SSB (Single Side Band), What Is It? **John L Stewart P Eng**

Some Background

You have probably noticed the myriad of different modulation schemes in use, in particular over the past few years. All of these are the result of only three possible modulation techniques or a combination of them. It doesn't matter whether they are applied to Microwave, Radio Frequency (RF) or even to power frequencies such as 60 Hz. The three possible ways to modulate a waveform are as follows-

AM (Amplitude Modulation)- The amplitude of the envelope is varied
FM (Frequency Modulation)- The instantaneous frequency is controlled
PM (Phase Modulation)- The phase of the carrier is varied by a modulating signal

If you were to examine a modulated signal with a Spectrum Analyzer or Wave Analyzer you would find that it most always consists of two parts. One of these is the carrier frequency. The other is a number of frequencies located each side of the carrier. These are the so-called 'sidebands' and they convey the information or intelligence to be transmitted by the system. Normally the sidebands are symmetrical each side of the carrier. One of the indicators of problems in a transmitter is an unsymmetrical set of sidebands. There may be a combination of AM and FM on the same signal. Designers of communication systems take great care to minimize these problems. Important measurements of a transmitter's performance include incidental AM and FM.

When an RF signal is unmodulated it is said to be CW (Continuous Wave). If the amplitude of that signal is varied by some controlling signal, then we have AM. As the modulating signal level is increased, the sidebands visible on a Spectrum Analyzer show up on each side of the carrier signal. The height of the sidebands represents the level of modulation. The distance of the sidebands from the carrier is an indication of the modulating frequency. For example, if the modulating frequency were one KHz, the sidebands would appear at one KHz above and below the carrier. A complex signal such as speech contains many frequencies, so there results in that case many sidebands. Frequencies above the carrier are referred to as USB (Upper Side Bands). Those below are LSB (Lower Side Bands).

It was realized fairly early in the age of electronics that all the information to be transmitted was in both of the upper or lower sets of sidebands. It should be possible to move all the information by transmitting just one of the sidebands. No carrier needed. Single Side Band (SSB) systems were developed that make use of this fact.

Systems using SSB have a considerable performance advantage over ordinary AM systems. Part of that is a result of all the power in the transmitter being used to transmit the information. In a 100% modulated AM system, only one-sixth of the power is in each of the sidebands, while two-thirds of the power is in the carrier. If there is no modulation, then all of the power is in the carrier. If all of the power went into transmitting one of the sidebands the improvement could be 6X (7.78 dB). The other advantage has to do with the Bandwidth (BW) occupied by the signal. For SSB, that is one-half of the AM case. Signal-to-Noise (S/N) Ratio is proportional to the square root of the Occupied BW (OBW). So that gets the SSB system another improvement of 1.4X (1.46 dB).

To get the same performance from a conventional AM system the transmitter power would have to be increased by a factor of 8.4. That is a lot when you start to build a communication system. Alternatively you could improve the receiver and its antenna by the same factor. Not always easy to do.

Why doesn't everyone use SSB? The short answer is that the circuitry at both ends of the system is fairly complex. And when these systems were first put into use, they were a bit tricky for non-technical people to operate. More recent equipment is much more user friendly.

Who Uses SSB?

At present, SSB is used by the Coast Guard and Military. Quite a few Hams (Amateur Radio Operators) are using SSB as well. 99% of the activity is found between 1.705 and 30 MHz. If you see a military vehicle with what looks like a whip antenna about 2 meters long, there is probably an SSB communication system inside.

Testing SSB Radios

Industry Canada publishes many documents on the minimum requirements for communication systems. One of these is RSS (Radio Systems Specification) 125, which refers to SSB. Another is RSS 181 which covers Coast & Ship Stations. As well, you should refer to the radio manufacturer's recommendations on how their radio should be tested. All of the standard performance tests are normally conducted while operating in the USB mode.

A Communication Monitor with two audio generators and a spectrum analyzer is required. That would include the Aeroflex 2975 and Aeroflex 2945B.

Receiver Test

For the receiver test, one needs to generate an RF signal at a frequency that will result in a One KHz tone at the Audio Frequency (AF) output of the receiver. For example, if the receiver was set to 28.400 MHz, an RF signal of 28.401 MHz at its antenna terminals should result in an AF output at One KHz, provided the receiver was operating in the Upper Sideband (USB).

The RF level needs to be adjusted so that a series of performance measurements can be made. These might include SINAD, Distortion, Output Level & AF Frequency Offset.

The AF Frequency Offset is a result of the radio time base not being locked to the time base in the test set. For example, if the time bases were different by one ppm (part per million), the Receiver AF output would be 28.4 Hz offset from One KHz.

Transmitter Test

The Communication Analyzer internal audio generators are set to equal modulation level sine waves of 850 and 1950 Hz[1] (per RSS 125, Issue 1). This 2-tone signal is applied to the input (microphone) connector of the transmitter. The RF output of the transmitter under test will contain two signals at 850 and 1950 Hz above the Suppressed RF Carrier. The transmitter output is monitored through an attenuator that is taken to the T/R port of the Comm Analyzer. The Peak Envelope Power (PEP) of the resulting RF can be measured directly, since the power meter circuit in modern communication analyzers are of the Peak Responding type. The 2-tone test modulation is increased until the rated PEP is reached.

While the RF output is monitored, the internal spectrum analyzer function can be selected. The spectral display of the RF signal resulting from the original modulating signals can be identified by selectable Markers 2 and 3. One observed point of interest are the 3rd Order Intermodulation Products. There are a new pair of frequencies in the output of the transmitter as a result of non-linearity's in the system. They are identified by Markers 1 and 4.

If you take the 2nd Harmonic (2H) of the 1950 Hz signal and subtract from that the 850 Hz of the other signal there will be a result at 3050 Hz above the suppressed carrier frequency. This shows up in the spectrum display identified by Marker 4. The other signal appears in the transmitter output at the 2nd Harmonic of the 850 Hz less the 1950 Hz signal, that being 250 Hz below the Suppressed Carrier. On the spectrum display this spurious signal is identified by Marker 4.

Most other communication systems operate on a frequency at the center of their sidebands. But for the SSB system the assigned frequency is the Datum frequency plus 1400 Hz.

For transmitters up to 100 watts the spurious responses (3^{rd} Order Intermod's) need to be at least 32 dB down from the rated PEP. From 100 to 1000 watts PEP there is a sliding spec so that at 1000 watts the spurious responses must be down 40 dB.

Another measurement taken is the suppression of the carrier. Specification for the suppression of the carrier varies depending upon the system. That requires measurement of the residual RF output of the transmitter when there is no modulation.

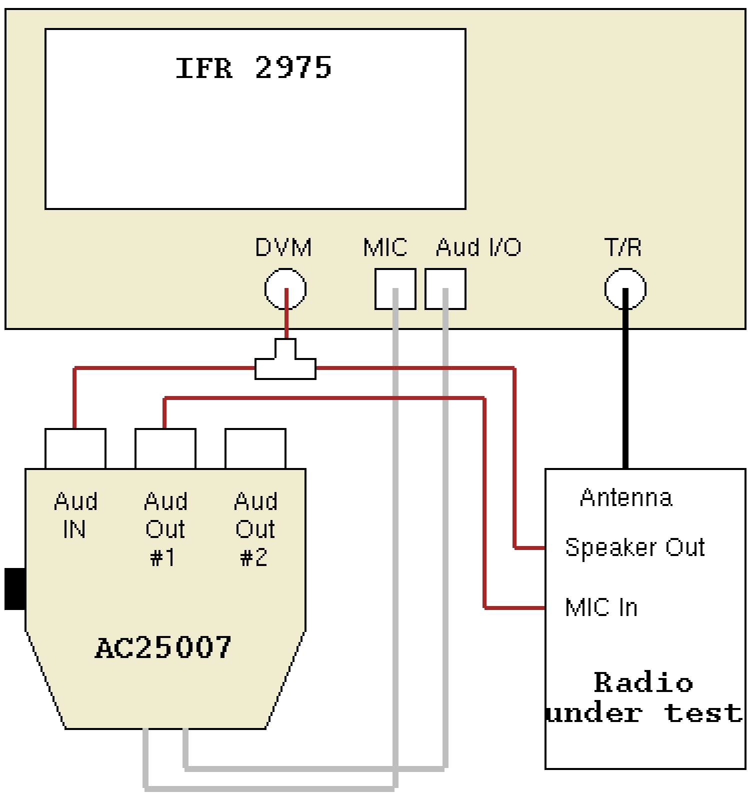
There are several other spurious signals, but are either at a much lower level or they fall outside the pass band of the system. This is a property of any non-linear system, when driven by two or more frequencies. In general, the spurious frequencies are given by the formulae $mf_1 + nf_2$ and $mf_1 – nf_2$ where m and n are integers (1, 2, 3,….). In this example the spurious responses are called 3^{rd} Order, since the coefficients of f_1 and f_2 (m and n) add up to 3.

Testing the SSB Receiver with the Aeroflex 2975 Comm Analyzer

Connections as follows-

Tranceiver RF 'UHF' Connector through 50 Ohm coax to Aeroflex 2975 T/R 'N' Connector. The test set can handle 50 watts of RF power continuously and 125 watts for one minute. Some higher powered radios may require you to connect an external RF attenuator between the test set & the radio. The test set can be adjusted to take this into account.

Receiver Audio Out to Aeroflex 2975 DVM Connector and Audio In Connector on the Aeroflex AC25007 Accessory.



The other connections on the diagram are used during transmitter testing.

Be sure the test equipment & the radio in test have been run long enough to reach operating temperature.

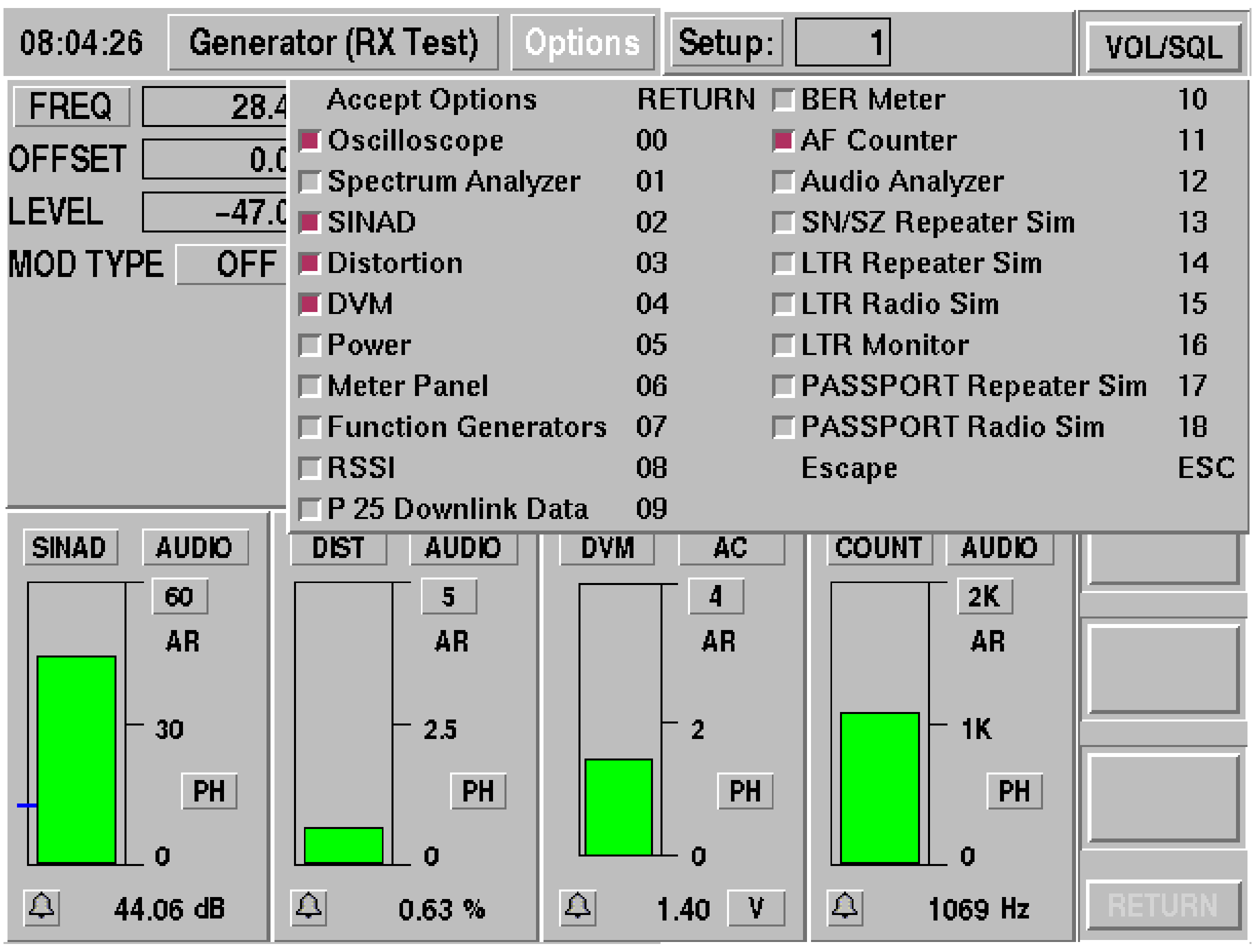
In the drop down menu at the top LHS of the 2975 display, select 'Generator (RX Test)   1'

In the Options menu, select the following functions to be displayed-

Oscilloscope	**00**
SINAD	**02**
Distortion	**03**
DVM	**04**
AF Counter	**11**

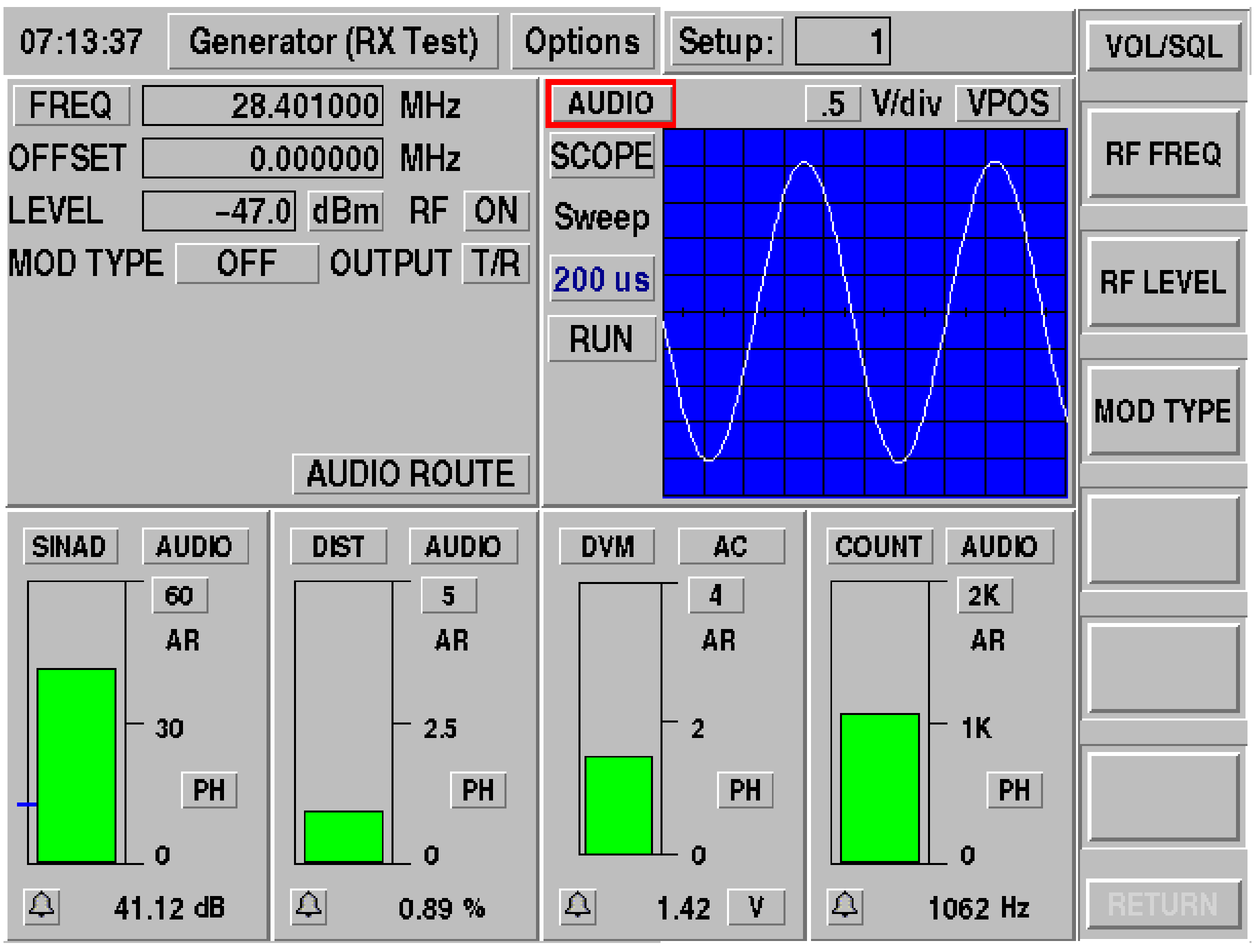
Be sure all of the other functions are set to OFF. Those you have selected will occupy all of the space on the display.

Then click on 'Accept Options' or press RETURN.



In the upper LH Quarter of the display set the following-

FREQ	**Input frequency required to produce a One KHz note at the receiver output terminals. This will usually be One KHz higher than the frequency set on the receiver (USB). In the example given, that would be the RF generator set to 28.401 MHz while the receiver is set to 28.400 MHz.**		
OFFSET	**0.000000 MHZ**		
Level	**-47 dBm (1000 mvolts)**	**RF**	**ON**
MOD TYPE	**None**	**OUTPUT**	**T/R**
M1 and M2	**OFF**		
MIC	**OFF**	**RX**	**OFF**
AUDIO	**OFF**	**AUDIO ROUTE**	**Not Applicable**



You will need to select a source for each of the functions in the display.

On the Oscilloscope tile, click on the box above ‘SCOPE’ and select ‘AUDIO 4’ from the drop down menu. AUDIO should appear in that box. Click on the V/div box above the display and set .5 V/div. Click on the Sweep box and set 200 □S.

Click on the box to the RHS of SINAD and from the drop down menu select ‘AUDIO 5’.
AUDIO should appear in that box and in a similar box in the DIST tile.

Click on the box to the RHS of COUNT and select ‘AUDIO 5’.

Click on the box to the RHS of DVM. The connection will toggle between ‘AC’ and ‘DC’. The setting will depend upon the radio you are testing.

The display will include all of the results required for the receiver test.

Setting Limits and Alarms

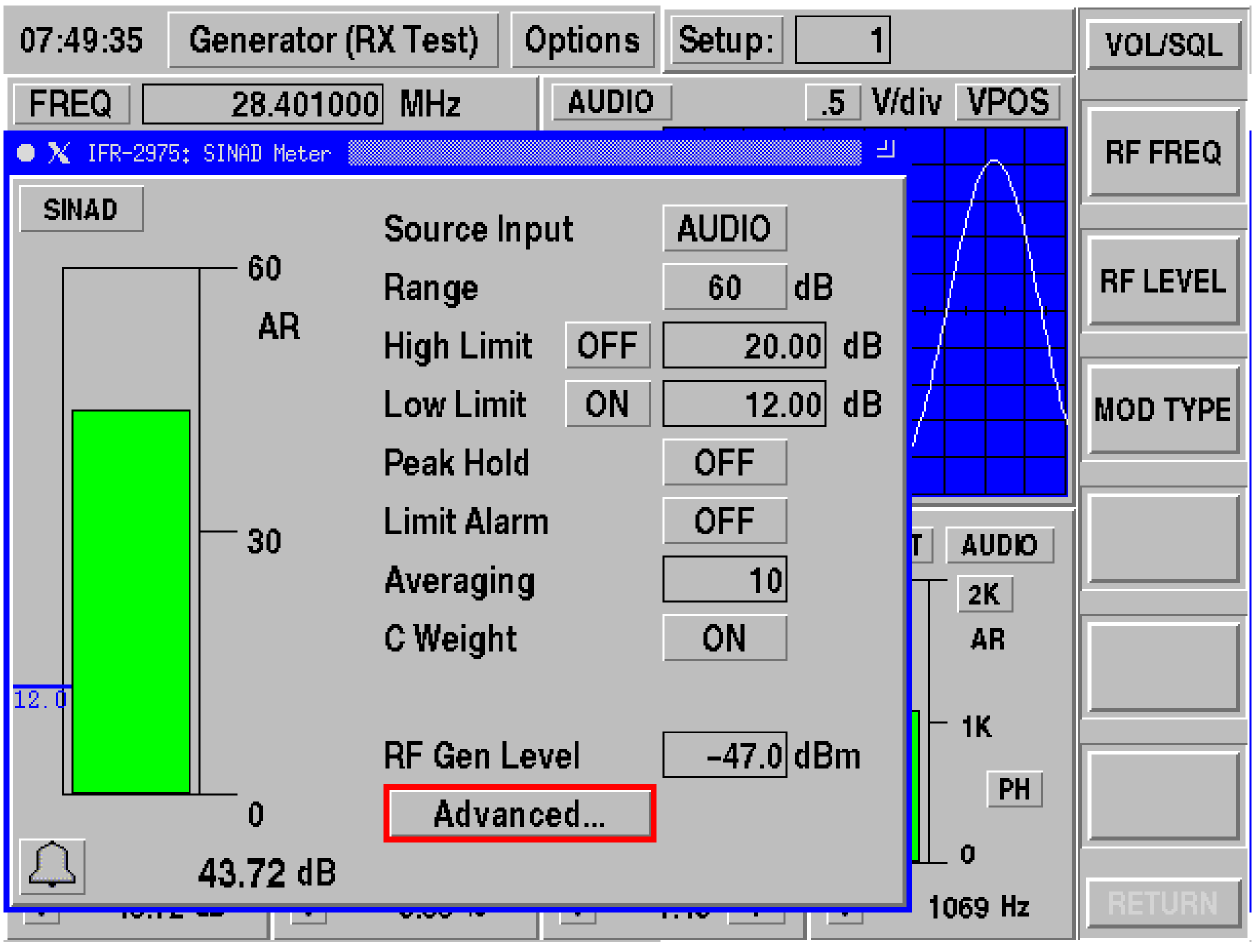
Each of the SINAD, Distortion, AF Counter and DVM tiles can be expanded to allow further information to be available from the test.

For example, using the mouse to click on 'SINAD', you will be able to set upper and lower limits, range and so on. Click on the 'Range' box and set AR for auto ranging of this function. AR will appear in the display.

If you set upper and lower limits and turn on these functions, you will find markers on the LHS of the SINAD bar graph. The bell icon beneath the bar graph will enable an audible alarm to indicate that SINAD is outside the set limits.

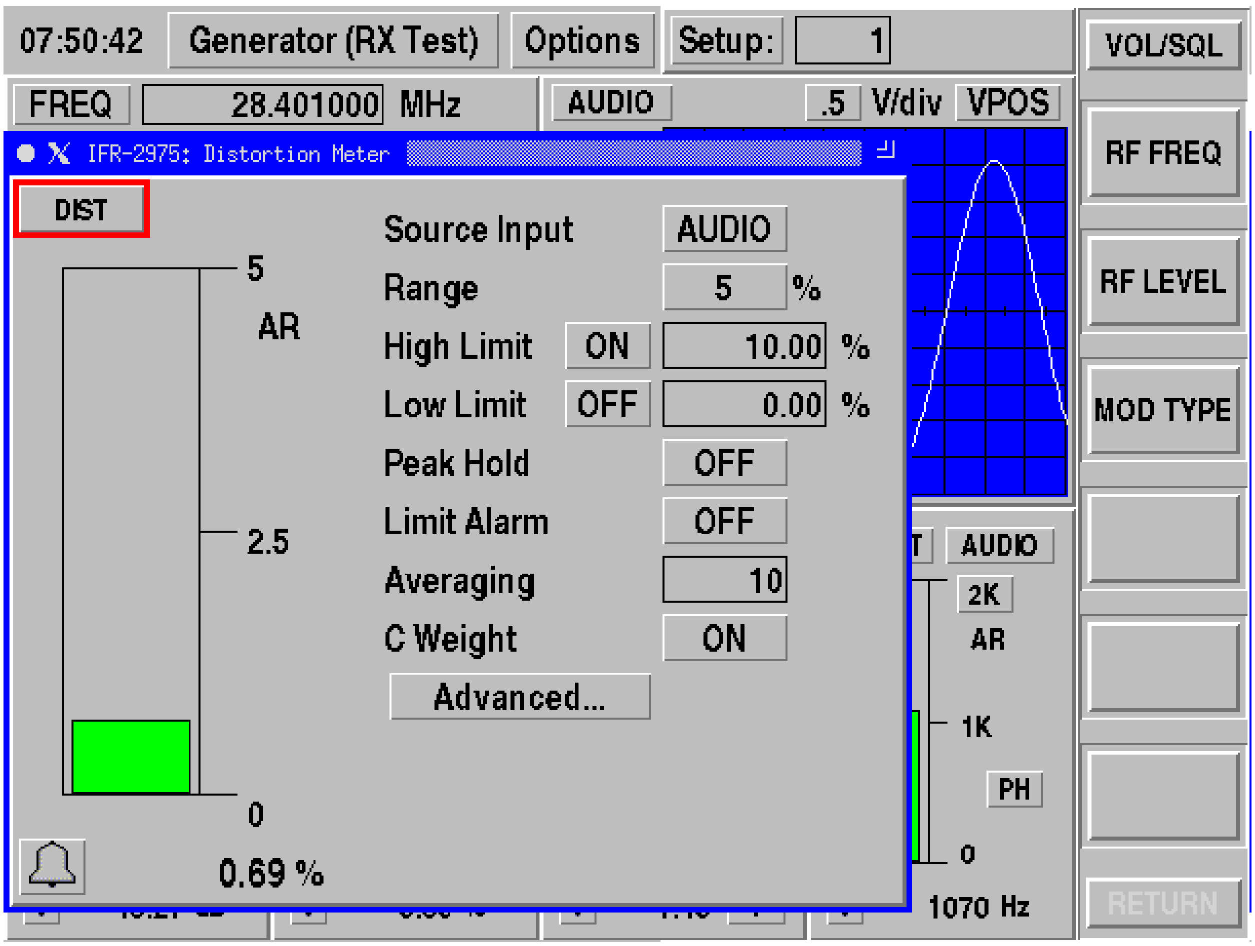
Some of the measurements you will need to make will include noise. To get a more stable indication you should set the 'Averaging ' function for SINAD at about 10.

Some measurements will require turning on the 'C Weight' filter. This limits the audio to a band of 300 to 4000 Hz. This filter is sometimes called the 'C Message' filter and originates with the wireline telephone system.



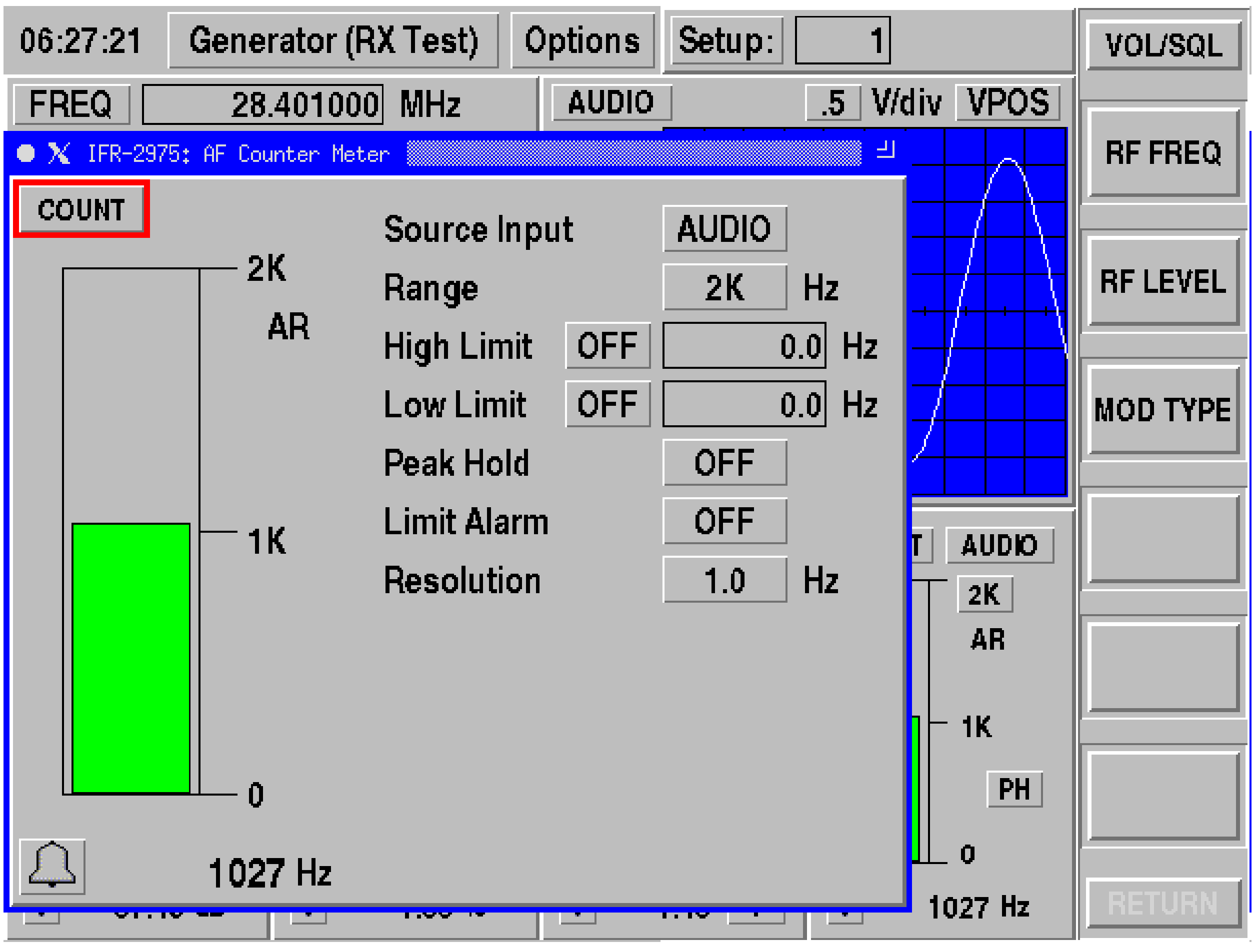
Go back to the main screen by pressing the RETURN softkey.

Click on ‘DIST’ to see the expanded distortion tile. It is possible again to set limits, alarms and so on. Turn on ‘High Limit’. Then set to 10 % as required by RSS 125. Or set another limit as required by the radio manufacturers specification. If the distortion exceeds the set limit, the bar will turn red. Pass is indicated in green.



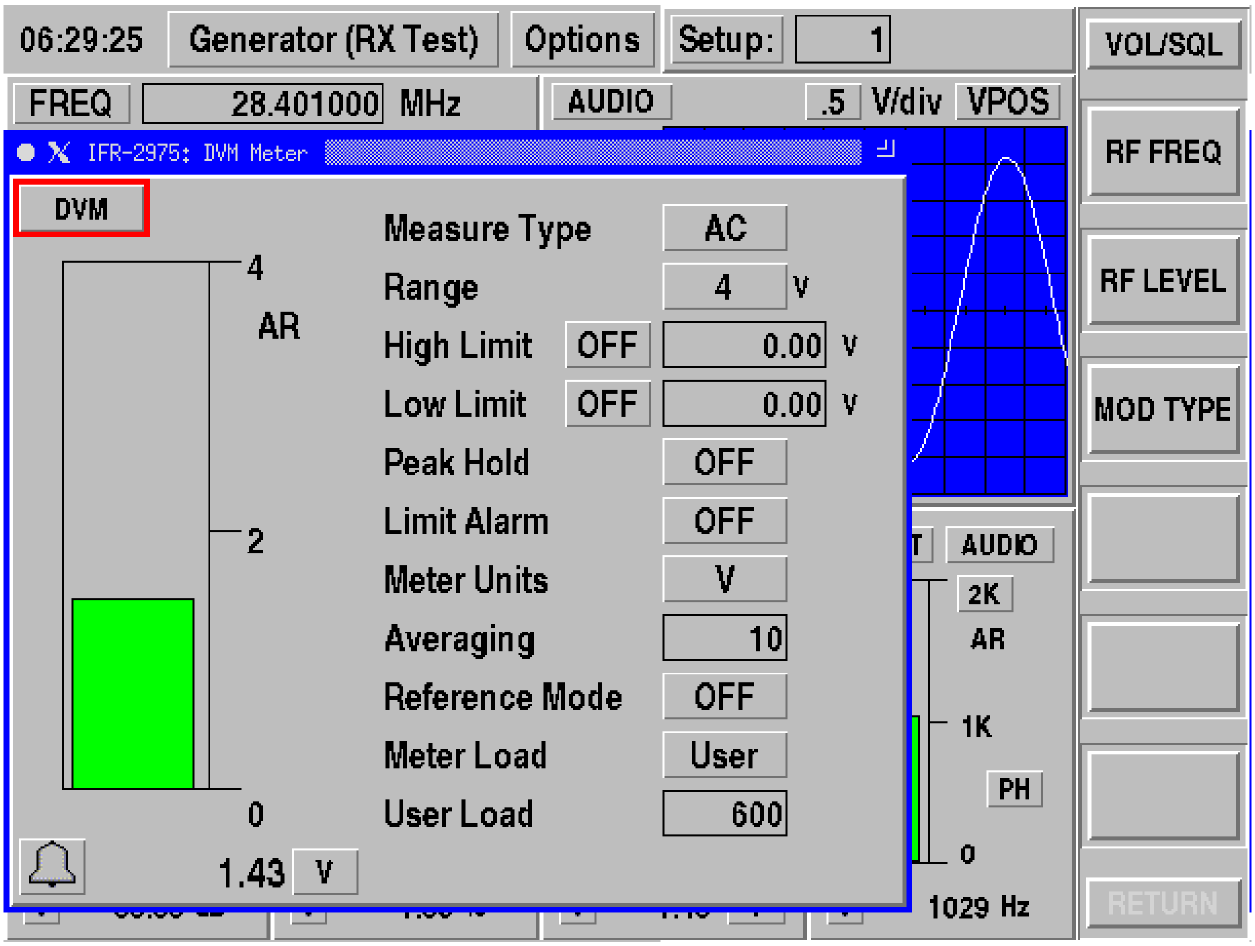
Go back to the main screen by pressing the RETURN softkey.

Click on COUNT to see the expanded audio counter. If the radio was right on frequency, this should indicate 1000 Hz. The offset from that will tell you how far the receiver frequency is in error. Here again you can set upper and lower limits, audible alarms and so on. Resolution set to 1 Hz on this function is sufficient for most applications.



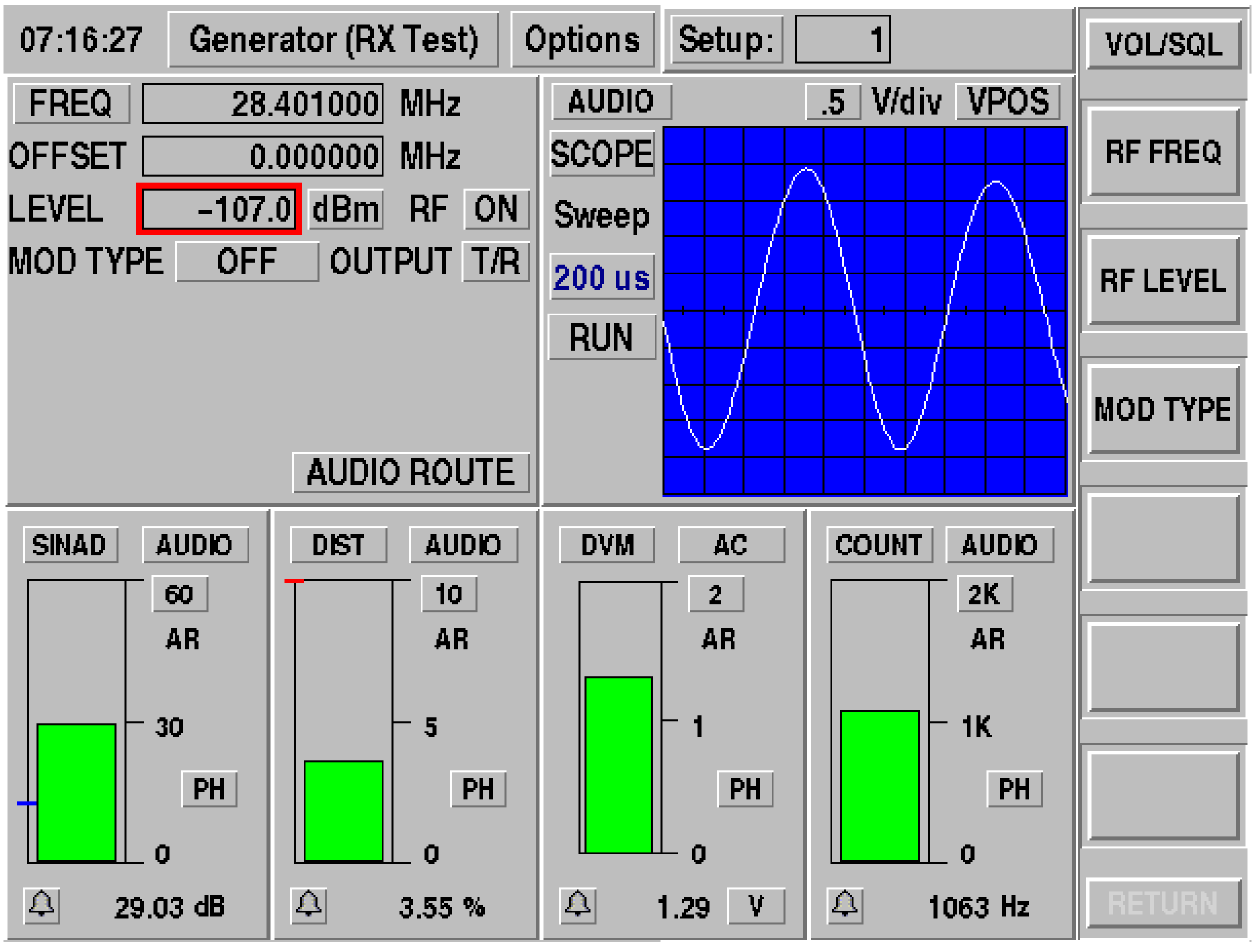
Go back to the main screen by pressing the RETURN softkey.

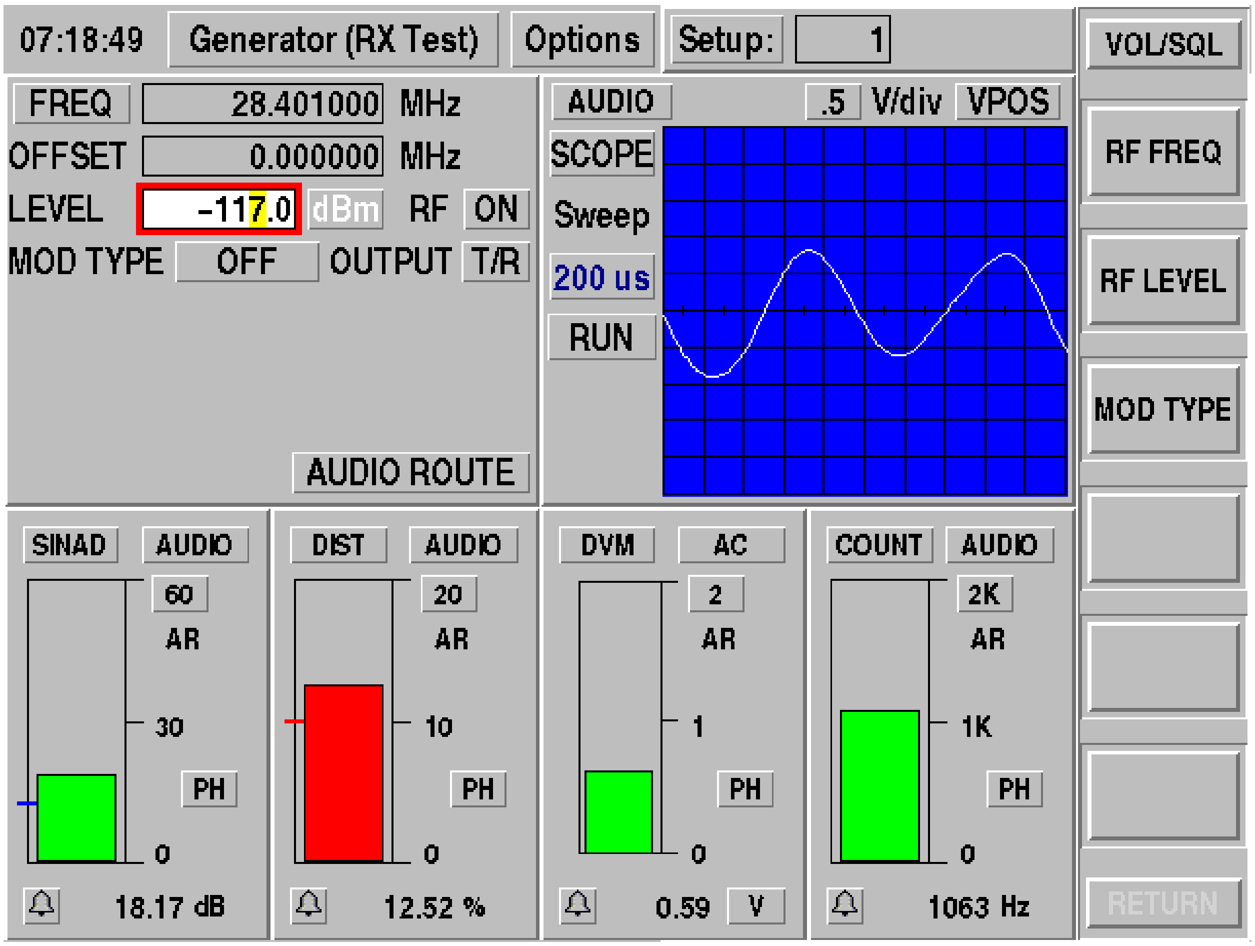
Click on DVM to see the expanded Voltmeter. You can set for AC or DC measurements, limits and so on..



Go back to the main screen by pressing the RETURN softkey.

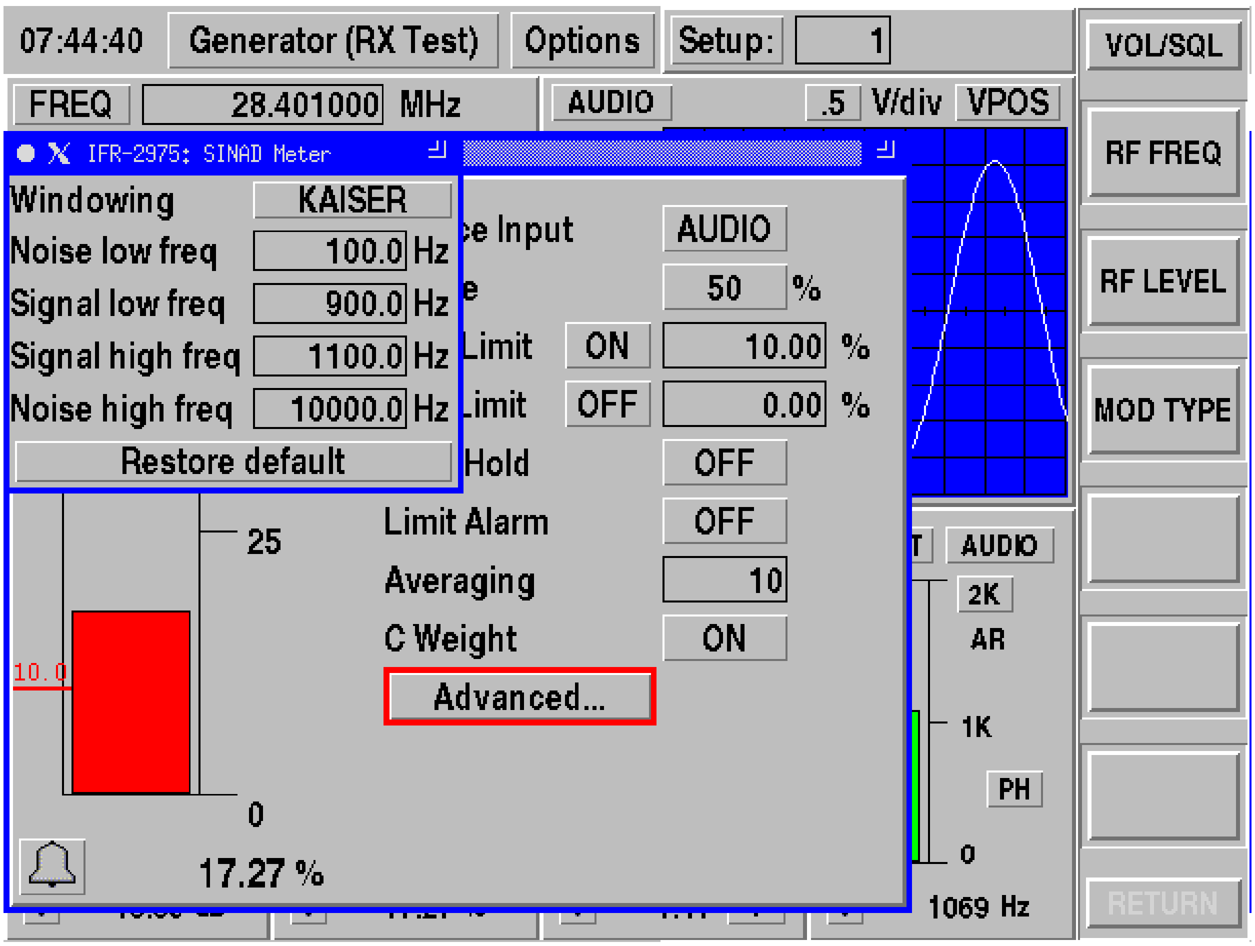
Adjust the receiver gain control so that the audio output is about 60 % of the manufacturers specification as indicated by the audio DVM tile. Then reduce the input RF level until the SINAD indicates 12 dB. You could start at –107 dBm and then go negative One dB at a time. Highlight the units digit in the LEVEL display and use the DOWN ARROW key to do that.



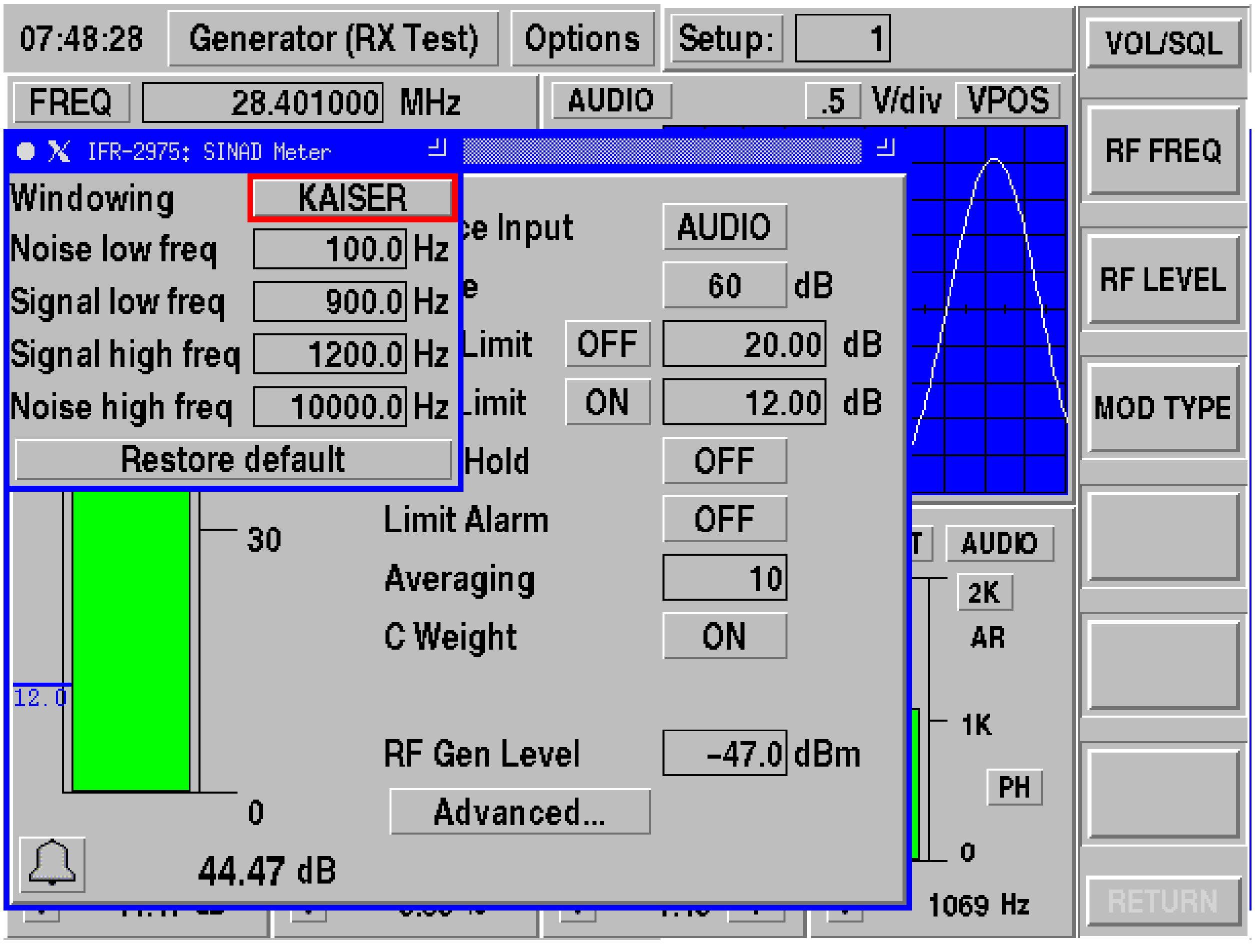


You can see here on the COUNT tile that the Audio Frequency has drifted away from One KHz. The filter used in measuring SINAD & Distortion in the test set defaults to One KHz, so good measurements may not be possible without some adjustment. This can be done by accessing the Kaiser filter accessible through the zoomed SINAD tile. Click on ADVANCED & see the KAISER filter

The Signal Low & High Frequencies in the Kaiser filter default to 900 & 1100 Hz respectively. By raising the Signal High Frequency to 1200 Hz, a more accurate measurement of SINAD & Distortion is possible on the drifted AF.



Results after adjustment of the Kaiser filter-

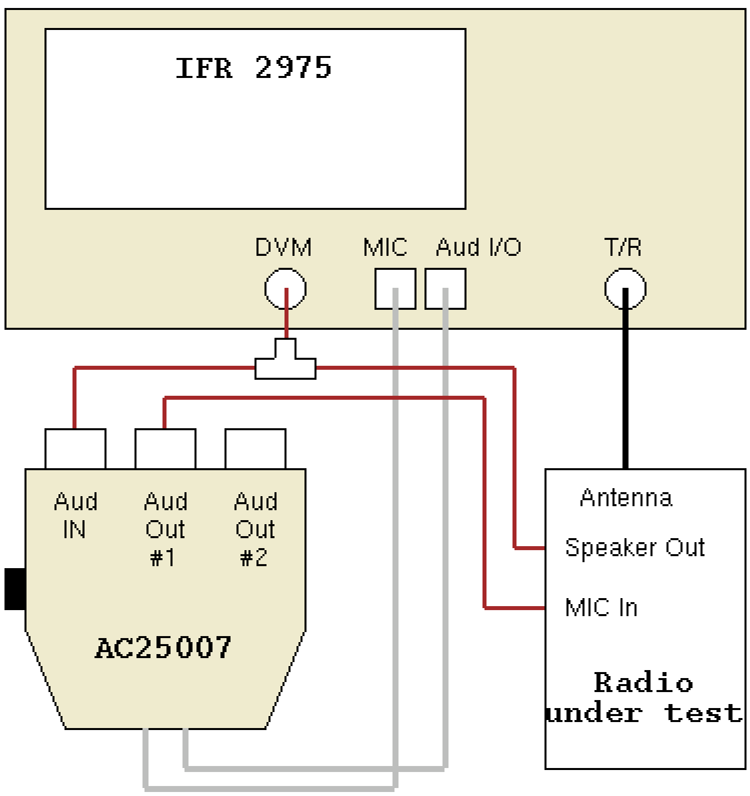


Testing the SSB Transmitter with the Aeroflex 2975 Comm Analyzer

Connections as follows-

Tranceiver RF 'UHF' Connector through 50 Ohm coax to Aeroflex 2975 T/R 'N' Connector. The test set can handle 50 watts of RF power continuously and 125 watts for one minute. Some higher powered radios may require you to connect an external RF attenuator between the test set & the radio. The test set can be adjusted to take this into account.

Aeroflex AC25007 Accessory Audio Out 1 Connector to the radio audio input.



The other connections on the diagram are used during receiver testing.

Be sure the test equipment & the radio in test have been run long enough to reach operating temperature.

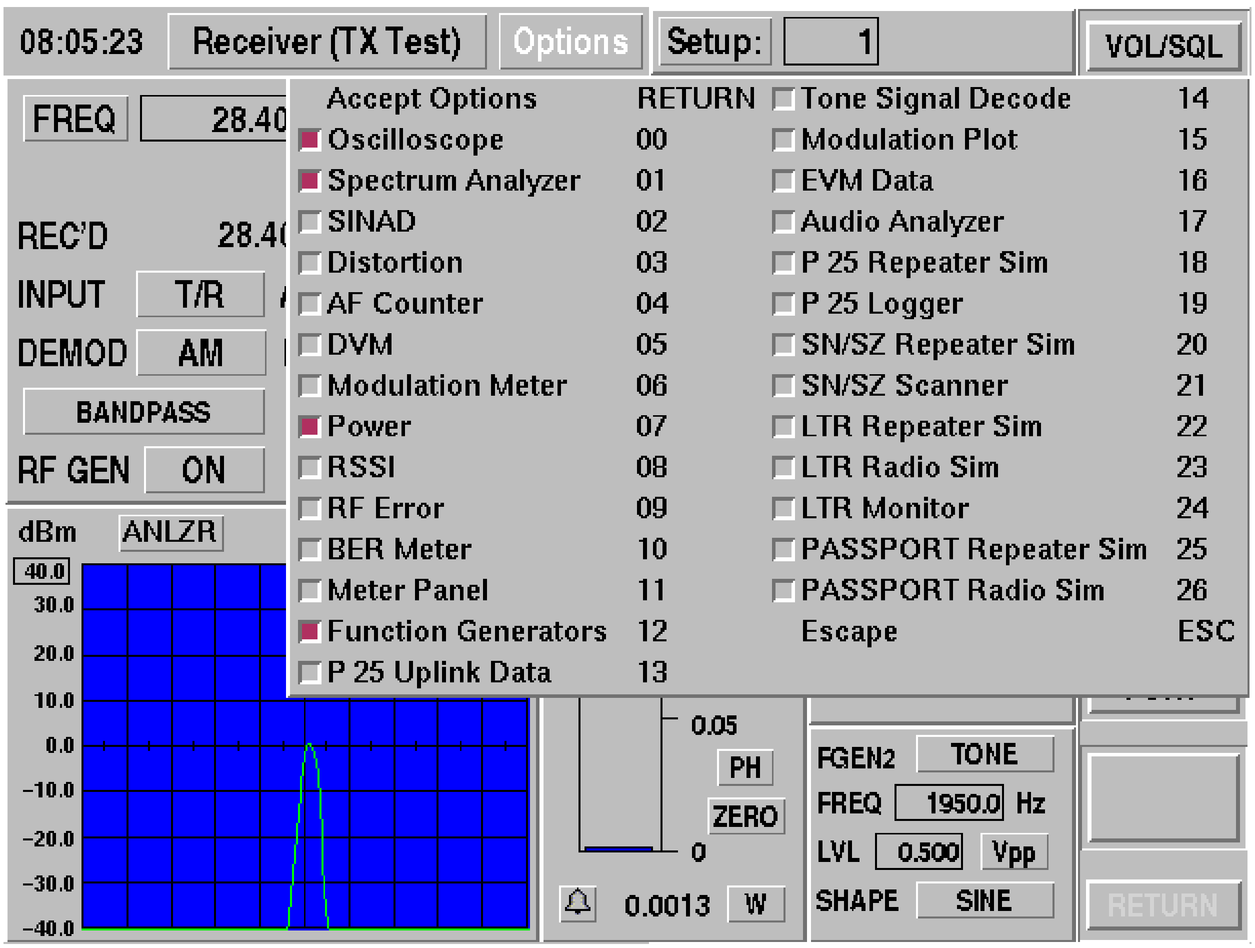
In the drop down menu at the top LHS of the 2975 display, select 'Receiver (TX Test)   2'

In the Options menu, select the following functions to be displayed-

Oscilloscope	**00**
Spectrum Analyzer	**01**
Power	**07**
Function Generators	**12**

Be sure all of the other functions are set to OFF. Those you have selected will occupy all of the space on the display.

Then click on 'Accept Options' or press RETURN.



In the upper LH Quarter of the display set the following-

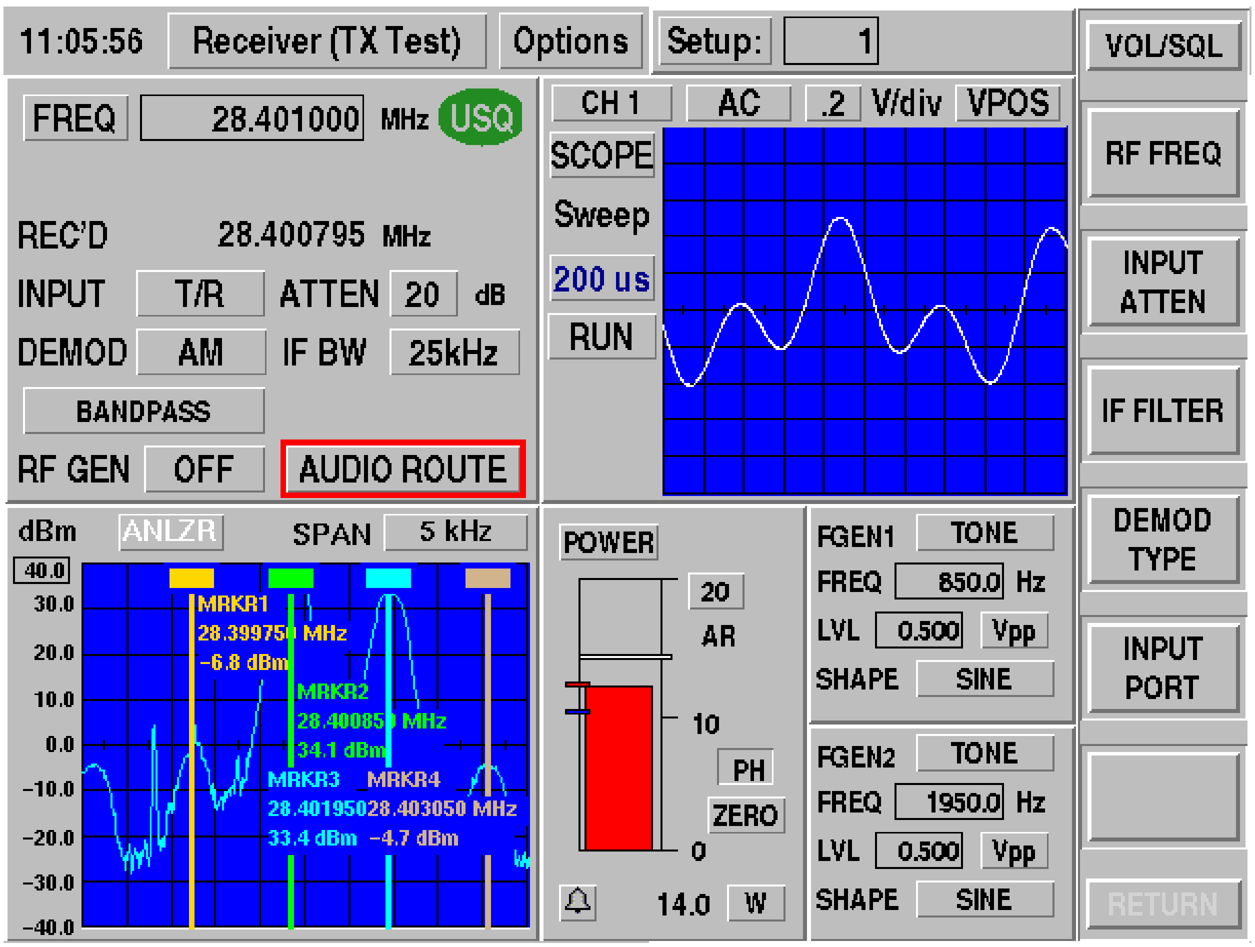
FREQ — **One KHz above the Channel center. For example, if the SSB radio is set to 28.400 MHz, FREQ on the 2975 is set to 28.401 MHz.**

INPUT — **T/R** — **ATTEN 20 dB**

DEMOD — **AM** — **IF BW** — **25 KHz**

BANDPASS — **(300-4000 Hz)**

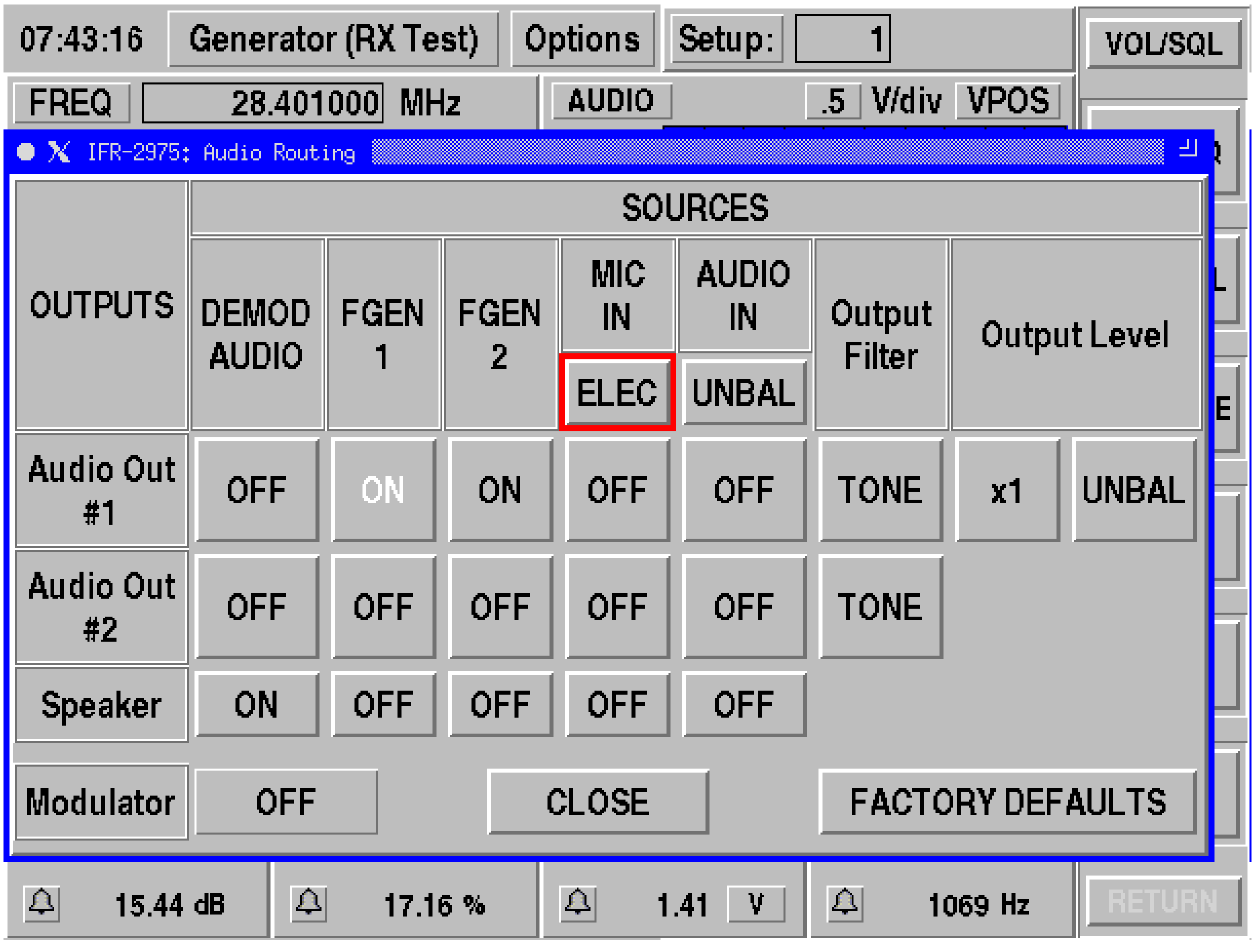
RF GEN — **OFF** — **AUDIO ROUTE** — **FGEN 1 and FGEN 2 to Audio Out #1. All others OFF.**



On the Audio Generator tile, set FGEN1 and FGEN2 to Tone.

For FGEN1 set FREQ to 850 Hz. For FGEN2 set FREQ to 1950 Hz.
Check the manufacturers spec for the audio input level to the transmitter.
Then set LVL on FGEN1 and FGEN2.
Set SHAPE to Sine on FGEN1 and FGEN2.

Click on the AUDIO ROUTE box to see the routing of GEN 1 and GEN 2



Click on CLOSE to go back to the main menu.

You will need to select a source for each of the functions in the display.

On the Oscilloscope tile, click on the box above 'SCOPE' and select 'DEMOD 6' from the drop down menu. DEMOD should appear in that box. Click on the %/div box above the display and set 10 %/div. Click on the Sweep box and set 200 □S.

On the Spectrum Analyzer tile click on ANLZR to zoom that display. The center frequency will already be set to 28.401 MHz in this example. In the SPAN drop down menu set 5 KHz.

For Transmitters up to 10 watts set the dBm scale along the LHS to 40 dBm. For transmitters up to 100 watts set the dBm scale to 50 dBm.

Set RBW (Resolution Bandwidth) to 300 Hz.
If the AUTO/MAN toggle is set to AUTO, the VBW (Video Bandwidth) will automatically go to 300 Hz. If it doesn't, set the AUTO/MAN toggle to AUTO. The SWEEP time will go to 500 mS.

While in the zoomed Spectrum Analyzer screen you can set some useful markers. Under the Options drop down menu select Configure Markers 7.

Set Vertical Markers to ON as follows-

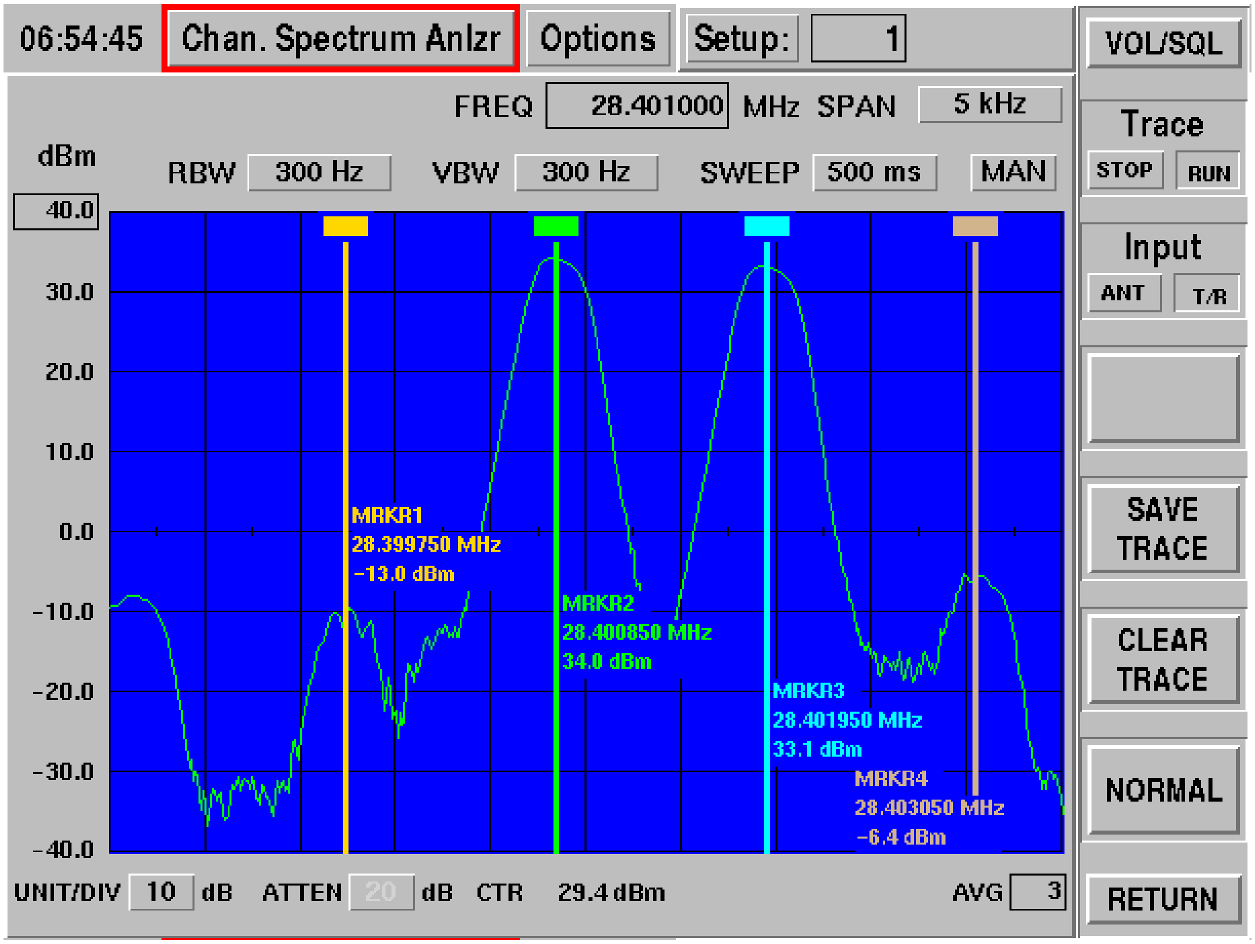
Marker One 28.399750 MHz This is the lower frequency 3rd Order Intermodulation Product of the 850 and 1950 Hz modulating tones. 250 Hz below 28.400 MHz, since 2 X 850 Hz minus 1950 Hz is minus 250 Hz.

Marker 2 28.400850 MHz RF result of one of the modulating tones.

Marker 3 28.401950 MHz RF result of the 2nd modulating tone.

Marker 4 28.403050 MHz This is the upper Frequency 3rd Order Intermodulation Product of the 850 and 1950 Hz modulating tones. 3050 Hz above 28.400 MHz, since 2 X 1950 Hz minus 850 Hz is 3050 Hz.

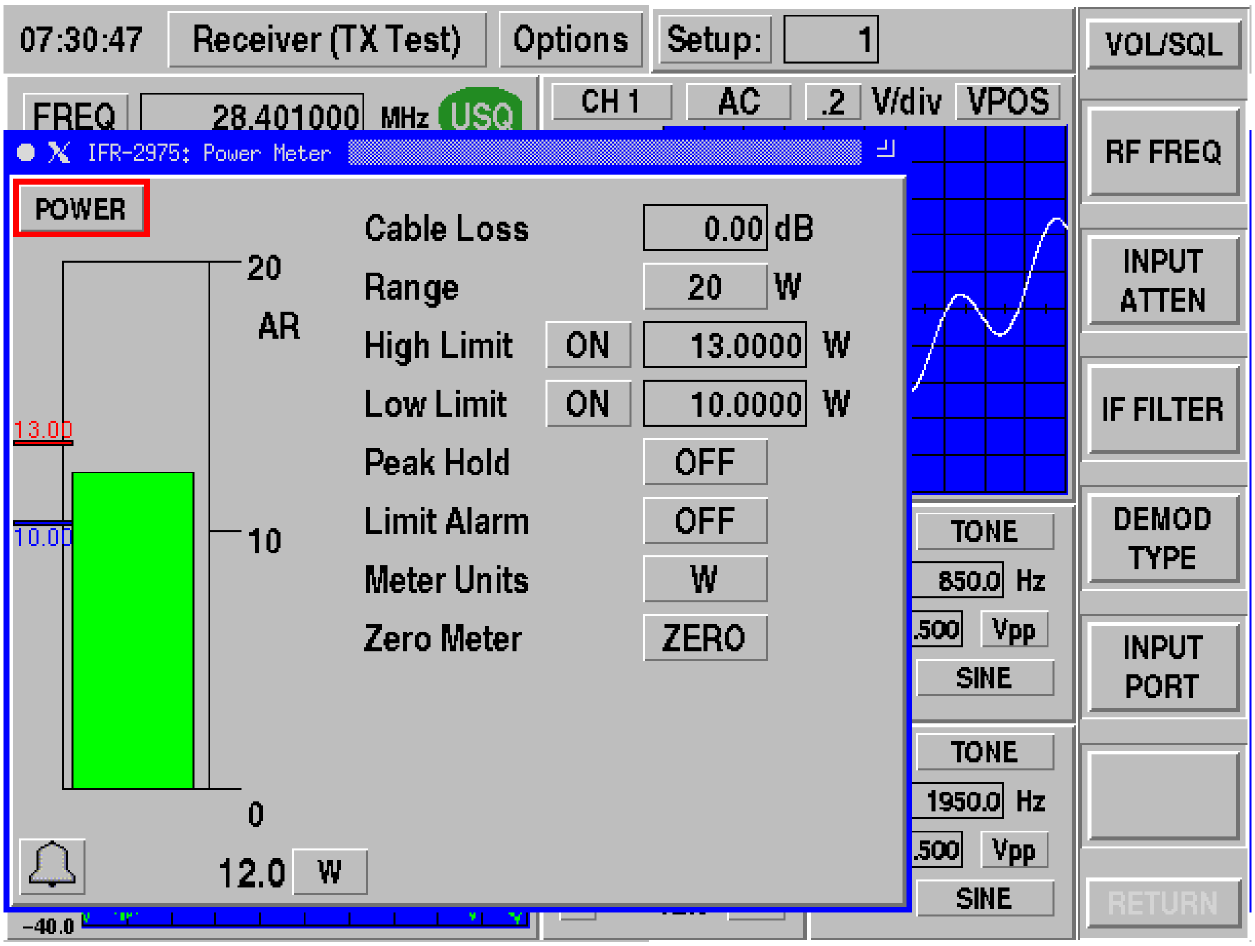
While in the Spec Analyzer drop down menu, select 'Live' and 'Peak'. Then press RETURN. The display will store the spectral results after the PTT on the radio is released. The levels indicated on the MARKERS are for the LIVE trace.



Press RETURN to exit the zoomed SPECTRUM ANALYZER tile.

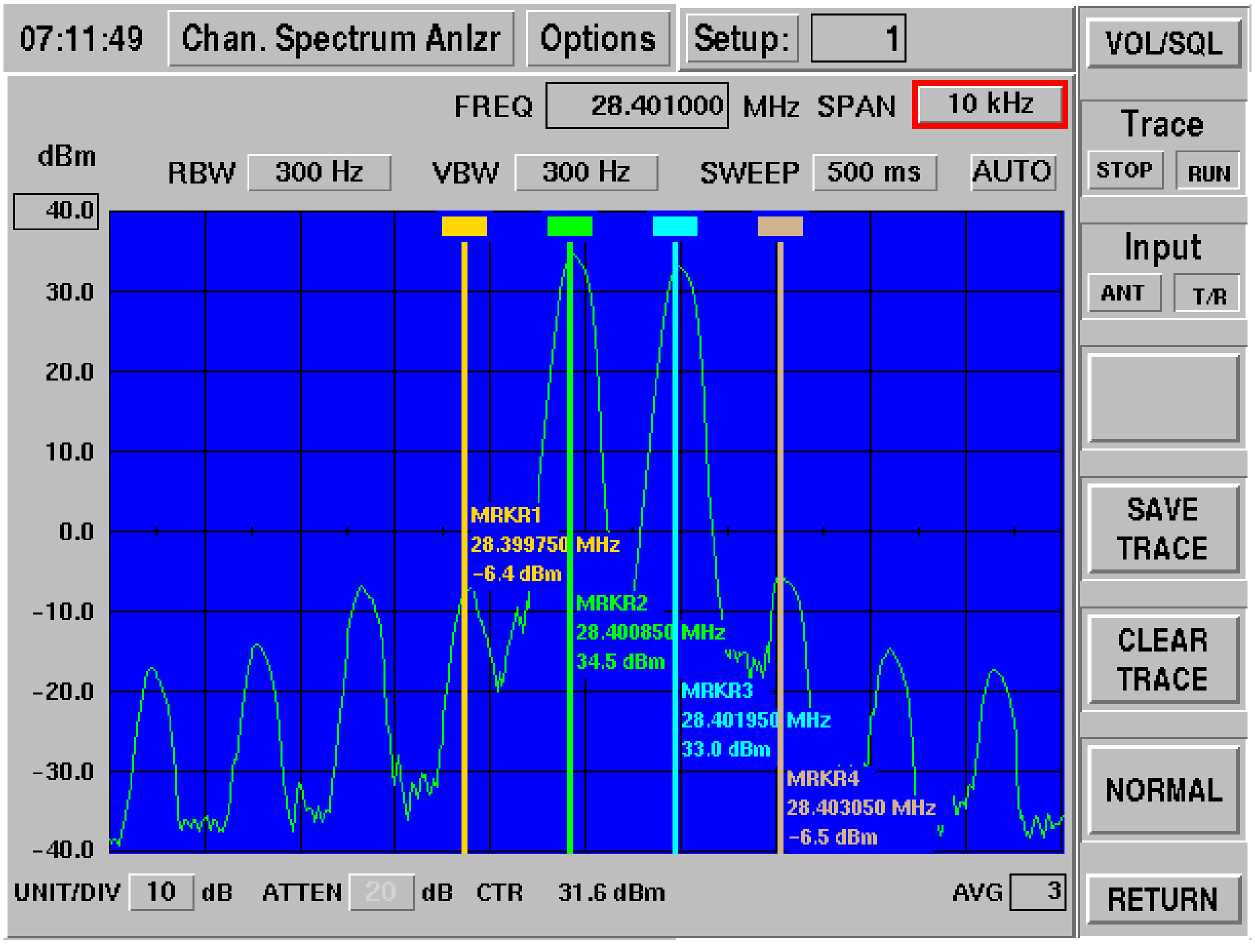
Click on the POWER tile to zoom it. If there are lossy cables or an external attenuator you can set that in at 'Cable Loss'.

Set Range to AR (Auto Range)
Set the High Limit and Low Limit to the manufacturers specs.
Set Peak Hold to ON.
Set the Meter Units to W (Watts).
You may want to Zero the Meter. Consult the Operating Manual.

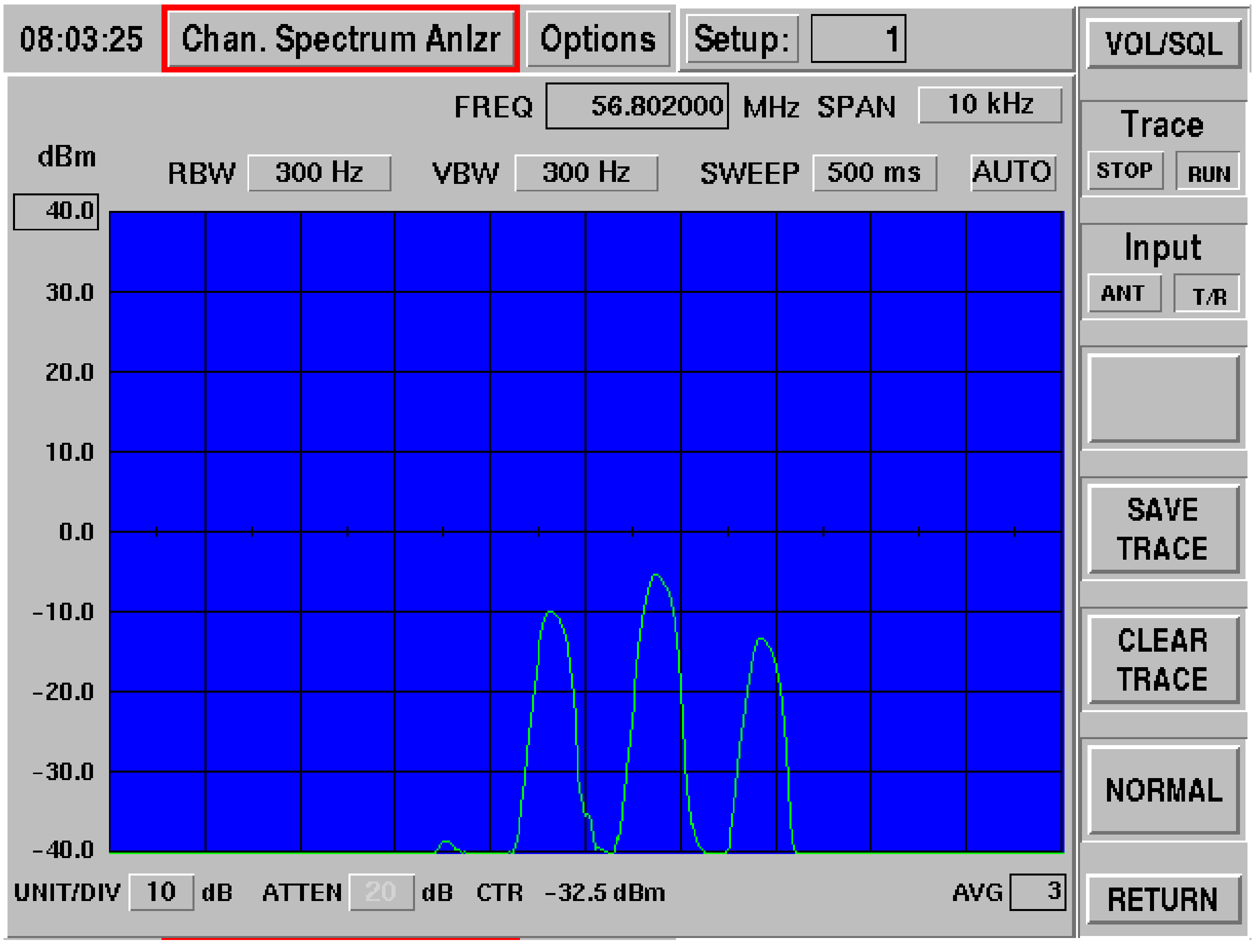


Press RETURN to exit the zoomed POWER tile.

Example of Higher Order Intermodulation Products



Example of Spurious RF Power at the transmitter 2nd Hamonic (2H).



The 2nd Harmonic is down about 40 dB.

Notes

1 RSS 125 Issue 2 uses audio frequencies of 400 Hz & 1800 Hz