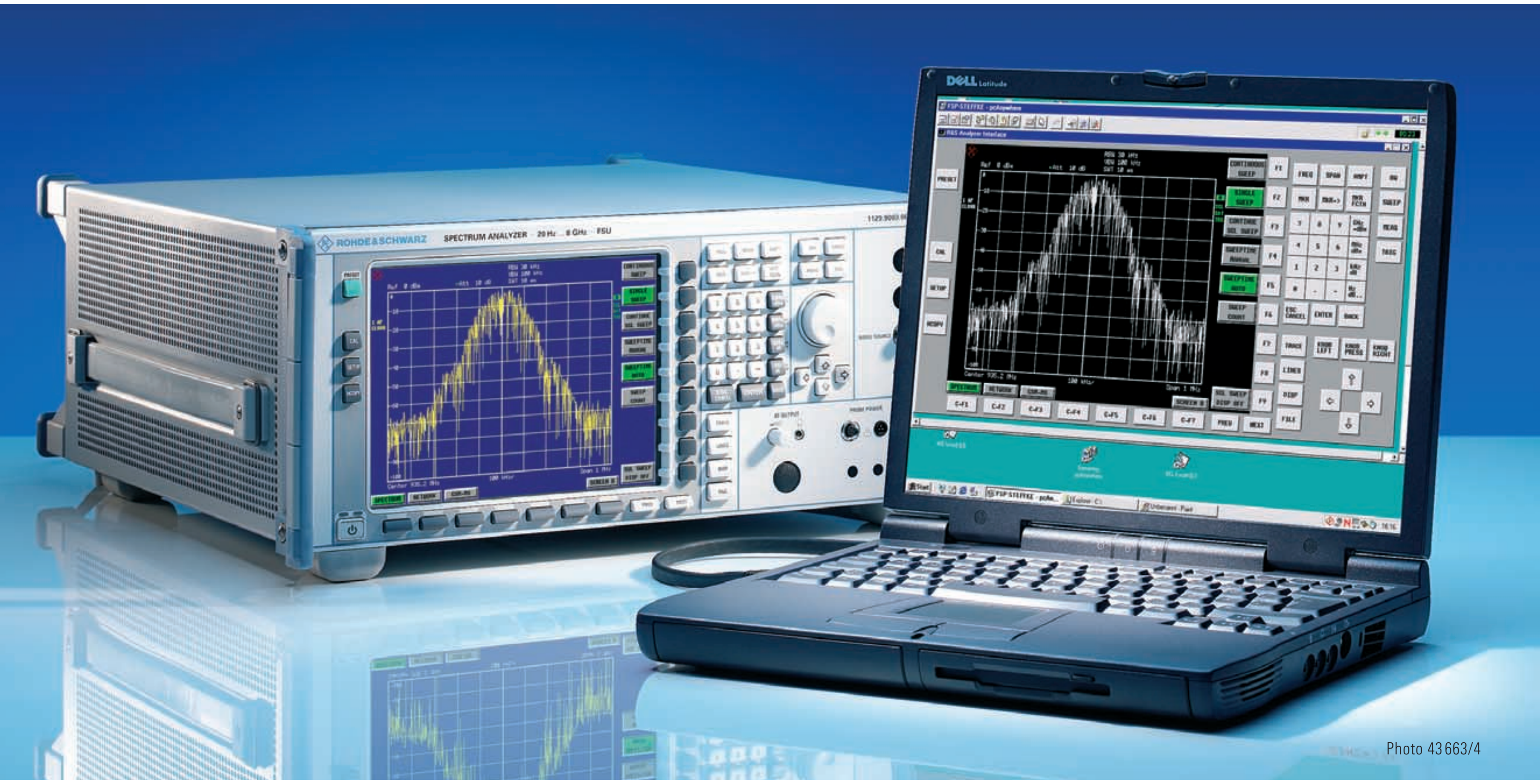


FIG 1 The FSU family consists of two analyzers for the RF range and the lower microwave range: the FSU 3 (20 Hz to 3.6 GHz) and the FSU 8 (20 Hz to 8 GHz). The PCAnywhere software allows remote control of the analyzers with a mouse.

Spectrum Analyzer FSU

Best RF performance – third generation of high-end analyzers

With the new FSU spectrum analyzers, Rohde & Schwarz launches its third generation of high-end analyzers on the market. Like their predecessors – the FSA (1986) and the FSE (1995) [1] – they again set high standards and offer measurements which previously were not possible with spectrum analyzers, or at least were insufficient.

Excellent RF performance

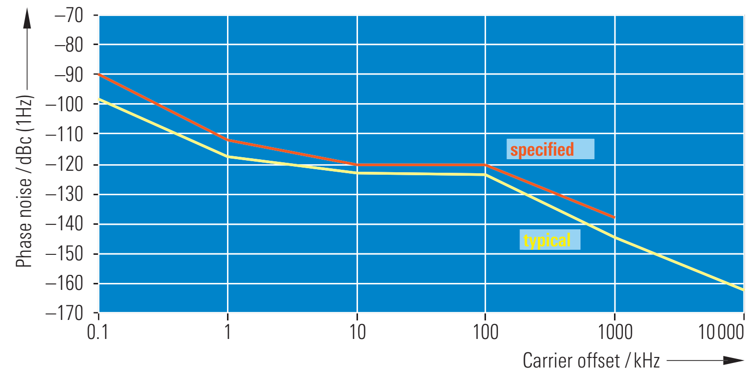
High-end spectrum analyzers distinguish themselves from medium-class instruments by their outstanding RF performance, in particular, minimal inherent noise floor and phase noise and excellent intermodulation characteristics. In these disciplines, the FSU (FIG 1) anticipates the future increased demands placed on dynamic range, measurement accuracy and speed. The FSU 3 and FSU 8 are based on the general-purpose spectrum analyzers of the FSP family [2], in which the RF hardware has been replaced by a high-end concept satisfying the most exacting requirements.

The FSU's advanced concept is most apparent in large-signal behaviour such as intrinsic intermodulation and compression characteristics as well as in phase noise.

In the frequency ranges around 1 GHz and 2 GHz, which are important for mobile communications, the FSU is the first spectrum analyzer to guarantee a third-order intercept point of >+20 dBm. Typically, even +25 dBm are achieved.

The 1 dB compression point of the input mixer is +13 dBm. Such a high dynamic range is associated with a high usable mixer level; the reference level can be set up to +5 dBm without RF attenuation (mixer level: the level at the RF input minus the attenuation of the RF attenuator). With all other customary spectrum analyzers on the market, the maximum mixer level is limited to –10 dBm. Thus, the FSU displays a considerably larger dynamic range on the screen, for example with phase noise or spurious measurements, without the carrier signal overdriving the signal path.

FIG 2
Phase noise of the FSU at an input frequency of 1 GHz



Unrivalled low phase noise

The high dynamic range does not come at the expense of higher inherent noise, however. With <–145 dBm and typically –148 dBm displayed average noise level up to 2 GHz at 10 Hz resolution bandwidth, the FSU remains state-of-the-art. This outstanding dynamic range is the result of a new symmetric frontend design (patent pending).

Phase noise is another parameter that has a particular influence on measurements of densely occupied spectra with widely different signal levels as well as on noise power measurements in the adjacent channels of radio transmission systems. The extremely low phase noise of the FSU's local oscillators prevents very low signals from being covered up. With broadband transmission systems such as WCDMA according to 3GPP, a low phase noise far off from the carrier is important. But spurious emission measurements are often limited by phase noise, as with GSM for example. The FSU provides the best results ever produced by a spectrum analyzer. At a 10 MHz carrier offset, for example, the phase noise is –162 dBc (1 Hz) as is shown in FIG 2. In order to minimize the phase noise for critical applications and different carrier offsets, the user can change the PLL bandwidths of the first local oscillator in the FSU, as is also the case with the FSA and FSE.

For general applications, the FSU sets the PLL bandwidth automatically, of course.

The adjacent-channel power measurement of a 3GPP-WCDMA signal serves as an example which demonstrates the extremely high usable dynamic range. With an adjacent-channel leakage ratio (ACLR) of 77.5 dBc, the FSU even surpasses the Signal Analyzer FSIQ from Rohde & Schwarz, which until now exhibited the best performance on the market with 75 dBc. FIG 3 shows the attainable adjacent-channel leakage ratio as a function of the mixer level applied.

The 5 dB steps of the RF attenuator guarantee an optimal setting of the mixer level for maximum dynamic range. Thus, the FSU achieves an ACLR dynamic range of at least 76 dB for all RF signal levels.

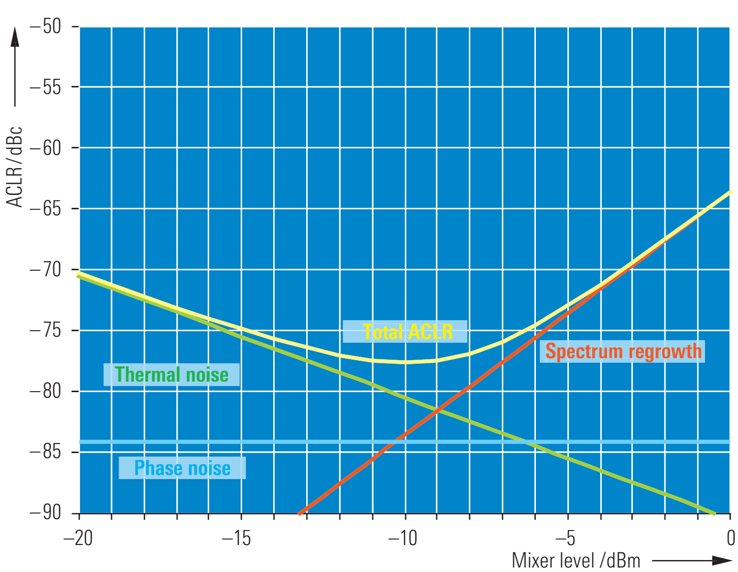


FIG 3
ACLR for a WCDMA signal (3.84 MHz bandwidth, 12 dB crest factor)

Previously unmatched measurement level accuracy

In addition to the RF dynamic range, the measurement level accuracy plays an important role for all applications. The FSU again offers unprecedented values. A low level measurement error provides more room for tolerances in production and helps to achieve a higher throughput (FIG 4).

One parameter that influences the level accuracy is the frequency response of the RF input. Due to the exceptional 50 Ω matching of the first mixer, the uncorrected frequency response is decidedly flat. Thanks to extensive internal correction tables, the FSU can thus guarantee a frequency response of less than 0.3 dB up to 3.6 GHz for attenuator settings from 10 dB upwards. The FSU sets the gain of the signal path during the sweep according to a Rohde & Schwarz-patented method so that all frequency response errors up to the first intermediate frequency are corrected (FIG 5).

The digital filters (10 Hz to 100 kHz bandwidth) result in an extremely small display nonlinearity. The level linearity is only dependent on the linearity of the 14-bit A/D converter used at the last intermediate frequency, whose nonlinearity is kept very low by dithering of the signal.

The display linearity, which in conventional devices is dependent on analog logarithmic amplifiers, is practically error-free in the FSU due to arithmetic taking of the logarithm. So the guaranteed values for the display linearity of the FSU are rather a problem for verification

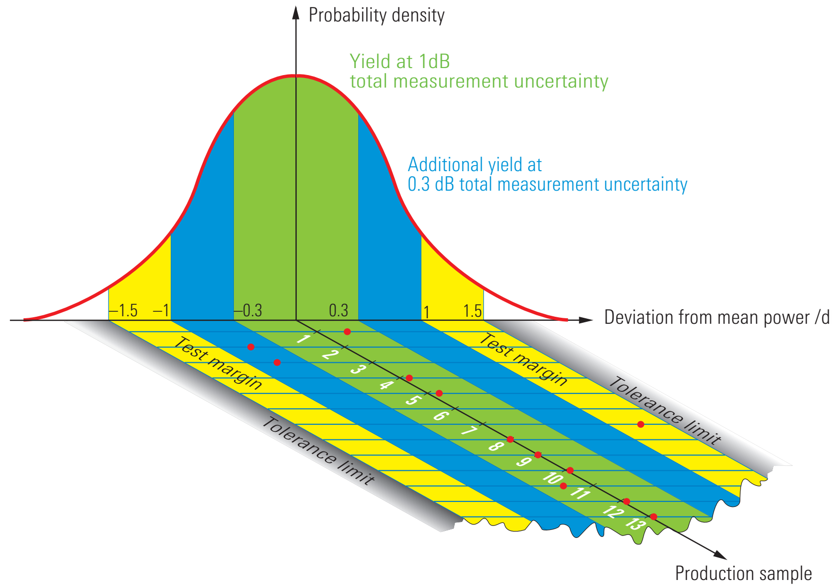


FIG 4 The extremely accurate FSU can increase production yields

by external measurement devices and their traceability to standards. The converter itself has a nonlinearity of approx. 0.03 dB over a display range of 70 dB. With a reasonable outlay for calibration tools, the guaranteed value for the display linearity is ≤0.1 dB.

The total measurement uncertainty of the FSU for frequencies up to 3.6 GHz and 70 dB display range is 0.3 dB (95% confidence level), which makes power meters unnecessary in many cases and leads to unprecedented accuracy for selective power measurements without requiring elaborate correction procedures. Above all, with digitally modulated signals such as WCDMA, the RMS detector contributes considerably to accurate and stable power measurements, whose results are independent of the signal characteristics. By selecting the appropriate sweep time, the user can influence the reproducibility of the measurements.

The video signal for power integration is available with a resolution of 24 bits, which results in an unrestricted dynamic range of over 100 dB for the RMS detector.

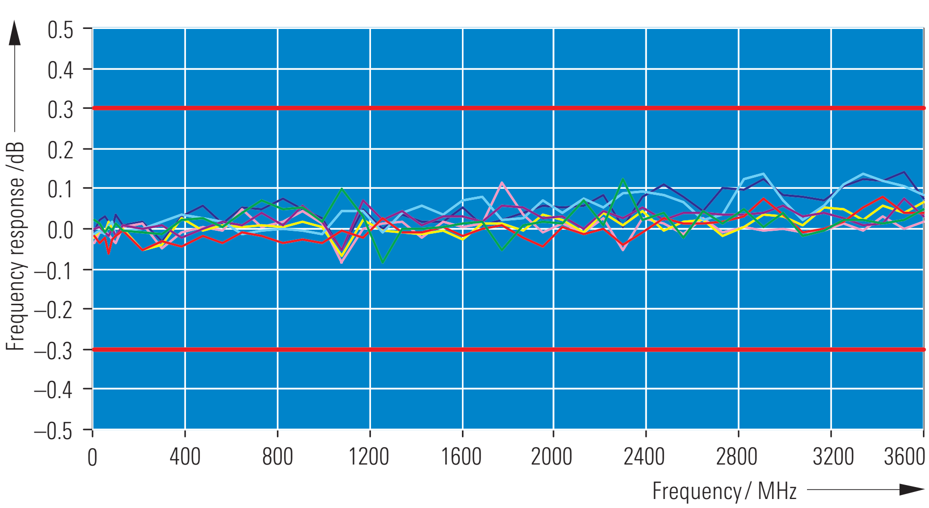


FIG 5 Frequency response of the FSU between 10 MHz and 3.6 GHz (7 different devices)

Numerous bandwidths

An essential feature of spectrum analyzers is the number of resolution bandwidths, since this determines the resolution of the measured signal spectra. The FSU offers a wide variety of bandwidths and filter characteristics. For very

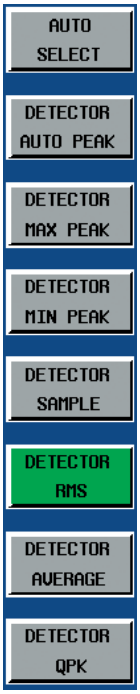


FIG 6
The FSU provides all detectors

narrow resolution bandwidths from 1 Hz to 30 kHz, FFT filters are provided, which offer a considerable advantage when examining spectra close to the carrier (for example, phase noise in the immediate vicinity to oscillators). In comparison to sweep filters, the measurement time is significantly reduced for small bandwidths through the use of the FFT algorithm.

The FSU utilizes digital sweep filters with Gaussian characteristics (in 1/2/3/5 sequence) in the range from 10 Hz to 100 kHz. Not only do they provide a higher selectivity (shape factor 60 dB : 3 dB = 4.5) than conventionally implemented 5-pole filters (shape factor 60 dB : 3 dB = 9), but due to their precisely known characteristics and their transient response, they allow a sweep that is faster by a factor of 2.5. Because of their higher selectivity, a wider filter can be used in many applications. Doubled bandwidth reduces the sweep time to a fourth. And finally, digital sweep filters improve measurement accuracy, since their gain is precisely known and no additional level error occurs when switching bandwidths.

For the bandwidth range from 200 kHz to 50 MHz, analog sweep filters (in 1/2/3/5 sequence) are available, which are built as a 5-pole filter for up to 5 MHz bandwidth. The 10 MHz, 20 MHz and 50 MHz bandwidths are implemented with fixed-tuned channel filters. With a 50 MHz bandwidth, the FSU offers the largest bandwidth ever for any spectrum analyzer designed for general industry applications, and takes into account the development of wideband transmission systems.

As is the case with the FSP, the FSU also contains additional channel filters with nearly rectangular passband characteristics, in conjunction with 38 different bandwidths from 100 Hz and up. Root-raised cosine filters are available in the FSU and FSP – again a first for a spectrum analyzer – which are prescribed for power measurements according to the IS 136, TETRA or WCDMA standards. In addition, channel filters are available for adjacent-channel power measurements according to ETS 300… for analog radio transmission systems with 12.5 kHz or 25 kHz transmission bandwidths. Once again, the FSU allows measurements which were previously not possible or were insufficient with spectrum analyzers.

Complete set of detectors

A complete set of detectors is available in the FSU (FIG 6). In addition to the usual detectors such as Max Peak, Min Peak, Auto Peak and Sample, the RMS and average detectors used in the FSE family of analyzers are naturally included as well. For EMI precompliance measurements, the quasi-peak detectors according to CISPR16 with their associated 6 dB bandwidths of 200 Hz, 9 kHz and 120 kHz can be used. All detectors are implemented digitally so that detection and hold time, temperature drift, aging and errors due to switching are not present. Of course, the trace operations Max Hold, Min Hold and Average are implemented, which allows trace averaging to be carried out in both logarithmic and linear scaling.

Numerous standard functions for laboratory and production

For general applications in the laboratory or in production, the FSU offers numerous functions which considerably simplify measurements and help to avoid errors:
- Two independent measurement settings selectable at a keystroke
- Split-screen display with independent measurement settings in both windows
- 4 markers or delta markers
- Noise marker for measuring noise power density
- Phase noise marker for measuring oscillator phase noise
- Automatic intermodulation measurements for determining the third-order intercept point
- Frequency counter with 0.1 Hz resolution for a 30 ms measurement period
- Measurement of the amplitude modulation depth
- AM and FM demodulator
- Power measurement in time domain (mean, RMS and peak power)
- Measurement of occupied bandwidth
- User-definable limit lines (absolute or relative) with selectable limit values and pass/fail indication

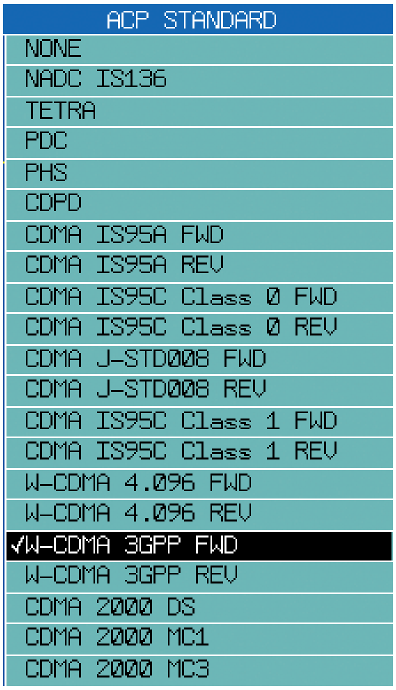


FIG 7 **The FSU provides simple-to-use functions for all of the important transmission standards**

Numerous functions for convenient measurements

The FSU combines its exceptional RF dynamic range with a series of functions which considerably simplify measurements, particularly on digitally modulated signals. Measurements can now be carried out which previously were not possible with a spectrum analyzer.

Special attention should be given to the digital transmission methods, whether they are TDMA for GSM or EDGE or CDMA for WCDMA according to 3GPP.

Adjacent-channel power

One of the most important spectrum measurements is the measurement of the adjacent-channel power, which determines whether the subscribers in the adjacent channels are disturbed by excess power. The FSU is ready for all the important transmission standards (FIG 7) with simple-to-use functions, which configure the analyzer so that it carries out the measurement concerned with the correct settings and optimal dynamic range. The user chooses the desired standard from a list; the FSU sets the optimal attenuation and reference level.

The FSU automatically uses the prescribed filters for all standards and calculates the power in the various channels by integration of the measurement values within the channel. The RMS detector guarantees very precise and reproducible measurement results. In addition to the integration method, the FSU also offers measurement of the adjacent-channel power in the time domain; the power in the individual channels is measured over a selectable time period, which clearly saves time compared to the integration method. For the WCDMA standard, speed advantages of up to a factor of 4.5 can be achieved with the same stable measurement results. This is particularly an advantage in mass production, when nearly a 100% test of all components must be carried out.

The power or adjacent-channel power measurement in TDMA systems requires special functions such as triggering on a TDMA burst, gated sweep and power measurements in the time domain. For triggering, the FSU creates a threshold derived from the RF signal. With a bandwidth of 50 MHz and the gated sweep function, it triggers on a TDMA signal in time or frequency domain and measures within the chosen time period. DUTs which do not offer a trigger signal can therefore be operated without additional circuitry. In the time domain, the FSU measures the power by integration over the selected time span. In addition to the numerical values, the standard deviation is also output, which provides information about the stability of the measurement result.

Amplitude statistics

Digitally modulated signals often contain both an FM and AM component, as for example the QPSK-modulated 3GPP WCDMA signal. When designing transmitters and receivers, not only the average power is important, but also the power peaks and the frequency of their occurrence. In addition to the spectrum and time characteristic, the FSU measures the amplitude distribution of signals; the usual representation is the com-

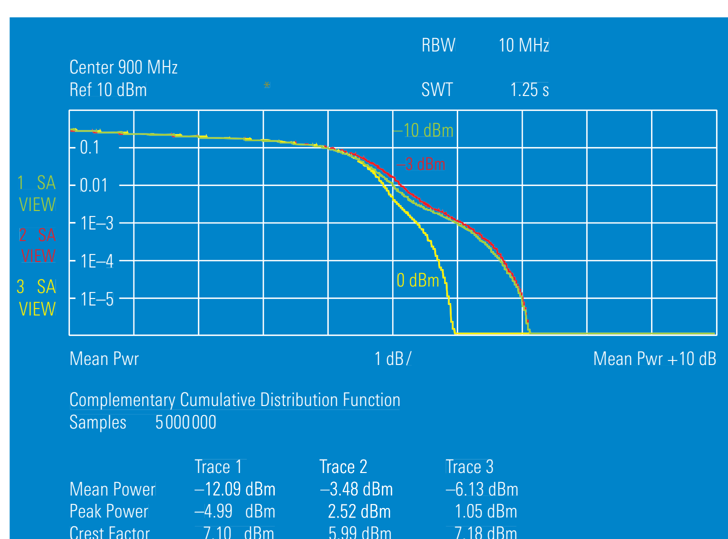


FIG 8 **CCDF measured at the output of a power amplifier for different input levels**

plementary cumulative distribution function (CCDF). Beginning with the average power, the percentage of the power peaks in the signal is represented. FIG 8 shows the CCDF of a WCDMA signal measured at the output of a power amplifier for different input levels. With this function, the FSU adds a further dimension to the assessment of RF signals.

IQ data

For applications which in addition to the magnitude also require the phase of an RF signal, the FSU provides the inphase and quadrature components via the IEC/IEEE bus or LAN interface. It saves the data for each component in a half-megaword RAM. The sampling rate of max. 32 MHz for the IQ signal and the memory size (0.5 k to 0.5 M) are configurable.

High measurement speed

In addition to measurement accuracy, high throughput is an absolute must when using spectrum analyzers in production. The throughput determines how much investment is required for a particular production goal.

A high measurement rate for both manual and remote-controlled operation is the basic prerequisite for high measurement speed. With 25 traces displayed per second, the FSU provides for convenient alignments. In remote-controlled operation, it is extremely fast in the zero span mode, providing more than 60 traces consisting of 625 points each via the IEC/IEEE bus or LAN interface.

However, this does not say everything about the speed at which measurements can be carried out by the FSU. Intelligent measurement routines and functions in this high-end device contribute considerably to avoiding “measurement overhead“ in the specific task. The FSU provides a frequency list mode, in which a record can be entered via the remote interface which contains the frequency and associated settings such as bandwidth, detector, measurement period and reference level. Upon receiving a command, the FSU measures at the given frequency and returns the results as a data record. With harmonic measurements, for example, only the interesting frequencies are recorded, and uninteresting frequency ranges are skipped. And finally, the short settling time of the FSU synthesizer contributes to the measurement speed.

FSU compatible with FSE

The FSU family expands the functionality of the FSE family. Above all, the compatibility for remote operation is of special importance. Previous investments in test programs are not lost when switching to the FSU, since it is command-compatible with the FSE and FSIQ, as far as the functions are supported by both families. Even functions which have been implemented differently in the FSU in comparison to the FSE – for example, the summary marker – are command-compatible with the FSU, and can still be used.

Josef Wolf

More information and data sheet at www.rohde-schwarz.com (search for FSU)

REFERENCES

[1] Spectrum Analyzer FSEA/FSEB – New dimensions ins spectrum analysis. News from Rohde&Schwarz (1995) No. 148, pp 4–8

[2] Spectrum Analyzer FSP – Medium class aspiring to high end. News from Rohde&Schwarz (2000) No. 166, pp 4–7

ADDITIONAL REFERENCES

– Measurement of Adjacent Channel Leakage Power on 3GPP WCDMA Signals with the FSP. Application Note 1EF41

Condensed data of Spectrum Analyzer FSU

Frequency range (FSU3/FSU8)	20 Hz to 3.6 GHz/8 GHz
Amplitude measurement range	–155 dBm to 30 dBm
Amplitude display range	10 dB to 200 dB, 10 dB steps, linear
Amplitude measurement uncertainty	<0.3 dB (to 3.6 GHz), <2 dB (3.6 GHz to 8 GHz)
Resolution bandwidths	1 Hz to 30 kHz, FFT filter in steps of 1/2/3/5, 10 Hz to 20 MHz in steps of 1/2/3/5 and 50 MHz, EMI bandwidths 200 Hz, 9 kHz and 120 kHz, channel filters 100 Hz to 4.096 MHz
Detectors	Max Peak, Min Peak, Auto Peak, Sample, Average, RMS, Quasi-Peak
Display	21 cm (8.4") colour TFT LCD, SVGA resolution
Remote control	IEC 625-2 (SCPI 1997.0), RS-232-C, LAN via 100Base-T
Dimensions (W x H x D)	465 mm x 197 mm x 517 mm
Weight (FSU3/FSU8)	14.6 kg/15.4 kg