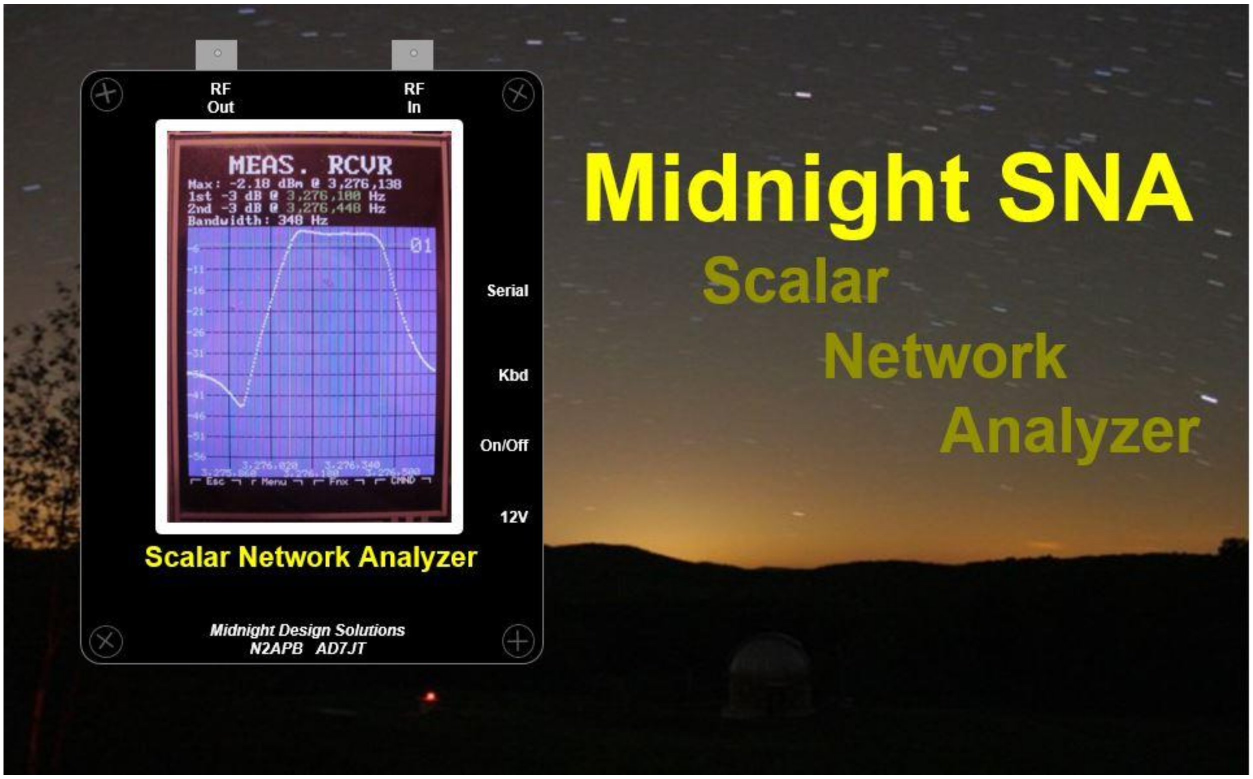

Tutorial 9 - Measurement Receiver Segmented Scans and Harmonics

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2016-04-01

This tutorial takes you through the steps to configure and use your MSNA along with a Measurement Receiver to perform very wide frequency scans and to find and analyze harmonic content. It includes a discussion of the theory behind the Measurement Receiver and some description of the PHSNA Measurement Receiver.

CONTENTS

1. APPLIES TO

All Midnight SNA units running V5.00 firmware or later.

2. PREREQUESITES

The following calibration procedures should be performed before starting this tutorial:

- Tutorial M1 ....Power Level Calibration
- Tutorial 0....................Reference Clock Calibration
- Tutorial 3 or 3T..........Frequency Response Calibration

It is recommended that you perform these calibration in the order of the above list.

3. ADDITIONAL REQUIREMENTS

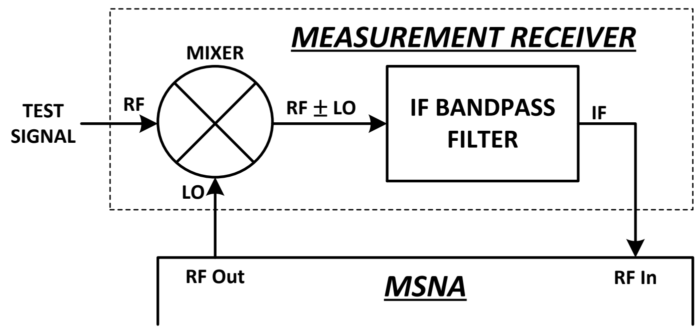
In addition to the MSNA, the following will be needed to complete this tutorial:

- A PS2 keyboard. Several of the helper functions associated with MR operation are not available on the touch screen, they are only available using keyboard hot-keys.
- A measurement receiver and the necessary cables to connect it to the MSNA and an RF signal source. Attenuators may also be necessary to avoid exceeding the maximum signal levels of the measurement receiver RF inputs.
- An RF signal source, preferably a square wave.

4. MEASUREMENT RECEIVER

A Measurement Receiver (sometimes called a "Measuring Receiver" or simply "MR") is used to measure the basic characteristics of RF signals. The primary characteristics measured are the power levels at specific frequencies across a frequency spectrum. This information can be displayed graphically for spectrum analysis to, for example, determine the purity of a signal source and detect and identify parasitic and spurious elements. It can also be used to measure the levels of harmonics in the output of a transmitter circuit to assure compliance with FCC regulations.

The following is a simplified block diagram of a basic MR showing how it is connected to an MSNA:



In general, an MR is a very sensitive instrument and it may be necessary to add attenuators in the inputs to the mixer to avoid overdriving the mixer. This tutorial assumes we are using the PHSNA MR which has the following input specifications:

- RF (TEST SIGNAL)....................-3dBm maximum
- LO (LOCAL OSCILLATOR)........... -10 dBm maximum
- IF FILTER FREQUENCY ....3.2768 MHz
- IF FILTER BANDPASS....................400 Hz

https://groups.yahoo.com/neo/groups/PHSNA/files/Measurement%20Receiver/

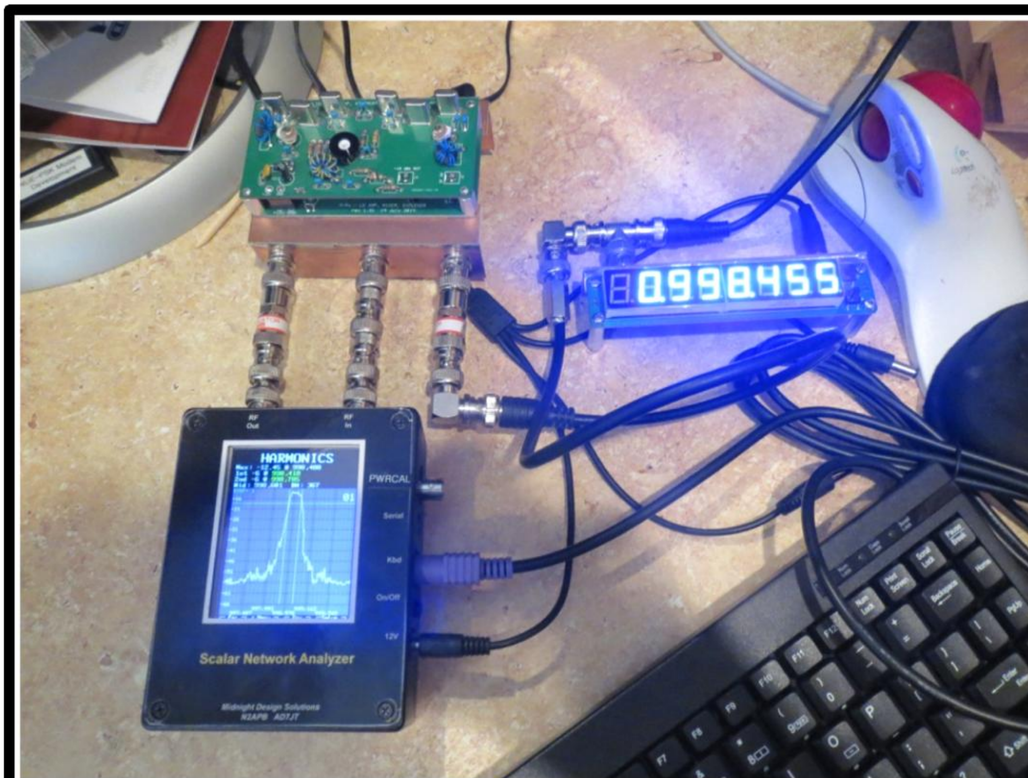
The operation of an MR is very simple. Two signals, RF and LO (Local Oscillator), are combined in a balanced mixture so that the mixer's output contains both the sums and the differences of all the component frequencies in the input signals. The mixer output is then passed through a band pass filter to limit the filter output (Intermediate Frequency or "IF") to a narrow frequency range.

The LO signal is a pure sine wave so it only has a single frequency component. When the LO frequency is set higher than the filter's pass band, it will not appear in the filter output. Instead, the IF will contain only frequencies that, when subtracted from the LO frequency are within the pass band of the band pass filter. For example, to look at the power level of a 1 MHz component in the test signal, set the LO oscillator to the IF filter frequency plus 1 MHz (in our case, 3.2768 + 1.0 = 4.2768 MHz). The output of the mixer will contain both the sum and differences of the 4.2768 MHz signal and the 1.0 MHz. The lower frequency component (4.2768 - 1.0 = 3.2768 MHz) will be in the filter's pass band and will be measurable in the filter output. The upper frequency component (4.2768 + 1.0 = 5.2768 MHz) is well above the filter's pass band and will not appear in the output.

For spectrum analysis, a frequency range (or spectrum) is scanned in a series of discrete steps and the power level of the filter output is recorded for each frequency. Plotting the results gives a visual indication of what frequency components are in the test signal within the frequency spectrum tested and their relative signal strengths.

For harmonic analysis, the fundamental frequency is determined and located within a narrow frequency band. A series of "mini-scans" is then made covering the expected harmonic frequencies. The mini-scan results are then plotted, not against frequency but against harmonic number (the fundamental frequency is defined to be the first harmonic). The resulting plot shows the signal strength of each harmonic relative to the fundamental.

5. HOW IT'S DONE



While the principals behind the MR are fairly straight-forward, there are a couple significant problems: first, collecting and processing what could be a huge amount of data and, second, displaying that data in a meaningful way in a 240 x 240 pixel plot area.

To do a meaningful spectrum analysis, all frequencies must be included in the data set. The only way to do that is to make sure the frequency step used is smaller than the band pass of the MR IF filter. The PHSNA MR has a nominal 400 Hz IF pass band. To make sure everything is covered, I generally use a 250 Hz frequency step. This means a 60 MHz spectrum scan would require 240,000 steps. In V5.00 the data buffer has been expanded to 4,000 cells which is enough to hold one MHz worth of data at 250 Hz per data point. It takes 60 buffer loads to hold the results of a 60 MHz spectrum scan.

The frequency scaling operation used for normal plots essentially segments the contents of the data buffer into 240 sections, one for each horizontal (frequency) pixel. It then plots each Nth data point where N is the number of points in each of the 240 sections. This works fine for representing smooth and slow-changing frequency response plots like we get with filters, RF amps, Return Loss Bridges, etc. (All data points are used to determine minimums, maximums, roll-off points and bandwidths.) Each point on a frequency spectrum analysis, however, is a very narrow spike at a specific frequency. Using only every Nth point in the data would generally miss most if not all of the interesting data.

Both of these problems are addressed with the V5.0 firmware's segmented spectrum scan and cursor-driven zoom functions. New functions have also been added to aid the analysis of harmonics.

Segmented Spectrum Scans and Zooming

Segmented spectrum scans are specified the same as any other scan and the first scan done is a "normal" scan. The normal scan gives the firmware what it needs to set up and perform a segmented scan. Once the normal scan is completed and plotted, the user can initiate a segmented scan. At this point, the firmware analyzes the current data and determines how many frequency steps will be required and how many buffer loads it represents. The number of frequency steps that must be represented by each of the 240 vertical slices of the plot area is also determined. Each buffer load covers a portion of the frequency spectrum called a scan "segment". Each segment is divided into "sub-segments" each of which is represented by a single vertical plot slice. MSNA scan parameters must be integers and there are no provisions for sub-segments crossing segment boundaries. In setting up the segmented scan parameters, some of the original scan parameters may have to be adjusted so all of the new parameters are whole numbers. These adjustments are minor and will normally not be noticed by the user.

Since the MSNA does not have buffer space for more than one segment of data, segments must be processed "on the fly". After a segment is buffered, the data for each sub-segment is scanned to identify the highest and lowest power levels in that sub-segment. These values are saved in a 240-cell buffer before the next segment is scanned. After all segments have been scanned, the contents of the sub-segment buffer are plotted. Each vertical slice in the resulting plot represents one sub-segment as a vertical line, the top of which is the highest value recorded in that sub-segment and the bottom of which is the lowest. Neither is an average, they are the absolute highest and lowest values in the sub-segment. The resulting plot identifies the general areas in the frequency spectrum having signal components that can be examined in more detail using the cursor-driven zoom function.

When a segmented plot is displayed, there are two cursors, one at each end of the frequency range. They can be moved by the operator to define the start and end of a portion of the displayed frequency spectrum. The user can then initiate another normal scan covering the frequency range between the cursors. A new segmented scan can be done based on the new plot data. This process can be repeated several times, each plot giving better resolution as the spectrum is narrowed. Once a point has been reviewed, the user can direct the MSNA to redo the original plot in order to review other points in the spectrum.

Analyzing Harmonics

Harmonics present a unique challenge. Besides having the problems present with spectrum analysis described above, we may have to pick the harmonics out of a frequency spectrum crowded with other signals. To simplify the process, you set up a scan that includes the first harmonic (fundamental) as the highest point in the plot. You then center the first harmonic (fundamental) in a narrow frequency range using a couple helper functions provided by the firmware. Once you are satisfied with this plot, you direct the MSNA to do a harmonic scan.

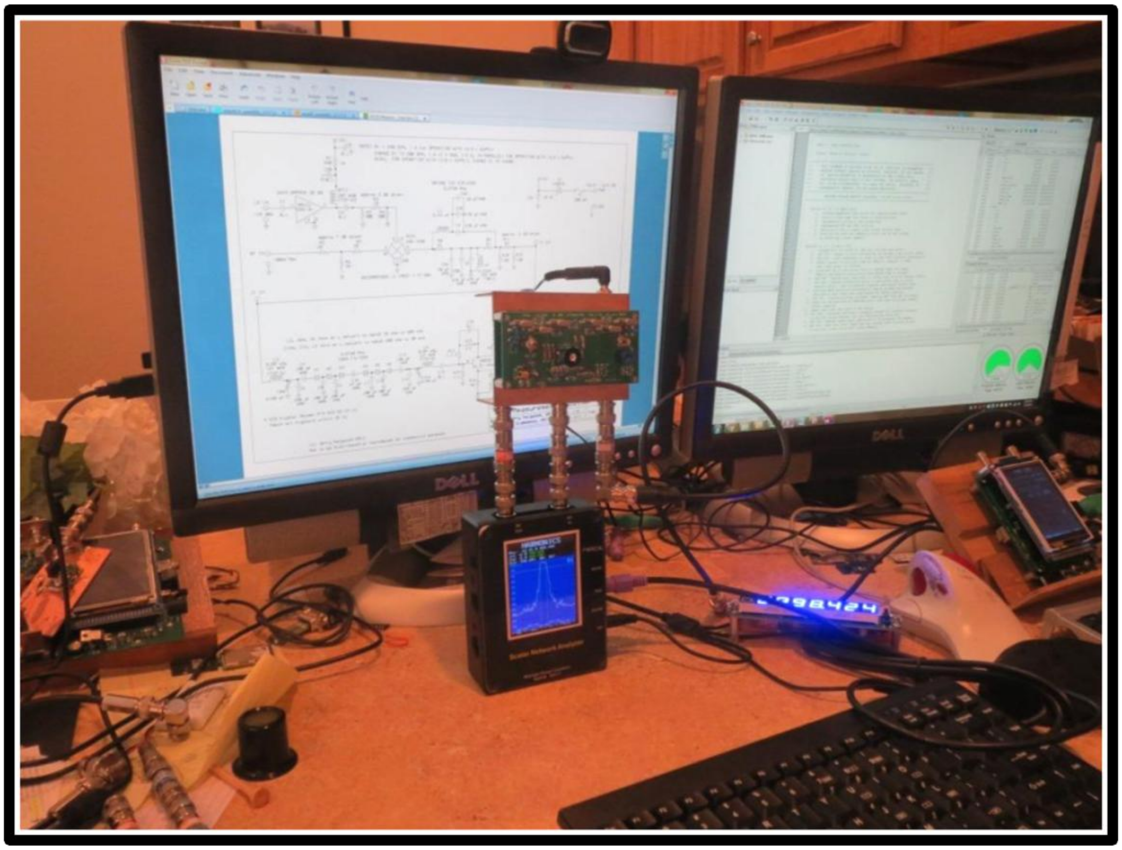
A harmonic scan consists of a number of scan segments centered on the first ten expected harmonic frequencies. Each scan segment is as wide as the one you set up around the fundamental frequency. The data is normalized so that the first harmonic power level is 0.0 dBc. Each of the following nine harmonic levels are then shown relative to the first one (negative dBc readings). The horizontal scale is shown as harmonic numbers instead of frequencies. The display also digitally displays the fundamental frequency and harmonic power levels (dBc).

6. USING THE MEASURMENT RECEIVER STEP-BY-STEP

The following step-by-step procedures use a 1 MHz square wave for the test signal. The procedure illustrates the setup and use of the PHSNA MR and some changes may be needed if a different MR is used but the basic steps should be the same.

The following procedures are illustrated here:

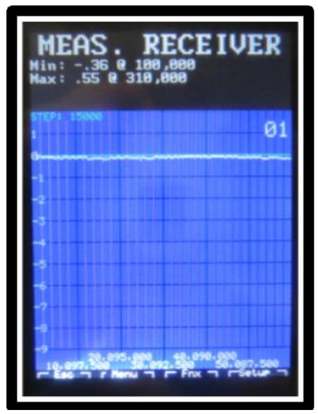
- Adjust the signal levels to meet the MR requirements.
- Determine the MR IF frequency for setting the offset frequency.
- Perform a 60 MHz segmented scan and zoom in for more detail.
- Plot the first ten harmonics of the 1 MHz square wave.



Signal Levels

The input signal levels to the MR must be checked and, if necessary, attenuated to meet the MR input specifications. The PHSNA MR requires the test signal level to be no more than -3dBm and the local oscillator signal level to be less than -10 dBm.

1. Create a macro to cover the 60 MHz frequency range with 4000 steps (ROWS), no entries are required on the second page.
2. Connect a short coax from the MSNA RF Out connector to the RF in connector.
3. Activate the macro and observe the plot.
4. If necessary, add an attenuator in series with RF Out, rerun the macro, and verify the signal level is below -10 dBm over the entire frequency range.



Macro form page 1 ***Initial RF Out Level*** ***Attenuated RF Out***

5. Connect RF Out to MR LO with attenuator (if any) from step 4 above in series with the coax line.
6. Connect your test signal to the MSNA RFIn.
7. Activate Power Meter mode [Scroll Lock > Ctrl-W].
8. Observe the Peak Power level and, if necessary, add an attenuator in series with the cable to lower the Peak Power level to below -3 dBm.

…

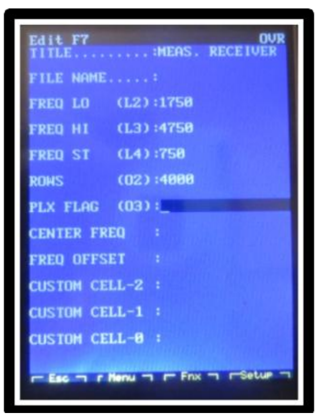

Initial ***Attenuated***

9. Connect your signal source to the MR test signal input with the attenuator in series.

Setting Frequency Offset Plus Cursor Basics

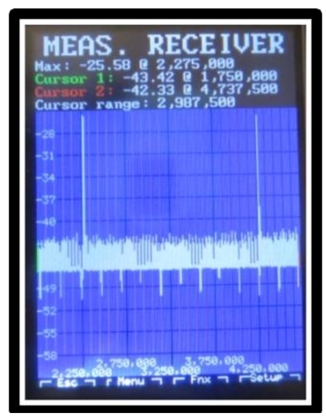
It is not necessary to set the frequency offset but it is much more convenient. By setting the frequency offset to the MR IF frequency, all frequency readings will be corrected to compensate for the frequency shift caused by the MR mixer. Here we are still using the 1 MHz square wave as our test signal.

1. Create a macro to cover a frequency range from below the IF frequency minus the test frequency to above the IF frequency plus the test frequency. Since we are using the PHSNA MR with a nominal IF frequency of 3.2768 MHz and a 1 MHz test signal, we will sweep from below 2.2768 MHz to above 4.2768 MHz. Set ROWs to 4,000; leave all page two entries blank.
2. Start the macro and press [SPACE] to scan and plot the frequency range. Note the two peaks at about the IF frequency plus and minus the test frequency.
3. Press [S] to generate a segmented scan of the same frequency range and activate the cursors.
4. Note the colored bars at each end of the plot. These are the cursors and they are initially positioned at the first and last slices of the plot. The left and right arrow keys will move the cursor one slice; the up and down arrow keys will move the cursor ten slices. Holding an Alt key while pressing an arrow key will select the right cursor. Holding a Ctrl key while pressing an arrow key will move both cursors. The current cursor positions and the maximum power levels at those positions are shown above the plot. The distance between the two cursors is also shown.



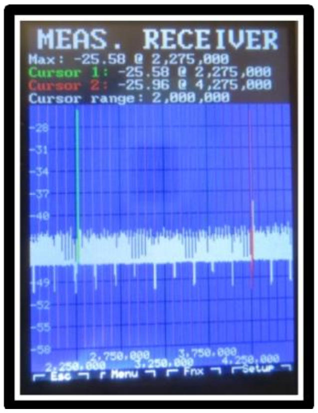
Macro Page 1

Normal Scan

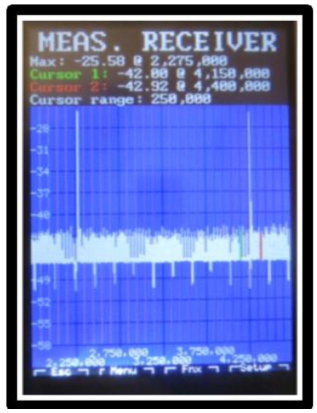


Segmented Scan

5. Position the left cursor on the first peak. Use the power level shown for that cursor to accurately place the cursor at the maximum power level. Position the right cursor on the second peak. The distance between the two cursors should equal about twice the test frequency (in our case, 2 x 1 MHz = 2 MHz).
6. Now we need to pick which mixer output we are going to use. Generally the higher frequency one (IF frequency plus test frequency) will be best. Move the cursors to positions just below and just above the chosen peak. This defines a zoom range. Pressing [Z] will plot the area between the cursors as a normal plot.



Cursors at peaks



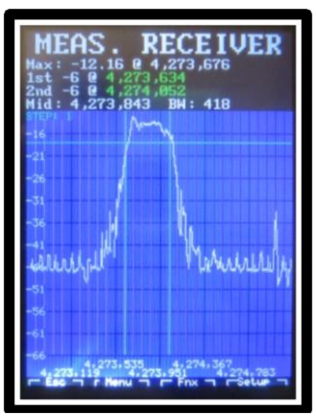
Right peak selected

Right peak plotted

7. Press [8] to center and reduce the frequency step. Press [2] to gain more resolution. This process can be repeated. The goal is to have a step of 1 (as shown in the upper left corner of the plot area) and a stated bandwidth of about the bandwidth of the MR IF filter (about 400 Hz for the PHSNA MR).

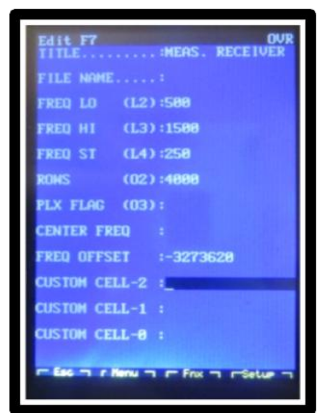
8. Note the Mid frequency for the plot (4,273,819 Hz). Edit the macro form and enter this frequency minus the test frequency (1,000,199 Hz in our case) for FREQ OFFSET on page one (4,273,819 - 1,000,199 = 3,273,620). Since we chose the higher-frequency peak, we want the displayed frequency shifted down and the FREQ OFFSET must be entered as a negative number (-3273620).

9. With the frequency offset entered, we no longer have to include the IF frequency in the frequency values entered in the macro form. Change FREQ LO to just below the test frequency and FREQ HI to just above the test frequency.



Right peak centered

Right peak expanded



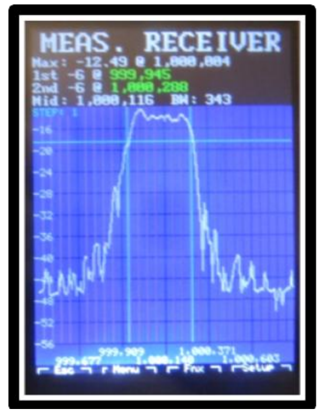
Updated macro p1

10. Start the macro and press [SPACE] to run a scan and plot.

11. Note that the plot frequency is close to the test frequency. Enter numbers ([2] through [8]) to expand the plot and improve the resolution.

12. Use the FREQ OFFSET value determined here in all macros used with this MR.

Plot with freq offset

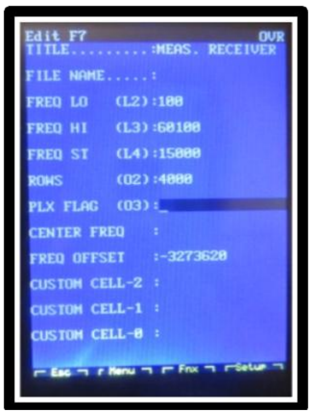


Centered and expanded

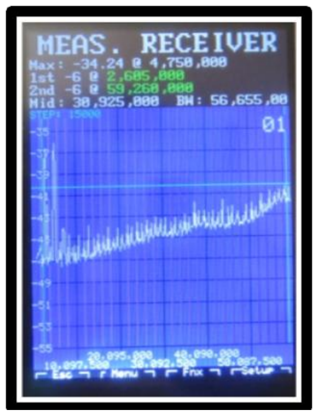
Segmented Wide-Spectrum Scan

We can use segmented scans to cover wide frequency spectrums and get a pretty good idea of the signal content in the spectrum. We can then use cursors to mark interesting frequency ranges and zoom in for more detailed views of these frequency ranges. The following step-by-step illustrates these features using a 60 MHz frequency spectrum and our 1 MHz square wave as the test signal.

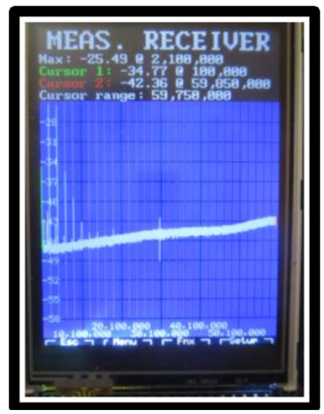
1. Create a macro to cover the 60 MHz frequency range with 4000 steps (ROWS). Make sure to enter the FREQ OFFSET value determined above. No entries are required on the second page.
2. Activate the macro, press [SPACE], and observe the resulting plot.
3. Not much meaningful information here due to the coarse FREQ ST and limited plot width. Press [S] to generate a segmented plot. Recall that a 60 MHz segmented plot requires 240,000 power level readings. It takes approximately 45 seconds to complete this scan.



Macro page 1

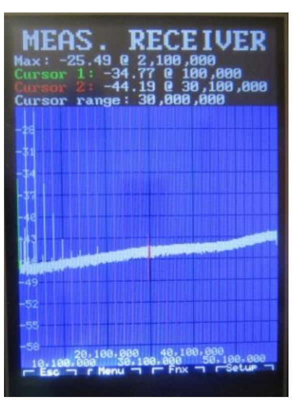


Initial "normal" plot

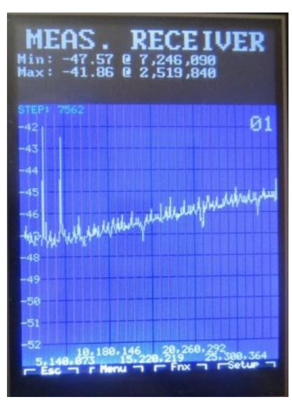


Segmented plot

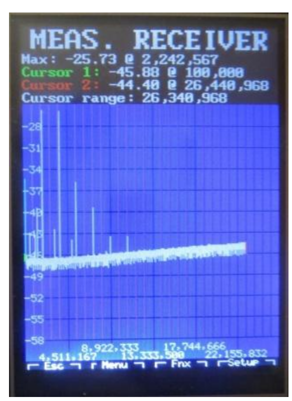
4. That's better but all the information appears to be in the first 30 MHz of the scan. Let's zoom in on that half. Mover the right (red) cursor to about the midpoint of the plot.
5. Press [Z] to plot the frequency range between the cursors.
6. Press [S] to generate a segmented plot of this range.



Cursor at 30 MHz

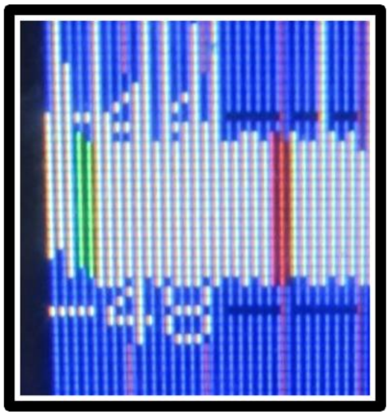


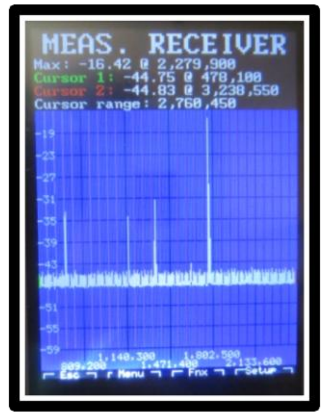
30 MHz normal



30 MHz segmented

7. Note that this plot is shortened. This is the result of adjusting the segmented plot parameters to make them all integers.
8. Position the cursors around an interesting and narrow range of frequencies and zoom in to inspect it in more detail. Generate a normal and segmented plot of the frequency range.





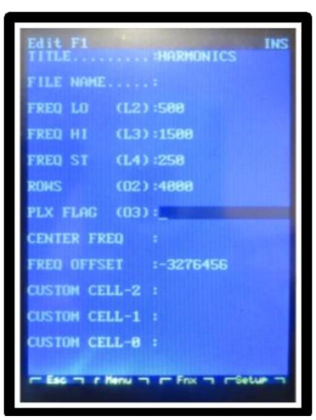
Measuring Harmonics

Before measuring harmonics, the fundamental frequency must be determined to fairly high accuracy. A 250 Hz error in the fundamental frequency will cause a 2.5 KHz error in the tenth harmonic's frequency. Power level measurements are made by scanning a narrow frequency band around each harmonic. The wider this frequency band is, the more error in the fundamental frequency can be tolerated. However, a wide frequency band also increases the possibility that non-harmonic signals will be picked up. Once the fundamental frequency is determined and a frequency scan band is determined, a scan is made around each harmonic frequency and the maximum and minimum power level from each scan is saved. After all scans have been completed, the results are plotted.

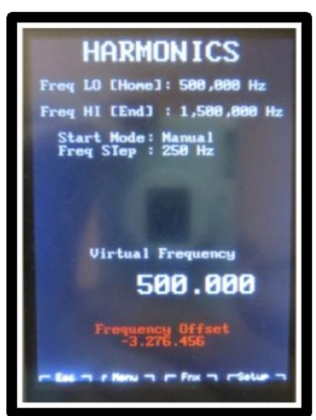
The following step-by-step shows how to plot the harmonics generated by a square wave with a frequency of about 1 MHz. (The frequency of my square wave source was a little high and was not very stable.)

You may use any convenient square wave source; however, if a harmonic frequency exceeds the DDS-60's upper frequency limit (about 70 MHz), its power level reading will not be accurate.

1. Create a macro to cover a frequency range from 500 KHz below to 500 KHz above the nominal fundamental frequency. Specify 4000 steps (ROWS). Make sure to enter the FREQ OFFSET value determined earlier. No entries are required on the second page.
2. Activate the macro by pressing [Fn].
3. Press [SPACE] to initiate a scan and observe the resulting plot.



Macro Page 1



[F1] Macro Started

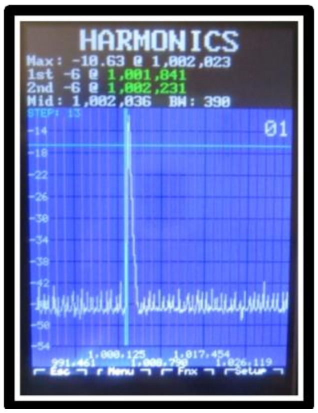
[SPACE] First Plot

4. The first plot is usually not what we are looking for. Here we see the frequency ("Mid:") is way too high and the bandwidth shown is much wider that the 400 Hz expected. This is due to the large frequency step (250) and the resulting wide frequency band covered (250 x 4000 = 1 MHz) giving us very poor resolution. Press [8] to improve the resolution. The firmware does a new scan reducing the frequency coverage to eight times the bandwidth (8 x 6,250 = 50KHz) and the step size is adjusted (to 13) to maintain about the same number of steps.

5. The second plot is better in that the bandwidth is now shown to be 390 Hz which is close to the expected 400 Hz. The frequency, however, is still pretty far off. Press [8] again to further increase the resolution.

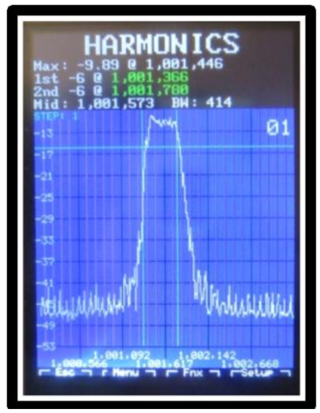
6. The third plot is close to what we are looking for, the frequency is only 17 Hz off and the bandwidth is only about 50 Hz off. The plot, however, is a little off-center and we want the frequency band to center on the fundamental so it will center on the harmonics too. Press [8] again.

7. The fourth plot is the one we've been looking for! The step is 1 Hz, the frequency is almost dead on, the bandwidth is very close, and the peak is near dead center of the plot. Press [H] to start the harmonic scans.



[8] Second Plot

[8] Third Plot

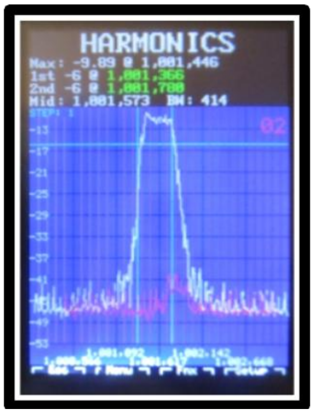


[8] Fourth Plot

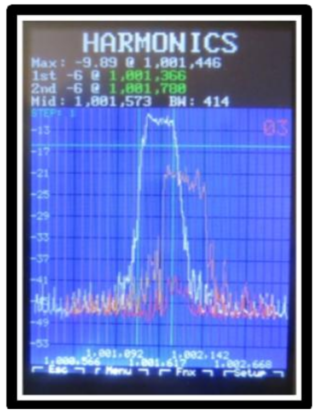
8. The second harmonic is scanned and the firmware pauses. Here we see the second harmonic plotted in red over the fundamental (first harmonic) plot. It is pretty low power but that's to be expected from a square wave. The peak may be shifted a little to the right but it is hard to tell with the signal level so low. To scan the third harmonic, press [SPACE] again.

9. The third harmonic is scanned and plotted in orange. Note that the plot screen is not reinitialized for each harmonic as it would be if Reinitialize each plot were specified in the OP MODES field of page two of the macro's data form. The third harmonic's power level is much higher than the second's as we would expect from a square wave.

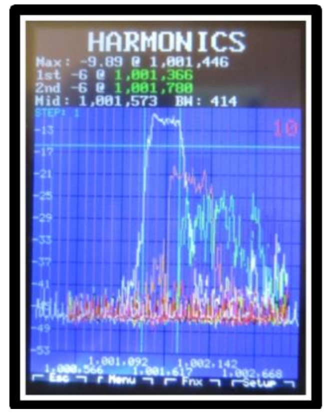
10. The next harmonic will be plotted each time [SPACE] is pressed. Pressing [A] will temporarily enable Automatic start mode and the remaining harmonics will be scanned sequentially without having to press [SPACE] for each one.



[H] 2Harmonics

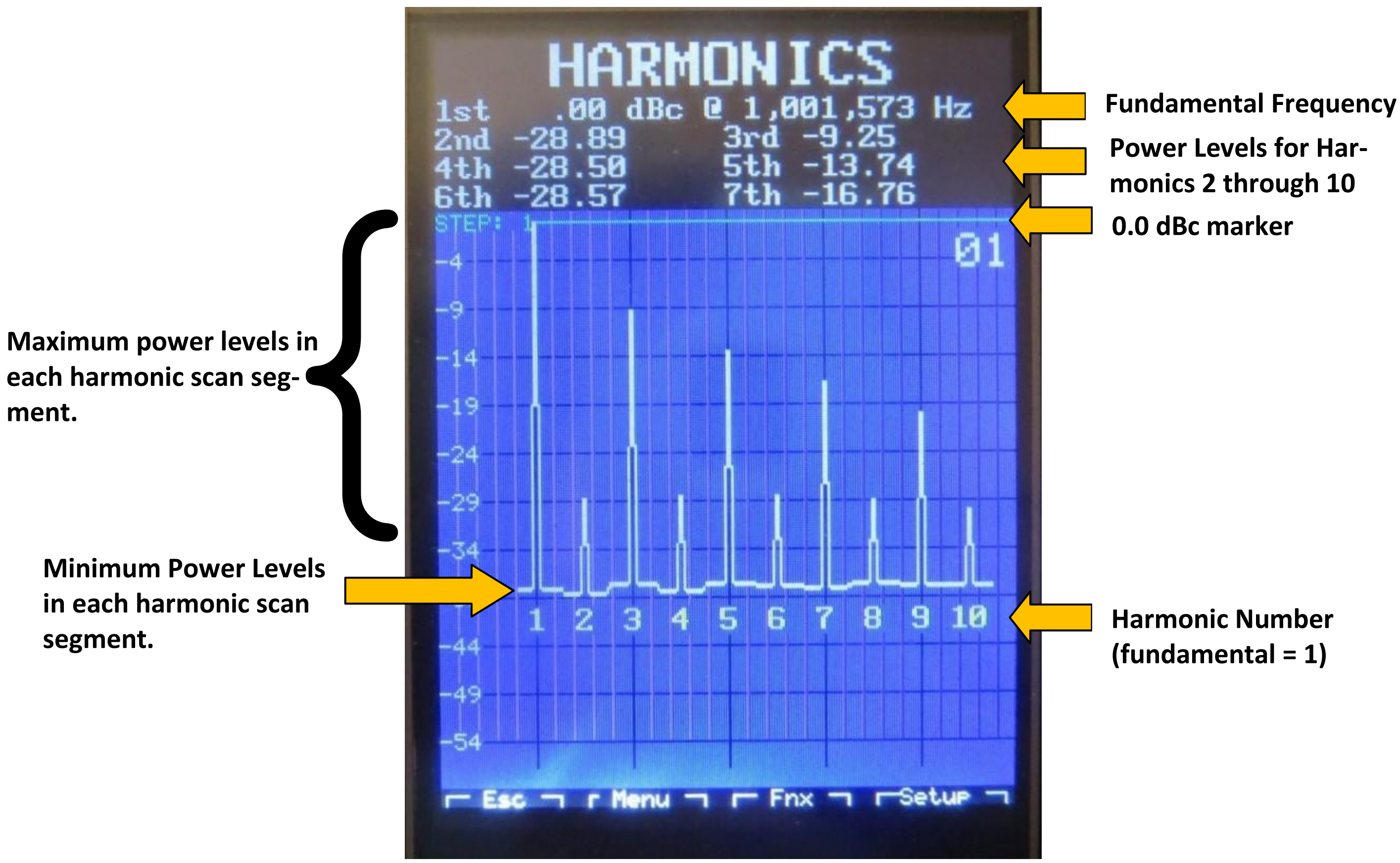


[SPACE] 3 Harmonics



[...] 10 Harmonics

11. Pressing [SPACE] (or [A]) after the tenth harmonic has been scanned and plotted initiates the summary plot showing all ten harmonics. The power levels are normalized such that the fundamental (first harmonic) power level is 0.0 dBc.



Harmonic Summery Plot