

TETRA Measurements

Application Note

Products:

R&S®SMW200A	R&S®FSQ
R&S®SMU200A	R&S®FSU
R&S®SMATE200	R&S®FSH4/8
R&S®AMU200A	R&S®TSMW
R&S®SMJ100A	R&S®ZVH
R&S®SMBV100A	R&S®PR100
R&S®SMB100A	R&S®DDF05A/E

TETRA is the professional mobile radio standard used world wide by governmental safety and security authorities and organizations, as well as by private utilities from energy suppliers through to transport.

Rohde & Schwarz provide test instruments ideally suited for both the development and production of TETRA base stations and user equipment, as well as for network planning, network coverage and quality of service, network monitoring and optimization, maintenance, and service.

This Application Note shows examples for measurements with R&S instruments covering the entire range of TETRA test requirements.

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1 Introduction

TETRA, the TERrestrial Trunked RAdio, is the professional mobile radio standard (PMR) used world wide by governmental safety and security authorities and organizations, as well as by private utilities from energy suppliers through to transport.

Rohde & Schwarz provide test instruments ideally suited for both the development and production of TETRA base stations and user equipment, as well as for network planning, network coverage and quality of service, network monitoring and optimization, maintenance, and service.

This Application Note shows examples for measurements with R&S instruments covering the entire range of TETRA test requirements.

Chapter 2 provides an overview of the most important features in the TETRA standard. Chapter 3 covers measurements in R&D, production, and conformance testing. It highlights the instruments used for general T&M tasks, signal generators, and signal and spectrum analyzers.

Chapter 4 discusses the planning and analyzing of TETRA networks. The R&S®TSMW universal radio network analyzer and the drive test software R&S®ROMES4 are presented in this chapter.

Chapter 5 covers the detection and elimination of interference using the R&S®PR100 portable receiver.

Chapter 6 describes precision direction finding of base and mobile stations using the R&S®DDF05E digital HF/VHF/UHF monitoring direction finder.

Finally, Chapter 7 describes measurements using portable, battery-operated instruments to perform on-site service and maintenance. It presents the R&S®ZVH cable and antenna analyzer and the R&S®FSH4/8 spectrum analyzer.

Notes:

To correlate with the usage in the standard, this document uses the term "mobile station" (MS) to refer to both portable and built-in TETRA user equipment.

The R&S®SMW200A vector signal generator is referred to as the SMW.

The R&S®SMU200A vector signal generator is referred to as the SMU.

The R&S®SMATE200A® vector signal generator is referred to as the SMATE.

The R&S®SMJ100A® vector signal generator is referred to as the SMJ.

The R&S®SMBV100A® vector signal generator is referred to as the SMBV.

The R&S®AMU200A baseband signal generator and fading simulator is referred to as the AMU.

The R&S®FSQ signal analyzer is referred to as the FSQ.

The R&S®FSU spectrum analyzer is referred to as the FSU.

The R&S®FSH4/8 spectrum analyzer is referred to as the FSH.

The R&S®TSMW universal radio network analyzer is referred to as the TSMW.

The R&S®ROMES4 drive test software is referred to as the ROMES.

The R&S®PR100 portable receiver is referred to as the PR100.

The R&S®ZVH cable and antenna analyzer is referred to as the ZVH.

The R&S®DDF05A digital HF/VHF/UHF scanning direction finder is referred to as the DDF05A.

The R&S®DDF05E digital HF/VHF/UHF monitoring direction finder is referred to as the DDF05E.

2 The TETRA standard: Its goals and technology

TETRA is a well established ETSI standard for public and private-sector secure radio-communications. In 2010, TETRA services were provided in more than 100 countries around the world; 57 % of the providers were civilian users, and the other 43 % were government authorities and other organizations with security missions.

TETRA was introduced in response to challenging requirements. First among these requirements are unlimited system availability and the guarantee of secure, uninterrupted, and stable wireless communication. These requirements cannot be met without very good radio coverage throughout the usage area, making careful network planning and gap-free coverage checks necessary. Some TETRA mobile stations can also function as repeaters, and mobile stations can communicate with one another directly without connecting to the base station (*direct mode operation, DMO*). This ensures additional security and can help to overcome inadequate coverage; for example, in buildings.

The most frequent TETRA operating mode is the group call (point to multipoint). Users must be able to contact all other group members directly by pressing a single button, without dialing any numbers. This requires very fast call setup. Call hierarchies are needed to ensure, for example, that emergency calls are not dropped. Typically, a dispatcher is included to monitor communications and to interrupt calls as necessary. Secure radiocommunication also requires consistently good voice quality and protection against eavesdropping. In that, TETRA as a digital system is superior to any existing analog networks.

Security, reliability, group management, and quality are the four most important TETRA network characteristics. Refer to [4] for a good summary of differences between TETRA and public cellular networks.

The following listing applies primarily to the physical layer; that is, the air interface (*AI*). Table 1 lists the most important system parameters for TETRA Release 1:

TETRA (Release 1)	
Parameter	Value
Frequency	about 400 MHz
Carrier Spacing	25 kHz
Access Method	TDMA, 4 Timeslots / Carrier
Uplink / Downlink Spacing	10 MHz
Modulation	$\pi/4$ DQPSK
Carrier Data Rate	36 Kb/s
Voice Coder Rate	7.2 kb/s gross
User Data Rate per Timeslot	7.2 kb/s (no error protection)
Voice + Data	4.8 kb/s (low error protection)
	2.4 kb/s (high error protection)

TETRA (Release 1)	
Parameter	Value
Packet Data Only (PDO) Data Rate	36 kb/s gross (4 Timeslots)

Table 1: TETRA system parameters

TETRA uses separate frequency bands for the uplink and the downlink. In Release 1, a TETRA channel covers a spectrum of 25 kHz in the uplink band or in the downlink band. In full duplex mode, the user has one uplink channel and one downlink channel. In addition to full duplex mode, half duplex mode is also available, in which a MS may either send or receive, but not both.

The uplink frequency and the downlink frequency are separated by 10 MHz.

In TETRA Release 1, a physical channel is defined as an uplink or as a downlink channel with a bandwidth of 25 kHz, one frequency, and one or more timeslots. One physical channel can encompass multiple logical channels. Slot 1 in frame 18 of the downlink channel, for example, holds the logical channels BNCH (Broadcast Network Channel) and BSCH (Broadcast Synchronisation Channel), with network information and synchronization signals.

TETRA is a TDMA system with four timeslots per frame. Normally, these four timeslots are allocated to four users (four physical channels). To increase throughput, however, it is also possible to allocate up to four slots to one user. To ensure adequate system capacity, each network typically has reserved a set of multiple 25-kHz uplink and downlink channels (frequencies).

One TETRA multiframe is made up of 18 frames. In general, the first 17 frames are for traffic (voice or data), and frame 18 holds signaling information. This applies to both the uplink and the downlink. From time to time traffic frames may be used for fast signaling as well (frame stealing).

TETRA uses the following traffic modes:

In trunked mode operation (TMO), the traffic is handled via the base station. The voice and data system (V+D) and the packet data only system (PDO) are used in this mode.

The voice and data system offers circuit mode voice and data, packet mode data, and short data service (SDS). Voice and data are multiplexed, and SDS takes advantage of unused capacities in the signaling channels. One user uses one to four timeslots. The PDO system always uses all four timeslots (exclusively for data).

Various channel codings are possible depending on the requirements - either low, medium, or high error protection.

In direct mode operation (DMO), mobile stations communicate directly without involving a base station. Traffic is limited to one timeslot. V+D, data transfer, and SDS are all possible.

The maximum net data rate in Release 1 is 28.8 kb/s (4 timeslots, unprotected).

Over time, however, the demand for data throughput has increased significantly around the world, primarily by private users. For example, one mass transit network in southern Germany already processes about 80,000 data messages daily. TETRA Release 1 is reaching its limits.

The standard has therefore been expanded to include the TETRA Enhanced Data Service (TEDS). TETRA plus TEDS is also known as TETRA II (TETRA Release 2).

TEDS includes new layer 1 functions. To increase data throughput, four additional modulation schemata were introduced: $\pi/8$ D8PSK, 4-QAM, 16-QAM, 64-QAM. The bandwidth of the physical channels was also expanded. Bandwidths of 25 kHz, 50 kHz, 100 kHz, and 150 kHz are now possible. Within these bandwidths, the symbols are distributed (for QAM) onto narrow subcarriers at intervals of 2.7 kHz. This increases the robustness of the transmission. A 25-kHz band now includes 8 transmit frequencies, a 50-kHz band has 16, and so on.

This makes the following data rates possible:

Gross Bit Rates				
Modulation and Channel Type	Gross Bit Rate (kb / s)			
	25 kHz	50 kHz	100 kHz	150 kHz
$\pi/4$ DQPSK 1 Slot	9			
$\pi/4$ DQPSK 4 Slots	36			
$\pi/8$ DQPSK 4 Slots	54			
4-QAM 4 Slots	38.4	76.8	153.6	230.4
16-QAM 4 Slots	76.6	153.6	307.2	460.8
64-QAM 4 Slots	115.2	230.4	460.8	691.2

Table 2: Data rates for TETRA II [1]

The TEDS expansions apply exclusively to data transmissions. All Release 1 functions (e.g., Voice+Data) remain in place without modification. TEDS makes new applications available, such as image transmission within seconds.

However, this is far from sufficient for many users. Applications such as realtime video transmission require significantly higher data rates. This is why a TETRA III specification is being considered.

At present, the trend is increasingly toward linking TETRA and existing broadband technologies, such as the UMTS Long Term Evolution (LTE). Rohde & Schwarz is involved in both standards. In particular, the TSMW universal radio network analyzer discussed in Chapter 4 can measure TETRA as well as LTE networks in parallel.

3 Measurements in R&D, production, and conformance testing

Measurements carried out on base and mobile stations are derived primarily from the measurements prescribed by the ETSI standard for conformance tests [3].

In the case of measurements for R&D, however, the limits are often stricter. The applied stimulus signals use more critical levels and signal degradation is often deliberately implemented e.g. IQ impairments, additional noise (AWGN) or modified fading profiles. The demands placed on T&M instruments in R&D are high.

In principle, the measurements during production are the same as those for conformance testing. However, as few tests as possible are used, and they have to be carried out in the shortest possible time. Therefore the conformance test procedure will often be modified:

For example, for the transmitter tests, the standard stipulates that an MS under test has to read the cell information from an air interface downlink signal at first. Then the parameter *T1_T4_burst_type* of the cell information defines which uplink signal the MS has to generate. In production this is typically set directly.

In production, it's also important that as many results as possible are derived from every single measurement. This is achieved by using analyzer options customized to the specific standard.

In contrast to other mobile radio standards, TETRA uses most of the same RF tests for both base and mobile stations. However, the BS and MS tests do use different test signals as well as different limits and tolerances, of course. The manner in which the DUT is controlled during the test also differs.

Radio test modes and test signals

For both base and mobile stations the two test modes *transmit* and *receive* are available. These test modes are enabled individually following the manufacturer instructions. Additional settings, especially for MS tests, are then made via the air interface. For example, a parameter in the downlink signal specifies which signal the MS should supply during a transmitter test.

For the air interface, TETRA uses T1 to T4 to specify four groups of test signals with several variants that make up the channel types [3]:

TETRA Test Signals / Test Modes		
	Link Direction	Channel Type
T1	downlink	0, 1, 2, 3, 4, 21, 22, 24 (Phase Modulation)
	uplink	7, 8, 9, 10, 11, 21, 23, 24 (Phase Modulation)
T2	downlink / uplink	TETRA Interferer
T3	downlink / uplink	CW Interferer
T4	downlink	27 (QAM)
	uplink	25, 26 (QAM)

Table 3: TETRA test signals and channel types according to the ETSI standard

T1 and T4 are used for receiver and transmitter tests, while the interferer signals T2 and T3 are used only for the receiver tests. T1 is responsible for the phase modulations $\pi/4$ -DQPSK and $\pi/8$ -D8PSK; T4 exclusively for QAM.

There are 16 channel types in the T1 group. Each channel type represents a set of burst parameters (link direction, type of burst, modulation, data rate, etc.). In T2 there are variants for QPSK and QAM and the different channel widths, and in T4 variants for the three QAM modulation types and the different channel widths.

All test signals from T1 to T4 can be generated very easily with the K68 option for the R&S[®] generators. Use Table 4 to select the appropriate generator type.

R&S [®] Generators for TETRA Release 1 / 2					
	SMU200A/SMW200A	SMATE200A	SMJ100A	SMBV100A	AMU200A
TETRA Release 1 / 2	+	+	+	+	+
Fading	+				+

Table 4: Generators for TETRA

If fading is not needed, all listed generators are suitable. All channel types from T1 to T4 are preprogrammed. For proprietary applications, these configurations can be modified individually, stored as "User Defined," and later reloaded.

SMW, SMU and AMU additionally provide fading profiles as needed for R&D and for conformance testing. The AMU is a baseband generator without RF section. It is particularly suited to R&D applications where IQ data is required in place of RF signals.

SMW, SMU and AMU are two-channel instruments. This simplifies receiver tests with interferers. The T3 CW Signal can be provided by the low cost SMB generator. For more Information about the generators, see [5].

Figure 1 shows the first TETRA configuration screen of the signal generators in Table 4 as well as the screen for setting the BSCH and BNCH broadcast channels (see Chapter 2):

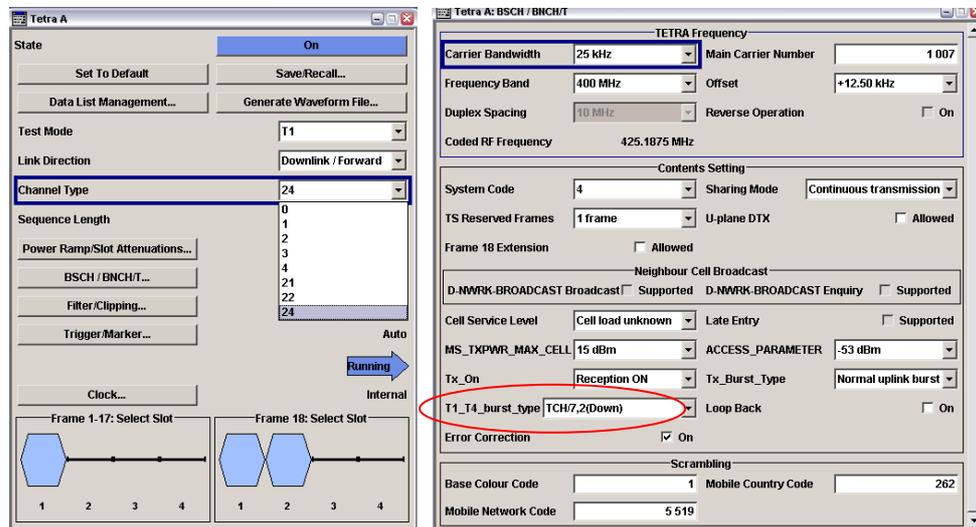


Figure 1: Generator configuration for TETRA

On the left, you see the setting options for the *Test Mode* (signal groups T1 to T4), the *Link Direction*, the *Channel Type*, and the *Sequence Length*. The burst *Ramps* and the *Slot Attenuations* can be configured. The *Trigger*, the *Marker* signals supplied by the generator, and the system *Clock* can be defined.

The test mode list on the generator include a *User Defined* mode in addition to T1 to T4. While the settings for T1 to T4 are fixed in accordance with the TETRA specification, there are no restrictions in user defined mode. The channel types are no longer binding, and the filter parameters and a clipping can be set individually.

In the lower part of the screen, you can define the desired slot(s). Frames 1 - 17 and frame 18 can be configured independently of one another.

The *BSCH / BNCH* button in the middle of the screen on the left opens the screen on the right. This is where you can program the *T1_T4_burst_type* parameter (sent via the air interface) to specify which signal the DUT should generate, for example.

Working with signals in a simulated multipath scenario (fading) is important in both R&D and conformance testing. All TETRA-specific profiles are preprogrammed in the SMW, SMU and AMU. Figure 2 (on page 10) shows the responsible configuration windows. Under *Standard*, you find the TETRA profiles DR50 (1 path), DU50 (1 path), TU50 (2 paths), TU50 (6 paths), BU50 (2 paths), HT200 (2 paths), HT200 (6 paths), and ET200 (2 paths). Here, too, you can define your own user profiles and then save them for later reloading.

Figure 2 on page 10 shows the 6 paths for TETRA profile HT200. These profiles are applied in the baseband. Fading is therefore also possible with the AMU baseband generator. To ensure that the profiles are calculated correctly, you must enter your desired RF transmit frequency under *Virtual RF*. (The SMW/SMU RF generator applies the output signal frequency automatically.)

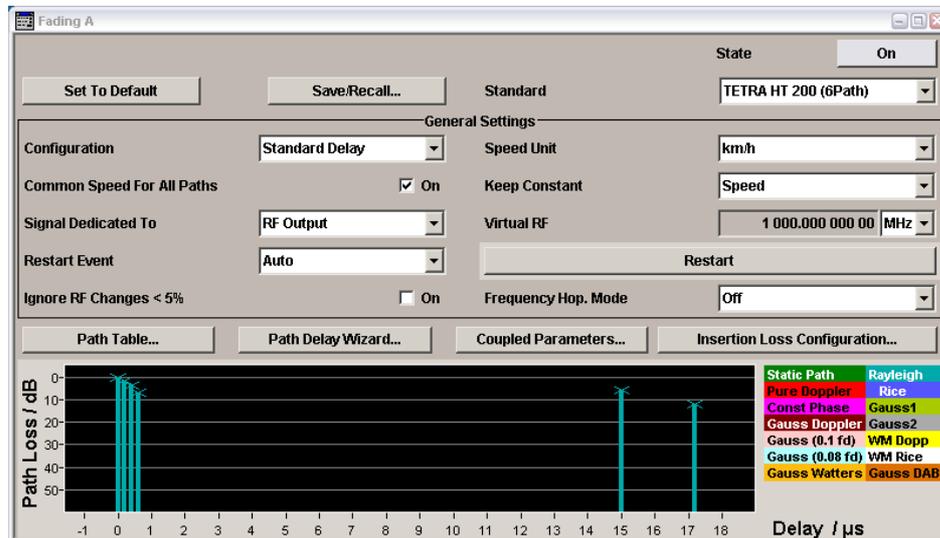


Figure 2: HT200 fading paths

The presented test signals T1 to T4 can now be used for the receiver and the transmitter tests. The following statements apply equally to TETRA Release 1 and TETRA Release 2 (TEDs).

Receiver tests

Receiver tests measure the bit error rate (BER), the message error rate (MER), or the frame erasure rate (FER). Measurements are taken during operation both with and without interference. Additional fading simulates a realistic radiocommunications scenario. The ETSI conformance testing [3] includes the following receiver tests:

- *Reference Sensitivity*
- *Reference Interference Performance*
- *Adjacent Channel Interference*
- *Co-Channel Interference*
- *Blocking Characteristics*
- *Spurious Response Rejection*
- *Intermodulation Response Rejection*

All of these measurements are required in R&D. In production, testing is typically restricted to the *reference sensitivity* and the *RSSI (Received Signal Strength Indication)* accuracy.

In all cases, a useful signal T1 or T4 is applied to the DUT alongside interferers T2 or T3 with various levels and frequencies.

The DUT has an output where the demodulated data is available. If the error rate cannot be determined in the DUT itself, an external device, which evaluates the error rates, is connected here.

(The standard also specifies an optional RF loopback. However, development of the DUT must be quite advanced to use this loopback, and so it will not be discussed here.)

BS receiver tests

A proprietary control program switches the BS into test mode *receive* so that it can process the uplink test signal.

The standard specifies that the test equipment should synchronize to the frame timing of the BS downlink signal. In practice, a BS downlink signal is not needed because each BS provides a multiframe trigger output.

Figure 3 shows a universal test setup for BS receiver tests. (The DUT controller is not shown here and in the subsequent figures.)

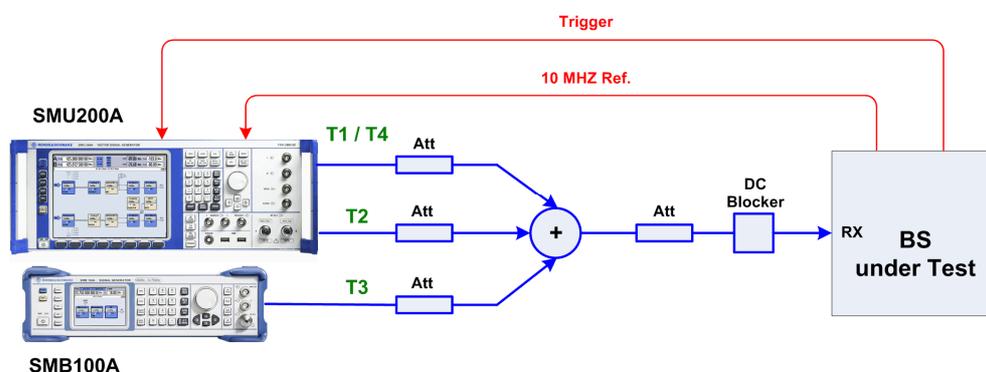


Figure 3: Test setup for BS receiver tests

The upper generator (an SMU in this example) generates the uplink useful signal T1 or T4. The BS and the generator are coupled via the 10-MHz reference signal. At frame 18, the BS supplies a trigger signal to the SMU. A trigger delay of six slots (four slots of frame 18 + two slots downlink / uplink delay) causes the T1 / T4 generator to start in the correct timeslot.

The interferer signals T2 (modulated) and T3 (unmodulated) needed for some RX tests are generated by the second generator in the SMU and by an SMB here.

Attenuators in the signal paths improve the impedance matching and decouple the instruments.

The summation signal for the generators is received at the RX input of the BS under test via an attenuator and a DC blocker. (The DC blocker is needed if the BS provides a bias for a mast amplifier.)

The test setup shown in Figure 3 takes advantage of the fact that the SMU has two independent channels. If fading is not required, it's possible to work with two different generators from Table 4. If interferers are not needed for a test, the RF on the generators can be disabled, and parts of the test setup can even be eliminated if no interferer tests need to be performed.

MS receiver tests

A proprietary control program switches the MS into test mode *receive* so that it can process the downlink test signal.

Figure 4 shows the test setup for MS receiver tests:

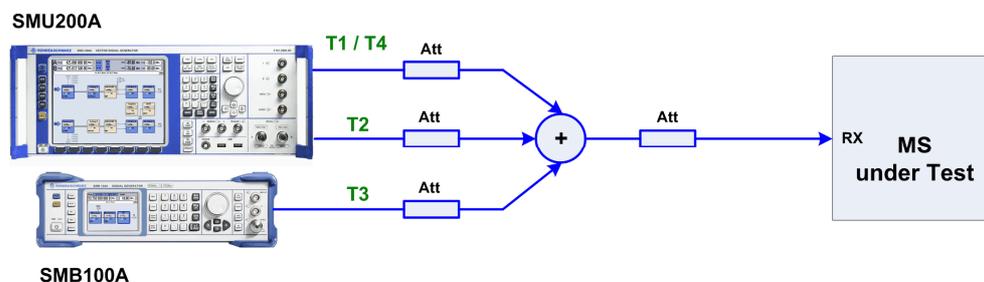


Figure 4: Test setup for MS receiver tests

The upper generator (an SMU in this example) generates the downlink useful signal. The MS synchronizes to the BSCH channel of the signal.

The interferers T2 (modulated) and T3 (unmodulated) needed for some RX tests are generated by the second generator in the SMU and by an SMB.

The summation signal for the generators is received at the RX input of the MS under test via an attenuator.

Once again, if fading is not required, the SMU can be replaced with two other generators from Table 4 on page 8. If interferers are not needed for a test, the RF on the generators can be disabled, and parts of the test setup can be eliminated if no interferer tests need to be performed.

The MS receiver tests MS *receiver performance for synchronization burst acquisition, MS frame alignment performance, and MS link control* are analyzed differently in the DUT than the BER, MER, and FER tests. However, the test setup and the required downlink signals are the same.

Transmitter tests

Transmitter tests are performed using spectrum & signal analyzers. They measure the timing characteristics, the power, frequency, and useful spectrum, as well the modulation quality of the transmit signal and unwanted emissions. During the *transmitter intermodulation attenuation* test, a CW interferer is additionally applied in order to check whether unwanted mixture products exceed the defined limits.

The conformance testing [3] includes the following transmitter tests:

- *Transmitter Output Power*
- *Unwanted Output Power in Non-active Transmit State*
- *Adjacent Channel Power Due to Modulation*
- *Adjacent Channel Power Due to Switching Transients*
- *Unwanted Emissions Far From the Carrier*
- *Unwanted Radiated Emissions*
- *Unwanted Emissions During the BLCH/CLCH Linearization*
- *Transmitter Intermodulation Attenuation*
- *Modulation Accuracy (Error Vector Magnitude EVM)*
- *Carrier Frequency Accuracy*

All of these measurements are required in R&D. In production, testing is typically restricted to the *transmit output power*, *error vector magnitude*, and the *carrier frequency accuracy*.

The FSQ and FSU instruments are suited to these measurements, particularly in R&D. Only these two analyzers have the necessary dynamic range to handle the wideband noise measurements without an additional notch filter (in the *unwanted emissions far from the carrier* test)¹.

The general vector signal analysis option (R&S®FSQ-K70 or R&S®FSU-B73) offers preprogrammed settings and filters for TETRA Release 1 signals, while the TETRA II / TEDS option (R&S®FS-K110) offers these settings and filters for TETRA Release 2 (FSQ: R&S®FS-K110, FSU: R&S®FSU-B73 + R&S®FS-K110).

BS transmitter tests

A proprietary control program switches the BS into test mode *transmit* to generate a standard downlink signal.

Figure 5 shows a typical test setup.

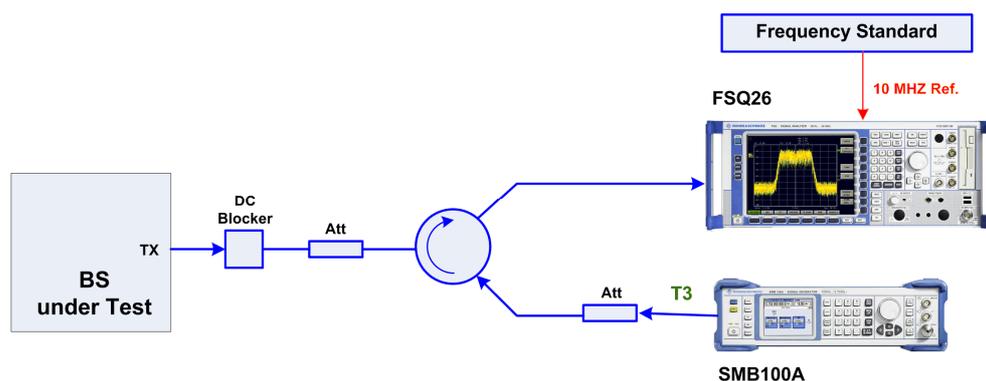


Figure 5: Test setup for BS transmitter tests

¹ This saves time and money, because the filter has to be tuned for each test frequency once again. To compensate for the frequency response each time the forward transmission of the filter has to be measured and entered into transducer Tables at the analyzer.

All measurements are performed using the analyzer. Again, the path between the BS and DUT contains an DC blocker that is required when the BS supplies a mast amplifier. The attenuator must be adequately dimensioned to handle the power from the base station.

To achieve the greatest accuracy for the frequency error measurement, a frequency standard is needed at the analyzer 10-MHz reference input. If a relative statement regarding the frequency accuracy is sufficient, the 10-MHz reference signal from the base station can be used.

The SMB generates the T3 signal for the transmitter intermodulation attenuation test. If this test is not performed, the generator is not needed and the analyzer is connected to the DUT directly via the DC blocker and attenuator.

MS transmitter tests

A proprietary control program switches the MS into test mode *transmit*. The MS expects a T1 / T4 downlink channel. Which signal the MS has to send is either set by the control program directly, or the MS derives it from the *TX_Burst_Type* parameter contained in the BNCH of the downlink signal.

Figure 6 shows a typical test setup:

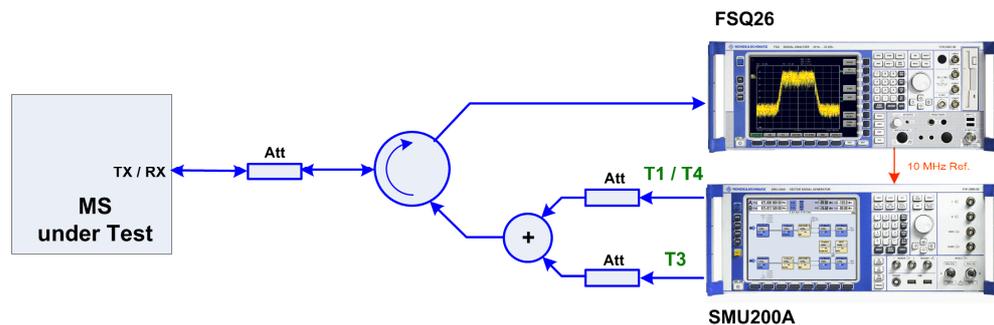


Figure 6: Test setup for MS transmitter tests

The generator (an SMU in this example) generates the required T1 / T4 downlink signal as well as the T3 interferer for the *transmitter intermodulation attenuation* test. Because fading is not required here, two RF generators from Table 4 on page 8 can be used in place of the SMU. If the MS is capable of operating without a downlink signal, the test setup is simplified accordingly.

Like for the BS test, the analyzer handles all evaluations.

Measurement results

To keep the size of this Application Note within bounds, only a few of the many possible measurement results are provided as examples here. You can find detailed descriptions of all test options and discussions of the result displays in the respective manuals for the analyzers and instrument options [6].

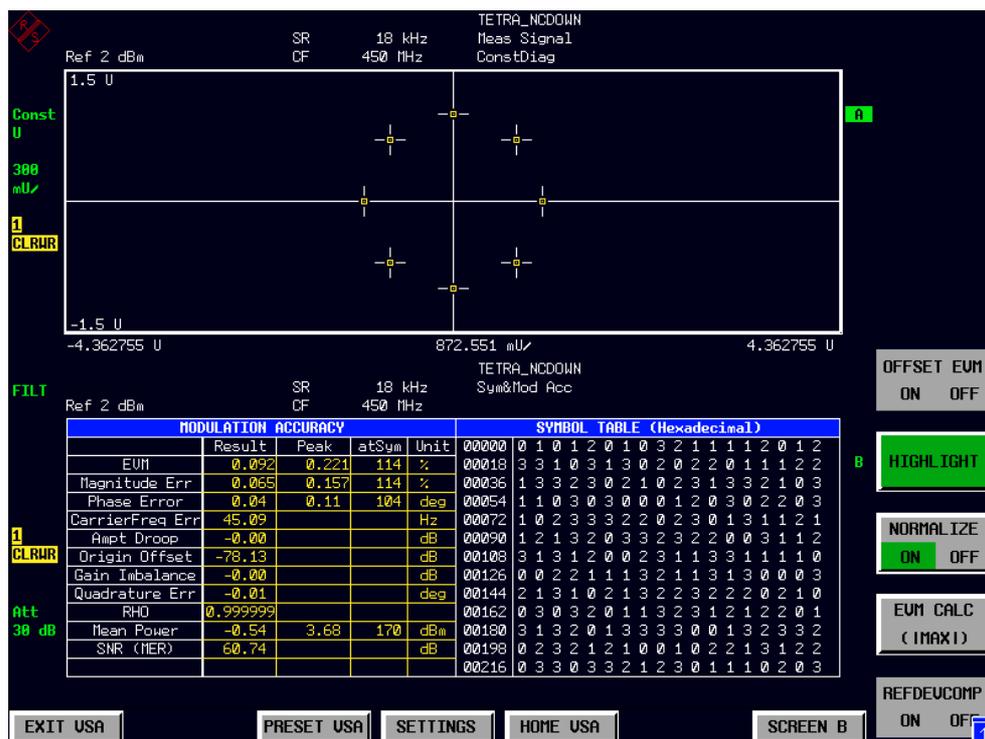


Figure 7: Overview of the most important signal parameters for a TETRA 1 signal with the R&S®FSQ-K70 option. All results are derived from a single recording.



Figure 8: Analysis of a TETRA Release 2 signal using the R&S®FS-K110 option. The green bar marks the signal section which is used to derive the numerical results. It is positioned automatically.

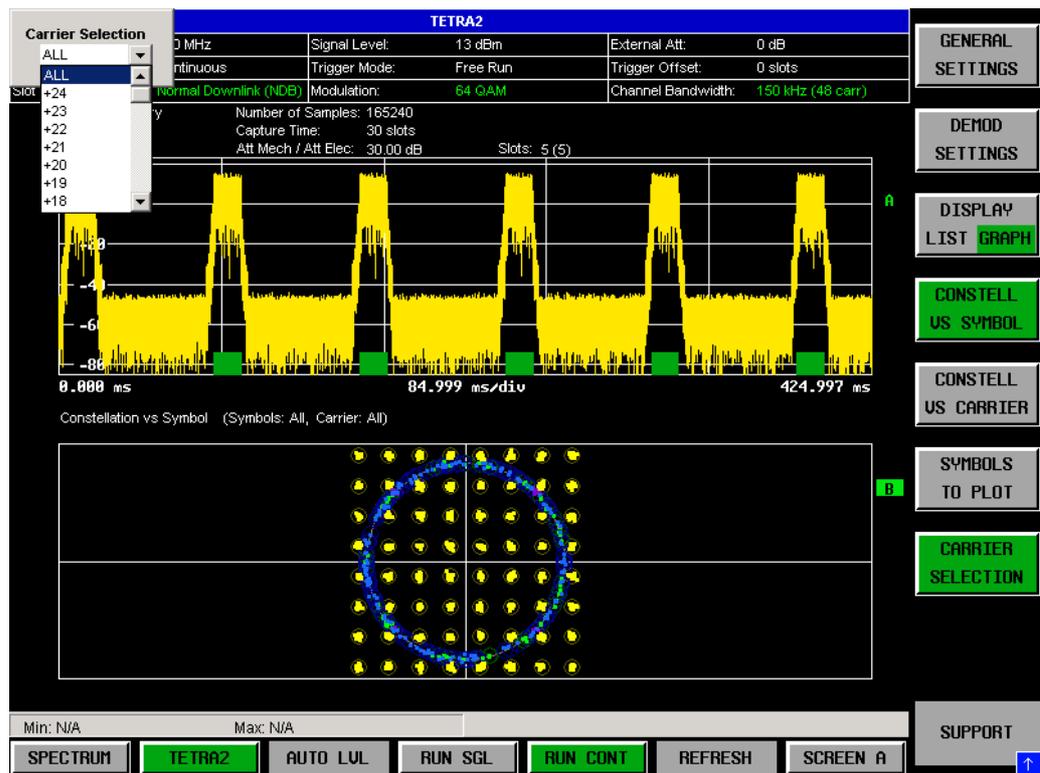


Figure 9: Constellation with the R&S®FS-K110 option. The user can select individual carriers or a summary view.

The examples provided here are comparable to the measurement options offered by R&S® analyzers for other wireless communication standards (e.g. LTE). However, TETRA poses particular challenges to analyzers in the *unwanted emissions far from the carrier* test.

Unwanted emissions far from the carrier (BS and MS)

This test stipulates to measure the transmitter noise power - starting at a distance of 100 kHz and extending to a distance far from the carrier. The limit values are defined relative to the transmit signal power and extend down to -100 dBc. Conventional analyzers do not have an adequate dynamic range. This is why the test setup usually includes a notch filter in the test path to reduce the DUT transmit signal significantly. A disadvantage of this arrangement is not only that this filter must be re-adjusted for each of the various measurement frequencies, but also that the filter characteristic must be measured each time using a network analyzer and the results entered into the analyzer transducer tables.

However, the excellent R&S® analyzers FSQ and FSU specifications for dynamic average noise level (DNAL) and phase noise mean that this filter can be left out of the test setup.

4 Network coverage and service quality measurements, network optimization

One of the basic requirements of a functional wireless communication system is that it be capable of providing regional coverage with signals of sufficient field strength. However, whether a stable and secure radio link is truly possible - even with sufficient power at the receiver antenna - very much depends on the quality of the signal at the receiver antenna which is defined as the signal / noise ratio SNR.

The coverage of an area to provide at least a minimum receive power, available everywhere, by a set of basestations is firstly planned by means of network planning software. Experience shows, however, that first measurements, in the early test operation of the network, will return results that in some cases differ considerably from the previous theoretical network planning. So only a complete battery of tests in the coverage area can guarantee full network availability later. This typically uncovers trouble spots that must then be gradually eliminated. Measures that can be taken to achieve this network optimization include adding base stations to close gaps in coverage, changing frequencies to reduce the strength of interferers, using different antennas or changing the antenna alignment, and so on.

TETRA networks serve government authorities and organizations with security missions, such as police, fire, and rescue, as well as civilian agencies, such as power supply companies or regional transportation agencies. Coverage measurements are essential for both types of users, although the first group naturally has stricter requirements.

Setup of a TETRA infrastructure, equipping of a region with base stations, and commissioning of the network are carried out in the following phases:

- Planning
- Base stations setup
- Test operation
- Full operation

Software tools are used for planning the locations of base stations and estimating the local field strength theoretically. In this first phase, measurements are sometimes the only way to find out whether a specific site is actually suitable for a BS. It is especially important to check this when difficult wave propagation without a clear line of sight is expected; for example, in hilly regions, or because of shadow effects and reflection from buildings, etc.

In these situations, a test transmitter is set up at the potential site with the same antenna configuration as the BS will have. Drive tests in the neighborhood provide the actual antenna footprint. The theoretical planning data should then be corrected as needed.

Even with less stringent propagation scenarios, it is good practice to remeasure the coverage immediately after a base station is set up. Areas with inadequate coverage could then be additionally provisioned by adjacent base stations if their location and antenna configuration are set up appropriately.

When the network is in test mode, the planned base stations for the region already operate in normal traffic mode. This allows the signal quality to be measured along with the actual field strength distribution. Additional base stations may be needed; network optimization is alternated with drive tests to audit the results.

Once the network is in full operation, testing includes periodic performance measurements and capacity tests (benchmarks), as well as interference analysis and elimination.

As an independent producer of coverage measurement technology, Rohde & Schwarz offers the TSMW RF network scanner and the ROMES4 software platform as a high-end measurement system for all phases of TETRA network operation. See [8] for an overview of the TSMW features.

Hardware



Figure 10: Base components for the R&S® coverage measurement system

The TSMW RF network scanner can be delivered as a standalone instrument, or it can be installed in a 19" rack together with up to 16 TETRA mobile stations. This makes the system suitable for installation in motor vehicles, ships, or helicopters. The TSMW can be supplied with 9-18 VDC, 110-230 VAC, or a battery pack.

For portable use, Rohde & Schwarz ships the TSMW in a backpack together with batteries and a notebook computer. This makes the scanner suitable for use in the countryside as well as for temporary use in trains.

A wide range of accessories (antennas, bandpass filter, rack adapter, etc.) round out the offering.

The TSMW has two independent receivers with preselection that function in parallel. This makes it possible to observe two TETRA bands simultaneously, for example. The scanner frequency range is from 30 MHz to 6 GHz. As a result, all of the possible frequency bands for the communications standards TETRA, GSM, UMTS, TD-LTE, LTE-FDD, CDMA2000®, EVDO, and WiMAX can be monitored at the same time. The TSMW analyzes networks in accordance with TETRA Release 1 and Release 2

(TEDS) with the new modulations $\pi/8$ -D8PSK, 4-QAM, 16-QAM, and 64-QAM, for 25 / 50 / 100 and 150 kHz channel bandwidth.

An integrated GPS receiver automatically logs its position during the drive tests. Reliable operation is assured for motor vehicle or flight speeds of up to 200 km/h.

Software

The ROMES software evaluates and displays the signals received by the TSMW in realtime during the drive test. The user determines what test results should be displayed on the monitor at the same time (in various configurable windows). All data coming up during the drive test are saved to hard disk independent of this selection. They can be redisplayed offline at any time and processed using additional applications (such as the R&S® NPA network power analysis software).

Examples

Figure 11 shows a snapshot from a drive test log.

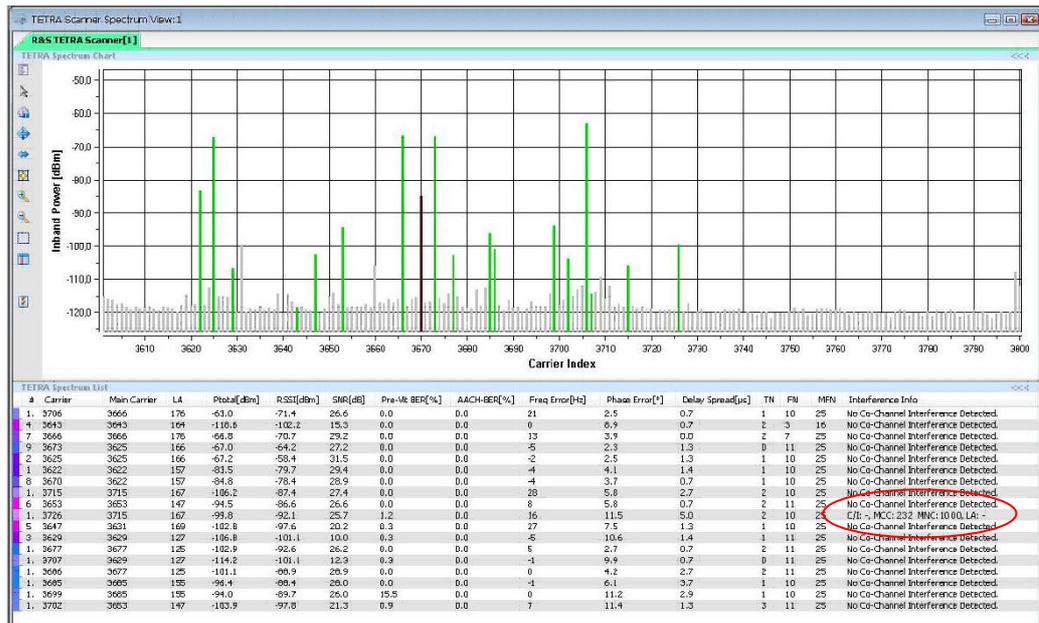


Figure 11: Summary view with the most significant cell and signal information

The upper half shows the current channel power for the available TETRA base stations in the spectrum, and the lower half shows the results of a numeric analysis. During the drive test, 20 readings are taken per second, and up to 600 channels can be recorded. This display provides a good overview. Then, in practise, one would reduce the number of displayed base stations to observe the few that can be received best.

During the drive, ROMES continually generates lists of all received base stations. The TSMW scanner identifies these based on the respective BNCH broadcast network channel, and the cell information it contains is analyzed automatically. This allows the ROMES software to distinguish TETRA BS signals from non-TETRA interferers. If the

co-channel interferer is also a TETRA base station, the BS is identified and displayed; see the interferer information in the right lower part of Figure 11.

The list in Figure 11 shows the *channel number*, the *location area (LA)*, the *field strength (Ptotal)*, the *SNR*, the *frequency error and phase error*, and the *delay spread* from a passive analysis. The *RSSI* and the *bit error rate (BER)* columns show the results of an active analysis. They are provided by the test cell phones after a mobile originated call. These results come up in seconds.

To make it easy to recognize critical signals, the entries in the list can be marked by colored label at the start of each row: different colors can be assigned to different value ranges of a result.

ROMES makes it possible to integrate maps which allows better visualization of drive tests. Figure 12 marks the field strength variations along the drive route using various (configurable) colors. The serving cell and the adjacent cells are identified accordingly.

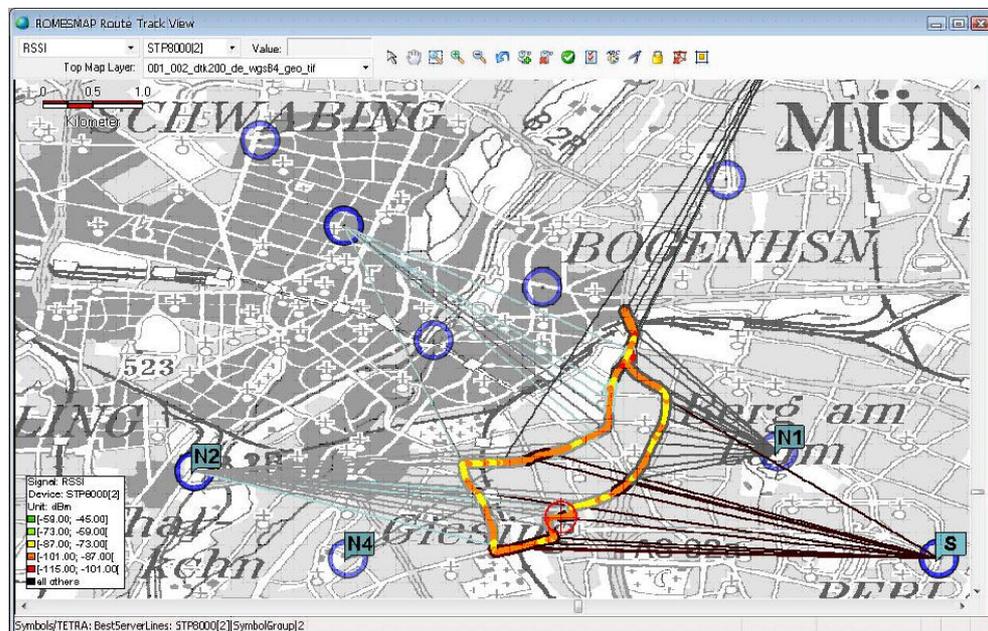


Figure 12: Visualizing the test route in realtime

Figure 13 on page 21 shows a detailed analysis of the radio links from one of the connected test cell phones. At first there are the values for the transmitter signal from the current base station, including the registration *status*, the *mobile country* and *network code*, the current *RSSI* or *BER* results (if *BER* measurements were made), and so on.

This is followed by statistics for the entire test run, including the best cell (*Best NC*) values, how many calls were stable (*Good Call*), how many calls were not answered (*Blocked*), and how many calls were *Dropped*. The *Frequency* and *RSSI* values are saved for all previously observed base stations (*NC1*, *NC2*, etc.).

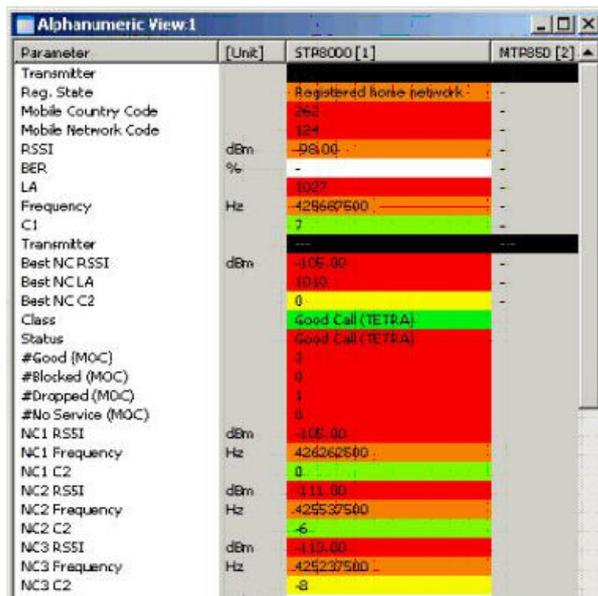


Figure 13: Mobile station log

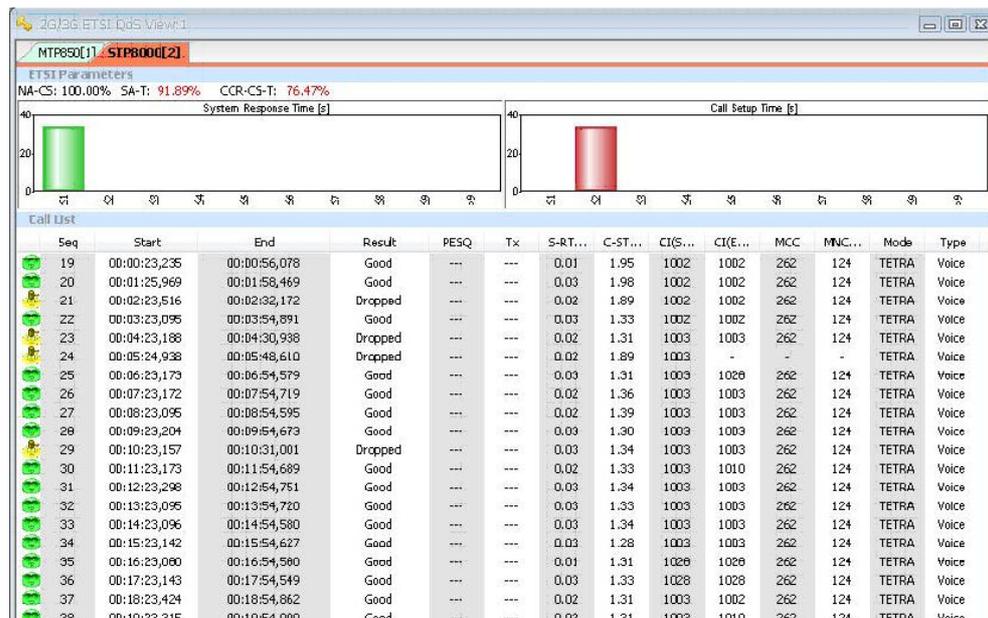


Figure 14: Additional details from the test run

Figure 14 shows additional call information from a test cell phone. (There is a separate tab for every MS). The upper portion contains a statistical evaluation of the entire test run. The numeric data regarding the NA-CS (network accessibility circuit switched), SA-T (service accessibility telephony), and CCR-CS-T (call completion rate circuit switched telephony) are included in the Quality of Service value in accordance with ETSI standard TS 102.250-3.

The lower portion of the screen shows results from every single call, including the system response and call setup time (S-RT... and C-ST..) and the cell identity at the start CI(S) and end of every call CI(E).

No speech quality measurements (PESQ) are provided in Figure 14. They can be done by specific mobile stations (using a special adapter and a PC sound card); see Figure 15:

Parameter	[Unit]	SQA [1]	SQA [2]
PESQ Score P862.1 (Narrow Band)(DL)		3.537	3.825
PESQ Score P862.1 Noise (Narrow Band)(DL)		4.390	4.309
PESQ Score P862.1 Speech (Narrow Band)(DL)		3.215	3.635
MOS-LQO P862.1 (Narrow Band)(DL)		3.605	3.967
Attenuation (DL)	dB	-0.536	4.823

Figure 15: PESQ quality parameters

All data recorded during a drive test is saved on the hard drive of the controller PC. It is then available for offline analysis (e.g. using the ROMES NPA network problem analysis). Emphasis is placed on

- Detection and identification of problem zones
- Coverage analysis for the individual base stations (footprint)
- Overall coverage analysis

Figure 16 provides an example: During a drive test, there were certain areas where the radio link was lost. An analysis showed that in the problem area the wanted field strength (red) is receding while at the same time an interferer signal (green) exceeded a critical value.

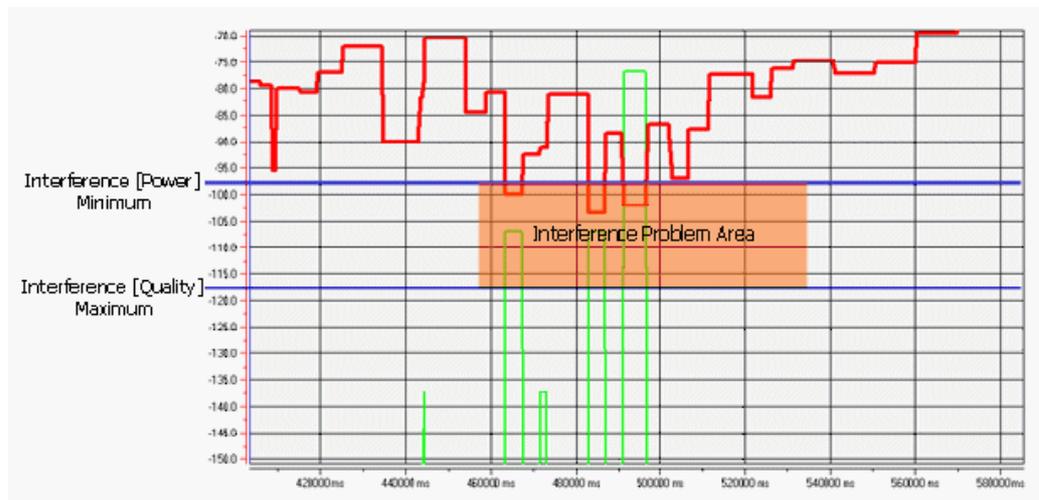


Figure 16: Offline analysis using the NPA software

Of course, space limitations mean that this Application Note can present only a limited number of the many test and analysis options provided by the TSMW test system. However, the selected examples clearly demonstrate how the radio coverage can be systematically measured and potential network problems recorded and analyzed.

If an interferer that does not originate from a TETRA base station is recorded by the TSMW, it can be further analyzed and traced using a non-TETRA-specific portable receiver. This is described in the following chapter.

5 Detecting interferers

Interferers in a radio band either originate from other transmitters which are regular working in the same radio band, or are general in nature. For example, interference resulting from TETRA signals in the same band could be caused by neighboring base stations. These stations can be identified and located using the TSMW test system. TETRA interferers resulting from defective mobile stations or similar instruments can be tracked down using the instruments described in the next chapter.

This chapter covers interferers of a general nature. These typically arise from defective electrical or electronic devices (for example, those with defective filters or shielding), or else from jammers that are purposefully used. The primary task of the PR100 receiver from Rohde & Schwarz is to find these sources of emissions.



Figure 17: PR100 portable receiver and HE300 directional antenna

Together with the HE300 directional antenna, the PR100 was designed specifically for the challenges associated with portable radio monitoring. With its small dimensions and low weight, it is primarily suited for use at locations not readily accessible by car.

By digital signal processing the PR100 achieves an exceptionally good RX sensitivity. This makes it possible to pick up even extremely weak interferers. The panorama scan mode provides a quick overview of the frequency allocation. In audio monitoring mode, use the marker to select the interferer in question, and to demodulate and analyze the content.

The PR100 can indicate the receive level using the pitch of an acoustic signal so that the user can concentrate on the terrain without having to keep an eye on the instrument display at all time.

Searching for interference in the spectrum

Interferers are sometimes pulsed at irregular intervals, so that they are very difficult to discern in a normal spectrum display. In this case, the *spectrogram* display on the PR100 can help, see Figure 18, lower half. This so called *waterfall* diagram shows the spectrum slowly dropping down with time. The signal strength is indicated by user definable colors.

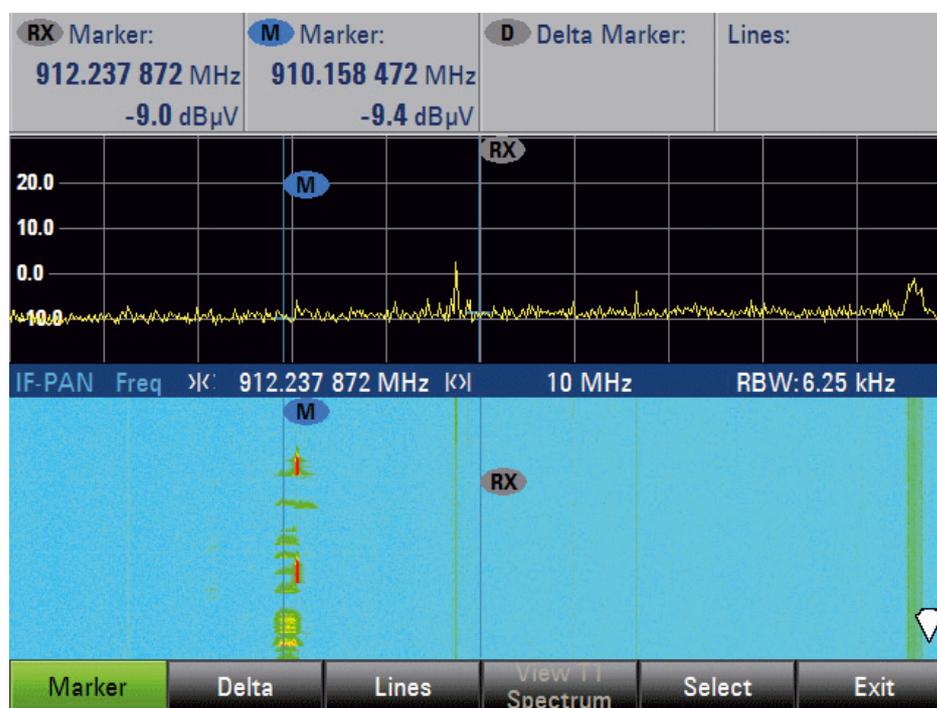


Figure 18: Detecting a pulsed interferer (red) in the PR100 waterfall diagram

Near to marker *M*, strong unmodulated signal pulses (red) interfere with the useful signal (green).

Also, a *Differential Mode* is available in the PR100 to visualize infrequently occurring interferers.

First, at a time when presumably no interferer is transmitting, the spectrum is saved as a reference; see Figure 19:

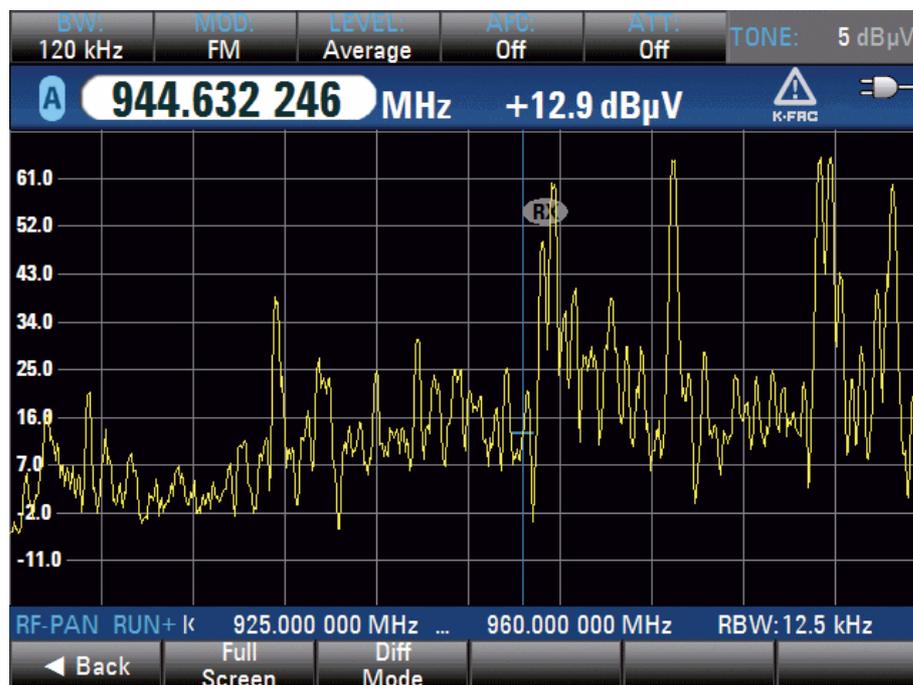


Figure 19: Typical spectrum with no interferer

Then the *Differential Mode* is activated. Now, only the differences between the new recording and the stored reference spectrum are displayed. An interferer is clearly seen; see Figure 20:

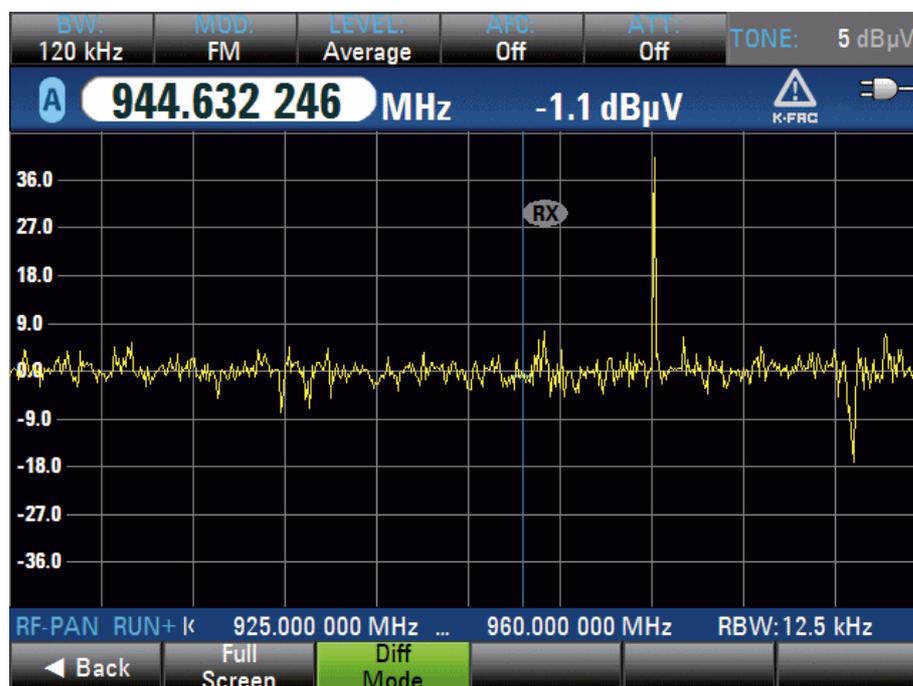


Figure 20: Interferer clearly visible in differential mode

Location finding

The direction that the HE300 antenna is held is displayed on a compass rose on the PR100.

The direction finding (DF) results can be stored along with the position data from an external GPS. Free map data available for the PR100 is used to overlay the DF results from various measurements on a map in the PR100.

The press of a single button then starts the triangulation and the location of the interferer is determined; see Figure 21:

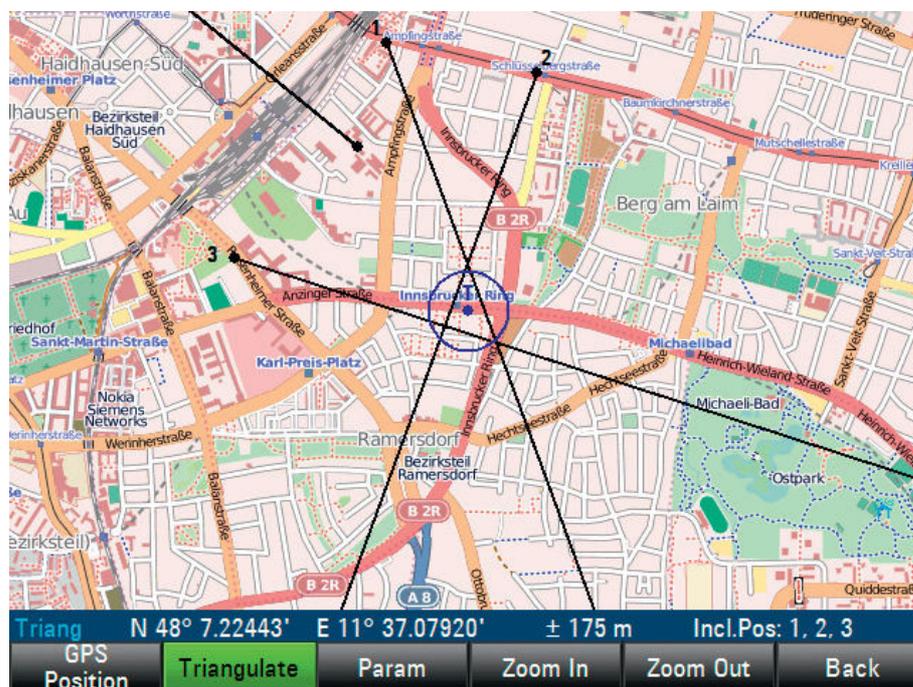


Figure 21: Triangulation based on multiple DF results

The process makes it possible to reliably detect and eliminate interferers in the radio network.

The examples described here are only a small sample of the possibilities that the instrument affords. For example, the instrument includes a comprehensive remote control software that can be used to operate the PR100 conveniently and efficiently from a PC workstation, and much more. For more information, see [8], [9].

6 Location finding of mobile and base stations

Radio network operation can be disturbed by defective or incorrectly configured mobile stations. Or, an unauthorized person could be misusing a mobile station. Or, it might be necessary to determine the location of an emergency call. In all of these instances, the goal is to identify and locate an individual MS quickly. More rarely, e.g. near national borders, BS must also be located.

For these tasks, Rohde & Schwarz offers the DDF0xA/E family of direction finders alongside a wide variety of options, analysis software, and a large selection of antennas. All direction finders provide a high degree of immunity against reflections plus rapid measurement speeds.

The model DDF05A and DDF05E together with the DDF-TRA TETRA DF option suit best the TETRA requirements in terms of frequency range and speed. When used together with the TETRA Air-Analyzer from fjord-e-design GmbH (<http://www.fjord-e-design.com>), the DDF05A/E can identify and locate TETRA MS and BS quickly and precisely.



Figure 22: The DDF05E test system

A TETRA MS typically transmits in only one of the four available slots per frame. The preceding and subsequent slots are used by different MS. Direction finding must therefore take place during the correct slot within the network frame.

The DDF05A/E digital direction finders are fast enough to perform a complete direction finding in less than the duration of one slot. However, they do need a trigger signal that announces the correct slot.

The frame and slot timing in a radio cell is defined by the BS. An instrument is therefore needed to synchronize to the BS signal, to identify the MS (or BS), and to provide a trigger signal for the direction finder.

The TETRA Air-Analyzer from fjord-e-design GmbH provides the optimum solution. In addition to extensive analysis options, it also provides all interface signals required for the DDF05A/E direction finders.

This ensures that only transmissions from the desired station are used. After the Air-Analyzer has identified the TETRA MS (or TETRA BS), the DDF05A/E direction finders work automatically and determine the direction from which the wanted station is transmitting.

The RAMON Local and MapView software can be used to display the DF values from multiple locations simultaneously that intersect at the transmitter location (triangulation); see Figure 23:

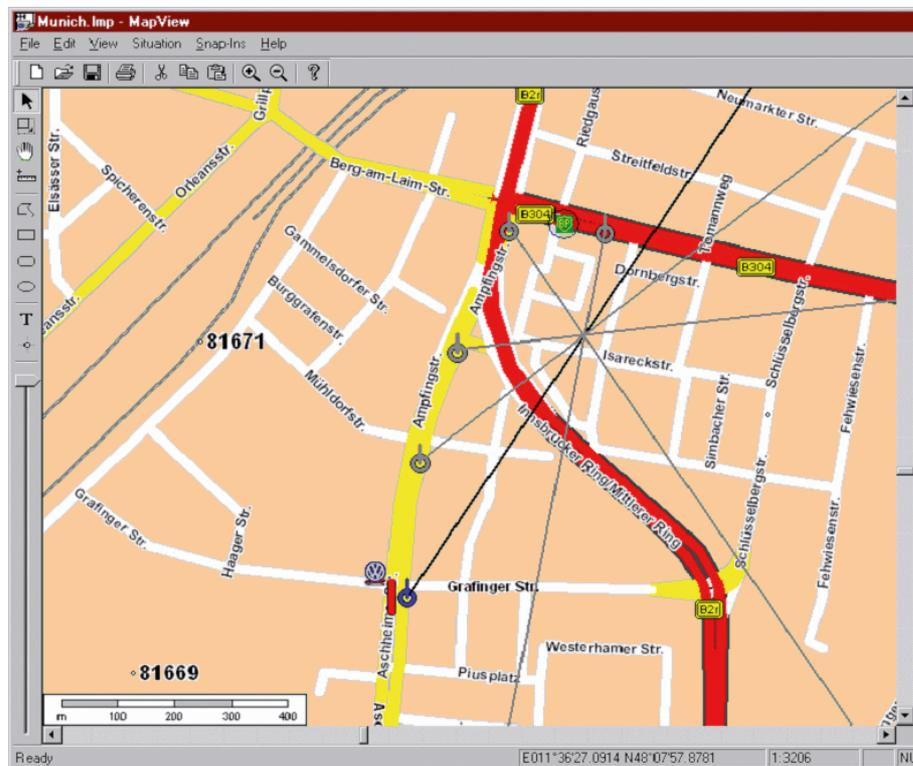


Figure 23: *Finding the position of a TETRA terminal with running fix and display on R&S@MapView.*

The TETRA Air-Analyzer and the DDF05A/E direction finders can be operated when stationary or in a motor vehicle. The compact ADD253 DF antenna can even be mounted to the roof of a car.

The DDF0xA/E family of instruments is not limited to TETRA, either; instead it represents a universal DF system with a broad frequency range. For more information, see [10].

7 Installation, service, and maintenance

For "on site" usage - for example, when measuring antenna installations, Rohde & Schwarz offers portable, battery-operated test equipment. This chapter describes measurements using the ZVH cable and antenna analyzer and the FSH4/8 spectrum analyzer.



Figure 24: ZVH in use

ZVH cable and antenna analyzer

In its basic configuration, the ZVH cable and antenna analyzer can handle the most important measurements needed for the installation and maintenance of antenna installations; i.e., distance to fault (DTF), cable loss, and SWR measurement (s_{11}).

Figure 25 on page 30 shows an example of a DTF measurement.

Defects in a cable installation can arise from crimped cables as well as from corroded plugs, short circuits, or cut off lines. In all cases, this leads to impedance variations that generate a reflected wave. The ZVH calculates the distance from the feed point based on the reflected signal. Figure 25 shows a fault at which about 5% of the transmitted wave is reflected. The marker can be used to identify the exact location of the problem (13.56 m).



Figure 25: DTF measurement results

Figure 26 shows the results of a cable loss measurement.



Figure 26: Cable loss versus frequency

Figure 26 shows a cable with no flaws. The cable loss remains steady over the examined frequency range; in particular there are no resonances that could be caused by defects.

The ZVH base functions can be expanded by means of software licensing or by adding accessories:

- Power measurement to 8 GHz or to 18 GHz with the FSH-Z1 or FSH-Z18 probes
- Spectrum analysis, network analysis, vector voltmeter
- GPS reception (location data can be saved together with the test data)
- Remote control

It is usually not only test specialists who perform measurements. This is why the ZVH is equipped with an automated workflow (wizard). Because tests can be automated, it's no longer necessary to have an expert on site:

Test sequences can be predefined centrally on a PC and then sent to one or more ZVHs. On site, the so called ZVH wizard guides the user step-by-step through the predefined test sequence. All measurement results are stored in one single file that can be uploaded to a central computer via LAN, USB, or memory card (or even via email). There, the report generator provided with the ZVHView software (included with every instrument) is used to generate a uniform, clearly formatted log in just a few steps.

FSH4/8 spectrum analyzers

For more extensive needs, the FSH4/8 spectrum analyzers (abbreviated here as FSH) are available.

Depending on the configuration, the FSH can additionally be used as a power meter, a cable and antenna tester, or a two-gate vector network analyzer.

In its default configuration as a spectrum analyzer, the instrument is suitable for all conventional analyzer tasks. This includes measurements in the time and frequency domain, measurements of pulsed signals with gated sweep, determining the channel and adjacent channel power, etc.

The FSH has a very high input sensitivity (< -141 dBm / 1Hz or with preamplifier -161 dBm / 1Hz) and a low measurement uncertainty (< 1 dB). This makes the instrument particularly suited for measuring the free-field strength, together with directional and isotropic antennas, and for tracking down interferer sources.

Figure 27 shows the FSH8 with different R&S® antennas.



Figure 27: FSH8 with isotropic antennas and the HE300 DF antenna

Other typical applications include measuring the radiation characteristics for motor vehicle antennas and auditing emission limit values from the BS. The integrated GPS receiver (option HA-Z240) provides the required position data at the same time as it increases the FSH initial carrier frequency tolerance to ppb (25×10^{-9}).

The GPS data appears in the results screen as shown in Figure 28. Like for the ZVH, the the GPS information is stored together with the measurement data.

With the R&S® near-field probes, EMC problems caused by inadequate shielding can be quickly and accurately located. Sometimes, this is possible only with portable, battery-operated instruments, e.g. at fixed base stations.

The FSH can be equipped with power sensors up to 18 GHz or with forward power probes to 4 GHz. When used together with the VSWR bridge circuit, the FSH can then simultaneously measure the output power and the matching of antennas under operating conditions. The power sensors measure average power up to 120 W and normally eliminate the need for any extra attenuators.

Like the ZVH, the FSH can locate cable defects. A DC bias can also be fed to supply a mast amplifier.

FSH measurements can be started automatically at defined intervals and the readings stored automatically. This makes the instrument an excellent choice for automated signal monitoring. With the free R&S® FSH4Remote software, the FSH can be controlled remotely and measurements results can be read via LAN / Internet; see Application Note 1MA180 [11].

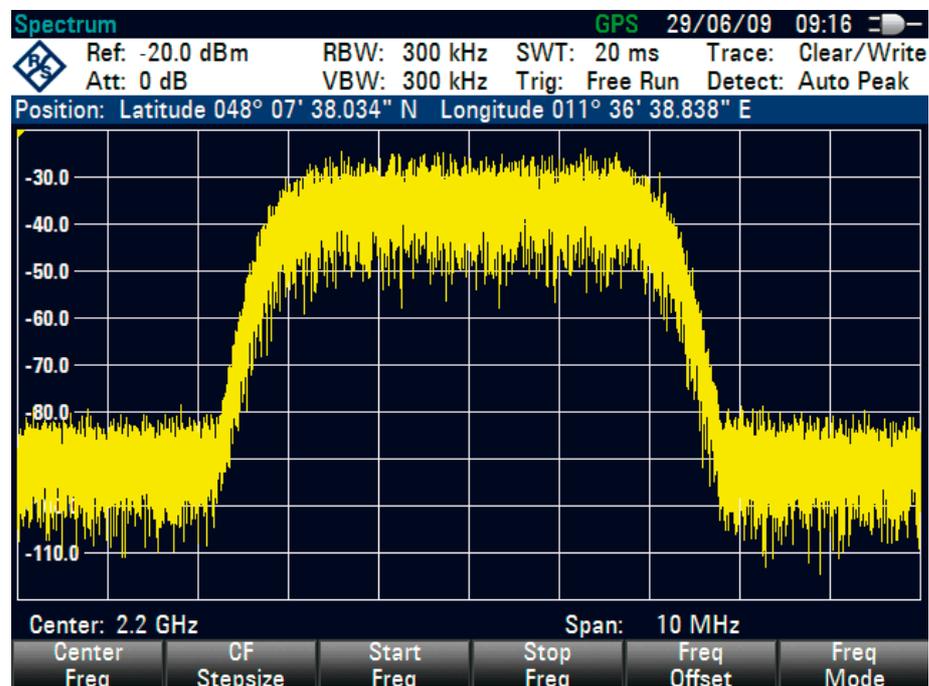


Figure 28: Signal measurement with GPS data

The included FSHView software can then be used to process the readings on your PC: You can insert, remove, or move markers, or you can add masks to the trace.

The many FSH functions not touched on in this Application Note (such as tracking generator, two-gate vector network analyzer, options for the most important mobile radio standards, and so on) are too extensive to mention here. For detailed documentation of all characteristics and options, refer to the FSH4/FSH8 brochures [12].

Both the ZVH and FSH are optimized for portable use by virtue of their low weight, ergonomic housing, and a keyboard layout that allows use even with gloves. The housing is robust and water-spray resistant, and the brilliant color displays can be read even under difficult lighting conditions. A battery allows operation for up to about 4.5 hours, and the battery pack can be swapped out in just a few seconds without requiring any tools.

This makes the ZVH and FSH ideally suited for on-site operation. The modular option concept means that instruments can be equipped with only those functions that are needed at any given moment. And as requirements increase, the required options are ready for use.

8 Summary

TETRA is a globally accepted standard with a steadily growing number of users in both the public and the private sector. Existing networks are being opened to private users at the same time as entire new networks are being built.

Establishing a reliable TETRA network requires many measurements, starting with R&D testing of base and mobile stations and extending to network planning and coverage testing, station commissioning, interferer detection and elimination, and service and maintenance activities.

Rohde & Schwarz supports all of these areas of application with its broad palette of T&M equipment. This Application Note presented example applications, T&M equipment, and measurement results.

The TETRA standard continues to evolve. With the introduction of TETRA Enhanced Data Services (TEDS, or TETRA II), data rates of up to 691 kb/s are being achieved. However, this is far from adequate for many advanced applications (such as video streaming). The current trend is therefore toward coupling TETRA with existing broadband technologies, like LTE.

Rohde & Schwarz is active here, as well. R&S® generators, analyzers, and radio communication testers generate and measure LTE signals at many companies during R&D and production. Of particular note is that the TSMW universal radio network analyzer is able to simultaneously analyze coverage, measure signal quality, and identify interferers for both TETRA and LTE (and other mobile standards) in parallel.

9 Appendix

Literature

- [1] ETSI, EN 300 392-2, Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)
- [2] ETSI, TR 102 580 V1.1.1, Terrestrial Trunked Radio (TETRA); Release 2; Designers Guide; TETRA High-Speed Data (HSD); TETRA Enhanced Data Service (TEDS)
- [3] ETSI, EN 300 394-1, Terrestrial Trunked Radio (TETRA); Conformance Testing Specification; Part 1: Radio
- [4] John Dunlop, Demessie Girma, James Irvine, "Digital Mobile Communications and the TETRA System", John Wiley & Sons Ltd, 2000
- [5] Signal Generators: http://www2.rohde-schwarz.com/en/products/test_and_measurement/signal_generation/
- [6] Signal and Spectrum Analyzers: http://www2.rohde-schwarz.com/en/products/test_and_measurement/spectrum_analysis/frequencies/
- [7] Drive Test Tools, TSMW: http://www2.rohde-schwarz.com/en/products/test_and_measurement/Drive_Test_Tools/
- [8] Portable Receiver, PR100: <http://www2.rohde-schwarz.com/en/products/radiomonitoring/receivers/PR100.html>
- [9] Active Directional Antenna, HE300: <http://www2.rohde-schwarz.com/product/HE300.html>
- [10] Digital HF/VHF/UHF Scanning Direction Finder, DDF05A: <http://www2.rohde-schwarz.com/product/DDF0xA.html>
Digital HF/VHF/UHF Monitoring Direction Finder, DDF05E: <http://www2.rohde-schwarz.com/product/DDF0xE.html>
- [11] FSH4Remote Remote Control for R&S ® FSH4/8 and R&S ® FSC, Application Note 1MA180, Rohde&Schwarz, 2010: http://www2.rohde-schwarz.com/file/1MA180_0e.pdf
- [12] FSH4 / FSH8 Spektrum Analyzer Produktbroschüre: http://www2.rohde-schwarz.com/file_16151/FSH4_FSH8_bro_de.pdf

Further information:

This application note is updated from time to time. Download the latest version from our website

<http://www.rohde-schwarz.com/appnote/1MA189>.

Please direct your comments and suggestions regarding this application note to

<mailto:TM-Applications@rohde-schwarz.com>

Be sure to visit our technology page at

<http://www.rohde-schwarz.com/technologies>.

Ordering Information

Note: Not all instrument options are listed in Table 5. To put together your individual instrument list please contact your local Rohde & Schwarz sales office for further assistance.

Bestell-Informationen		
Signal Generators		
SMW200A	Vector Signal Generator	1412.0000.02
SMW-B106	RF Path A 100 kHz to 6 GHz	1413.0104.02
SMW-B206	RF Path B 100 kHz to 6 GHz	1413.0904.02
SMW-B13T	Baseband Main Module, two I/Q paths	1413.3003.02
SMW-B10	ARB 64 Msample (120 MHz, realtime)	1413.1200.02
SMW-K512	ARB Memory Extension to 1 Gsample	1413.6919.02
SMW-K68	TETRA Release 2	1413.4439.02
SMU200A	Vector Signal Generator	1141.2005.02
SMU-B106	Option: Frequency range 100 kHz - 6 GHz for 1st RF path	1141.8803.02
SMU-B10	Baseband generator with digital modulation and ARB	1141.7007.02
SMU-B13	Option: Baseband Main Module	1141.8003.04
SMU-B14	Fading Simulator	1160.1800.02

Bestell-Informationen		
SMU-K68	Option: Digital standard TETRA Release 2	1408.8217.02
SMATE200 + Options	Vector Signal Generator for ATE, base unit	1400.7005.02
SMJ100A + Options	Vector Signal Generator	1403.4507.02
SMBV100A + Options	Vector Signal Generator	1407.6004.02
SMB100A + Options	Signal Generator	1406.6000.02
AMU200A + Options	Baseband Signal Generator and Fading Simulator	1402.4090.02
Signal Analyzers		
FSQxx	Signal Analyzer	1155.5001.xx
FSQ-K70	Option: Vector signal analysis for FSQ	1161.8038.02
FS-K110	Analysis of TETRA II / TEDS signals for FSQ / FSU	1309.9668.02
FSUxx	Signal Analyzer	1313.9000.xx
FSU-B73	Option: Vector signal analysis for FSU	1169.5696.03
FSH4/8	Handheld Spectrum Analyzer	1309.6000.xx
FSH-K40	Remote Control via LAN or USB	1314.3006.xx
TETRA Air Interface Drive Test Solution		
TSMW	Universal Radio Network Analyzer	1503.3001.02
TSMW-K26	TETRA Scanner Option (QPSK) for TSMW	1510.8792.02
TSMW-K26Q	TEDS Scanner Option (64QAM) for TSMW	1514.5969.02
ROMES4	Drive Test Software Platform for Measurement & Replay	1117.6885.04
ROMES4T1W	TSMW Scanner Driver Option for ROMES4	1117.6885.02
ROMES4N15	ROMES4NPA Plugin: Mobile Network Coverage	1510.9424.02
ROMES4TEP	TETRA Radio Terminal Driver (PEI) Option for ROMES4	1514.5169.02

Bestell-Informationen		
Cable and Antenna Analyzer		
ZVHx + Options	Handheld Cable and Antenna Analyzer	1309.6800.2x
Portable Receiver and Antenna		
PR100 + Options	Portable Receiver 9kHz-7.5GHz	4071.9006.02
HE300	Active directional antenna, 20 MHz to 7500 MHz	4067.5900.02
Direction Finder		
DDF05A + Options	Digital VHF/UHF scanning direction finder 20 MHz to 3000 MHz	4059.9200.02
DDF05E + Options	Digital VHF/UHF monitoring direction finder 20 MHz to 3000 MHz	4059.9700.02

Table 5: Ordering Information

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radio-monitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment

- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system



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