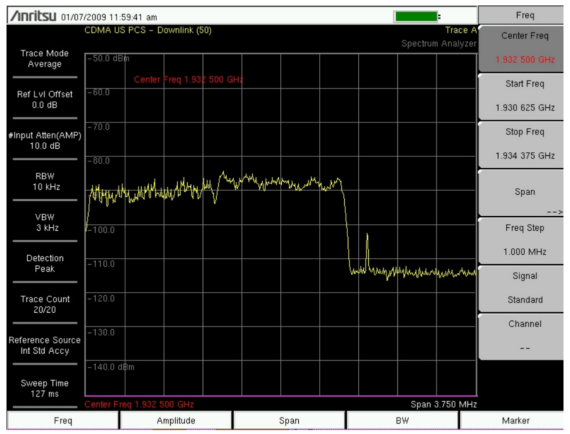
Spectrum Analyzers Field User Guide – utilizing Anritsu's Handheld Spectrum Master™, Site Master™, Cell Master™, and BTS Master™

RF Measurements
Why use a Spectrum Analyzer?
Spectrum Analyzer Setup (Part 1)



A Spectrum Analyzer lets you see signal problems. If you can't see it, you can't fix it.

Why use a spectrum analyzer?

Spectrum analyzers display RF signals from base stations and other emission sources. They find rouge signals, measure carriers and distortion, and verify base stations. Unlike a power meter, they validate carrier frequency and identify desired and undesired signals.

Spectrum Analyzer Setup

RF signals have a frequency, bandwidth, and power. To best view an RF signal, three things need to be set.

Adjust the center frequency to center the desired signal. Entering a known carrier frequency is a common way to do this. Other common methods use the knob or arrow buttons, a channel number, or the Marker to Center function.

Adjust the span so that the desired signal covers about half of the screen.

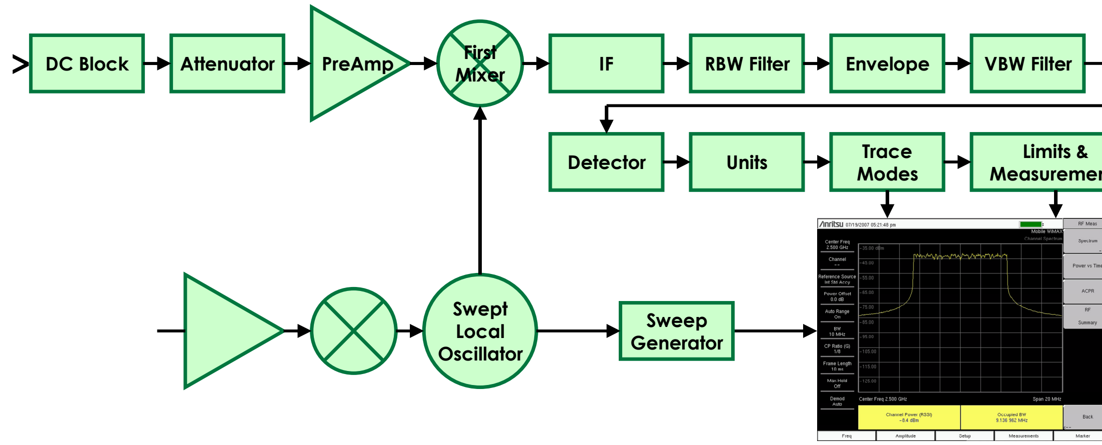
Adjust the reference level to bring the top of the signal near the top of the screen.

This is a flexible process. Often, it is best to start out with a close center frequency, an approximate reference level, and narrow the span (span down) in stages, re-centering the signal as you go. Otherwise, the signal may move off the side of the screen as you span down.

Common Cellular Bands (MHz)

E-UTRA Band	Uplink	Downlink
12	698-716	728-746
13	777-787	746-756
5	824-849	869-894
8	880-915	925-960
3	1710-1785	1805-1990
2	1850-1910	1930-1990
1	1920-1990	2110-1270
10	1710-1770	2110-2170
7	2500-2570	2620-2690

A Users' Spectrum Analyzer Block Diagram Description



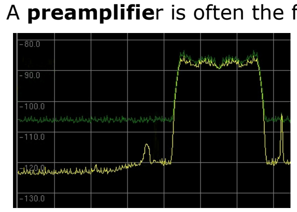
Block Diagram Description

Spectrum analyzer users need to understand major analyzer functional blocks. While most of the choices described here are made automatically, manual selections are possible and can be helpful.

The **DC block** prevents DC voltage from entering the instrument, and allows measuring lines with DC power.

The **step attenuator** helps to prevent overdriving the first mixer; excessive level at the first mixer causes distortion visible on the display. Spectrum analyzers normally enable the step attenuator when the reference level is over -20 dBm or so. The step attenuator raises the noise floor when enabled, but allows measuring higher signal levels. You can think of this as matching the dynamic range of the analyzer to the input signal level.

A **preamplifier** is often the first block in a spectrum analyzer. Use it for weak signals, lower than about -50 dBm. When on, it reduces the noise floor by about 10-15 dB. Turn it off if the RF signals are higher than -40 dBm or so.

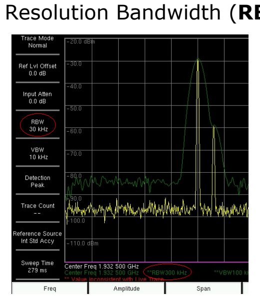


The preamplifier reduces the noise level, allowing lower-level signals to be seen in the yellow trace, where they couldn't be seen without the preamp in the green trace.

The **first mixer** is the first down-conversion stage, the stage that changes the RF frequency to an intermediate frequency (IF). The step attenuator and preamplifier allow adjusting the input signal to match what the first mixer needs to see.

IF section contains further mixers and creates more IF frequencies.

Resolution Bandwidth (**RBW**) sets the level of signal detail displayed. RBW also affects the noise floor. Lower RBW settings show more detail and create a lower noise floor, but cause slower sweeps. Higher RBW settings are good for wider spans since they sweep faster, at the cost of less detail and a higher noise floor.



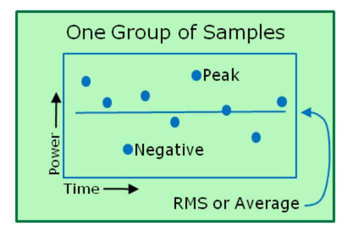
Two traces showing the effect of two different resolution bandwidths (30 kHz in yellow and 300 kHz in green)

The **Envelope** detector converts the signal into a video signal that can be displayed.

The **video filter** (VBW) averages the envelope, giving more stable answers for noisy or noise-like signals (such as digital modulation). It is also useful when looking for small consistent signals near the noise floor, such as spurious CW signals, as well as when measuring noise or Signal-to-Noise Ratio (SNR).

Block Diagram Description (continued)

The **detector** samples the IF signal and converts it to digital samples. The input to the detector normally is many more samples than can be displayed on the screen.



The detector chooses how to display signals when the RBW is less than a display point.

The detector groups samples, creating one group for each display point. It then chooses one number related to each group for display.

- **Peak** displays the largest sample of each group. This is the default detector and is useful when looking at CW signals, as well as an intermittent or bursty signal.
- **RMS** calculates the average power of the grouped samples and displays that. This is useful when measuring noise or noise-like signals. Many cellular signals are noise-like.
- **Negative** displays the smallest sample of each group. This is useful when looking for dropouts of a signal, mostly in zero span.
- **Sample** picks just one of the input samples
- **Quasi Peak** (not shown) is useful and EMC (Electromagnetic Compatibility) measurements. This is a special detector type that emulates the response of the human ear to impulses.

Sweep speed is normally set automatically. It can be helpful to set lower sweep speeds manually when working with intermittent signals. In this case, the Max-Hold trace setting is also helpful.

Units converts the trace into other units, such as Watts or Volts.

Trace Modes include normal, average, max-hold and min-hold. Average reduces the variation of noise and noise-like signals. Max-hold and min-hold creates a record of the signals' highest and lowest excursions, respectively, and is useful for finding transients and measuring the power of wideband bursted signals—ones that can't be measured in zero span due to the bandwidth.

Limits and Measurements examine the trace to see if a limit line has been exceeded, and create numerical answers such as channel power.

The **Sweep Generator** tunes the Local Oscillator (LO) over frequency (Center – Span/2 to Center + Span/2), and provides a reference for the x-axis of the display. The rate of tuning is controlled by the sweep time control. Normally this is left to run as fast as possible for spectrum displays.

RF Measurements
Why use a Spectrum Analyzer?
Spectrum Analyzer Setup (Part 2)

The **first mixer level** is critical for proper performance. If an Over-the-Air (OTA) signal is overdriving the first mixer, false signals, or spurs, may appear. The noise floor may also rise and hide signals of interest. This can happen even if the OTA signal is outside of the current span.

Spectrum analyzers display an "overload" message if overload occurs. The first response is often to raise the reference level, either directly or by manually increasing the attenuation of the step attenuator.

An alternative is to use an external band pass filter to limit OTA signals to the band of interest. While filters do a great job of attenuating unwanted signals, you must have the right filter that passes the signal you are measuring with minimal loss. Anritsu has a selection of filters for this purpose.

An external filter can reject high-level signals that limit low-level measurements.

Coupled mode is the default operating mode for spectrum analyzers. In this mode, attenuation, RBW, and VBW values adjust automatically, set by the user's choice of reference level and span. In coupled mode, both span and reference level affect the noise floor.

Manual mode allows attenuation, RBW, VBW and to be set directly from the instrument's front panel. Manual mode allows making finer tradeoffs in noise level, distortion, trace variation, and sweep speed.

Manual attenuation capability is helpful when checking for distortion. A quick check to see if a signal is spurious is to change the step attenuator 10 dB. If the signal doesn't change, all is well; it is a real signal. If it changes by 10 dB or more, it is an internally generated intermodulation product. Sometimes the distortion can simply be ignored; in other cases increase the attenuation until the distortion level doesn't change.

Manual RBW capability is helpful when a lower noise floor, even at the expense of a slower sweep speed, is desirable, or faster sweep speed is needed, at the expense of higher noise floor and poorer frequency resolution. Every 10 times change in RBW means a 10 dB change in the noise floor.

Some spectrum analyzers will have a lower noise floor, at any given RBW, than others. The noise figure specification determines this, or you can estimate noise figure from

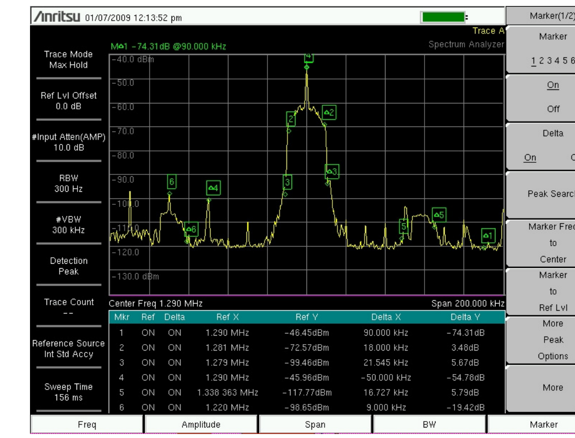
NF ≈ (DANL – 10*log(RBW for DANL))-174.

where DANL is the Displayed Average Noise Level specification, and RBW for DANL is the RBW used for the DANL spec—often this is 1 Hz, or the spec is normalized to 1 Hz, but this is not always the case.

Low-level signals are easier to see if attenuation is minimized and the preamplifier is on. Selecting lower RBW directly reduces the noise floor, and makes CW signals easier to see; unfortunately, many cellular communication signals are also noise-like and do not benefit from reduced RBW. Selecting lower VBW smoothes both the noise and noise-like signals, and can make it easier to see signals near the noise. Trace Averaging can also be used to further smooth the noise.

Intermittent signals can be viewed or monitored by max hold traces, gated sweep (on the next page), Save on Event with Limit Lines, and spectrograms.

Using Markers
Instrument Setup
Marker Measurements



Markers make it easy to verify amplitude & frequency points on the spectrum; the marker table lets you see up to 6 markers and delta values at a glance.

Instrument setup is faster when using Markers. The marker functions "Peak Search" and "Marker Freq to Center" can be very helpful, as they will find and center the strongest signal.

Unique **marker measurement** capabilities include fixed and tracking delta measurements ("Delta" or "Δ"is shorthand for difference).

Fixed markers are useful for delta measurement when the signal is intermittent. In this case, the reference marker can be fixed, or frozen, at a specific amplitude, even if the signal goes away. A tracking marker follows changes in trace amplitude.

Marker delta measurements can either use marker 1 as the reference, allowing six delta measurements, or use each of the six markers to have their own delta marker. This will allow up to 6 delta measurements and 12 total markers on one screen. This is a good way to measure and document signals.

Quick Conversion: dBm to Watts

Rule of doubles: Every 3 dB change in power doubles or halves the power.

The "Times Ten" rule: Notice how the 10's digit in the dBm row corresponds to the number of zeros on the milliwatt (mW) row. (e.g. 40 dBm = 4 zeros in mW, 10,000)

40 dBm	10,000 mW	10.0 Watt
30 dBm	1,000 mW	1.0 Watt
20 dBm	100 mW	0.1 Watt
10 dBm	10 mW	0.01 Watt
0 dBm	1 mW	0.001 Watt
-10 dBm	0.1 mW	100.0 µWatt
-20 dBm	0.01 mW	10.0 µWatt
-30 dBm	0.001 mW	1.0 µWatt

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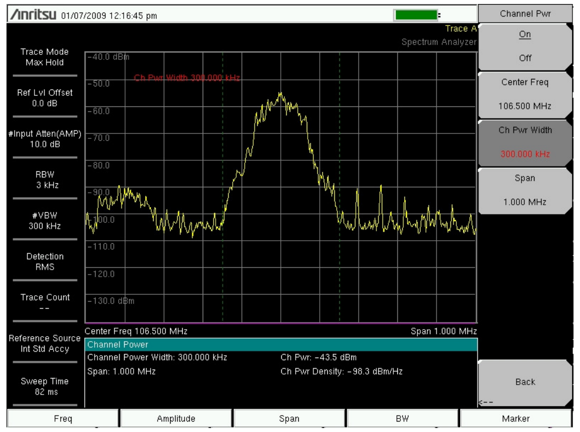
General Purpose Measurements
Channel Power, Rx Noise Floor
Field Strength Measurements



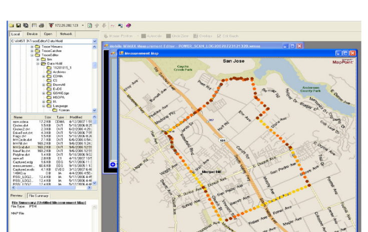
Channel Power measurements show the total power over a channel width.

Channel power measurements check transmitter power. The measurement represents the sum of RF power over the channel bandwidth. It yields a more meaningful number than a single frequency marker measurement. Channel power is often the first thing checked on a transmitter. It is both a first pass diagnostic for the radio and determines cell size, so it needs to be set accurately. A 1.5 dB difference in transmitted power translates to approximately a 15% difference in coverage area.

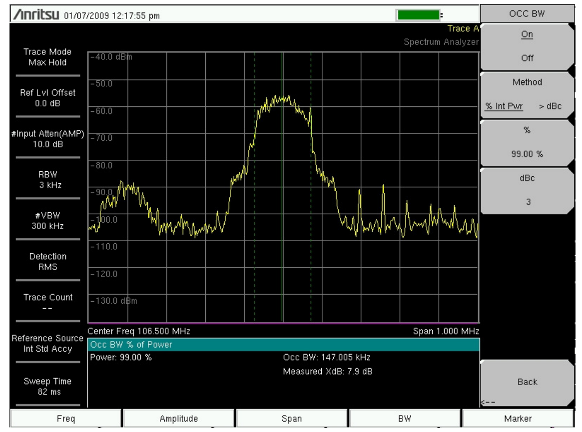
If a transmitter's channel power is off slightly, an adjustment often will fix it. If the power is a long way out of adjustment, the cause may be a radio, antenna, or feedline fault.

Rx Noise Floor uses the channel power measurement, but on the uplink, or receive channel. In this application, the spectrum analyzer measures power while the receive channel is not being used. Rx Noise Floor indicates the power levels of receive channel interference. Typical limits for Rx Noise Floor are approximately 20 dB above the ideal noise floor numbers for the channel width. This would be -100 dBm for GSM/ EDGE, -90 dBm for cdma2000/1xEVDO, and -80 dBm for WCDMA. To measure these low signal levels, turn on the instrument's preamp. If you are near a base station, you may need to adjust the input attenuation or move to where the base station signal is weaker; sometimes this can be *closer* to the base station.

Field Strength is channel power run through a conversion to compensate for the gain or loss of the external antenna, and to convert to the strength of the field. Since a field is spread out over an area the units are different—instead of dBm, you get dBm/m^2; instead of Volts, you get Volts/m. This is because the bigger the area, the more signal there is. Users can export field strength measurements, with GPS based location information, to PC-based mapping programs. Mapping coverage or interference is a powerful way to gain insight when the RF situation is complex.



General Purpose Measurements
Occupied Bandwidth (Occ BW)
Adjacent Channel Power Ratio (ACPR)



Use the Occupied Bandwidth measurement as a quick check that the transmitter is operating properly.

Occupied bandwidth is the spectrum width that contains a large percentage of the carrier power, often 99%. This measurement is used to make sure that carriers fit within assigned channel bandwidths.

Occupied bandwidth violations typically indicate a gross fault in the transmitter. In this case, look for signal distortion and modulation quality faults such as EVM, as well as failed filters.

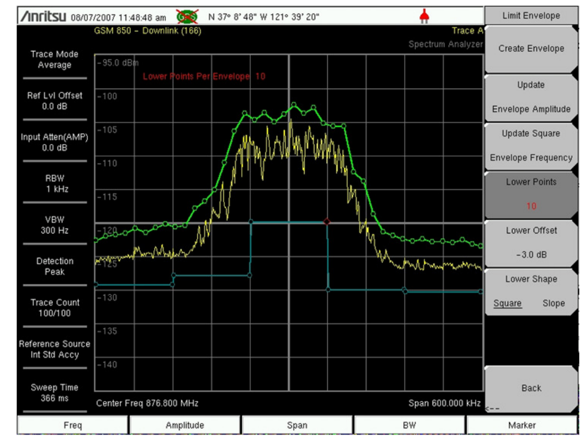
Adjacent Channel Power measures the amounts of carrier power leaking into the next channel (the adjacent channel) and the channel past that (the alternate channel). High values of adjacent channel power generally indicate a transmitter fault.

Adjacent and alternate channel power measurements refer to the occupied channel, so the numbers are in "dB down from the carrier" or "dB down" for short. Another common measurement unit is dBc, which means dB relative to the carrier.

Adjacent channel power measurements are normally standard specific, so exact limits depends on the signal standard. Most standards specify values between -45 and -65 dB down for the adjacent channel and perhaps 10 dB lower for the alternate channel.

Use the ACPR measurement to check if there is leakage into nearby channels

Limits and Intermittent Signals
Spectrum Masks
Gated Sweep



Spectrum Masks make it easy to check regulatory compliance.

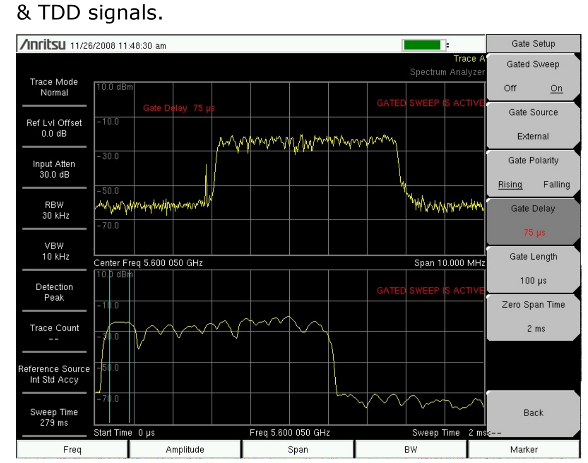
Spectrum Masks provide a pass-fail test on the spectrum. A spectrum mask will create an alarm if violated. Once shared, they ensure consistent pass-fail standards for all users.

Masks may be used when custom limits are needed, or for many different in-band and out-of-band spurious emission tests. They are also useful for spectrum monitoring since they can cause an alarm when a new signal appears or an old signal goes away.

When making a spurious emission test, a violation generally indicates low-level distortion of the carrier. If a violation occurs, it is a good idea to any check external filters and the modulation quality measurements.

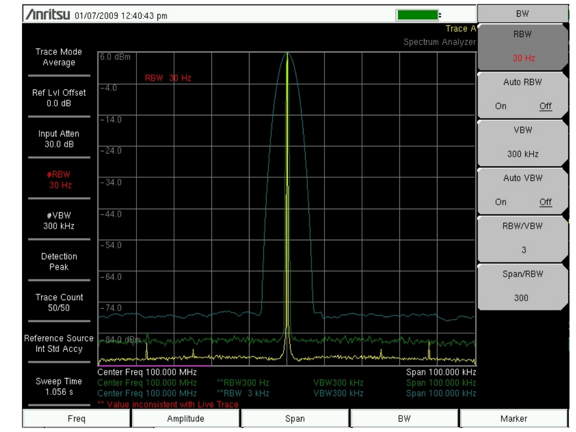
Gated Sweep allows a spectrum analyzer to pause the sweep when the signal goes away, and resume sweeping when the signal is present. This can eliminate the spectrum due to the signal being switched on & off, or it can be used to measure the noise level when the signal is off. Gated sweep is often the quickest way to see the spectrum shape of just the modulation for TDMA & TDD signals such as GSM, TD-SCDMA, WiMAX, and WiBro.

Gated sweep and spectrum masks, when used together, allow checks for spurious emissions on TDMA & TDD signals.



Gated Sweep setup screen shows the zero-span signal (bottom trace) with markers for the gate and the resulting spectrum (top trace)

Specifications & Accessories
Sensitivity and DANL
Prefilters



Instrument specs such as DANL indicate performance under specific conditions; changing the RBW, attenuation, and preamp setting adapts the instrument to the measurement need.

Displayed Average Noise Level (DANL) is one measure of a spectrum analyzer's inherent noise level. A DANL of -160 dBm with a 1 Hz RBW filter is a very good number for a handheld spectrum analyzer.

The rule of thumb is that for every 10 times increase in RBW, the noise floor increases by 10 dB. So a spectrum analyzer with a good DANL at 1 Hz RBW, relative to other spectrum analyzers, will have a good DANL at any RBW. A low DANL is very helpful when hunting for interference or spurs since these signals may be weak when first spotted, even if they are strong at the site of the interference.

Prefilters
Spectrum analyzers have a wide RF front end. Stronger signals at any input frequency, even if not in the current span, may reduce their sensitivity, causing front-end overload and/or a higher noise floor.

The solution is either to move away from locally strong out-of-span signals, such as those coming from broadcast towers, to use a directional antenna, pointed away from the strong signal, or to use an external prefilter.

External prefilters take two forms. Antennas, particularly highly directional antennas often have a sharp roll-off, creating some filtering effect on the signal.

More formally, external prefilters are available in a wide range of configurations.

The proper prefilter will greatly reduce out-of-band signals and make over-the-air signal analysis much easier.

Choose the proper filter to eliminate large signals

For more information, please see "Interference Concepts, Tools, and Techniques" at www.Anritsu.com.

Tracking Generator Measurements
Transmission Measurements

A tracking Generator is useful for transmission measurements (2-port).

Tracking Generator measurements require both generation and measurement of a signal. This allows characterization of a wide array of passive and active radio components including amplifiers, filters, antennas, and even much of a radio's signal path. These are scalar measurements.

Transmission measurements include:

- Gain, which is useful for amplifier measurements
- Loss, which is useful for passive devices including filters and cables
- Passband width, showing the frequency range over which the device works
- Passband tilt, showing gain or loss at various frequencies within the passband
- Filter slope, the change in gain over frequency at the edges of a pass band.

One of the most valuable two-port checks is to measure power loss in all or part of a BTS signal path.

Dynamic Range

Dynamic Range is the ability of an analyzer to measure both small signals and large signals at the same time. It can be measured in many different ways, to reflect the ability to make different kinds of measurements. One of the popular metrics for Dynamic Range shows the ability to measure 3rd order distortion—2/3(TOI-DANL). This shows the case where 3rd order distortion products for 2 tones are at the noise floor. Be careful to use DANL in dBm, rather than dBm/Hz.

Optimizing the Dynamic Range of a spectrum analyzer is done by using **Manual Mode** to trade off distortion and noise levels versus sweep time. The optimization will be different for different signals and different measurements. For example, the best dynamic range for 3rd order distortion on CW signals is achieved by using minimum RBW & VBW, and setting the input attenuator so that instrument-generated distortion is at the noise floor. This can be further refined by using trace averaging.

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