Seamless realtime analysis of frequency hopping with the R&S®FSW

A new option has been added to the R&S®FSW high-end signal and spectrum analyzer for realtime applications. It measures the spectrum in a frequency band up to 160 MHz wide, and even detects signals with a duration of only 1.87 μs with 100 % certainty and with accurate level. Infrequent and ultrashort events are made visible thanks to spectrogram displays and persistence mode.

Realtime analysis – vital for measurements on frequency hopping systems
Wireless communications systems that use frequency hopping have the advantage that their data transmission is less susceptible to interference and that diverse applications can share one frequency band. Cordless headsets and microphones, for example, operate very reliably in an extremely small space and in the same frequency band. Frequency hopping is also useful for tactical radios or radar applications in which, among other things, the influence of wanted interference must be minimized. In order to analyze frequency agile systems of this type, it is essential that the signals are displayed accurately and without interruption. This is also a prerequisite for being able to analyze brief interference effects such as those caused by frequency hops or digital circuits and to examine frequency hopping algorithms. Realtime spectrum analysis is ideal for performing these tasks [1, 3, 4].

Realtime spectrum analysis up to 67 GHz with the R&S®FSW
The R&S®FSW-K160R 160 MHz realtime spectrum analyzer option turns the R&S®FSW high-end signal and spectrum analyzer (Fig. 1) into a realtime analyzer. It digitizes a frequency band of up to 160 MHz and calculates up to 600 000 spectra per second (see Fig. 2). In order to achieve different resolution...
Because the human eye can only process up to 30 images per second, the analyzer combines several thousand spectra in one detector so that each peak is recognizable. However, this combining leads to loss of the extremely high time resolution. Other display modes, such as the persistence spectrum and the spectrogram, or the frequency mask trigger (FMT), solve this problem. The FMT can automatically evaluate all 600,000 spectra per second and respond to certain user-defined events, even if these are only a few nanoseconds long.

**Persistence mode displays color-coded signal frequency**

In persistence mode, the analyzer seamlessly writes all spectra on top of each other in a diagram, color-coded according to their probability of occurrence. For example, it marks signals that occur very frequently in red, and those that occur rarely in blue. If a signal no longer occurs, it disappears after the selected persistence time. This allows the user to...
recognize even extremely short signals and see their amplitude and frequency. The persistence spectrum (Fig. 3) therefore provides a good overview of the dynamics of frequency agile systems. Frequency hops occur, for example, in the industrial, scientific and medical (ISM) bands, where data rates are reduced by collisions between Bluetooth® signals and WLAN signals, for example. However, this display is not only an essential tool for analyzing wireless communications. It is also indispensable for measuring modern radar applications, because these applications also use frequency hopping to minimize interference caused by atmospheric noise, other systems and hostile signals.

The persistence spectrum also displays signals that are hidden beneath a stronger signal and cannot be detected with a conventional spectrum analyzer, as shown in the example in Fig. 3 with a Bluetooth® and a WLAN signal. These interferers are capable of reducing data transmission rates. In all of these applications, transients that occur during frequency hopping or due to digital signal processing can be transmitted, significantly disrupting other systems as well as the user’s own application. The ability to make transients visible in persistence mode is extremely useful for troubleshooting. A current example of this is the interaction between LTE signals in the 800 MHz band and short range devices.

Fig. 4: The spectrogram shows the hop sequence of the Bluetooth® signals, and the zoom function makes it possible to perform a closer analysis, particularly at the point where a WLAN device is active.
**Spectrogram function seamlessly records signals**
The persistence spectrum helps users with new ways of analyzing errors by displaying the dynamic behavior in the frequency domain. The spectrogram, however, shows errors in detail in the time domain. Each pixel of the spectrum is assigned a color that corresponds to the amplitude. This makes it possible to display each spectrum as a horizontal line. All spectral lines are continuously sequenced, seamlessly representing the time development in the frequency domain. In this mode, the R&S®FSW sequences up to 20000 spectra per second and stores up to 100000 spectra in a ring buffer. This lets users record the frequency domain seamlessly for up to five hours, depending on the update rate setting, and see at a glance when signals were transmitted, at which frequencies and with what power.

A closer analysis can be performed using markers, which the user can move over the frequency and time axes to measure the time and frequency difference between events. The spectrum of each individual line can be displayed in a separate window. Since the R&S®FSW stores the I/Q data in a 400 Msample ring buffer in realtime mode, at a bandwidth of 160 MHz the most recently recorded data with a duration of approximately one second is available for a more accurate or repeated calculation. This makes it possible to zoom into scenarios of interest with a minimum time resolution of 30 ns. Collisions between different signals or extremely brief interferers can be analyzed in detail in this way, as shown in Fig. 4. Zooming into the area where two signals are simultaneously active helps to analyze collisions and improve frequency agile systems.

**Frequency mask trigger uncovers events of interest**
The information from the spectrogram or the persistence spectrum can be used to define a trigger in the frequency domain. The FMT responds to signals that violate a defined frequency mask in the spectrum. Fig. 5 shows how the mask is defined. When the trigger is active, the R&S®FSW...

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Fig. 5: If the frequency mask (red area) is violated, the trigger is activated. The mask can be entered numerically via a table or easily defined on the touchscreen.
Fig. 6: The frequency mask trigger is defined in the realtime spectrum analyzer (top). Automatic analysis of the hop sequence (bottom) takes place in the R&S®FSW-K60 transient analysis option.

Fig. 7: Two ISM bands in one display. Top: The 5.6 GHz ISM band, where only devices that are compliant with WLAN standard 802.11n are active. Below: The 2.4 GHz ISM band is at the bottom of the display, in which both Bluetooth® and WLAN signals can be seen.
compares each individual spectrum – 600 000 per second – with this frequency mask. If the mask is violated, it stores the data for further analysis. The user can define which time range before and after the event is to be recorded, and whether recording stops or analysis restarts when the trigger event occurs. This function makes it possible to detect brief interferers or only analyze signals of a certain frequency and amplitude. The user can concentrate on the signals of interest and does not have to evaluate large quantities of seamlessly recorded data. The stored signals can, for example, be analyzed in detail in the spectrogram, processed on an external computer or examined on the R&S®FSW using other measurement applications.

**MSRT combines realtime analysis with other applications**
The multistandard realtime (MSRT) operating mode makes it possible to use the frequency mask trigger also in other measurement applications. In such cases, the realtime analyzer acts as master. The user sets the frequency mask and determines the analysis bandwidth and the record length. When an event has activated the trigger, the data that has been acquired is made available to the other measurement applications and analyzed by them. This is extremely useful if the signal that is being analyzed only occurs rarely and is therefore difficult to record. Fig. 6 shows a typical application. In order to measure the hop sequence of a transmitter that is only occasionally active, it is advisable to use the frequency mask trigger in realtime mode in order to trigger at a certain frequency. Subsequently the data is examined in the transient analysis (R&S®FSW-K60 option) and the hop sequence is automatically evaluated. This used to be a complicated task, since users were forced to record extremely long data sequences in the hope of capturing the transmitter’s active phase by chance. Now, however, this succeeds with the very first measurement.

**Parallel display of different modes makes evaluation easier**
The R&S®FSW-K160R measurement application is merely a software option for the R&S®FSW signal and spectrum analyzer; only the R&S®FSW-B160 bandwidth extension is additionally required. The R&S®FSW can still be operated as a conventional spectrum analyzer, and the different modes can be displayed simultaneously, as shown in Fig. 3. Users can simply switch between these channels or display them in parallel. Applications such as the realtime measurement application can also be started multiple times. Seamless spectrum analysis is only possible in one window, but users can easily compare the frequency utilization of different bands in this way, as shown in the example in Fig. 7 with the ISM band at 2.4 GHz and 5.6 GHz.

**Summary**
The R&S®FSW signal and spectrum analyzer [2], equipped with the R&S®FSW-K160R option, is the third realtime spectrum analyzer from Rohde & Schwarz following the R&S®FSVR realtime analyzer [3] and the R&S®ESR EMI test receiver [4]. With almost 600 000 spectra per second, it is twice as fast as competitor products. With a probability of intercept of 100 %, it detects signals accurately up to a minimum duration of 1.87 µs and comes out on top in any comparison. Together with its outstanding RF characteristics and new modes such as MSRT (all controlled via its convenient user interface), it is a unique measuring instrument on the market.

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References