VANIER COLLEGE – Computer Engineering Technology – Winter 2021

Telecommunications (247-410-VA)

Leonardo Fusser (1946995)

# LABORATORY EXPERIMENT #2

# AM in time and frequency domains

NOTE:
To be completed in one lab session of 3 hrs.

Answers to the lab question, calculation, screen shots, observation& analysis has to be submitted **via Lea before the deadline stated**. Clearly label the step number in your answers.

This exercise is to be done **individually** except where specified in the procedure. **Each** student must submit a lab report with original observations and conclusions.

## *OBJECTIVES:*

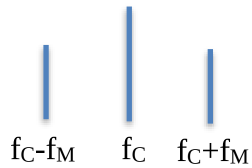
After performing this experiment, the student will be able to:

1. Display amplitude modulations signals in the time domain and frequency domain
2. Predict the power and frequency of the sideband components.
3. Explain why non-sinusoidal waves produce multiple side-band components.
4. Get ready to work with spectrum analyzer.

## *DISCUSSION OF THEORY*

In this experiment, we will amplitude-modulate a carrier wave and we will analyze the modulated signal in the frequency domain, in addition to the time domain.

As we have seen in class, when a carrier frequency ($f_C$) is modulated with a sinusoidal tone of frequency $f_M$, the modulated signal contains 3 components: the carrier $\mathbf{f_C}$**,** and two side-bands $\mathbf{(f_C + f_M)}$ and $\mathbf{(f_C - f_M)}$



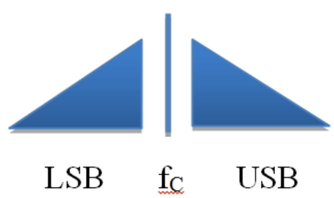

As the modulation frequency $f_M$ increases, the sidebands move farther away from the carrier frequency $f_C$. The total power of the modulated signal is given by:

$$P_T = P_C\left(1 + \frac{m^2}{2}\right)$$

And the power of each sideband is:

$$P_{SB} = \frac{m^2}{4} P_C$$

In real life, carriers are rarely modulated with pure sine waves. Non-sinusoidal waves include a range of frequencies. The full bandwidth of the modulating signal is duplicated above the carrier frequency and also as a mirror image below the carrier frequency.



# *PROCEDURE*

## Part 1 AM modulation

For the following questions you can use the display on the other pages.

1) Consider that we set a function generator as an AM modulator with a carrier frequency of 200KHz with amplitude of 2V and the modulation signal of 20KHz. For this test we set the modulation depth to 100%. If we connect the output of signal generator to oscilloscope what will be the shape of the signal.

   *Note: all the answers below can be found in the Excel spreadsheet attached to this submission. The colors below correspond to the highlighted portions in the Excel spreadsheet in each sheet.*

   a) Sketch the waveform.
   b) What will be the Peak Amplitude?
   c) What will be the Minimum Amplitude?
   d) Calculate the modulation index using the formula learned in class.
   e) Draw the signal in the frequency domain.
   f) Power of carrier.
   g) Power of each sideband.

2) Repeat question 1 for modulation depths of:

   *Note: all the answers below can be found in the Excel spreadsheet attached to this submission. Each modulation depth has its own corresponding sheet in the Excel spreadsheet.*

   a) 20%
   b) 40%
   c) 60%
   d) 120%

3) In order to see the signal in the question 1, what will be the setting of Oscilloscope if we want to see two or three modulation signals?

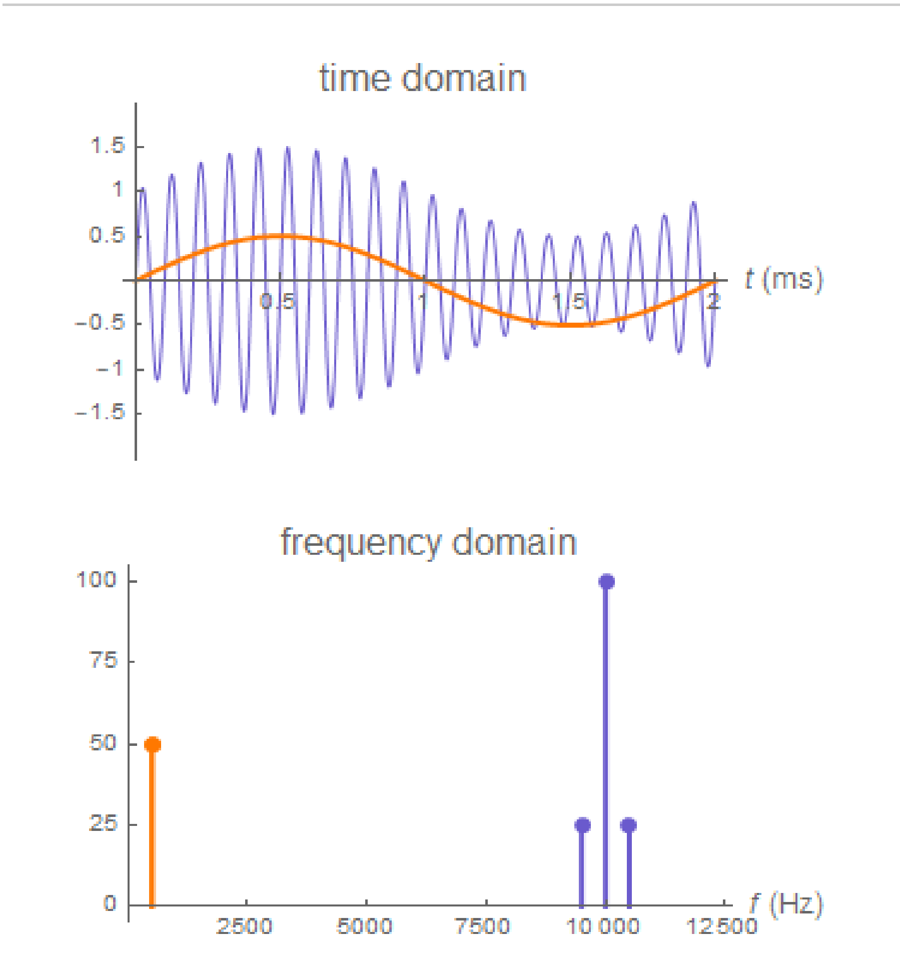
   a) Volt/div: 1V or 1.5V
   b) Freq/div: 5uS

4) Consider a square wave with a period of 50us that is modulated with the carrier in Question 1. Modulation index is 100%. Draw the signal in time domain and frequency domain.

5) Check the following link which is a demonstration of an AM modulation with carrier of 10KHz with amplitude of 1V in time and frequency domain.

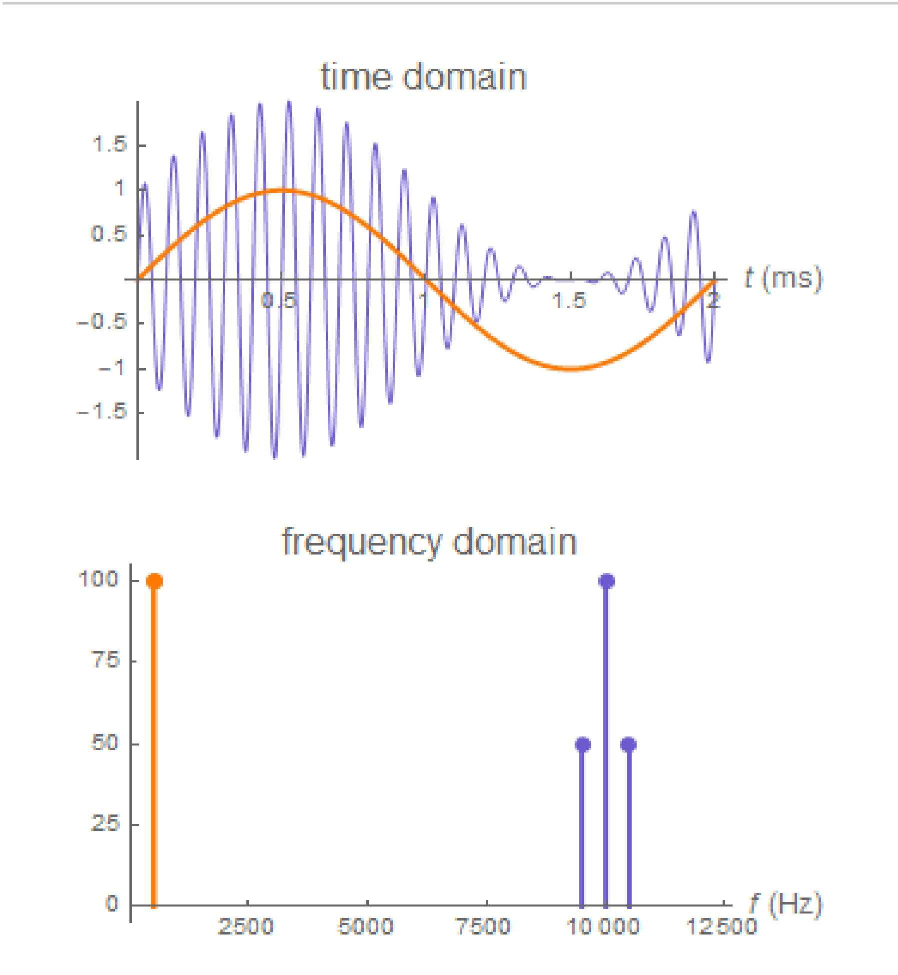
   https://demonstrations.wolfram.com/AmplitudeModulation/

   a) Set the modulating frequency to 500HZ and test for 50% modulation index and 100% modulation index. Take a screen shot and explain your observation.




$F_C = 10kHz, F_m = 500Hz \ \& \ m = 0.5 \ (50\%)$

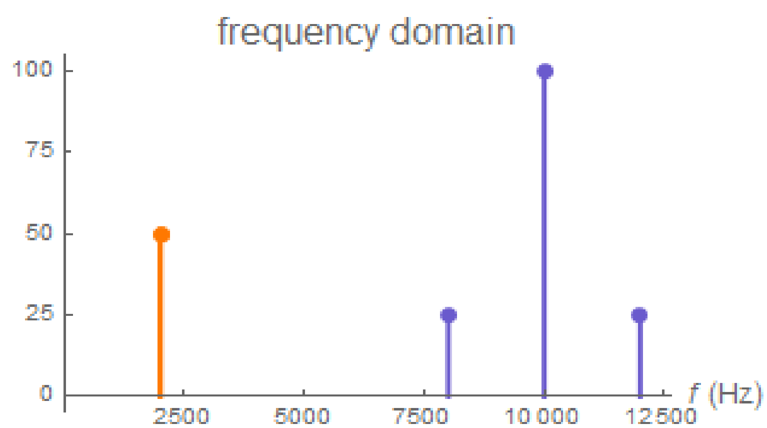
*Here, with a 50% modulation index, the amplitude of the modulating signal and sidebands are lower than when the modulation index is at 100%. When the modulation index is at 100%, the amplitude of the modulating signal and sidebands are greater than when the modulation index is 50%. The peak voltage of the carrier frequency will remain the same when the modulation index is 100%. The shape of the AM signal will change as well. The results with 100% modulation index are shown on the next page.*




$F_C = 10kHz, F_m = 500Hz$ & $m = 1$ (100%)

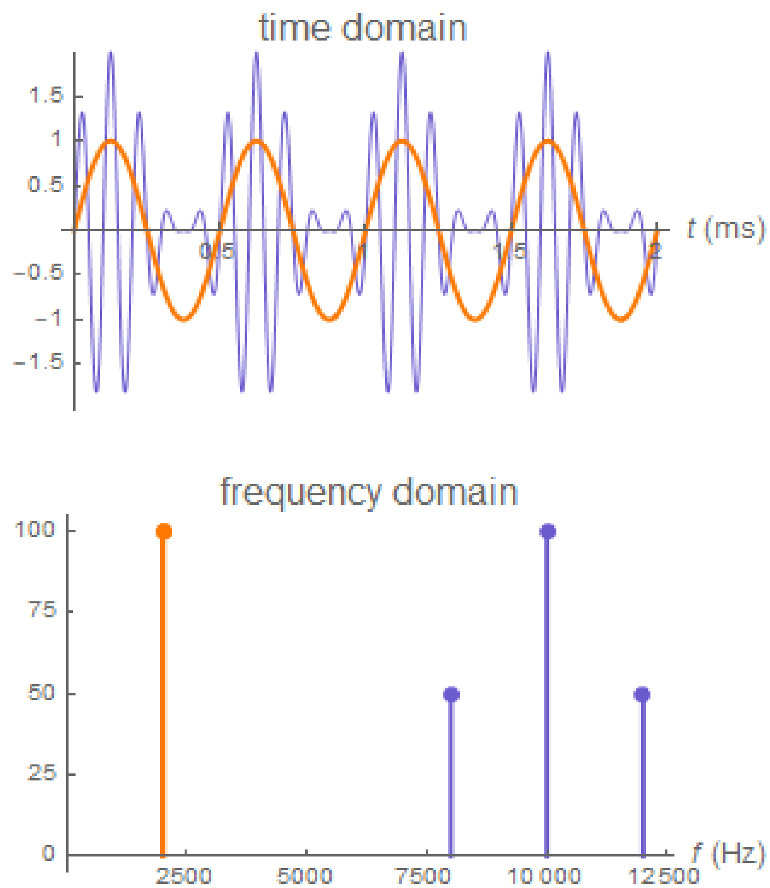
*Here, with a 100% modulation index, the amplitude of the modulating signal and sidebands are greater than when the modulation index is at 50%. The shape of the AM signal has changed. Furthermore, the modulation frequency has the same peak voltage as the carrier frequency. When the modulation index is at 100%, the amplitude of the modulating signal and sidebands are greater than when the modulation index is 50% (shown above). The peak voltage of the carrier frequency remains the same for both 50% and 100% modulation indexes.*

b) Repeat (a) with frequency of close to 2KHz.


$F_C = 10kHz, F_m = 2kHz \;\&\; m = 0.5\ (50\%)$

*Other than the change in carrier frequency and modulation frequency, the results from (a) and (b - here) are similar. Here, the sidebands are further spaced out in the frequency domain than what was shown in the frequency domain in (a). Also, same as before, with a 50% modulation index, the amplitude of the modulating signal and sidebands are lower than when the modulation index is at 100%. When the modulation index is at 100%, the amplitude of the modulating signal and sidebands are greater than when the modulation index is 50%. The peak voltage of the carrier frequency will remain the same when the modulation index is 100%. The shape of the AM signal will change as well. The results with 100% modulation index are shown on the next page.*




$F_C = 10kHz, F_m = 2kHz \;\&\; m = 1\ (100\%)$

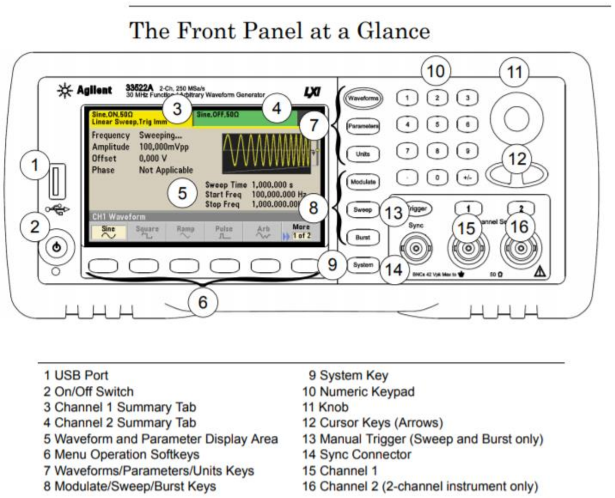
*Here, with a 100% modulation index, the amplitude of the modulating signal and sidebands are greater than when the modulation index is at 50%. The shape of the AM signal has changed slightly. Furthermore, the modulation frequency has the same peak voltage as the carrier frequency. When the modulation index is at 100%, the amplitude of the modulating signal and sidebands are greater than when the modulation index is 50% (shown above). The peak voltage of the carrier frequency remains the same for both 50% and 100% modulation indexes.*

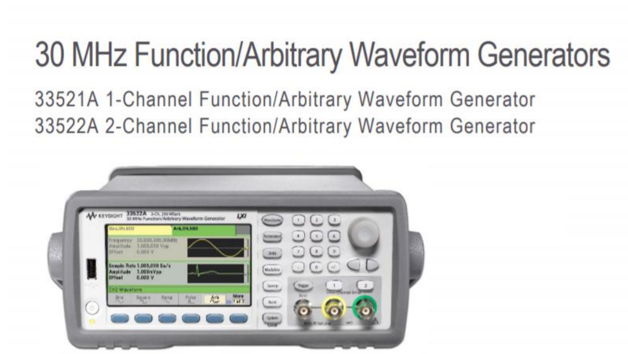
# Part 2 Equipment:

## 1) Function generator

Read the manual of function generator to see how you can set the function generator for AM modulation (page 102). Explain.

[http://www.mdc.umn.edu/facility/files/electrical/Elec%20Manuals/Agilent%20Waveform%20Generator.pdf](http://www.mdc.umn.edu/facility/files/electrical/Elec%20Manuals/Agilent%20Waveform%20Generator.pdf)




To configure waveform generator properly for AM modulation:

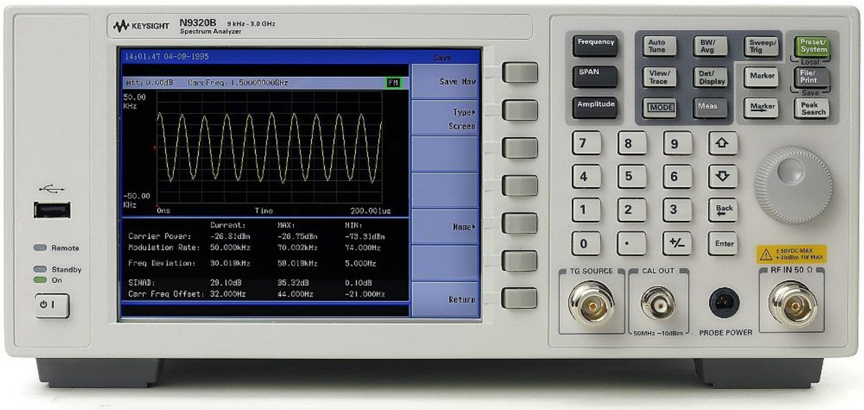
- Turn on the function generator.
- Press "Modulate" on the front panel and then select "AM" using the "Type" softkey.
- Change carrier shape by selecting any possible waveform found from pressing "Waveforms". (for arbitrary waveforms, press "Arb" and "Arbs", and then choose the "Select Arb" softkey to select the active waveform.
- Change the carrier frequency by pressing the "Parameters" button, then the "Frequency" softkey. Use the knob or keypad to enter the desired frequency.
- Select the desired modulating waveform shape by pressing the "Shape" softkey and then select the desired shape. Note: For this step and others below, this can only be done after enabling the AM modulation feature (done in previous steps).
- Change the modulating waveform frequency by pressing the "More" and then the "AM Freq" softkey. Enter desired modulating waveform frequency.
- Select the desired modulation depth (index) by pressing the "AM Depth" softkey. Use the knob or keypad to enter the depth. The default is 100%.
- Select the modulation source by pressing the "Source" softkey. Note: Internal modulation source is default.
- In addition to DSFC AM, the waveform generator can be configured for DSSC AM as well.

## 2) Spectrum analyzer

Listen the following video about spectrum analyzer and explain why we use spectrum analyzer and what is the minimum setting in a spectrum analyzer? You can find more videos on YouTube. Also refer to the manual of spectrum analyzer for more information and minimum setting.

https://www.youtube.com/watch?v=WnKK11UEvVE

https://www.keysight.com/upload/cmc_upload/All/N9320B_Quick_Start_Guide.pdf



- Essentially, a spectrum analyzer is used to measure signals in the frequency domain, where the x-axis is frequency measured in Hertz (Hz) and the y-axis is amplitude measured in volts (V). The oscilloscope is used to measure signals in the time domain, where the x-axis is time measured in seconds (s) and the y-axis is amplitude measured in volts (v). When it comes to observing signals, an oscilloscope is often very good at measuring one to two signals at a time, but when dealing with many signals at a time, this becomes the weak point of the oscilloscope as it cannot display all the signals very well (it will become messy!). This is the primary reason we use the spectrum analyzer, so that we can observe many signals at a time, each being displayed uniquely on the screen. In order to start measuring signals, initial setup of the spectrum analyzer must occur (steps on how to do it are shown on the next few pages):

<u>To configure minimum spectrum analyzer settings for measurements</u>:

# Making a Basic Measurement

In this guide, the keys labeled with [ ], for example, [Preset/System] refer to front-panel hardkeys. Pressing many of the hardkeys accesses softkey menus that are displayed along the right side of the screen. The softkey menu labels are aligned so that they are located next to the softkeys at the right side of the display screen. For example, Preset is a softkey menu selection when first pressing [Preset/System].

## Using the Front Panel

This section provides you with the information on using the front panel of the spectrum analyzer.

### Entering Data

When setting the measurement parameters, there are several ways to enter or modify the value of the active function:

| | |
|---|---|
| Knob | Increments or decrements the current value. |
| Arrow Keys | Increments or decrements the current value by a step unit. |
| Numeric Keys | Enters a specific value. Then press the desired terminator (either a unit softkey, or [Enter] hardkey). |
| Unit Softkeys | Terminate (enter) a value with a unit softkey from the menu. |
| Enter Key | Terminates an entry when no unit of measure is required, or the instrument uses the default unit. |
| Back Key | To delete the current input digit prior to entering the value. |

### Using Softkeys

Softkeys are used to modify the analyzer function parameter settings. Some examples of softkey types are:

| | |
|---|---|
| Toggle | Turn on or off an instrument state. |
| Submenu | Displays a secondary menu of softkeys, {More}. |
| Choice | Selecting from a list of standard values or filenames. |
| Adjust | Highlights the softkey and sets the active function. |

# Presetting the Spectrum Analyzer

Preset function provides a known instrument status for making measurements. There are two types of presets, factory and user:

**Factory Preset** When this preset type is selected, it restores the analyzer to its factory-defined state. A set of known instrument parameter settings defined by the factory. Refer to “Factory Default Preset State” on page 159 for details.

**User Preset** Restores the analyzer to a user-defined state. A set of user defined instrument parameter settings saved for assisting the user in quickly returning to known a instrument measurement setup.

Press Preset/System > Pwr on/Preset > Preset Type to select the preset type.

When Preset Type is set to Factory, pressing Preset/System > Preset triggers a factory preset condition. The instrument will immediately return to the factory default instrument parameter setting.

When Preset Type is set to User, pressing Preset/System > Preset displays both User Preset and Factory Preset softkeys. The user may then select the preset desired from the softkey menu selections.

## Setting up a User Preset

To quickly return to instrument settings that are user defined, perform the following steps to save the instrument state as the user-defined preset:

1 Set the instrument parameters to the values and settings necessary for the user preset state. This would include the frequency, span, amplitude, BW, and measurement type and any other setup details desired.

2 Press Preset/System > Pwr on/Preset > Save User Preset, to save the current instrument settings as the ‘user preset’ state. The user preset will not affect the default factory preset settings. User preset settings can be changed and saved at any time.

# Viewing a Signal

Refer to the procedures below to view a signal.

1 Press **Preset/System** > Pow on/Preset > Preset Type > Factory to enable the factory-defined preset state.

2 Press **Preset/System** > Preset to restore the analyzer to its factory-defined state.

3 Connect the 10 MHz REF OUT on the rear panel to the front-panel RF IN.

## Setting the Reference Level and Center Frequency

1 Press **Amplitud** > 10 > dBm to set 10 dBm reference level.

2 Press **Frequenc** > 30 > MHz to set 30 MHz to center frequency.

## Setting Frequency Span

Press **SPAN** > 50 > MHz to set 50 MHz frequency span.

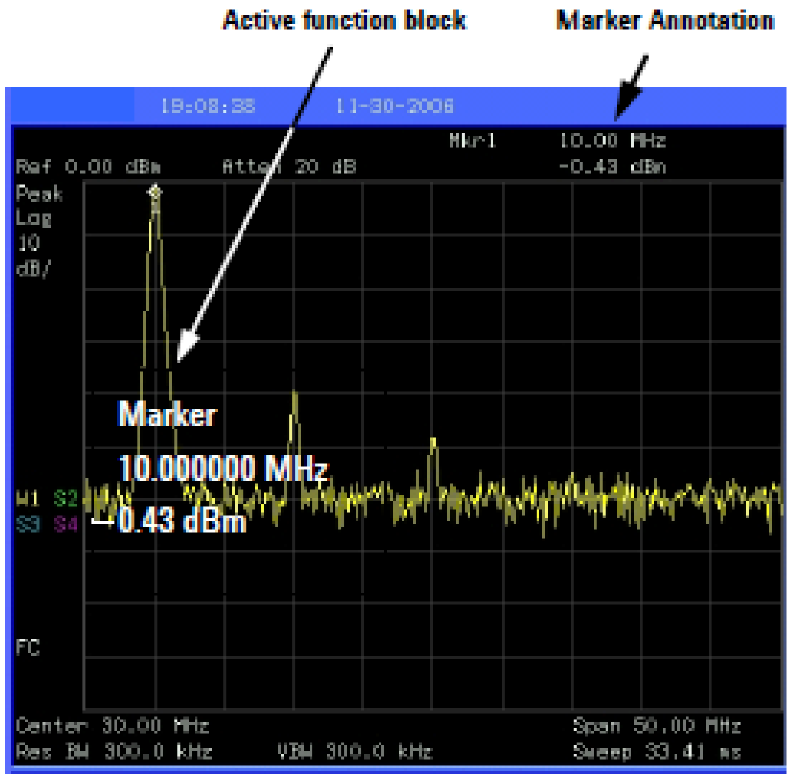
**NOTE** Changing the reference level changes the amplitude value of the top graticule line. Changing the center frequency changes the horizontal placement of the signal on the display. Increasing the span will increase the frequency range that appears horizontally across the display.

## Reading Frequency and Amplitude

1 Press **Peak Search** to place a marker (labeled 1) on the 10 MHz peak.

Note that the frequency and amplitude of the marker appear both in the active function block, and in the upper-right corner of the screen.

Figure 3-1 10 MHz Internal Reference Signal




2 Use the knob, the arrow keys, or the softkeys in the Peak Search menu to move the marker. The marker information will be displayed in the upper-right corner of the screen.

## Changing Reference Level

1 Press **Amplitude** and note that reference level (Ref Level) is now the active function.

2 Press **Marker** > Mkr-> Ref Lvl.

**NOTE** Changing the reference level changes the amplitude value of the top graticule line.