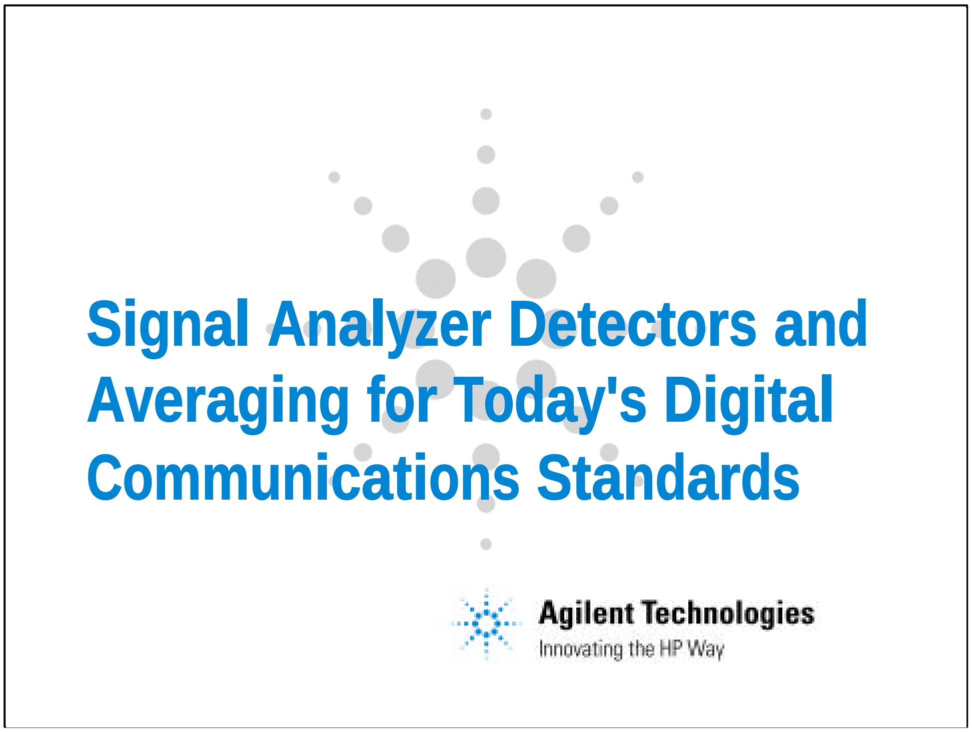

Signal Analyzer Detectors and Averaging for Today's Digital Communications Standards

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Innovating the HP Way

Fast and accurate measurements on today's digital communications signals require the appropriate use of signal analyzer detector modes and averaging types. Measuring transmitted signals, spurious signals, adjacent channel power, and noise with optimum speed and confidence is more complicated than ordinary continuous wave (CW) signal measurement. This paper describes different spectrum analyzer detector modes and averaging types, and their relationship to major communications standards such as W-CDMA, IS-2000, GSM, and EDGE. Implications for measurement accuracy, speed and statistical confidence levels will also be discussed.

Simple Measurements of Complex Signals

- Spectrum analyzers are often the wireless engineer’s primary tool
- Spectrum Analyzers measure CW signals, noise, noise-like signals, signals with other statistical characteristics
- Accurate measurements require proper analyzer operation, particularly attenuation, detectors, averaging
- Measurements are influenced by spectrum analyzer history and tradition, sometimes determined by standards requirements
- New signals and new analyzers are changing measurement practices

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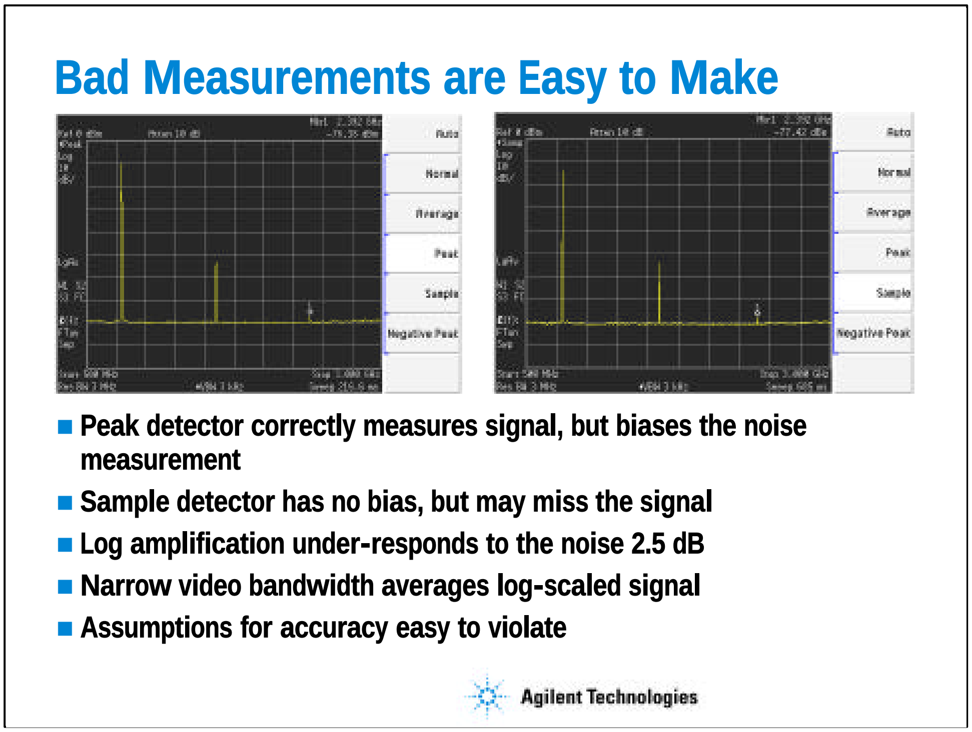
Design of RF wireless systems and components requires the accurate measurement of a wide variety of signals including CW, noise and noise-like signals.

Spectrum analyzers are excellent tools to make these measurements, but they must be set up correctly to ensure that the measurements are accurate and repeatable. For noise or noise-like signals, some form of averaging is often necessary to reduce the variance of the signal and arrive at a representative amplitude value.

All digital wireless signals are noise-like and many are bursted. The following discussion of different types of detectors and averaging will explain how to set up spectrum analyzers to get fast and accurate results.

Most measurements of wireless signals are based on traditional swept analysis, but new types of signals and new analyzer architectures are changing analysis techniques.



Bad Measurements are Easy to Make

- Peak detector correctly measures signal, but biases the noise measurement
- Sample detector has no bias, but may miss the signal
- Log amplification under-responds to the noise 2.5 dB
- Narrow video bandwidth averages log-scaled signal
- Assumptions for accuracy easy to violate

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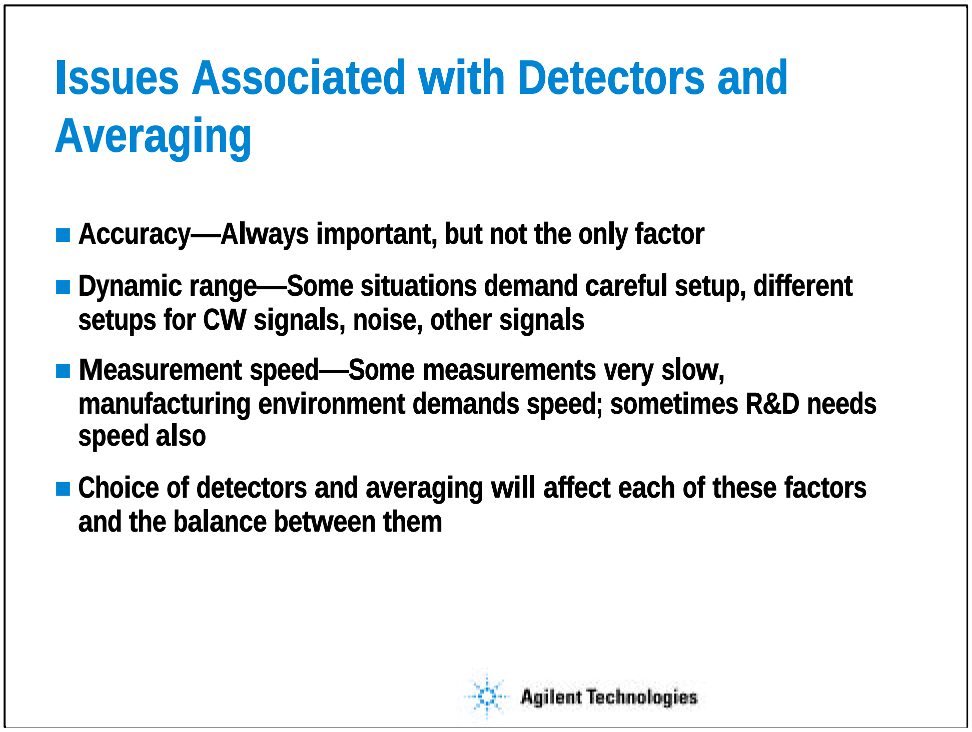
In many cases, the behavior of analyzers is different when measuring CW signals, noise and noise-like signals with unknown signal statistics. Since the design of wireless systems can involve all of these signal types, it is relatively easy to make a "bad" measurement. That is, a measurement that is in error in some fashion, but may appear to be accurate.

A peak detector is used in the measurement on the left, producing accurate measurements of the CW signal and its harmonics. However the peak detector produces a bias in measurements of Gaussian noise. The peak detector also produces a bias for noise-like signals with statistics other than Gaussian, though the bias will be different than it would be for Gaussian noise.

A sample detector is used in the measurement on the right, and will not produce a bias in measurements of noise. However it may miss or may incorrectly measure CW signals, especially when the resolution bandwidth (RBW) is extremely narrow compared to the frequency span.

Log amplification in spectrum analyzers also distorts the average value of noise and noise-like signals. For Gaussian noise, this error is a known under-response of 2.51 dB, and corrections can be made. For signals with non-Gaussian statistics this 2.51 dB correction would not be accurate.

The use of video bandwidth (VBW) filtering may also cause errors when measuring some signals because this form of averaging may be on a different scale than the one used for measuring the signal.



Issues Associated with Detectors and Averaging

- Accuracy—Always important, but not the only factor
- Dynamic range—Some situations demand careful setup, different setups for CW signals, noise, other signals
- Measurement speed—Some measurements very slow, manufacturing environment demands speed; sometimes R&D needs speed also
- Choice of detectors and averaging will affect each of these factors and the balance between them

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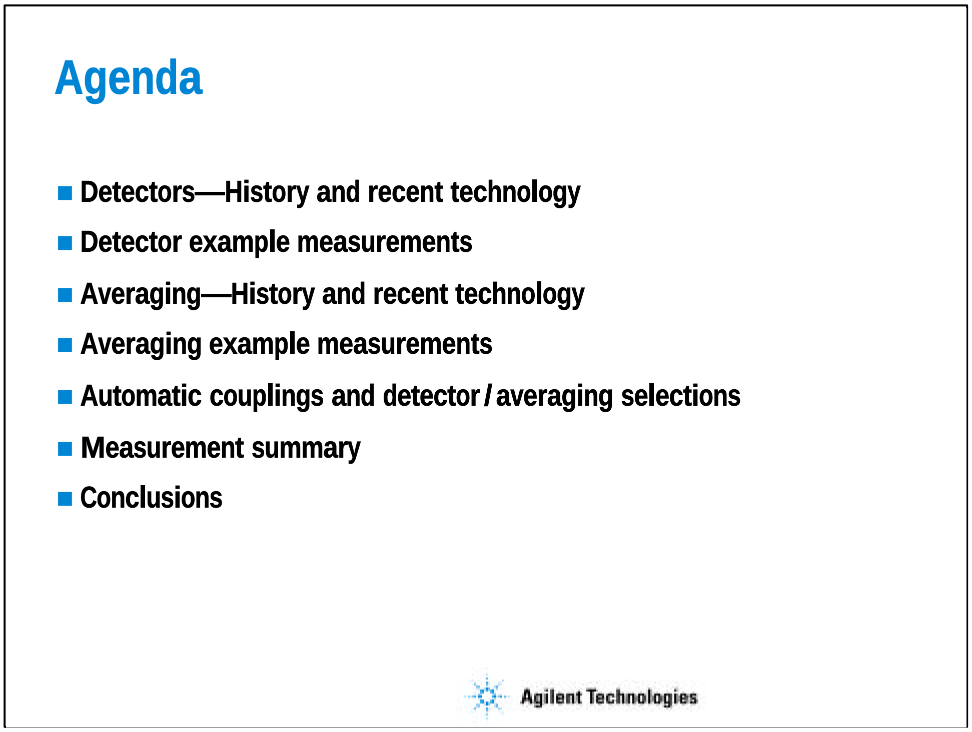
The proper use of detectors and averaging obviously is important for measurement accuracy.

Detectors and averaging also affect measurement speed, since it is often necessary to reduce the variance of (or "smooth") measurements of noise and noise-like signals. Some detectors make better use of measurement data inside the analyzer, and some measurements converge faster on one measurement scale than others.

The proper use of detectors can also provide better dynamic range for certain measurements, particularly those of small signals near the noise floor of an analyzer.



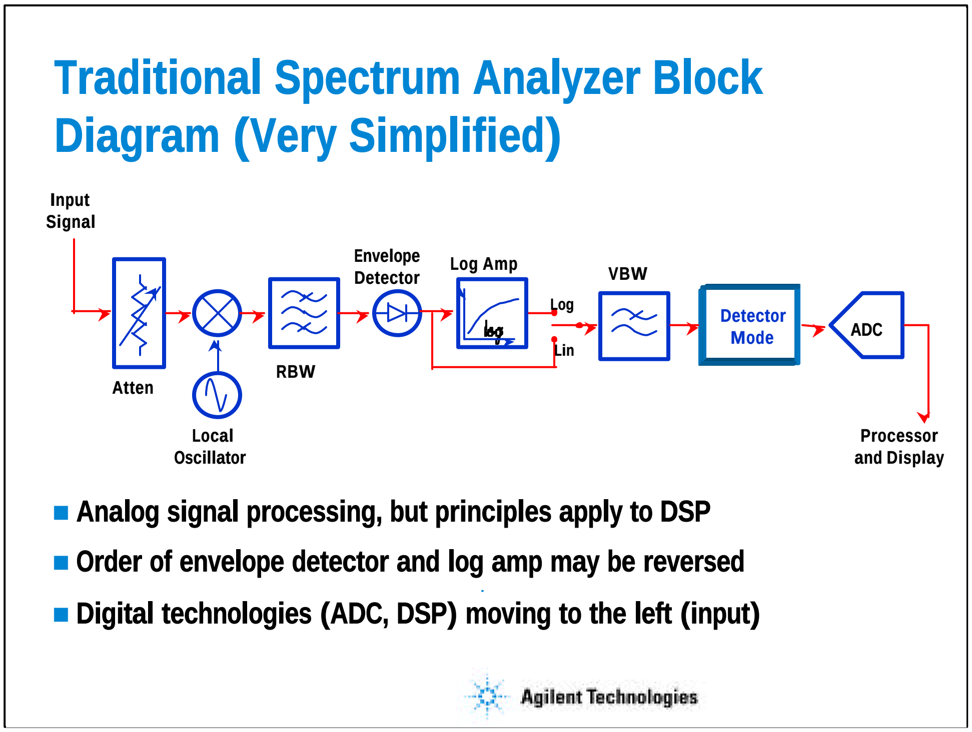
Agenda

- Detectors—History and recent technology
- Detector example measurements
- Averaging—History and recent technology
- Averaging example measurements
- Automatic couplings and detector / averaging selections
- Measurement summary
- Conclusions

Understanding the effects of different detectors and averaging techniques is easier if one first understands the architecture of spectrum analyzers and the historical development of this architecture.

History and tradition are powerful forces, and they continue to influence measurement practice and terminology. These forces and this terminology will be discussed in this presentation as they apply to measurements of modern wireless signals.

Tool familiarity and availability also influence the measurement choices that engineers make. Since spectrum analyzers are such familiar and generally available tools, it is important to make the fullest and most accurate use of them, and to fully understand their operation.



Traditional Spectrum Analyzer Block Diagram (Very Simplified)

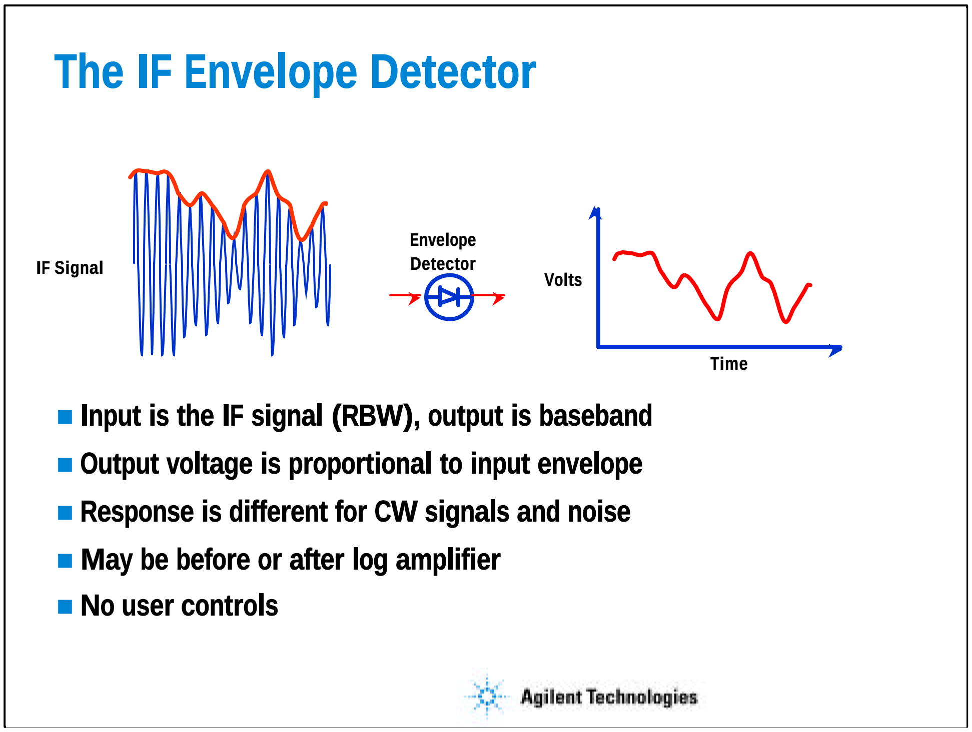
- Analog signal processing, but principles apply to DSP
- Order of envelope detector and log amp may be reversed
- Digital technologies (ADC, DSP) moving to the left (input)

This (very simplified) block diagram of a traditional spectrum analyzer will be used in discussing different detector types and averaging.

One source of confusion in discussions of detector types is the fact that spectrum analyzers actually have two different circuits that are typically called "detectors." Both will be described in this presentation.

Though much of the signal processing chain illustrated here has been implemented using analog technologies, innovations in analog-to-digital converters (ADCs) and digital signal processing (DSP) have gradually allowed more of it to be implemented digitally. These digital implementations can provide significant benefits in accuracy and flexibility.

In this block diagram, the envelope detector follows the final IF (RBW) filter section, and its output is fed to a log amplifier when the analyzer is in its logarithmic (log) mode. In some analyzers the log amplifier immediately follows the final IF section, and therefore the input to the envelope detector is already logarithmically processed. The order of logarithmic processing and envelope detection does not change the general suggestions and conclusions of this presentation.



The IF Envelope Detector

- Input is the IF signal (RBW), output is baseband
- Output voltage is proportional to input envelope
- Response is different for CW signals and noise
- May be before or after log amplifier
- No user controls

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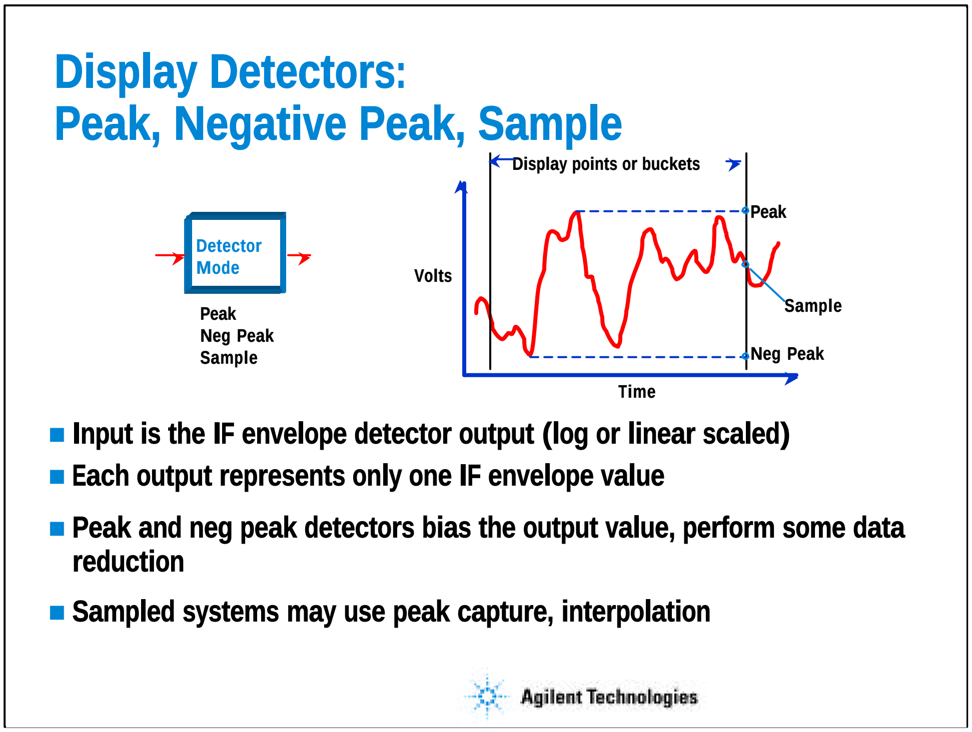
If a signal is followed through the block diagram of a typical spectrum analyzer, the first detector that is encountered is called the intermediate frequency (IF) detector or envelope detector.

This detector converts the output of the analyzer's IF section into a unipolar voltage representing the amplitude of the IF signal. Since this voltage represents the changes in the magnitude of the IF signal during a sweep and could be used (along with the ramp voltage corresponding to the sweep position) to generate a spectrum display, this IF detector output is typically called a "video" signal.

The envelope detector is a critical part of the spectrum analyzer block diagram, and can be implemented in analog or digital circuitry. Traditional implementations have used a diode circuit, and so the usual representation for this IF detector in spectrum analyzer block diagrams is a diode. Regardless of whether this IF detector is implemented using analog or digital technology, its characteristics are fixed by the spectrum analyzer designer and not the user. Therefore this envelope or IF detector will not be discussed further in this paper, and all subsequent references to detectors will deal with the other spectrum analyzer detector--the "display" detector.



Display Detectors: Peak, Negative Peak, Sample

- Input is the IF envelope detector output (log or linear scaled)
- Each output represents only one IF envelope value
- Peak and neg peak detectors bias the output value, perform some data reduction
- Sampled systems may use peak capture, interpolation

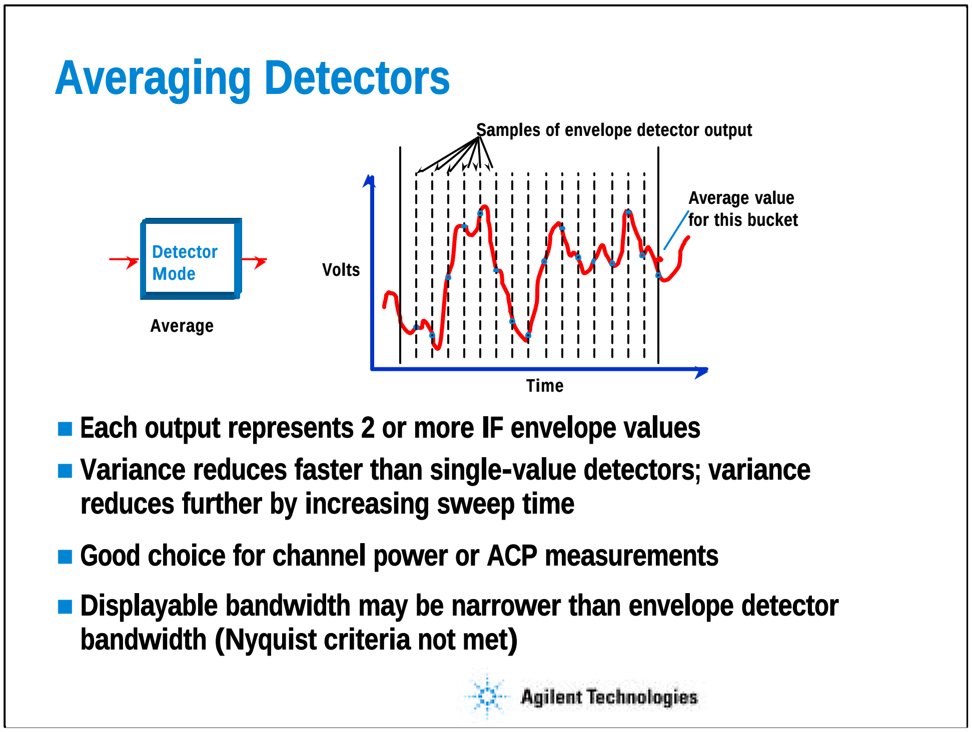
The need for a display detector in spectrum analyzers results from of the use of digital technology to generate and store spectrum displays. Early spectrum analyzers used analog display techniques, typically in the form of variable-persistence displays such as those used in storage oscilloscopes. The continuous signal output from the IF detector was fed to the Y-axis of the storage display and plotted against an X-axis generated by the ramp signal described previously. The result was a continuous display of the of the signal spectrum.

Digitizing the video signal provides a number of benefits for spectrum storage and display. However, the combination of sampling frequency and associated processing must be capable of capturing the desired peaks accurately. Some systems may use peak capture and/or interpolation to ensure that maximum and minimum peaks are accurately represented.

The simplest data reduction or detector algorithm is the sample detector. This detector simply saves and displays the final value of the video signal digitized for each bucket. Sample detectors are often chosen when measuring noise or noise-like signals. When a peak detector is used to measure noise, the result is peak-biased, and this can increase the apparent noise level or reduce the apparent signal/noise ratio of a measurement.

Peak and negative peak detectors employ slightly more complicated algorithms. If the highest signal value measured during a bucket is saved and displayed, the result is a peak detector. Similarly, if the lowest signal value for each bucket is displayed, the result is a negative peak detector, also called a pit detector.

Peak detectors are commonly used in spectrum analyzers because they save and display the peak value of the signal, no matter where in a bucket the signal peak falls. This is particularly important for very wide frequency spans, where the resolution bandwidth is narrower than a single bucket.



Averaging Detectors

- Each output represents 2 or more IF envelope values
- Variance reduces faster than single-value detectors; variance reduces further by increasing sweep time
- Good choice for channel power or ACP measurements
- Displayable bandwidth may be narrower than envelope detector bandwidth (Nyquist criteria not met)

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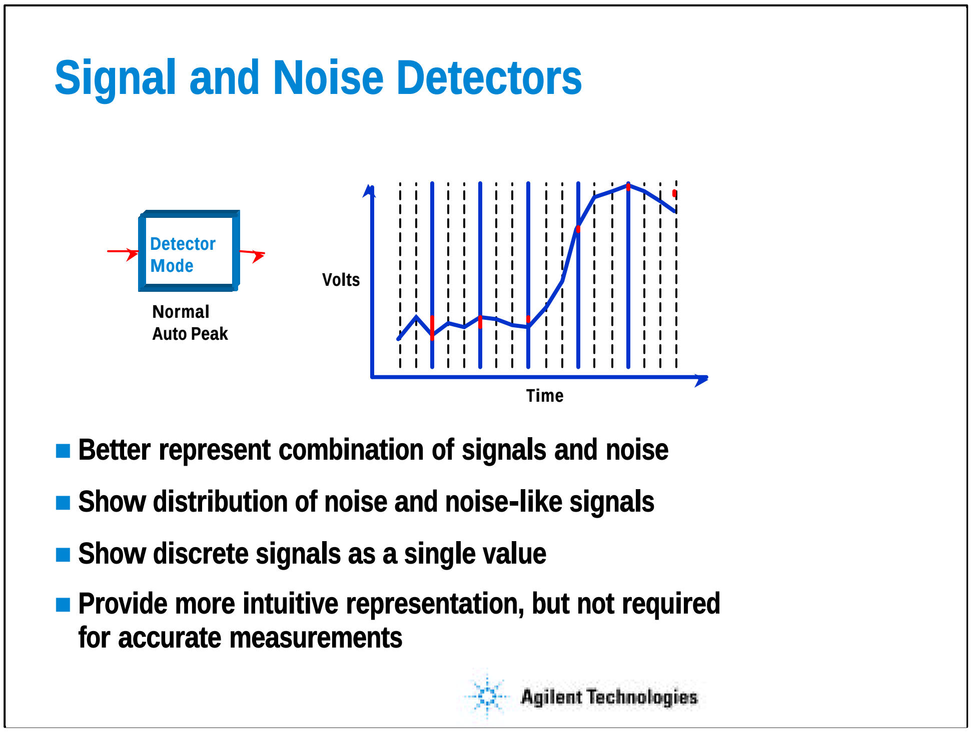
Fast signal processing allows other types of detectors to be implemented--detectors that perform more sophisticated operations on the video signal samples than simply choosing the maximum or minimum value. One of the most useful detectors to employ this processing is the averaging detector. Although the specific implementation technique may vary, the averaging detector generally processes all of the video signal samples from a bucket to yield an average value.

Digitizing the video signal provides a number of benefits for spectrum storage and display. However, some combinations of RBW, span, sweep rate, and ADC sample frequency may violate the Nyquist criteria for sampling the video signal. The measurement errors resulting from this non-Nyquist sampling will be different for different types of signals, and therefore it is important to select the appropriate display detection algorithm to reduce or eliminate them.

Averaging detectors are an excellent choice for making channel power or adjacent channel power (ACP) measurements, where measurement results involve summing power across some number of display buckets. By retaining and processing more of the measurement data from each sweep, the averaging detector will produce a measurement with lower variance than the sample detector in the same measurement time. Because of the averaging operations during a sweep, the variance of the measurement can be further reduced by simply increasing the sweep time.



Signal and Noise Detectors

- Better represent combination of signals and noise
- Show distribution of noise and noise-like signals
- Show discrete signals as a single value
- Provide more intuitive representation, but not required for accurate measurements

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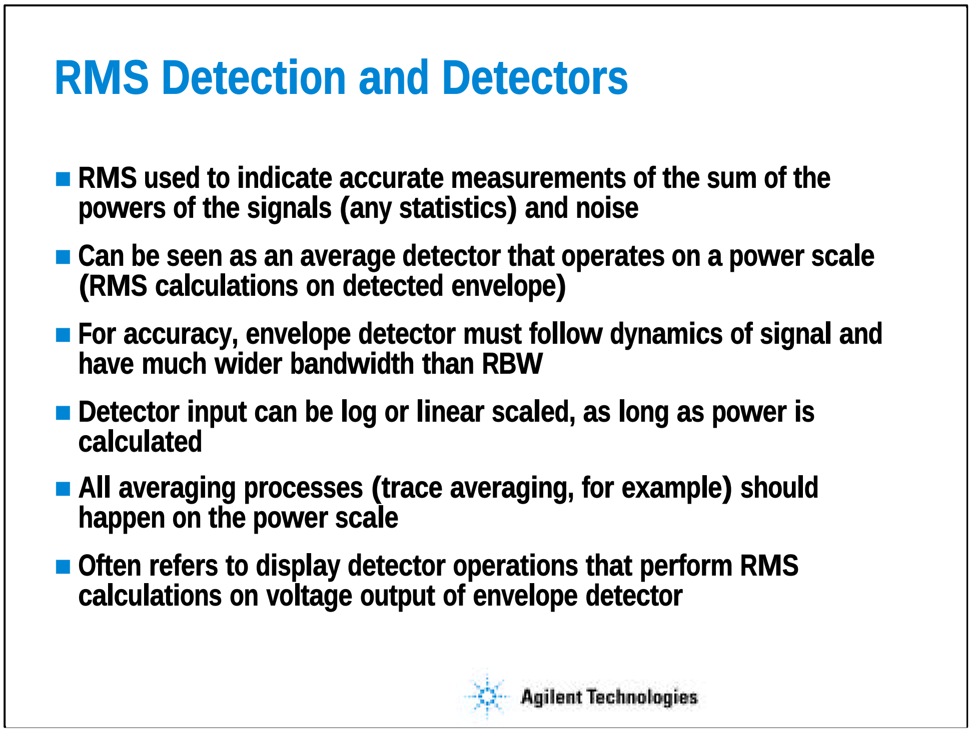
The analog spectrum analyzer displays described previously could provide an intuitive feel for the amplitude distribution characteristics of a signal, due to their ability to show multiple values and display intensities at a single frequency display point.

Applying signal processing to the video samples from a single bucket to create a more informative display is the purpose of a class of detectors called signal-and-noise detectors. These detectors can be implemented in a variety of ways, though the goal always is to more completely represent both signals and noise.

With names such as "normal" and "auto peak," etc., these detectors seek to represent the peak-to-peak amplitude excursions of noise and noise-like signals by giving that portion of the spectrum an apparent vertical height. At the same time, these detectors reveal CW signals as a single-valued trace. While these advanced detectors do provide a more intuitive representation of some signals, they are not necessary for accurate measurements, and are not provided in all spectrum analyzers.



RMS Detection and Detectors

- RMS used to indicate accurate measurements of the sum of the powers of the signals (any statistics) and noise
- Can be seen as an average detector that operates on a power scale (RMS calculations on detected envelope)
- For accuracy, envelope detector must follow dynamics of signal and have much wider bandwidth than RBW
- Detector input can be log or linear scaled, as long as power is calculated
- All averaging processes (trace averaging, for example) should happen on the power scale
- Often refers to display detector operations that perform RMS calculations on voltage output of envelope detector

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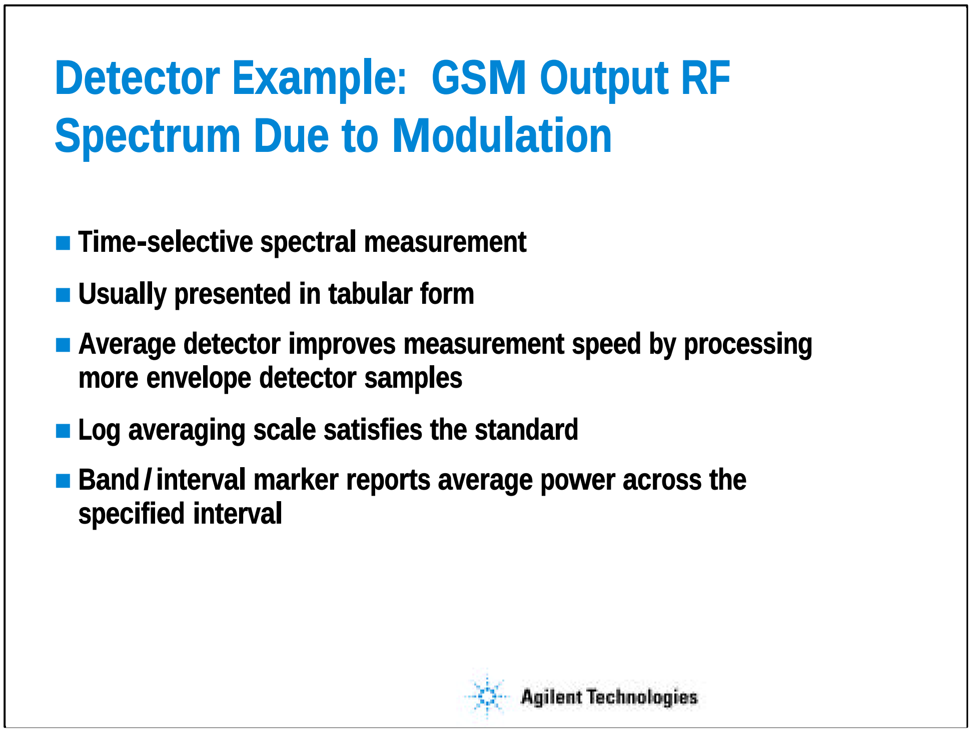
The term RMS (root mean square) is used in several different ways in signal analysis, in both generic and very specific fashions. It is often used to indicate a measurement where the sum of the power of any discrete signals and noise (with any statistics) is accurately measured.

RMS detection can be performed by an average detector (display detector) that operates on a power scale.

For accuracy of power calculations, it is important that the envelope detector be able to follow the dynamics of the signal from the final IF, and that the bandwidth of the detector be much wider than the RBW.

It is also important that all averaging processes involved in an RMS power measurement happen on the power scale.

RMS detection often refers to display detector operations that perform RMS calculations on the voltage output of the envelope detector. If the conditions mentioned above are met, power measurements will accurately indicate total signal+noise power, without regard to the statistics of the signals involved.



Detector Example: GSM Output RF Spectrum Due to Modulation

- Time-selective spectral measurement
- Usually presented in tabular form
- Average detector improves measurement speed by processing more envelope detector samples
- Log averaging scale satisfies the standard
- Band / interval marker reports average power across the specified interval

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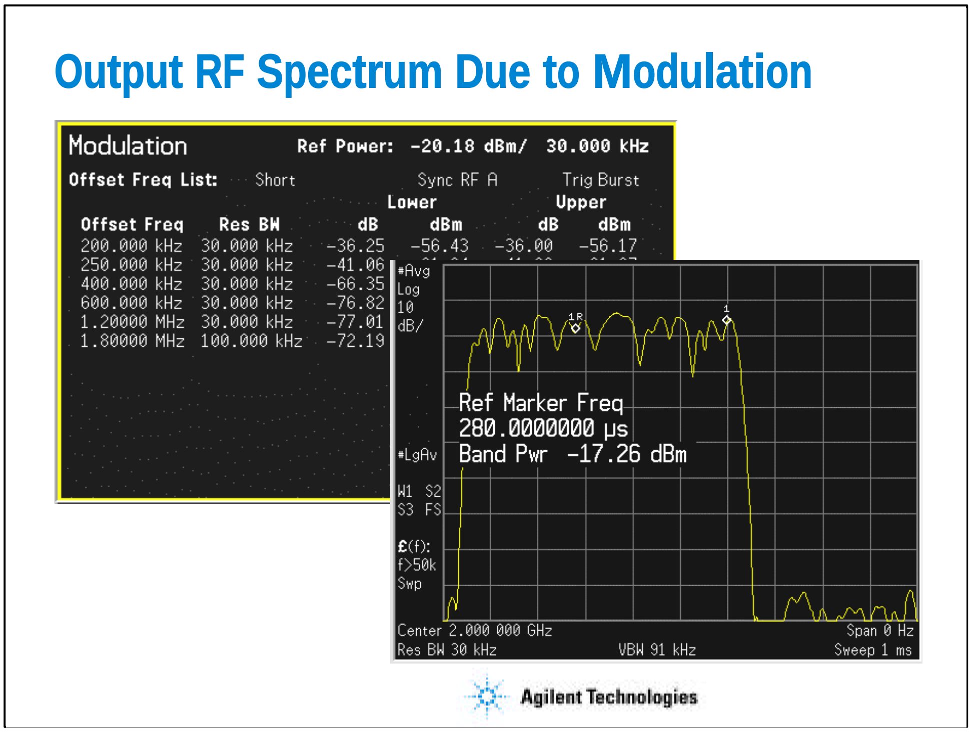
One example of a detector choice is the measurement of output RF spectrum (ORFS) due to modulation for global system for mobile communications (GSM) signals. This is a time-selective spectral measurement that can be performed by spectrum analyzers, though the results are compiled from multiple spectral measurements and may be presented in tabular form. The spectrum analyzer performs this measurement in a zero span configuration.

In this measurement, an average detector is a better choice (if available) than a sample detector because it is able to process more envelope detector samples and improve measurement speed by reducing variance faster.

Many other spectrum analyzer setup selections for the measurement of ORFS (due to modulation) are made with reference to GSM standards. For example, the log average is taken across the 40-90% times of the bursts. This time selectivity may be achieved by using a band/interval marker in its (time) interval marker mode.



Output RF Spectrum Due to Modulation

Modulation **Ref Power: -20.18 dBm/ 30.000 kHz**

Offset Freq List: Short Sync RF A Trig Burst

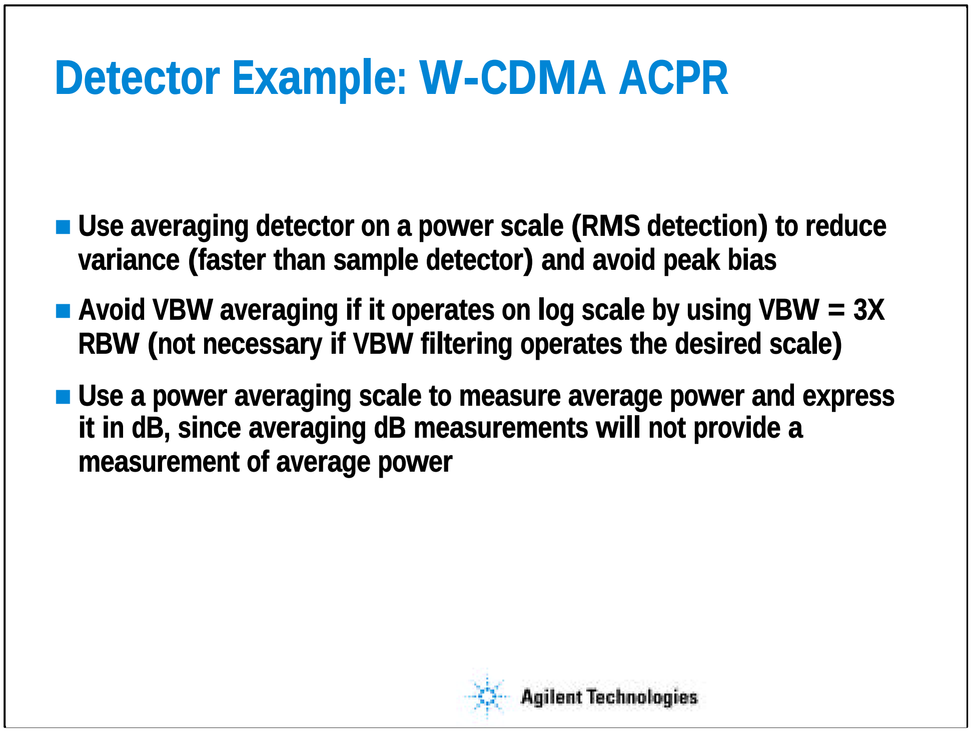
		Lower		**Upper**	
Offset Freq	**Res BW**	**dB**	**dBm**	**dB**	**dBm**
200.000 kHz	30.000 kHz	-36.25	-56.43	-36.00	-56.17
250.000 kHz	30.000 kHz	-41.06			
400.000 kHz	30.000 kHz	-66.35			
600.000 kHz	30.000 kHz	-76.82			
1.20000 MHz	30.000 kHz	-77.01			
1.80000 MHz	100.000 kHz	-72.19			

Ref Marker Freq
280.0000000 µs
Band Pwr -17.26 dBm

These example measurements show a measurement of GSM ORFS due to modulation in two different forms.

The tabular display on the left shows the entire ORFS measurement, with the relative and absolute powers of the upper and lower offset frequencies. This measurement was made not with a spectrum analyzer, but with an Agilent VSA-Series transmitter tester.

The traditional zero-span spectrum measurement on the right is of the main channel, with relative markers at the 40 and 90% times of the burst. In this zero span configuration the band power marker functions as an interval marker.



Detector Example: W-CDMA ACPR

- Use averaging detector on a power scale (RMS detection) to reduce variance (faster than sample detector) and avoid peak bias
- Avoid VBW averaging if it operates on log scale by using VBW = 3X RBW (not necessary if VBW filtering operates the desired scale)
- Use a power averaging scale to measure average power and express it in dB, since averaging dB measurements will not provide a measurement of average power

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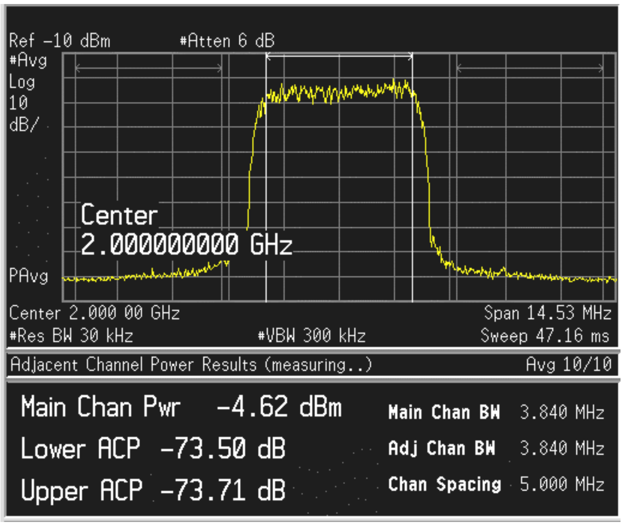
Since ACPR is a ratio measurement of the power of two noise-like signals, there is the potential for some measurement errors due to detector selection and averaging to cancel each other. However it is always better to make the measurement in a way that will be independent of signal statistics, since these statistics may not be precisely known, and some CW signals may be present in the signal. In addition, some standards will call for measurements of absolute power in adjacent channel measurements where no ratio operation is performed.

If available, an averaging detector is desirable for these measurements because it will reduce measurement variance faster than a sample detector.

To avoid VBW averaging, it is recommended to use a VBW that is at least three times larger than the RBW. However if the video filtering is able to operate on the desired scale, this precaution is not necessary.

Averaging scales will be described later in this presentation, but in general it is important to use a scale that accurately averages signal power and expresses it in dB, rather than averaging dB measurements.

W-CDMA ACPR



```
Ref -10 dBm          #Atten 6 dB
#Avg
Log
10
dB/

Center
2.000000000 GHz
PAvg
Center 2.000 00 GHz                              Span 14.53 MHz
#Res BW 30 kHz             #VBW 300 kHz          Sweep 47.16 ms
Adjacent Channel Power Results (measuring..)         Avg 10/10

Main Chan Pwr    -4.62 dBm      Main Chan BW   3.840 MHz
Lower ACP  -73.50 dB            Adj Chan BW    3.840 MHz
Upper ACP  -73.71 dB            Chan Spacing   5.000 MHz
```

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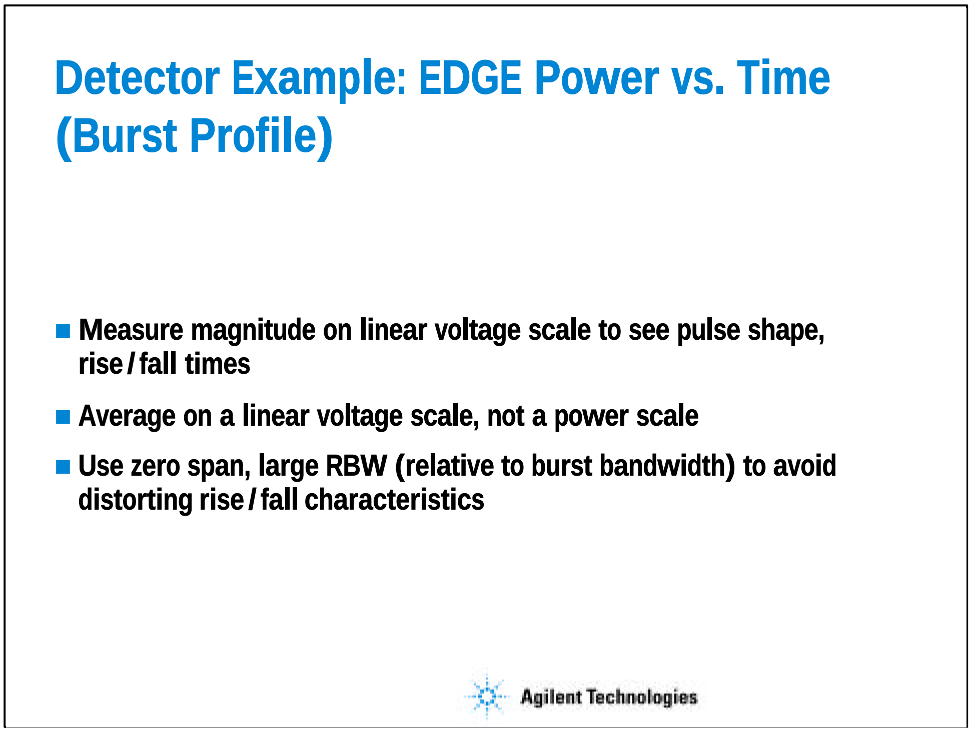
This is a basic ACPR measurement, covering the main channel and the upper and lower first adjacent channels. The channel power is measured in frequency bands 3.84 MHz wide, with a channel spacing of 5 MHz.



Detector Example: EDGE Power vs. Time (Burst Profile)

- **Measure magnitude on linear voltage scale to see pulse shape, rise / fall times**
- **Average on a linear voltage scale, not a power scale**
- **Use zero span, large RBW (relative to burst bandwidth) to avoid distorting rise / fall characteristics**

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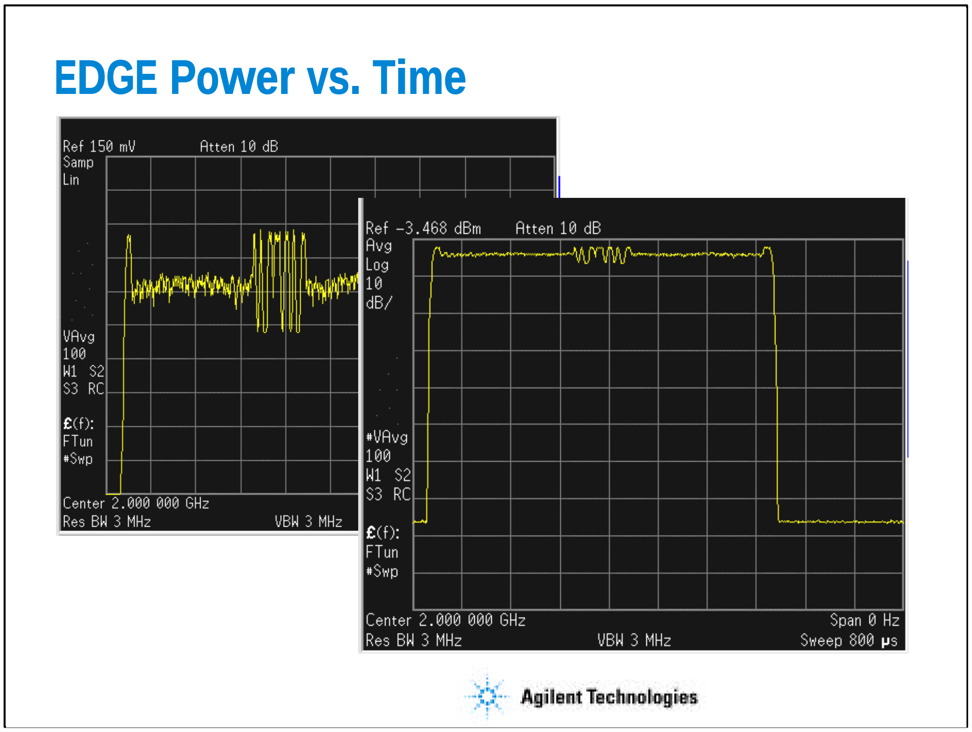
EDGE signals are generally measured in a way very similar to GSM, though EDGE modulation causes amplitude variation in the signal and consequently some differences in specified tests and test setups. For example, amplitude limits are wider for the useful part of the burst, and modulation quality parameters are changed from global phase error-to-error vector magnitude (EVM).

For measurement of pulse shape and rise/fall times, a linear voltage scale is a good choice. Accordingly, averaging is also performed on a linear voltage scale rather than a power scale.

This measurement is made in a zero span mode. It is important to measure the pulse shape characteristics accurately, and avoid distortion by the filters in the spectrum analyzer. Accordingly, RBW and VBW are set to values that are large relative to the burst bandwidth.



EDGE Power vs. Time

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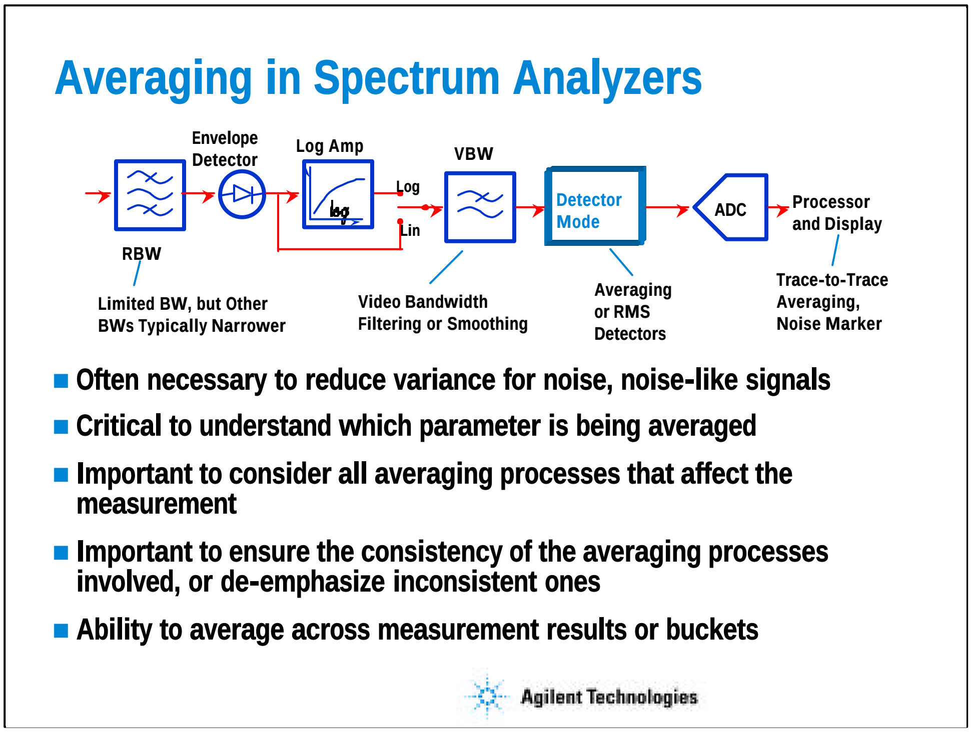
Power vs. time measurements of an EDGE signal are shown here in two different display formats. The Y-axis of the display on the left is in linear (voltage) form, while the Y-axis of the display on the right is in logarithmic form.

The linear scale is often used to observe pulse rise/fall times, while the log scale is able to represent large on/off power ratios.

In both displays, note the effect of averaging on the different portions of the burst. The tail bits and midamble of the signal are repeated from burst to burst, and averaging reveals a consistent amplitude value for each point in time. For the useful part of the burst, however, the random data in the modulation causes the signal average to converge on a value that does not represent a specific modulation state.

These measurements were made with an Agilent PSA Series spectrum analyzer, and illustrate a unique benefit of this analyzer—though the display scales are different, the averaging for both displays is able to operate on the desired linear scale.



Averaging in Spectrum Analyzers

- Often necessary to reduce variance for noise, noise-like signals
- Critical to understand which parameter is being averaged
- Important to consider all averaging processes that affect the measurement
- Important to ensure the consistency of the averaging processes involved, or de-emphasize inconsistent ones
- Ability to average across measurement results or buckets

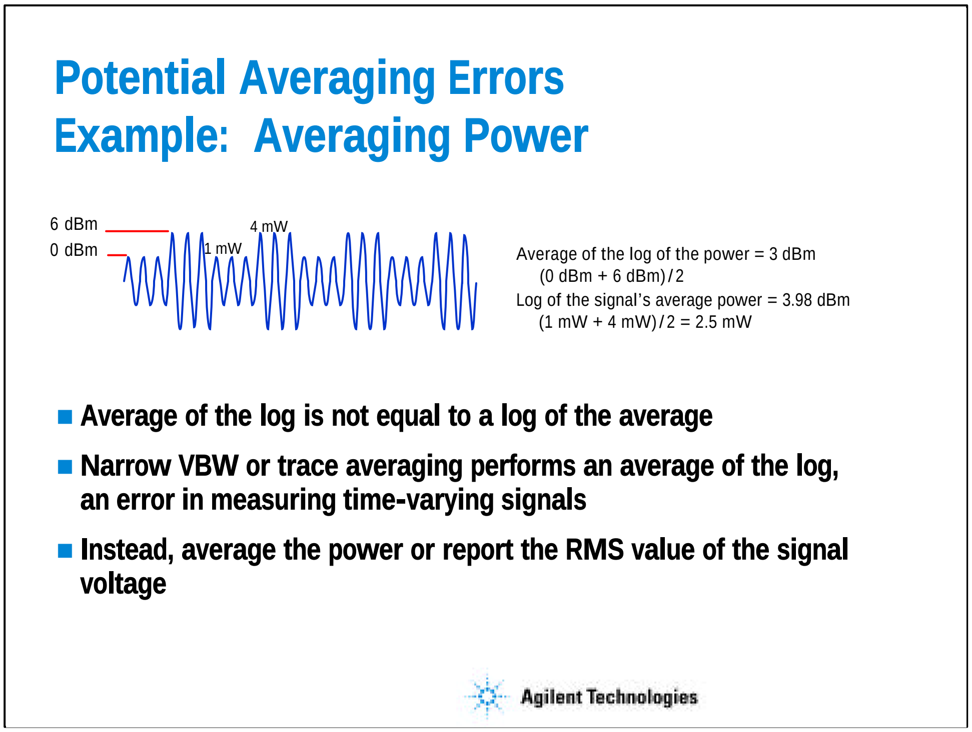
Averaging is obviously important in measuring noise and noise-like signals. While it is true, in general, that it is signal amplitude that is being averaged in all cases, it is still necessary to choose (and understand) the correct averaging scale.

For example, the logarithmic value of the amplitude could be averaged by calculating the average in decibel units, a logarithmic scale. Alternatively, the amplitude could be averaged on a power scale, say in watts units.

As shown here, there are a number of averaging processes available in the spectrum analyzer. Since each one of these can affect the accuracy and speed of measurements, it is important to consider all averaging processes that can affect the measurement.

In particular, it is important to ensure that the averaging processes used in a measurement are consistent in their operation. Alternatively, it is often possible to de-emphasize averaging processes that are inconsistent with the desired measurement. On example of this de-emphasis would be the previously-mentioned choice of a VBW that is at least three times greater than the RBW. For more detail on the effects of this de-emphasis, see Application Note 1303, mentioned in the references section at the end of this document.

So far we have been concentrating on averaging processes that operate to produce individual display results or buckets. One averaging process that is very useful in some measurement is the averaging of display results or buckets into a composite measurement. The noise marker function available in some analyzers is an example of this process.



Potential Averaging Errors
Example: Averaging Power

Average of the log of the power = 3 dBm
(0 dBm + 6 dBm)/2
Log of the signal's average power = 3.98 dBm
(1 mW + 4 mW)/2 = 2.5 mW

- **Average of the log is not equal to a log of the average**
- **Narrow VBW or trace averaging performs an average of the log, an error in measuring time-varying signals**
- **Instead, average the power or report the RMS value of the signal voltage**

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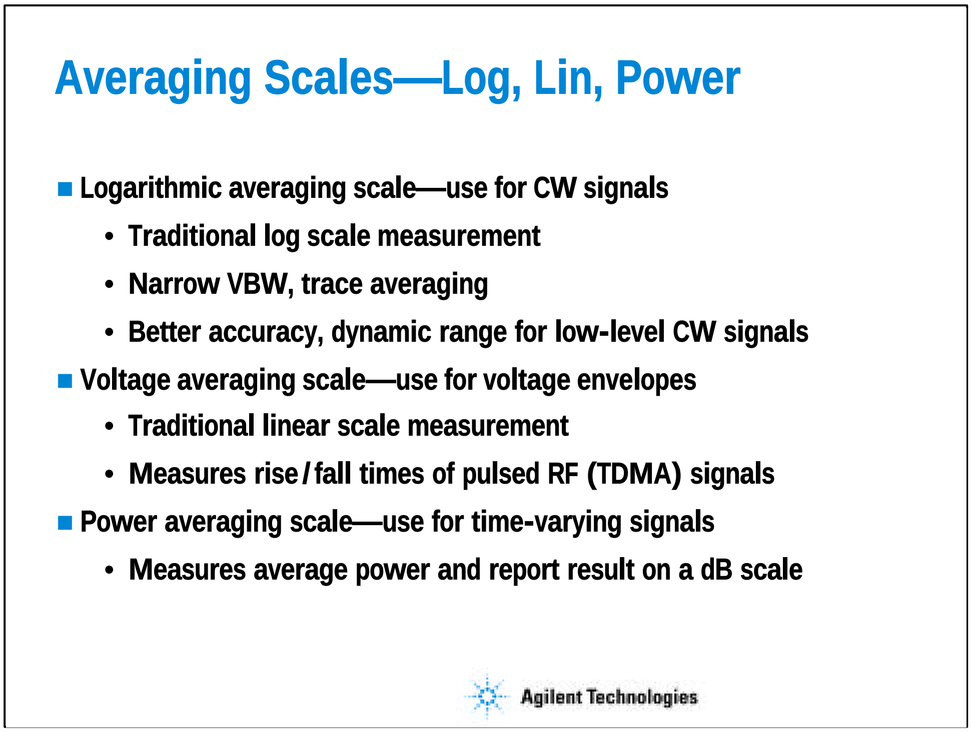
Traditional swept spectrum analyzers average the logarithm of the envelope when the display is in logarithmic mode (as it usually is). However if one wants to measure the average power of the signal and to express it in logarithmic (dB) units, there is a problem with this approach. The problem is that the average of the logarithmic value of the power (which the traditional swept analyzer would display) is not equal to the logarithm of the average of the power.

An example will illustrate this difference: Consider a signal with a power of 0 dBm (1 mW) for 10 ms and a power of +6 dBm (4 mW), also for 10 ms. For measurement times much longer than 20 ms, the average of the log of the power is +3 dBm, while the signal's average power is 2.5 mW or 3.98 dBm.

Therefore when making power measurements it is important to average the power of the signal or, equivalently, to report the root of the mean of the square (RMS value) of the signal voltage.



Averaging Scales—Log, Lin, Power

- Logarithmic averaging scale—use for CW signals
  - Traditional log scale measurement
  - Narrow VBW, trace averaging
  - Better accuracy, dynamic range for low-level CW signals
- Voltage averaging scale—use for voltage envelopes
  - Traditional linear scale measurement
  - Measures rise / fall times of pulsed RF (TDMA) signals
- Power averaging scale—use for time-varying signals
  - Measures average power and report result on a dB scale

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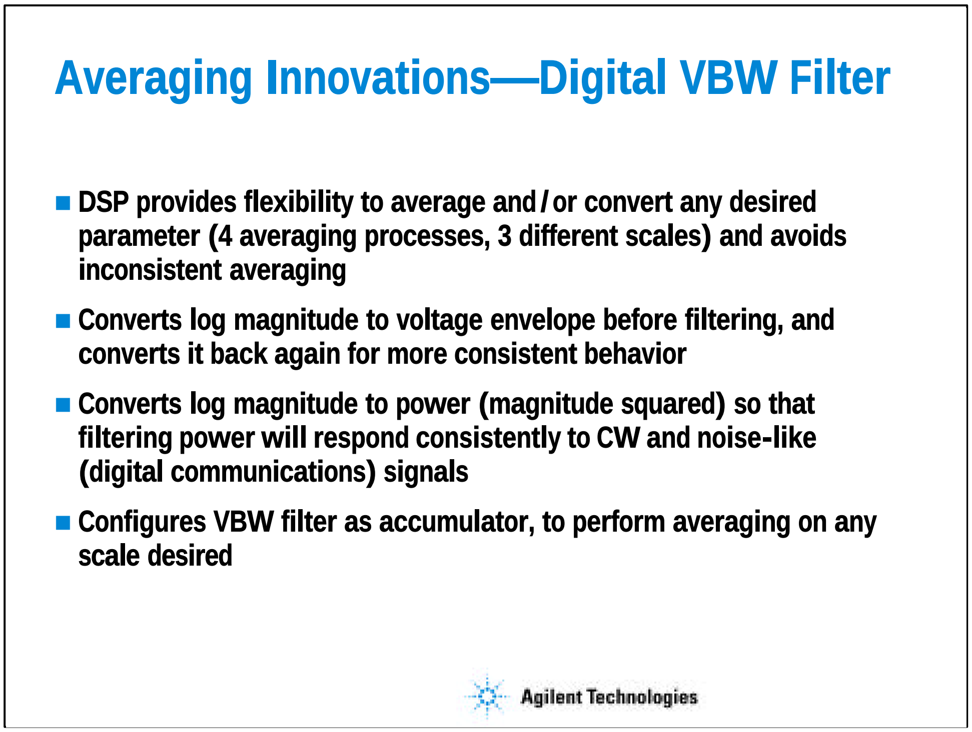
Logarithmic averaging is the traditional scale used in spectrum analyzers. It is a good choice for CW signals and can be implemented as a narrow VBW or trace-to-trace averaging of logarithmically-scaled values.

Though power averaging is the best way to measure the power of complex signals, it is not the best technique for CW signals. For accurately measuring low-level CW signals in the presence of noise, logarithmic averaging is a very useful tool. Because logarithmic averaging under-responds to noise but does not under-respond to signals, it actually improves the signal/noise ratio of these measurements. Therefore if you measure the average value of the signal level in the presence of noise, the log scale will give you much smaller errors in signal measurements.

In some cases, one may want to measure and average a voltage envelope. One typical example is the measurement of the rise and fall times of pulsed RF signals, such as the timeslots in a time division multiple access (TDMA) frame of a digital communications signal such as IS-136 or GSM. This is often called a linear (or "lin") scale measurement, though it might better be called a voltage average to distinguish it from averaging on a linear wattage scale. A linear wattage scale (a power scale) is different from a linear voltage scale.



Averaging Innovations—Digital VBW Filter

- DSP provides flexibility to average and / or convert any desired parameter (4 averaging processes, 3 different scales) and avoids inconsistent averaging
- Converts log magnitude to voltage envelope before filtering, and converts it back again for more consistent behavior
- Converts log magnitude to power (magnitude squared) so that filtering power will respond consistently to CW and noise-like (digital communications) signals
- Configures VBW filter as accumulator, to perform averaging on any scale desired

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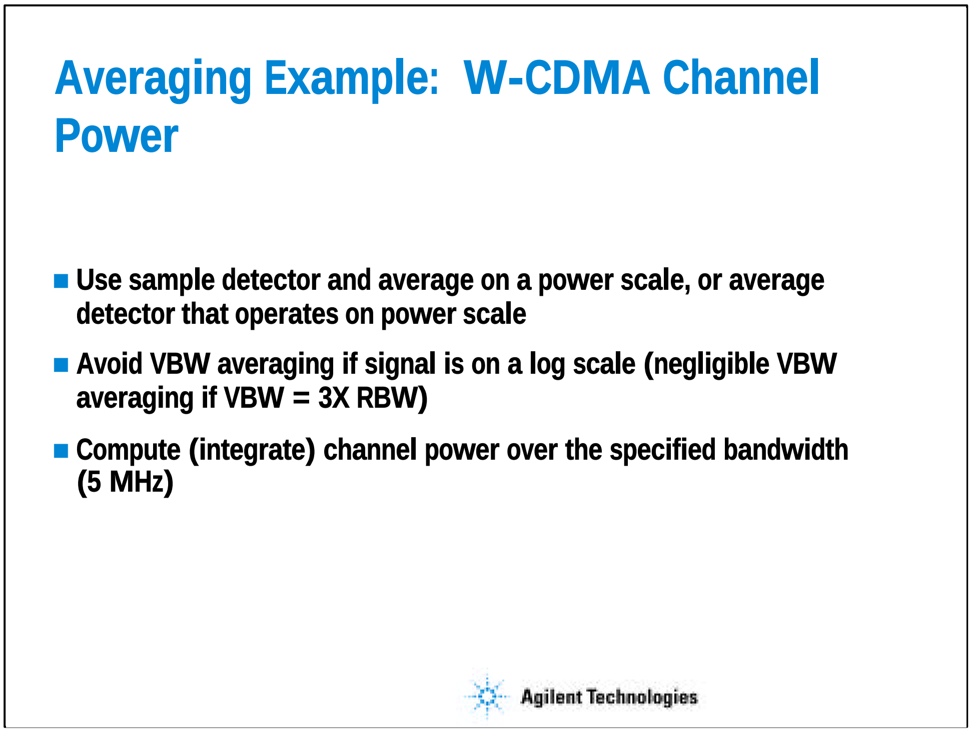
Digital signal processing offers a number of advantages and opportunities in averaging techniques. In particular, DSP and digital filters can provide the flexibility to average a parameter using several different averaging processes and different scales. This offers a significant benefit to the spectrum analyzer user in terms of avoiding inconsistent averaging.

The digital VBW filter can be configured to convert signals from one form to another. For example, it can be used to convert a log magnitude signal to power and filter or average the signal in power form. The average can then be converted back into log form, providing a logarithmic measurement of a signal that will yield the same response to CW signals and noise.

Using DSP it is also possible to convert the VBW filter to other processes. For example, the VBW filter can be configured as an accumulator, enabling it to perform averaging on any desired scale.



Averaging Example: W-CDMA Channel Power

- Use sample detector and average on a power scale, or average detector that operates on power scale
- Avoid VBW averaging if signal is on a log scale (negligible VBW averaging if VBW = 3X RBW)
- Compute (integrate) channel power over the specified bandwidth (5 MHz)

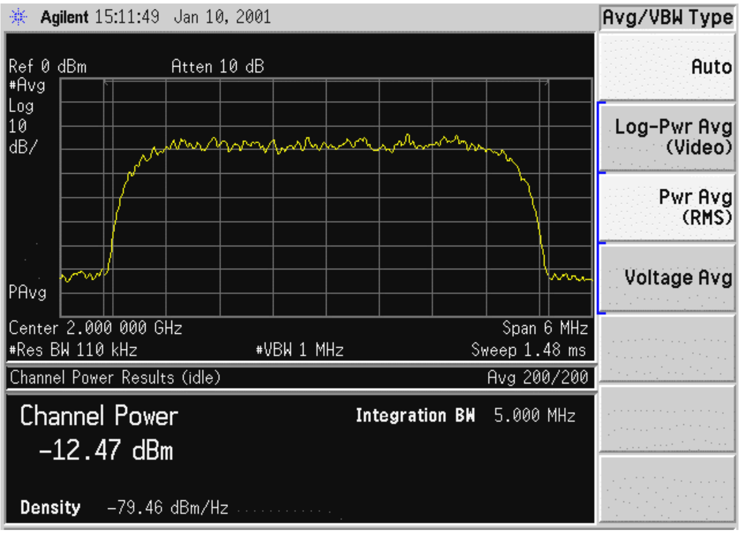
Agilent Technologies

The basis of a channel power measurement is an accurate power measurement that covers the specified channel. For noise-like signals such as W-CDMA, this means that the typical detector and averaging choices for noise should be used.

One obvious detector choice would be the sample detector, to avoid peak detector bias. This is an acceptable choice, but the average detector operating on a power scale (if available) has the advantage of processing more samples from the envelope detector. Processing these additional samples provides a given level of variance faster.

As with the measurements described previously, it is important to avoid VBW averaging if the signal is measured on a log scale. Using a wide VBW will avoid averaging, but it is desirable to average on a power scale if available. The final step in the channel power measurement is to compute or integrate the channel power over the specified bandwidth, 5 MHz in the case of W-CDMA.

W-CDMA Channel Power



Center 2.000 000 GHz Span 6 MHz
#Res BW 110 kHz #VBW 1 MHz Sweep 1.48 ms

Channel Power Results (idle) Avg 200/200

Channel Power
-12.47 dBm

Integration BW 5.000 MHz

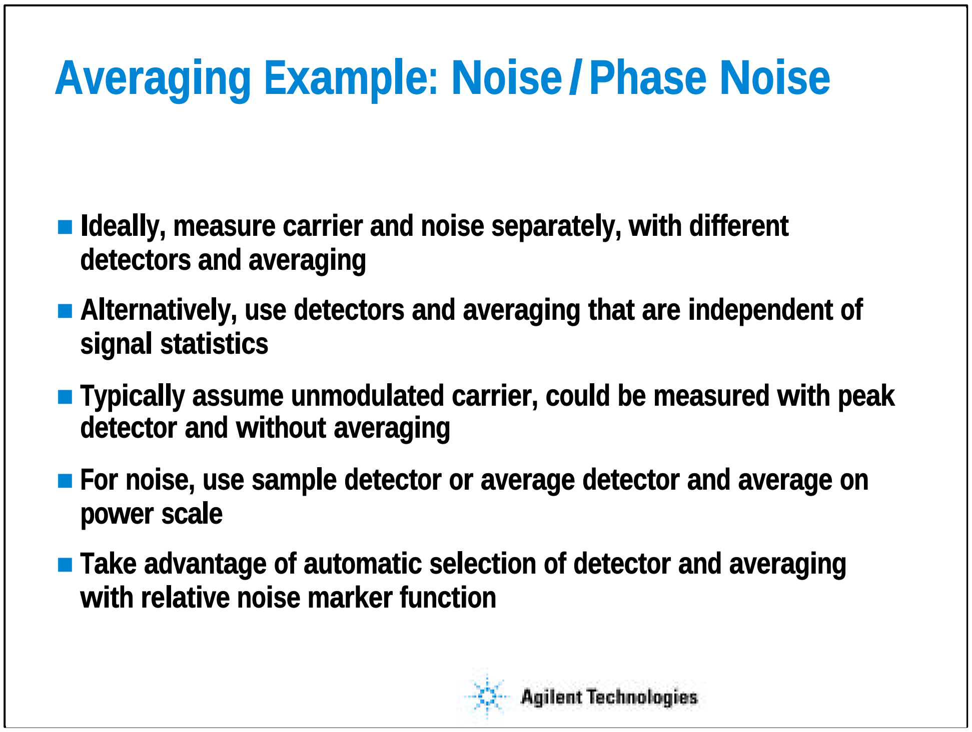
Density -79.46 dBm/Hz

Agilent Technologies

This is a channel power measurement of a W-CDMA signal.

The Agilent PSA Series spectrum analyzer used to make this measurement has automatically selected the power average (RMS) scale because a channel power measurement has been selected.

Since the VBW averaging of the PSA Series operates on the desired scale, there is no need to make the VBW wider than the RBW, though that has been done in this case.



Averaging Example: Noise / Phase Noise

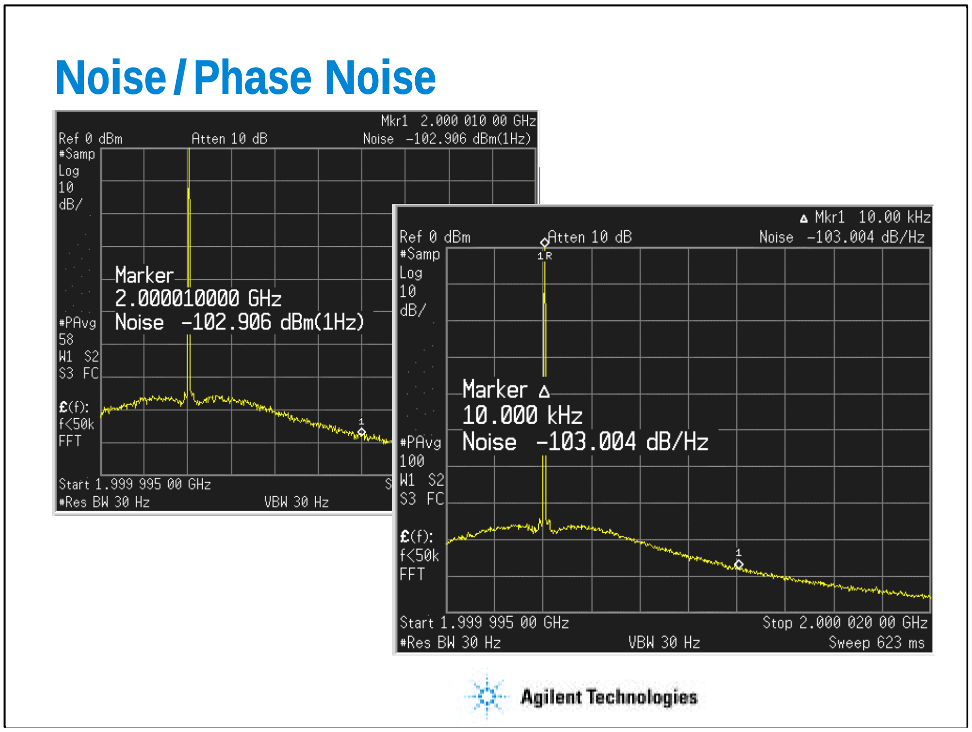
- Ideally, measure carrier and noise separately, with different detectors and averaging
- Alternatively, use detectors and averaging that are independent of signal statistics
- Typically assume unmodulated carrier, could be measured with peak detector and without averaging
- For noise, use sample detector or average detector and average on power scale
- Take advantage of automatic selection of detector and averaging with relative noise marker function

Agilent Technologies

Phase noise measurements offer considerable opportunity for subtle, though significant, errors. One major source of error is the need to accurately measure both carrier power (typically an unmodulated CW signal) and noise at a specified offset or over a designated frequency band.

If possible, it is desirable to make measurements of the noise and perform averaging on the power (RMS) scale. This will reduce more quickly the variance of the measurement. Both trace averaging and video averaging can be used, if performed on the proper scale.

For measurements at a specific offset, a noise marker function (if available) can be used to speed and simplify the measurement. Depending on the analyzer used, the noise marker function may be able to automatically choose detector and averaging functions.



Noise / Phase Noise

Mkr1 2.000 010 00 GHz
Ref 0 dBm Atten 10 dB Noise -102.906 dBm(1Hz)
#Samp
Log
10
dB/
Marker
2.000010000 GHz
Noise -102.906 dBm(1Hz)
#PAvg
58
W1 S2
S3 FC
£(f):
f<50k
FFT
Start 1.999 995 00 GHz
#Res BW 30 Hz VBW 30 Hz

Δ Mkr1 10.00 kHz
Ref 0 dBm Atten 10 dB Noise -103.004 dB/Hz
#Samp
Log
10
dB/
Marker Δ
10.000 kHz
Noise -103.004 dB/Hz
#PAvg
100
W1 S2
S3 FC
£(f):
f<50k
FFT
Start 1.999 995 00 GHz Stop 2.000 020 00 GHz
#Res BW 30 Hz VBW 30 Hz Sweep 623 ms

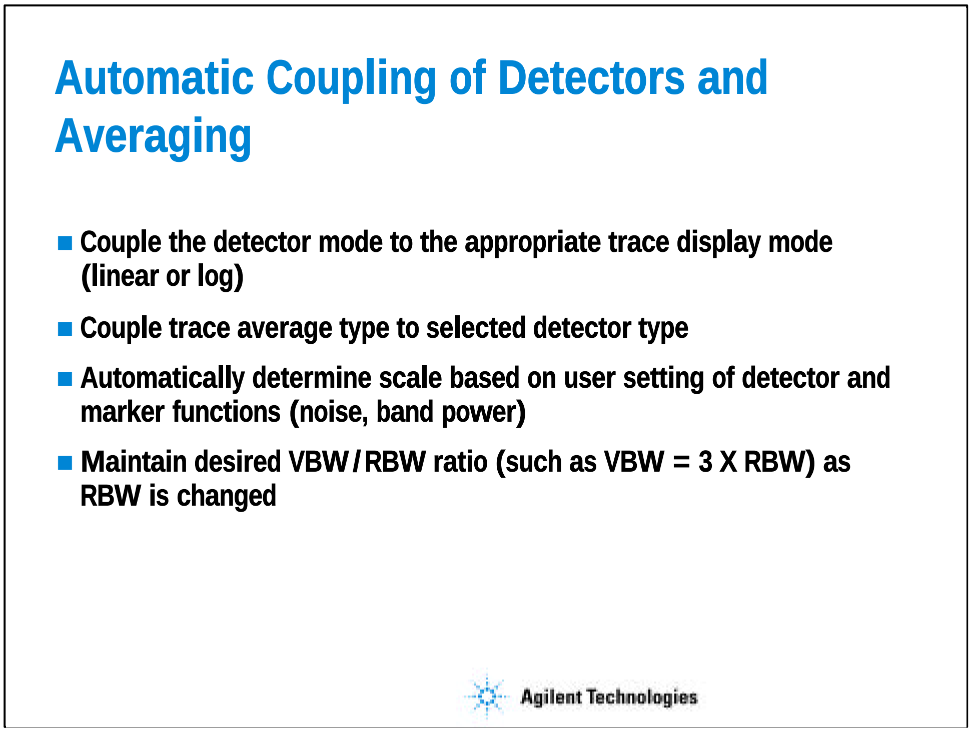
These are two equivalent measurements of the phase noise of 2 GHz CW carriers. The measurements have been performed with an Agilent PSA Series spectrum analyzer, which has automatically selected an FFT measurement mode for this measurement. The FFT mode in the PSA Series operates in a similar fashion (including detectors, averaging, spans, RBW/VBW, etc.) to swept analysis, though measurements are made much faster than swept analysis when RBWs are narrow.

In both cases, a power averaging scale has been used. Each measured trace represents 100 averages.

Phase noise is typically measured as power spectral density (noise density), and is usually normalized to a 1 Hz bandwidth.

For measurements at a specific offset (10 kHz in this case), the noise marker function has been used to speed and simplify the measurement setup. The noise marker function averages the power over 32 display buckets and reports the average power spectral density.

The measurement on the left is absolute power spectral density at a 10 kHz offset. The measurement on the right is a more typical phase noise measurement, where power spectral density at the 10 kHz offset is expressed relative to the carrier power. The noise marker and delta marker functions can be used together to facilitate this measurement. Since the reference point for the delta marker is the carrier, the relative measurement is thus in units of dBc/Hz.



Automatic Coupling of Detectors and Averaging

- Couple the detector mode to the appropriate trace display mode (linear or log)
- Couple trace average type to selected detector type
- Automatically determine scale based on user setting of detector and marker functions (noise, band power)
- Maintain desired VBW / RBW ratio (such as VBW = 3 X RBW) as RBW is changed

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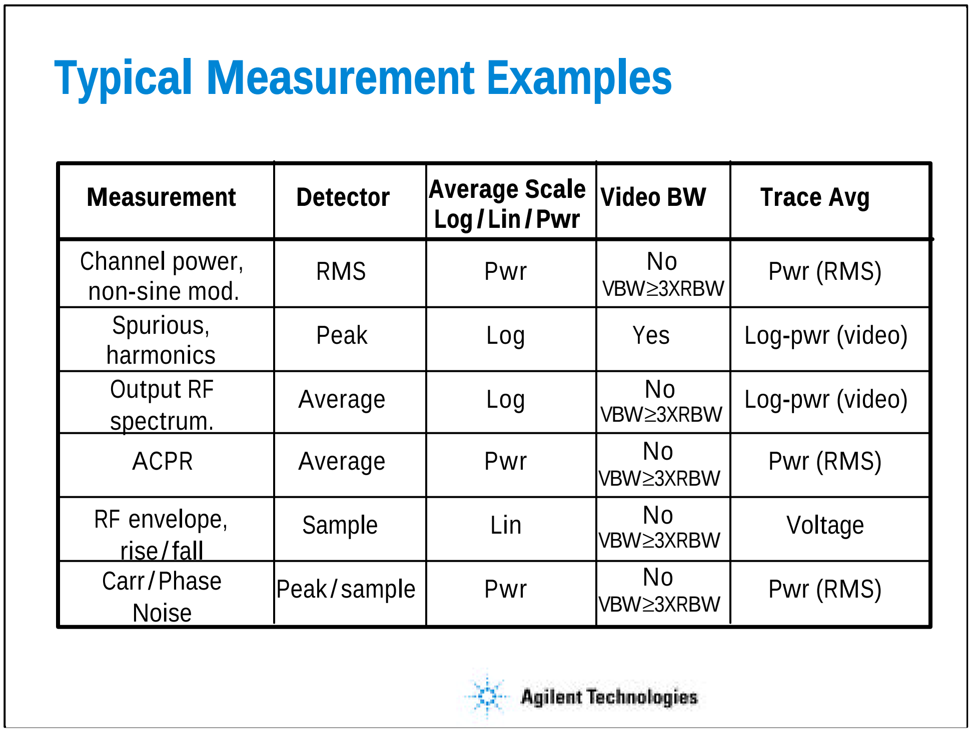
Since certain relationships between detector modes and averaging types are important for accurate measurements, it makes sense to automatically couple these parameters. This coupling can take several different forms, depending on other analyzer selections.

In many cases, the trace display mode can be used to drive the selection of the detector mode. The average type can then be automatically selected to be consistent with the detector mode.

The selection of other analyzer functions, such as band power calculations and noise markers, can also be used to automatically determine detector mode and averaging type.

Automatic coupling can also be used to maintain a desired relationship between analyzer settings, such as the selection of VBW wider than RBW to avoid video averaging.



Typical Measurement Examples

Measurement	Detector	Average Scale Log/Lin/Pwr	Video BW	Trace Avg
Channel power, non-sine mod.	RMS	Pwr	No VBW≥3XRBW	Pwr (RMS)
Spurious, harmonics	Peak	Log	Yes	Log-pwr (video)
Output RF spectrum.	Average	Log	No VBW≥3XRBW	Log-pwr (video)
ACPR	Average	Pwr	No VBW≥3XRBW	Pwr (RMS)
RF envelope, rise/fall	Sample	Lin	No VBW≥3XRBW	Voltage
Carr/Phase Noise	Peak/sample	Pwr	No VBW≥3XRBW	Pwr (RMS)

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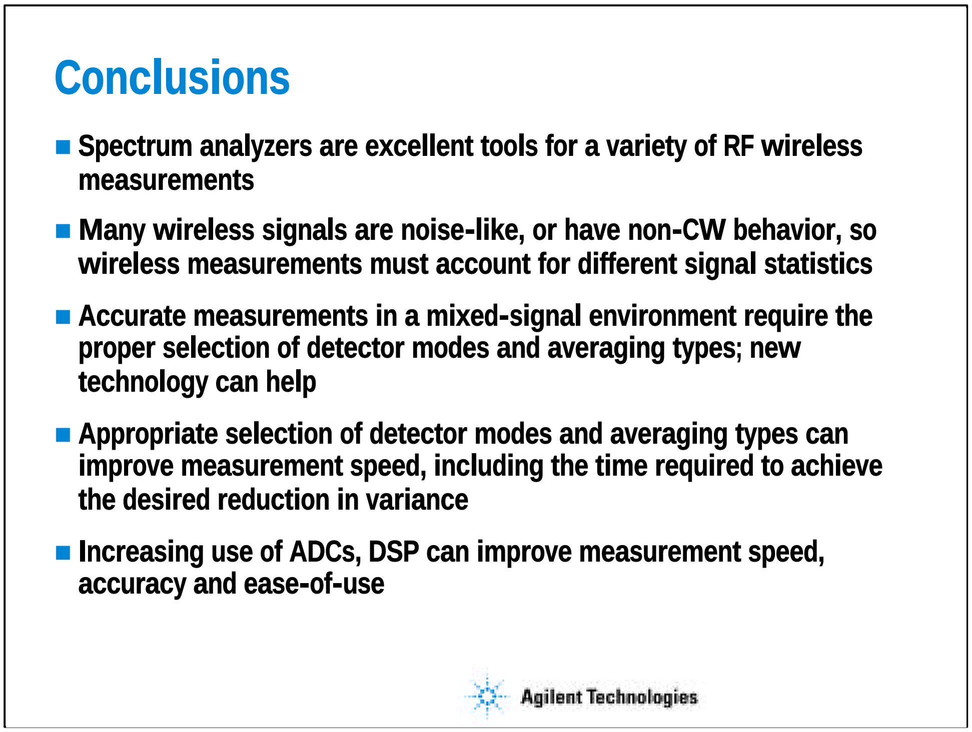
This table summarizes the typical selections for detectors and averaging for a number of common measurement types.

While these settings are recommended for accuracy and measurement speed, other settings may provide acceptable performance.

Settings other than those shown above may, however, be necessary if specified by a particular standard, or for compatibility with measurements made previously.



Conclusions

- Spectrum analyzers are excellent tools for a variety of RF wireless measurements
- Many wireless signals are noise-like, or have non-CW behavior, so wireless measurements must account for different signal statistics
- Accurate measurements in a mixed-signal environment require the proper selection of detector modes and averaging types; new technology can help
- Appropriate selection of detector modes and averaging types can improve measurement speed, including the time required to achieve the desired reduction in variance
- Increasing use of ADCs, DSP can improve measurement speed, accuracy and ease-of-use

Agilent Technologies

The spectrum analyzer will retain its role as the wireless engineer's primary signal analysis tool, even as measurement types and signals become more complex.

With proper selection of measurement parameters, spectrum analyzers are capable of accurate measurements of noise and the noise-like signals used in wireless applications, in addition to the CW and sinusoidally-modulated signals they were originally designed for.

New technology in spectrum analyzer can help the wireless designer in a number of ways. More extensive use of ADCs and DSP will allow for more sophisticated and flexible detector modes and averaging types. Carefully designed automatic selection of spectrum analyzer parameters, such as detector modes and averaging types, can make measurements easier and more reliable.

Whether analyzer parameters are automatically or manually chosen, it is important to understand detectors and averaging as they apply to wireless measurements. This understanding will ensure that measurements are properly optimized for measurement accuracy, speed and dynamic range.

References

- **Gorin, Joe. *Spectrum Analyzer Measurements and Noise*. Agilent application note 1303, literature number 5966-4008E** (6/00)
- **Peterson, Blake. *Spectrum Analysis Basics*. Agilent application note 150, literature number 5952-0292** (11/00)

(**Application notes available at www.Agilent.com)**

- **Avenell, Brian. *Optimizing Dynamic Range for Distortion Measurements*, Agilent PSA Series product note, literature number 5980-3079EN (see www.Agilent.com/find/PSA)**
- **Gorin, Joe. *"All-Digital IF Gives New Spectrum Analyzers FFT Speed and Swept Dynamic Range,"* Applied Microwave & Wireless Magazine, December, 2000 p. 88-96**