Upgrade to ATSC Mobile DTV
Application Note

Products:

| R&S®AEM100BU	| R&S®SX801
| R&S®AEM100I	| R&S®AVE264
| R&S®AEM100S	| R&S®AVE264-K1
| R&S®SX800	| R&S®AVE264-K2

This application note illustrates the upgrade from the available wireless TV standard ATSC to its expansion ATSC Mobile DTV described in the new standard A/153 (ATSC-M/H), in which Rohde & Schwarz has played a major development role. An upgrade package makes it possible to efficiently extend existing ATSC infrastructures for ATSC Mobile DTV services. A central component of the ATSC Mobile DTV equipment is the R&S®AEM100 multiplexer. Together with the R&S®AVE264 H.264 Encoders, digital TV exciter (R&S®SX800) and Transmitters, it forms a complete ATSC-M/H system.

ROHDE&SCHWARZ

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1 Main ATSC System

ATSC, developed by the Advanced Television Systems Committee, is the North American standard for digital terrestrial television (A/53). The baseband signal is the MPEG-2 transport stream featuring MPEG-2 video and Dolby digital audio. SDTV and HDTV are broadcast via ATSC. The transport stream data rate is fixed at 19.39 Mbit/s. ATSC is currently used in the USA, Canada, Mexico and South Korea.

The structure of ATSC is completely different from that of DVB-T. ATSC has the following main features:

- Concatenated Reed-Solomon (188, 208) and Trellis error protection, with interposed short Forney interleavers in the channel coder
- 8VSB single-carrier modulation mode with eight-level vestigial sideband filtering
- Pilot carrier at the former band center of the vestigial sideband mode.

The output signal in the modulator is an eight-level step signal prior to the mixing process, to which a direct voltage offset for pilot generation is added. The lower sideband is partially suppressed, in a similar way as with analog television. However, this results in a Q portion that gives the constellation diagram its typical vertically striped appearance.

Frequency: VHF band III, UHF band IV, V
Modulation: 8VSB
Bandwidth: 6 MHz
Symbol rate: 10.76 Msymbol/s
Bits per symbol: 3
Net data rate: 19.39 Mbit/s
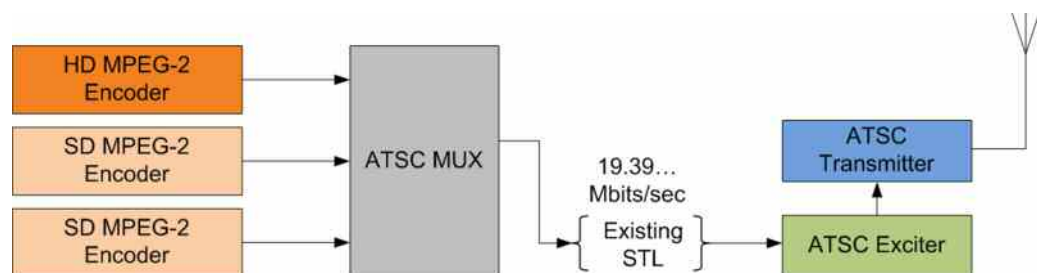Source coding: MPEG-2 video, Dolby digital audio

Figure 1: Transmission chain main ATSC

The ATSC headend according to A/53 consists of a playout which produces A/V and meta data, 1 to n encoders (MPEG-2, SDTV, HDTV), a PSIP Generator and an ATSC multiplexer.
The studio transmitter link (STL) is the connection between headend and transmitter.

1.1 Headend system in main ATSC

In a main ATSC headend, the signal from the playout can be analog (composite, S-Video, …) or digital (SD-SDI, HD-SDI). Video signals are encoded according to MPEG-2 (A/53 Part 4). There is an automation interface (A/76).

In the following table shows the used MPEG-2 formats:

Resolution		Aspect ratio	Pixel aspect ratio	Form of scanning	Framerate (Hz)
Vertical	Horizontal				
288	352	4:3 or 16:9	non-square	progressive	25
				interlaced	29.97 (59.94 fields/s) 30 (60 fields/s)
480	640	4:3	square	progressive	23.976 24 29.97 30 59.94 60
	704	4:3 or 16:9	non-square	interlaced	29.97 (59.94 fields/s) 30 (60 fields/s)
				progressive	23.976 24 29.97 30 59.94 60
576	352	4:3 or 16:9	non-square	interlaced	25 (50 fields/s)
				progressive	25
	480	4:3 or 16:9	non-square	interlaced	25 (50 fields/s)
				progressive	25
	544	4:3 or 16:9	non-square	interlaced	25 (50 fields/s)
				progressive	25
	720	4:3 or 16:9	non-square	interlaced	25 (50 fields/s)
				progressive	25 50
720	1280	16:9	square	progressive	23.976 24 25 29.97 30 50 59.94 60
				interlaced	25 (50 fields/s) 29.97 (59.94 fields/s) 30 (60 fields/s)
1080	1920	16:9	square	progressive	23.976 24 25 29.97 30

Figure 2: MPEG-2 Video System Characteristics (A/53 Part 4) an Standard for Coding 25/50 Hz Video (A/63)

The encoded signal and PSIP tables (MPEG-2 TS-packets) are sent to the ATSC multiplexer. The physical output of the encoders and the PSIP generator is either ASI or IP. A multi-transport stream with a data rate of 19.39 Mbps is generated.
The physical output of the ATSC multiplexer is SMPTE-310 or ASI.

1.2   Transmitter in main ATSC

Rohde & Schwarz is able to offer convincing products for digital television for many years and is involved in many operating networks and major trials around the world. Thus TV viewers and radio listeners in more than 80 countries receive their programs via transmitters from Rohde & Schwarz. Our unique product portfolio including both broadcasting and measuring equipment acts as a catalyst for the worldwide development of digital broadcasting.
The current R&S product line for ATSC and ATSC Mobile DTV covers all power classes from low to high power.

1.3   Interface between headend and transmitter

In legacy ATSC the defined physical interfaces between the output of the headend and the input to the transmitter's exciter is either ASI or SMPTE-310. It is required that the interface does not change the content or timing of the transport stream. The delay must be only minimal to avoid synchronisation problems.
The transport infrastructure between the headend and the transmission site may be of various types. Common scenarios include IP networks, satellite transmission or radio relay systems.

2   Introduction of ATSC Mobile DTV

ATSC Mobile DTV has been designed to provide a reliable digital TV signal which can be received by mobile devices (laptops, portable media players or navigation devices) whether the consumer is on the highway, on the golf course, strolling through the shopping mall or even at home. Broadcasters can offer localized services, such as news, traffic information or weather, to offer viewers the content they want, when they want it.

ATSC Mobile DTV (ATSC-M/H A/153) enhances main ATSC and therefore is fully backward compatible. It shares the same RF channel as the standard ATSC broadcast service described in ATSC A/53 and is coupled with a chain of extremely complex FEC mechanisms (Reed Solomon and Turbo codes) and training sequences for the receiver equalizer.

The standard is optimized for stationary reception of high-quality services at home on one hand and robust mobile reception on the other. In total, a data rate of 19.39 Mbps is available for now dual transmission.

The video content is compressed using the efficient H.264 (MPEG-4 AVC) video and HE AAC v2 audio coding. The video format is fixed to 416 pixels x 240 lines (16:9) to meet the requirements for mobile devices. Mobile data is transported by means of the Internet Protocol (IP) mechanism.

2.1 Upgrade: What has to be changed to get ATSC Mobile DTV?

Rohde & Schwarz offers a complete product portfolio for this new mobile DTV standard, from signal generators, demodulators and analyzers via encoders, multiplexers to transmitters.

The implementation of the ATSC-M/H standard by inserting the ATSC-M/H emission multiplexer R&S®AEM100 into the main chain allows a compact upgrade of any ATSC headend as it is docked onto the system and put in-between ATSC headend and transmitter. The broadcaster's existing infrastructure and configuration can nonetheless be used.

The ATSC-M/H emission multiplexer, which is placed between the ATSC multiplexer and the transmitter, generates ATSC Mobile DTV specific signaling, adds IP-streams for mobile services and restructures the main ATSC transport stream (TS).

Audio and video signals for mobile services have to be inserted into a low definition MPEG-4 encoder whereas one service can be handled by one encoder. The data related to such additional mobile services will be provided by an optional OMA BCAST ESG via IP.

The transmitter has to be upgraded by an ATSC-M/H capable exciter which modulates the ATSC-M/H RF signal and which can be synchronized with other transmitters to build a single frequency network (SFN). For all multistandard exciters of the 800 series which are used in all power classes, the change-over to ATSC Mobile DTV can easily be done by a firmware update. For all new exciters delivered after June 2009, ATSC Mobile DTV is already integrated. It can simply be activated via a software key just as any other standard.

With the R&S®SX800 and a retrofit kit which includes the respective mounting frames and cabling, transmitters from the existing R&S®Nx7000 TV series can be changed to ATSC Mobile DTV ready transmitters. Additionally, the new air-cooled low to medium power transmitter series R&S®SCx8000 with the exciter R&S®SX801 is also fully ATSC Mobile DTV ready.

Two Ethernet switches or one VLAN capable switch with at least 2 VLANs can be installed for control network and multicast network.

A signaling generator can be optionally integrated to generate/have OMA BCAST ESG and SMT.

2.2 Where will the new components be inserted?

R&S AVE264 mobile TV audio and video encoder
−   The audio / video input is connected to the playout, or in case of simulcast it is connected to MPEG-2 HD/SD decoders or the monitoring output of MPEG-2 HD/SD encoders.
−   The output (ethernet) is connected to the ethernet switch (multicast network).
−   The control interface (ethernet) is connected to the Ethernet switch (control network).

R&S AEM100 ATSC-M/H emission multiplexer
−   The ATSC input is connected to the ATSC multiplexer (ASI).
−   The A/V input (Ethernet) is connected to the Ethernet switch (multicast network).
−   The ATSC-M/H output is either directly connected to the ATSC-M/H exciter or to the STL input (ASI).
−   The control interface is connected to the Ethernet switch (control network).

ATSC-M/H exciter
−   The input of the exciter is connected to the ATSC-M/H output of the AEM100 or to the output of the STL
−   The output of the exciter is connected to the power amplifiers of the transmitter
−   The power amplifiers are transmitting the ATSC Mobile DTV signal via antenna to the respective mobile devices

Signaling generator
−   The input of the signaling generator is connected to the automation interface of the playout (according to A/76 PMCP).
−   The interface for SMT output is connected to the Ethernet switch (control network).
−   The OMA BCAST ESG output is connected to the Ethernet switch (multicast network).

3 ATSC-M/H Headend

3.1 Setup of the ATSC-M/H system

For our scenario, we are using the following components:

1x   R&S®AEM100
4x   R&S®AVE264 in CBR mode
1x   R&S®SX800
1x   Ethernet switch
        set of cabling

3.1.1 How are the components connected to each other

► At first, the R&S®AVE264s and the R&S®AEM100 have to be connected to the power supply.

Figure 3: Power supply

► The R&S®AVE264 encoders have to be connected to the A/V sources. In case of digital video signal (SDI), the cable is a coaxial 75Ohm cable with a BNC female plug.
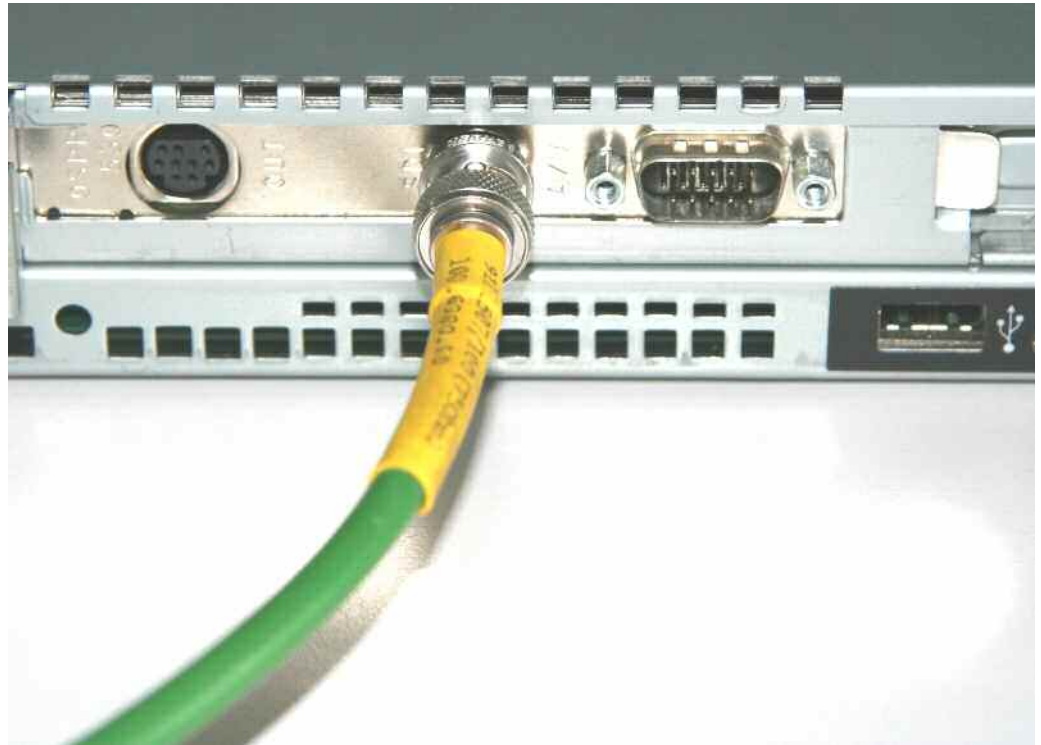
Figure 4: BNC cable for A/V source connection

► The audio signal can be included in the SDI signal or be separately transmitted digitally (AES/EBU signal on XLR plug) or analog (XLR or RCA). In case of analog video, the signal can be a Y/C (S-Video via Hosiden) or composite (BNC or RCA via adapter) with an 75 Ohm cable. The format of the video signal can be NTSC or PAL.
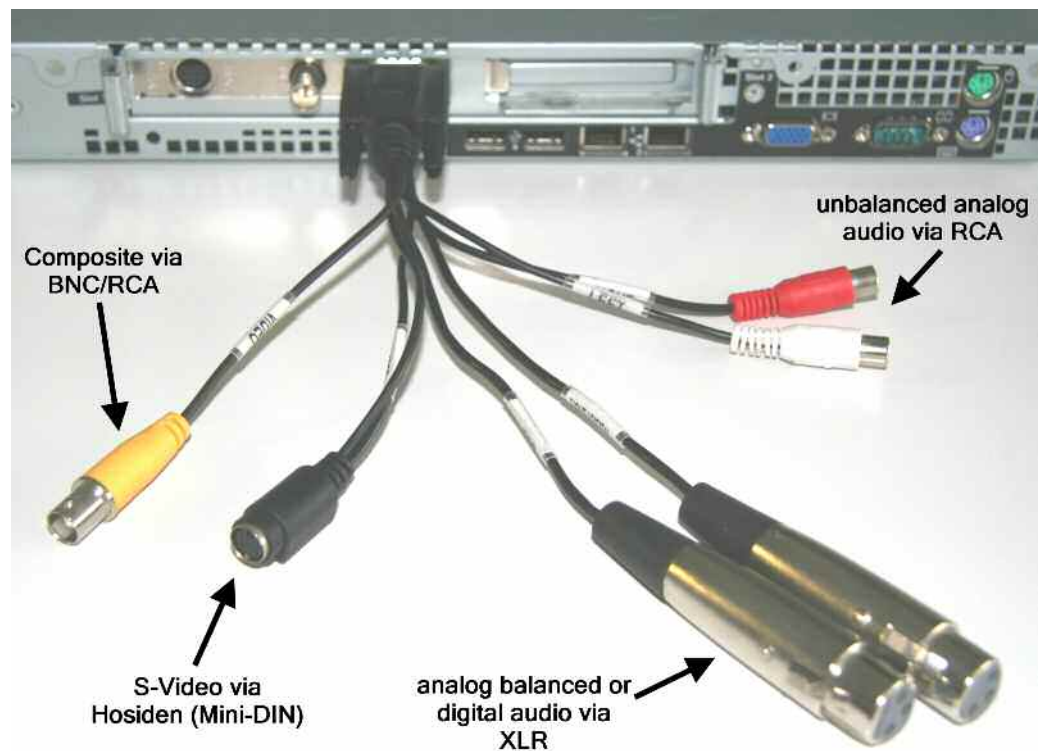
Figure 5: Encoder breakout cable

► The multicast IP interface of the R&S®AVE264 has to be connected to the multicast Ethernet switch by a network patch cable (whereas the assignment can be done later). And the control IP interface of the encoder has to be connected to the control Ethernet switch by a patch cable. If there is only one Ethernet switch available, at least two VLANs have to be configured and the network cables have to be connected to the respective ports on the switch. The networks have to be separated because of the interference between the control and multicast data.
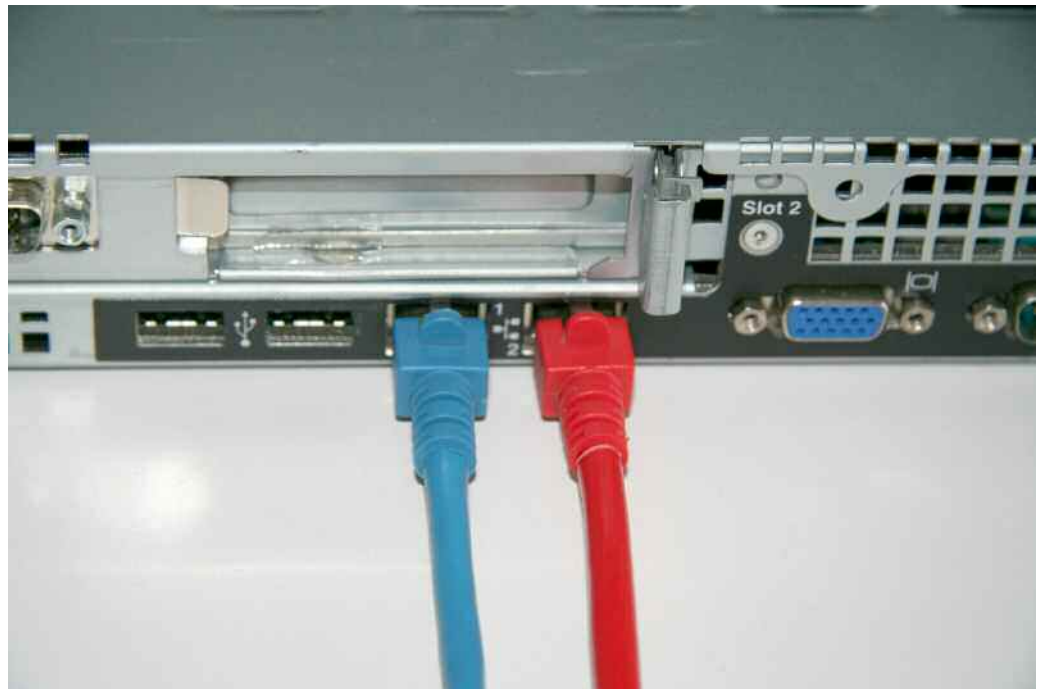
Figure 6: Encoder network patch cables for multicast and control IP interface

► On the R&S®AEM100, the control IP interface is assigned to port one. This port has to be connected to the control Ethernet switch by an Ethernet patch cable. The multicast network switch has to be connected to multicast IP interface on port two of the R&S®AEM100. Port three can be used for the transport stream output via IP and has to be connected to an additional switch accordingly. Port four is used for redundancy purposes of the transport stream output via IP.
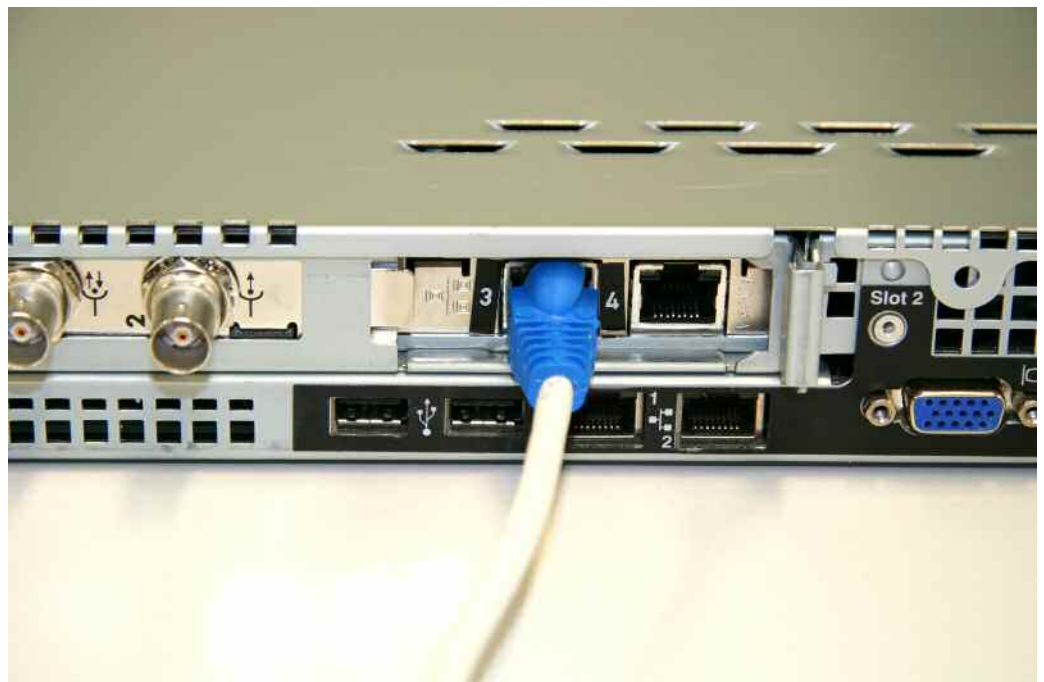
Figure 7: Encoder Ethernet patch cable

► The ASI output connector (2) of the R&S®AEM100 has to be connected to one of the inputs of the exciter.

Figure 8: ASI output connection of the ATSC-M/H multiplexer

► Finally, the ASI output of the ATSC multiplexer can now be connected to the ASI input connector (1) of the R&S®AEM100. When the R&S®AEM100 is switched off or **has factory settings**, there is a hardware bypass which passes the transport stream from the ASI input directly to the ASI output. So there is no interruption.

Figure 9: ASI input connection of the ATSC-M/H multiplexer

► As soon as the secondary input of the exciter is activated, the transmission chain is working and the ATSC-M/H multiplexer has been successfully integrated into the existing system.

3.1.2 Configuration of the R&S®AEM100

► After the device has connected as described above, the R&S®AEM100 can be accessed via your web browser. The R&S®AEM100 is set to the IP address**: 192.168.41.101 (NIC1)**. Therefore, please configure your control device (PC) to the same subnet (e.g.xxx.41.102).

► The IP address of the multiplexer can then be changed via web interface.

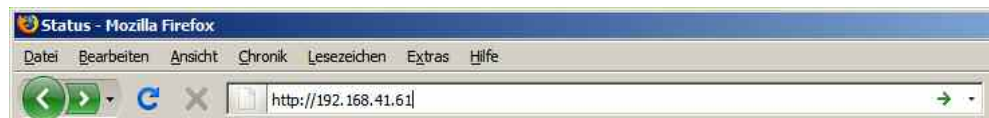► Please enter the IP address in the address field of your web browser.

Figure 10: Address field of the web browser

► The status page of the R&S®AEM100 opens.
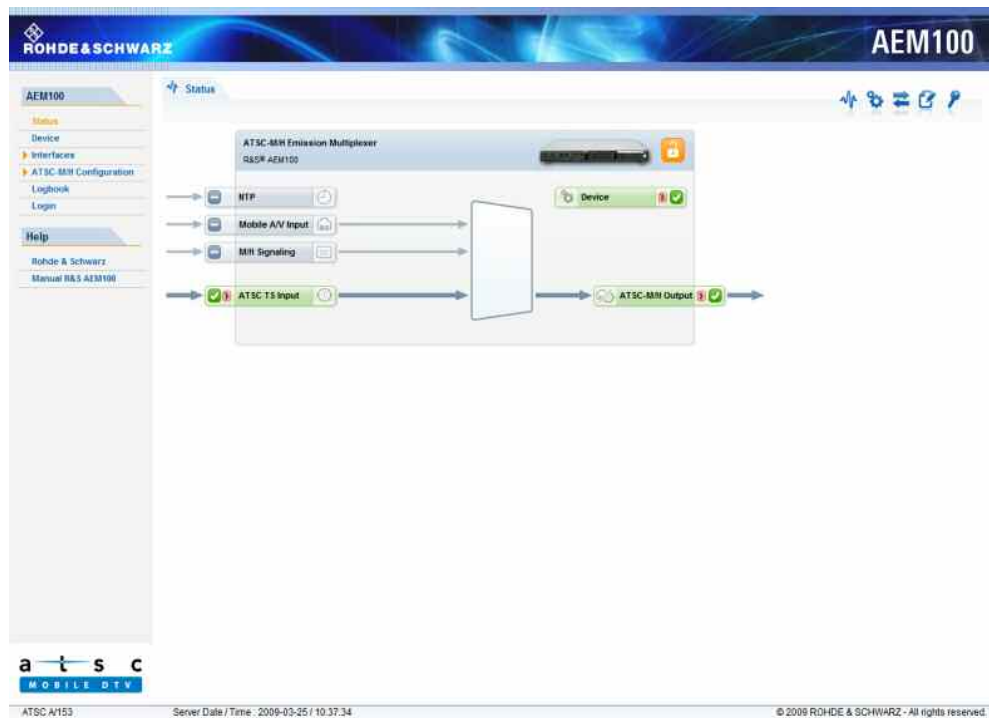
Figure 11: Status page of the R&S®AEM100

► To integrate the R&S®AEM100 into your network, please change the IP address of the device. Click on "Interfaces" in the navigation bar, then "IP Network" and insert the IP address and subnet mask for NIC1 (see Figure 12: Page Interfaces/IP Network). If the R&S®AEM100 is located behind a router, the gateway address must also be defined, to assure the communication. After changing the IP address of the device, the R&S®AEM100 is no longer accessible from the remote device. To re-establish the access between the two, please change the IP address of the remote device, too.
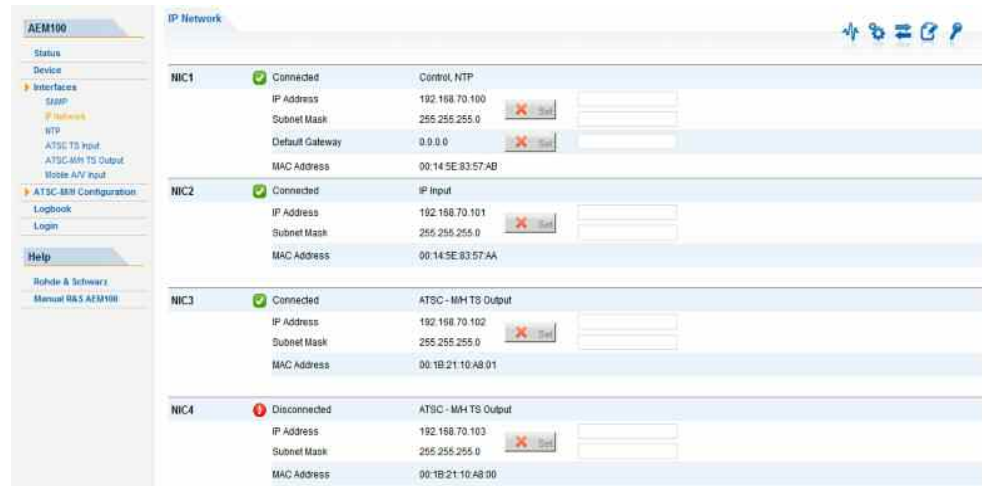
Figure 12: Page Interfaces/IP Network

► The R&S®AEM100 can be configured and monitored via SNMP as well. To configure the SNMP TRAP target address, click on "SNMP" under "Interfaces" in the navigation bar.

Figure 13: Page Interfaces/SNMP

► For synchronization of all devices in the network, a network time protocol (NTP) server is commonly used in the network environments. The IP address of one or more NTP servers (up to ten) can be specified **under "NTP / Interfaces"** in the navigation bar. If no NTP server is used, the UTC time can be defined manually.
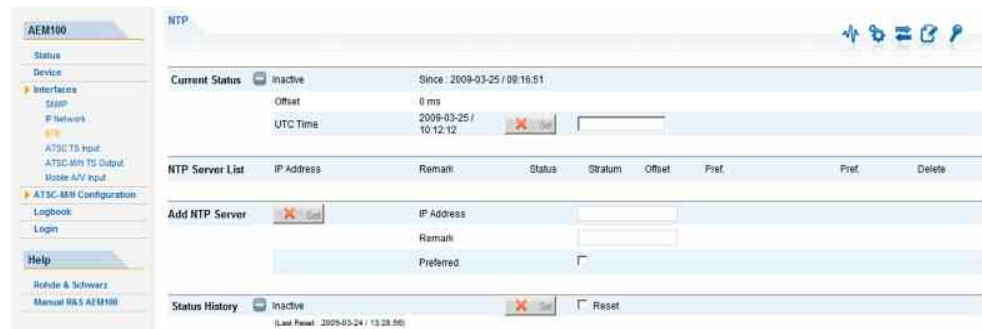
Figure 14: Page Interfaces/NTP

► The M/H data will be inserted into transport stream packets which will be ignored by the legacy ATSC receiver. The assigned PID must be unique in this multiplex and should not be referenced by any table (PAT, PMT, …). Go to "ATSC-M/H Configuration" in the navigation bar. Click on "Multiplexer Config" and enter *8185* into the line "ATSC-M/H Packet ID". If the PID is already used by another service in the multiplex, a warning appears. In the exciter, the MH packet ID has to be set to the same value as in the multiplexer at this page.

► To verify that the ATSC input has enough capacity and is well **formed/shaped/ structured**, please click the "ATSC TS Input" under "Interfaces" in the navigation bar. On this page, detailed information about the incoming ATSC stream is shown.

Figure 15: Page Interfaces/ATSC TS Input

► The average free TS data rate must be higher than the expected transport stream usage for M/H data.
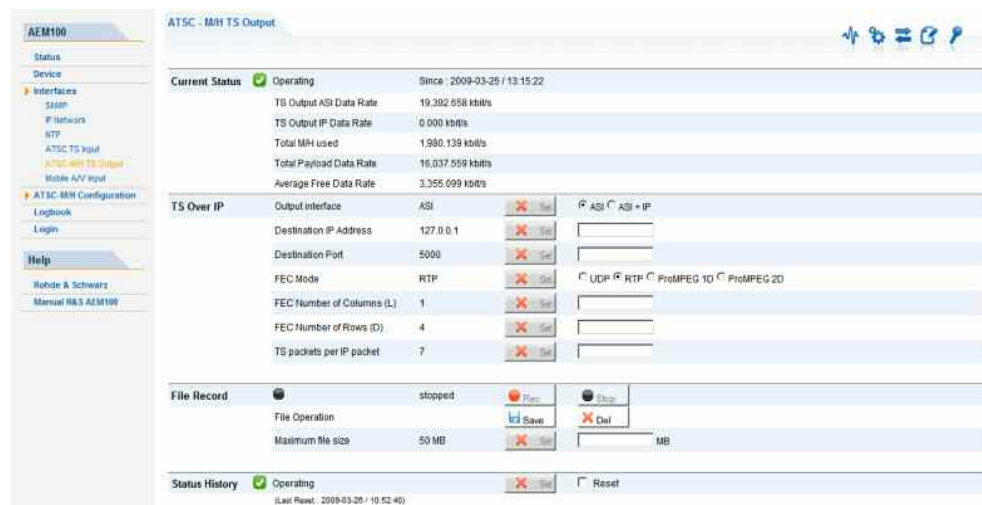
Figure 16: Page Interfaces/ATSC-M/H TS Output

► To control the output of the generated M/H transport stream, the link "ATSC-M/H TS Output" under "Interfaces" in the navigation bar can be used to display the page. The default transport stream output of the device is set on ASI and can be switched to ASI and IP. During the switchover, the ASI transport stream is not interrupted or affected. For the distribution of the transport stream via IP, several mechanisms are available and can be configured.

● **Transmission over UDP:** The transport stream packets are directly contained in UDP/IP packets.

● **Transmission over RTP:** The UDP/IP packet contains an additional RTP header with timestamp and sequence numbers. They allow a detection of lost or interchanged IP packets and allow a reordering process at the receiver side.

● **ProMPEG 1D:** The transport stream packets are additionally protected by a one dimensional FEC (columns). These additional data is sent via an additional UDP/RTP stream which has the same destination IP address, and the UDP port (n) is incremented by two (n+2). This protection allows a reordering and recovery of damaged and lost TS packets. The value for columns specifies the number of payload columns and the value for rows specifies the number of payload rows in the matrix for the FEC calculation.
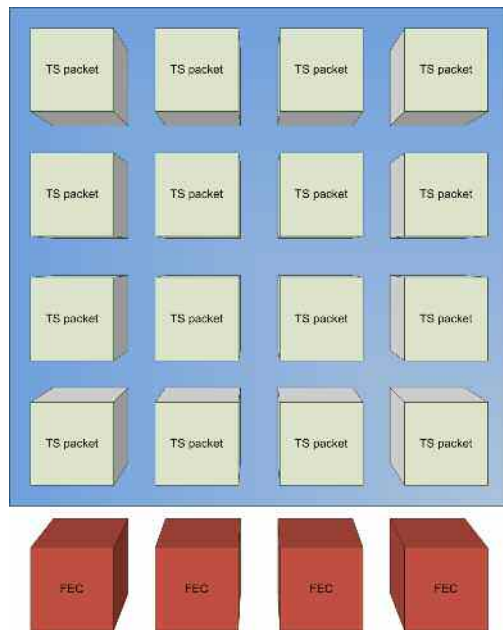
Figure 17: ProMPEG 1D matrix

- **ProMPEG 2D:** The transport stream packets are additionally protected by a two dimensional FEC (columns and rows). These additional data is sent via two additional UDP/RTP streams which have the same destination IP address and the UDP port (n) is incremented by two (n+2) for the column FEC data and incremented by four (n+4) for the row FEC data. This protection allows a reordering and recovery of damaged and lost TS packets. The value for columns specifies the number of payload columns and the value for rows specifies the number of payload rows in the matrix for the FEC calculation.
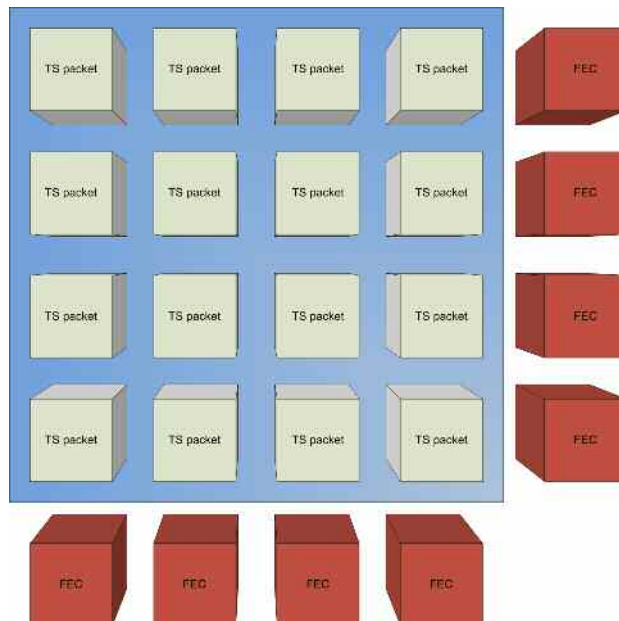
Figure 18: ProMEG 2D matrix

3.1.3   Configuration of the encoders R&S®AVE264

Figure 19: Remote desktop connection

► In order to access the encoders, you have to establish an RDP connection to the R&S®AVE264. This application is built into each Windows operating system and also available for Linux/Unix and MacOSX. Under Windows, the software can be accessed via **Start → Programs → Accessories → Remote desktop Connection**. The user name and password are "wod".

► Once you have logged in, you can change the IP addresses as **under** a normal Windows XP environment. After the IP address has been changed to the same subnet in your network, you can access the R&S®AVE264 via the web interface.
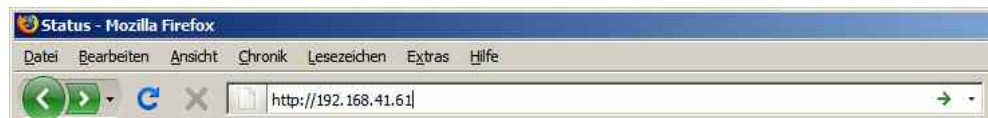

Figure 20: Address field of the web browser

► Please enter the IP address in the address field of your web browser. Then log in using "wod" as username and password. Make sure that cookies are allowed and JavaScript is enabled. If requested, please press "Update".
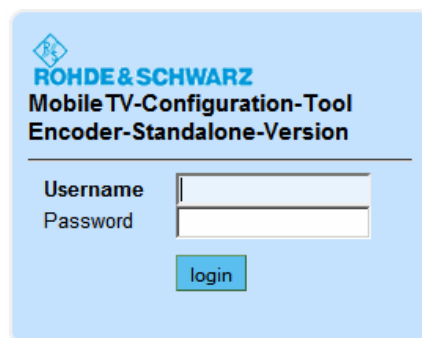

Figure 21: Login prompt

Figure 22: Encoder GUI

► At the start page, click on the "Configuration" tab and "Add a new configuration". Select "R&S Preset8".

► First of all, enter the name for the new service ("service-caption"). Please specify the maximum bit-rate and the multicast-address for the video stream. The dimension of the video is restricted to 416x240 in ATSC-M/H. The Multicast-address can be defined (i.e. 225.1.1.1:1000 for video and 225.1.1.1:1002 for audio). The audio is specified in ATSC-M/H to AAC-HEv2 and therefore the bitrate can be chosen from 18 kbit/s to 56 kbit/s. To save these settings into a configuration, click **"Add Service"**.

► To activate the configuration, choose the "control device" tab and choose your configuration name from the selection field "Next Configuration". Furthermore, "Video-Input", "Video-Standard" and "Audio-Input" have to be set. Click on the button "Select", set "Time to live (TTL)" and click on the respective button. Finally, click on "(Re-)Start encoder with next configuration".

The green button shows that the encoder is running.
In the tab "Download SDP-file", you can download the SDP file.

4 ATSC-M/H enabled exciter

Using state-of-the-art technology, the R&S TV exciters can be accommodated in a housing of only one height unit. They perform full signal processing of the incoming transport stream and produce an RF output signal in accordance with the standard. For digital TV standards, the input interface of the R&S exciter is equipped with SMPTE-310M or ASI inputs. This makes them universal input stages – capable of handling all operating modes of ATSC and ATSC Mobile DTV.
The input interface monitors the packet synchronization and the data rate of the input signals. Input data buffers eliminate line-side jitter and wander effects.

For operation in an ATSC SFN, R&S uses a unique approach for Bit Stream synchronization which is different from legacy A/110 systems.
This method exploits the inherent properties of the ATSC M/H frame structure and thus provides a very elegant solution to the problem of non-deterministic Trellis coding present in ATSC.

4.1 Connecting the exciter

If the exciter has not yet been connected to your transmission system, connect the exciter as explained in the respective manual.

► When the transmitter is used in an ATSC Mobile DTV multi frequency network (MFN) the system is connected in the same manner as legacy ATSC.

► When the transmitter is used in an ATSC Mobile DTV SFN a GPS reference signal is required. Either connect the reference signals from the GPS receiver (1PPS and 10MHz) to the respective interface of the exciter (see manual) or use the internal GPS receiver of the exciter (R&S$^{®}$SX801 and R&S$^{®}$SLx8000 systems).

4.2   Configuring the exciter for ATSC-M/H

To prepare the M/H capable exciter for ATSC-M/H operation, it takes just a few adjustments.

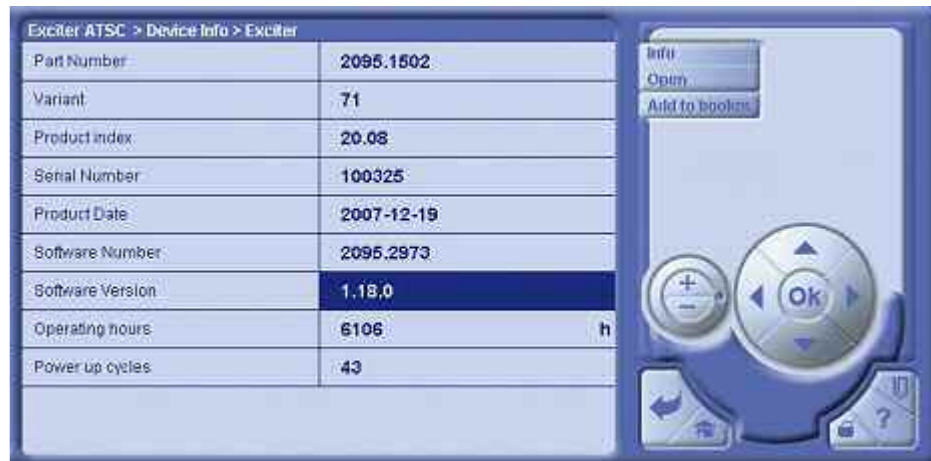► First of all check whether SW version **1.18.0** or higher is installed:

Figure 23: Device info

► Check whether all required option keys are loaded:

Figure 24: Option keys status

► The following keys are required:

Transmission	Option Keys		
ATSC	**K13**		
ATSC Mobile DTV in MFN	**K13**	**K10**	
ATSC Mobile DTV in SFN	**K13**	**K10**	**K09**

► In case an internal GPS receiver is used (R&S®SLx8000 and R&S®SX801), select **Intern GPS** as **Reference** in the menu **Reference > Common**.

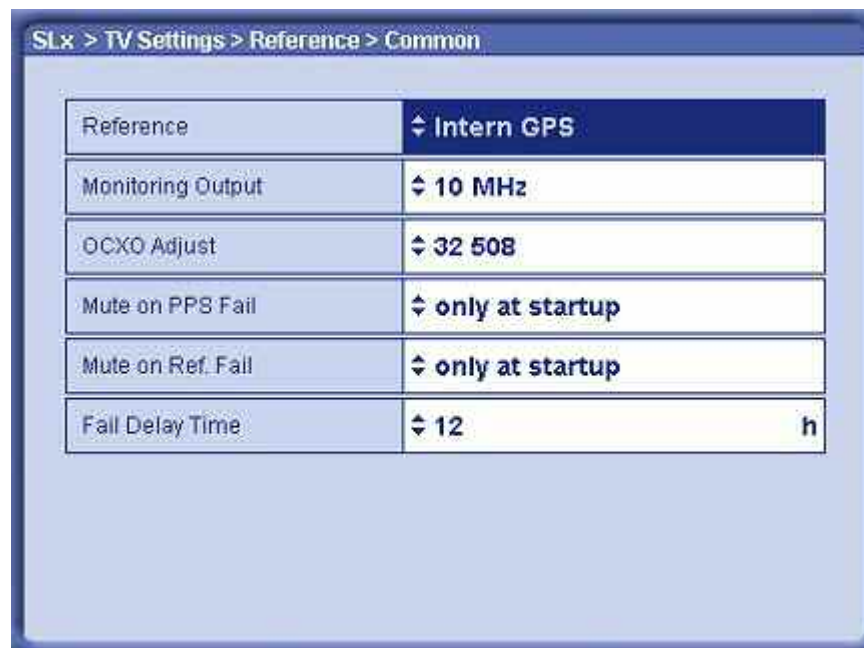*Figure 25: Reference*

► Select the respective network mode **MFN** or **SFN** and set Mobile DTV to **ON:**

Figure 26: ATSC parameters 1

► Type in the value of the **MHE-PID** as set in the configuration of the R&S®AEM100 (see chapter 3.1.2)

Figure 27: ATSC parameters 2

► Check **Input Config** to see whether the **Frame Status** is **Locked**. If the frame status is locked, the MHE-PID was recognized and correctly used for synchronization.

Figure 28: Input configuration

► Double-check menu **Tx Identification** to make sure **MTX ID** and **Watermark** are set to **OFF**. Please note that the values in this menu should only be changed in case watermark is used. Detailed information about watermark can be found in the ATSC standard A/110.
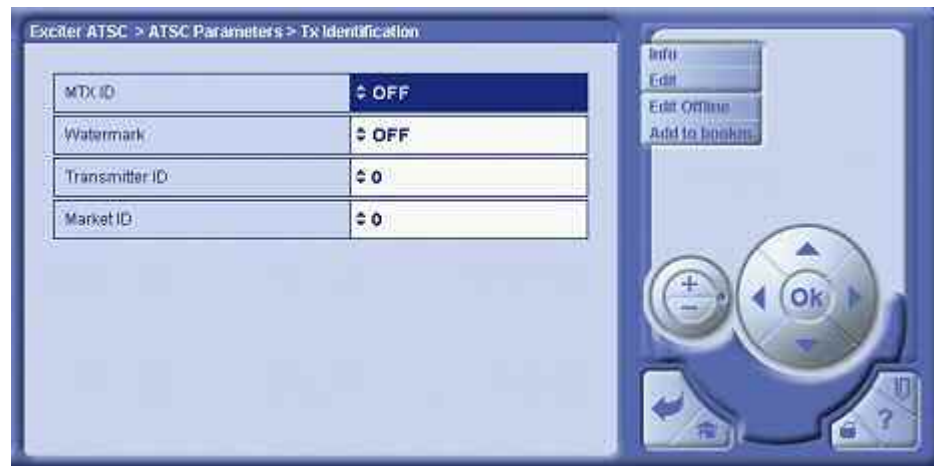
Figure 29: ATSC parameters 3

The exciter is now configured to process the ATSC-M/H transport stream.

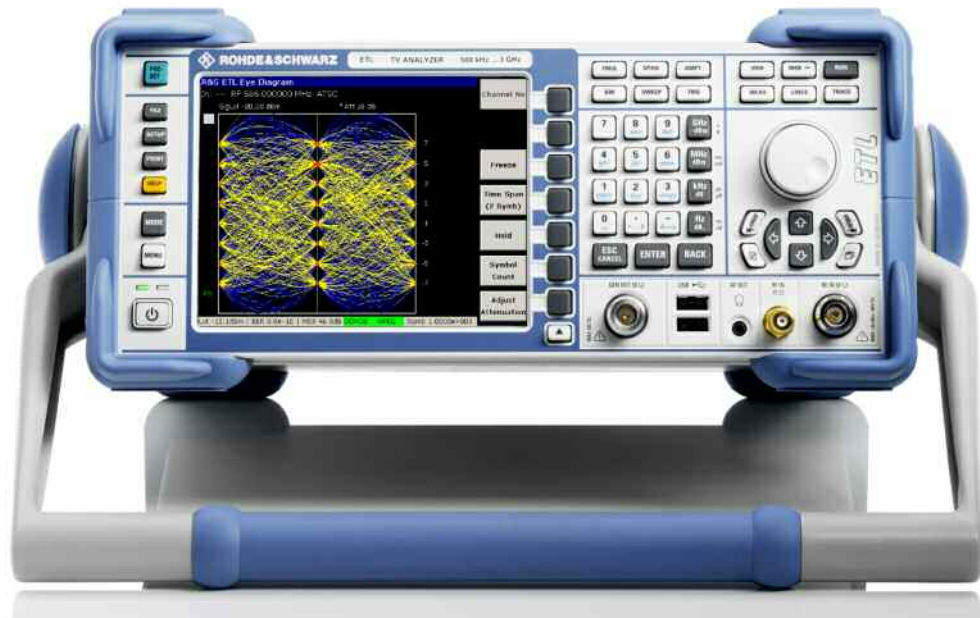# 5 ATSC Mobile DTV Verification at Transmitter Site

Figure 30: R&S®ETL TV analyzer

The R&S®ETL is a multi-standard instrument, which combines TV test receiver and spectrum analyzer functionality in a single unit. It has been designed for the commissioning, installation and servicing of TV transmitters, for carrying out coverage measurements on terrestrial TV networks, and for performing measurements on cable head ends.

The R&S®ETL can also be utilized together with the new ATSC Mobile DTV standard, since the compatible physical layer structure permits the use of the instrument's conventional ATSC receiver.

Concerning the domain of digital transmitter tests, the R&S®ETL's range of functions exceeds the coverage of all important measurements, since besides RF output level, MER / BER measurements and shoulder attenuation, it also handles topics like I/Q imbalance, out-of-band emissions, amplitude frequency response / group delay, initial carrier frequency tolerance or eye / constellation diagram analysis.
A detailed description is provided in **>> Application Note 7BM102**.

Another highlight is its easy and comprehensive solution for single-frequency networks. Level, delay spread and frequency deviation of the different signals are analyzed with an unmatched precision and at a glance.
Please refer to **>> Application Note 7BM75** for more information.

In conclusion, the R&S®ETL is the right choice for transmitter verification after an upgrade to ATSC Mobile DTV.

6 Literature

- In order to learn more about M/H specific settings, structures, etc., please consult the ATSC web site (www.atsc.org) to find the recent standard description documents.
- For general information on the technology behind ATSC Mobile DTV, R&S provides a poster and a white paper which gives an overview of the system. These materials can be requested from our web site:
  http://www.rohde-schwarz.com / Technologies / ATSC Mobile DTV / Downloads

7 Additional information

For more detailed information about the R&S transmitter systems, headend products kindly refer to the respective user manuals.

8 Ordering information

R&S equipment for ATSC Mobile DTV		
Designation	**Type**	**Order no.**
ATSC-M/H Emission Multiplexer Channel coding and signaling, encapsulation of IP packets, consisting of:	R&S®AEM100MUX	5302.8532.02
ATSC-M/H Emission Multiplexer Base Unit Channel coding and signaling; service and support for hardware limited to five years	R&S®AEM100BU	5302.8403.02
ATSC-M/H IP Encapsulator Encapsulation of IP packets from internal and external IP sources In combination with the R&S®AEM100BU	R&S®AEM100I	5302.8390.02
Mobile TV Video and Audio Encoder for one program with video and audio. Input video: SDI digital input, composite PAL/NTSC analog input Input audio: embedded SDI, digital AES/EBU, analog L/R Video encoding: H.264/AVC baseline profile Audio encoding: HE AAC (LC AAC) Output: IP/RTP1)	R&S®AVE264	5301.8000.12

R&S equipment for ATSC Mobile DTV		
Designation	**Type**	**Order no.**
CBR Video Encoder H.264 Allows constant bit rate (CBR) for video in one encoder.	R&S®AVE264-K1	5301.8039.13
ATSC Mobile DTV ready Exciter	R&S®SX800	2098.9004K50
Retrofit kit for integration of one Sx800 exciter (single drive) into a Nx7000 series TV transmitter	Retrofit kit	2105.2657.11
Retrofit kit for integration of two Sx800 exciters (dual drive) into a Nx7000 series TV transmitter		2105.2657.12
Air-cooled low to medium power transmitter R&S SCx8000	R&S®SCx8000	2104.6507K02
Cisco Catalyst 2960G-24TC Fixed-configuration standalone switch, 20 Gigabit Ethernet 10/100/1000 ports and 4 dual-purpose Gigabit Ethernet 10/100/1000 uplink ports (BaseT or SFP), NAC, QoS, 1 HU, LAN Base image installed	CC2960-24	5302.8661.00

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, 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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