THE HISTORY OF MEASURING RECEIVERS AT ROHDE & SCHWARZ

A long tradition

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ROHDE & SCHWARZ

Make ideas real

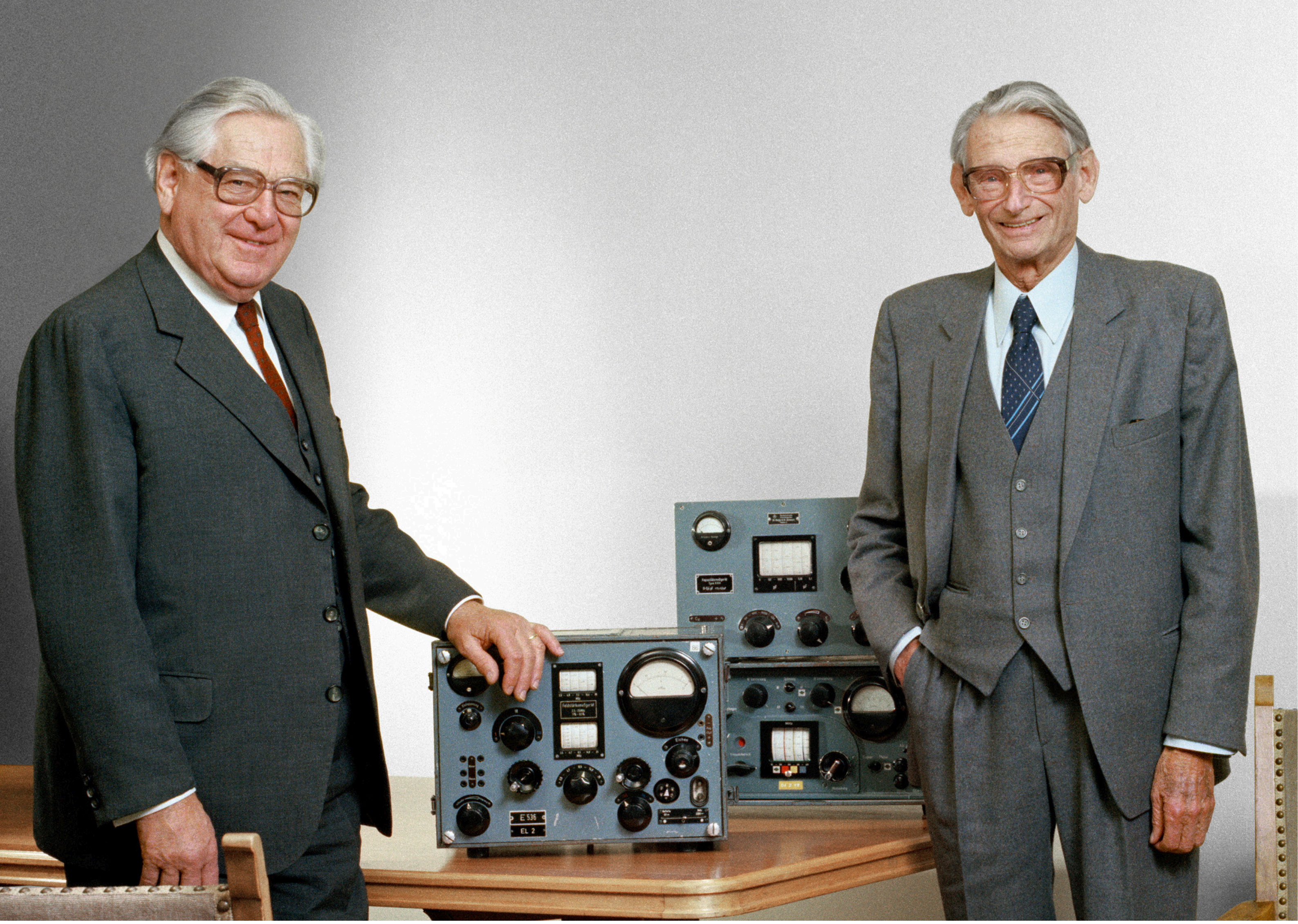


Fig. 1: Dr. Lothar Rohde (right) and Dr. Hermann Schwarz in front of products from the first decade of the company, with the HHF far-field meter in the foreground. It was developed in 1937, roughly the birth year of test receivers at Rohde & Schwarz.

THE HISTORY OF MEASURING RECEIVERS AT ROHDE & SCHWARZ

Rohde & Schwarz has been building EMI test receivers for a long time. The first field strength meter for measuring electromagnetic interference was built in the 1930s. Today Rohde & Schwarz is the world market leader for instruments of this type.

The need for EMI test receivers arose with the introduction of AM broadcasting in the 1920s. Numerous interference complaints from radio listeners made RFI suppression necessary for existing electrical devices and equipment, but suitable measurement procedures and instruments were not yet available. Systematic research for defining uniform measurement procedures to protect broadcasting started only after the establishment of the International Special Committee on Radio Interference (CISPR) in 1933.

It was soon recognized that the effect on radio reception depended on the type of interference (broadband or narrowband) and the radio service concerned. In particular, the dependence on the pulse repetition frequency led to the definition and introduction of the now familiar quasi-peak detector. The aim was to keep RFI suppression costs low, which meant RFI suppression should only be applied where relevant. The test equipment should only indicate a need for action at frequencies where such action was subjectively justified. Low pulse frequencies are perceived as much less disturbing than higher ones (for example, a 100 Hz impulsive disturbance has the same effect on a medium-wave receiver as a 10 dB stronger 10 Hz disturbance), so they could be underweighted in the measurement. This in fact is exactly what a quasi-peak detector does. Quasi-peak evaluation can therefore be likened to simulation of an AM radio receiver together with subjective noise sensitivity.

In 1941, the Association for Electrical, Electronic & Information Technologies (VDE) published the draft standards VDE 0876 "Specification for radio disturbance and immunity measuring apparatus" and VDE 0877 "Principles for measuring radio disturbance voltages". This nomenclature is still valid today. VDE 0876 mirrors the CISPR 16-1-x series of basic standards (apparatus for measuring radio disturbance emissions), while VDE 0877 mirrors the CISPR 16-2-x series of basic standards (methods for measuring radio disturbance emissions).

The first epoch: early beginnings

Rohde & Schwarz started developing and building field strength meters in the 1930s. The first instruments were the HHK field strength meter and the HHF far-field meter in 1937 (Fig. 1). The HHK was available in two versions for the frequency ranges 2.3 MHz to 23 MHz and 23 MHz to 107 MHz. With three versions, the HHF covered a total frequency range from 100 kHz to 100 MHz and enabled field strength measurements from 1 μV/m to 0.1 V/m. It was followed by the HHN near-field meter in 1938, also available in three models covering the frequency range from 100 kHz to 100 MHz.

Fig. 2: The advent of radio broadcasting made RFI suppression necessary. This bronze American figure is listening to a radio speech by President Franklin D. Roosevelt in his memorial in Washington, DC.

In the postwar period, Germany was confronted with a new situation for broadcasting. The Copenhagen plan for radio frequencies in Europe, which took force in 1948, was not kind to the losing countries of World War II and allocated them only very few and unfavorable frequencies in the medium-wave band. As a result, Germany pushed the exploitation of the VHF and UHF bands for broadcasting. A milestone of this development was the first European VHF transmitter, built by Rohde & Schwarz and operating at 90.1 MHz, which was put into service by the Bavarian public broadcasting service on February 28, 1949, in Munich-Freimann. Field strength meters were needed for planning the transmitter site and monitoring transmitter operation. In 1949, Rohde & Schwarz launched the HFD field strength meter for frequencies from 87 MHz to 470 MHz as a companion to the HHF. The HFD core was the ESD measuring receiver, a superheterodyne receiver with a built-in 100 MHz calibration generator. The good reproducibility of voltage calibration enabled very accurate comparison measurement in the linear measuring range even with small changes in the field strength, while the logarithmic measuring range allowed the measurement and recording of strongly varying field strengths. Reception of FM or AM transmitters was also possible.

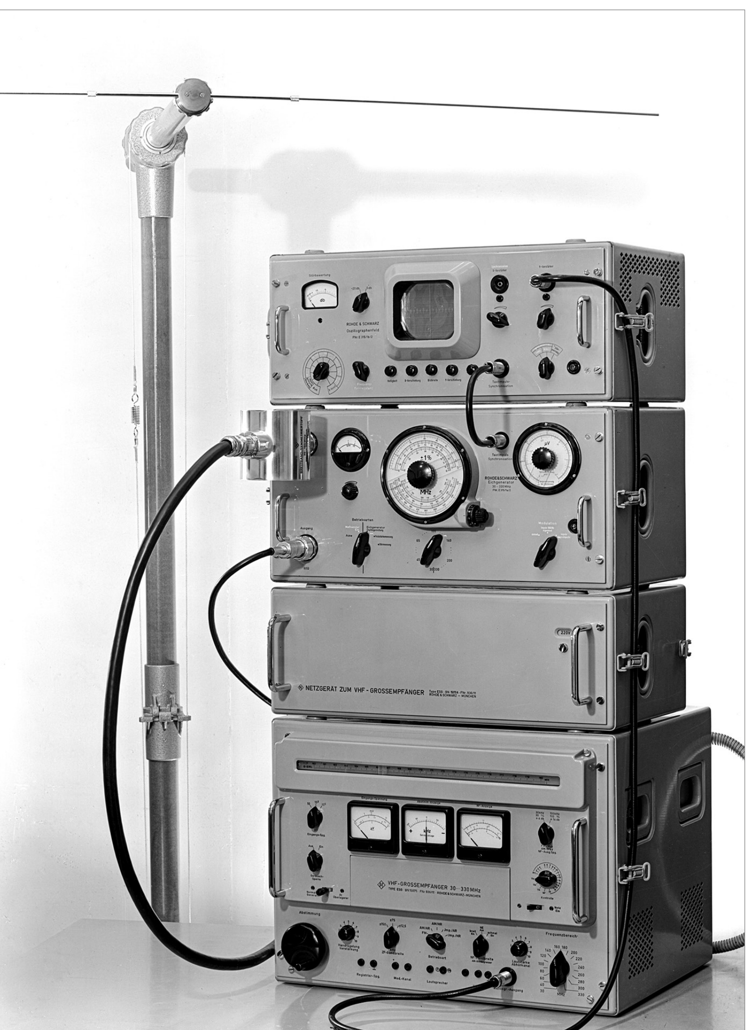


Fig. 3: VHF disturbance measuring system (new model from 1957) with ESG VHF test receiver (bottom) and EZS interference measurement supplement (top).

Opening of the VHF band from 30 MHz to 300 MHz for radio and TV broadcasting brought new requirements for EMI measuring equipment. The standards also had to be updated, from disturbance voltage measurements up to 20 MHz to disturbance field strength measurements up to 300 MHz. CISPR additionally demanded measurement of the disturbance voltage from the DUT at the AC line connection below 30 MHz and the radiated disturbance field strength above 30 MHz. Rohde & Schwarz supported this process with the development of a UHF interference measuring system that was used by the German Telecommunication Engineering Center (FTZ) in Darmstadt and the interference measuring stations of Deutsche Bundespost to investigate the effect of interference on UHF broadcasting.

The noise effect of electrical interference on AM radio broadcasting was known from earlier investigations, but the effect of interference on TV and FM radio broadcasting was largely unexplored. At first it was thought that the effect of interference could be determined by measuring the peak value of the interference pulses. Accordingly, an unweighted peak value display independent of the pulse repetition frequency was selected. An oscillograph (as the instrument was known at the time) was used for qualitative assessment of the interference pulses in terms of shape and width and for comparison of interference and test pulses. It turned out that clearly defined individual pulses were fairly uncommon. The usual pattern was pulse trains with more or less distance between the pulses, e.g. from bouncing contacts, ignitions of internal combustion engines, sparking commutators of electric motors, or corona discharges on high voltage transmission lines. Experience showed that the oscillographic measurement method for acquisition and evaluation of pulse trains was not satisfactory. For instance, the readout varied considerably depending on whether the rare very high pulses of the disturbance signal were used for comparison with the test pulse from the calibration generator or a more frequent average value was assumed. Furthermore, a measurement procedure was needed that directly mapped the effect of interference on TV reception.

It was found that the subjective perception of picture distortion was also dependent on the pulse repetition frequency of the interference pulses, but with a steeper drop compared to aural interference perception with radio reception [1]. Mapping the weighting all the way down to individual pulses would have required measuring receivers able to process amplitude differences greater than 50 dB without overloading. This was not possible at the time, and even now it would be a major challenge for a measuring instrument. The CISPR therefore proposed and implemented a flattened weighting curve for quasi-peak indication in CISPR band C (30 MHz to 300 MHz), which is still part of the CISPR 16-1-1 standard [4]. It specifies a 43.5 dB devaluation for single pulses relative to the peak value. For the rectifier, CISPR defined a charge time constant of 1 ms and a discharge time constant of 550 ms to ensure reproducible results. Finally, the measurement bandwidth had to be adapted to the new broadcasting services. It was initially set to 200 kHz for VHF interference measuring systems, but later the CISPR recommended a value of 120 kHz. All this was integrated in the EZS interference measurement supplement, replacing the oscillographic measurement method by an instrument display. The system was deployed from 1957 by Deutsche Bundespost and the supervisory authorities of other European countries as the standard measuring system. Initially (from 1953) the VHF instruments ESM 180 (30 MHz to 180 MHz) and ESM 300 (85 MHz to 300 MHz) were used as the measuring receiver. From 1955 these were replaced by the ESG measuring receiver (Fig. 3) (30 MHz to 330 MHz).

The HUZ VHF field strength meter for the frequency range from 47 MHz to 225 MHz was also launched at this time. It had a peak voltage display with CISPR weighting. Although this instrument did not meet the high requirements of CISPR Recommendation 305 [2] or the revised VDE Regulation 0876 with regard to absolute accuracy and overload resistance, the portable HUZ could be used for exploratory field measurements, for example to investigate ignition interference in connection with motor vehicle interference suppression.

In 1959, the tried and tested HHF far-field meter was replaced by the HFH (Fig. 4). Unlike the separate instrument variants of the previous generation HHF, the HFH covered the entire frequency range from 100 kHz to 30 MHz in a single instrument. It could be used for direct field strength measurements with a choice of three

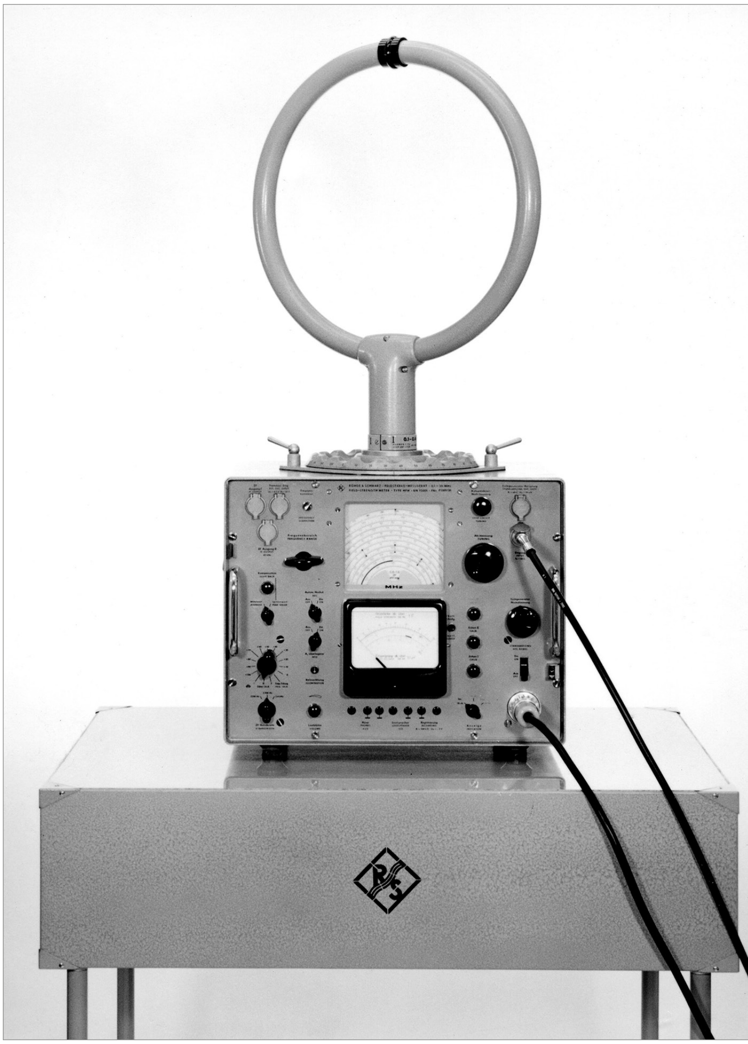


Fig. 4: HFH field strength meter with attached loop antenna for direct field strength readout in the 100 kHz to 30 MHz frequency range. The transport case has been converted into an equipment table.

loop antennas for the ranges 0.1 MHz to 0.4 MHz, 0.4 MHz to 1.6 MHz and 1.6 MHz to 30 MHz, or with a remote rod antenna and later with a remote loop antenna. The tracking calibration generator was an innovation. It enabled calibration at every frequency, including the loop antenna, allowing direct readout of field strength values without the use of calibration curves. The display could be switched between average and peak voltage measurement for disturbance voltage measurements. The instrument came with inductive and capacitive probe antennas for purposes such as testing shielding effectiveness. As a special feature, the transport case could be converted into a table for the test equipment. In addition, the frequency range could be extended down to 10 kHz with the HFHL longwave supplement.

The second epoch: the age of analog superheterodyne receivers with CISPR weighting detectors

The ESU VHF/UHF test receiver (Fig. 5) was launched in 1961. It covered the frequency range from 25 MHz to 900 MHz with three interchangeable plug-ins: RF Part I (25 MHz to 225 MHz), RF Part II (160 MHz to 475 MHz) and RF Part III (460 MHz to 900 MHz). RF Part IV (900 MHz to 1300 MHz) was added in 1969. The ESU was a superheterodyne tube receiver with a spiral analog scale for frequency display. With its sturdy metal enclosure, it weighed in at 30 kg, and it had a measuring signal input conforming to the Dezifix-B standard – a connector type developed by Rohde & Schwarz that was commonly used in the 1960s.

The tracking calibration generator, which could be used to calibrate the instrument at every

Fig. 5: The ESU VHF/UHF measuring receiver had interchangeable RF plug-ins and a measuring signal input conforming to the Dezifix-B standard – a connector type developed by Rohde & Schwarz and commonly used in the 1960s.

measuring frequency, was a major advancement. Operation was also simplified by selectable display ranges (linear 20 dB, logarithmic 40 dB or 60 dB), switchable average or peak value display, selectable passband (25 kHz or 120 kHz) and optional automatic frequency control.

The ESU was the core element of the HFU VHF/UHF field strength meter, which also included a broadband dipole antenna for 25 MHz to 80 MHz, a broadband log-periodic antenna for 80 MHz to 1000 MHz, a stand and a mast, cables with Dezifix connectors and a transport case. The HFU was intended as a frequency extension supplement for the HFH and replaced the previous HHF and HFD field strength meters.

The ESU did not have a built-in weighting function for disturbance field strength measurement according to VDE 0876. The separate EZS interference measurement supplement had to be connected to the IF output (2 MHz) for this purpose. After frequency tuning and calibration, the EZS display had to be set to approximately 0 dB using the ESU level switch and the EZS attenuator. The measurement result in dB above 1 µV was calculated as the sum of the dB value of the EZS attenuator, the ESU level switch setting and the deviation from 0 dB on the EZS display. Then the disturbance field strength in dB above 1 µV/m was calculated by adding the antenna factor. This complicated manual process can be illustrated using a field strength measurement as an example:

- ESU level switch setting: 30 dB
- Attenuation of EZS attenuator: 2 dB
- Deviation from 0 dB on EZS instrument: –0.5 dB
- Antenna factor: 10 dB

This yields a weighted measured field strength of 41.5 dB above 1 µV/m, or 119 µV/m.

Portable instruments were also necessary to cover the UHF band. This led to the launch of the HUZE UHF field strength display in 1964 for the frequency range 470 MHz to 850 MHz, as a sort of extension to the tried and tested HUZ. With peak value rectification and an IF bandwidth of 500 kHz, the HUZE was highly suitable for determining the propagation conditions of television signals in the UHF band.

The portable HFV VHF field strength meter (Fig. 6) followed in 1970. It could measure the field strengths of wanted and disturbance signals from 25 MHz to 300 MHz. The entire band could be tuned without switching ranges. The switchable average and peak value display, the large measuring range of 130 dB, AM and FM demodulation, and disturbance weighting according to VDE and CISPR with the standardized measurement bandwidth of 120 kHz made this instrument ideal for a wide variety of radio monitoring and interference measurements. The HFV was the first Rohde&Schwarz interference measuring receiver with standard-compliant weighting.

In terms of measurement bandwidth, image rejection, overdrive resistance and pulse weighting, the HFV complied with the VDE 0876 standard (December 1955 edition) and CISPR Publ. 2 (1961 edition). The implemented weighting

Fig. 6: HFV mobile VHF field strength meter with dipole antenna. This model was not only the first fully solid-state Rohde&Schwarz test receiver, but also the first able to perform automatic disturbance weighting according to VDE 0876 or CISPR Publ. 2.

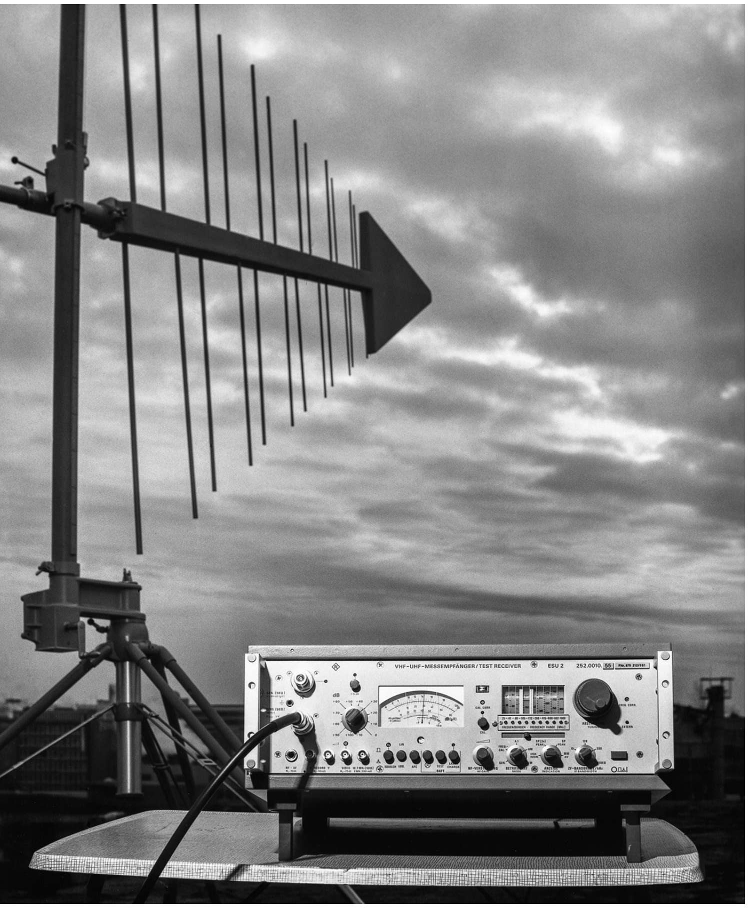


Fig. 7: HFU2 VHF/UHF field strength meter with ESU2 test receiver and HL023 log-periodic broadband antenna for 80 MHz to 1300 MHz.

curve corresponded to the now widely known quasi-peak detector. By contrast, the older HHF, HHN, HFD and HFH did not have any weighting function.

The ESU2 VHF/UHF measuring receiver, the first fully solid-state dual conversion superheterodyne receiver for the frequency range from 25 MHz to 1000 MHz, followed in 1976. The ESU2 (Fig. 7) was a compact instrument with nine selectable overlapping frequency ranges and a built-in weighting circuit compliant with VDE 0876 and CISPR Publ. 2 (25 MHz to 300 MHz) and Publ. 4 (300 MHz to 1000 MHz). This made standard-compliant disturbance emission measurements up to 1000 MHz, with a defined measurement bandwidth of 120 kHz, possible for the first time. In addition, broadband disturbance signals could be measured according to a MIL standard. The precision calibration line at the receiver input, adjustable from 0 dB to 90 dB, contained motor-driven attenuators in steps of 10 dB and extended the linear indication range from 20 dB to a voltage measurement range from –10 dB(μV) to +120 dB(μV).

The ESU2 could be combined with other instruments to make it the first remotely controlled test receiver. The EZK frequency controller used a free-running local oscillator together with a frequency control loop for highly accurate receiver tuning. The EZP panorama adapter, a precursor of the present IF analysis function, displayed the spectrum in the vicinity of the tuned receiver frequency to simplify searching for signals. The control lines and analog outputs were connected to the ESU2-Z4 remote control adapter, which in turn provided the A/D converters and IEC/IEEE bus interface for access to the

Fig. 8: MSUP VHF/UHF tester. The common instrument case contained the ESU2-Z4 IEC/IEEE bus adapter with built-in frequency counter, the EZP panorama adapter, the EZK frequency controller and the ESU2 measuring receiver (from top to bottom). The Tektronix 4051 desktop computer combined all this into an automated test setup.

Year of introduction	Model	Description
1937	HHK	Field strength meter in two variants: 2.3 MHz to 23 MHz and 23 MHz to 107 MHz
1937	HHF	Far-field meter in three variants: 100 kHz to 3 MHz, 2.5 MHz to 25 MHz, and 20 MHz to 100 MHz
1938	HHN	Near-field meter in three variants: 100 kHz to 3 MHz, 2.5 MHz to 25 MHz, and 20 MHz to 100 MHz
1949	HFD	ESD field strength meter with test receiver, 87 MHz to 470 MHz
1953/1955/1957	UKW-Störmessplatz	Disturbance test setup with VHF test receivers ESM 180 (30 MHz to 180 MHz) and ESM 300 (85 MHz to 300 MHz), from 1955 with VHF test receiver ESG (30 MHz to 330 MHz) and from 1957 with EZS disturbance measurement supplement
1954	HUZ	VHF field strength indicator, 47 MHz to 225 MHz
1959	HFH	Field strength meter, 100 kHz to 30 MHz, successor to HHF
1960/1969	HFU	Field strength meter with ESU test receiver (three RF plug-ins for the frequency range 25 MHz to 900 MHz, from 1969 a fourth for 900 MHz to 1300 MHz) and EZS disturbance measurement supplement
1964	HUZE	UHF field strength indicator, 470 MHz to 850 MHz
1971	HFV	VHF field strength meter, 25 MHz to 300 MHz
1976	HFU 2	Field strength meter with ESU 2 test receiver, 25 MHz to 1000 MHz
1979	HFH 2	Field strength meter with ESH 2 test receiver, 10 (9) kHz to 30 MHz

Rohde & Schwarz test receivers from 1937 to 1979.

digital domain. This marked the birth of the first system-capable EMI test receiver which was actually a small system in itself (Fig. 8).

Finally, the ESH 2 triple conversion superheterodyne test receiver was launched in 1979. With a frequency range of 10 (9) kHz to 30 MHz, it was the ideal complement to the ESU 2. Shortly after the instrument presentation, the CCIR and then the CISPR extended the radio frequency range to 9 kHz, for which reason the ESH 2 was ultimately supplied with a start frequency of 9 kHz. This manually operated measuring receiver could be semi-continuously tuned through the entire frequency range in steps of 100 Hz or 10 kHz, without range switching. The synthesizer was controlled by an up-down counter, which in turn was controlled by a mechanical/electronic rotary encoder with magnetic detents. The counter was powered directly from the internal battery, so the last frequency setting was saved when the instrument was power cycled. Another innovation was the six-digit LCD frequency display with quartz crystal accuracy.

Naturally, the ESH 2 had a built-in weighting circuit for EMI measurements according to VDE 0876 or CISPR Publications 1 and 3. Thanks to its compact design, relatively low weight (still around 20 kg) and battery operation, the instrument was suitable for portable use. Addition of the HFH 2-Z1 whip antenna, the HFH 2-Z2 loop antenna and the HFH 2-Z4 inductive sensor head resulted in the HFH 2 field strength meter (Fig. 9).

Fig. 9: HFH 2 field strength meter with ESH 2 test receiver and associated antennas for the frequency range 9 kHz to 30 MHz.

The third epoch: the age of microprocessor-controlled measuring receivers

With the ESU2, four individual instruments were necessary to form a system-capable, remotely controllable measuring receiver, but the next generation integrated the complete functionality in a single instrument.

ESH3 and ESVP EMI test receivers

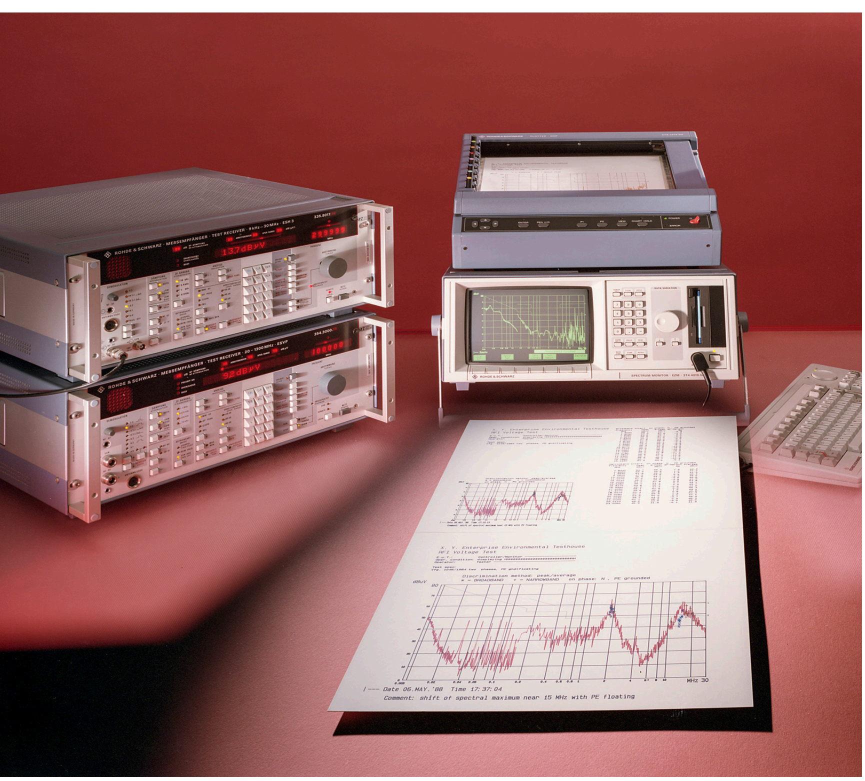
One receiver (ESH3) for measurement of conducted disturbances up to 30 MHz and a second receiver (ESVP) for disturbance field strength measurements up to 1300 MHz covered the frequency range for commercial EMC measurements in those days.

An 8085 microprocessor, which was state of the art at the time, ticked away in the ESH3 (1980, Fig. 10). The display was digital, and the receiver had, for the first time, an IEC/IEEE bus connector for remote control. Memory space was tight, so a lot of code was written in assembly language, and otherwise in PL/M. At first the developers tried to fit the executable code in 8 kbytes of memory, but they were forced to expand it to 16 kbytes and then again to 24 kbytes to make room for all the functions. In the early days of microprocessor technology, memory was expensive and therefore always scarce, so optimization was the rule of the day.

The ESVP, which was launched in 1983, boasted two 8085 microprocessors. One communicated with the modules, while the other communicated with the outside world through the control panel and the remote control interface. They talked with each other through dual-port RAM, truly high-tech at the time. For traditionalists there were comparable models with the same RF section but without any microprocessor technology or software: the ESV and ESH2. Of course, a bit of digital technology was integrated to control the individual modules. With this two-pronged approach, these highly successful models paved the way for the transition to the age of microprocessor-controlled test receivers.

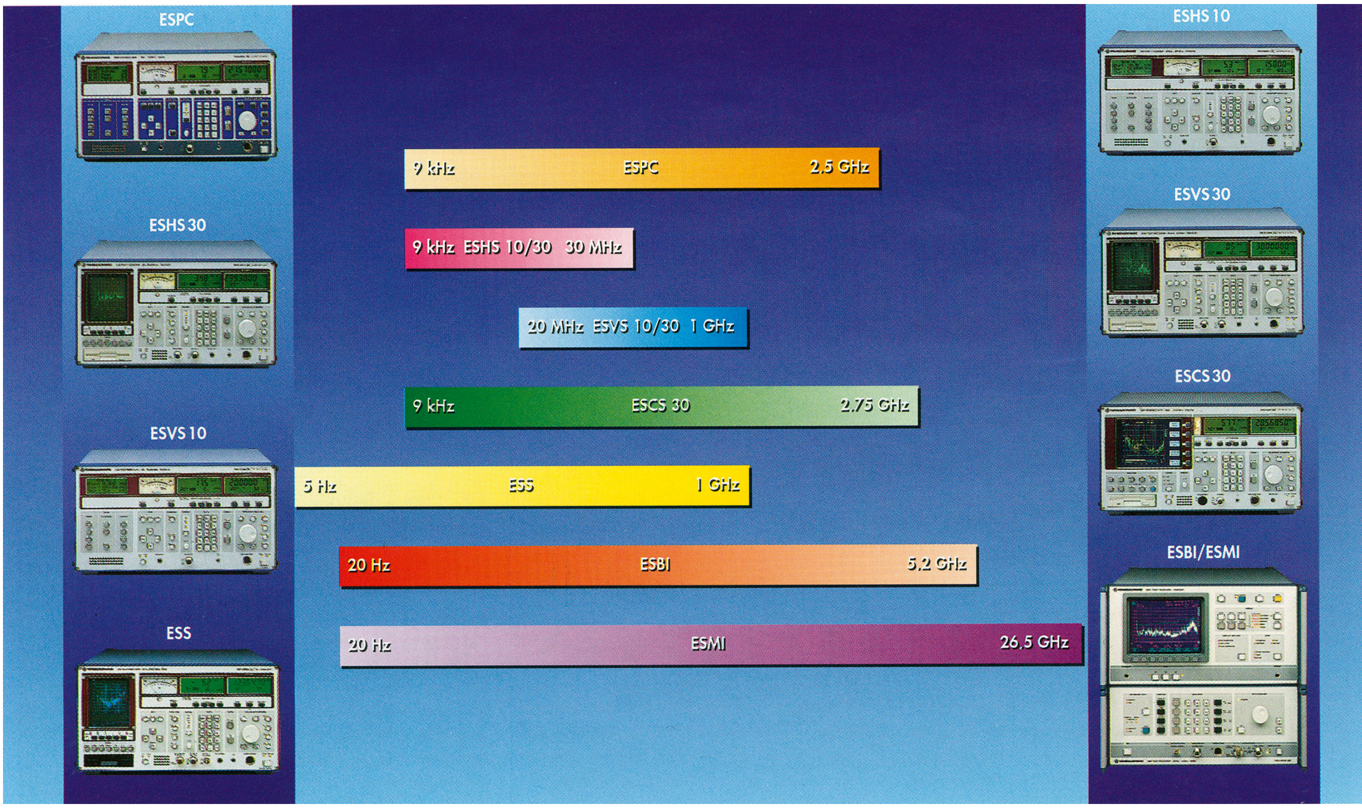
This generation also followed the same path as the ESU2, starting with several separately operated instruments forming a small system with extended functional range. In the next step, this tried and tested functionality was then merged through a central control unit. Here, this role was assumed by the EZM spectrum monitor, a PC-like device with the MS-DOS operating system that remotely controlled the ESH3 and ESVP and displayed the measured spectrum on a screen with a fabulous resolution of 1024 × 512 pixels. Softkeys were also part of the picture. The first EMC measurement software from Rohde&Schwarz – EZM-K1 – ran on the processor. It extended measurement automation to control of the mast and turntable for field strength measurements. Measurements according to different standards and libraries of limit lines were already standard then. Output of test reports on dot matrix printers or plotters rounded out the functional range. The ESH3/ESVP/EZM combination of instruments enjoyed great popularity in test labs for both commercial and military standards.

Fig. 10: Test receivers ESH3 (9 kHz to 30 MHz, top) and ESVP (20 MHz to 1300 MHz) with EZM spectrum monitor.



ESHS and ESVS EMI test receivers

For the next generation of instruments, the initial approach was again to develop separate



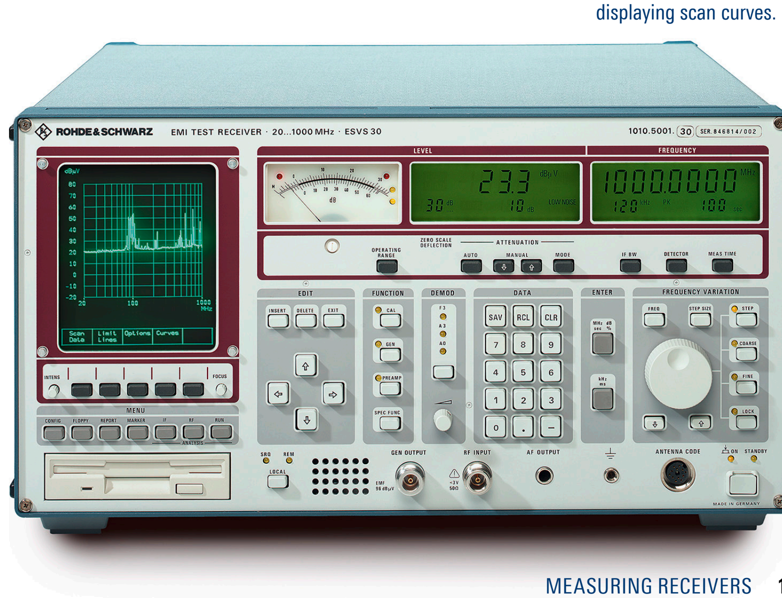
The Rohde & Schwarz test receiver product line in the 1990s, shown in contemporary graphic style [3].

models for measurement of conducted and radiated disturbances. A second main feature was a four-line LC display or a screen with vector graphics (Fig. 11) on the instruments. Even the instruments with the LC display had built-in automation functions that enabled them to automatically control artificial mains networks and at the same time (thanks to a multitasking operating system) output test reports to a plotter or printer. The possibility of mains-independent battery operation made the instruments ideal for mobile applications, and open area test sites were certainly common. The instruments with higher-end configurations had a CRT with electrostatic deflection, such as typically installed in oscilloscopes – a solution that generates very little electromagnetic disturbance. In addition to text, the vector graphics could display scan curves and the IF spectrum. A 3.5-inch diskette drive was integrated for saving and loading measurement results, limit lines, correction value tables and scan data sets. The instruments also contained a tracking generator for use in four-pole measurements or specifically for the determination of cable loss.

ESS EMI test receiver

The flagship of this instrument family was the ESS test receiver, which along with a frequency range of 5 Hz to 1 GHz supported all CISPR and MIL bandwidths up to 1 MHz. It was an impressively uncompromising technical solution in a compact instrument with the greatest possible

Fig. 11: As one of the top models of its generation, the ESVS featured analog and numerical measurement data display as well as vector graphics for displaying scan curves.



sensitivity and high pulse immunity. Three separate RF input modules with different mixing concepts ensured first-class RF characteristics. ESS instruments are still deployed worldwide.

ESCS 30 EMI test receiver

In 1997 the German Federal Office for Posts and Telecommunications (BAPT) – now the German Federal Network Agency – issued a call for bids for a considerable number of EMC test receivers, since the BAPT was responsible for protecting radiocommunications against interference. The requirements were very demanding and could not be met by the existing product line, e.g. in terms of frequency range. A development project was therefore quickly launched to take advantage of this opportunity. The result was an instrument with unique features. Its highlights included a continuous frequency range from 9 kHz to 2.75 GHz and a color LC display with VGA resolution for measurement curve visualization, combined with a bargraph display for up to three detectors operating in parallel. Another new feature was time domain analysis for assessment of the time progression of a disturbance signal – a measurement function oriented to daily practice and helpful for tasks such as tracking down a defective heating controller. All this was built into the enclosure of the existing models. As was to be expected, the ESCS 30 fulfilled all requirements of commercial EMC standards according to CISPR and VDE. Fully automatic and semi-automatic test sequences combined high measurement convenience with fast and reliable receiver setup. The possibility of mains-independent operation for up to 4 hours with the internal battery, along with the built-in 3.5-inch diskette drive, made this model suitable for mobile use as well. The ESCS 30 won the BAPT call for bids, making it a first-class reference after its market launch.

Rohde & Schwarz test receivers from 1980 to today.

Year of introduction	Model	Description
1980	ESH 3	EMI test receiver, 9 kHz to 30 MHz
1982	ESV	EMI test receiver, 20 MHz to 1000 MHz
1983	ESVP	EMI test receiver, 20 MHz to 1300 MHz
1991	ESHS	EMI test receiver, 9 kHz to 30 MHz, series 30 with built-in spectrum display
1991	ESVS	EMI test receiver, 20 MHz to 1000 MHz, series 30 with built-in spectrum display
1991	ESAI	EMI test receiver, 20 Hz to 1.8 GHz
1991	ESBI	EMI test receiver, 20 Hz to 5.2 GHz
1992	ESS	EMI test receiver, 5 Hz to 1 GHz
1994	ESMI	EMI test receiver, 20 Hz to 26.5 GHz
1995	ESPC	EMI test receiver, 150 kHz to 1 GHz
1997	ESCS 30	EMI test receiver, 9 kHz to 2.75 GHz
1999	ESI/ESIB	EMI test receiver in three models for the frequency ranges 20 Hz to 7 GHz, 20 Hz to 26.5 GHz, and 20 Hz to 40 GHz
2004	ESCI	EMI test receiver, 9 kHz to 3 GHz
2006	ESU	EMI test receiver in three models: 20 Hz to 8 GHz, 20 Hz to 26.5 GHz, and 20 Hz to 40 GHz
2008	ESL	EMI test receiver in two models: 9 kHz to 3 GHz and 9 kHz to 6 GHz
2009	ESCI7	EMI test receiver, 9 kHz to 7 GHz
2012	ESR	FEMI test receiver in three models: 10 Hz to 3 GHz, 10 Hz to 7 GHz, and 10 Hz to 26.5 GHz
2013	ESRP	FEMI test receiver in two models: 10 Hz to 3 GHz and 10 Hz to 7 GHz
2016	ESW	EMI test receiver in three models: 2 (1) Hz to 8 GHz, 2 (1) Hz to 26.5 GHz, and 2 (1) Hz to 44 GHz

ESPC EMI test receiver

The ESPC was specifically developed for deployment in the precompliance area, as indicated by the letter "P" in its name. Despite its somewhat reduced technical performance, it provided measurement results with significantly higher accuracy and reliability than pure spectrum analyzers. It was therefore primarily used for measurements during development in all branches of industry and for all product classes, as well as in research and education. Even in test houses it was often used as an auxiliary instrument.

ESAI, ESBI and ESMI EMI test receivers

These models established a new era. For the first time, Rohde & Schwarz test receivers were based on the operating principle of a spectrum analyzer. The previous line of conventional test receivers was still maintained in parallel for a few years, but ultimately it was discontinued in favor of instruments based on a spectrum analyzer.

Their particular advantage was fast multiple sweeps with a max-hold function for prescan measurement, resulting in improved acquisition of fluctuating narrow-band disturbance signals. In addition, the instruments combined the precision, selectivity, dynamic range and sensitivity of a selective test receiver with the ability to perform any desired spectrum measurements. Due to the frequency range from 20 Hz to 1.8 GHz, 5.2 GHz or 26.5 GHz and the technical configuration, this receiver type was very popular with test houses as well as in military applications, research, education and the aerospace industry.

The fourth epoch: the digital era

The advent of digital broadcasting and communications systems also impacted disturbance weighting methodology. CISPR investigated the effect of impulsive disturbances on numerous digital radiocommunications services, with that result that new weighting functions were adopted in the basic standard CISPR 16-1-1 [4] in 2007: the RMS-average detector and the amplitude probability distribution (APD) measurement function.

The first test receiver with an RMS detector was the ESIB, based on the FSE spectrum analyzer and launched in 1999. The advantageous combination of a spectrum analyzer and a test receiver, which began with the ESAI and has remained very popular until today, was a result of progress in digital technology. The more stages in the signal path that are implemented with digital signal processing, the easier it is to provide different operating concepts, which receivers and spectrum analyzers inherently have, on the same platform. In that case the analog hardware is designed to support both the sweep function of the spectrum analyzer and the stepwise frequency scan of the receiver. This is complemented by RF preselection, which is active in all operating modes and is essential to meet the high demands for measurement dynamic range.

The ESIB was the first compact test receiver with a frequency range up to 40 GHz, which covered the requirements of commercial EMC standards as well as the frequency ranges for military standards and the FCC. The instrument utilized a digital signal processor (DSP) and provided FFT support to shorten the measurement time in spectrum analyzer mode, which is now a standard feature in spectrum analysis and receiver technology.

The practice of basing new test receivers on the current series of spectrum analyzers, which started with the ESIB, was continued with the R&S®ESU (from 2002, all Rohde & Schwarz products had the brand abbreviation in their name). The high-end R&S®FSU was the godfather of the R&S®ESU. The name ESU came from the combination of FSU and the letter "E" for "Empfänger" (German for "receiver"), and with this designation the instrument paid tribute to the ESU tube receiver from 1961. The same approach was followed in the midrange segment, where the platform source was the R&S®FSP spectrum analyzer. This resulted in three EMI test receivers: the top-end R&S®ESU for automotive and MIL-spec applications, the R&S®ESCI for compliance measurements (as indicated by the letter "C") primarily according to commercial standards, and the R&S®ESPI with more modest RF characteristics for the precompliance area (indicated by the letter "P" in the name).

The R&S®ESPI and R&S®ESCI were traditional test receivers that could only measure at one receive frequency, but the R&S®ESU went significantly further. With its FFT-based frequency scan using digital signal processing, it considerably reduced measurement times. Unreserved use of this technology, which was new in the EMC world, required standardization, but this was not yet finalized. Nevertheless, large parts of the automotive world accepted the advantages of faster measurement. The measurement results are the same as long as general conditions are met, such as a sufficiently long measurement time. In addition, for the first time the R&S®ESU had an APD measurement function compliant with the CISPR 16-1-1 standard [4]. The trio of R&S®ESU, R&S®ESCI and R&S®ESPI was widely accepted in the professional world.

The current generation of test receivers was born in 2012. The midrange instruments were the first to be replaced. Digital signal processing was front and center in the development of the R&S®ESR. The aim was to perform the compute-intensive FFT in real time in field programmable gate arrays (FPGAs). Many technologies were taken over from the R&S®FSVR real-time spectrum analyzer, which was based on the same platform and completed a short time earlier. The R&S®ESR was the first test receiver that could be equipped for real-time spectrum analysis as an option. This gave the EMC world completely new ways to analyze disturbance signals, but the real highlight of the new generation was frequency scanning with quasi-peak detection fully conforming to the requirements of the CISPR 16-1-1 standard. Depending on the required measurement bandwidth, the overall measurement time was reduced dramatically, turning hours into seconds. The R&S®ESR was the first receiver to master the art of visualizing the entire CISPR band B (150 kHz to 30 MHz) in real time with standard-compliant quasi-peak detection. The spectrogram presents the user with a seamless progression of the disturbance signals over time. The effects of changes to the equipment under test can be seen immediately, and the test depth achieves an unprecedented dimension.

Fig. 12: The current flagship of the EMI test receiver fleet: the R&S®ESW, shown here with the APD multichannel measurement function on the screen.

Test receivers are often controlled by EMI test software, but a "real" test receiver like the R&S®ESR must have an "analog" feel when operated manually, e.g. when tuning the frequency with a rotary knob. The R&S®ESR additionally increased ease of operation with an integrated touchscreen, for the first time in this instrument class. The R&S®ESRP, the current precompliance variant of the R&S®ESR with the same exterior design, also has this feature.

Major progress was also seen on the standardization side. Edition 3.1 of the commercial EMC standard CISPR 16-1-1 [4] was published in 2010. It describes FFT-based test receivers, in effect legitimizing the deployment of this technology. The MIL Standard Committee took note of this prior work and in 2015 defined the conditions for the use of FFT-based test receivers in MIL-STD-461G.

The current product line was rounded out with the top-end R&S®ESW (Fig. 12) in 2016. Along with even better RF characteristics and higher measurement speed, the R&S®ESW picked up a number of innovations along the way, such as a pulse limiter to protect the input against strong interference pulses. Switchable notch filters suppress WLAN signals to enable sensitive measurements on devices with activated radio modules (welcome to the internet of things!). The user interface has also been refined. Clearly organized menus with a total absence of submenus increase ease of use and shorten the learning curve. Like the R&S®ESU and R&S®ESR, the R&S®ESW naturally has a CISPR APD measurement function, which since 2020 can also be ordered as a multichannel version. This allows assessment of quickly fluctuating interferers, for example in disturbance emission measurements on household microwave ovens in the frequency range of 1 GHz to 18 GHz.

Rohde & Schwarz has been in the EMI test receiver business for more than 80 years. From the very first EMI test receivers in the 1930s through the era of analog superheterodyne receivers to advanced FFT-based instruments, Rohde & Schwarz has repeatedly introduced innovations and set standards. Naturally, the company is keeping true to this course. In the emerging age of the wirelessly networked internet of things with rising requirements for the coexistence of components, careful use of the spectrum plays an increasingly important role. In addition to test receivers, this requires a whole range of test & measurement equipment extending as far as turnkey EMC test facilities. As a full-service provider, Rohde & Schwarz can cover the full range of these needs.

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For more information and data sheets, visit www.rohde-schwarz.com.

The HHF far-field meter, which marked the beginning of the measuring receiver history at Rohde&Schwarz, in a contemporary advertisement.

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