one memory while the second memory displays a continuous update. The MAX HOLD function maintains the maximum amplitude level in memory updating only when a larger signal level occurs. This permits randomly occurring transients to be captured as well as small shifts in amplitude and frequency. Digitization of the stored signal allows the average value to be arithmetically computed. A display cursor can be positioned anywhere on the screen. Peak levels are displayed above the cursor while average level is shown below the cursor. In this way the noise level is reduced through averaging without disturbing the display of random high level transients.

The front-end characteristics of the 7L5 are determined by the plug-in module used. Three modules are presently available. The L1 with 50 Ω input, the L2 with 75 Ω input, and the 1 MΩ L3 with 50 Ω and 600 Ω terminations. The user can convert L3 terminations and calibration values to any impedance up to 900 Ω by selecting three resistors. Thus an impedance of 124 Ω such as used to terminate a transformer for balanced lines is easily accommodated. If an external feedthrough termination is to be used the L3 is set at 1 MΩ and measurements are made in dBV. The following formula expresses the conversion between dBV and dBm:

$dBm = dBV - 10 \log Z + 30$ where Z equals input impedance. For example, $dBV = [dBm\ (75\ \Omega) - 11.25] = [dBm\ (124\ \Omega) - 9.07]$.

Lines which should not be loaded because of double termination problems can be bridged using the 1 MΩ L3. Measurement of balanced lines may be facilitated by means of a transformer, such as the Tektronix type 013-0169-00*.

A more detailed description of the special capabilities of the 7L5 is found in "Noise Measurements Using the Spectrum Analyzer Part One: Random Noise" TEKTRONIX AX-3260, and "Part Two: Impulse Noise" TEKTRONIX AX-3259.

Figure 1 illustrates the measurement parameters indicated by a 7L5 display.

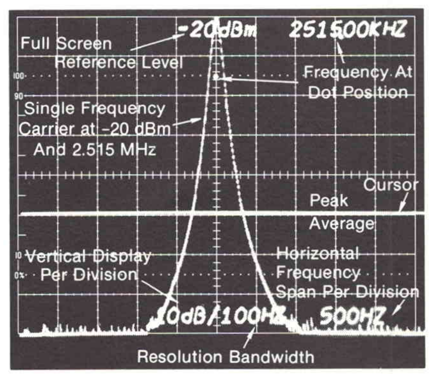


Figure 1—Spectrum analyzer display of unmodulated carrier.

**Transformer 013-0169-00 has essentially zero insertion loss and is quite flat in a 124 Ω system. However, the standard unit is equipped with clip leads which may be inconvenient for baseband hook-up. Therefore modification may be necessary.*

Figures 6, 10, and 11 display the intermodulation resulting from the three-tone test signal. Figure 6, discussed previously in relation to carrier leak, shows the two 114 kHz tones from (a) above. Figure 10 shows the two 2657 kHz components computed in (b), and Figure 11 shows the output at 2828 kHz.

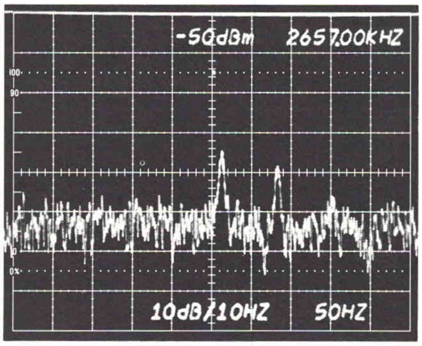


Figure 10—Three tone intermodulation products.

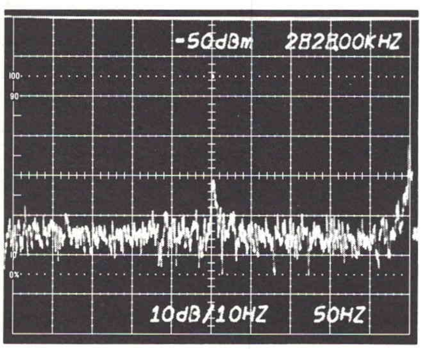


Figure 11—Three tone intermodulation products.

Figure 11 also illustrates the usefulness of the 7L5's averaging functions to pick a low level signal out of the noise. Here the peak/average cursor has been moved to the top graticule line to average the displayed noise. Also the sweep time is set quite long at 10 seconds/div (not shown on readout) to produce maximum averaging. Thus we are able to distinguish an intermodulation signal at −90 dBm from the average channel noise level of −100 dBm in a 10 Hz bandwidth. The 7L5 internal noise is less than −135 dBm at a 10 Hz resolution.

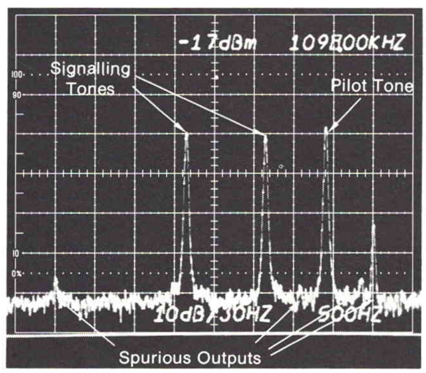


Figure 12—Illustrating pilot tone, signalling tones and spurious outputs.

Finally, pilot and signalling tones along with various spurious outputs are illustrated in *Figure 12.* The three strong tones at a level of −47 dBm are a pilot tone at 1099.4 kHz and two signalling tones at 1097.6 kHz and 1098.6 kHz respectively. The three quite small signals at about −85 dBm, and the 1100 kHz tone at −70 dBm are caused by harmonics intermodulation and carrier leak.