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Application Note | SignalShark

From sweep time to measurement time to interference search on TDD systems such as 4G / LTE and 5G / NR

If you were taught to use an analog spectrum analyzer and you now want to use a real time analyzer like the Narda SignalShark, you will have to get to grips with a few new terms. You will, however have a device in your hands that will produce result data at a rate that leaves analog spectrum analyzers standing. When used properly, the SignalShark provides new concepts for solving measurement tasks faster and more efficiently than ever before. But, let's start at the beginning.

Contents:

From analog spectrum analyzer to real time analyzer

If you are accustomed to using a traditional, analog spectrum analyzer, you will also be familiar with the term sweep time (SWT). The sweep time is the time that the analog spectrum analyzer needs to sweep through the frequency range from the starting frequency FStart to the stopping frequency FStop. Even if the heterodyne oscillator were capable of it, sweeping as fast as you like would not work. The system has to wait for the analyzer filter RBW to respond and settle, otherwise there will be errors in the amplitude and frequency values displayed.

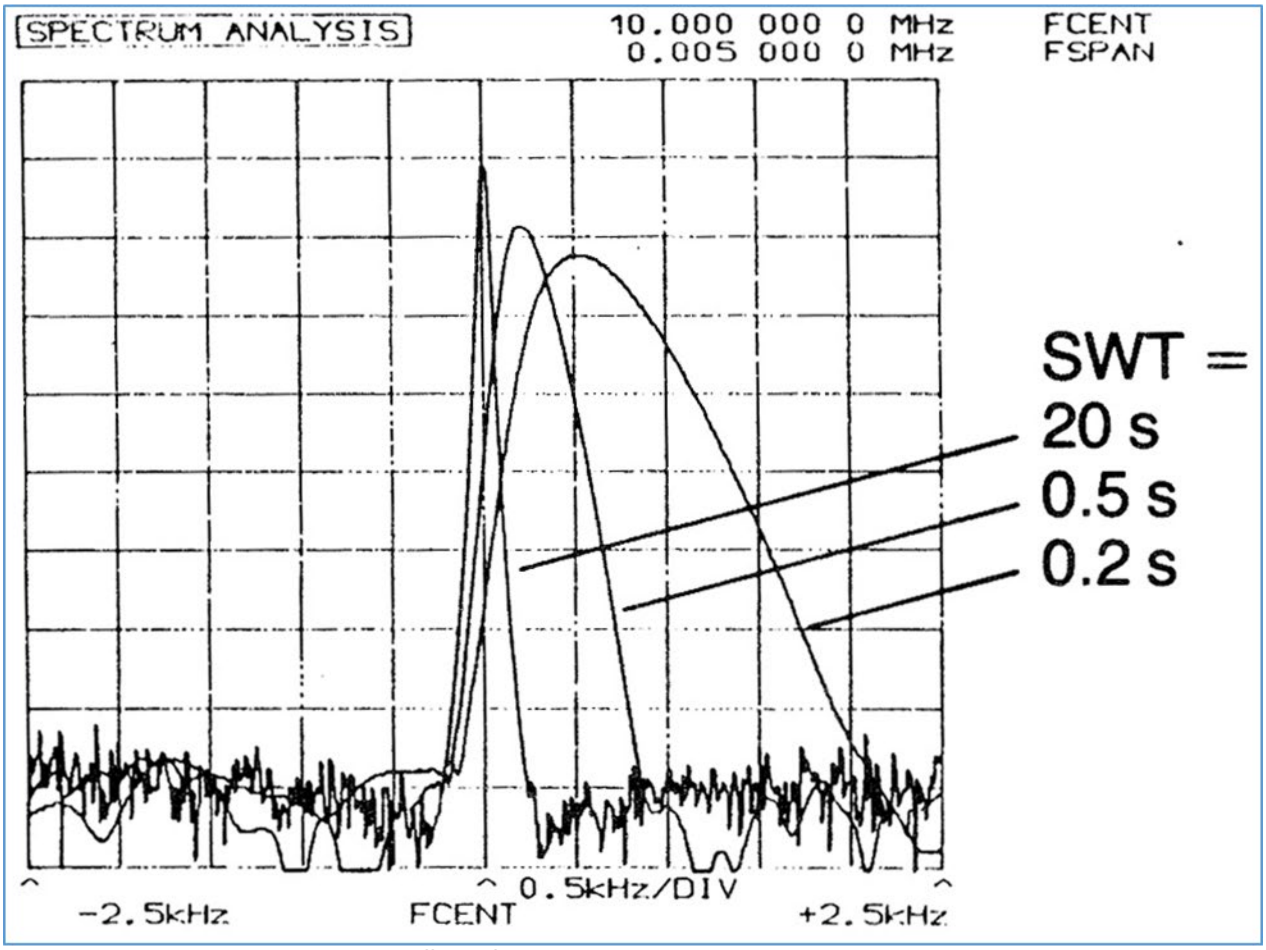


Fig. 1. Analog spectrum analyzer and the effects of choosing a sweep time that is too short. The signal is skewed to the right.

This physical principle also applies to a digital analyzer using a Fast Fourier Transformation (FFT). Here, too, the response time has to be waited out. However, unlike an analog analyzer that only has one filter, a digital analyzer has the great advantage that it digitalizes an entire frequency band F and computes the spectrum using several hundred if not thousands of analysis filters in parallel. In this way, an FFT analyzer can carve out definite speed advantages, particularly with narrow analysis filters. If the device can digitalize and compute fast enough to allow the spectrum to be captured without any time gaps, it is called a real time analyzer.

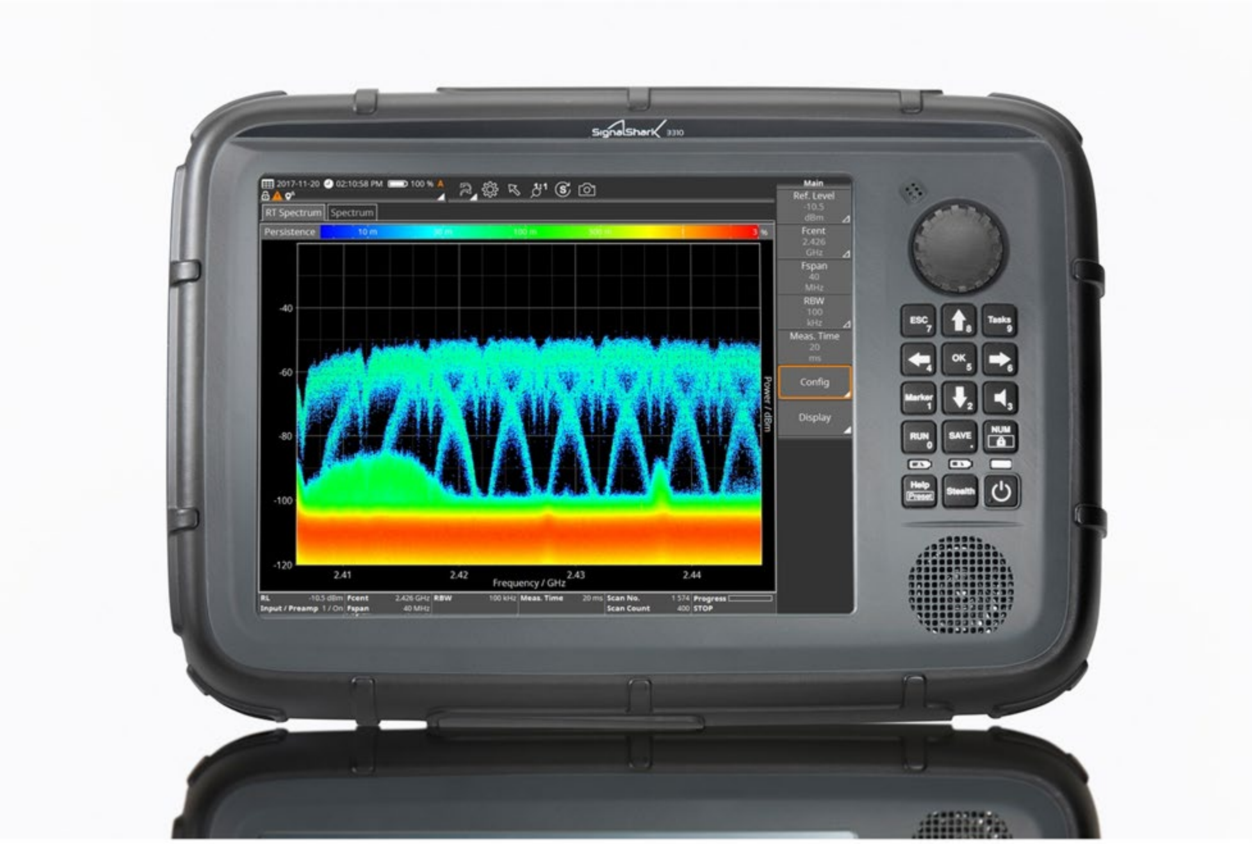


Fig. 2. Narda SignalShark, 40 MHz real time bandwidth, frequency range 8 kHz to 8 GHz. Available as a handheld device (shown here), a 19" remote unit for rack mounting, a stand-alone unit for benchtop use with separate display, and as an outdoor version for mounting on a mast or tower.

The Narda SignalShark is one such real time analyzer. It can capture a frequency band 40 MHz wide in real time. That is a significant achievement for a portable device, considering the computing power that is required. Until recently, such performance was only available from line operated equipment.

But why can't you set the sweep time on the SignalShark?

To answer that question, let's take a look at signal processing in a real time analyzer using the SignalShark as an example. Following downconversion by the superheterodyne receiver, the base band signal of 0 Hz to 64 MHz is passed on for digital conversion.

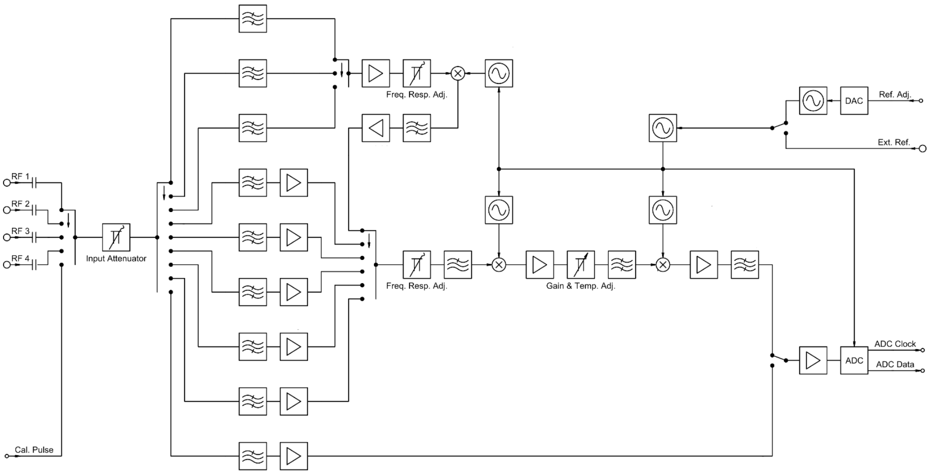


Fig. 3. SignalShark block circuit diagram, showing the analog path with superheterodyne receiver, sub-octave preselector, and mixer stages

Digital conversion results in a data stream of 204 million samples per second (MSPS) with a resolution of 16 bits. This corresponds to 408 Mbyte/second or 3.2 Gbit/second. In other words, it would take a little over 40 minutes to fill a 1 terabyte drive, or if an HD video uses a data stream of 10 to 20 Mbit/s, this is equivalent to streaming 200 HD videos in parallel. That may give you some idea of the quantities of data that are being processed here.

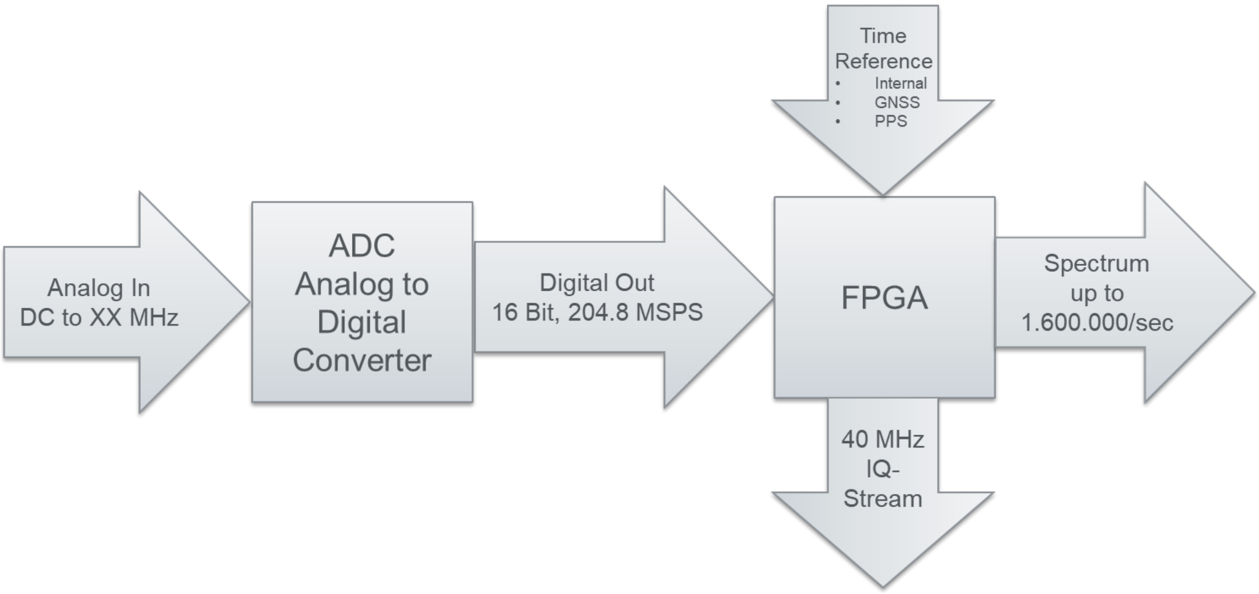


Fig. 4. Signal processing in the SignalShark following A/D conversion

This data stream is further processed by a field-programmable gate array (FPGA). This FPGA generates a VITA49 compliant IQ data stream with high precision timestamps derived from the internal time reference or synchronized to an external time standard or GNSS. The 1 Gbit Ethernet port represents a bottleneck at the full 40 MHz bandwidth. The Ethernet interface is up to about 90% capacity with a bandwidth of “only” 20 MHz. However, this is still a data throughput of more than 100 Mbyte/second. A 1 terabyte drive would now take around 150 minutes to fill.

From FPGA to detectors and traces

The FPGA computes the spectrums. At its fastest, the SignalShark computes 1,600,000 spectrums per second. In an analog spectrum analyzer, this would correspond to a sweep time of 625 ns (nanoseconds), and a sweep rate of 64 THz/s. Sweep times in analog spectrum analyzers are generally in the region of seconds or milliseconds. Anything faster than 20 milliseconds (50 Hz) is hardly sensible, since it is at the limit of human perceptive ability. Why switch, say from a sweep time of 625 ns to perhaps 1 µs (microsecond)? The human eye would be unable to see the difference. The real time analyzer is in a different dimension, so there is no such thing as a sweep time. As already mentioned, it does not take sequential samples like an analog analyzer, but operates on parallel samples taken at the same time, a completely different procedure that is real time operation.

Why then does the real time analyzer produce so much data if it cannot be distinguished by the human eye?
A good question, if you are measuring continuous wave (CW) signals. In such cases, the real time analyzer is, quite simply, overkill. But if you have ever tried to measure a simple radar signal with an analog spectrum analyzer, you will no doubt remember the long minutes spent waiting for the measurement trace to build up on the screen with the aid of the “max hold” function. The real time analyzer needs just one impulse to produce a definitive trace. There is no waiting, no need to make several sweeps to build up a picture. There are no gaps in the measurement. This produces huge quantities of data, but enables you to capture one off signals. And that is something that remains out of reach for an analog analyzer.

If you now want to hunt down interference signals, for example, then CW signals are a relatively trivial matter. However, interference sources are hardly ever CW signals. A bouncing control relay, a defective switching regulator for a solar panel array up on a rooftop emitting a storm of interference, maybe for only a few microseconds, but long enough to mess up the synchronization of some communications equipment every time it happens. An office complex without a reliable Internet connection is unthinkable these days. So, any interference must be quickly localized and nailed down. Which is where a real time analyzer is worth its weight in gold. In contrast to an analog analyzer, it does not miss even the briefest of interference signals, making it much more likely that the source of the interference will be localized.
That’s all good so far, but the analyzer must also make the signal it has detected visible to the human eye. Which is where the measurement time plays a role.

- The measurement time determines the period over which the results are collected and processed for display.
- The detectors determine the form in which the results are collected together.

For simplicity, let’s just consider a single frequency in the spectrum over a period of time. If we select a measurement time of 20 ms, for example, this also corresponds to the display refresh rate of the SignalShark and to the limit of human perception. If the measurement results occur every 625 ns, then 32,000 results will need to be aggregated.

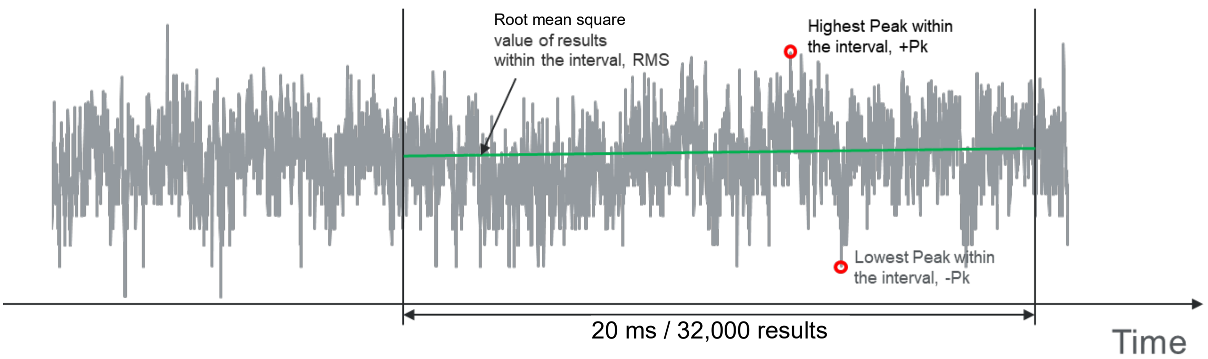


Fig. 5. Display of level measurement values versus time for one frequency point. 32,000 measured values are collected in an interval of 20 ms in this example

The SignalShark provides five different detectors for different forms of result aggregation. Up to three of these detectors can be shown on the display at the same time.

- The highest value of the 32,000 results is shown as the PlusPeak (+Pk)
- The root mean square value of the 32,000 results is shown as the RMS value

+Pk and RMS can always be displayed, along with one other of the following three detectors:

- The arithmetic mean of the 32,000 values is shown as the average (Avrg)
- The lowest of the 32,000 values is shown as the MinusPeak (-Pk)
- Any one value, for example always the first of the 32,000 values is shown as a sample (Smp)

As you can see, the measurement time has nothing to do with the detection of the measured values, so it has nothing to do with the sweep time, either. If you want to compare it to a traditional spectrum analyzer, the parameter most closely related to the measurement time would be the video bandwidth (VBW). The averaging time can be set using the measurement time. The longer the measurement time, the smoother the display of the traces will be, which is essentially the same effect that the video bandwidth setting has in an analog analyzer.

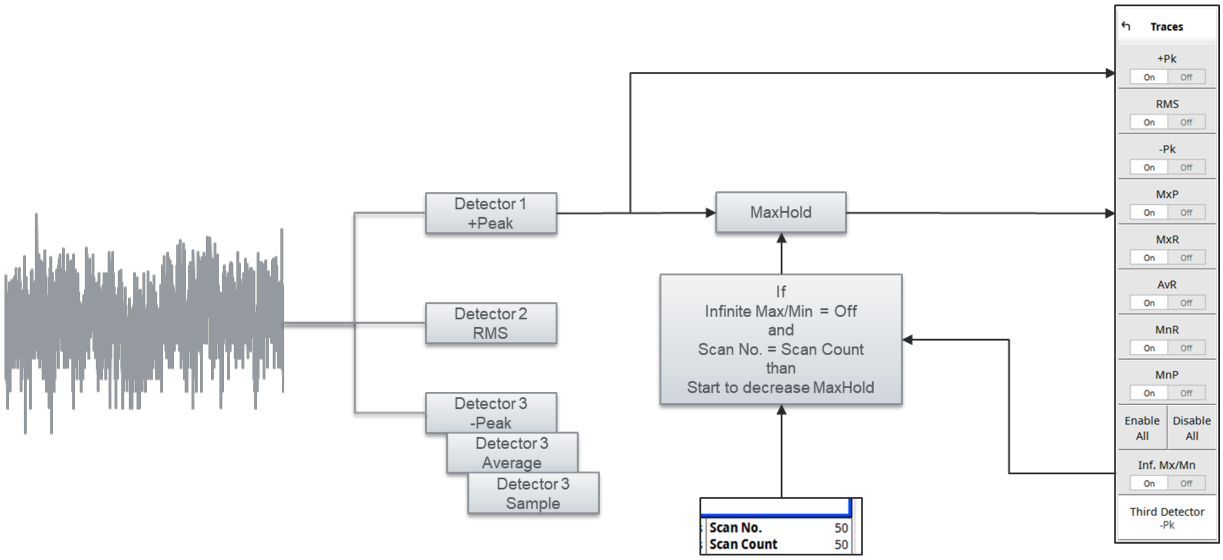


Fig. 6. Relationship between detectors and traces, shown here for the Peak detector

The values of one detector for all frequency points are shown on the display as a curve or trace. As well as the above-mentioned traces, the SignalShark can display further traces on the screen at the same time. For example, if you want to freeze the maximum measured value on the screen, you can select the MaxPeak trace (MxP) and switch the “memory” to infinite with the Inf. Mx/Mn setting. If you want this peak value to be reset automatically after a specific number of intervals rather than holding it infinitely, you can do this using the scan counter to determine the reset interval.

The display of measured values in the Spectrum view ends at about 20 ms (50 Hz), which is the limit of human perception. In contrast, much faster processes can be visualized in the Spectrogram view. Here, the SignalShark allows measurement times of down to 31.25 µs. That is, one line in the spectrogram represents the spectrum in an interval of 31.25 µs. At the maximum bandwidth of 40 MHz, this corresponds to a scan rate of 1.28 THz per second. Anything faster would also be beyond the limits of human perception.

Signal under signal, a challenge in the battle against interference

This rapid display in the Spectrogram view opens up some quite novel perspectives in the battle against interference. Traditional analyzers can show the spectrogram with a maximum resolution of 20 to 30 ms. This would show an LTE signal as a large colored area, with no details visible, and certainly no signals under the signals. If you push the spectrogram view of the SignalShark to its limits, it resolves the signal down to 31.25 µs, which is around 1,000 times finer! All this is live, in real time, and without any gaps. And not just IQ data from the memory, either. Pure speed.

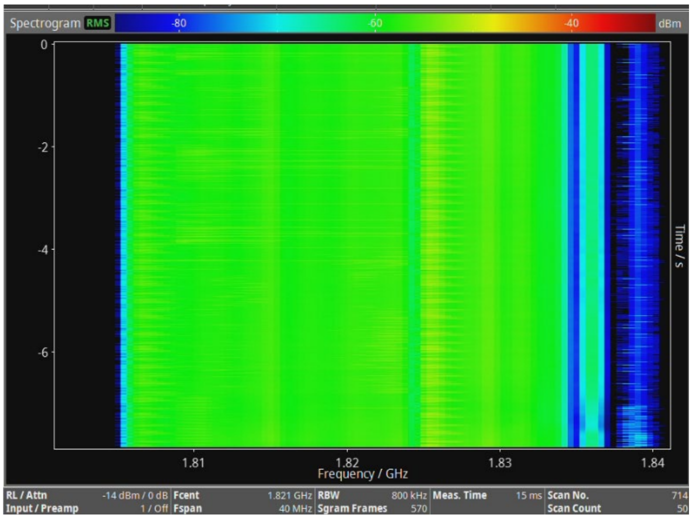


Fig. 7. Even at a measurement time of 15 ms, there are still no details visible in the LTE signal spectrum. An interference signal could be hidden perfectly beneath this and throw the receiving equipment out of sync.

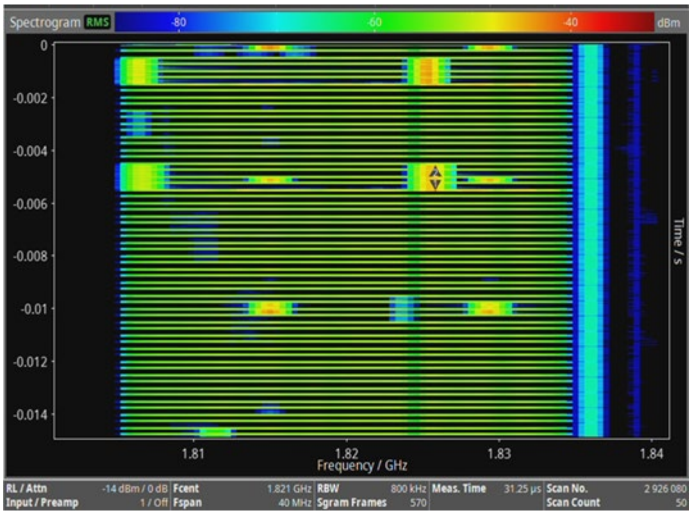


Fig. 8. Resolved down to 31.25 µs, the SignalShark now starts to split the LTE signal into its component parts. That which was compressed into one line in figure 7 is now spread out across the entire screen. You can see the frame structure of the signal, and are able to see signals under the signals by looking through the signaling grid at periods where no information is being transmitted.

In addition to this, the SignalShark has a high precision timebase. After all, the IQ measurement data are intended to be used for time difference of arrival (TDOA) systems. It is precise down to a few nanoseconds. If you need even more precision, you can use the GNSS signal for synchronization or feed an external synchronization signal into the pulse per second (PPS) input.

However, even without external help, the SignalShark timebase is so stable that the signaling in a cellphone system will always be shown at the same point in the spectrogram. No triggering required. The display remains static, even after hours have passed.

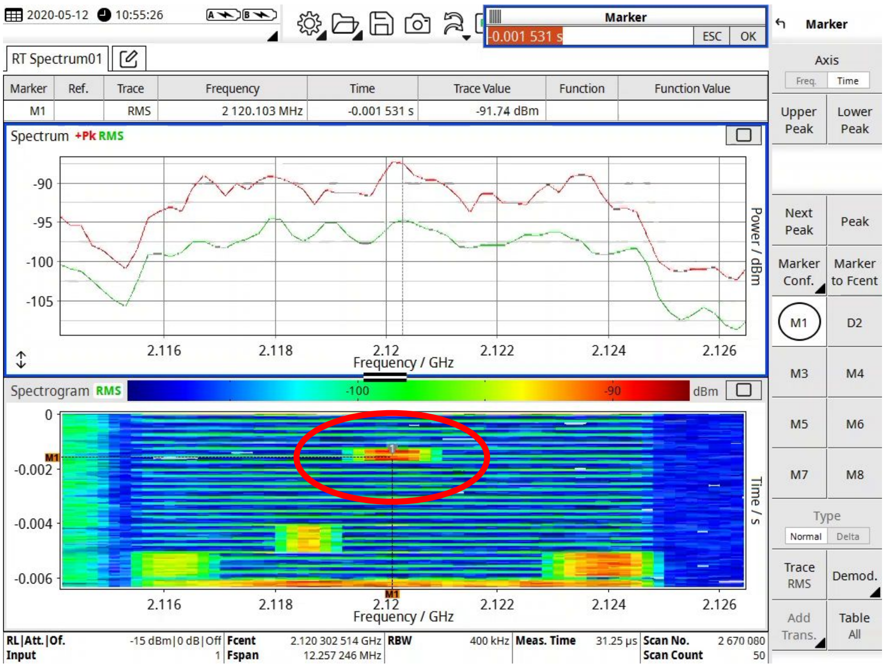


Fig. 9. *At 10:55 the spectrogram of an LTE signal shows a signaling signal (outlined in red). The payload data flows by on all sides, but the signaling remains static in the display. The cellphone system and the analyzer are clocking at the same rate, without any triggers or other tools.*

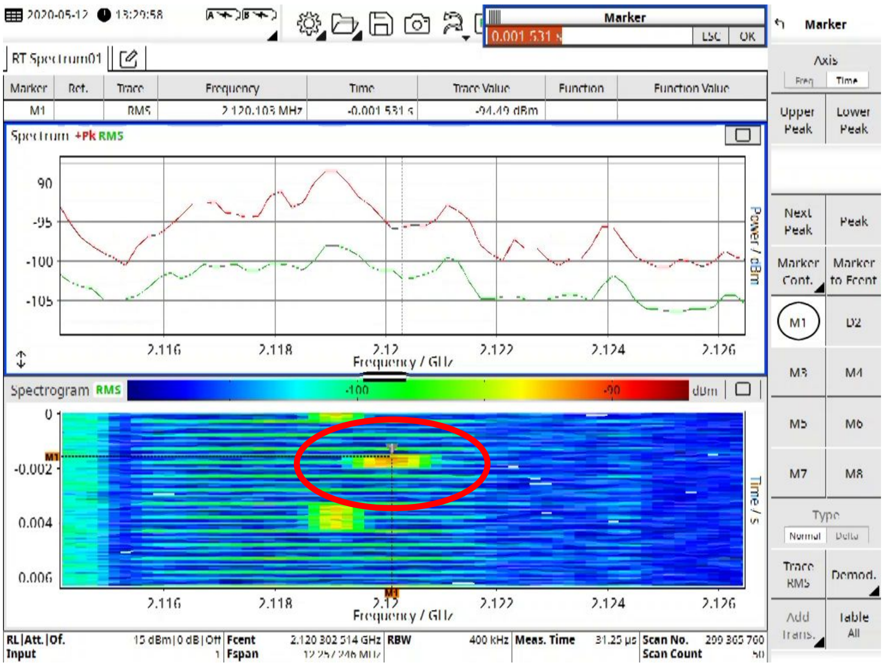


Fig. 10. *At 15:29, i.e. 4 ½ hours and approximately 300 million scans later, the marker and the signal are still at the same spot. The SignalShark is operating from the internal time reference only, with no synchronization with, say, the GNSS signal. Despite this, the signal remains firmly fixed on the display.*

This is particularly advantageous when hunting down interference in time division duplex (TDD) networks. This technology is already in use to some extent in 4G networks, and such coverage will be practically universal in 5G networks. The time structure of the signal allows for localization of in band interference during the time slots reserved for the uplink, without the interference being swamped by the high output power of the base station.

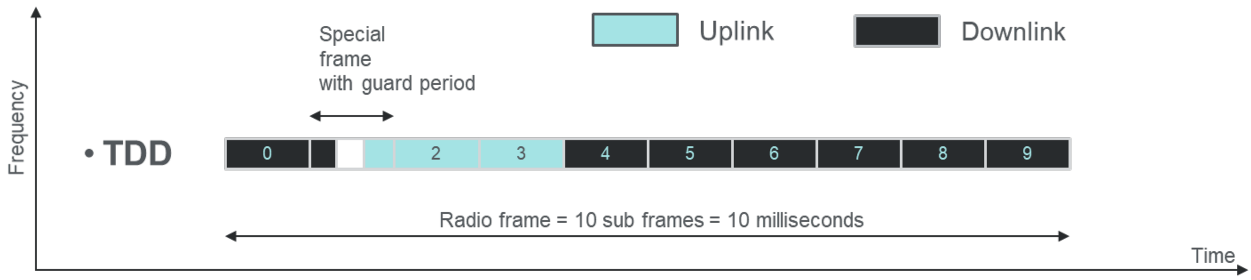


Fig. 11. Time structure of a possible TDD configuration. The radio frame is repeated every 10 ms precisely, and consists of 10 so-called subframes. The uplink frame – or even better the guard period – is the ideal point in time to look for interference signals because the base station is not transmitting anything at this time.

These slots can be seen perfectly in the spectrogram, and are always shown in the same place, which makes it very much easier to perform a search for in band interference.

As we have already indicated above, it makes little sense to use the short measurement times of the spectrogram to flood the normal Spectrum view. For this reason, the Spectrum view is reduced for measurement times shorter than 20 ms. This is a quite normal procedure in real time analyzers. For example: if you set a measurement time of 1 ms, only every twentieth spectrum will be displayed in the Spectrum view. The other nineteen spectrums will be discarded.

The Spectrum view is thus, unlike the Spectrogram, no longer without gaps. To make sure that no signals are missed despite such extremely short measurement times, Narda recommends the simultaneous display of the Max trace. As a reminder, measurement times of less than 20 ms are shown in red in the menu.

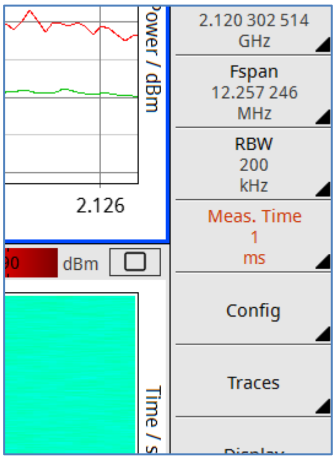
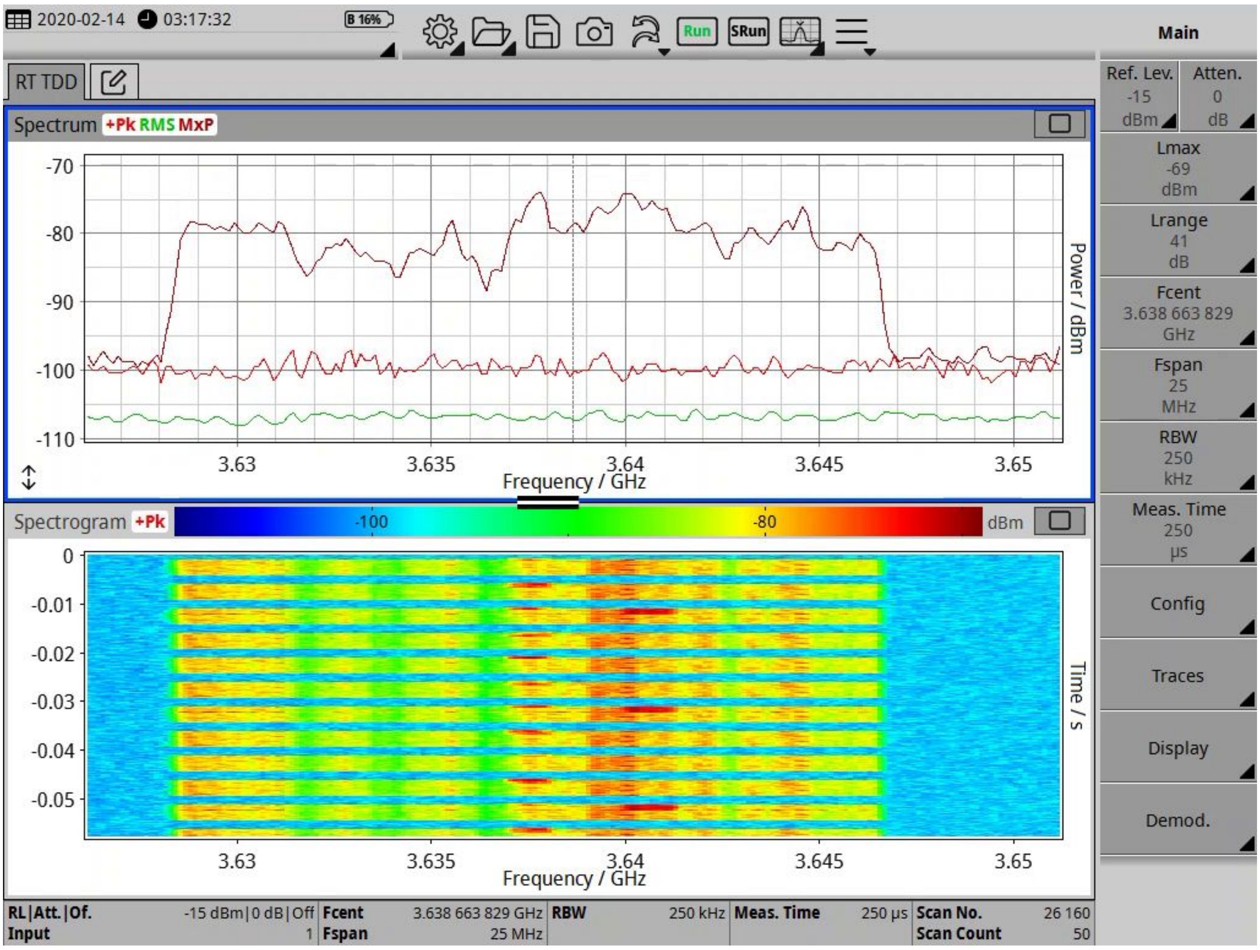


Fig. 12. The measurement time is shown in red if the measurement time is shorter than the 20 ms update interval of the Spectrum display

This effect is not a fault, it is merely the result of the limitations in human perception. It can actually be used to great advantage. If you position this spectrum that is displayed precisely every 20 ms in the uplink timeslot of the TDD signal, then only the uplink spectrum will ever be displayed in the Spectrum view.

You can now hunt down interference signals in the TDD system using the settings thus selected. This provides you with a time gated measurement. Because the timebases of the SignalShark and the mobile communications signal are in sync with each other, you do not need any triggers or other tools. Once you have made the setting, the measurement will always take place in the uplink window.



This example would be even more impressive if an interference signal was also visible. However, no one wants to deliberately impair a real live signal simply for test purposes. For this test, then, we superimposed an interference signal on another telecommunications signal from a DECT phone located in a screened chamber. In this way, nothing other than our own telephone was affected by the interference, and so this can be inserted at will.

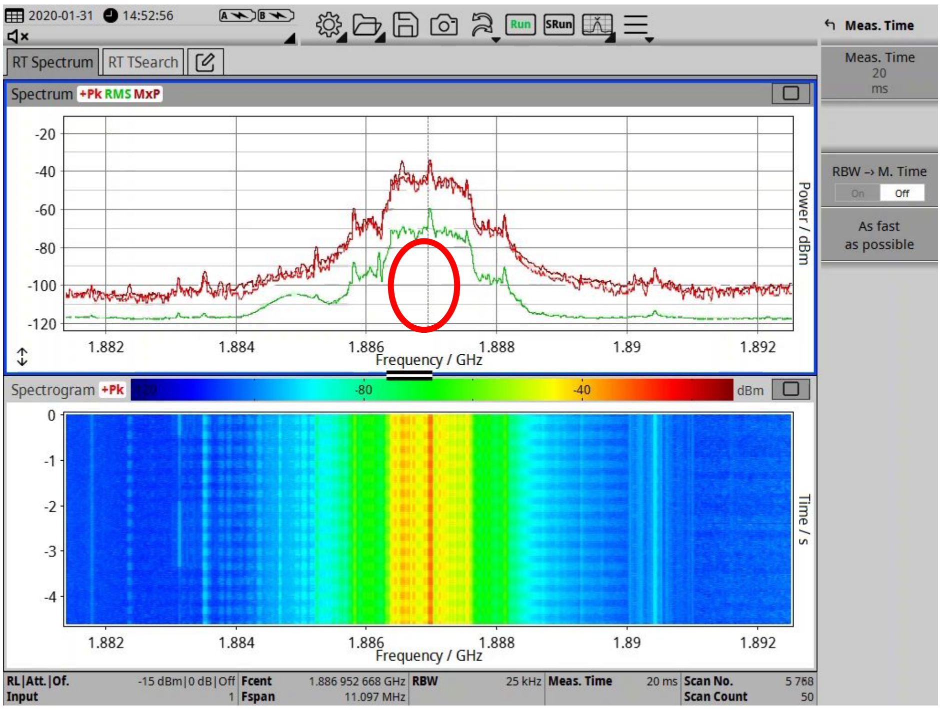


Fig. 14. Measurement on a DECT telephone. The measurement time here is 20 ms, so there are no gaps in the display in the Spectrum view. The interference signal, which is underneath the DECT telephone transmission signal, is swamped by it.

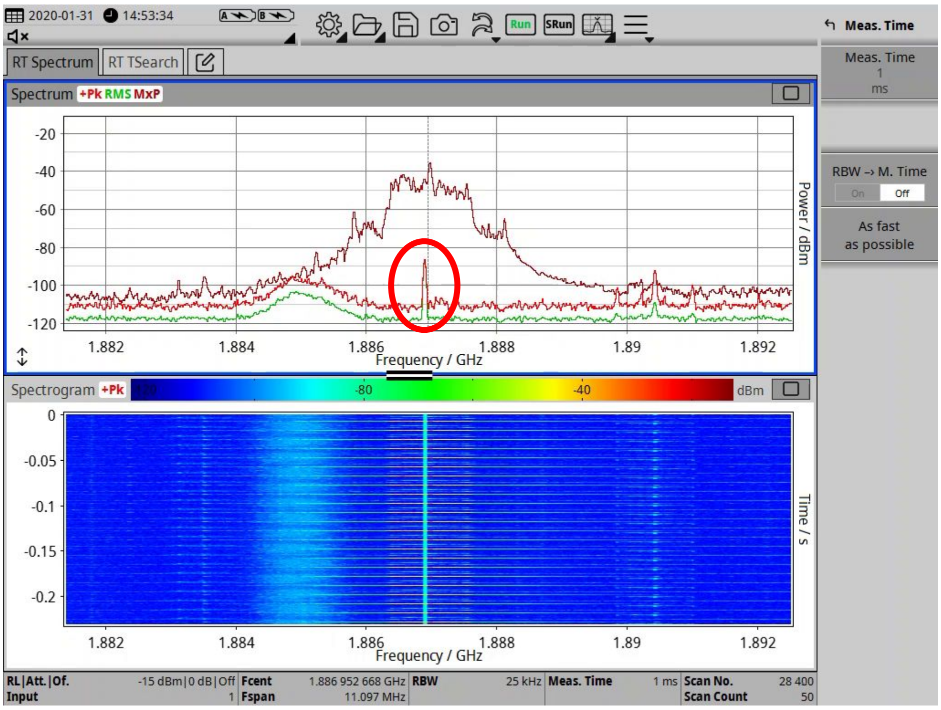


Fig. 15. The same configuration as in figure 14, but this time with a measurement time of only 1 ms. +Pk and RMS are positioned so that the breaks in transmission are always shown on the display. The interference signal can now be seen clearly in the spectrum. The spectrogram also clearly displays the interference signal in these breaks in transmission.

Options that will enable such measurements for other time structures too will be available for retrofitting to the SignalShark. However, it is already possible to produce without problems this time gated display for 4G, 5G and, for example, DECT signals, which are based on a fixed 10 ms frame structure.

What is the SignalShark Scan Time?

If you want to use a real time analyzer to display frequency spectrums that are wider than the real time bandwidth, the analyzer will start to break the spectrum up into segments. The real time analyzer puts the spectrum together from several consecutive spectrums, each measured with the real time bandwidth.

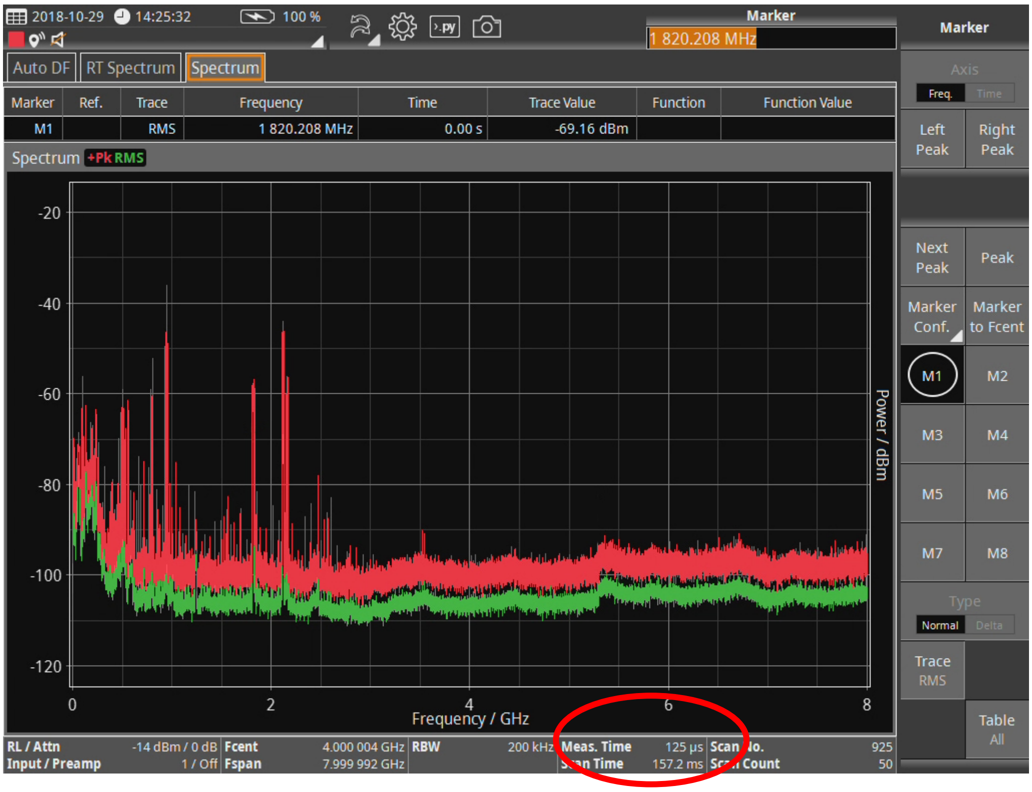


Fig. 16. Full span measurement with the SignalShark. Measurement time 125 µs, scan time 157 ms

But now the analyzer is no longer real time, as it is making consecutive measurements. Each of these part segments is measured for the specified measurement time. The total time taken for this process, that is n times the measurement time plus the time needed for the switching processes, is called the scan time. And that brings us back full circle: The scan time, which is the time that the SignalShark takes to scan from FStart to FStop in Scan mode, can most likely be compared to the sweep time of a traditional spectrum analyzer. Only the SignalShark is much faster.

Summary

Using a real time analyzer, you can track down signals that were previously impossible to get hold of. This does require a tradeoff between the immense flood of data that such an analyzer can deliver, and the quantity that can actually be observed by the user. However, if you understand what is meant by measurement time, detectors, and traces in this context, you will be well on the way to making seemingly invisible signals visible using this kind of instrument.

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