RADIO FREQUENCY NRSC MEASUREMENTS WITH THE 2710

Introduction

The FCC has adopted the AM radio standards developed by the National Radio Systems Committee (NRSC). These standards reduce interference and improve the fidelity of AM radio stations. This is done by specifying an audio pre-emphasis curve and an allowable spectrum occupancy. The pre-emphasis curve provides a known treble boost to the transmitted audio similar to that used in FM broadcasting. This allows receiver manufacturers to produce inexpensive sets with improved fidelity. The spectrum occupancy specification limits adjacent channel interference from other stations. Taken together, the standards are intended to substantially improve AM broadcast reception quality.

The NRSC standards are in two parts, NRSC-1 and NRSC-2.

NRSC-1 specifies an audio processor that is inserted before the transmitter. This filter includes a pre-emphasis section and a sharp 10 kHz lowpass filter. The pre-emphasis provides a treble boost to overcome the high frequency roll off encountered in most AM receivers. The low-pass filter limits the maximum audio frequency that can be applied to the transmitter, which is the first step in controlling occupied bandwidth. The NRSC-2 standard specifies the stations occupied bandwidth, which requires measuring the station's off air signal.

While it was thought by many that implementing only NRSC-1 by installing the required audio filtering would be enough, experience has shown that other operating parameters affect whether or not the occupied bandwidth specification is met. If the transmitter is slightly overmodulated or has excessive incidental phase modulation or has excessive distortion, its transmitted spectrum will not fall to the low levels required above 10 kHz. Just adding the NRSC-1 filter will not change these factors. This reasoning caused the FCC to require occupied RF bandwidth measurements starting in July,1994.

The 2710 is ideal for making RF NRSC measurements. When equipped With Option-01 (phase lock) the 2710 has both the stability and the narrow bandwidth (300 Hz) necessary to make the long term measurements required. It is also small and light, ideal for field measurements and at a price low enough to bring it within the reach of station owners and consultants.

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The NRSC Standards

To understand the NRSC standards, we need to look a a block diagram. Fig. 1 shows the basic elements of an AM station. The actual transmitted signal is what matters, so the antenna system is included because it has a major effect on the station's performance. The standards require verifying performance using off-air signals.

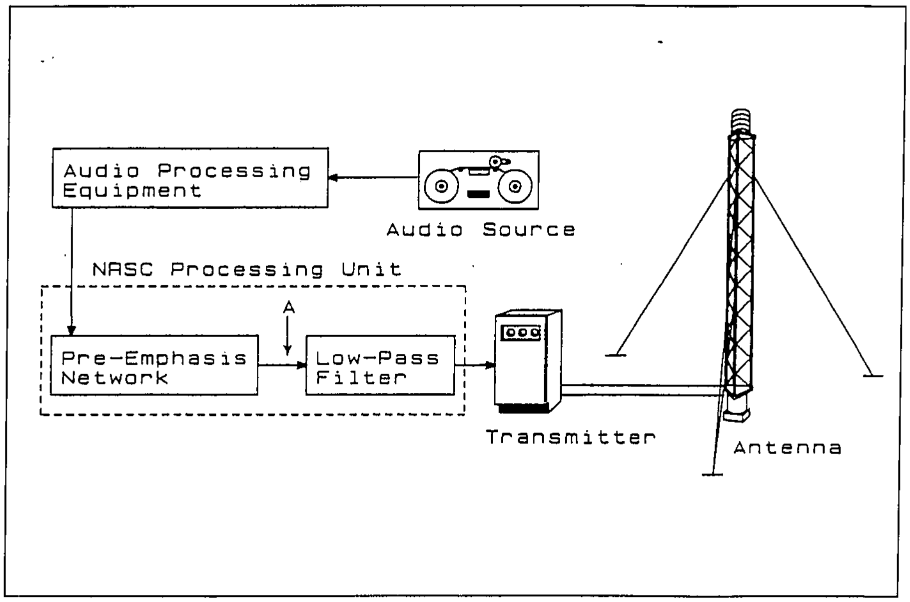

Figure 1. Block Diagram of an AM Transmitter System

As mentioned above, the NRSC-1 standard has two elements: a pre-emphasis curve and a low pass filter. Figure 2. shows the pre-emphasis curve that would be measured at point A in the block diagram, before the low-pass filter. It is similar to the pre-emphasis curve used in FM broadcasting in that a 75µS time constant treble boost is used. It is different in that the response flattens above 8700 Hz. In engineering jargon, the curve is said to have a pole at 2122 Hz and a zero at 8700 Hz.

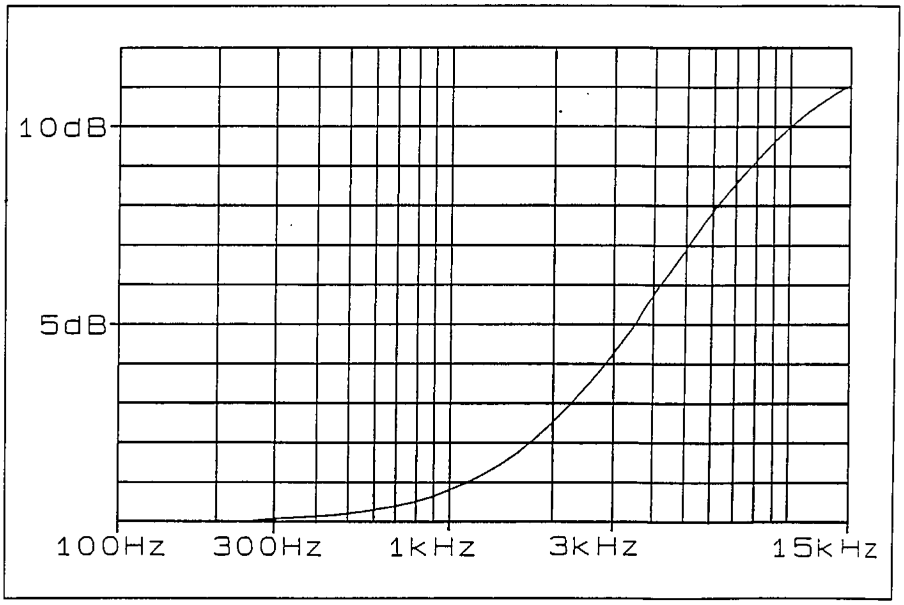

Figure 2. The NRSC Pre-Emphasis Response Curve.

The pre-emphasis network is followed by a very sharp low-pass filter. The exact shape of this filter is not specified. Instead, the spectral content of the audio output when driven from a special noise generator is given. Because this low-pass filter has a very sharp cut-off, it will ring and overshoot, which can cause overmodulation. The various vendors of NRSC hardware have been challenged to develop filters with active damping systems to limit this effect.

The NRSC-2 standard specifies how much bandwidth an AM transmitter may occupy. Briefly, the standard says that the emissions from an AM transmitter must be below the limit curves given in Figures 3 and 4. The standard also gives the standardized measurement conditions required to perform the test.

Figures 3 and 4 are reprinted directly from the NRSC-2 standard. Figure 3 shows the entire limit curve or "mask". Figure 4 gives a detailed look at the spectrum near the transmitter's frequency.

The solid line is the limit for an operating transmitter with program material. The dotted line is a more stringent standard for compliance testing using the special noise source mentioned above. The curve adopted by the FCC is very similar to the solid line except that the drop from 0dB to 25dB is at 10.2kHz instead of 10kHz as shown.

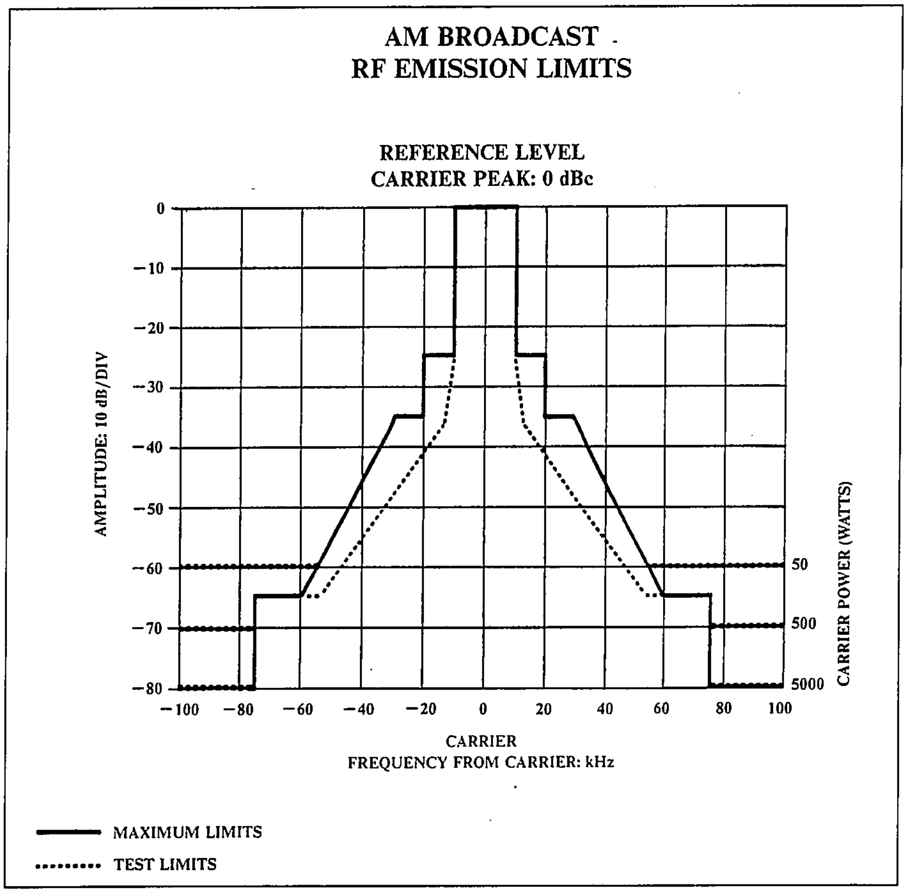

Figure 3. The Wideband Spectral Occupancy Limit Curve from the NRSC-2 Standard.

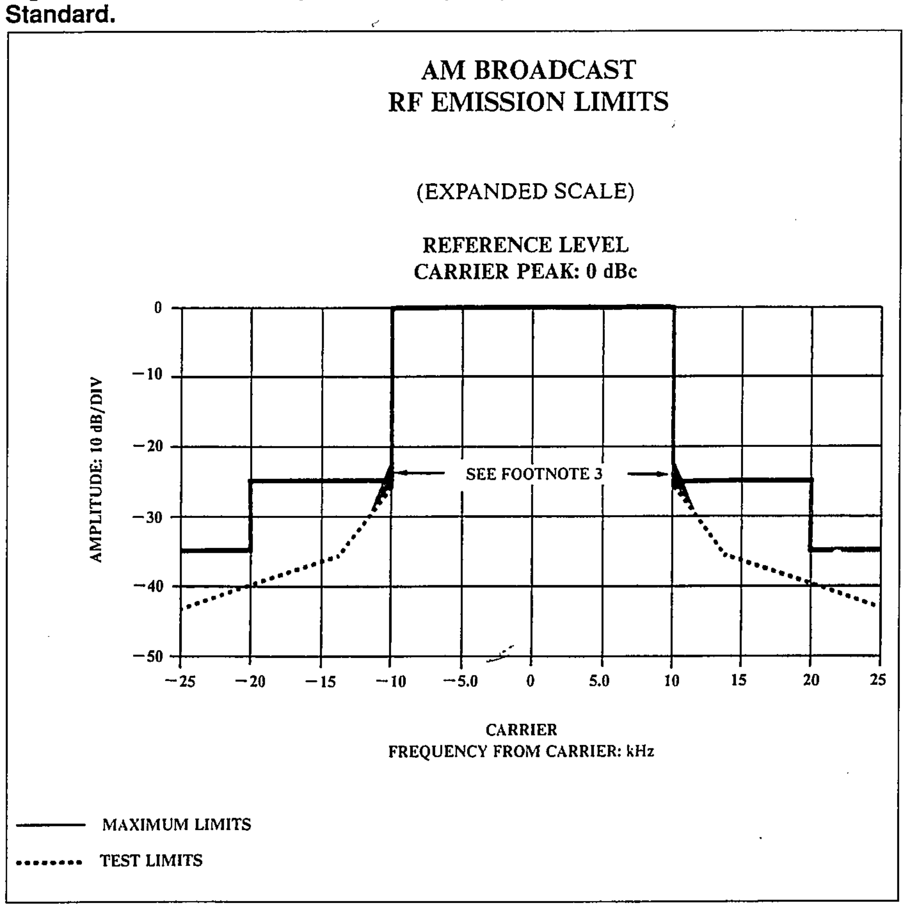

Figure 4. The Close-In Spectral Occupancy Limit Curve from the NRSC-2 Standard.

[3]The region between 10 kHz and 11 kHz of the NRSC-1 specification is slightly relaxed. The NRSC-2 specification is to follow the NRSC-1 standard in this frequency range with a 6 dB offset.

Making NRSC Measurements

General Considerations:

The quality of an AM radio station's signal is limited by the transmitter and its antenna system. Audio equipment has become relatively perfected but the problem of generating a high power signal and passing it through a relatively narrow band antenna system remains a central issue for the AM broadcaster. Therefore, it is important that the transmitter and its antenna system be included in any test. RF testing is specified when testing the pre-emphasis curve in NRSC-1 (unless the total transmitter-antenna system is known to be flat) and when testing occupied bandwidth in NRSC-2 .

Spectrum analyzers are ideal for these measurements. A swept spectrum analyzer such as the TEK 2710 is presently specified by NRSC-2 for occupied bandwidth measurements. Such an analyzer will also give an important picture of the amplitude response of the transmitter and its antenna system for pre-emphasis measurements.

Two different types of antennas can be used for AM broadcast band testing: loops or whips. Because of the low frequency of the AM broadcast band, a whip will produce a low amplitude signal if hooked directly to a low impedance spectrum analyzer input. Therefore, to be useful anywhere except very near the station, a whip should be preamplified. Several different vendors can provide such antennas.

A loop antenna is very useful in the AM broadcast band. They can also be purchased but tend to cost much more than a whip. One can easily build a loop antenna of either the shielded or the unshielded variety. The shielded loop responds to only the magnetic component of the field and rejects many sources of power line noise. They also exhibit directionality; signals traveling toward either face of the loop are rejected.

The directionality of the loop antenna is a major advantage over the whip. After the station's signal is measured, the antenna can is turned to null the station's carrier so the amplitude of signals near the station's frequency can be checked. In this way one can see if a given signal is coming from the transmitter under test or is a signal in the environment. Many articles on loop antennas are available in the antenna, ham radio or shortwave listener literature.

The antenna used to obtain the data shown in this application note was build out of a hula hoop! The hoop is cut along its outer edge with a saw and the metal balls removed. Four turns of number 16 insulated wire are installed through the slot inside the hoop. Wire with a large amount of insulation to space the turns away from each other is best. Then a .002" thick piece of self adhesive copper tape is used to cover the hoop, leaving a 1/2" gap just opposite the point where the wires come out. One end of the inner coil is grounded to the foil and the other connected to the center conductor of a coaxial cable. The braid of the coaxial cable is also grounded to the foil. The impedance of the coaxial cable can be either 50 or 75 ohms.

When making RF measurements, the location where the tests are made must be carefully chosen, especially with directional transmitting antenna arrays. NRSC-2 says that one should be at least 10 wavelengths away from the center of such an array to make the measurements.

The reason for this is that, especially in checking the pre-emphasis characteristics, the sideband response of each tower in the array may vary. If one measures at a location too close to the array, the signals of the individual towers will not contribute in the same way as they would farther away.

With non-directional antennas one can make measurements much closer to the antenna. The near field should be avoided, but one can measure anywhere up to edge of the antenna's ground field. Don't forget that like a proof, performance must be verified in each operational mode. For instance, high power and low power transmitter operation, or day and the night antenna patterns each must be checked.

Spectral Occupancy

NRSC-2 gives specific instructions on using a spectrum analyzer to make occupied bandwidth measurements:

> §3.3.2. Use of Spectrum Analyzer. A suitable swept-frequency RF spectrum analyzer shall be used to measure compliance with the NRSC-RF occupied bandwidth specification. The analyzer shall measure the over-the-air RF spectrum occupancy as perceived in the far field (i.e., at least 10 wavelengths from the antenna center). Some caution should be used in measuring spectrum occupancy with directional antennas.

The analyzer's setup shall consist of:

> a. 300 Hz resolution bandwidth.
> b. 5, 10, or 20 kHz/horizontal division (as appropriate).
> c. 10 dB/vertical division.
> d. Reference: carrier peak.
> e. Peak Hold: 10 minute duration minimum.
> f. No Video filter.

A video filter is a RC-filter used to reduce the post detection bandwidth to reduce the "grass" so that small signals are easier to see. For practical purposes, "No Video Filter" means that the post video detection is wide enough so that the analyzer's risetime is not made longer than the response limitation caused by the IF bandwidth. In practice, a video filter of equal or greater than the resolution bandwidth will not slow the video risetime.

The 2710 automatically selects a video filter equal to the resolution bandwidth. This gives excellent results. If, however, one wishes to comply with the letter of the specification, the 2710's video filter can be manually set to a much wider, say 300 kHz bandwidth. The first step in making an occupied bandwidth measurement is to select a test antenna and the measurement site. The measurements must be made in the field. The 2710 option 07 (battery operation) allows operation of the 2710 without an external power source. If more convenient, almost any AC inverter or generator that can light a 100W light bulb can also be used to power the 2710.

The site selection must be carefully made. It must be close enough to the transmitting antenna so that the amplitude of the station's carrier is very large with respect to the other nearby signals and noise. Yet, as mentioned above, with directional antenna systems, it must be far enough away from the antenna system to make the measurement valid. In testing directional systems, one must also take care that the testing be done at a site in the main lobe of the antenna's output.

Measurements made in a pattern null often have much higher sideband energy with reference to the carrier. This is because the carrier is normally nulled more than the sidebands.

After selecting the site and hooking up the antenna and power source to the 2710, you are ready to make spectral occupancy measurements. NRSC-2 specifies that the measurements "shall be conducted using ordinary program material". This is very important. The modulation's spectral content varies drastically with program content. In general, wait until the station is playing music typical to the format. A talk show will produce very misleading results.

Turn on the analyzer. As the 2710 warms up, press the "Mkr/Freq Menu" key. Now press "0" to choose the Frequency Entry mode, and enter the station's frequency. Press <> repeatedly to narrow the span until the analyzer is in the 10kHz/DIV Span. The frequency control system of the analyzer will keep the signal centered as the analyzer warms up, but there will be some sweep to sweep drift and some overall drift until the analyzer is warm. After the analyzer is reasonably stable, we are ready to progress. This wait can be eliminated by warming up the 2710 before leaving the station.

Use the "Frequency/Markers" knob to exactly center the station in the display and press "Max Hold". Select the A trace and turn off the D trace by pressing buttons "A" and "D". Wait 10 minutes.

You should have a picture similar to the top trace in Figure 5. If you have a 2710 option 09 (Centronics interface) and a TEK HC100 plotter, you can plot the results of this measurement as in Figure 6. Don't forget to turn on the graticule lights before starting the plot so the plotter will show the graticule.

If you are using a loop antenna it is wise to check the background amplitude of signals near the station's frequency. Press "Save" and then "A" to hold the first trace. Press "B" to turn on the B trace and then "Max Hold" again to temporarily turn off this mode.

While watching the carrier amplitude on the 2710, carefully turn the loop until a null is observed in the B display. When the null has been obtained, press "Max Hold" again and wait long enough for the display to stabilize. When making these measurements, most of the display builds up very rapidly after "Max Hold" is turned on. You do not need to wait as long for the background measurements. You should get results similar to those shown in Figures 5 and 6. If a whip antenna is used to make the measurements instead of a loop, the carrier will need to be turned off to make the residual measurement.

Note that turning the loop to ascertain the background amplitudes has a limitation. If the source of a interfering signal is also nulled as you turn the loop, you will get a wrong answer. If in doubt, move to a new site that is at right angles with respect to the station from the first site. Now, as the loop is turned to null the carrier, it will have a maximum sensitivity in the same direction as the original measurement.

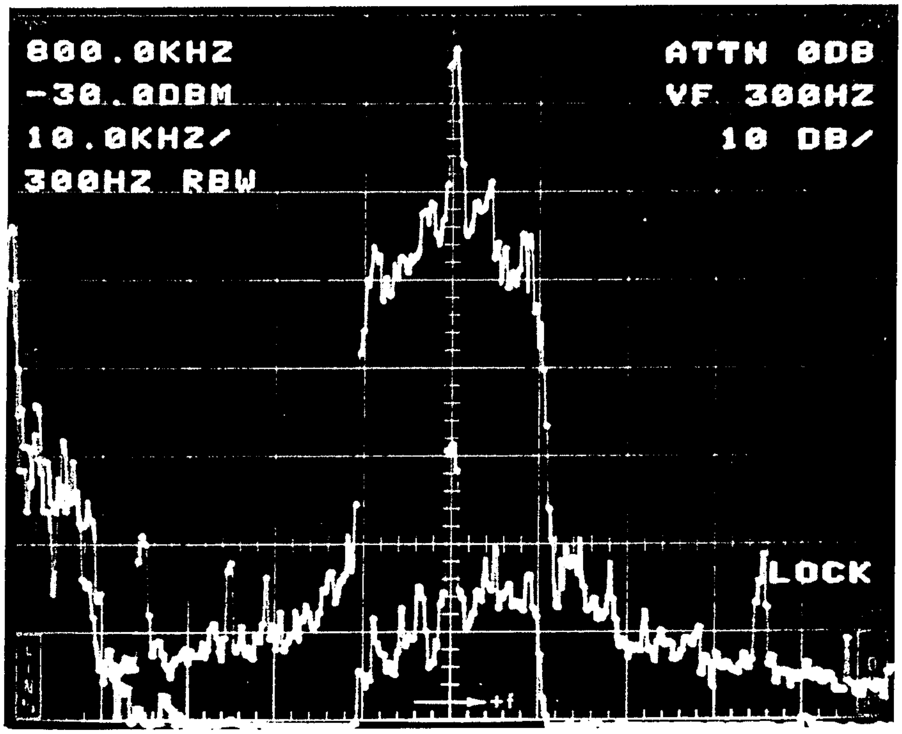

Figure 5. Top Trace: Measured Spectral Occupancy in 20 kHz/Div.
Bottom Trace: Residual Response with the Carrier Partially Nulled.

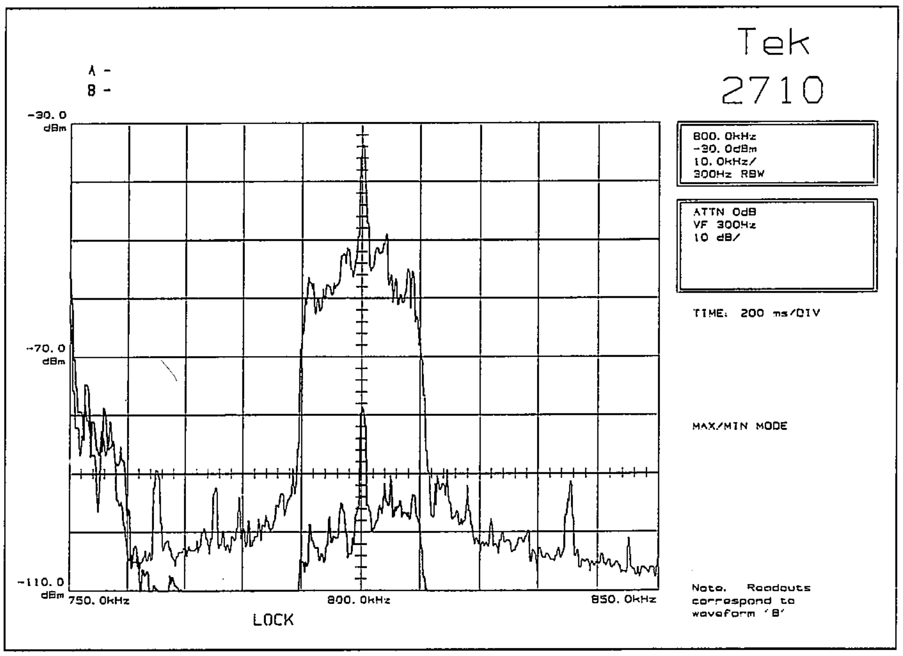

Figure 6. A Plot of Figure 5 Obtained Using a 2710 Option 09 and a Tek HC100 Color Plotter

Now that we have taken the wide measurements, push the <> key twice more to reduce the span to 5 kHz/DIV and repeat the measurement. Do not forget to turn of the Max Hold mode and to un-Save the A trace. Reposition the loop for maximum carrier amplitude. It is not usually necessary to check the background amplitudes when measuring the close-in spectral occupancy. The results of this measurement should look like Figure 7.

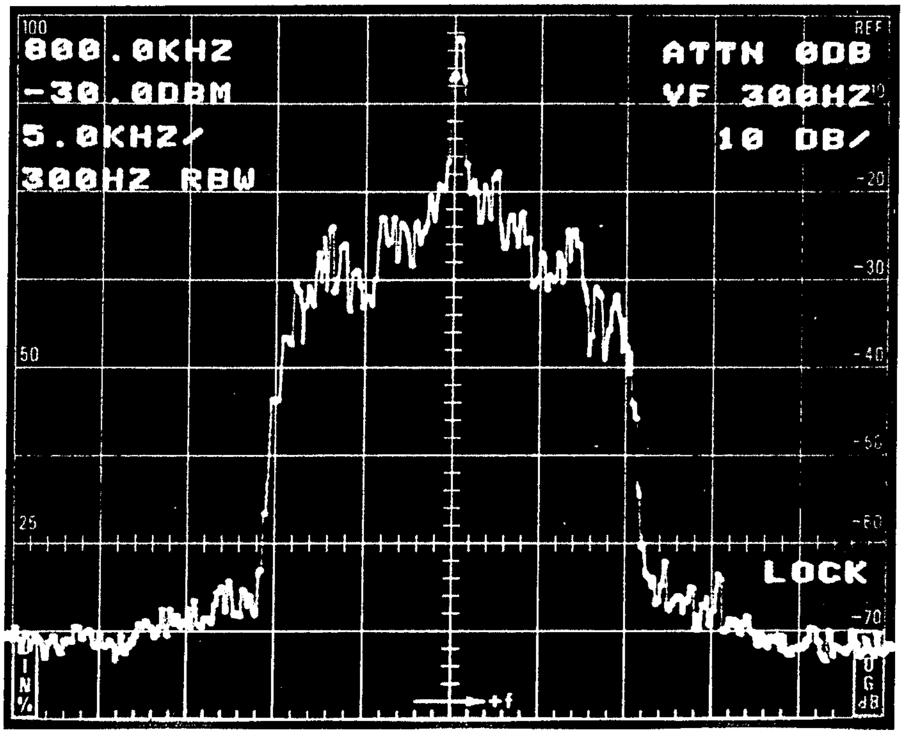

Figure 7. Measured Spectral Occupancy in 5 kHz/Div.

Pre-Emphasis

The pre-emphasis curve can also be measured with the 2710. There are two basic ways this can be done. One is to use a swept audio tone and the other is to use a white noise source to modulate the transmitter. To make the measurement, first adjust all the station's limiting and processing equipment for a normal proof. Arrange to modulate the transmitter with either a sine wave tone or a flat white noise source. If you plan to use the tone, you will need an assistant to help you make the measurement.

Set the 2710 up as before. Select a 2 kHz/DIV span, a 5 dB/DIV display mode and press "Max Hold". If the noise generator is used, the display will build up over several sweeps until it stops increasing. The displayed response will show the station's pre-emphasis response.

If the tone source is used, your assistant will have to change the frequency bit by bit until the display is filled out as shown in Figure 9. In actual practice, it is not necessary to make fine grain changes in frequency. Making measurements at 1 kHz intervals from 1 to 10 kHz will show the characteristics of the curve quite well.

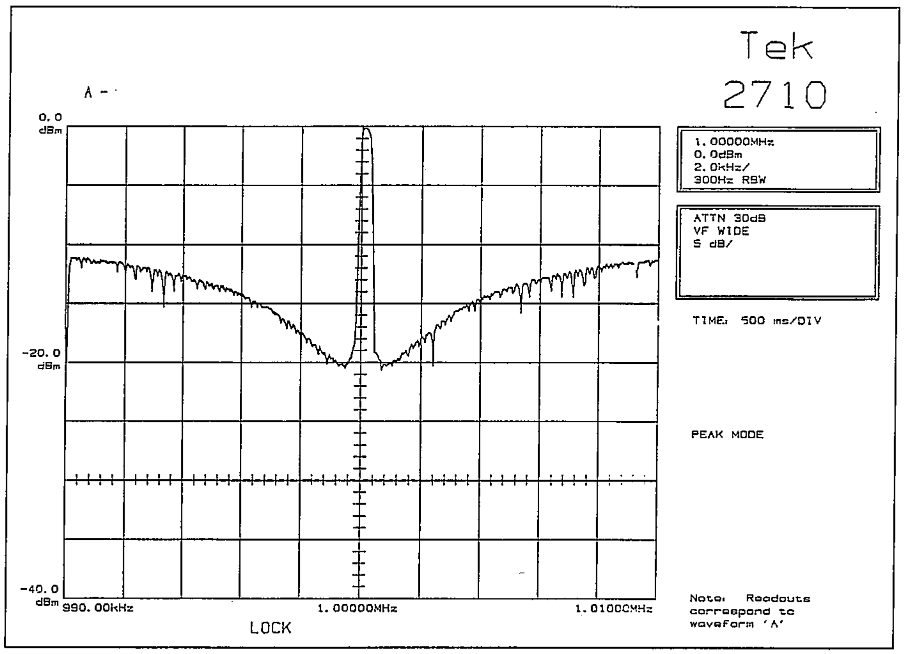

Figure 8. Measured Pre-Emphasis Response.

One major advantage to making pre-emphasis measurements using the 2710 is that the response of each sideband is shown. Adjusting the transmitter and antenna system to make them equal is an important first step in obtaining a wide bandwidth, low distortion sound.