Errata

Document Title: Single Shot BPSK Signal Characterization (AN 358-8)

Part Number: 5952-8002

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HP References in this Application Note

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Application Note 358-8
Single Shot BPSK
Signal Characterization

Description

BPSK (Binary Phase Shift Keying) is a form of phase modulation used in many applications, such as radar, computer modems and radio communication networks. As shown in Figure 1, the BPSK signal is usually a sinewave carrier alternating in time between two phases: 0 degrees and 180 degrees. Each phase indicates a digital one or zero.
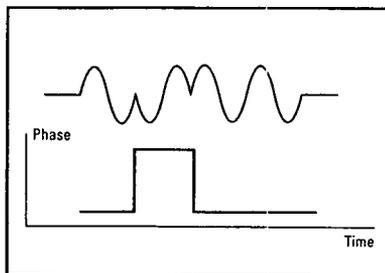

Figure 1. Time domain view of a BPSK signal and corresponding phase vs. time plot.

Problem

Two difficult and critical parameters to measure on a BPSK signal are the size and location of a phase change. An oscilloscope or spectrum analyzer do not display results in the desired form of phase versus time. I and Q demodulation techniques are not single shot, which can be crucial to accurately profiling a BPSK test pattern or random bit stream.

The correct size and location of a phase change increase the chances of detection by a radar or radio communication receiver, and they improve the range resolution in a radar system. Similarly for modems, errors in a computer system are reduced with the correct size and location of phase change.
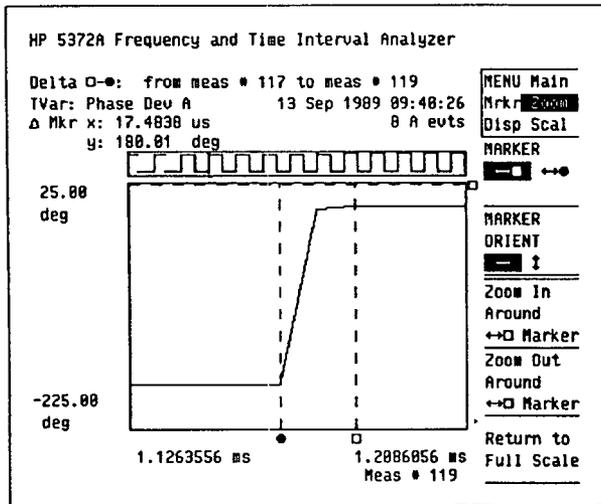
```
HP 5372A Frequency and Time Interval Analyzer

Delta □-●:  from meas # 117 to meas # 119      MENU Main
TVar: Phase Dev A          13 Sep 1989 09:48:26  Mrkr Zoom
Δ Mkr x: 17.4838 us                8 A evts      Disp Scal
      y: 180.01  deg                             MARKER
                                                 ▭□ ↔●
 25.00
 deg                                             MARKER
                                                 ORIENT
                                                 ▬ ↕

                                                 Zoom In
                                                 Around
                                                 ↔□ Marker
                                                 Zoom Out
                                                 Around
-225.00                                          ↔□ Marker
 deg                                             Return to
     1.1263556 ms        1.2086056 ms  Full Scale
                        Meas # 119
```

Figure 2. An individual phase change of 180.01 degrees on the HP 5372A.

HP 5372A Frequency and Time Interval Analyzer

Solution

The HP 5372A Frequency and Time Interval Analyzer captures single shot BPSK signals and clearly shows the magnitude and timing of the phase changes. Using the input Channel A or B, the HP 5372A measures phase deviations up to 500 MHz. The HP 5372A can also detect an individual phase as short as 75 ns in duration. This translates to a phase modulation rate of approximately 6.67 MHz. Furthermore, a coherent reference signal is not required as with other measurement techniques.

The HP 5372A's continuous measurement capability enables it to capture up to 8191 phase deviation measurements in a single pass without compromising phase or timing resolution. These measurements are stored internally and shown on the built-in display. Figure 2 shows an individual phase change of a BPSK signal captured with the HP 5372A. The vertical axis is phase, and the horizontal axis is time. The size and location of the phase change is determined using the measurement markers on the display. The size of the phase change, in this example, is 180.01 degrees.

- *Characterize BPSK signals up to 500 MHz with single-shot capability*

- *View phase versus time directly*

- *Determine magnitude and timing of each phase change with precision*

Measurement Considerations

Proper configuration of the HP 5372A is important to obtain the desired measurement. For the BPSK signal, this means having a basic understanding of how the HP 5372A phase deviation measurement works. It is also important to consider the following: total measurement time, sampling interval, number of measurements, phase resolution, carrier frequency, input trigger conditions and arming modes.

Background Information on the Phase Deviation Measurement

The HP 5372A's phase deviation measurement is optimal for characterizing a BPSK signal. It is a single-channel measurement that simplifies system configuration because a coherent reference signal is not required. Results are determined by computing the magnitude of phase difference between an input signal and a computed reference value. The reference can be mathematically determined by the HP 5372A, or it can be a manually entered carrier frequency value. (See the Appendix for a description of how the carrier is computed automatically in the HP 5372A.)

Figure 3 provides a simplified view of the phase deviation measurement on a 10 MHz carrier. The HP 5372A establishes the time of occurrence (or time stamp) for each event, in this case, a rising edge. It then compares each time stamp of the input signal to the computed reference value, and determines the difference in time. This deviation is expressed in degrees, where one period of the computed reference corresponds to 360 degrees. (See the Appendix for an in-depth discussion of the phase deviation measurement.)
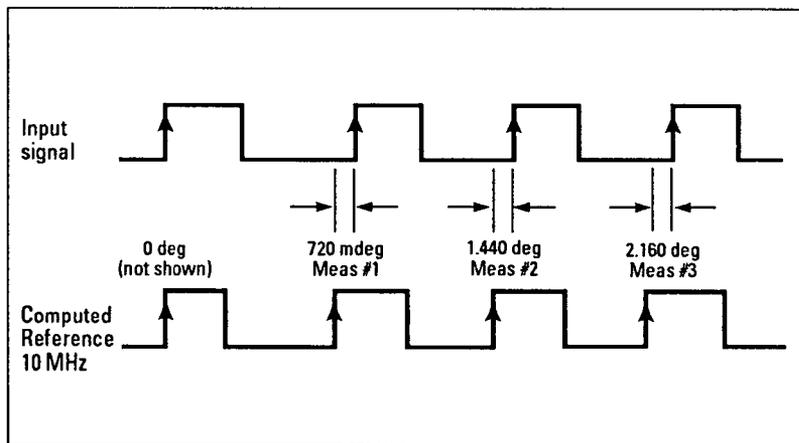

Figure 3. Simplified view of the phase deviation measurement.

The phase deviation results may be viewed numerically, or graphically in one of two ways: modulo 360 or cumulative. The modulo 360 form is the more common way to view the results of a BPSK measurement because only two alternating phases are displayed. With the cumulative display, the phase deviation begins at 0 degrees and accumulates. This means the resultant display for a BPSK signal is a "stair-step," where each step represents a 180 degree phase shift. Figure 4 illustrates the modulo 360 and the cumulative forms of graphically displaying the phase deviation measurement.
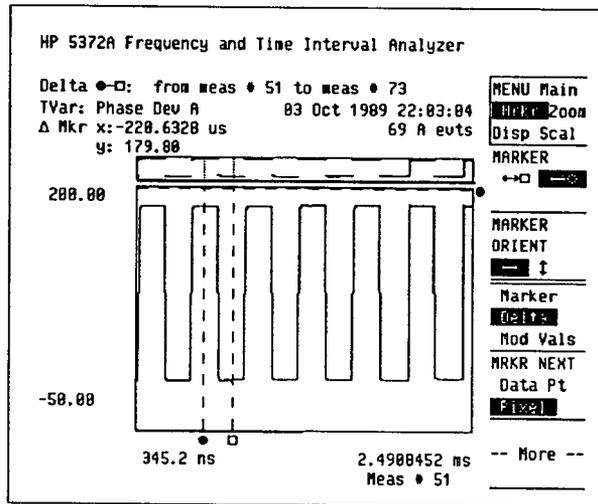

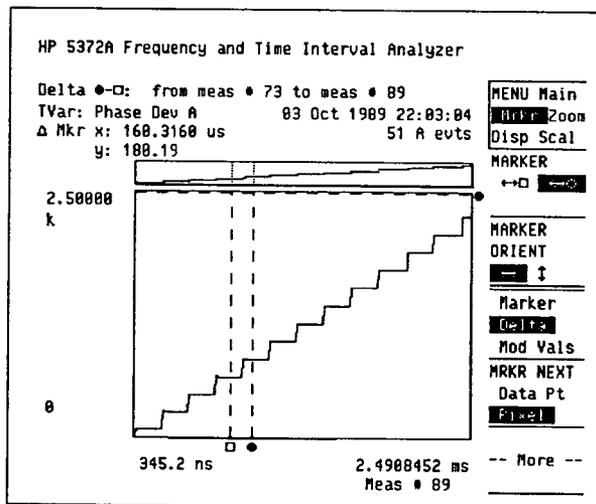*Figure 4a. Modulo 360 phase deviation of a BPSK signal.*

Figure 4b. Cumulative phase deviation of a BPSK signal.

Total Measurement Time

One of the first items to consider before making a measurement is the total measurement time. This is the time over which the BPSK modulation needs to be measured, and is helpful in determining a sampling interval and the number of measurements to be made. Normally, the total measurement time will be determined by the length of a BPSK test pattern or random bit stream. If multiple test patterns or bit streams must be captured, then the total measurement time would increase accordingly.

Sampling Interval and Number of Measurements

Selecting the proper sampling interval and the number of measurements is dependent on the total measurement time, as the equation below shows.

Total Measurement Time = Sampling Interval x Number of Measurements[1]

The range of selectable sampling intervals is 100 ns to 8 seconds in 100 ns increments. Furthermore, up to 8191 measurements can be selected as well. To obtain the best time resolution (horizontal axis), select the shortest sampling interval of 100 ns, provided the equation below holds true.

$$\frac{\text{Total Measurement Time}}{100 \text{ ns}} < 8191 \text{ Measurements}$$

If it does not, then increment the sampling interval by 100 ns until the condition is met.

Another quick way to choose a sampling interval is to select an interval that is 10 to 20 times faster than one cycle of the phase modulation. This will also yield good time resolution. (As a guideline, the sampling interval should be at least 5 times faster.) Once the total measurement time and sampling interval are known, use the equation below to determine the number of measurements to make.

$$\text{Number of Measurements} = \frac{\text{Total Measurement Time}}{\text{Sampling Interval}}$$

Phase Resolution

The single-shot phase resolution of the HP 5372A is given by:

Phase Resolution (LSD) = 200 ps x (Carrier Frequency) x 360 degrees

This relation shows that the lower the carrier frequency, the better the resultant phase resolution. For example, a 500 MHz carrier will yield 36 degrees of phase resolution. If that same signal were downconverted to 10 MHz, the single shot phase resolution would improve to 0.72 degrees.

Carrier Frequency

The HP 5372A will automatically calculate the reference value for the phase deviation measurement. (This is the default condition.) If the reference frequency is already known, it can be manually entered as the carrier frequency . For best results when measuring a BPSK signal, manually enter the carrier frequency value. (Refer to the Appendix for a description of how the carrier is computed automatically in the HP 5372A.)

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[1] When the period of the input signal is greater than the sampling interval, then Total Measurement Time= (period of signal) × Number of Measurements

Adding Math Offset to Modulo 360 Measurements

It may be necessary to use the math offset feature in the MATH menu when viewing results in modulo 360 format on a BPSK signal.

The display range for modulo 360 is from -180 degrees to +180 degrees. If the two phase states of a BPSK modulator fall within this range, then no math offset is necessary. However, many BPSK modulators that alternate between 0 and 180 degrees may have some overshoot, for example at 184 degrees. Because a 184 degree measurement falls outside the modulo 360 range, it would be displayed as -176 degrees. Figure 5 illustrates this "wrap-around" effect. The phase changed from 0 degrees to 180 degrees, but had some overshoot. The (↔ ●) marker shows the overshoot as -176.04 degrees.
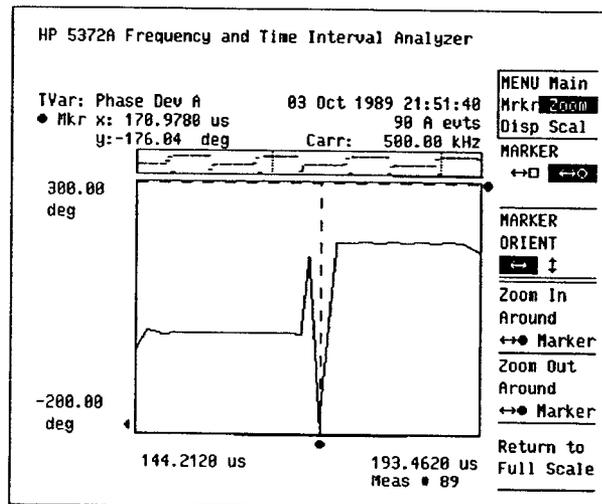

Figure 5. Example display of "wrap-around" effect with modulo 360.

Avoiding this "wrap-around" effect requires using the math offset feature in the MATH menu. Effectively, this changes the modulo 360 range by the amount of the offset. The new modulo 360 range becomes:

Upper Range: +180 degrees - Offset
Lower Range: -180 degrees - Offset

For example, an offset of -10 degrees would change the upper range to +190 degrees and the lower range to -170 degrees.

Input Trigger Conditions

A voltage threshold and slope must be defined in order to tell the HP 5372A how to detect the input signal. The trigger level should be set at the 50% point of the input peak-to-peak voltage. This can be done automatically or manually. For signals between 1 kHz and 200 MHz, the HP 5372A can automatically determine the trigger threshold as a percentage of the peak-to-peak signal amplitude. Also, the threshold can be entered manually as a voltage level.

Arming Modes

The HP 5372A has extremely powerful arming mode selections. These arming modes allow the user to control when to start and stop taking data. A holdoff condition specifies when a block of measurements begin. A sampling condition specifies how each individual measurement within the block is acquired. A combination of holdoff and sampling (hold/sample) conditions can also be specified.

There are four arming modes available for the phase deviation measurement: automatic, edge holdoff, interval sampling and edge/ interval. The automatic and edge holdoff arming modes automatically sample as often as every 100 ns or at the rate of the input signal, whichever is smallest. (A 75 ns measurement rate can be achieved by setting the measurement mode to "fast" in the SYSTEM menu.) The interval sampling and edge/interval arming modes allow the user to select a desired sampling interval between 100 ns and 8 seconds.

The edge holdoff and edge/interval arming modes require a holdoff condition to occur before sampling begins. Either of these arming modes are especially useful for initiating a block of measurements at the beginning of a test pattern or random bit stream of BPSK data. (Consult the HP 5372A Operating Manual for detailed information on these four arming modes.)

Measurement Setup

The typical equipment setup for measuring a BPSK signal with the HP 5372A is simple. Connect the output of the BPSK modulator to the input Channel A or B. If present, an arming signal that is synchronous with the beginning of a test pattern or random bit stream can be connected to the External Arm input of the HP 5372A. If downconversion is necessary, connect the downconverted I.F. to the HP 5372A input channel, as shown in Figure 6.
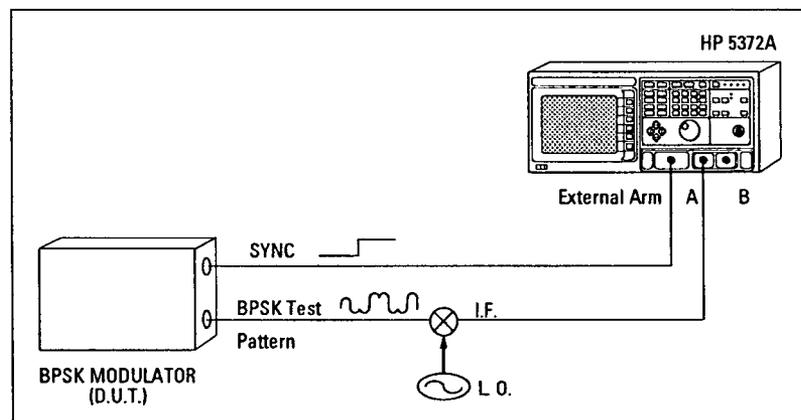

*Figure 6. Typical equipment setup to measure a downconverted BPSK signal.*

In this example, the device under test (D.U.T.) is a BPSK modulator used in a radio communication network. An output test signal with a carrier of 400 MHz is generated. For improved resolution on the phase deviation measurement, the signal is downconverted to 500 kHz with the characteristics listed on the next page.

(A 400 MHz carrier will provide approximately 30 degrees of phase resolution. By downconverting to 500 kHz, the resultant phase resolution improves to approximately 36 millidegrees.)

I.F. carrier: 500 kHz, 1 Vp-p sinewave
Duration of one phase: 25 µs (20 kHz phase modulation rate)
Phase change magnitude: 180 degrees
Test pattern: alternate between digital 1 and 0
Test pattern length: 1.25 ms (50 bits)
Arming signal: synchronous with start of test pattern

The following procedure sets up the HP 5372A to measure phase deviation on the I.F. by capturing one sequence of the test pattern.

Function Menu

⬜
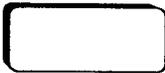
1. Preset

Start by pressing the green **Preset** hardkey. **Preset** places the HP 5372A into a known default state while bringing up the FUNCTION menu. (See Figure 7.) Next press the **Single/Repet** hardkey so that the adjacent green LED is lit. This places the HP 5372A into a single cycle mode so that a single set of measurements are made and held indefinitely, or until **Restart** is pressed.

```
HP 5372A Frequency and Time Interval Analyzer


Time Int A:                         1.997 4 us    Time
                                                  Interval
FUNCTION ─────────────────────────────────────
 Time Interval   Measurement  Channel   A        Continuous
 Acquire         1  block  of      100  meas      Time Intvl
 Pre-trigger Off     Total Meas = 100
                                                  +/- Time
                                                  Interval
 Automatic        Arming Mode ───────────────
 Block Holdoff:
   Arm a block of measurements automatically
                                                  Frequency

 Sample Arm: ─────────────────────────────────
 |Arm sampling on meas channel automatically |   Period
 |                                            |
 |                                            |
 └────────────────────────────────────────────┘  -- More --
```

Figure 7. FUNCTION menu after pressing Preset.

2. Select the Measurement Function

Time Interval will be highlighted in the Measurement field. Press the --**More**-- softkey until **Phase Deviation** is an available softkey selection. Select the **Phase Deviation** softkey to measure the phase deviation on the BPSK signal. Channel **A** will already be selected as the measurement channel with Pre-trigger forced **Off**.
(See Figure 8.)

8

```
HP 5372A Frequency and Time Interval Analyzer

Phase Dev A:                        143.54  deg   Duty Cycle

FUNCTION
  Phase Deviation   Measurement  Channel   A       Phase
  Acquire          1  block  of       100   meas
  Pre-trigger  Off      Total Meas = 100
                                                    Phase
                                                    Deviation
  Automatic        Arming Mode
  Block Holdoff:
     Arm a block of measurements automatically       Time
                                                     Deviation

  Sample Arm:                                        Peak
   Arm sampling on meas channel automatically        Amplitude

                                                     -- More --
```

Figure 8. FUNCTION menu after selecting the phase deviation
measurement.

3. Select the Arming Mode and Sampling Interval

Move the cursor (the highlight) to the Arming Mode field using the
arrow keys. Press the topmost softkey until **Hld/Samp** is high-
lighted. Next select the **Edge/Interval** arming mode. Select the
block holdoff condition such that it reads "After **Pos** edge of **Ext
Arm**". The HP 5372A will holdoff the start of the measurement
until after the positive edge of the external arm input, which is
synchronous with the start of the BPSK test pattern. (See
Figure 9.) If the synchronizing signal is not present, then use the
interval sampling arming mode.


```
HP 5372A Frequency and Time Interval Analyzer

Phase Dev A:                        -8.77  deg   Chan A

FUNCTION
  Phase Deviation   Measurement  Channel   A       Chan B
  Acquire          1  block  of       100   meas
  Pre-trigger  Off      Total Meas = 100
                                                    Ext Arm
  Edge/Interval     Arming Mode
  Block Holdoff:
     After  Pos  edge of  Ext Arm ,
     Arm a block of measurements

  Sample Arm:
   Following the block arming condition,
   Arm sampling on meas channel after
                 10.0 us  intervals

  Acquisition Time/Block = 1.0000 ms
```

Figure 9. FUNCTION menu after selecting Edge/Interval arming mode.

The next field to determine is the interval field, which is where the
sampling interval is entered. The test signal remains at each phase
for 25 µs. This corresponds to a 50 µs phase modulation interval.
From the measurement considerations, a sampling interval of 10 to
20 times faster than the modulation interval yields good time
resolution. In this case, select a sampling interval of 2.5 µs (20
times faster). Move the cursor to the interval field and enter **2.5**
from the front panel keypad, then press the µs softkey.

4. Select the Number of Measurements

The last field to determine in the FUNCTION menu is now the number of measurements to make.

Number of Measurements = Total Measurement Time/Sampling Interval

The total measurement time will be one interval of the test pattern, or 1.25 ms. From the equation above, 1.25 ms/2.5 µs is 500 measurements. Move the cursor up to the number of measurements field and enter "**1** block of **500** meas". (Be sure to press the **Enter** hardkey to complete the numeric entry.) The FUNCTION menu is now set up and should appear as shown in Figure 10.
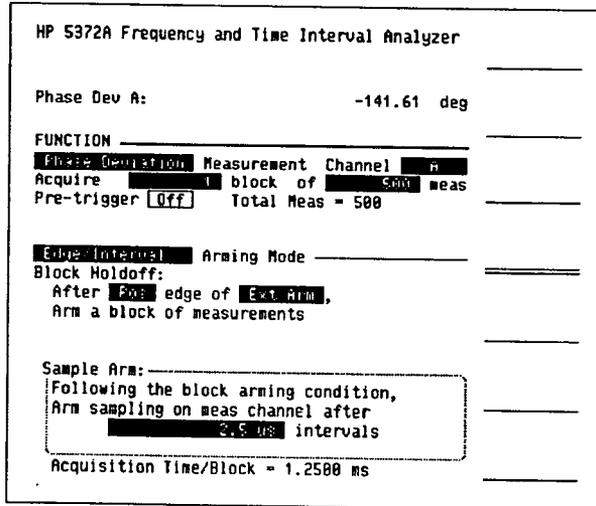
```
HP 5372A Frequency and Time Interval Analyzer


Phase Dev A:                              -141.61  deg

FUNCTION
 Phase Deviation  Measurement  Channel  A
Acquire          1 block of    500  meas
Pre-trigger Off     Total Meas = 500


 Edge Interval   Arming Mode
Block Holdoff:
  After POS edge of Ext Arm ,
  Arm a block of measurements


 Sample Arm:
 Following the block arming condition,
 Arm sampling on meas channel after
                2.5 us  intervals

  Acquisition Time/Block = 1.2500 ms
```

Figure 10. Completed FUNCTION menu setup.

Input Menu
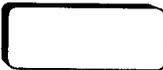
To set the HP 5372A input trigger conditions, press the **Input** hardkey, to display the INPUT menu, as in Figure 11.

```
HP 5372A Frequency and Time Interval Analyzer


Phase Dev A:                    -8.82  deg  Separate

INPUT
 Separate  Input Channels                    Common
Trigger Event:
        Slope   Mode     Level
Chan A: Pos  Sgl Auto   50 %  =  -4 mV
Chan B: Pos  Sgl Auto   50 %  =   0 V
Chan C: POS  MANUAL      0 V
Ext Arm Level     0 V

          Channel A    Channel B    Channel C

Input Pod   HP 54002A    HP 54002A    -----
Impedance    50 Ω         50 Ω        50 Ω
Bias Level    GND          GND         GND
Attenuation   1:1          1:1         0 %
Hysteresis    Min          Min        -----
Max Input    2 V peak     2 V peak    +20 dBm
```

Figure 11. Preset INPUT menu.

5. Set Trigger Thresholds and Slopes

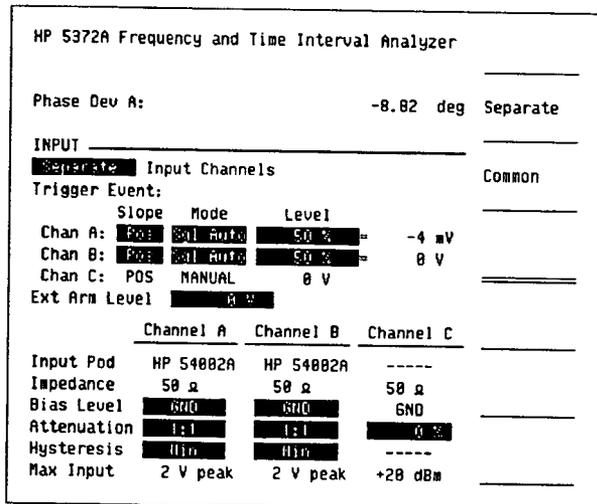This is a single channel measurement, so leave the input channels in **Separate**. Move the cursor down to the Channel A Slope, Mode and Level fields and use the softkeys to enter respectively **Pos**, **Manual Trig.** and **0 V**. (Channels B and C can remain as they are since they will not be used for this particular measurement.) The positive slope selection defines an event on the channel to be a rising edge. **Manual** mode instructs the HP 5372A to use the trigger level set by the level field, in this case, 0 volts. At 500 kHz, both the manual trigger mode or the single auto trigger mode will work.

The External Arm signal from the BPSK modulator is a 1 Vp-p pulse centered about 0 volts, therefore leave **0 V** in the Ext Arm Level field.

Below the trigger fields are setups for the input pods. They should read **GND** for Bias Level, **1:1** for Attenuation, and **Min** for Hysteresis. The INPUT menu is now setup and should appear as in Figure 12.

Figure 12. Completed INPUT menu setup.

Math Menu
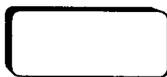
6. Determine the Carrier Frequency

Press the front panel **Math** hardkey to display the MATH menu. It should appear as in Figure 13.

Figure 13. Preset MATH menu.

Move the cursor to the Carrier Frequency column so that **Automatic** is highlighted. Press the softkey **Compute Carrier Manual** to manually enter a carrier value. Move the cursor to the new field below **Manual** and enter the I.F. value of 500 kHz.

Leave the Phase Result field in its default selection of **Modulo 360**. No math offsets are required for the measurement setup. (To compensate for the "wrap around" effect, a math offset can be entered in the MATH menu. This is done by turning the math field **ON** for the selected measurement channel, then by entering the offset in the Offset field.) The final MATH menu setup is shown in Figure 14.
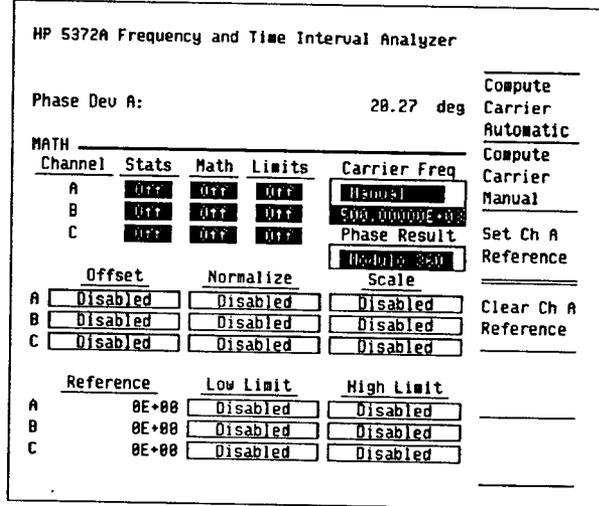
Figure 14. Completed MATH menu setup.

Measurement Results

This section of the note will guide you through various HP 5372A analysis features for characterizing the BPSK signal.

The HP 5372A is now set up to measure and analyze the BPSK signal. Press the front panel **Restart** hardkey to initiate a new block of 500 measurements. The adjacent GATE LED should momentarily flash indicating that measurements are being made.

Graphic Results

Press the **Graphic** results hardkey. The topmost softkey is the **MENU** softkey. There are five menus: the Main **(Main)** menu, the Marker **(Mrkr)** menu, the Zoom **(Zoom)** menu, the Display **(Disp)** menu and the Scale **(Scal)** menu. Press the topmost softkey 5 times to skim through the menus. Notice the softkey options below are different for each menu. Where a softkey option presents more than one option, the currently active choice is shown in inverse video. Pressing the softkey will cause the next option to become active.

1. Using the Main Menu to Display the Time Variation Graph

The current graph displayed is the histogram, which is not useful for this measurement. With **MENU** set to **Main**, select the Time Variation graph by pressing the second softkey from the top until **Time Var** is highlighted. This will initiate a new graph display of phase deviation versus time. Figure 15 shows a plot of the 500 phase deviation measurements versus time.
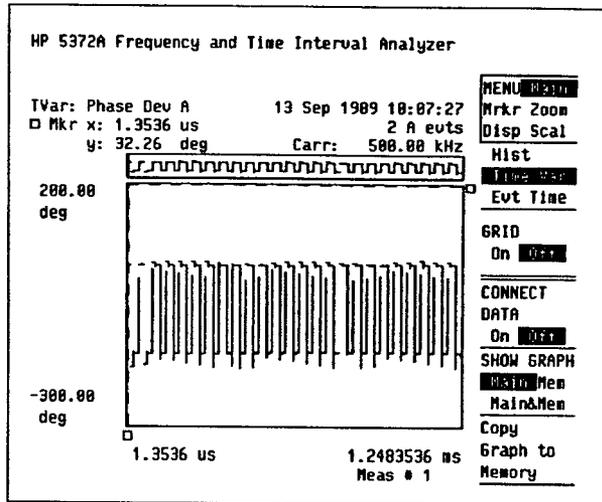
Figure 15. Time Variation graph shows phase deviation versus time.

With **MENU** still set to **Main,** press the **CONNECT DATA On/Off**
softkey so that **On** is highlighted. **CONNECT DATA On** enables a
connect-the-dots display of the measurement data. Lines are drawn
on the display to connect each pair of consecutive data points. No
interpolation is done. (See Figure 16.)
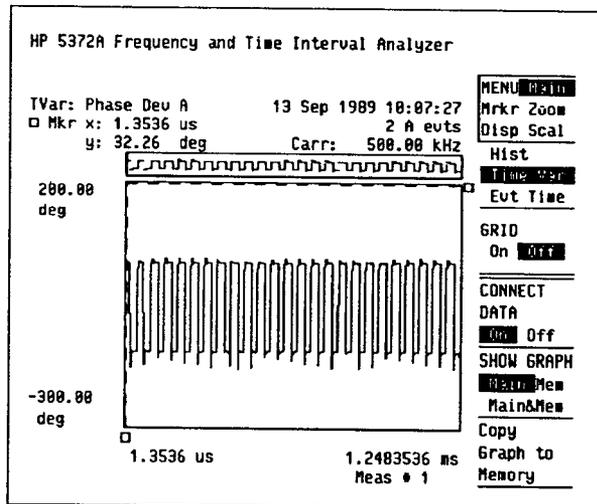
*Figure 16. Phase deviation versus time with CONNECT DATA On
selected.*

Other features in the **Main** menu are: adding grid lines to the dis-
play, copying a graph to memory, and displaying a graph from
memory.

2. Using the Markers to Measure Phase Change Magnitude and Timing

Select the Marker menu by pressing the top softkey so that **Mrkr** is highlighted. A new set of softkeys below the Menu softkey appears. There are two ⟷ markers that move along the x-axis and two ↕ markers that move along the y-axis. The ↕ and ⟷ markers can be activated by the **MARKER ORIENT** softkey.

3. The ⟷ Markers

The ⟷ □ marker should already be the active marker. The other ⟷ marker is ⟷ ●. Rotate the front panel **ENTRY/MARKER** knob to move the ⟷ □ marker along the time axis. Notice that the (x,y) values in the upper left corner of the display correspond to the marker location. As expected, approximately 1.25 ms of data was captured. Furthermore, the phase modulation is a square wave alternating, in this case, between 32 degrees and -148 degrees with occasional overshoot and undershoot. Figure 17 shows the ⟷ □ marker at approximately 661 μs in time with 31.79 degrees of phase deviation from the carrier. The phase resolution is approximately 36 millidegrees, which agrees with the earlier estimates. Continuing along the x-axis, the 50 individual phases (bits) captured in this test pattern can be counted.
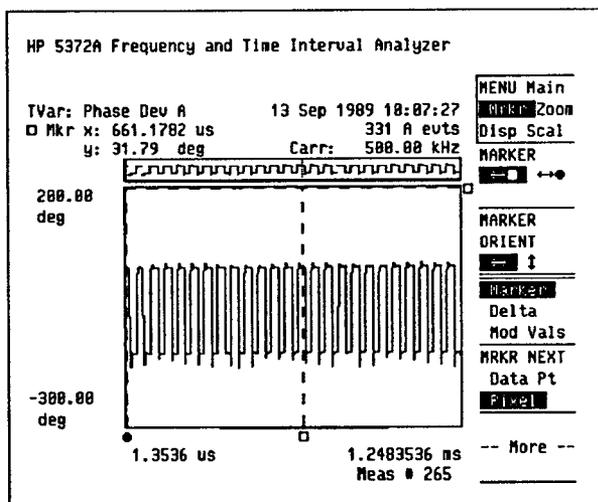
Figure 17. ⟷ □ *marker at (x,y) coordinates (661.1782 μs, 31.79 deg).*

Next, use the ⟷ ● marker and the **Delta** marker mode to verify the phase modulation interval of 50 μs. The **Delta** marker mode displays the difference in position of the two markers. First, activate the ⟷ ● marker. Move the ⟷ ● marker to within one period away from the ⟷ □ marker. Next, press the fourth softkey from the top so that **Delta** is highlighted. The top left display now shows the △ **Mkr x** and △ **Mkr y** coordinates. In Figure 18, the △ **Mkr x** and △ **Mkr y** coordinates indicate a phase modulation interval of approximately 50 μs.

```
HP 5372A Frequency and Time Interval Analyzer

Delta ●-□:  from meas ● 265 to meas ● 285        MENU Main
TVar: Phase Dev A          13 Sep 1989 18:87:27   ████ Zoom
Δ Mkr x: 49.9996 us                  27 A euts    Disp Scal
       y: 38 mdeg                                 MARKER
                                                   ↔□  ███
  200.88
  deg                                             MARKER
                                                  ORIENT
                                                  ███  ↕
                                                  Marker
                                                  █████
                                                  Mod Vals
                                                  MRKR NEXT
                                                  Data Pt
  -388.88                                         █████
  deg
                                                  -- More --
        1.3536 us           1.2483536 ms
                            Meas ● 285
```
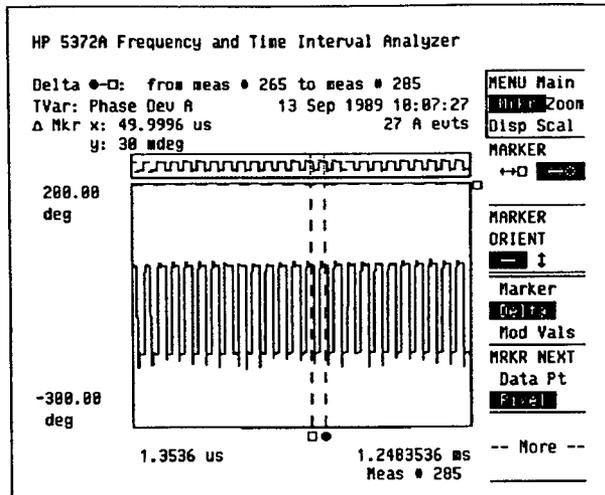
*Figure 18. **Delta** ● - □ marker indicates phase modulation interval of 49.9996 µs.*

4. The ↕ Markers

The ↕ markers can be used to verify the general magnitude of phase change on the carrier across the entire test pattern. Activate the ↕ markers so that **MARKER ORIENT** ↕ is highlighted. Rotate the **ENTRY/ MARKER** knob to move the ↕● marker so that it is level with the digital zero phase states. Next, activate the ↕□ marker and move it so that it is level with the digital one phase states. With the **Delta** marker mode still activated, observe in the top left corner the general size of phase change between the two digital states for all 500 measurements. Figure 19 shows a △ **Mkr y** of 180.56 degrees.

```
HP 5372A Frequency and Time Interval Analyzer

                                                  MENU Main
TVar: Phase Dev A          13 Sep 1989 18:87:27   ████ Zoom
Δ Mkr y: 188.56  deg                              Disp Scal
                                                  MARKER
                                                   ██  ↕●
  288.88
  deg                                             MARKER
                                                  ORIENT
                                                  ↔  ██
                                                  Marker
                                                  █████
                                                  Mod N/A
                                                  MRKR NEXT
                                                  Not Avail
  -388.88
  deg
                                                  -- More --
        1.3536 us           1.2483536 ms
```

Figure 19. Delta ↕ marker indicates overall phase change size of 180.56 degrees.

Cycle the --**More**-- softkey to observe the other softkey selections in the Marker menu.

5. Using the Zoom Menu to Characterize Individual Phase States

Select the **Zoom** menu by highlighting **Zoom** on the **MENU** softkey. The features in the **Zoom** menu make it possible to magnify a portion of the graph to examine an individual phase change. You will zoom-in to examine one cycle of phase modulation, and then zoom-in further to one individual phase change with overshoot.

First, notice that all four markers can be activated from the **Zoom**-menu without having to go back to the **Mrkr** menu. There are two softkeys that allow you to zoom-in and zoom-out around the "active" marker. You can magnify the graph horizontally, as well as vertically.

Activate the ↤ markers, then select the ↤□ marker and move it to a portion of the test pattern where there appears to be an overshoot. Move the ↤● marker on top of the ↤□ marker as shown in Figure 20.

```
HP 5372A Frequency and Time Interval Analyzer

Delta ●-□:  both markers on meas # 261      MENU Main
TVar: Phase Dev A           13 Sep 1989 10:07:27   Mrkr Zoom
Δ Mkr x: 0  s                        1 A evt   Disp Scal
        y: 0  deg
                                               MARKER
                                               ↤□  ↤○
200.00
deg
                                               MARKER
                                               ORIENT
                                               ↤  ↕

                                               Zoom In
                                               Around
                                               ↤● Marker
                                               Zoom Out
-300.00                                        Around
deg                                            ↤● Marker

                                               Return to
    1.3536 us         1.2483536 ms   Full Scale
                      Meas # 261
```
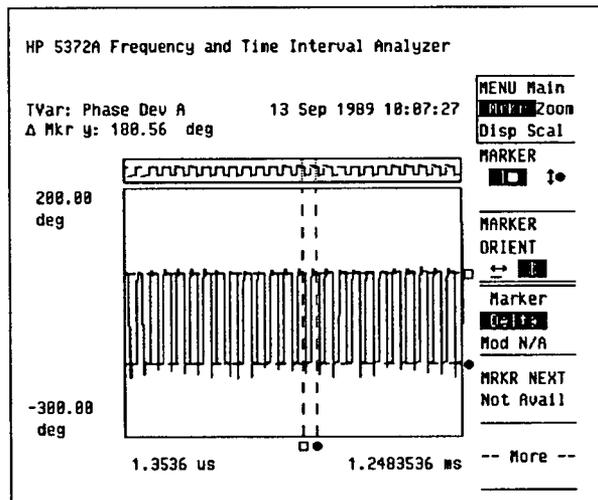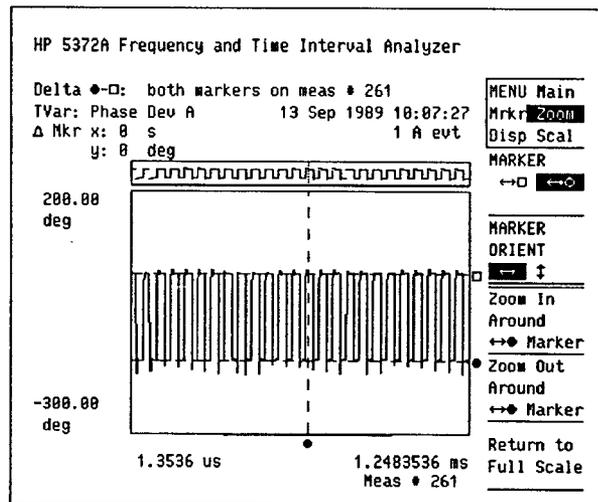
Figure 20. The two ↤ markers near an overshoot.

Use the **Zoom-in** softkey to zoom-in until roughly one cycle of the phase modulation is displayed as shown in Figure 21. Notice the panorama graph at the top. This shows all of the data collected, and is useful when zooming in on a portion of the graph. By observing the highlighted bar under the graph, the position of the results on the display can be determined within the entire block of data.
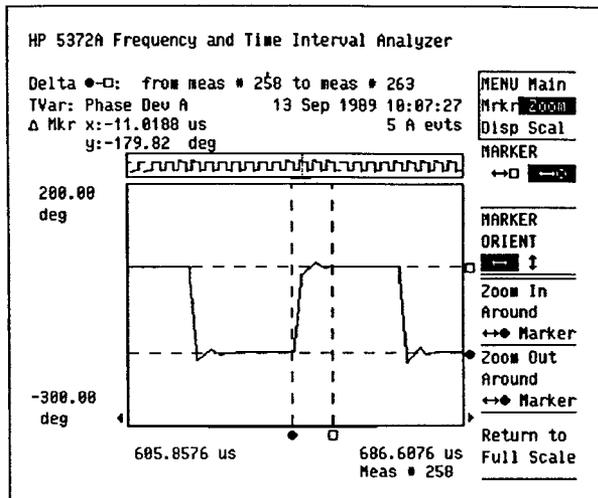
```
HP 5372A Frequency and Time Interval Analyzer

Delta ●-□:  from meas # 258 to meas # 263        MENU Main
TVar: Phase Dev A          13 Sep 1989 10:07:27  Mrkr Zoom
Δ Mkr x:-11.0188 us                    5 A evts   Disp Scal
      y:-179.82 deg                                MARKER
                                                   ↔□ ↔□
 200.00
 deg
                                                   MARKER
                                                   ORIENT
                                                   ↔  ↕
                                                   Zoom In
                                                   Around
                                                   ↔● Marker
                                                   Zoom Out
                                                   Around
 -300.00                                           ↔● Marker
 deg
                                                   Return to
      605.8576 us            686.6076 us  Full Scale
                             Meas # 258
```

Figure 21. One cycle of zoomed-in phase modulation.

Position the two ↔ markers to measure the duration of one digital zero phase. With **Delta** marker mode still activated from the Marker menu, notice in Figure 22 that the duration is 22.9994 μs.
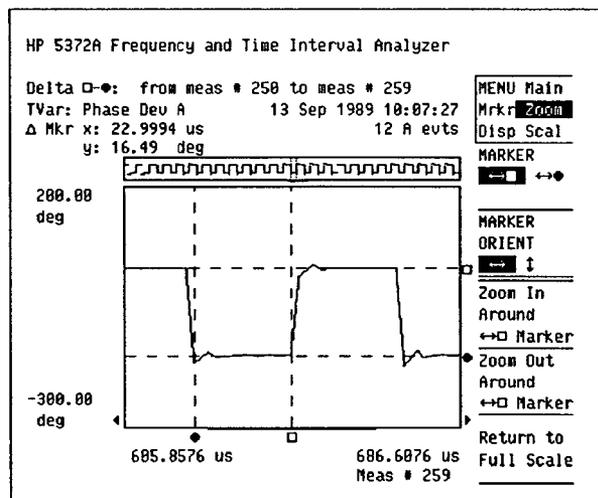
```
HP 5372A Frequency and Time Interval Analyzer

Delta □-●:  from meas # 258 to meas # 259        MENU Main
TVar: Phase Dev A          13 Sep 1989 10:07:27  Mrkr Zoom
Δ Mkr x: 22.9994 us                   12 A evts   Disp Scal
      y: 16.49 deg                                MARKER
                                                   ↔□ ↔●
 200.00
 deg
                                                   MARKER
                                                   ORIENT
                                                   ↔  ↕
                                                   Zoom In
                                                   Around
                                                   ↔□ Marker
                                                   Zoom Out
                                                   Around
 -300.00                                           ↔□ Marker
 deg
                                                   Return to
      605.8576 us            686.6076 us  Full Scale
                             Meas # 259
```

Figure 22. Digital zero phase duration is less than the desired 25 μs.

If desired, the ↔ markers can also be positioned to measure the digital one phase duration.

Next, you will use the ↕ markers to examine the magnitude of phase change. Activate the ↕ markers and position them as shown in Figure 23. In this case, the magnitude of phase change is 177.78 degrees.
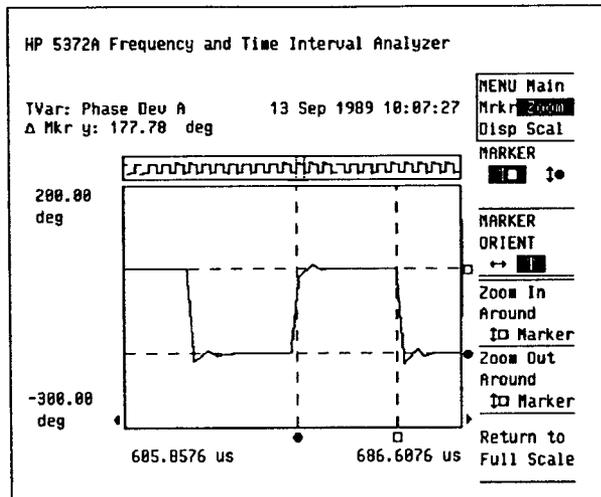
Figure 23. *An individual phase change of 177.78 degrees.*

Activate the ↦● marker and center it about the overshoot. Zoom-in to see a magnified view of the overshoot. Three tasks can be done to gain a clearer picture of this overshoot. First, move the ↧ markers to the top of the graph. (Be sure to re-activate the ↦● marker.) Second, go back to the **Main** menu and select the **CONNECT DATA Off** softkey to view only the individual phase measurements. Lastly, with **MENU** set to **Mrkr**, find the **Move ↦□ to ↦● location** softkey and press it. This will bring the ↦□ marker back into the displayed portion of the graph right on top of the ↦● marker. (The ↦□ marker may already be in the zoomed-in portion of the graph.) (See Figure 24.)
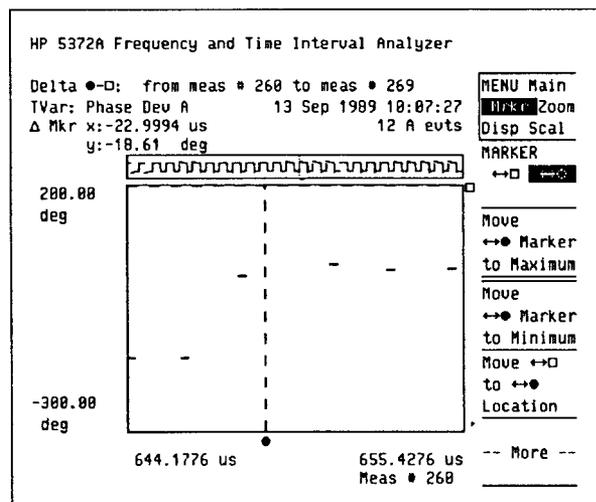
Figure 24. *Using the Move ↦□ to ↦● Location softkey in the Mrkr menu.*

Position the ↦● marker at the beginning of the overshoot, and the ↦□ marker at the peak of the overshoot. Figure 25 provides a clear view of this overshoot and the size is indicated at the top left, in this case, 188.13 degrees.
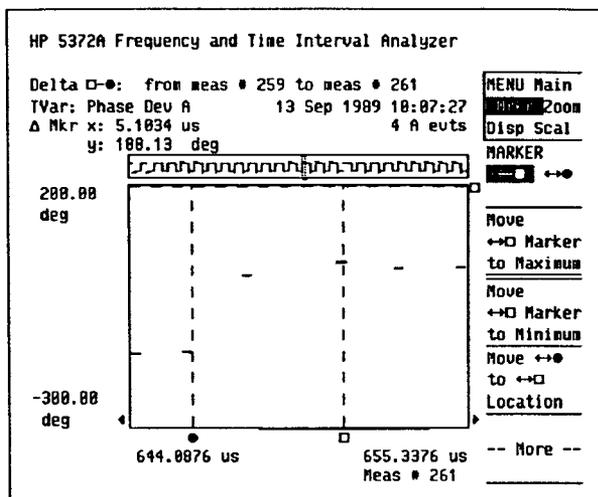
18

```
HP 5372A Frequency and Time Interval Analyzer

Delta □-●:  from meas ● 259 to meas ● 261      MENU Main
TVar: Phase Dev A          13 Sep 1989 10:07:27  █████Zoom
Δ Mkr x: 5.1034 us                   4 A evts    Disp Scal
        y: 188.13 deg                            MARKER
                                                 ██─■ ↔●
200.00
deg                                              Move
                                                 ↔□ Marker
                                                 to Maximum

                                                 Move
                                                 ↔□ Marker
                                                 to Minimum

                                                 Move ↔●
                                                 to ↔□
-300.00                                          Location
deg
        644.0076 us      655.3376 us             -- More --
                         Meas ● 261
```

Figure 25. Examining overshoot on an individual phase change.

6. Phase Result Cumulative

Take a brief look at the same 500 measurements in the cumulative format. To do this, press the **Math** hardkey and move the cursor to the Phase Result field. Select the **Phase Result Cumulative** softkey. The 500 phase deviation measurements will now start at 0 degrees and accumulate. Press the **Graphic** hardkey to view the "stair-step". If the phase modulation were perfect, the "stair-step" would always climb. Figure 26 reveals that the phase modulation is not perfect as indicated by the climbing and falling of the "stair-step".
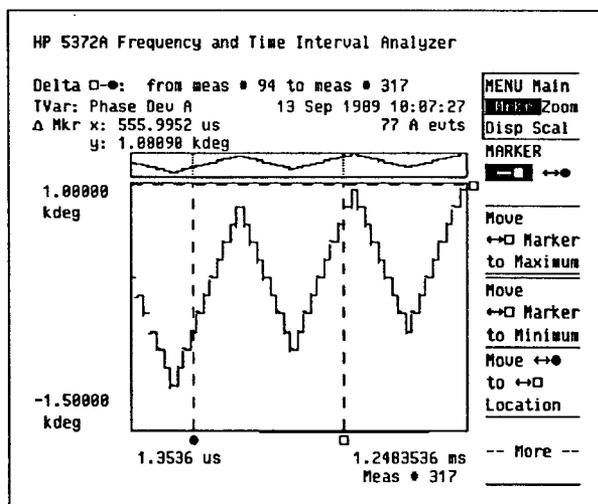


```
HP 5372A Frequency and Time Interval Analyzer

Delta □-●:  from meas ● 94 to meas ● 317       MENU Main
TVar: Phase Dev A          13 Sep 1989 10:07:27  █████Zoom
Δ Mkr x: 555.9952 us                 77 A evts   Disp Scal
        y: 1.88098 kdeg                          MARKER
                                                 ██─■ ↔●
1.00000
kdeg                                             Move
                                                 ↔□ Marker
                                                 to Maximum

                                                 Move
                                                 ↔□ Marker
                                                 to Minimum

                                                 Move ↔●
                                                 to ↔□
-1.50000                                         Location
kdeg
        1.3536 us       1.2483536 ms             -- More --
                        Meas ● 317
```

Figure 26. Phase deviation versus time in cumulative format.

Numeric Results

Press the front panel **Numeric** hardkey to individually display each phase deviation measurement. (See Figure 27.) The carrier frequency value is shown at the top of the display. Notice that at measurement number 11, the phase changed by roughly 180 degrees from 30.78 degrees (meas 9) to -148.75 degrees, with some overshoot at measurement number 10.
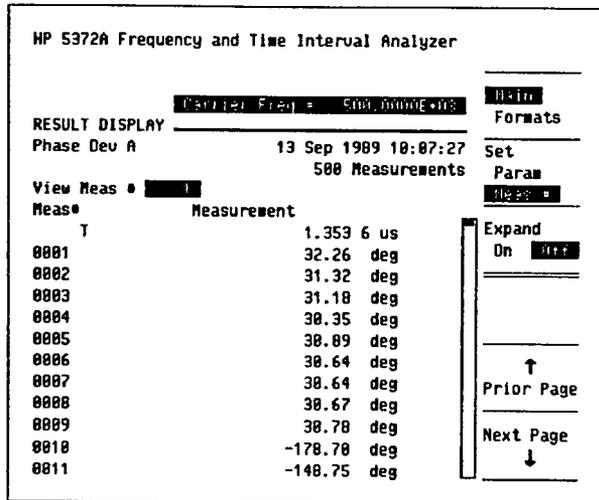
```
HP 5372A Frequency and Time Interval Analyzer


                          Carrier Freq =    500.0000E+03      Main
          RESULT DISPLAY                                     Formats
          Phase Dev A                     13 Sep 1989 10:07:27  Set
                                             500 Measurements   Param
          View Meas #    1                                   Meas #
          Meas#           Measurement
             T                          1.353 6 us           Expand
          0001                         32.26   deg           On   Off
          0002                         31.32   deg
          0003                         31.18   deg
          0004                         30.35   deg
          0005                         30.89   deg
          0006                         30.64   deg
          0007                         30.64   deg              ↑
          0008                         30.67   deg           Prior Page
          0009                         30.78   deg
          0010                        -178.78  deg           Next Page
          0011                        -148.75  deg              ↓
```

Figure 27. The Numeric display.

Selecting the **Expand On** softkey will show the gate time for each individual measurement.

HP 5372A Advantages

- Obtain excellent phase and timing resolution.

- Measurement configuration is simplified because no coherent reference is required to characterize the BPSK signal.

- Phase deviation results can be analyzed graphically or numerically.

- Phase versus time can be viewed directly in modulo 360 or cumulative format.

- Graph analysis features such as flexible zoom and marker options allow for complete characterization of the BPSK signal, i.e. phase change size, phase modulation rate, overshoot and undershoot.

- The HP 5372A offers a wide range of selectable sampling intervals for demodulating various phase modulation rates.

- Flexible arming modes control when sampling begins, for example at the beginning of a test pattern.

- HP 5372A provides single-shot capture so that repetitive bit streams and test patterns are not required.

For Further Information

For further information on characterizing phase modulated signals with the HP 5372A, refer to Application Note 358-10, Characterizing Barker Coded Modulation in Radar Systems, (5952-8005).

For additional general information on the HP 5372A, consult the following:

HP 5372A Data Sheet/Brochure (5952-7997)

HP 5372A Getting Started Guide (5952-8009)

HP 5372A Operating Manual (05372-90001)

Appendix

How phase deviation is computed in the HP 5372A.

The HP 5372A functions like an instantaneous phase digitizer. At user-specified sampling intervals, the HP 5372A detects the instantaneous phase of a signal relative to a starting phase. It does this by totalizing the number of events (or slope sensitive level-crossings), each of which represents a phase addition of 2π, and recording the exact time at which the totalize measurement is made. By saving the changing phase information in internal memory, the HP 5372A effectively captures the phase changes on a carrier.

Plotting these events as a function of time, and scaling them by 2π reveals a phase progression plot (cumulative phase versus time). A constant unmodulated carrier results in a straight line of positive slope equal to its frequency as shown in Figure A. (Frequency is the derivative of phase.)
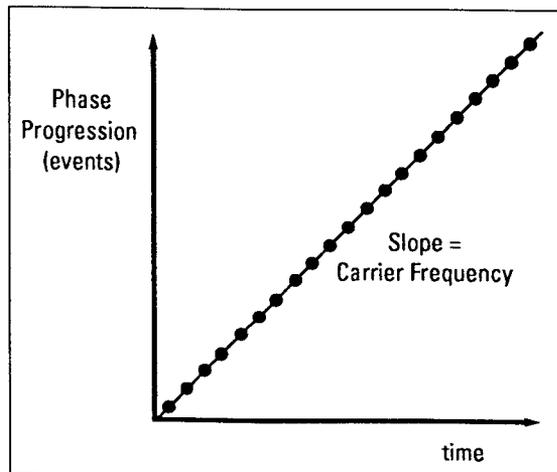
Figure A. Phase progression plot of unmodulated carrier.

Phase modulation is measured as the phase deviation of the signal from the constant carrier or deviation from the straight line as shown in Figures B and C.
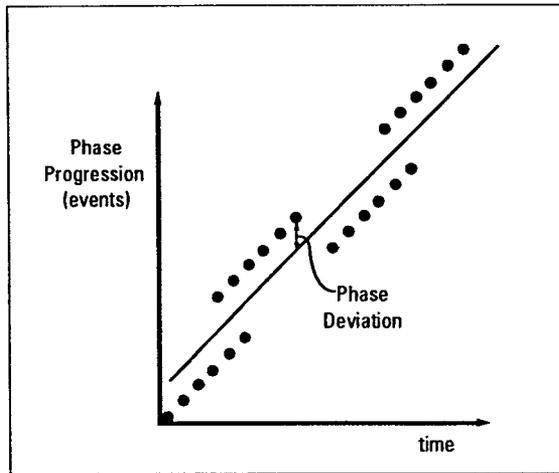

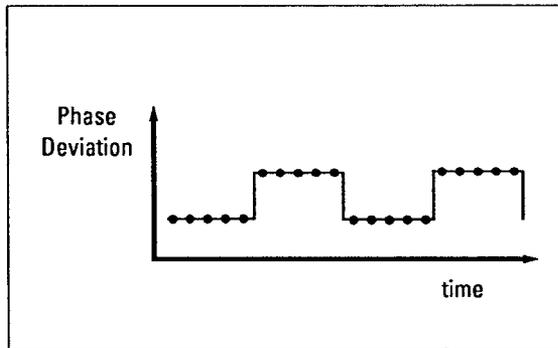*Figure B. Phase progression plot of phase modulated carrier.*

Figure C. Phase deviation plot shows phase modulation.

How the carrier is computed automatically in the HP 5372A.

When Automatic carrier is selected, the expected frequency (slope) is estimated by the HP 5372A from the input signal. The estimation method is called the bi-centroid mean. (See Figure D.) It is close in precision to a least squares fit, and significantly faster to perform.
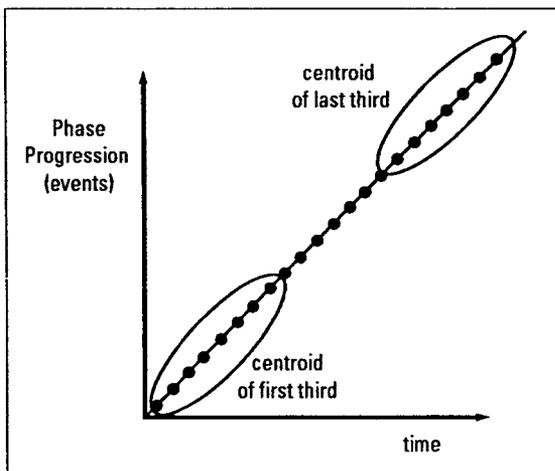

Figure D. Carrier frequency is automatically computed using a bi-centroid mean.

In the case of the example used in this note, the carrier will not be computed correctly unless the phase modulation on the signal is exactly symmetrical. If the carrier is not the correct frequency, a phase deviation plot that looks crooked (has a constant slope) will result. (See Figure E.)
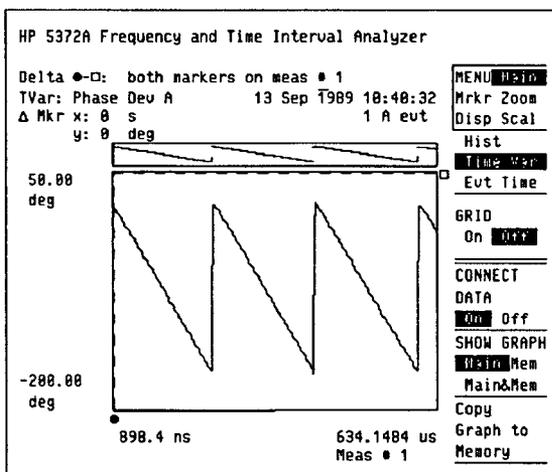

Figure E. Incorrect carrier results in a crooked phase deviation plot.

When measuring square wave phase modulated signals, it is generally better to manually enter the carrier because it is difficult to obtain exactly symmetrical modulation.

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U.K.:
(0734) 777 828

Middle East and Africa:
Geneva-Switzerland
41/22 780 7111

European Headquarters
Hewlett-Packard S.A.
150, Route du Nant d'Avril
1217 Meyrin 2
Geneva--Switzerland
41/22 780 8111

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