Coexistence Digital TV and LTE
Application Note

Products:

- R&S®SMU200A
- R&S®SMJ100A
- R&S®SMBV100A
- R&S®WinIQSIM2™
- R&S®TS8980
- R&S®SFU
- R&S®SFE
- R&S®SFE100
- R&S®ETL

Spectrum that was previously reserved for TV broadcasting is being freed up in many countries for use under the new Long Term Evolution (LTE) mobile radio standard (keyword: "digital dividend"). As a result, numerous coexistence scenarios are possible. So network operators and manufacturers from both the mobile radio and the broadcast sector have a vital interest in avoiding any interference and performing in-depth testing of their products. Rohde & Schwarz offers a wide-ranging product portfolio for such applications.

This Application Note presents Test & Measurement equipment for the broadcast and mobile radio sector and discusses some possible test setups.

ROHDE&SCHWARZ

Application Note

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The following abbreviations are used in this Application Note for Rohde & Schwarz test equipment:

- The R&S®SMJ100A vector signal generator is referred to as the SMJ.
- The R&S®SMATE200A vector signal generator is referred to as the SMATE.
- The R&S®SMU200A vector signal generator is referred to as the SMU.
- The R&S®AMU200A baseband signal generator and fading simulator is referred to as the AMU.
- The R&S®SMBV100A vector signal generator is referred to as the SMBV.
- The SMJ, SMATE, SMBV and SMU are referred to as the SMx.

- The R&S®SFU broadcast test system is referred to as the SFU.
- The R&S®SFE broadcast tester is referred to as the SFE.
- The SFU and the SFE are referred to as the SFx.

- The WinIQSIM2™ software is referred to as WinIQSIM2.

1 Introduction

In many countries around the globe, spectrum that was previously reserved for TV broadcasting is being freed up for use under the new Long Term Evolution (LTE) mobile radio standard (keyword: "digital dividend"). Moreover, LTE will operate alongside broadcast applications in the future in this frequency range. As a result, numerous coexistence scenarios are possible. So network operators and manufacturers from both the mobile radio and the broadcast sector have a vital interest in avoiding any interference and performing in-depth testing of their products. Rohde & Schwarz offers a wide-ranging product portfolio for use in performing the applicable measurements on devices (e.g. interference immunity of user equipment, set-top boxes, etc.) and networks.

This Application Note provides an overview of the coexistence topic, presents Test & Measurement equipment for the broadcast and mobile radio sectors and describes some possible test setups.

2 Technological Overview

2.1 TV Standards

Digital broadcast TV standards typically occupy the frequency ranges from 174 MHz to 230 MHz (VHF) and 470 MHz to 862 MHz (UHF). They can be roughly classified in three different areas:

- Mobile broadcast
- Terrestrial broadcast
- Cable broadcast

Table 1 shows the current status of the digital TV frequency bands.

Overview of digital TV standards						
Technology		Frequency range				Region
		174 MHz to 230 MHz VHF	470 MHz to 862 MHz UHF	1452 MHz to 1492 MHz L-Band	S-Band	
Mobile	DVB-H, DVB-SH	X	X		2170 MHz to 2220 MHz	Europe
	ISDB-T1 Seg	X	X			Japan South America
	MediaFLO™		X			USA
	T-DMB		X	X		Korea
	ATSC-M/H		X			USA
	CMMB	X	X		2635 MHz to 2660 MHz	China
Terrestrial	ATSC		X			USA, Korea
	DVB-T/T2	X	X			Europe
	DTMB	X	X			China
	ISDB-T		X			Japan South America
Cable	DVB-C/C2	X	X			Europe
	J.83/B	X	X			USA
	ISDB-C	X	X			Japan

Table 1: Overview of digital TV standards

In order to achieve the data rates needed, e.g., for high definition (HD) television, today's standards use orthogonal frequency division multiplexing (OFDM), higher-order modulation from 16QAM up to 256QAM (with even higher orders planned), channel bandwidths of up to 8 MHz and encoding techniques such as MPEG-4 and H.264.

2.2 3GPP LTE

Long Term Evolution (LTE) or Evolved Universal Terrestrial Radio Access (E-UTRA) as described by the Third Generation Partnership Project (3GPP) is the next step in the evolution of third-generation (3G) cellular systems after HSPA (high speed packet access) and HSPA+.

LTE can be operated in the frequency bands that are already available for existing 3G networks. Moreover, additional ranges such as the 2.5 GHz to 2.7 GHz band (Europe/Asia) and the 700 MHz band (USA) are allocated for usage. Table 2 shows the bands that are currently defined for LTE.

LTE operating bands							
E-UTRA operating band	**Uplink (UL) operating band BS receive UE transmit**			**Downlink (DL) operating band BS transmit UE receive**			**Duplex mode**
	F_{UL_low}	**to**	F_{UL_high}	F_{DL_low}	**to**	F_{DL_high}	
1	1920 MHz	to	1980 MHz	2110 MHz	to	2170 MHz	FDD
2	1850 MHz	to	1910 MHz	1930 MHz	to	1990 MHz	FDD
3	1710 MHz	to	1785 MHz	1805 MHz	to	1880 MHz	FDD
4	1710 MHz	to	1755 MHz	2110 MHz	to	2155 MHz	FDD
5	824 MHz	to	849 MHz	869 MHz	to	894 MHz	FDD
6[1]	830 MHz	to	840 MHz	875 MHz	to	885 MHz	FDD
7	2500 MHz	to	2570 MHz	2620 MHz	to	2690 MHz	FDD
8	880 MHz	to	915 MHz	925 MHz	to	960 MHz	FDD
9	1749.9 MHz	to	1784.9 MHz	1844.9 MHz	to	1879.9 MHz	FDD
10	1710 MHz	to	1770 MHz	2110 MHz	to	2170 MHz	FDD
11	1427.9 MHz	to	1447.9 MHz	1475.9 MHz	to	1495.9 MHz	FDD
12	698 MHz	to	716 MHz	728 MHz	to	746 MHz	FDD
13	777 MHz	to	787 MHz	746 MHz	to	756 MHz	FDD
14	788 MHz	to	798 MHz	758 MHz	to	768 MHz	FDD
15	Reserved			Reserved			FDD
16	Reserved			Reserved			FDD
17	704 MHz	to	716 MHz	734 MHz	to	746 MHz	FDD
18	815 MHz	to	830 MHz	860 MHz	to	875 MHz	FDD
19	830 MHz	to	845 MHz	875 MHz	to	890 MHz	FDD
20	832 MHz	to	862 MHz	791 MHz	to	821 MHz	FDD
21	1447.9 MHz	to	1462.9 MHz	1495.9 MHz	to	1510.9 MHz	FDD
...							
33	1900 MHz	to	1920 MHz	1900 MHz	to	1920 MHz	TDD
34	2010 MHz	to	2025 MHz	2010 MHz	to	2025 MHz	TDD
35	1850 MHz	to	1910 MHz	1850 MHz	to	1910 MHz	TDD
36	1930 MHz	to	1990 MHz	1930 MHz	to	1990 MHz	TDD
37	1910 MHz	to	1930 MHz	1910 MHz	to	1930 MHz	TDD
38	2570 MHz	to	2620 MHz	2570 MHz	to	2620 MHz	TDD
39	1880 MHz	to	1920 MHz	1880 MHz	to	1920 MHz	TDD
40	2300 MHz	to	2400 MHz	2300 MHz	to	2400 MHz	TDD
Note 1: Band 6 is not applicable							

Table 2: LTE operating bands (TS36.101 rel. 9 [3], color highlighting: bands in or near TV band)

LTE uses the higher-order modulation formats QPSK, 16QAM and 64QAM along with scalable channel bandwidths from 1.4 MHz to 20 MHz. The downlink (DL) uses orthogonal frequency division multiple access (OFDMA), while the uplink (UL) uses single carrier frequency division multiple access (SC-FDMA).

2.3 Additional Aspects

Cordless microphones have also used the TV frequency band under discussion. Depending on the region, there existed unlicensed channels with limited transmit power as well as channels which only registered users were allowed to access. In some regions, new frequency ranges are now specified for these microphones, but continued use of the old bands is permissible during a transition interval. The test setups described in this Application Note can also be used to make coexistence measurements for cordless microphones.

3 Coexistence Measurements

3.1 Allocated Spectrum

As described in section 2, some LTE frequency bands are placed within the former TV band. Figure 1 provides a graphical view of the frequency band allocations for TV and LTE in the range of interest. Like all mobile radio technologies, LTE transmits in both the downlink (DL) and the uplink (UL), while TV broadcasting uses the downlink (DL) only.

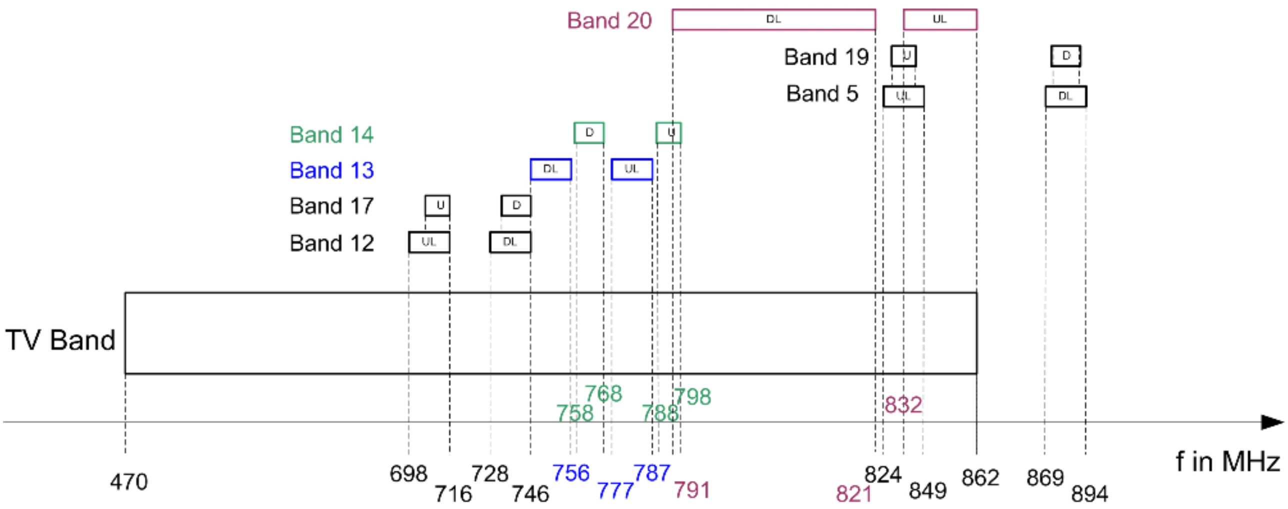

Figure 1: Spectrum allocation (not to scale)

3.2 Overview of Coexistence Scenarios Digital TV / LTE

The receiver of a (digital TV or LTE) system always receives the wanted signal as well as unwanted parts such as noise, or unwanted signals of other radio systems. Based on the spectrum situation as outlined before, various coexistence scenarios exist, where the signal of one system may act as an unwanted (interfering) signal to the respective other system. Depending on the severity of the interference, this may cause degradation of receiver quality, e.g. artefacts in case of digital TV reception or loss of throughput in case of mobile radio, up to complete failure to receive the wanted signal. The severity of this interference depends on the interferer's frequency offset to the wanted signal and on the level of the unwanted signal, as most important factors.

The test specifications from the individual standards are designed in a way to ensure coexistence with other standards. The different standards typically define limits in the transmitter's output RF spectrum, with the objective to limit interference to adjacent frequency bands and co-existing systems. This means that products meeting the specifications are typically not expected to cause any coexistence problems. Nonetheless, manufacturers and network operators may face situations where additional coexistence investigations are useful, e.g. due to legacy products deployed in the field, due to special regional deployment scenarios, or due to network operator specific quality requirements.

When analyzing coexistence scenarios, the frequencies of the unwanted signal(s) and wanted signal are critical. Under the current spectrum allocation for digital TV and LTE, there exist co-channel scenarios where the wanted and the interfering signals are located in the same frequency band. This applies to measurements for cable TV standards. The susceptibility of cable TV receivers against RF interfering signals on the same channel must thus be verified and ensured, e.g. by appropriate shielding. The majority of cases are adjacent channel scenarios, where the interference source transmits at a certain spacing from the wanted signal's channel.

The different coexistence scenarios for digital TV and LTE can be summarized as follows:

- **Influence of Digital TV on Mobile Radio**
  In this coexistence scenario, the digital TV transmitter may act as interferer on the cellular system LTE. Depending on the spectrum situation, the LTE base station receiver or the LTE terminal receiver could be impacted. As the LTE system and the digital TV system are operated in different frequency bands, this coexistence scenario will never be a co-channel scenario.

- **Influence of LTE on Digital TV**
  In this coexistence scenario, an LTE transmitter acts as interferer on the digital TV receiver, e.g. a settop box. The LTE transmitter can be either an LTE terminal (user equipment, UE) transmitting an uplink signal, or an LTE base station transmitting a downlink signal. In case of a terrestrial TV signal, adjacent channel scenarios may occur. In case of cable TV, also co-channel scenarios may occur where the operating frequencies of cable TV and LTE systems share the same frequency band.

Test setups with suitable test and measurement equipment for evaluating the impact of each of these coexistence scenarios are described in chapter 3.5.

The test specifications from the individual standards define the maximum permissible influence on other frequency bands as their most important consideration. These output RF spectrum emissions for LTE and digital TV standards are described in the following chapter.

3.3 Output RF Spectrum Emissions

The output RF spectrum emissions describe the signal output spectrum for a certain standard and in particular limit the interference effects outside of the occupied channel. Each standard defines individual requirements, but the following definitions are used in many standards:

- Channel bandwidth / occupied bandwidth
  Requirements for channel bandwidth and occupied bandwidth define the frequency range occupied by the wanted signal and ensure that the emission of the transmitter does not occupy an excessive bandwidth. The occupied bandwidth is typically defined as the bandwidth containing 99% of the total integrated mean power of the transmitted spectrum on the assigned channel.

- Spectrum emission mask (SEM)
  The spectrum emission mask limits out-of-band emissions immediately outside the nominal channel resulting from the modulation process and non-linearity in the transmitter, but excluding spurious emissions (see below). The SEM requirement typically defines limits and associated measurement bandwidths dependent on the frequency offset from the transmit channel. The transmitter's emissions shall not exceed these limits.

- Adjacent channel leakage power ratio (ACLR)
  The adjacent channel leakage power ratio is defined as the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on the adjacent channel frequency. It is used to verify that the transmitter does not cause unacceptable interference to adjacent channels.

- Spurious emissions
  Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products. The spurious emissions requirement applies to a frequency range far from the transmit channel (unlike ACLR and SEM which limit emissions close to the transmit channel).

Output RF Spectrum LTE

The output RF spectrum emissions for the LTE UE (user equipment) transmitter are defined in [3] and [6]. The output RF spectrum consists of three components; the occupied bandwidth (channel bandwidth), the out-of-band (OOB) emissions and the far out spurious emission domain (Figure 2):

- Channel bandwidth: range occupied by the LTE channel
- Out-of-band emission: unwanted emissions immediately outside the nominal channel, i.e. in a range from the user channel limits to Δf_{OOB} (dependent on the channel bandwidth; example: Δf_{OOB} = 15 MHz for a channel bandwidth of 10 MHz). Out-of-band emissions are specified in terms of a spectrum emission mask (SEM) and an adjacent channel leakage ratio (ACLR). ACLR requirements are specified for the case of an adjacent E -UTRA channel and for the case of an adjacent UTRA channel.

- Spurious emission: everything outside of Δf_{OOB}

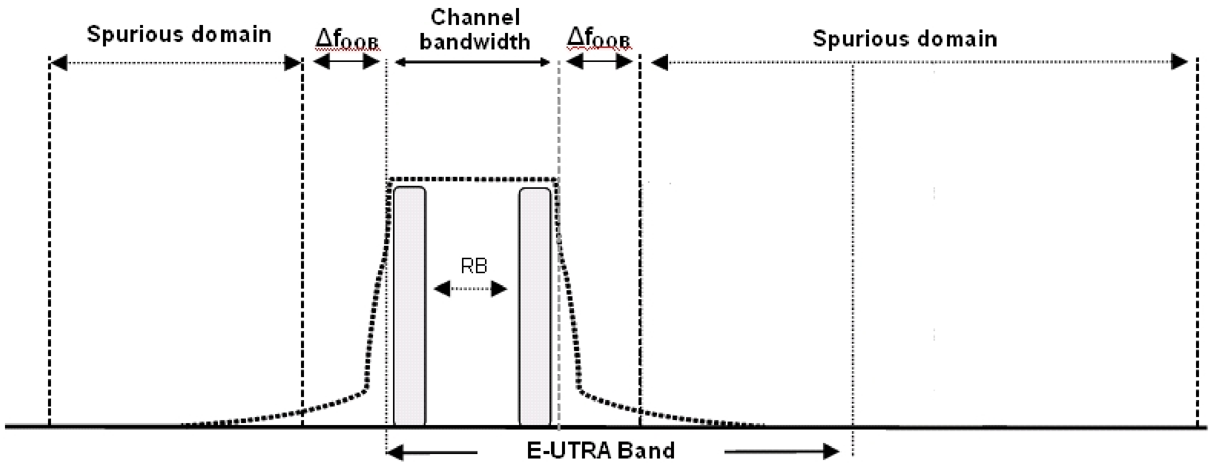

Figure 2: LTE output spectrum uplink

The unwanted emissions for the LTE BS (base station) transmitter are defined in [4] and [7]. The unwanted emissions consist of out-of-band emissions and spurious emissions. The out-of-band emissions are the emissions immediately outside the channel bandwidth . They are specified both in terms of the adjacent channel leakage power ratio (ACLR) and the operating band unwanted emissions. The operating band unwanted emissions define all unwanted emissions in the downlink operating band plus the frequency ranges 10 MHz above and 10 MHz below the band. Unwanted emissions outside of this frequency range are limited by a spurious emissions requirement.

Output RF Spectrum Digital TV

There is a similar situation among broadcast standards worldwide: The influence of adjacent channels due to out-of-band emissions is also handled on a country-by-country basis using spectrum masks. Depending on the usage of the adjacent channels, they are deemed "Critical" or "Uncritical". For an initial estimate, the shoulder attenuation, which corresponds to the power decrease at the band limit, is also commonly used. Unwanted components outside of the adjacent channels are also checked. Such components can occur in the form of harmonics of the transmit frequency.

3.4 Overview of the Rohde & Schwarz Product Portfolio

Rohde & Schwarz supplies test instruments for signal generation and analysis for both mobile radio and broadcast standards in addition to complete RF test systems. The following section summarizes the product portfolio as it relates to the coexistence issues described in this Application Note.

3.4.1 SFU Broadcast Test System

As a broadcast multistandard test platform, the SFU generates TV (analog and digital) and radio broadcast signals in a frequency range from 100 kHz to 3 GHz. The SFU offers high optional output power of up to +19 dBm (PEP), overrange +26 dBm. The instrument supports a wide range of digital TV standards such as DVB-H/T/C. It also functions as a transport stream signal source and can simulate a transmission channel with noise (AWGN) and fading. Moreover, it has an ARB generator which is supported by the WinIQSIM2 simulation software. As a result, interfering signals for coexistence analysis can be provided, for example.

The WinIQSIM2 simulation software has been especially developed to allow simple generation of digitally modulated signals. By offering a convenient way to create any standard-compliant waveform with all of the included standards and to generate multicarrier signals as well as multisegment waveforms, WinIQSIM2 is suitable for a wide range of applications.

In any application involving development, production and/or testing of TV components or devices, suitable test signals are needed. To meet this need, Rohde & Schwarz offers an extensive collection of stream libraries.
See reference [5] for further details.

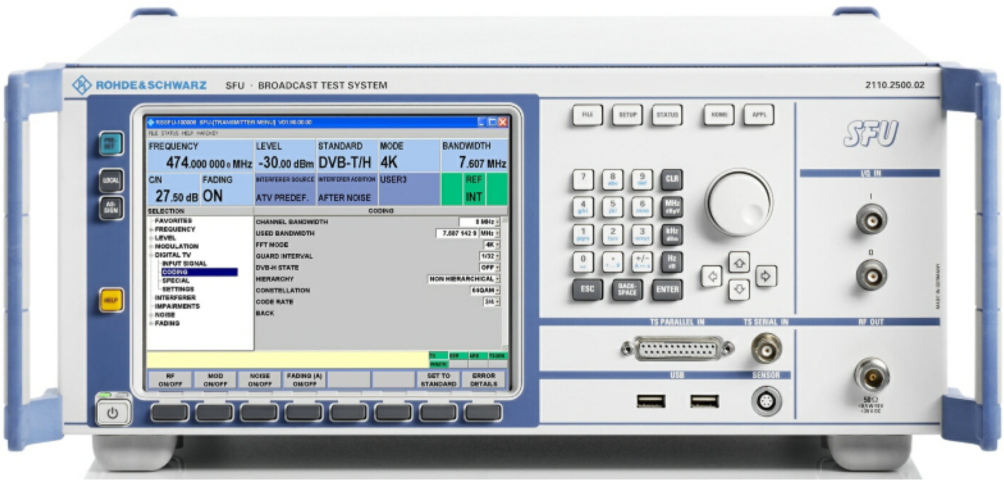

Figure 3: SFU broadcast test system

Additionally with the SFE broadcast tester and the SFE100 broadcast transmitter two compact instruments are available for use in generating TV broadcast signals.

3.4.2 Vector Signal Generator

SMU Vector Signal Generator

The SMU combines up to two independent signal generators in one cabinet and also offers unrivaled RF and baseband characteristics. The two-path concept is optimum for deployment of a compact test setup (e.g. for coexistence investigations) since both the wanted and the interfering signals can be generated in the same box.
The SMU allows addition of signals at the baseband level, or it can provide both signals as an RF signal. This ensures very high flexibility when analyzing coexistence scenarios.
The SMU offers different frequency options from 100 kHz to 2.2 GHz/ 3 GHz/ 4 GHz / 6 GHz for the first RF path and an optional second RF path up to 2.2 GHz or 3 GHz and high output power up to +19 dBm (PEP), overrange +26 dBm.
The SMU can be fitted with a wide range of options, including options for all of today's important digital standards such as HSPA(+) and LTE (FDD and TDD) as well as function and performance enhancements such as MIMO fading, additive white Gaussian noise (AWGN) and phase coherence. Other possibilities include options for DVB-H/T and DAB/T-DMB signal generation.
Moreover, ARB files created with the WinIQSIM2 simulation software can be played back.

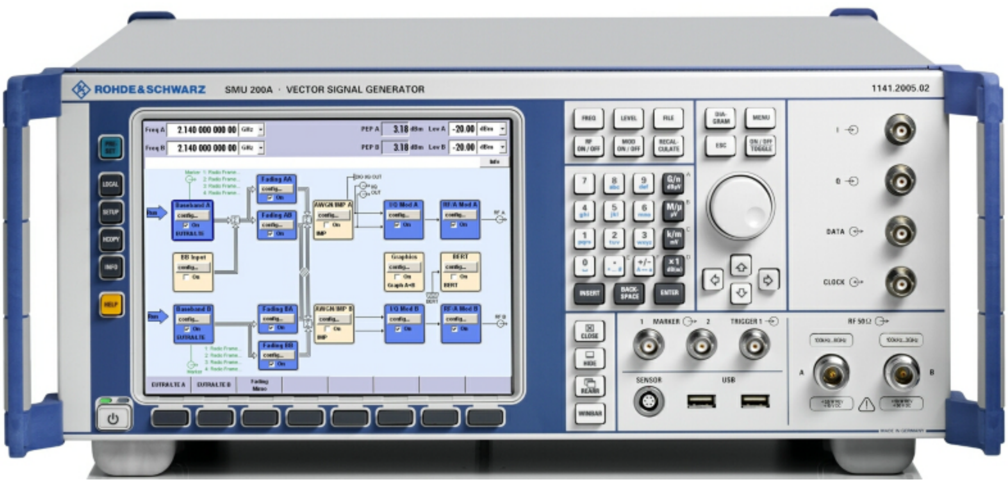

Figure 4: SMU Vector Signal Generator

SMBV Vector Signal Generator

The SMBV offers excellent RF performance along with very high output level (up to 18 dBm, 24 dBm overrange) and short setting times in the mid-range vector signal generator class. The SMBV has a wide frequency range up to 6 GHz. Due to its optimal scalability, the SMBV is easy to customize to meet specific customer requirements. For production applications, a cost-effective solution for playing back predefined test sequences is available with the optional baseband arbitrary waveform generator (ARB). An optional baseband coder provides impressive realtime capabilities. It can be fitted with options for all of today's important digital standards such as HSPA(+) and LTE (FDD and TDD), as well as function and performance enhancements such as additive white Gaussian noise (AWGN) and phase coherence. Also DVB-H/T and DAB/T-DMB signal generation is supported.
Moreover, ARB files created with the WinIQSIM2 simulation software can be played back.

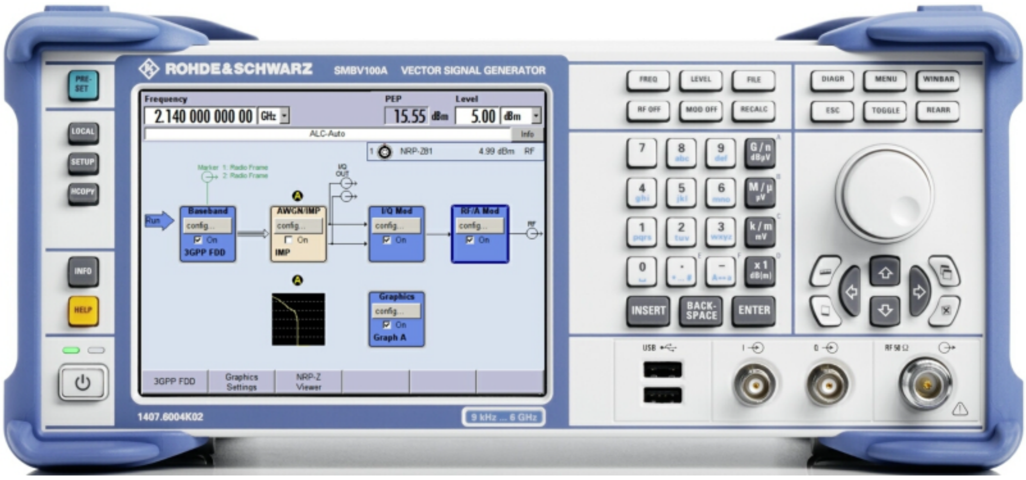

Figure 5: SMBV Vector Signal Generator

Besides the SMU and the SMBV, the SMATE and SMJ are also part of the R&S family of vector signal generators.

3.4.3 ETL TV Analyzer

The ETL TV analyzer is a universal multistandard platform for the analysis of TV signals. It combines TV test receiver and spectrum analyzer functionality in a single unit while providing high measurement accuracy. Both digital (e.g. DVB-T/H) and analog TV standards can thus be integrated in a single instrument. The ETL provides demodulation and thus BER measurements along with complete analysis in real time. In addition, the ETL may be equipped with MPEG options to provide detailed information about the MPEG transport stream.

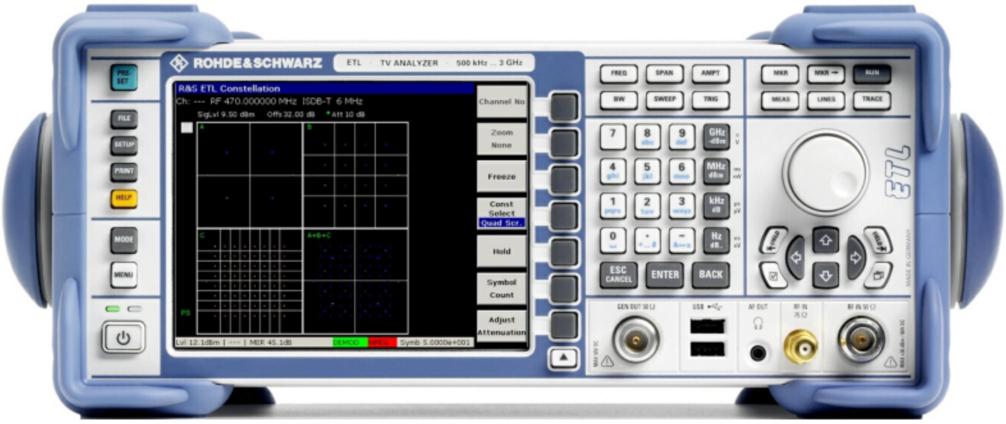

Figure 6: ETL TV analyzer

3.4.4 TS8980 Test System

The TS8980 is a highly modular and fully automated RF test system for mobile devices. The scalable platform offers test solutions for LTE and WCDMA (wideband code division multiple access) devices in accordance with the 3GPP TS 36.521-1 [5] and TS 34.121-1 [6] standards, respectively. The test system provides efficient tools to allow consistent R&D, preconformance and conformance tests in accordance with the 3GPP test specifications. Moreover, the platform can be used to perform network operator-specific tests such as TV interferer tests in order to check the susceptibility of mobile terminals to interference.

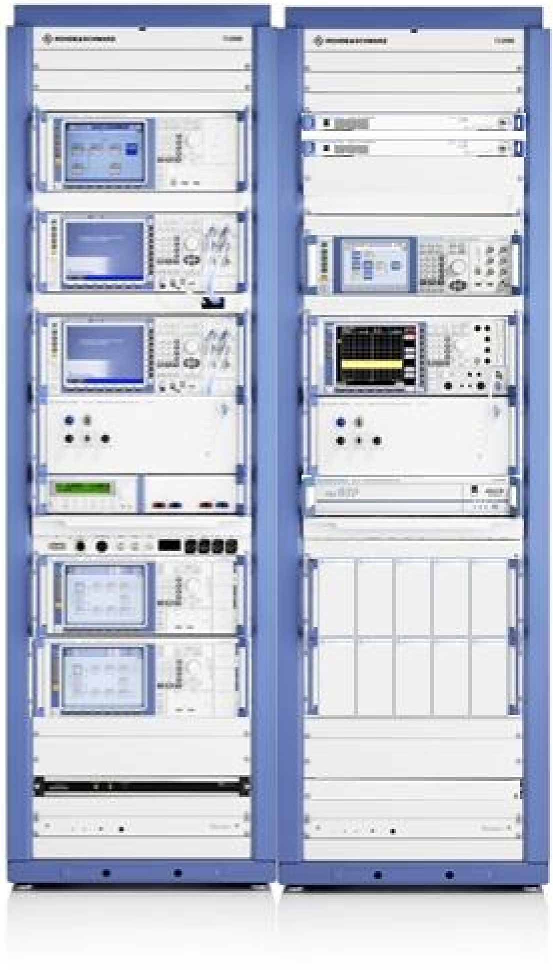

Figure 7: Fully equipped TS8980 FTA conformance test system

3.5 Test Setup

3.5.1 Influence of Digital TV on Mobile Radio (LTE and WCDMA)

The TS8990 test system is available for analyzing the influence of digital TV signals on WCMDA or LTE user equipment (see section 3.4.4 above). Most important in this context are the receiver tests on the user equipment (UE). A digital TV signal can affect the reception of the LTE signal (e.g. by receiver blocking and receiver intermodulation). Within the TS8980 test system, a radio communication tester (the R&S®CMW500) acts as base station simulator. The UE receives the (wanted) LTE downlink signal from the CMW500. At the same time, the SFU generates a digital TV signal which is also present on the UE antenna. The CMW performs a block error rate (BLER) measurement in order to detect any possible degradation in the receive quality.

A similar principle can be applied to testing of base station receivers. An example test setup is shown in Figure 8. Here, an SMU signal generator is used to provide the (wanted) LTE uplink signal. The interfering signal is generated via the SFU. Alternatively, in the case of DVB-H/T or T-DMB, the interfering signal could also be generated in the SMU's second generator path. Another alternative is to generate the interfering signal using an ARB file in the SMU's second generator path.
For testing base station performance, the SMU is the signal generator of choice. Equipped with software option SMU-K69 (LTE Closed-Loop BS Test), it can perform closed loop base station tests including HARQ (hybrid automatic repeat request) feedback as required by 3GPP LTE specifications [4, 7].

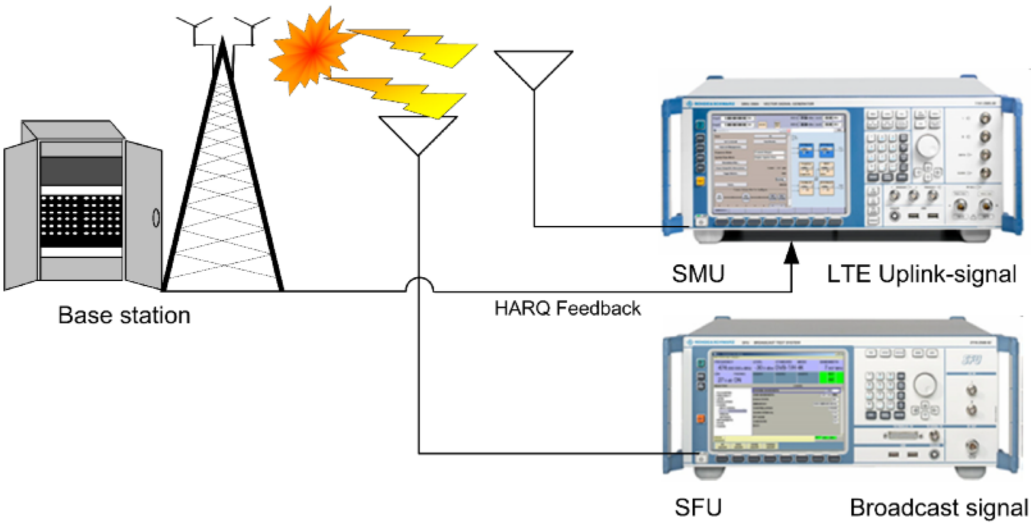

Figure 8: General test setup, TV -> LTE (base station test)

3.5.2 Influence of LTE on Digital TV

Figure 9 shows the basic test setup for evaluating the influence of LTE on digital TV. The SFU generates the broadcast signal which is received using a set-top box, demodulated and displayed on a TV monitor. The LTE signal generated by the SMU is received along with the broadcast signal from the receiving antenna. If the received TV signal is also to be analyzed in terms of the relevant test parameters, a splitter should be used to decouple the signal and feed it to the ETL. Please recall that the set-top box has an input impedance of 75 Ohm.
Note that instead of the SFU, an SFE could be used in this setup as well. Instead of an SMU, another R&S vector signal generator, e.g. the SMBV, could be used (see section 3.4.2 for the characteristics).

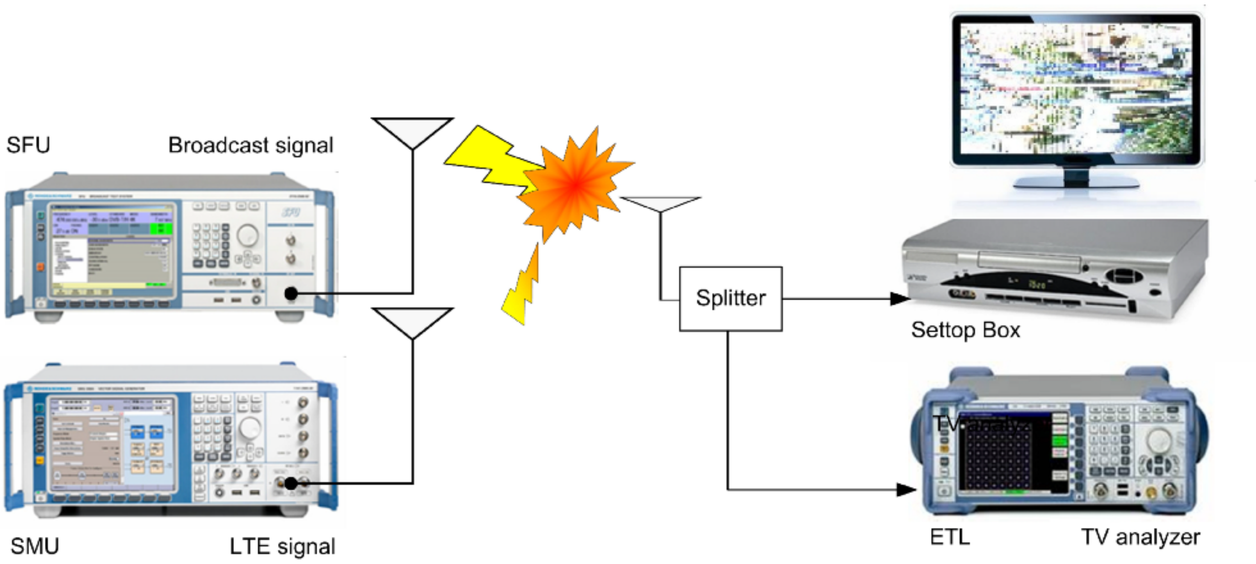

Figure 9: General test setup

The ETL provides a range of test capabilities for the TV signal. See reference [6] for further details on the individual measurements. Figure 10 to Figure 13 show a few important measurements as examples.

The first figure provides an overview of the most important measurement parameters such as the modulation quality (modulation error ratio (MER), error vector magnitude (EVM)) along with various bit and packet error rates.
The EVM is defined as the difference between the measured waveform and the theoretical modulated waveform. It is a measure of the difference between the ideal symbols and the measured symbols. This difference is called the error vector. It is typically expressed in dB or %.
The MER is a measure of the sum of all interference that affects a digital TV signal. It is typically expressed in dB as a logarithmic relationship between the RMS value of the ideal transmitted signal and the RMS power of the error vector. A high MER value indicates good signal quality.

The second figure shows the spectrum of a (wanted) DVB signal with an interferer in the adjacent channel. The interfering signal overlaps 1 MHz with the wanted signal. Due to the high wanted signal level, the overlapping cannot be seen from this measurement.
The third figure shows the MER versus the OFDM subcarriers as an example. Here the impact of the overlapping interferer can immediately be identified. You can see the significant drop of the MER from 45.7 dB down to 25 dB because of the interferer overlapping.

Also the fourth figure illustrates the impact of the interfering signal. It shows a constellation diagram (64QAM) of the DVB signal where the EVM (indicated by the blue dots) deteriorated because of the interferer.

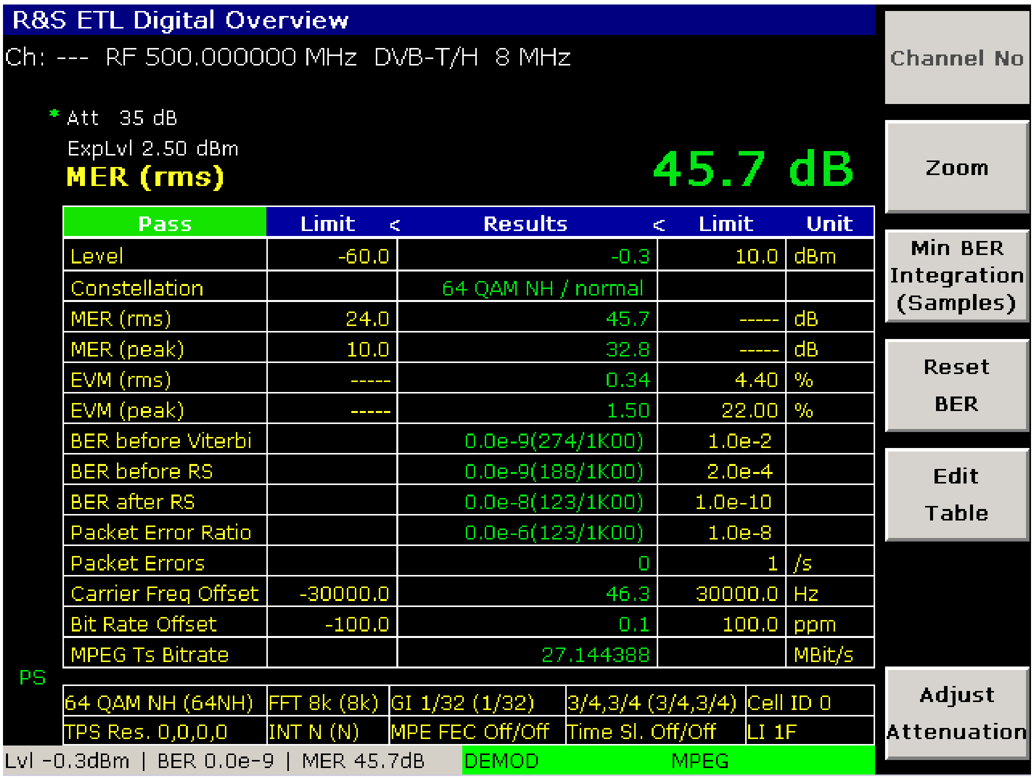

Figure 10: Overview measurements with the ETL, most important the MER

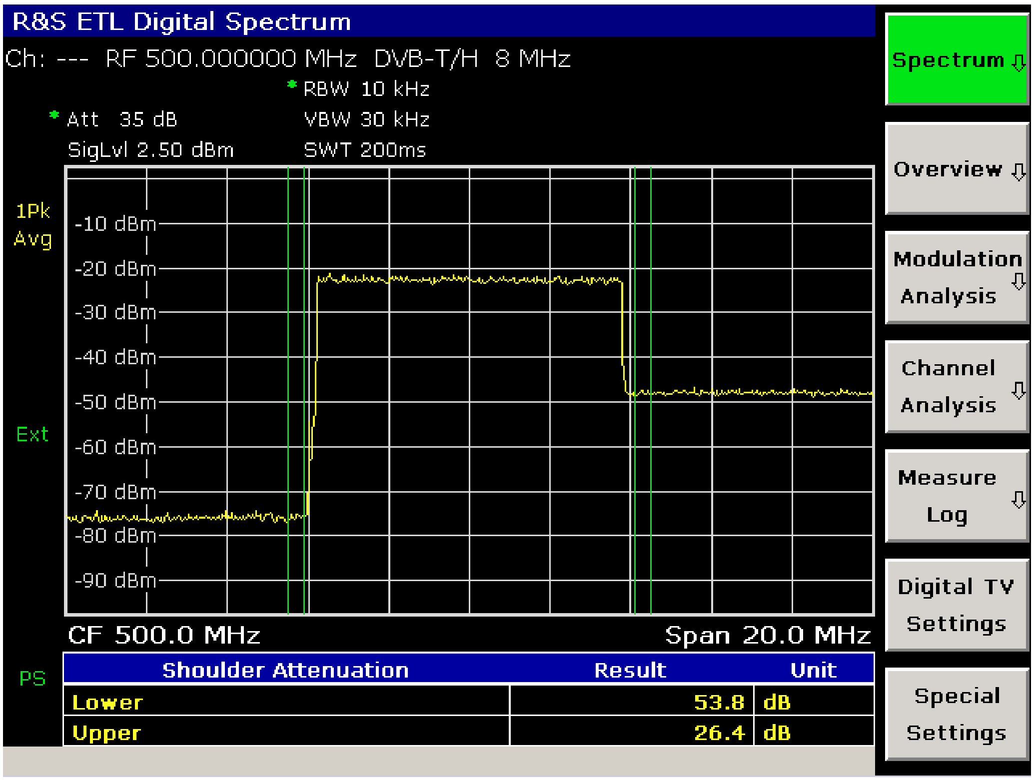

Figure 11: Spectrum of a DVB signal with an interferer in the neighbor channel overlapping 1 MHz with a level of -25 dB. The overlapping can not be seen here due to the high wanted signal level.

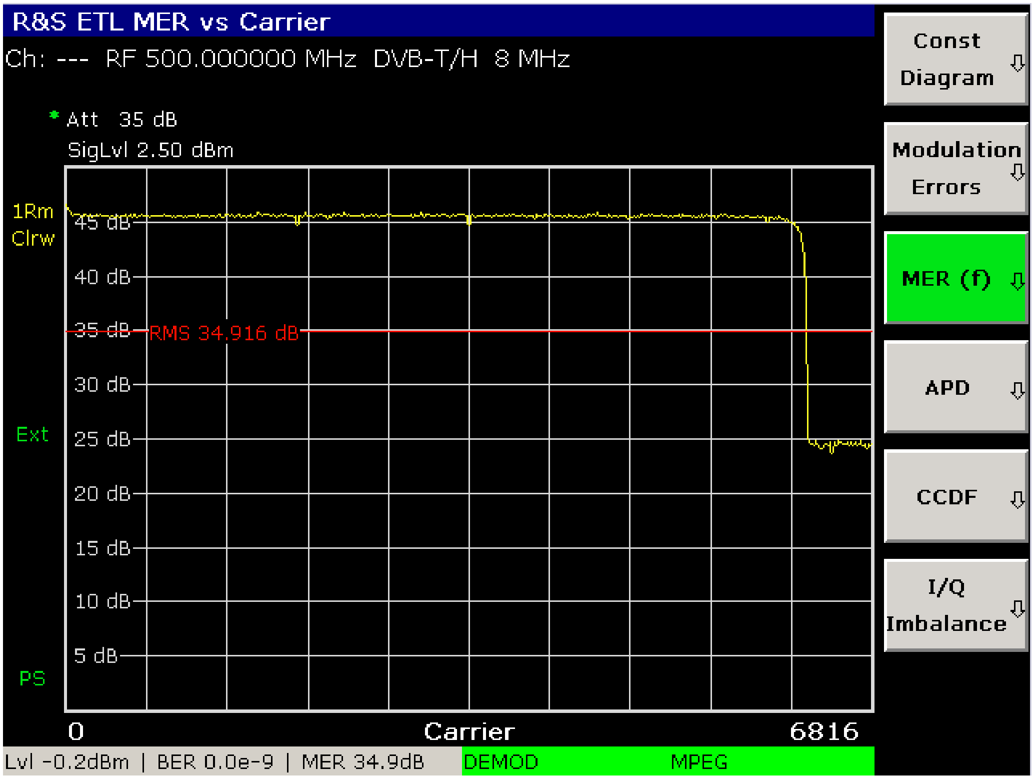

Figure 12: MER versus carrier measurement: in the 1 MHz overlapping area the MER drops down to 25 dB caused by the interferer.

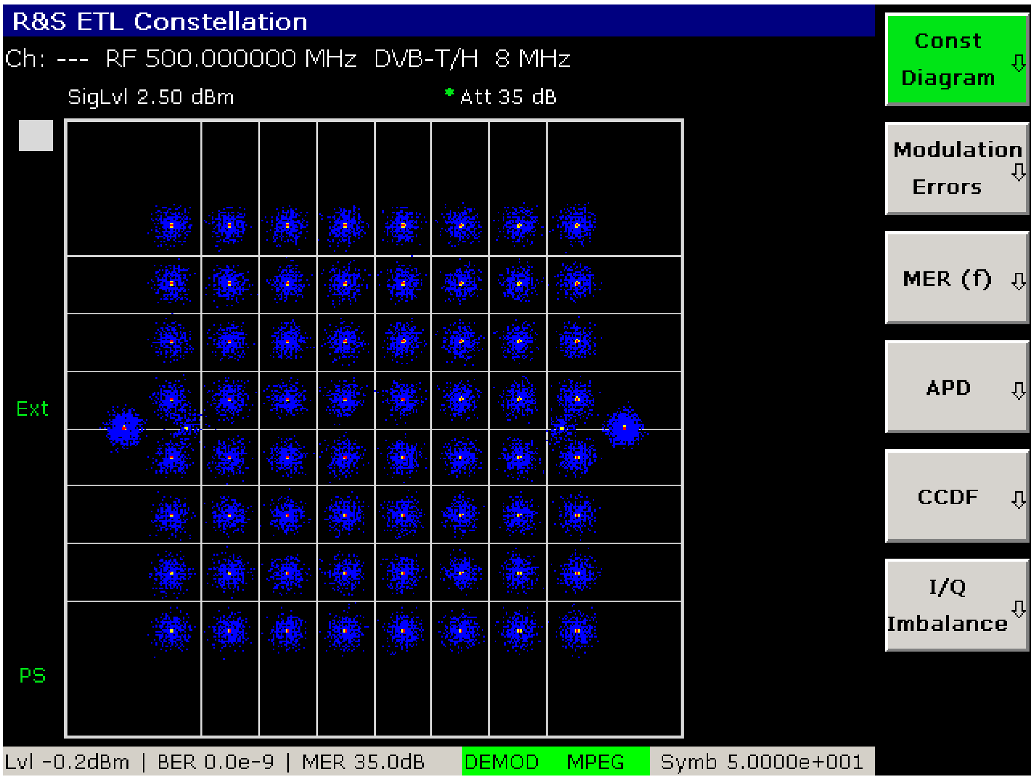

Figure 13: Constellation diagram of a 64QAM DVB signal again with a 1 MHz overlapping interferer. The 64 red dots in the middle show the ideal constellation points. The offset of the blue dots are caused by the interferer which leads to a worse EVM.

In the following sections, some more details for individual measurement setups are shown. It is shown how the setup will look like for terrestrial and cable TV, respectively. Furthermore, as indicated in section 3.4.2, the interfering LTE signal needs not necessarily be provided via RF, but may also be added in the baseband to the wanted signal. This is also described.

3.5.2.1 Test Setup for Terrestrial TV: Interferer Provided as RF Signal

Providing the interfering signal as RF signal provides the highest degree of flexibility. Figure 14 shows a block diagram of an example test setup. Here, the SFU generates a broadcast signal for terrestrial TV which is subject to interference from an LTE signal generated by the SMU. This configuration makes it possible to use the SMU's and SFU's flexible baseband coders. They provide realtime capabilities for direct signal generation of the wanted and interfering signal. AWGN and fading can be added to the signals if required. Another benefit of this setup is the possibility to use the large level range (up to +19 dBm, +26 dBm in overrange) and the full frequency range up to 6 GHz provided by the SMU for the interfering signal.
Alternatively to SMU, the SMBV could be used in this setup as well (if no fading simulation is required).

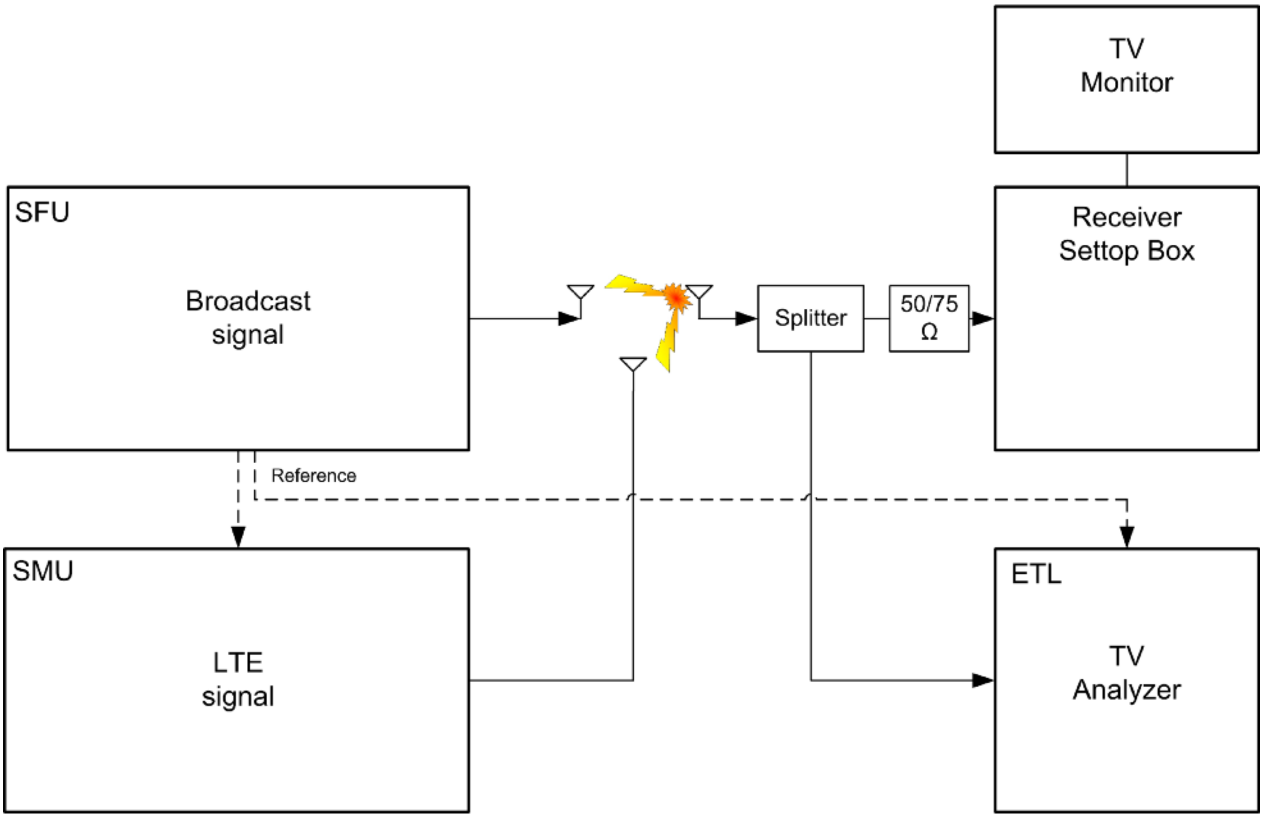

Figure 14: Test setup for terrestrial TV, RF interferer

3.5.2.2 Test Setup for Cable TV: Interferer Provided as RF Signal

If a cable TV standard is to be investigated, a test setup with an RF interferer according to Figure 15 should be used. In this case, a connection via cable TV is tested in terms of its immunity to interference. Here, the SFU generates a broadcast signal which is subject to interference from an LTE signal generated by the SMU. In this configuration, the flexible baseband generators with realtime capabilities provided by the SFU and the SMU can be used. AWGN can be added as well. Another benefit of this setup is the possibility to use the large level range (up to +19 dBm, +26 dBm in overrange) and the full frequency range up to 6 GHz provided by the SMU for the interfering signal. Alternatively to SMU, the SMBV could be used in this setup as well (if no fading simulation is required for the interferer).

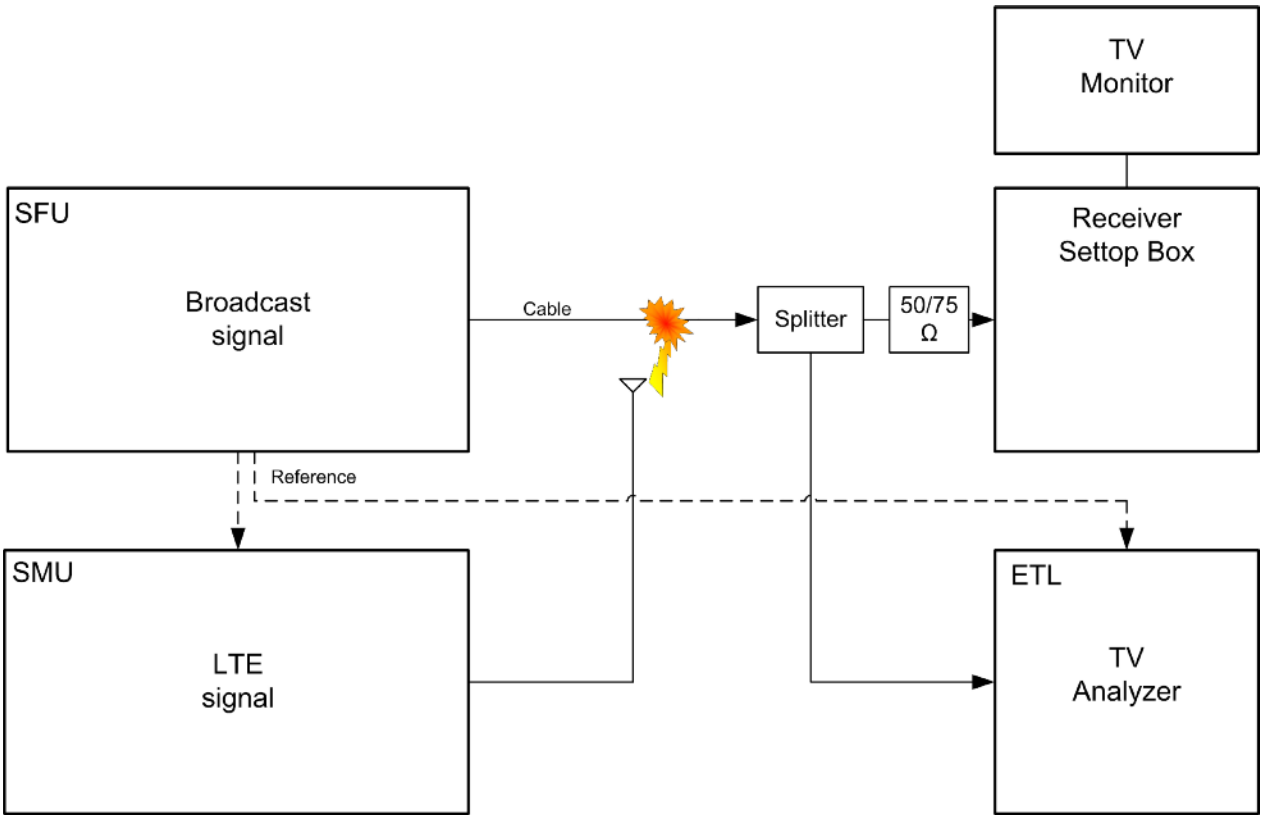

Figure 15: Test setup for cable TV, RF interferer

3.5.2.3 Test Setup for Terrestrial TV: Interferer Provided as Baseband Signal (by WinIQSIM2)

The interfering signal can also be added in the baseband. This makes it possible to generate the wanted and the interfering signal with one single instrument. Figure 16 shows a block diagram with an interferer that is generated internally in the SFU. Here, an LTE signal in the form of an ARB file in the baseband is used as the interfering signal. The ARB file can be generated using the WinIQSIM2 simulation software, for example. Also the SMU allows the use of ARB files. Therefore, depending on the digital standards to be investigated, the SMU could be used alternatively in the setup in Figure 16.
Due to the SFU/SMU's internal IQ modulator bandwidth of 80 MHz, the possible frequency offset between the wanted and interfering signal is restricted in this setup. A maximum frequency offset of ±40 MHz can be selected for the baseband interferer. This value may be further reduced depending on the channel bandwidths of wanted and interfering signal. The wanted signal and the interfering signal (spaced with a certain offset) together shall not exceed an overall bandwidth of 80 MHz.
Also the dynamic range is restricted because of the noise level: the level difference between wanted and interfering signal must not exceed 50 dB when the signals are added in baseband.

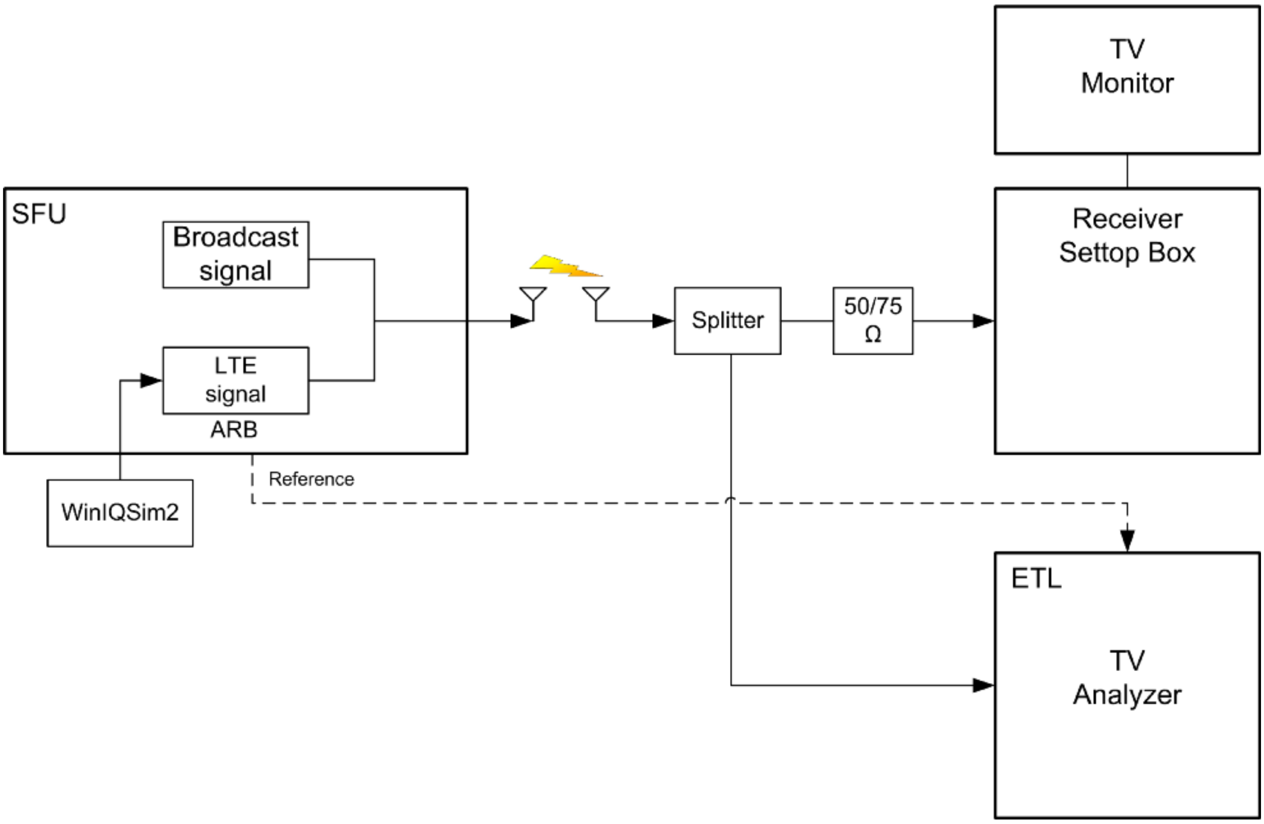

Figure 16: Test setup: baseband interferer

The SFU makes it possible to use a simple internal interferer configuration.

Figure 17 provides an overview of the settings. An ARB file can be used as the interferer signal. Its level and frequency can be set relatively to the wanted signal. See reference [2] for further details on the possible settings in the SFU.

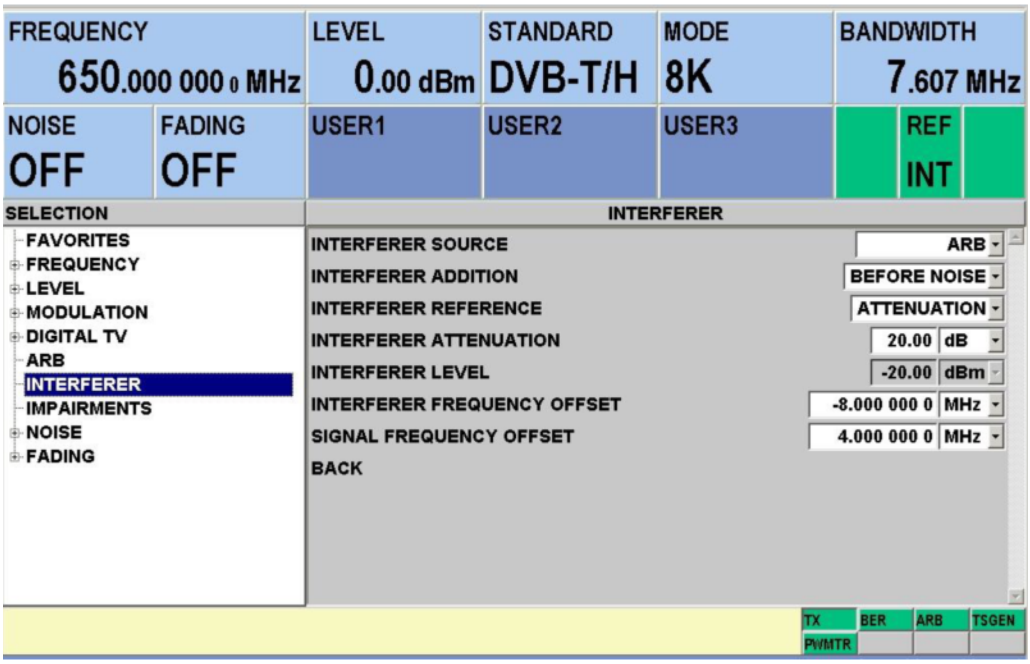

Figure 17: Interferer configuration in the SFU; Interferer signal is an ARB file; frequency and level are set relatively to the wanted signal.

3.6 Basic parameters

This section discusses some of the important parameters that can be adjusted in SFx and SMx test instruments for the broadcast or LTE standard insofar as they are relevant to coexistence issues.

3.6.1 TV Broadcast Signal (settings with SFx)

Digital TV standards

The SFx can be used to generate signals with appropriate parameters for different standards (Figure 18). Today's standards use orthogonal frequency division multiplexing (OFDM). All of the standards listed in Table 1 in section 2.1 can be generated.

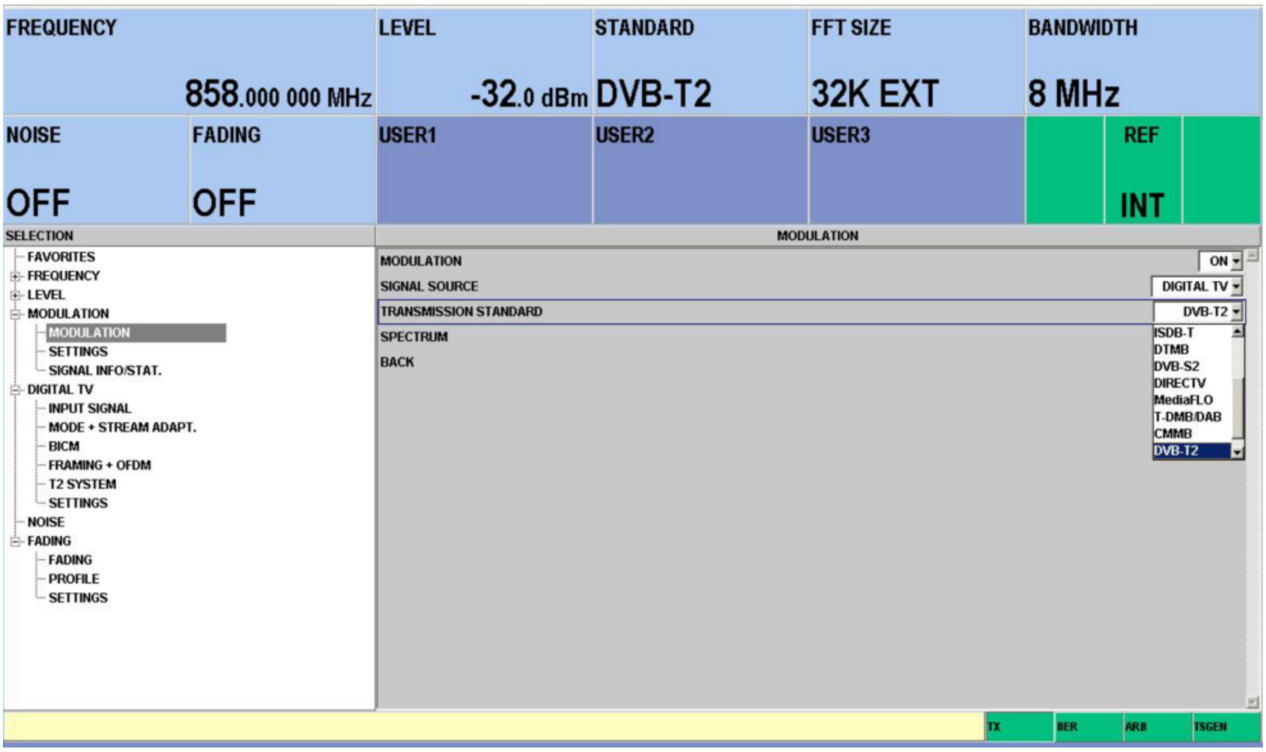

Figure 18: Overview of settings in the SFx; all important parameters are shown in the top rows; the Digital TV standard is selected via modulation: transmission standard.

After selecting the standard, further parameters can be adjusted (Figure 19).

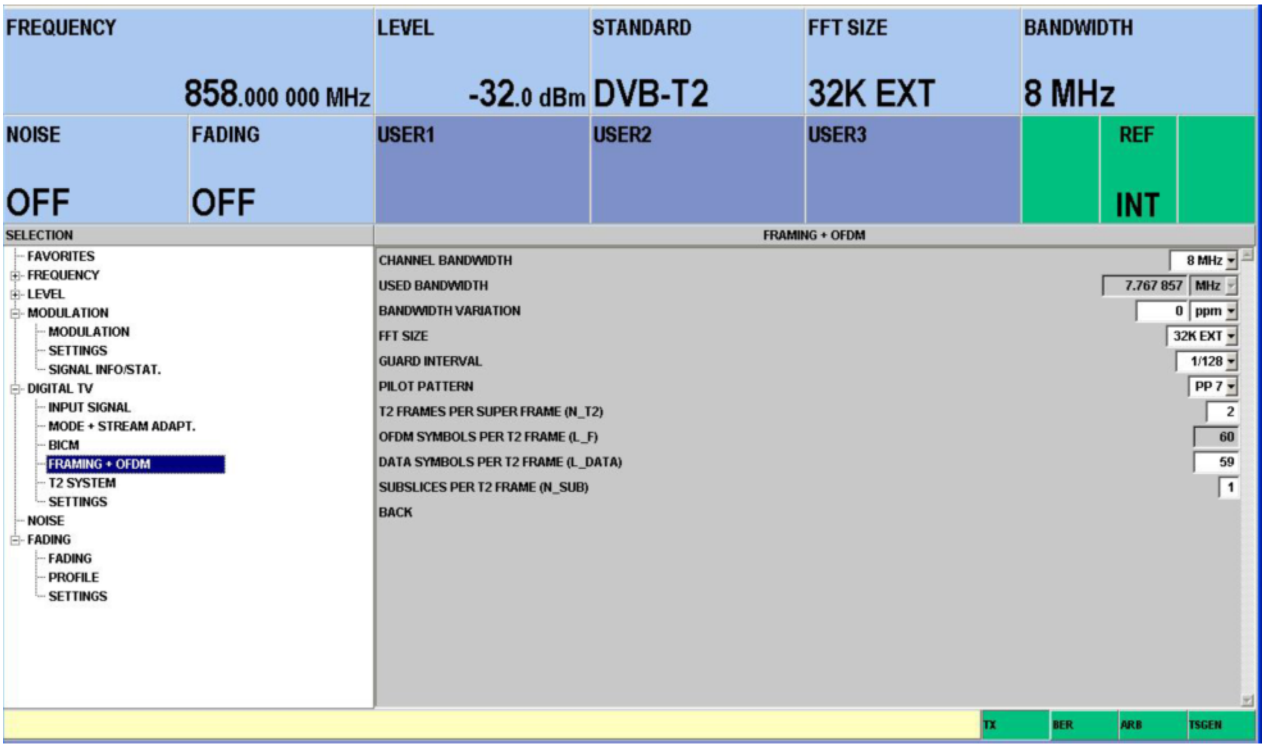

Figure 19: Further parameter settings; the default parameters can be adjusted to own needs.

Channel bandwidth

The channel bandwidth is one of the most important parameters for coexistence measurements as the receiver “sees” the all unwanted signals within the channel bandwidth. The channel bandwidth varies depending on the standard with typical discrete values of 5 MHz/6 MHz/7 MHz/8 MHz/10 MHz (also higher for satellite standards). The SFx supports all of the channel bandwidths. The most commonly used values in today's networks are 6 MHz and 8 MHz.

FFT (fast Fourier transform) mode

The FFT size (or FFT mode) determines the spacing between individual subcarriers and ultimately the symbol length in the OFDM. An increase in this value reduces the spacing between subcarriers and increases the symbol length. As a result, the radio cell size as well as the possible user equipment speed are influenced.
Depending on the standard, the FFT mode can assume discrete values of 2k / 4k / … 32k. Today's networks typically implement values in the range from 2k to 8k.

Guard interval

The guard interval is used in OFDM systems to protect against intersymbol interference. In the case of larger FFT modes, the symbol duration increases. By introducing shorter guard intervals such as 1/128 (of the symbol duration), the data throughput can also be boosted. Depending on the FFT size, typical values for the guard interval are in the range from ¼ to 1/32.

Modulation

The modulation that is used is BPSK, QPSK, 16QAM and 64QAM through 256QAM, while in the newer standards modulation of up to 4096QAM is used along with rotating constellations.

Code rate

The code rate indicates the ratio of net bits to gross bits resulting from the error encoding. Typical values are in the range from ½ to 5/6.

Test transport stream

In order to generate a live signal, Rohde & Schwarz has an extensive library including transport streams for all of the supported standards and also in HD quality.

Level and frequency

The level and frequency can be set in a variable manner with the SFx (SFU: 100 kHz to 3 GHz; High optional output power of up to +19 dBm (PEP), overrange +26 dBm).

3.6.2 LTE Signal (settings with SMx)

See reference [1] for a detailed description of LTE. Here, only the most important parameters in use are presented and a few scenarios are discussed. Relevant SMx settings are also mentioned in context.

Uplink/downlink

The SMx can be used to generate downlink as well as uplink signals. The assumption is that the level of a user equipment (UE uplink signal; maximum of 23 dBm for LTE) operated near to a set-top box is higher than the level of a base station (downlink signal).

FDD/TDD

LTE supports a frequency division duplex (FDD) mode with the downlink and uplink on different frequencies as well as a time division duplex (TDD) mode where the downlink and uplink are on the same frequency. The SMx can generate signals for both of these modes.

Channel bandwidth

The channel bandwidth can be set in discrete steps between 1.4 MHz and 20 MHz. The SMx supports all of the relevant bandwidths. The 10 MHz scenario has special relevance for the first commercial LTE networks.

Cyclic prefix

The guard interval in LTE is a cyclic prefix which is appended to each OFDM (or SC-FDMA) symbol in order to protect against intersymbol interference. For regular LTE operation, two different cyclic prefix lengths are defined to cover different cell sizes: a normal cyclic prefix (app. 5 µs) and an extended cyclic prefix (app. 16 µs). The cyclic prefix to use can be configured in the SMx LTE settings.

Frames/resource block (RB) allocation

LTE supports a high flexibility in terms of downlink and uplink resource allocation schemes. These are fully supported in the SMx.
A radio frame in LTE lasts 10 ms and consists of 10 subframes lasting 1 ms each. The smallest unit that can be allocated within a subframe is the resource block (RB). It comprises 12 subcarriers with 15 kHz spacing (corresponding to 180 kHz) in the frequency domain and half a subframe (corresponding to 7 OFDM symbols for the normal cyclic prefix) in the time domain. For the 10 MHz channel bandwidth, for example, 50 resource blocks are available for allocation in the frequency domain.
In principle, the resource blocks can be freely distributed among the downlink in the time domain and the frequency domain so that gaps can occur in both. In the uplink, only cohesive resource blocks can be allocated for one terminal, but they can undergo frequency hopping from slot to slot or from subframe to subframe. The SMx supports this flexible RB allocation in the downlink and the uplink. The resulting frame configuration can easily be displayed, see Figure 20 for an uplink example.

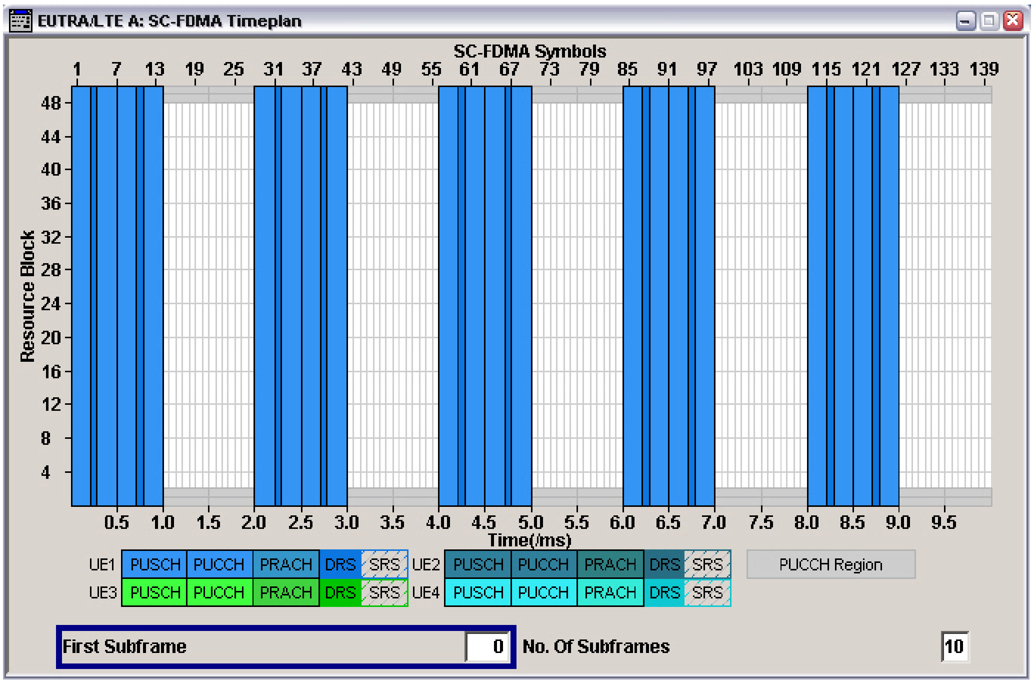

Figure 20: Flexible RB allocation (uplink) in the SMx; on the x-axis the 10 subframes, on the y-axis the max. allowed 50 RBs (in 10 MHz channel bandwidth) are shown; in this example the full bandwidth is allocated in every second subframe.

Filter settings

Since no filters are defined in the 3GPP LTE specifications, the SMx allows various filter settings (Figure 21 and Figure 22):

- Best EVM (error vector magnitude)
- Best ACP (adjacent channel power)
- Balance EVM/ACP

This makes it possible to achieve a trade-off between in-channel and out-of-channel performance for the generated signal. The selected filter is applied to the generated downlink or uplink signal. Optimum in-channel performance is achieved with the Best EVM Filter. Optimum out-of-channel performance is achieved with the Best ACP filter. To meet special test demands, selected parameters can be adjusted manually, for example the value of the cut-off frequency shift of the Best EVM filter.
Various filter settings can thus be used flexibly in the SMx to adapt the test signals to individual needs.

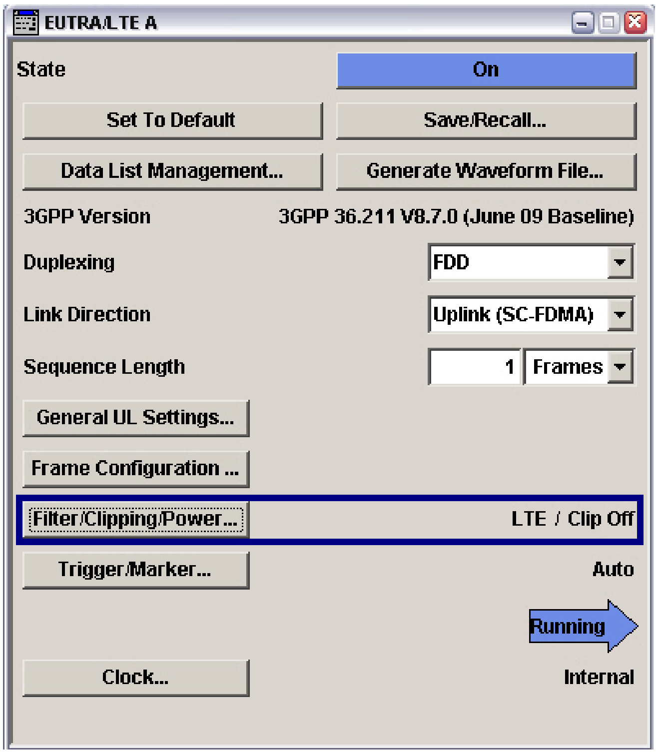

Figure 21: SMx LTE settings: Filter/Clipping/Power

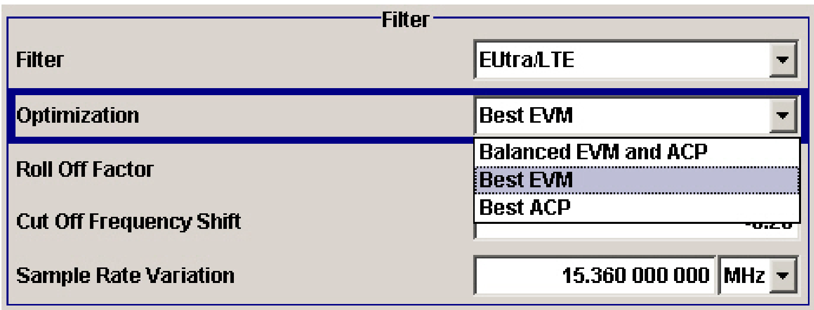

Figure 22: SMx filter settings

Level setting

In the uplink, it is important to watch for a comparable level setting in the SMx, especially if all of the subframes are not uniformly occupied in the time domain. The SMx provides the flexibility to select the reference level for the power setting. The **UE Burst RMS Power** setting guarantees that the set power for the PUSCH is actually referred to the occupied RBs (Figure 23).Otherwise, the PUSCH power would be referred to the RMS value of the total signal and the peak power would thus be higher.

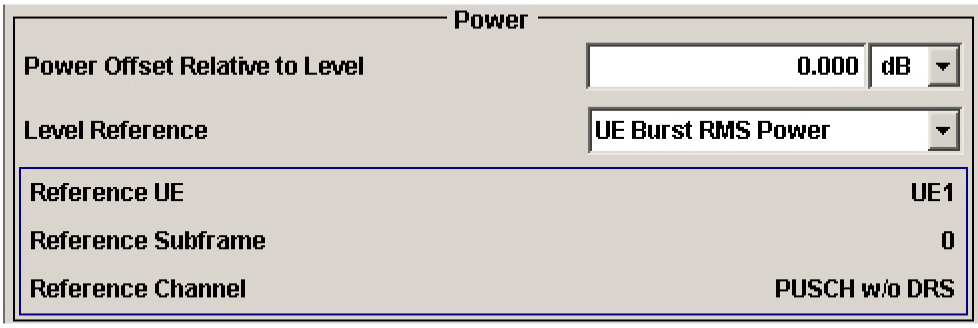

Figure 23: SMU uplink power setting

AWGN

In the SMx, the AWGN option (software option SMx-K62) can be used to superimpose noise on the LTE signal. This makes it possible to model the LTE signal spectrum in the adjacent channels as it would occur during "real-world" operation.

4 Appendix

4.1 Downloads

WinIQSIM2 is found at:

http://www2.rohde-schwarz.com/en/products/test_and_measurement/signal_generation/WinIQSIM2.html

4.2 References

[1] Rohde & Schwarz: **UMTS Long Term Evolution (LTE) Technology Introduction**, Application Note 1MA111, September 2008

[2] Rohde & Schwarz: **Generating Interference Signals Using the R&S® SFU-K37 Option**, Application Note 7BM50, December 2006

[3] Technical Specification Group Radio Access Network; **User Equipment (UE) radio transmission and reception**, Release 8; 3GPP TS 36.101 V 8.9.0, March 2010

[4] Technical Specification Group Radio Access Network; **Base Station (BS) radio transmission and reception**, Release 8; 3GPP TS 36.104 V 8.9.0, March 2010

[5] Rohde & Schwarz: **Broadcast Test System R&S® SFU**, V3.0, January 2008

[6] Technical Specification Group Radio Access Network; **User Equipment (UE) conformance specification radio transmission and reception Part 1**, Release 8; 3GPP TS 36.521 V 8.5.0, March 2010

[7] Technical Specification Group Radio Access Network; **Base Station (BS) conformance testing**, Release 8; 3GPP TS 36.141 V 8.6.0, March 2010

4.3 Additional Information

Please send your comments and suggestions regarding this application note to

TM-Applications@rohde-schwarz.com

5 Ordering Information

Ordering information		
Vector Signal Generator		
SMU200A	**Vector Signal Generator**	**1141.2005.02**
SMU-B9	Baseband Generator	1161.0766.02
SMU-B10	Baseband Generator	1141.7007.02
SMU-B11	Baseband Generator	1159.8411.02
SMU-B13	Baseband Main Module	1141.8003.04
SMU-B10x	1st RF Path	
SMU-B20x	2nd RF Path	
SMU-K62	AWGN	1159.8511.02
SMU-K55	Digital Standard LTE/EUTRA	1408.7310.02
SMU-K69	LTE Closed-Loop BS Test	1408.8117.02
SMU-K52	Digital Standard DVB-H/DVB-T	1408.7010.02
SMU-K53	Digital Standard DAB / T-DMB	1400.6209.02

Ordering information		
TV Generator		
SFU	**Broadcast Test System**	**2110.2500.02**
SFE	**Broadcast Tester**	**2112.4300.02**
SFE100	**Test Transmitter**	**2112.4100.xx**
SFx-K40	Noise AWGN	
SFx-K1	DVB-T/H Coder	
SFx-K2	DVB-C Coder	
SFx-K3	DVB-S/DVB-DSNG Coder	
SFx-K4	ATSC/8VSB Coder	
SFx-K5	J.83/B Coder	
SFx-K6	ISDB-T Coder	
SFx-K10	MediaFLO™ Coder	
SFx-K11	T-DMB/DAB Coder	
SFx-K12	DTMB Coder	
SFx-K15	CMMB Coder	
SFx-K18	ATSC-M/H Coder	
SFx-K35	ARB Generator	

Ordering information		
TV Analyzer		
ETL	**TV Analyzer**	**2112.0004.13**
ETL-B210	Digital Demodulator for Single Carrier	2112.0104.02
ETL-B215	Digital Demodulator for DTMB	2112.0156.02
ETL-B216	Digital Demodulator for Single Carrier and DTMB	2112.0162.02
ETL-K210	DVB-C Firmware	2112.0404.02
ETL-K213	J.83/B Firmware	2112.0504.02
ETL-K220	ATSC/8VSB Firmware	2112.0456.02
ETL-K240	DVB-T/H Firmware	2112.0556.02
ETL-K250	T-DMB/DAB Firmware	2112.0533.02
ETL-K260	ISDB-T Firmware	2112.0485.02
ETL-K340	DVB-T2 Firmware	2112.0527.02

Note: Available options are not listed in detail. The use of the SMATE and the SMBV vector generator is also possible (the SMATE and SMBV do not support fading).

Please contact your local Rohde & Schwarz sales office for further assistance.

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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, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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