Application Note

Advanced Spectrum Analyzer Marker Measurements

MS2721B, MS2723B, MS2724B, MS2717B, MS2718B, MS2719B, and MT8222A

Spectrum Master™ and BTS Master™

Introduction

Markers have traditionally been used to measure the amplitude of a signal on a spectrum analyzer display or to indicate certain places on the sweep, such as band or channel limits. Advances in marker technology have led to many enhanced functions and measurement capabilities that were previously unavailable. Using markers and delta markers, you can make many measurements that deal with the change in power with frequency or time. In this application, note that we will discuss the following these topics:

- Using Delta Markers
- How to use off-screen markers
- Fixed vs. Tracking Markers
- Using markers to measure changes at a single frequency
- Using Marker 1 Reference
- Using Marker 1 Reference for broadcast proofing
- Measuring filters
- Using markers to measure phase noise

Using Delta Markers

Delta markers are used to measure changes in amplitude and frequency from a reference marker. The MS272xB, MS271xB, and MT8222A have six reference markers and six delta markers. The reference markers and their associated delta markers can be set anywhere on screen. The reference markers are set to absolute frequencies. The delta markers are set to positive or negative values relative to the associated reference markers, and they show the relative amplitudes at the chosen offsets.

Off Screen Markers

When the instrument frequency is changed so that markers are off screen, as shown in figure 1, indicators at the edges of the screen show the direction to off-screen markers. An asterisk is used to indicate off-screen values. This asterisk is located in the marker table, in the active marker indicator, and in the marker indicator at the top left edge of the screen in front of the marker or delta marker amplitude value.

Figure 1. Off-screen Marker information

Fixed vs. Tracking Markers

Working in conjunction with delta markers, this capability allows you to do things that often were very difficult with markers. A tracking marker is one whose amplitude changes as the *amplitude* of the signal being measured changes. A fixed marker, on the other hand, stays at the *amplitude* it was at when the associated delta marker was turned on if the **Marker Style Fixed Tracking** is set to Fixed when the delta marker is turned on. You can decide when to make a reference marker fixed by toggling the **Marker Style Fixed Tracking** soft key from Tracking to Fixed when the reference marker is active for editing. A common use for this capability occurs when you are waiting for the amplitude of an averaged sweep to settle to a stable value. Once the value is stable, change the marker style to **Fixed** so that it holds the value as you make changes and read those changes using the delta marker.

Use a fixed reference marker when you are interested in the change of value of a parameter compared to a starting value. This could be to monitor path-loss variations on an over-the-air signal, for example, or when aiming an antenna for maximum signal.

Use a tracking reference marker when you want a comparison between two frequency points. The reference value changes with time or when adjustments are made to the signal being measured.

Using markers to measure changes at a single frequency

When tuning a transmitter or filter, or aiming an antenna, you want to see if performance is improving. By using a fixed marker with a delta marker at the same frequency, you can read the amplitude change by observing the delta marker value. In the following measurement (see figure 2) you can see the 4.22 dB change in carrier amplitude as the receiving antenna (a shielded loop) was rotated.

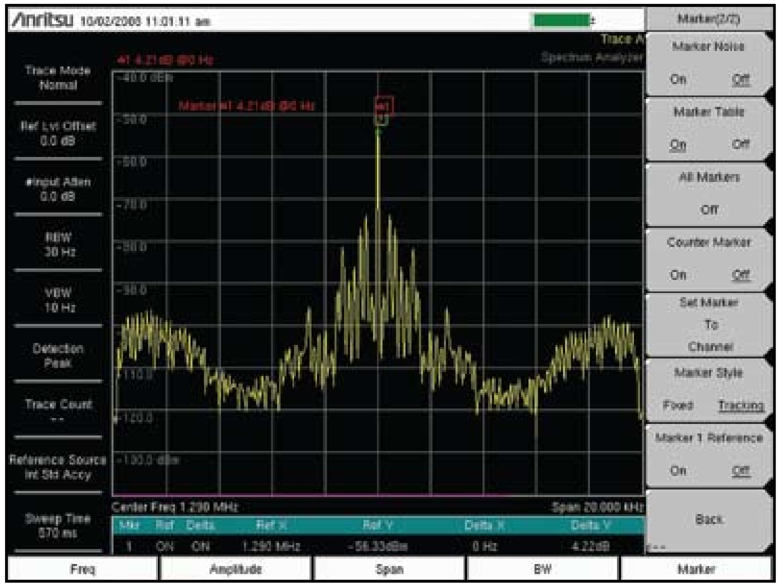

Figure 2. Using fixed marker to show the effect of rotating an antenna

Using Marker 1 Reference

Sometimes a user needs to know the relative amplitude of several points compared to a single reference point. Marker 1 Reference sets the instrument so that Marker 1 is the reference for all delta markers. The amplitudes and frequencies of all six delta markers are shown relative to Marker 1.

Measuring Filters

When measuring the frequency response of a filter using the tracking generator (available as an option in some models), you can readily observe changes in a filter passband response by using the delta marker amplitude relative to the Marker 1 Reference. In figures 3 and 4, **Marker 1 Reference** is used while adjusting the passband response of a filter to achieve the minimum insertion loss along with the flattest possible passband characteristics.

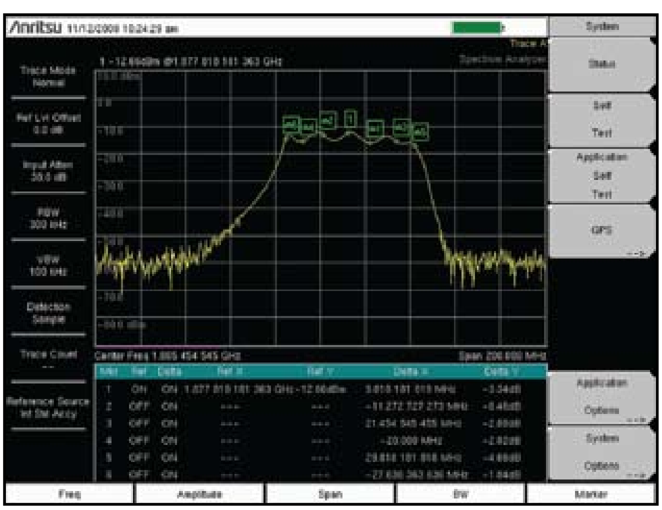

Figure 3. Measuring filter passband using fixed and delta markers.

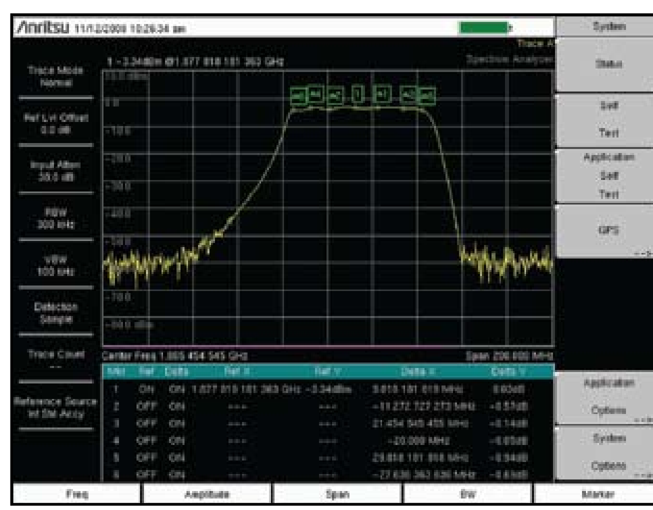

Figure 4. Filter passband after adjustment fixed and delta marker

The instrument default input attenuation and the use of the sample detector yield good results for the passband measurement. For the filter skirt measurements in figure 5, however, changes were needed from the default values for RBW and input attenuation. These changes lowered the noise floor sufficiently to see far down the filter skirts. To get the best sensitivity consistent with good measurements, reduce the input attenuation value. In this case, 5 dB of input attenuation is the lowest value that could be used without getting an ADC overrange warning. By using a narrower RBW filter, you can easily see well down into the filterís stop band without the need to do trace averaging. Avoid attenuation below 5 dB, however, to ensure good match (low VSWR) when measuring frequency response..

Figure 5. Measuring filter skirts

Using Marker 1 Reference for AM broadcast proofing

When a broadcast engineer measures an AM broadcast station to meet FCC measurement requirements he needs to know the amplitudes at ±10.2 kHz, ±25 kHz, and ±75 kHz from the carrier. Marker 1 Reference automatically sets those values when the center frequency is within the AM broadcast band (530 to 1700 kHz) and the span is greater than 150 kHz. If the span is less than that, or the frequency range is outside of the AM broadcast band, then the delta markers are evenly distributed across the screen. Figure 6 shows the measurement of an AM IBOC signal in Master Software Tools

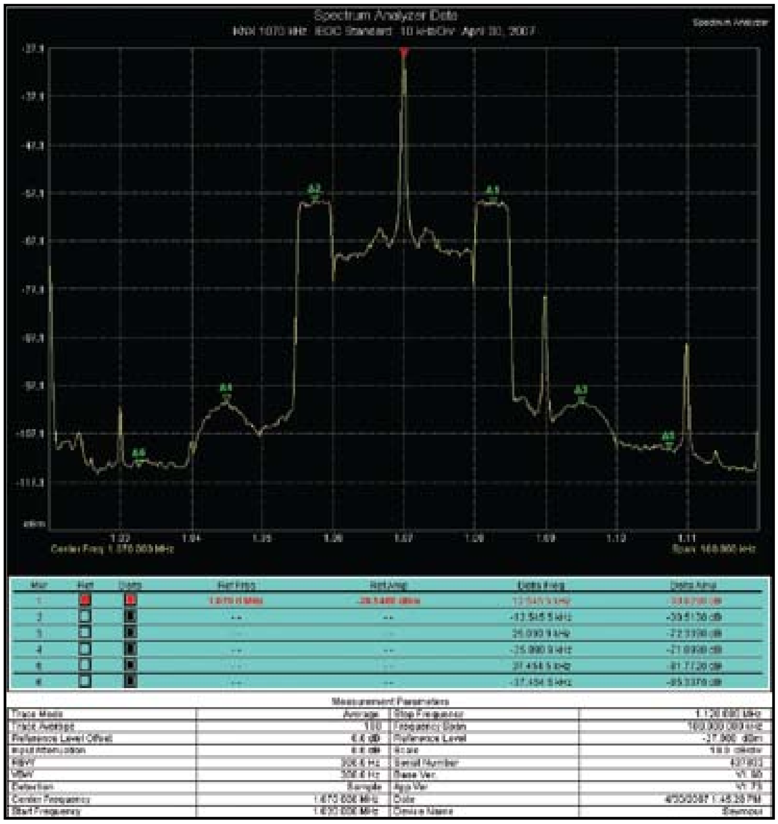

Figure 6. Markers on an AM Broadcast Signal with IBOC sidebands.
This measurement is courtesy of Burt I. Weiner Associates.

Using markers to measure phase noise

Phase noise measurements are made at certain offsets from the carrier and normalized to a 1 Hz bandwidth. To do this measurement using markers, set the reference marker on the peak of the signal, turn on a delta marker, and set it to be a Noise Marker. Set the delta frequency to the desired value. The value of the delta marker is the phase noise in dB/Hz relative to the carrier. To make sure the amplitude noise variations have been removed, use a narrow video bandwidth (VBW). You can also use averaging on Trace A to stabilize the amplitude of the measurements. Near the carrier, the measured noise is mostly phase noise, so trace averaging is generally not needed unless there are significant amplitude variations on the received signal. The default RBW value generally yields good measurements over two decades of offset frequency – a total span of 50 to 100 kHz. Beyond that, an RBW value narrower than the default value is generally needed so that the phase noise changes with frequency are not excessively averaged. In figure 8, the carrier was moved to the edge of the display, and marker 1 reference was employed. This gives us multiple delta markers allowing phase noise at several offsets. Measurements from 1 kHz to 50 kHz are shown. The RBW and VBW are set to 1 Hz

Trace averaging vs. narrow VBW

Trace averaging calculates an average of multiple sweeps to arrive at a value. Depending on the noisiness of the trace, many traces may need to be measured to arrive at a stable value, significantly increasing measuring time. Using a narrow VBW achieves approximately the same result by low-pass filtering the measured values, effectively reducing the amount of noise on the measurement in a single sweep.

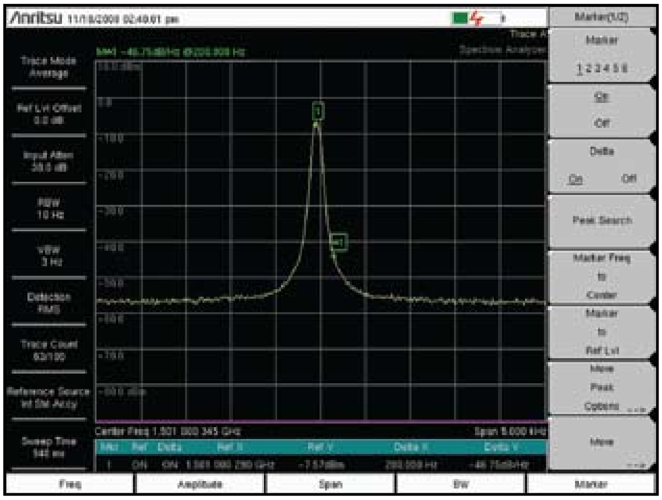

Figure 7. Using delta noise marker to measure phase noise

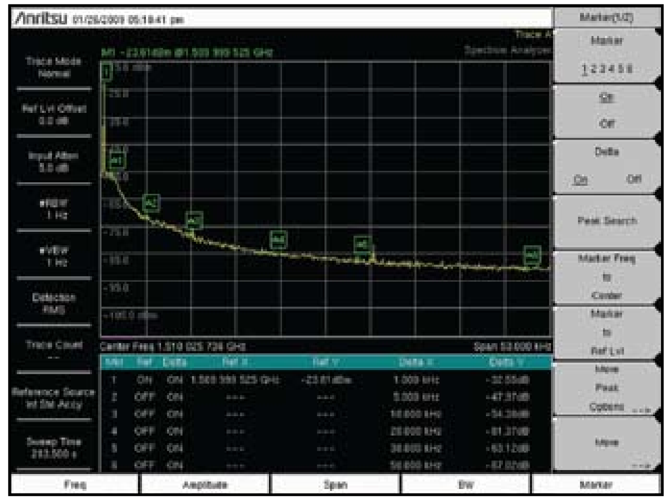

Figure 8. Measuring phase noise at multiple offsets

Using markers as a frequency counter

"Normal" markers report the center frequency of the marker display point, thereby resolving frequency to within ±(span/550). Normal markers are fast enough and precise enough for most applications. By comparison, the counter marker selection reports the frequency of the marked signal to a least significant digit of 0.001 Hz and increases the time between sweeps as the marker value is being determined – each counter marker takes about one second after the sweep is finished for value determination.

The best way to use the counter markers is with a relatively narrow span so you are sure to pick the signal you want to measure, not one that happens to be nearby and an RBW of 1 kHz or less. The marker does not have to be precisely on the peak of the signal as long as it is within about 20 dB of the peak, depending on the signal-to-noise ratio. To make a good measurement, the instrument needs to have a signal-to-noise ratio of 25 dB or more so the effect of noise is minimized. The counter marker is not useful for measuring the frequency of signals that rapidly change frequency – such as an FM modulated signal – or where there are many closely-spaced frequency components such as a CDMA or GSM signal and a center frequency signal is not obvious.

The internal method that the instrument employs yields both fast measurements and the ability to measure small signals. Starting with the marker at or near the peak of the signal, the instrument zooms in on the signal twice and reacquires the peak after each zoom. After the last zoom, the peak frequency is reported.

If the instrument has the GPS receiver option installed (Option 31), then you can improve the frequency accuracy by locking the time base to the GPS network before measuring frequencies. This will allow you to use a much more accurate reference oscillator frequency with an accuracy of 25 ppb or better when locked to the GPS signals, and better than 50 ppb for up to three days afterwards when no longer receiving the GPS signal. You will know what accuracy is being achieved by looking at the Reference Source information in the setting summary on the left side of the screen. You may see one of four different messages: "Int Std Accy" (0.3 ppm), "Int Hi Accy" (50 ppb for up to 3 days), "GPS Hi Accy" (25 ppb), or "Ext Ref". You may also see the message "Acquiring GPS" after the instrument has sufficient GPS data to begin setting high accuracy. That message generally lasts for less than one minute. If you are using an external reference, then the accuracy of the measurement is determined by the accuracy of the external reference signal being used and is outside the control of the instrument.

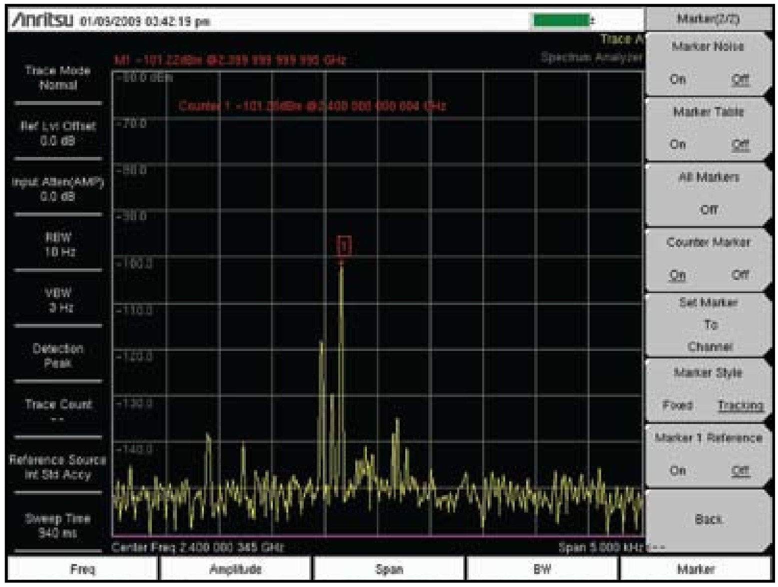

Figure 9. Measuring a signal frequency using Counter Marker

Figure 10 shows an off-the-air measurement of an AM broadcast signal with digital modulation sidebands (IBOC) showing the center frequency of the carrier and the two IBOC sidebands at approximately ±12 kHz of the carrier frequency.

Figure 10. Frequency counter marker being used to measure the center frequency of a hybrid HD AM broadcast signal.

Conclusion

By using fixed and tracking markers and delta markers, you can use markers to measure changes at a single frequency or over a band of frequencies. You learned how to use Marker 1 Reference both for broadcast proofing and for measuring filters using the tracking generator. You learned how to use markers to measure phase noise. Markers provide a flexible and easy-to-use method of making many measurements.

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