

DEPARTMENT OF PHYSICS, FACULTY OF SCIENCE, MAHIDOL UNIVERSITY

SCPY 350 PHYSICS LABORATORY  
LABORATORY 7 Harmonic Distortion Analysis

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การวิเคราะห์สัญญาณฮาร์โมนิกרבกวน

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This document is prepared for Physics Laboratory (SCPY350) of Department of Physics, Mahidol University. Its content is based on User's Guide for 8560 E-Series and EC-Series Spectrum Analyzers, Agilent Technologies.

## การทดลองที่ 7 การวิเคราะห์ฮาร์โมนิกרבกวน

### วัตถุประสงค์

เพื่อศึกษาการใช้เครื่อง Spectrum analyzer ช่วยในการวิเคราะห์ฮาร์โมนิกרבกวนของสัญญาณ sine wave และ square wave เพื่อหาค่าประกอบความถี่ย่อยที่ใช้ในการสังเคราะห์สัญญาณเหล่านี้

### งานที่มอบหมาย

- ศึกษาการใช้งานเครื่องกำเนิดสัญญาณ ออสซิลโลสโคป และเครื่องวิเคราะห์สัญญาณ
- วิเคราะห์ฮาร์โมนิกרבกวนของสัญญาณ sine wave และ square wave ความถี่มูลฐาน 1.0 MHz ให้อยู่ในรูปฮาร์โมนิกย่อย ที่มีความถี่ในช่วง 0.4 – 10.0 MHz และ 0.4 – 100.0 MHz ตามลำดับ แนะนำให้ใช้ ความสูงสัญญาณสองค่า 3.0 และ 6.0 โวลต์พีคคู่พีค การกำหนดความสูงสัญญาณ และความถี่ควรรใช้ ออสซิลโลสโคป ช่วย
- ถ้ามีเวลาลองใช้ฮาร์โมนิกרבกวน จากแหล่งจ่ายไฟกระแสสลับ ที่ความสูงสัญญาณ 3.0 โวลต์พีคคู่พีค

### ในรายงานควรประกอบด้วย

- รูปร่างที่ได้จาก oscilloscope ของสัญญาณขาเข้าความถี่ 1.0 MHz รูปร่างต่าง ๆ (ให้แสดง อัตราส่วนต่าง ๆ อย่างชัดเจน)
- ตารางและกราฟแสดงความเข้ม harmonic ที่เป็นองค์ประกอบย่อยของสัญญาณความถี่ 1.0 MHz
- รูปร่างที่ได้จากการผสมสัญญาณระหว่าง ความถี่มูลฐานและ Harmonic ที่ได้ ตามอนุกรม Fourier และเปรียบเทียบกับผลจาก oscilloscope
- วิเคราะห์หาค่าฮาร์โมนิกרבกวนรวม

### คำถามท้ายการทดลอง

- แหล่งจ่ายไฟนี้ ผ่านมาตรฐานของระบบจ่ายไฟ IEEE-STD 519-1992 หรือไม่

#### Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69kV and below	3.0	5.0 <sup>[1]</sup>
69.001kV through 161kV	1.5	2.5
161.001kV and above	1.0	1.5

[1] ที่สำหรับโรงพยาบาลและสนามบินค่า THD ของแรงดันไฟฟ้าจะจำกัดที่ 3%

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## Example 4: Harmonic Distortion

### What Is Harmonic Distortion?

Most transmitting devices and signal sources contain harmonics. Measuring the harmonic content of such sources is frequently required. In fact, measuring harmonic distortion is one of the most common uses of a spectrum analyzer. Harmonic distortion can be checked very quickly by using the measurement routine described below. This measurement routine measures harmonic amplitudes relative to the source frequency.

### Spectrum Analyzer Functions Used

The following harmonic distortion measurement applies an important group of spectrum analyzer operating skills: setting the frequency span using start and stop frequencies; setting the video bandwidth; and making relative measurements using two markers. It also demonstrates setting a signal to center frequency using a marker, and setting the frequency step size to the value of the center frequency.

There are two common ways to measure harmonic distortion using a spectrum analyzer. Procedure A illustrates the faster method, which permits a simultaneous display of the fundamental and its harmonics. Procedure B takes longer to perform but provides a better measurement of harmonics closer to the noise floor.

### Stepping through the Fast Harmonic Measurements: Procedure A

This example measures the harmonic content of a 1 MHz signal provided by a signal generator. You may use the 300 MHz calibrator signal of the spectrum analyzer, but be sure to adjust the spectrum analyzer start and stop frequencies to accommodate the source frequency and its harmonics.

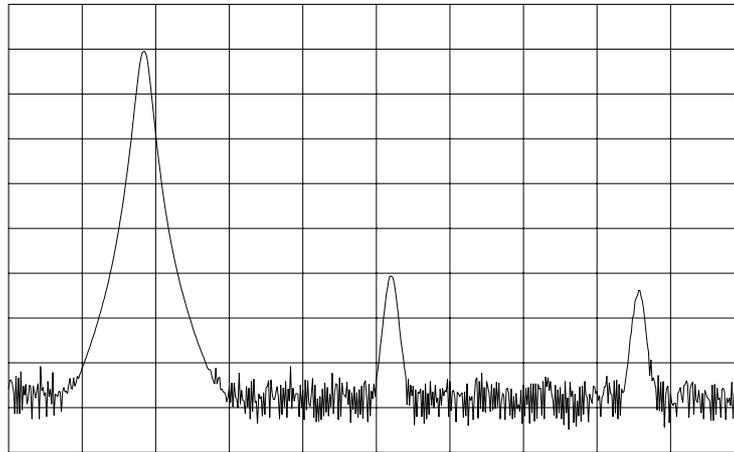
1. Connect the signal source to the spectrum analyzer INPUT 50  $\Omega$ . Press **PRESET** to start the procedure from a preset state.

#### Measure the 1 MHz fundamental and its first two harmonics

1. Set the start frequency to 450 kHz.
2. Set the stop frequency to 3.5 MHz.

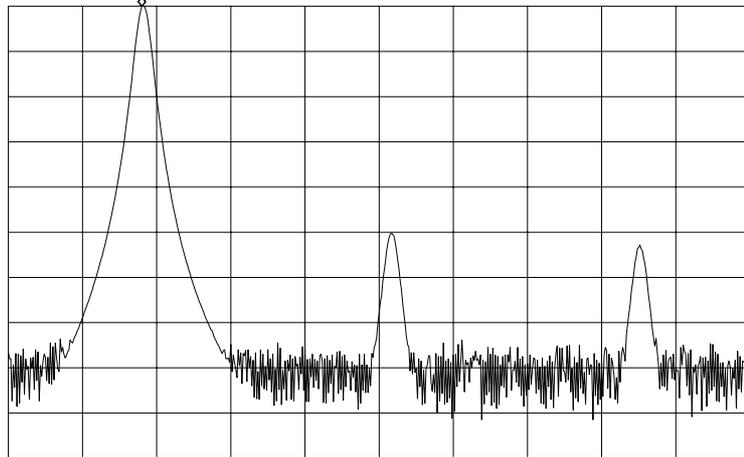
This displays the fundamental frequency and the second and third harmonics as shown in Figure 2-15 on page 68.

Figure 2-15 Input Signal and Harmonics



1. Set the video bandwidth to improve visibility by smoothing the noise:
  - a. Press **BW**.
  - b. Press **VIDEO BW AUTO MAN** until **MAN** is selected.
  - c. Use the step down  $\Downarrow$  key to select the video bandwidth.
2. For measurement accuracy, raise the peak of the fundamental to the reference level:
  - a. Press **PEAK SEARCH**, **MKR**  $\rightarrow$ , **MARKER**  $\rightarrow$  **REF LVL**. The result is shown in Figure 2-16.

**Figure 2-16** Peak of Signal is Positioned at Reference Level for Maximum Accuracy

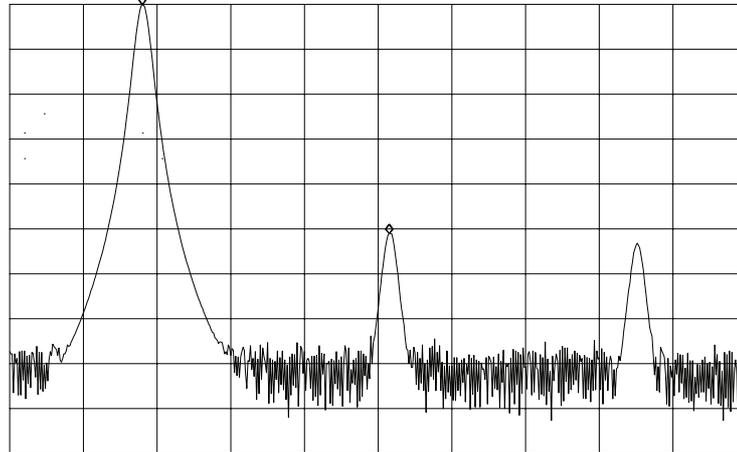


**Place a second marker on the second harmonic**

1. Set the peak threshold above the noise:
  - a. Press **PEAK SEARCH, MORE 1 OF 2, PEAK THRESHLD.**
  - b. Adjust the dashed line to a level above the noise using either the step keys or the knob.
2. Activate the second marker:
  - a. Press **PEAK SEARCH, MARKER DELTA, NEXT PK RIGHT.**

This places the anchor marker on the fundamental, and a second marker on the peak of the second harmonic, as shown in Figure 2-17 on page 70.

Figure 2-17 Harmonic Distortion in dBc (marker threshold set to  $-70$  dB)



#### Find the harmonic distortion (method 1)

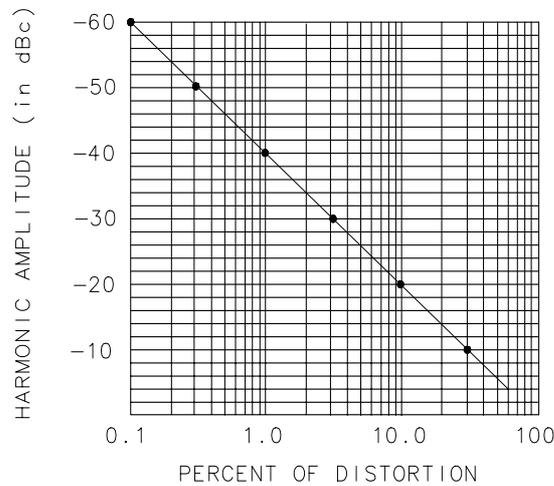
The difference in amplitude between the fundamental and second harmonic shown in the figure is about  $-50$  dB, or 0.33 percent harmonic distortion (see Figure 2-18).

1. To measure the third harmonic, press **NEXT PK RIGHT** again.

#### Measure additional harmonics

1. Continue reading amplitudes and comparing them to Figure 2-18 for each additional harmonic you want to measure. **PEAK EXCURSN** defines what is and what is not a peak; the next-peak routines find the corresponding peak.

Figure 2-18 Percentage of Distortion versus Harmonic Amplitude



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### Find the harmonic distortion (method 2)

1. Another easy way of determining the percent of distortion is to change the units to volts:
  - a. Press **AMPLITUDE, MORE 1 OF 3, AMPTD UNITS, VOLTS**. The marker readout automatically changes to voltage units.
  - b. To determine the percentage of distortion, use the ratio given by the marker and move the decimal point of this value two places to the right. However, the displayed ratio is limited to a minimum of 0.01, or 1 percent, before reaching zero.

### Plot the display

1. You may want to plot the display for hard-copy documentation:
  - a. Connect a graphics plotter (such as an Agilent 7440A ColorPro) to the analyzer via GPIB.
  - b. Set the plotter address to 5.
  - c. On the spectrum analyzer, press **CONFIG**, then **COPY DEV PRNT PLT** until **PLT** is selected.
  - d. Press **PLOTTER CONFIG** to view available plot functions.
  - e. Press **COPY** to transfer the entire display to the plotter.

Other plotter functions let you select certain traces or parts of the display for plotting. The **PLOT ORG DSP GRAT** function lets you choose the plotter reference points to correlate to the display (DSP) or to the display graticule (GRAT).

## An Alternative Harmonic Measurement Method: Procedure B

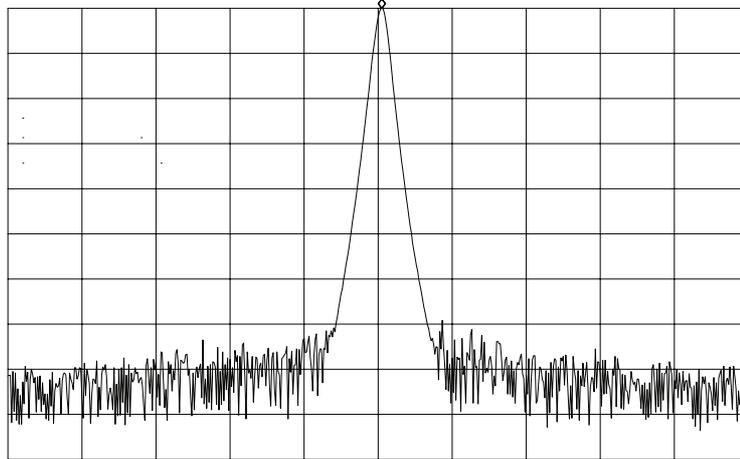
This method is somewhat longer, but because each signal is measured in a narrower span and resolution bandwidth, the signal-to-noise ratio is improved, making the results more accurate.

1. Using the present setup, clear the markers from the screen by pressing **MKR, MARKERS OFF**. Notice that when **MARKERS OFF** or **HOLD** is pressed, the display expands to the full size of the screen, for easier viewing.

### Measure the 1 MHz fundamental

1. Reduce the frequency span:
  - a. Press **PEAK SEARCH**, which activates a marker on the highest-level signal on-screen.
  - b. Reduce the frequency span to 1 MHz by pressing **SPAN, SPAN ZOOM**.
  - c. Enter 1 MHz. The span zoom function lets you quickly "zoom" to a narrower frequency span without losing the signal from the screen (because signal track is activated).
  - d. After the frequency span is reduced, turn off the signal-track function by pressing **MKR**, and setting **SIG TRK ON OFF** to OFF.
2. Set the center-frequency step-size to the frequency of the fundamental:
  - a. Press **MKR →, MARKER → CF STEP**
3. For better amplitude accuracy, move the signal to the top of the graticule:
  - a. Press **MARKER → REF LVL**. The resulting display should resemble Figure 2-19 on page 73.

Figure 2-19 Input Signal Displayed in a 1 MHz Span



#### Measure the second harmonic

1. Press **MKR**, **MARKER DELTA**, **FREQUENCY**, and the step up › key. This step retunes the spectrum analyzer center frequency to the second harmonic.
2. Adjust the harmonic to the reference level. (Note that the **MARKER** → **REF LVL** function is not available in marker-delta mode.) This displays the amplitude of the second harmonic as shown in Figure 2-20 on page 74.

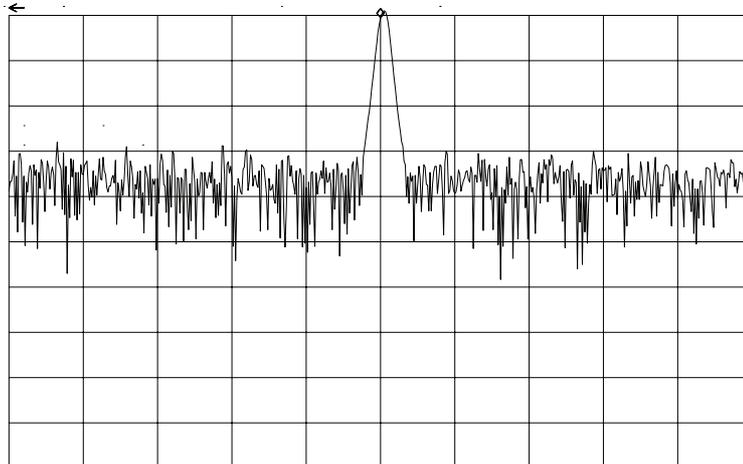
#### Find the harmonic distortion

1. Use Figure 2-18 on page 71 to convert the difference between the second harmonic and the fundamental to a percentage of distortion. Again, units can be changed to volts in order to read the voltage ratio of the two signals.

#### Measure additional harmonics

1. For each additional harmonic you wish to measure, press the step up › key and adjust the reference level. Note the arrow in the upper-left corner of the graticule indicates that the anchor marker is off-screen. However, the results are still valid.

Figure 2-20 Second Harmonic Displayed in dBc



### Percent of Harmonic Distortion

The total percent of harmonic distortion of a signal is also measured frequently. For this measurement, the amplitude of each harmonic must be measured in linear units (for example, volts) instead of dBc. To display amplitude units in volts, press **AMPLITUDE, MORE 1 OF 3, AMPTD UNITS, and VOLTS**. The amplitude values of these signals are used in the equation below to compute total harmonic distortion:

$$\frac{\sqrt{(A_2)^2 + (A_3)^2 + (A_4)^2 \dots + (A_n)^2}}{A_1} \times 100$$

1. Where:

- $A_1$  = the amplitude of the fundamental frequency, in volts
- $A_2$  = the amplitude of the second harmonic, in volts
- $A_3$  = the amplitude of the third harmonic, in volts
- $A_4$  = the amplitude of the fourth harmonic, in volts
- $A_n$  = the amplitude of the *n*th harmonic, in volts

If the signal amplitudes are measured carefully, as in the previous example, this procedure measures percent-of-harmonic distortion very accurately.