Interference and Direction Analyzer IDA 2

Technical Note TN106

IDA 2:
Receiver *or* Spectrum Analyzer?
Receiver *and* Spectrum Analyzer!

Both are correct, but not important.
It's what you do with it that counts.

Two questions are often asked: What's the difference between a receiver and a spectrum analyzer? And: How long must an event last to be sure of detecting it with one or other of these devices?

These questions are answered in this Technical Note. Put very simply, whether the IDA 2 is a receiver or a spectrum analyzer depends entirely on how and why it is being used. The specific examples given here will demonstrate this to you.

Contents

Part 1: The difference

The conventional receiver

Conventional receivers operate using the supersonic heterodyne principle, usually called superheterodyne or superhet: generally, several mixer stages are used to convert the high frequency input signal to the low frequency range. The IF filters determine the selectivity or channel bandwidth (CBW). This must match the signal bandwidth, so that exactly one channel is audible after demodulation. As a result, the filters normally have narrow bandwidths and the best possible adjacent channel suppression characteristics, so steep cutoff IF filters are preferred. Tuning is generally done manually.

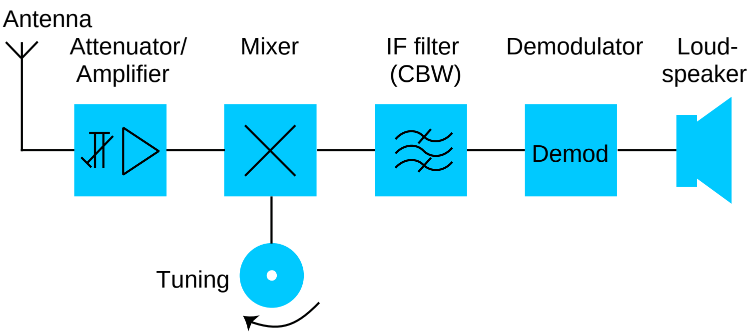

Figure 1: Conventional superhet receiver, highly simplified.

The conventional spectrum analyzer

In principle, a conventional spectrum analyzer operates using the same superhet principle as a receiver. However, it is tuned automatically through a range of frequencies. During this sweep, the device displays the measured level versus the frequency. The resolution bandwidth (RBW) determines how well the device separates adjacent signals, so narrow bandwidths are usually selected. However, a compromise must

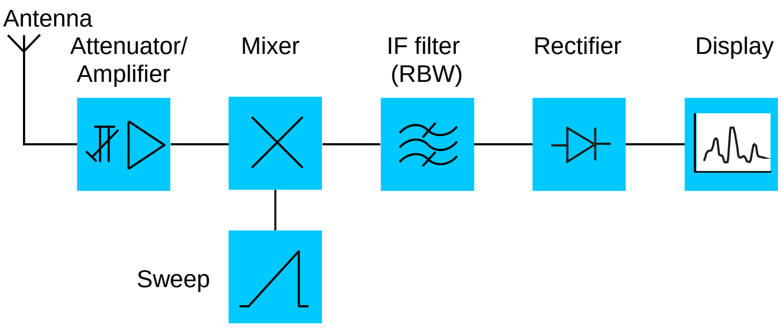

Figure 2: Conventional superhet spectrum analyzer.

Back to contents

be made between selectivity and sweep time: the steeper the IF filter, the longer it takes to settle, meaning that the sweep must be slower. For this reason, Gaussian filters are often used.

The differences between a conventional spectrum analyzer and a conventional receiver can be summarized as follows: automatic sweep instead of manual tuning, display instead of audio output, and relatively narrow but not steep resolution filters instead of steep channel filters.

The FFT analyzer

One basic drawback of conventional spectrum analyzers is that they are only tuned to a single frequency at any given point in time. Anything occurring outside the bandwidth captured at the time cannot be detected. The FFT analyzer elegantly gets around this problem by calculating the spectrum of the signal from the time response by fast Fourier transformation, for all captured frequencies simultaneously. This can be done without any gaps if there is sufficient computing power. This is then called real time analysis.

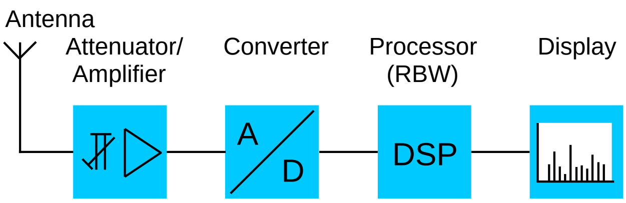

Figure 3: Principle of a purely digital FFT analyzer.

However, the frequency range of a pure FFT analyzer is quite narrow. The limit is set by the technology: the possible sampling rate and the computing power of the digital signal processor (DSP). Modern technology allows analysis of signal frequencies up to a few tens of megahertz with portable devices. Laboratory instruments have a wider range but still cannot reach the frequencies in the gigahertz range that are necessary for RF analysis.

Back to contents

Combined analog and digital techniques

An initial analog preprocessing stage is needed in modern digital analyzers for frequencies up to the gigahertz range. A superhet receiver converts the high frequency signal to a suitable lower frequency range, just like in a conventional receiver. Analog to digital conversion and computer processing in the DSP take place only after this stage.

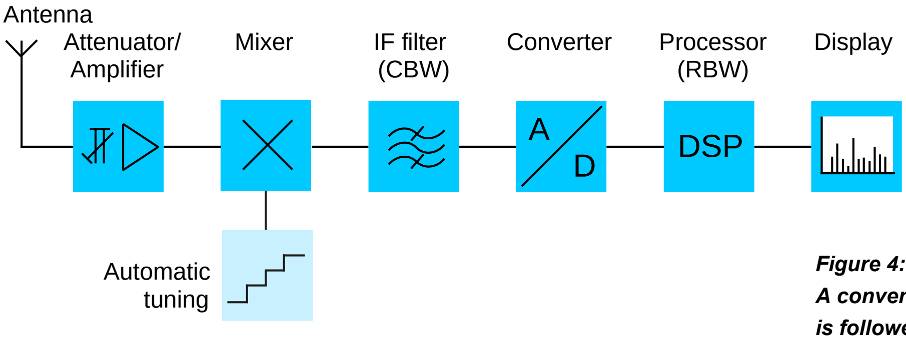

Figure 4: Modern spectrum analyzer.
A conventional superhet receiver for preselection is followed by a digital analyzer for finer selection and further processing.

In contrast with a conventional receiver, it is important here to capture as wide a channel bandwidth (CBW) as possible so that one FFT can be used to analyze a broad range. The superhet receiver then stays tuned to a single frequency in zero span mode, and the device gives you all the advantages of a FFT analyzer, such as parallel calculation of all spectral components and real time capability.

If the CBW is not enough to capture the desired frequency range, the mixer must be tuned stepwise to the adjacent ranges and the spectrum put or “stitched” together from several FFTs in so called “Stitched Mode”. This reintroduces the disadvantage that the device only captures one range at a time and is “blind” to the other ranges while doing so. Nevertheless, the instrument is superior to the conventional spectrum analyzer because it achieves the result within a range much faster with the FFT and is therefore faster overall. Also, a narrow spectral resolution bandwidth for the FFT does not affect the measurement speed as it would affect a conventional analyzer, so a fast sweep is possible even with a small RBW.

Back to contents

Part 2: The application

Example: Detecting and classifying interference beneath signals

One of the toughest applications for a spectrum analyzer or receiver is the detection and classification of in-band interference, i.e. signals that are hidden beneath the wanted signal. This is particularly difficult when the wanted signal itself changes frequency (frequency hopping) or the interference only occurs sporadically. What requirements must then be met by a receiver and by an analyzer?

Receivers must filter narrow channels with as steep an edge as possible and demodulate the selected signals. Experienced users can often tell the kind of interference that is present from the sound of simple modulation types such as AM, FM, and SSB. The device should be tunable across the recorded spectrum so that this can be subjected to an acoustical search. Simply listening is not enough for modern signals using digital modulation types; detailed analysis is needed.

Analyzers must be capable of displaying at least the basic structure of the wanted signal so that irregularities and things that shouldn't be there can be seen. Second, third and fourth generation mobile communications signals are often subject to interference, sometimes even intrinsically. The minimum requirements can be determined from their characteristics.

- **Analyzer channel bandwidth (CBW)**
  The UMTS communications channel bandwidth is 5 MHz. The LTE channel bandwidth is usually 10 MHz, but can be up to 20 MHz. The analyzer must therefore have a CBW of at least 20 MHz.

- **Analyzer frequency resolution (RBW)**
  GSM uses a channel spacing of 200 kHz. Individual carriers in LTE are spaced 15 kHz apart. The analyzer resolution must be at least three times finer for detection and about ten times finer for measurement. The analyzer must therefore be able to provide a RBW of 1 kHz.

- **Analysis duration**
  GSM has a frame length of about 4.6 ms, for LTE this is 10 ms. The analyzer must be capable of displaying at least one full frame.

Back to contents

- **Analysis time resolution**
  GSM timeslots are approximately 0.577 ms long, LTE timeslots, too, are around 0.5 ms. They each contain seven symbols of length 71.3 µs. The analyzer time resolution also needs to be three times finer for detection and about ten times finer for measurement. The "gaps" between timeslots can be detected with a resolution in the µs range.

The quantity of data becomes a problem when recording spectrums at microsecond intervals: Within one second a full one million spectrums have to be captured, processed, evaluated and displayed. There are several solutions to this:

Solution 1: Spectrogram with data compression

Spectrograms display the spectrums against a time and a frequency axis. Each line in the display represents a spectrum, with the amplitude values color coded. The advantage of spectrogram analysis is that the signals are captured in real time, so no time related events are missed. However, a continuous spectrogram with microsecond resolution would be too much to deal with, both technically and from a human point of view. Assuming that the display can show a maximum of 500 lines and the results are produced every microsecond, it would be possible to show a time range of 500 microseconds, after which the display would have to be refreshed. Thus, the display would refresh 2000 times a second – technically impossible, and absolutely useless for the viewer. For this reason, real time spectrum analyzers often compress the spectrums by combining several hundred or thousands together, reducing the data from the microsecond range to a few milliseconds in order to be able to display the results. This allows for a good overview, but makes precise time assignment impossible.

Solution 2: Persistence spectrum

This view uses the usual level versus frequency display. The rates at which each measured value occurred within the measurement period are represented by different colors. This method is ideal for recognizing low level continuous interference underneath the wanted signal. Even sporadic signals can be seen as "outliers" from the normal spectrum. Time correlation is, however, completely lost here, and with it an important source of information for classifying the interference signal. The persistence spectrum simply only shows the rate at which particular values occurred during the measurement period.

Back to contents

Solution 3: Snapshot spectrogram without compression

When classifying interference, it is often a question of whether the signal needs to be observed for a number of seconds or not. It is usually enough to record a frame (frame length of a digital signal) in real time and capture this as a set of data. Spectrums with different resolutions, or time characteristics, or persistence spectrums can be calculated from the stored data. The original data set is retained. Settings made for evaluation, such as frequency resolution, time period, or time resolution do not cause a reduction in the quantity of the data.

Back to contents

Part 3: IDA 2 as receiver and analyzer

Figure 5 shows the versatility of the IDA 2. Initially, it displays the spectrum in the usual form, just like a normal spectrum analyzer. The frequency range (Fspan) and resolution bandwidth (RBW) can be selected as required. The IDA 2 uses Gaussian filters with a favorable response for selection. When one of the demodulators is then activated, the marker can be used to select one of the spectral lines in the display. The IDA 2 demodulates the signal at this frequency using separately tunable steep cutoff channel filters, just like a receiver with a convenient spectrum display. Receiver or spectrum analyzer? The IDA 2 is both.

When operating as a receiver, the IDA 2 offers an unusually large channel bandwidth (CBW) of max. 32 MHz for a portable device. As a spectrum analyzer, it provides resolution (RBW) settings from 10 Hz up to 20 MHz – again much more than most portable devices. It is thus well equipped to meet the demands of modern communications systems including LTE with its 20 MHz channel bandwidth.

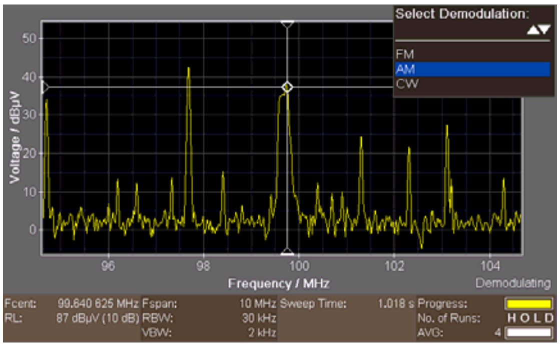

Figure 5: VHF radio band spectrum. The marker can be used to select a channel to listen to – just like tuning a conventional radio set to a particular channel. The obvious interference just below 100 MHz, recognizable by its wider bandwidth than a normal FM radio signal, is more interesting. The various demodulation types – not just FM but also AM, single sideband and others – make it possible for experts to recognize certain characteristics just from the sound of the interference.

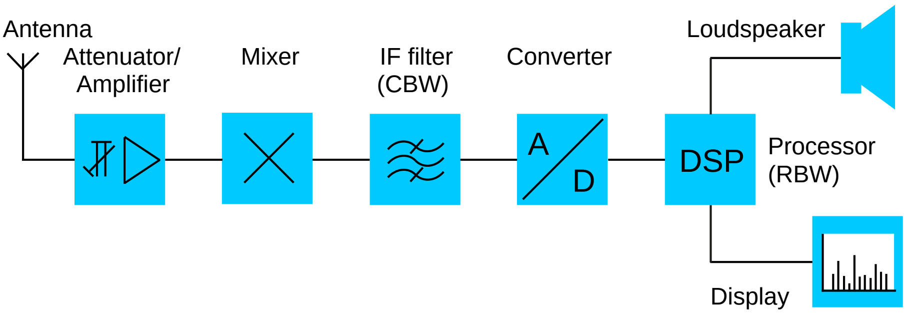

Figure 6: The IDA 2 can operate as a receiver and as a spectrum analyzer.

Back to contents

Frequency domain analysis

The IDA 2 records data and then analyzes it by FFT in *Spectrum Analysis* mode. Example: The IDA 2 takes about 20 ms to record a 1 MHz broad spectrum with 1 kHz resolution. By comparison, a conventional analyzer would take about 2 s to evaluate the same range at the same resolution.

The IDA 2 records spectrums line by line in *Spectrogram* mode. The amplitude values within each line are color coded. The spectrograms allow events to be correlated with time and frequency.

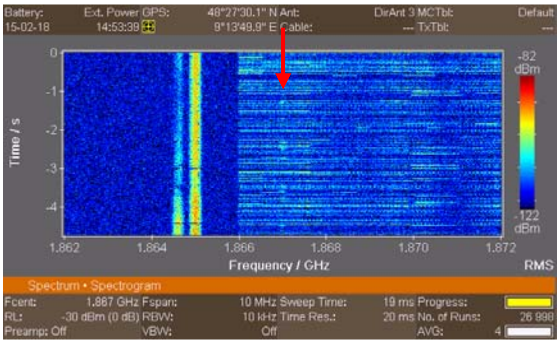

Figure 7: Spectrogram mode. Section of the 1800 MHz mobile communications band. Left: two GSM downlink BCCHs (Broadcast Control Channels). Right: LTE downlink Resource Block. Slight irregularities (arrow) probably indicate interference under the signal.

Time domain analysis

The IDA 2 has two more operating modes that allow constant observation.

In *Level Meter* mode, which other receivers also provide, the IDA 2 is tuned to a fixed frequency (zero span mode). The device indicates the level as a bargraph. The channel bandwidth (CBW) can be set between 100 Hz and 32 MHz. The IDA 2 measures in real time, without gaps. The audio function can also be used with this.

In *Time Domain (Scope)* mode, the IDA 2 displays the result as a graph versus time, similar to an oscilloscope. The trace corresponds here to the magnitude of the signal level which is recorded without gaps within the time span displayed. The time resolution is the inverse of the CBW; e.g. 31.25 ns at a CBW of 32 MHz.

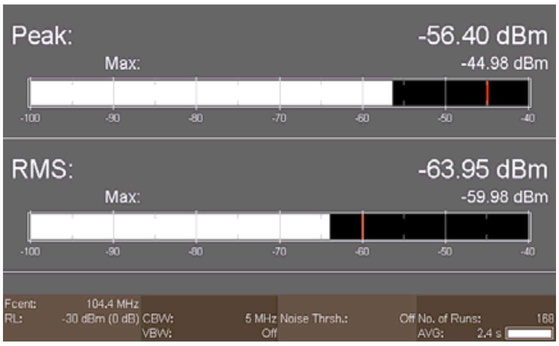

Figure 8: Level Meter mode. Suitable for manually finding the direction of an interference signal: The level bargraph indicator reacts instantly.

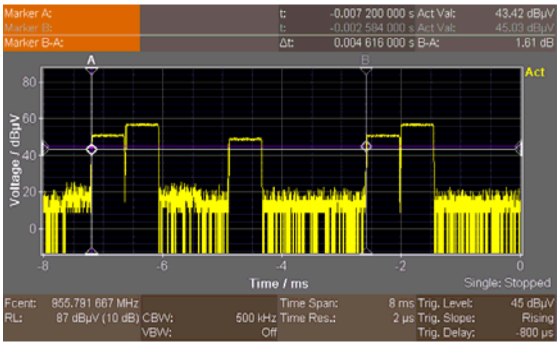

Figure 9: Time Domain (Scope) mode. Recording of a GSM TCH (Traffic Channel). The timeslot structure can be seen clearly; three of the eight possible timeslots are occupied. The markers can be used to measure the frame length (Δt = approx. 4.6 ms). Any signal not conforming to the time structure would be immediately apparent here.

Back to contents

I/Q analysis

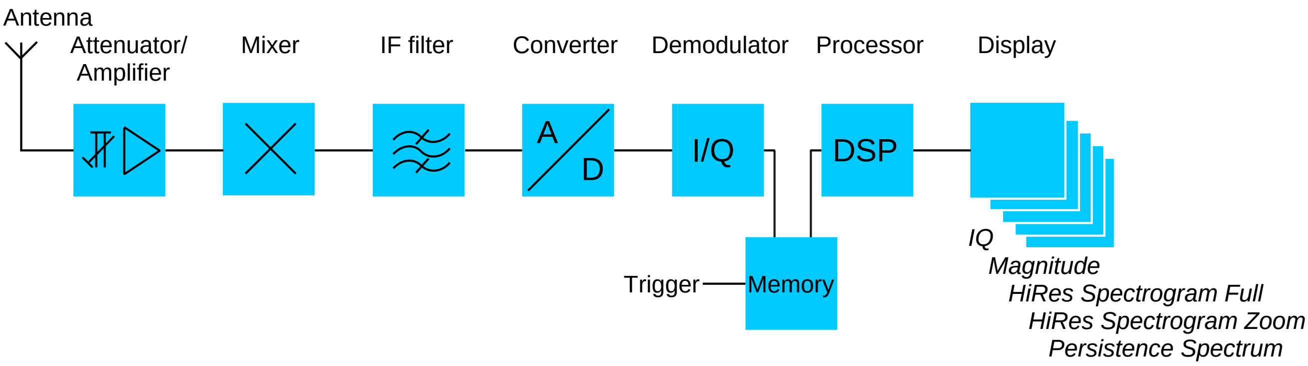

Figure 10: The IDA 2 as I/Q analyzer.

The IDA 2 is also tuned to a fixed frequency (zero span) in *I/Q Analyzer* mode. A demodulator separates the digitized signal data into its real (in-phase) and imaginary (quadrature) components. Up to 250,000 I/Q data pairs can be stored in the IDA 2 memory for subsequent analysis and generation of time responses, spectrograms, or persistence spectrums. This allows an extremely high degree of time resolution: Time responses can be resolved as finely as 31.25 ns, and spectrograms down to 1 µs.

Data recording is continuous during the measurement time. This makes it possible to display and analyze the time correlation between signals. For example, figure 11 leads to the conclusion that the interferer and the BCCHs are not coming from the same base station because they are offset in time.

The IDA 2 is equipped with trigger functions for capturing infrequent events. These allow recording of the event, its history (Trigger Delay), and its consequences.

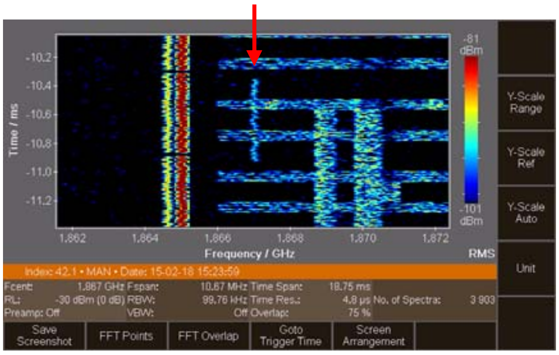

Figure 11: Enlarged section of the high-resolution spectrogram of the same signal as in figure 7 (HiRes Spectrogram Zoom) obtained from the I/Q data. The interferer is immediately apparent (arrow).

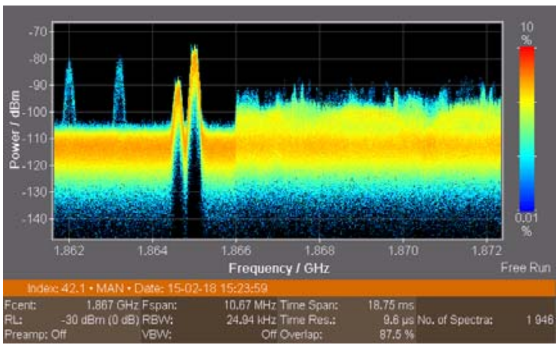

Figure 12: Persistence spectrum obtained from the same I/Q data set as the spectrogram in figure 11. Two TCHs (Traffic Channels, left-hand edge of the display) were briefly active during the measurement time.

Back to contents

The theory of I/Q data analysis is described in our Technical Note
TN101: Capturing I/Q data with NRA and IDA
sub-headed *A brief theoretical outline with practical examples*

Detailed information about the features of the IDA 2 as an I/Q analyzer is found in our Technical Note
TN103: I/Q Analyzer which has the more detailed title:
The signal beneath the signal: IDA 2 makes payload and interference signals clear

Further examples of the IDA 2 *High Resolution Spectrogram* display mode are given in our Technical Note
TN107: Recognizing and separating signals in spectrograms

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