Characterization of Frequency Agile Sources

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RF & Microwave Measurement Symposium and Exhibition

HEWLETT PACKARD

ABSTRACT:

This paper describes techniques for testing fast-switching frequency-agile sources, such as frequency hopping radios and synthesizers. Using the new HP 5371A Frequency and Time Interval Analyzer, dynamic, at-speed testing of these devices is now possible. Single-pass characterization techniques for five important device parameters will be discussed; 1) hopping sequency analysis, 2) switching transient analysis, 3) settling time verification, 4) hopping frequency distribution, and 5) carrier modulation analysis.

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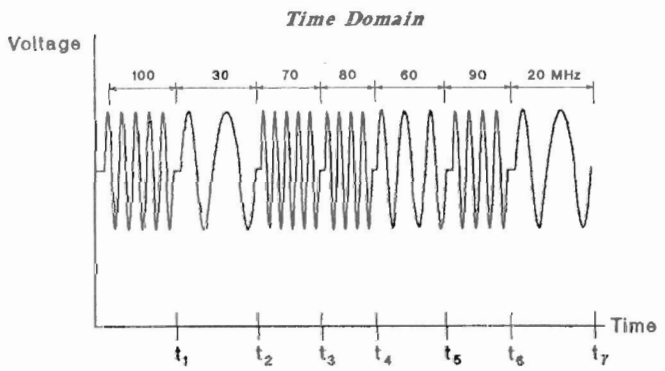
This paper will cover new techniques and tools for characterizing frequency-agile source parameters that were previously difficult or impossible to quantify.

Agile Carrier



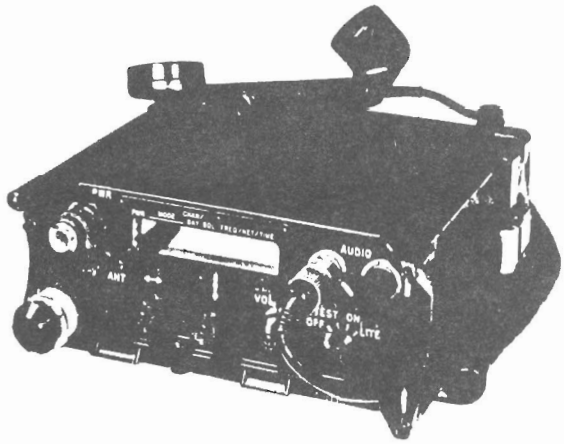
For the purposes of this paper, a frequency-agile source will be defined as a source that changes its output frequency in a serial way with time. An example is a VCO that is driven by a series of voltage steps.

Where Used

- Radios
- Radar
- Satcom

Frequency-agile sources find application in radios, radars, and satellite communications as carriers. They are primarily used for security, anti-jamming, or transmission clarity reasons.

Since the operation and testing of these sources is fundamentally the same in all three applications, the Rockwell International MP-83 frequency hopping radio will be used as the illustrative example. This radio is similar in operation to the SINCGARS and JTIDS radios.

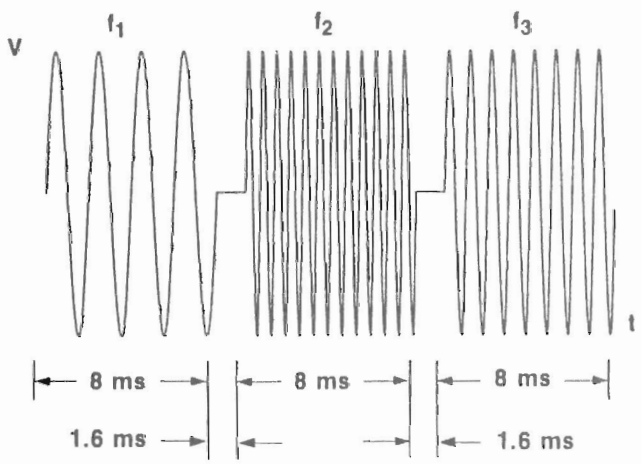


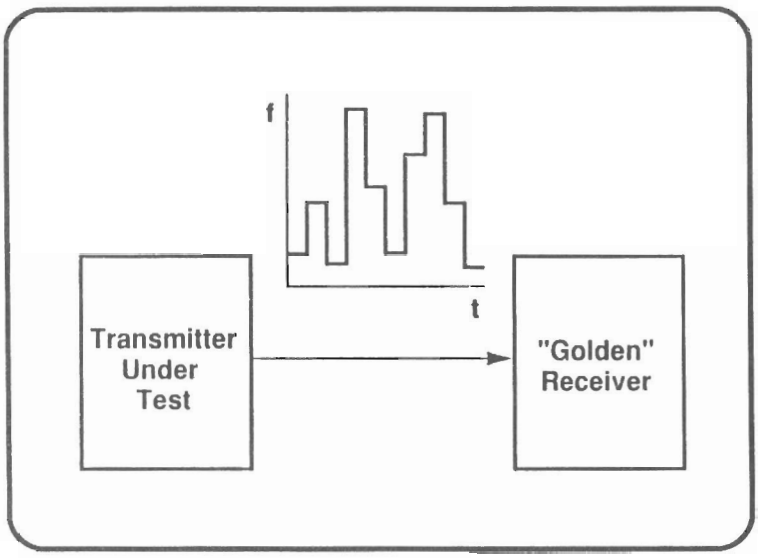
Photograph Courtesy Rockwell International

The specifications for the MP-83 are as shown.

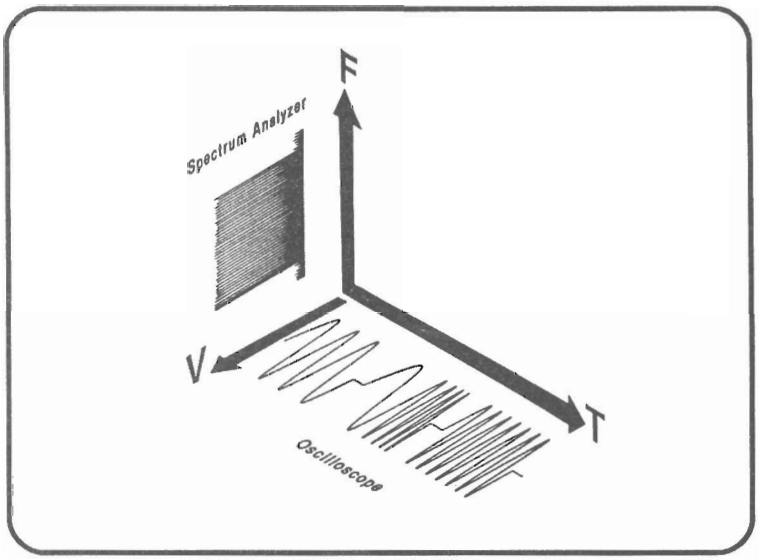
Frequency Range: 30 - 87.975 MHz
Channel Spacing: 25 kHz
Hopping Rate: 9.6 ms per hop
Settling Time: 1.6 ms
Modulation Modes: FM voice or 20 kb/s data
Modulation Deviation: ±7 kHz (FM voice and FSK data)

Graphically the specifications look like this. Information is transmitted during the 8 ms "dwell" time and frequency "hops" take place during the 1.6 ms transition and settling time. With current test equipment, verification of the radio's specifications is difficult at best.

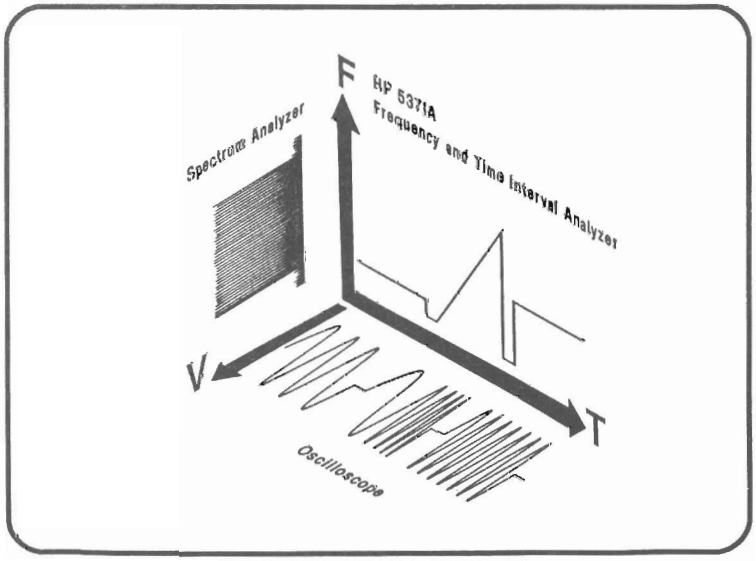




The only practical test procedure currently available is the "back-to-back" method employing a "golden" receiver. This method suffers from reliability, maintainability, and vendor-to-vendor compatibility problems.

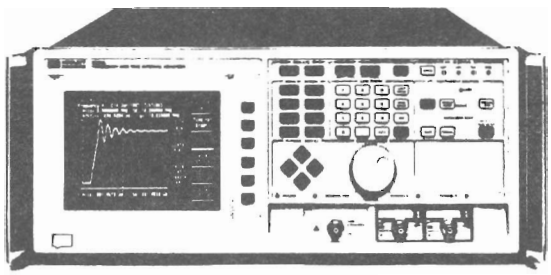


Time domain and frequency domain instruments are not well suited for the analysis of frequency-agile sources as they don't supply the needed information directly. It is difficult to analyze frequency transitions using an oscilloscope, and a spectrum analyzer does not provide a time record of events.

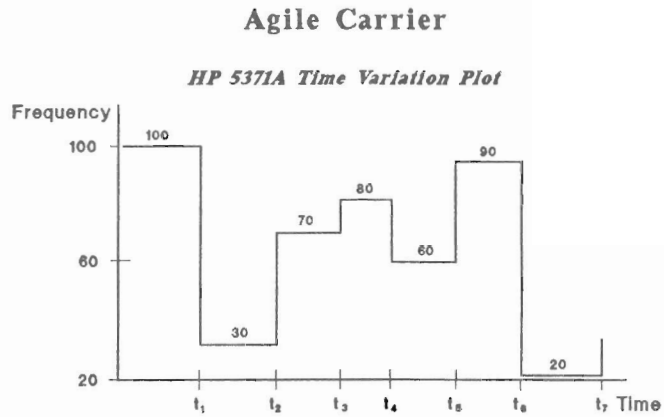


What is needed is an instrument that views the signal as frequency values versus time.

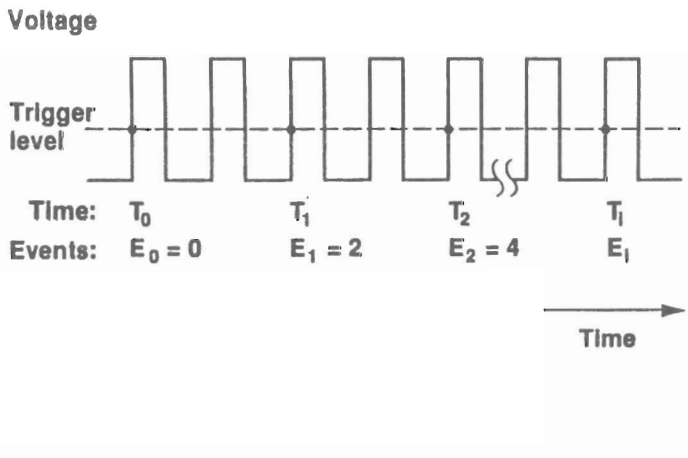
The new HP 5371A Frequency and Time Interval Analyzer does exactly that.

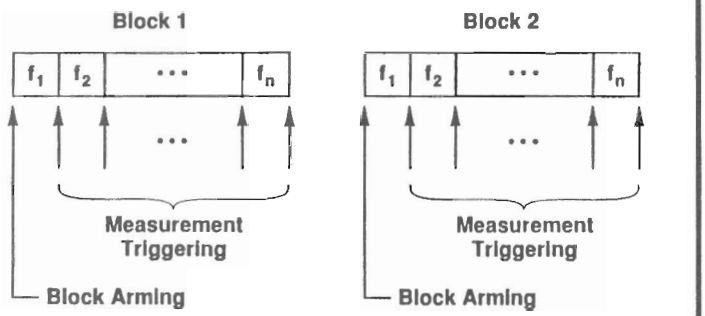


Now the radio's specifications can be verified directly, at full operating speed, and in one pass.

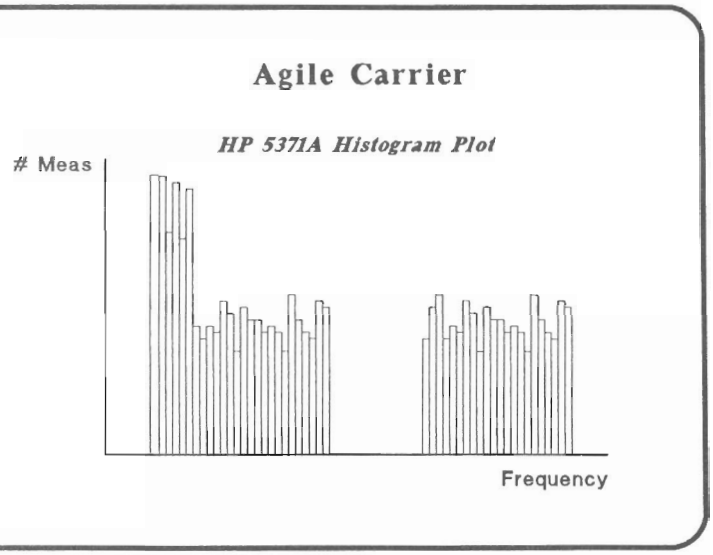


The HP 5371A does this by taking a new approach to frequency measurements. The event and time data is taken continuously with no dead time between measurements. After the measurement series is finished, the data is processed and displayed.

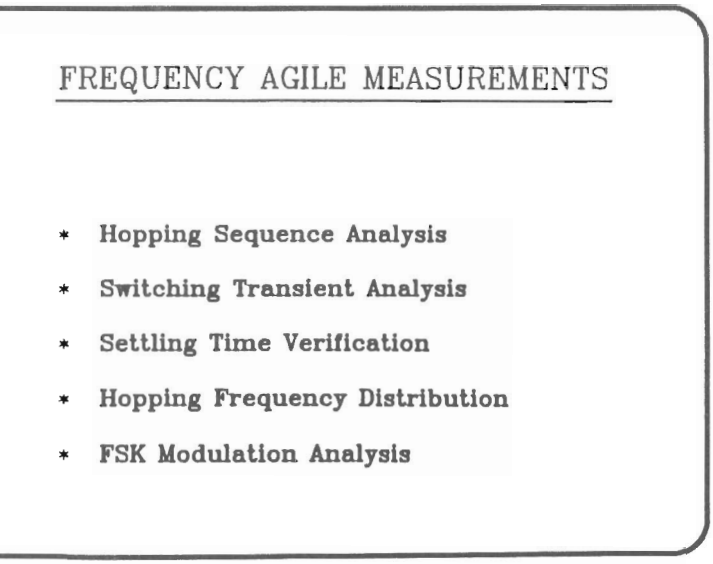




These measurements are made in blocks of up to 1000 measurements at a time, or 4095 measurements if an external controller is used. Both the block and the individual measurement timing are under the user's control.



Not only can the frequency measurements be looked at versus time, but a measurement histogram is also available. This provides the important anti-jamming information of how the radio is using its available spectrum.

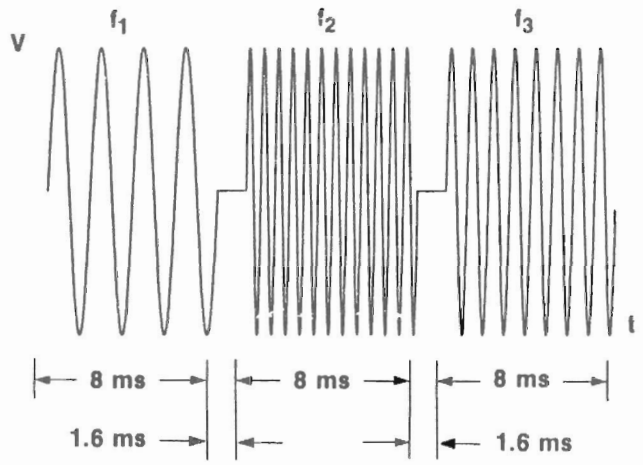


Now that we have a feel for the HP 5371A's general capabilities, let's look at five specific tests that can be made on a frequency-agile source. The transmitter portion of the MP-83 frequency-hopping radio will be the example.

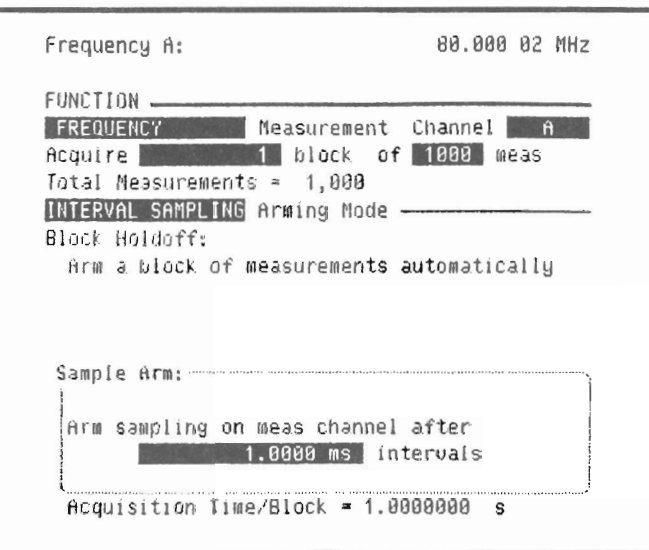
The first thing to look for is how the carrier frequency is behaving with time.

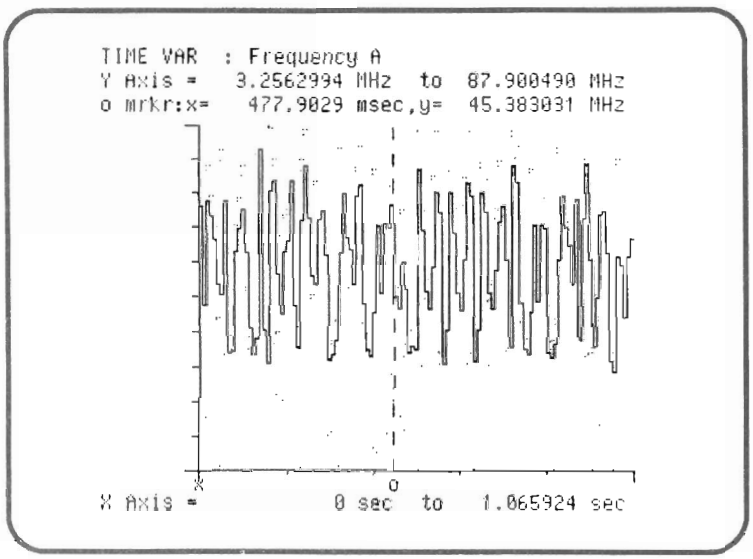
HOPPING SEQUENCE ANALYSIS

The signal looks like this in the time domain. It changes frequency every 9.6 ms and for security and anti-jamming reasons, it is important that the hopping pattern be pseudorandom.

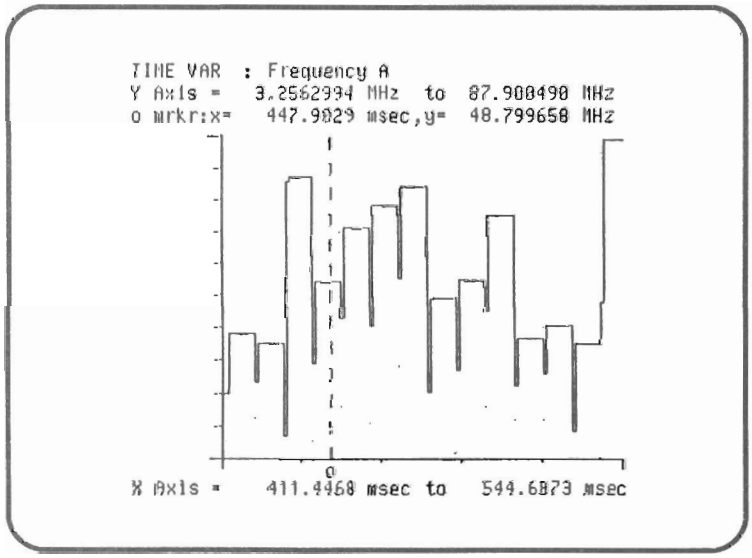


A block of 1000 back-to-back frequency measurements will be made with an integration time, or gate time, of 1 ms.

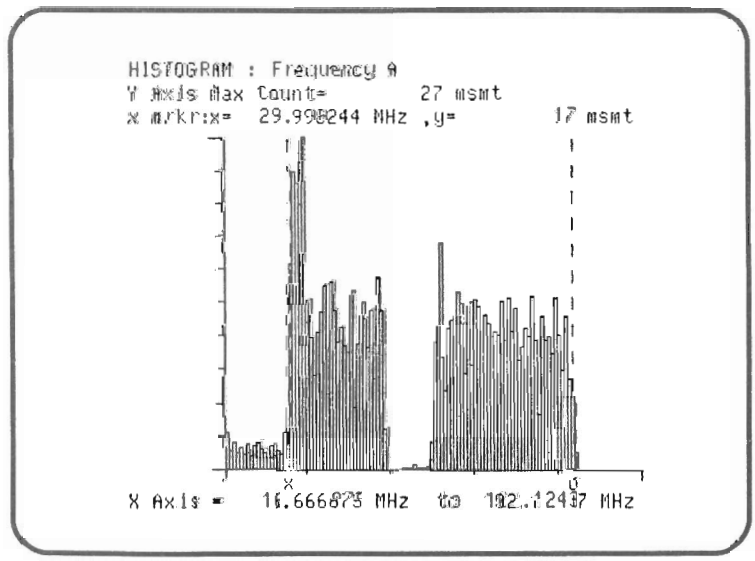




In one pass, the HP 5371A reveals 1 second of the radio's hopping scheme for analysis. This, of course, could also be very useful information when trying to identify or jam someone else's hopping radio.



A closer look is provided with the HP 5371A's zoom feature. The marker can be used to further analyze the hopping characteristics. Since the measurements are continuous, the transition frequencies are also shown.

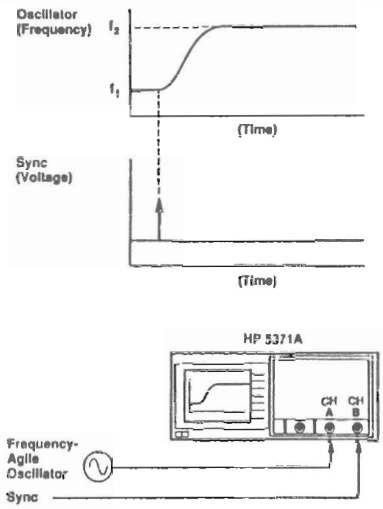


This information can then be rearranged to show the spectrum usage of the radio over the measurement period. Information also of great value in ECM work. Again the transition frequencies are shown.

Next, the HP 5371A will be used for a closer examination of an individual frequency hop.

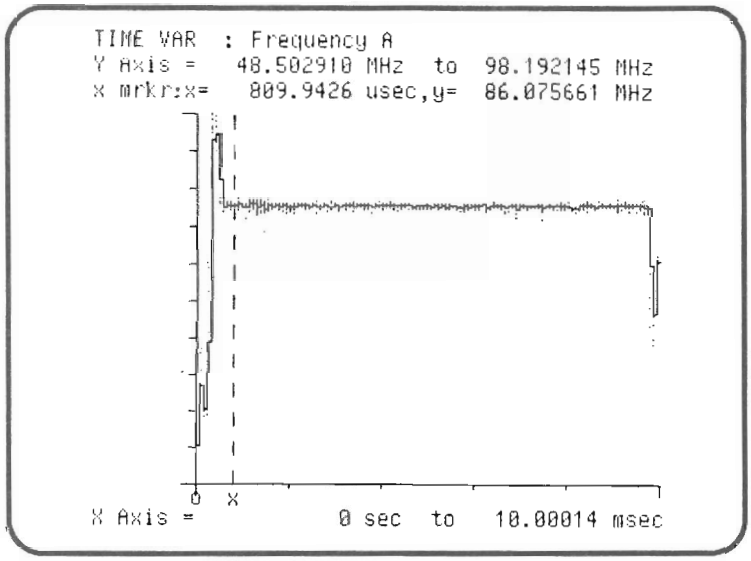
SWITCHING TRANSIENT ANALYSIS

Here, the radio's sync signal will be used to start the block of frequency measurements. The step response of a VCO can be analyzed in the same way.

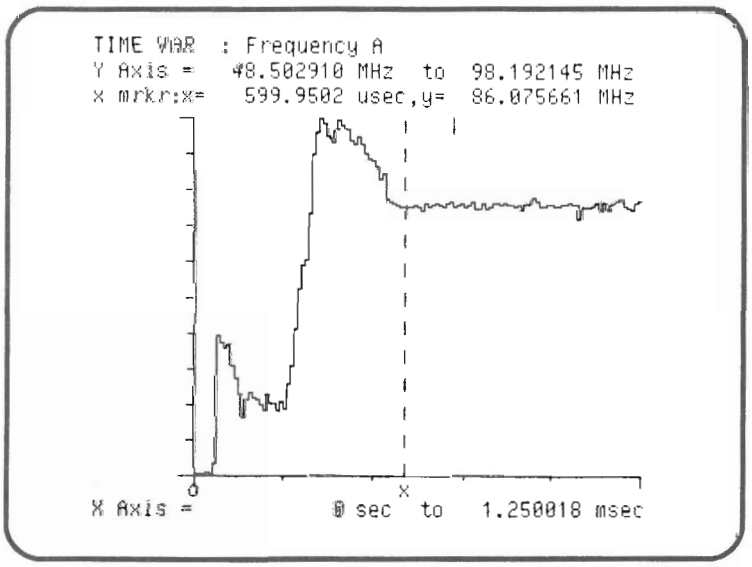


The gate time is now shortened to 10 us which will increases the hop's graphical resolution.

```
Frequency A:                              78.787 MHz

FUNCTION ──────────────────────────────────────────
 FREQUENCY          Measurement  Channel    A
Acquire              1  block  of  1000  meas
Total Measurements =  1,000
 EDGE/INTERVAL      Arming Mode ──────────────────
Block Holdoff:
  After  POS  edge of  CHAN B  ,
  Arm a block of measurements


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

 Acquisition Time/Block = 10.00000 ms
```



One full hop can now be examined for its switching and settling characteristics. This is the response of a single hop and not an average picture of many repetitive hops.

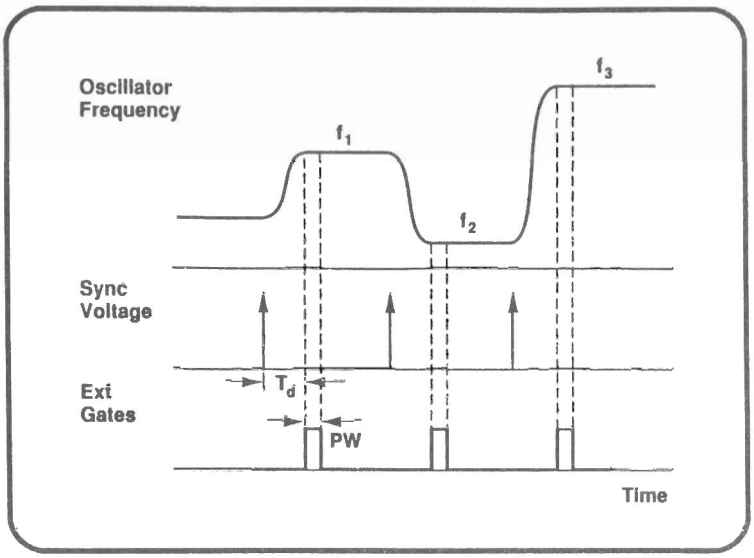


Again, the zoom and marker features can be used for a closer look at the interesting areas of the hop. This particular hop settled in 600 us, well under the 1.6 ms specification.

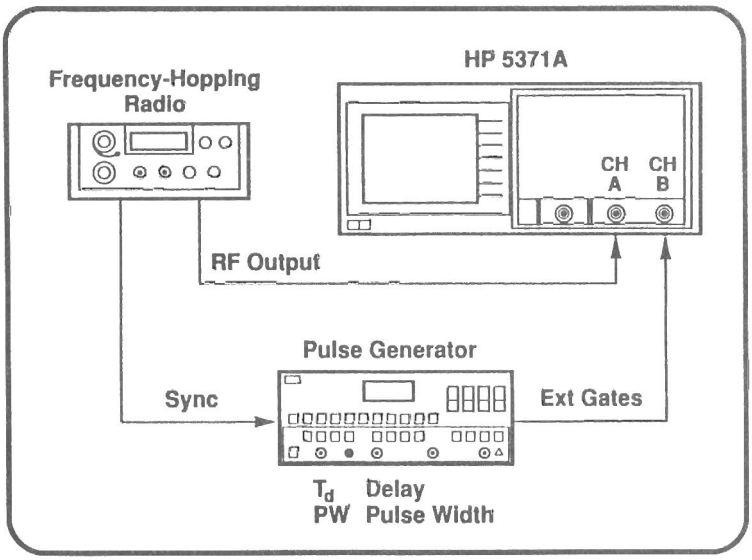
SETTLING TIME VERIFICATION

Now the HP 5371A will be used to verify the settling time specification on a series of hops.

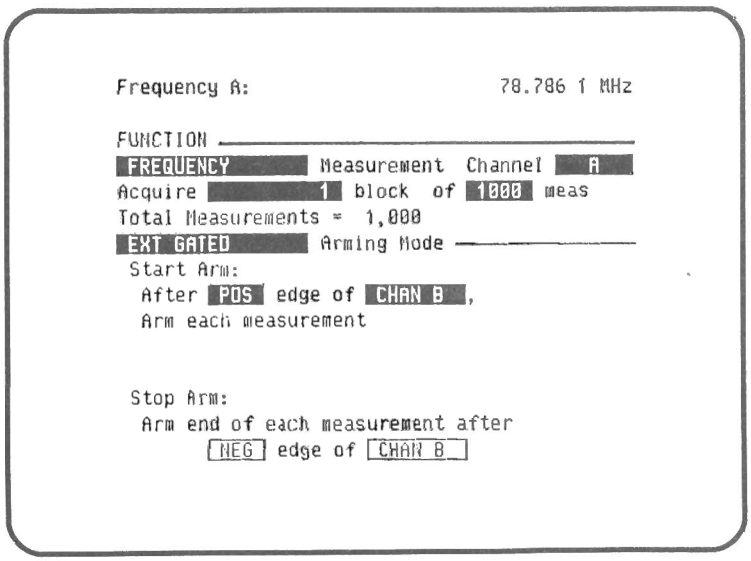
In this case, all that really needs to be determined is that the carrier frequency has settled to within specifications 1.6 ms after the hop sync signal. Thus a series of non-continuous measurements will be made as all the other measurements are not relevant.

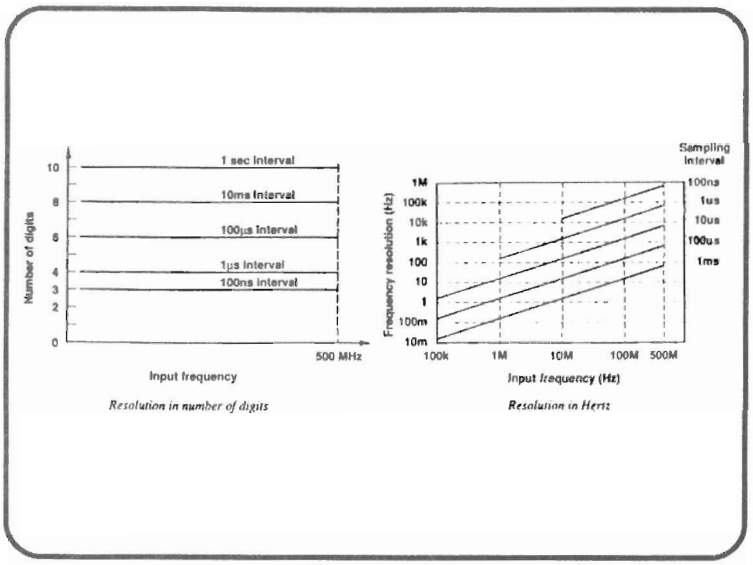


Using a pulse generator in the single pulse mode and with a delay of 1.6 ms will provide the required gate signal to the HP 5371A.

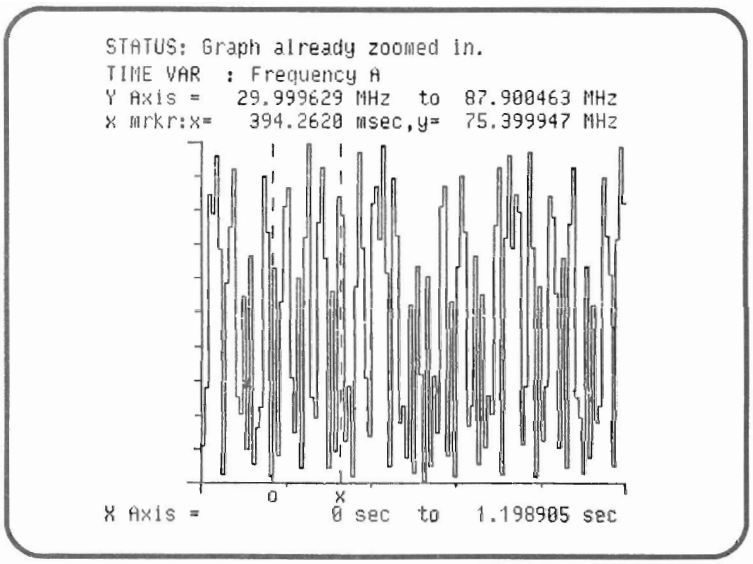


As can be seen, in the HP5371A's Externally gated mode, the pulse width will determine the gate time.

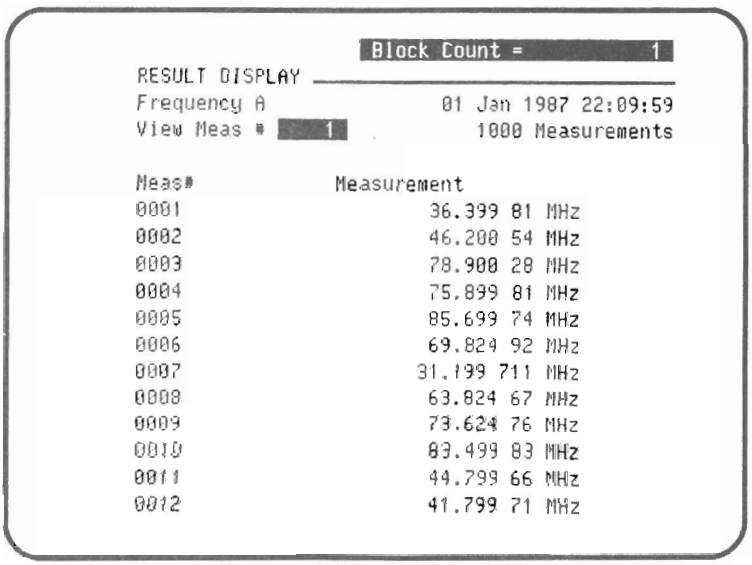




Choosing a gate time is always a trade off. Too long a gate time may hid frequency changes that occur during the gate time. Too short a gate time will not yield the required resolution. For the MP-83, the settling specification is + /- 700 Hz (or 5 digits of resolution on the carrier frequency). The HP 5371A gives this resolution with a 10 us gate time, far shorter than any of the observed transition changes.



The result is a one-pass verification of 1000 hops taken at full operating speed. The measurement time is the same as the sequence's running time.

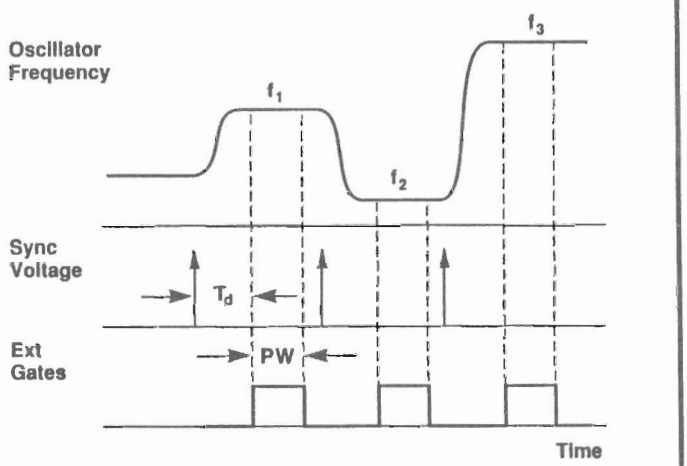


For record keeping and process control purposes, a hard copy of the measurement values can be dumped directly to a printer.

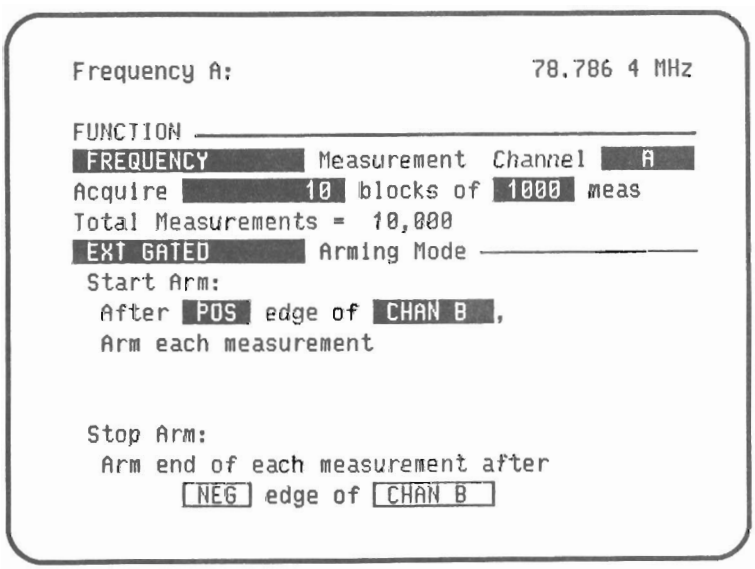
Now the HP 5371A will be used to determine the radio's information-carrying spectrum usage.

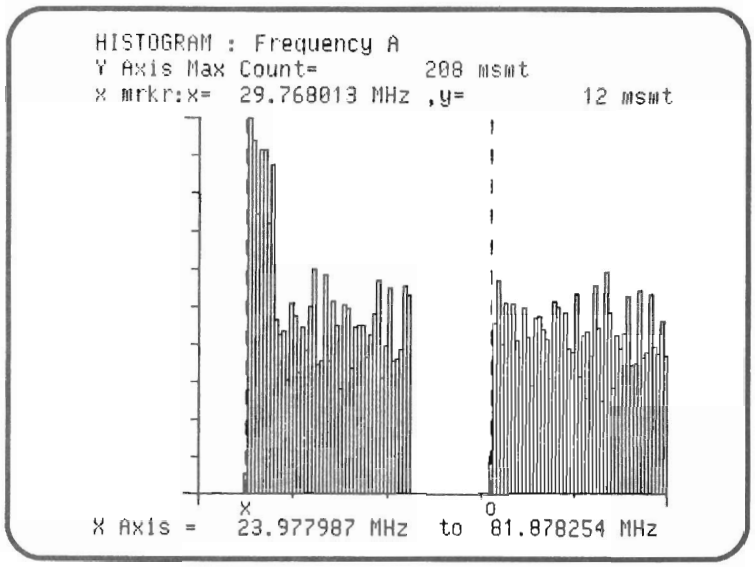
HOPPING FREQUENCY DISTRIBUTION

Again, the pulse generator's output will be used to externally gate the HP 5371A. This time the gate is positioned in the center, or well-settled, portion of the hop to capture the information-bearing frequencies only. The wider gate also increases the resolution.

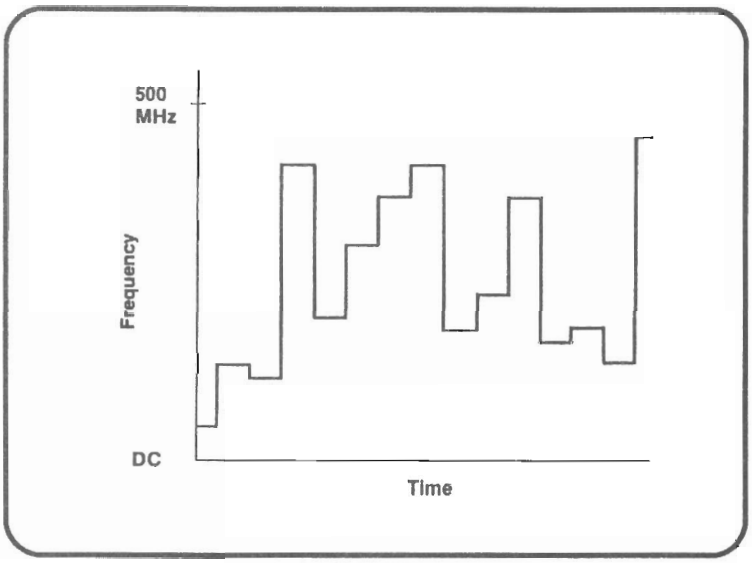


Since hopping sequences can be quite long, 10 blocks of 1000 measurement are made to ensure a true representation of the radio's spectrum usage.





The result is a clean version of what was obtained in the first test. All the transition frequencies have been eliminated. Only 2 minutes of test time was required for this 10,000 hop analysis.

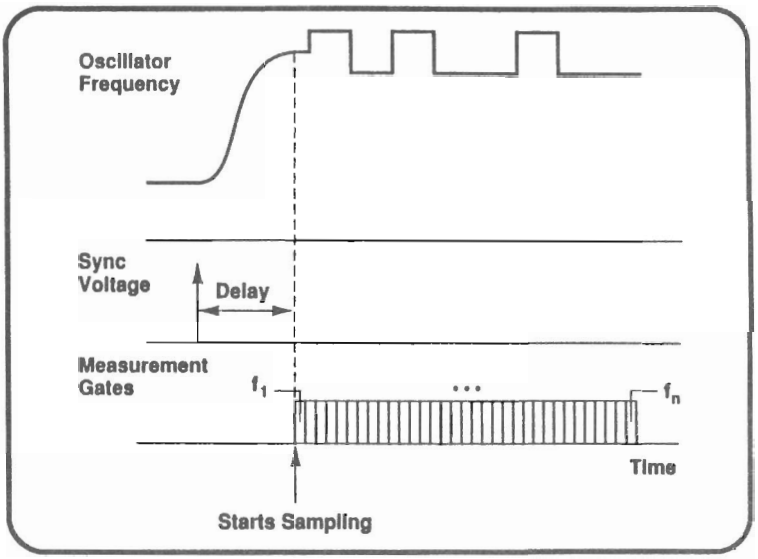


Of course this will also clean up the hopping sequence analysis.

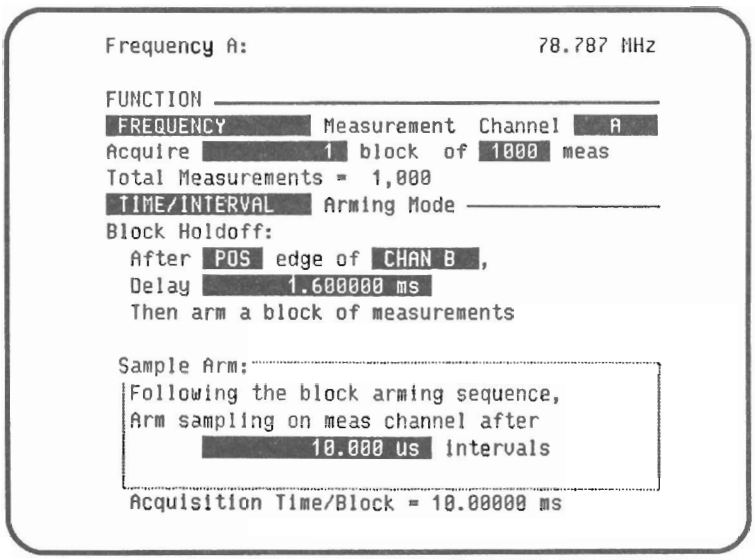
FSK MODULATION ANALYSIS

Now let's take a look at the actual information on the carrier.

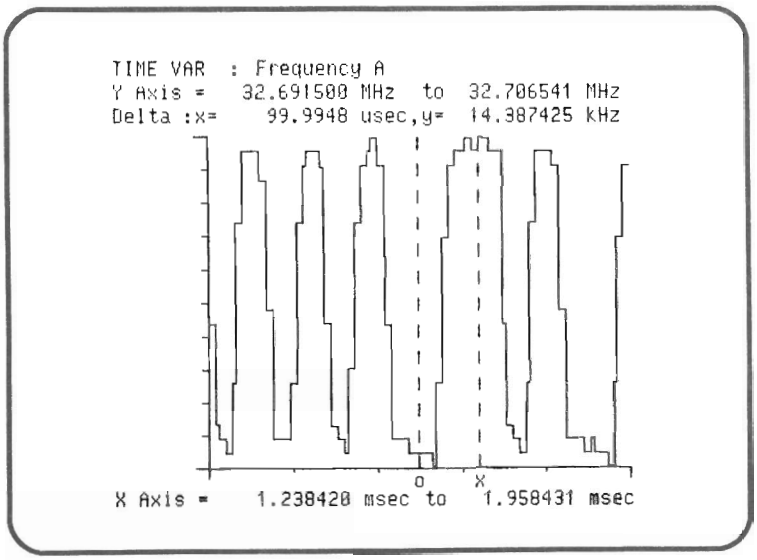
In this case, the pulse generator will not be used since continuous frequency measurements will be made to reveal the FSK modulation on one hop. The measurement block will be delayed the 1.6 ms settling time and a 10 us gate time used to get the required KHz resolution while still allowing several measurements per bit.

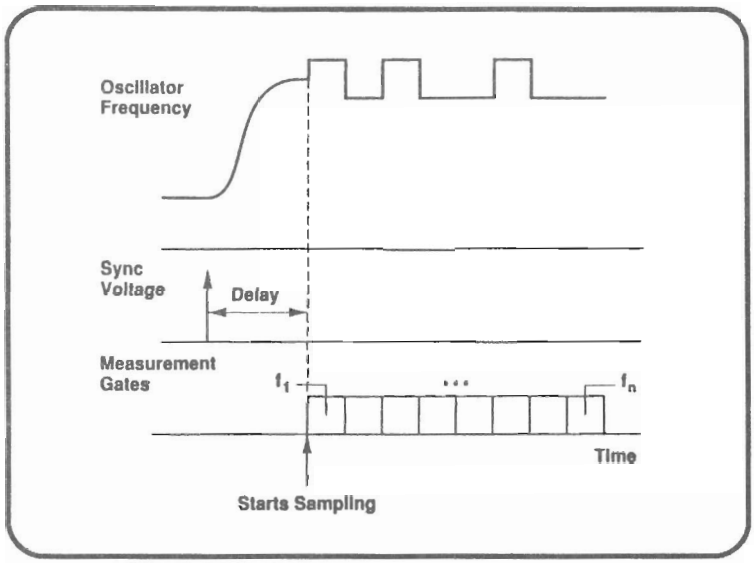


The HP 5371A has the ability to internally delay the block of measurements the 1.6 ms from the sync signal. No external equipment is required.

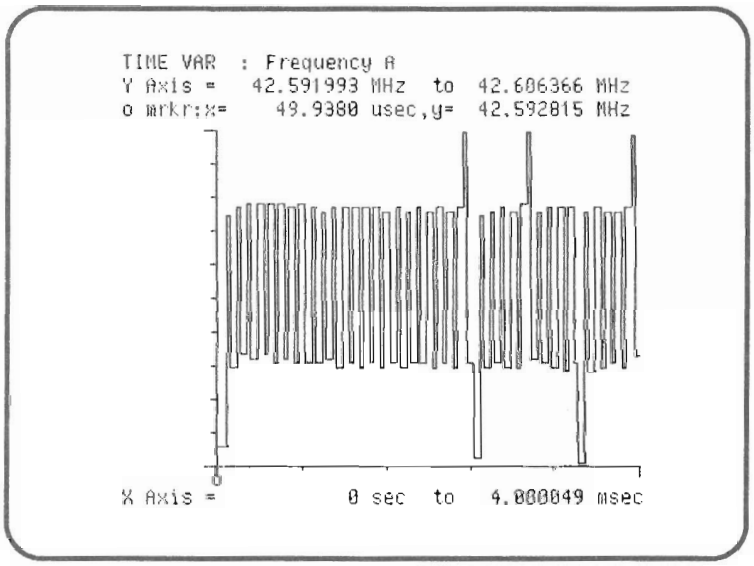


The resulting frequency versus time plot allows the 1's and 0's to be read directly from the screen. The markers can be used to verify the + /- 700 KHz FSK specification.

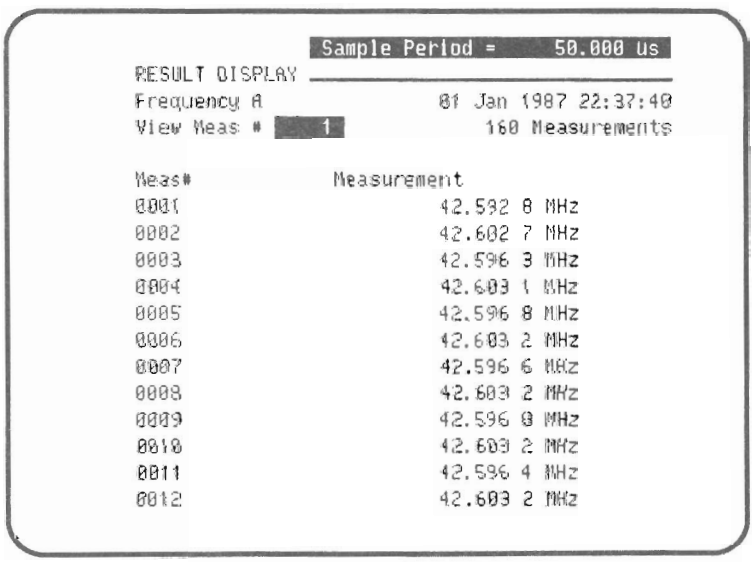




Now that the FSK bit timing has been established, the gate time can be widened to equal one bit. This will give better resolution on the shifted carrier frequency.

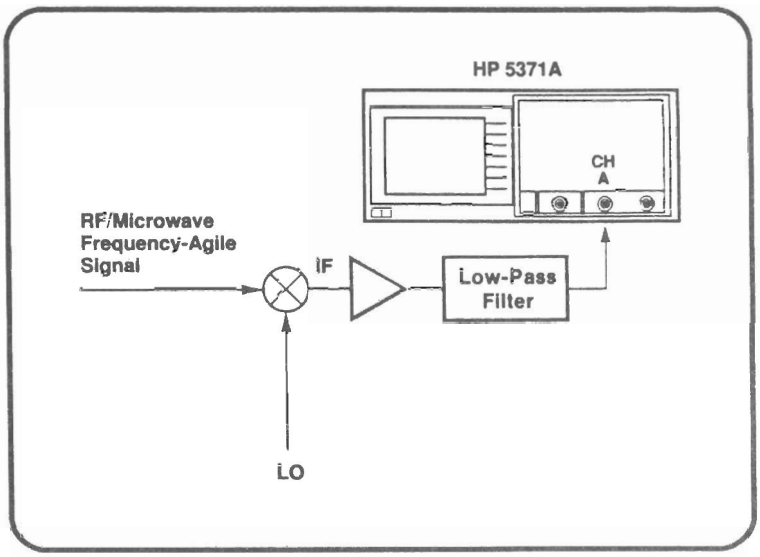


This makes the 1's and 0's pattern even clearer than before.

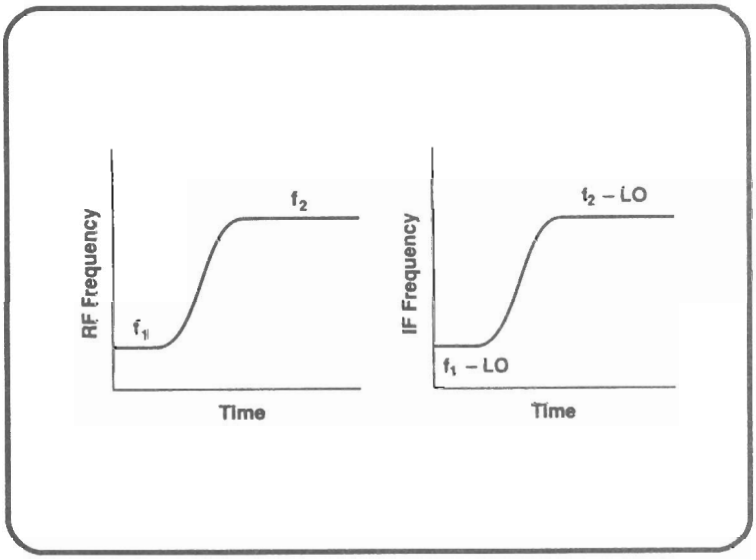


Of course, a hard copy of the results can be sent to a printer.

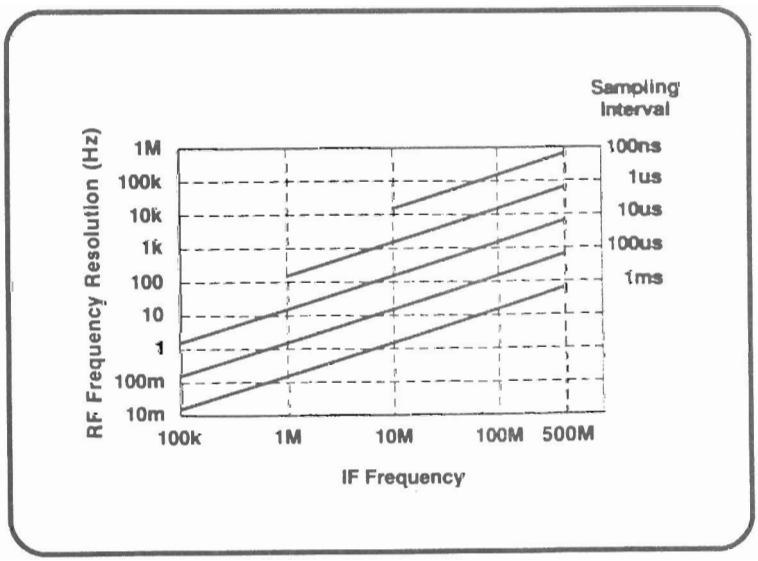
This same analysis can be done on agile microwave sources using a down converter to bring the hopping signal within the HP 5371A's 500 MHz bandwidth.



With this method, the timing characteristics of the hops are preserved and...



...the frequency resolution can be improved by choosing a lower IF frequency.



Advantages and Benefits
for
Agile Carrier

1. **Only practical solution**
2. **Repeatable, single-shot measurements**
3. **Histogram of spectrum usage**

In conclusion, the HP 5371A offers the only practical, cost effective way of testing frequency-agile sources. It provides a repeatable, calibrated, and maintainable test solution that gives a true one-pass, at-speed, analysis of frequency hop parameters. Also, for the ECCM designer, the histogram is an excellent anti-jamming analysis tool.

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