UHD 4K end-to-end broadcasting over DVB-T2

Application Note

Products:

- R&S®Clipster
- R&S®AVHE100
- R&S®THU9/TMU9
- R&S®ETL
- GMIT®BMM-810

In this application note, a UHD 4K end-to-end solution utilizing products from Rohde & Schwarz is described in detail from the point at which 4K content is captured until its delivery to households via a DVB-T2 SFN network.

Application Note

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ROHDE&SCHWARZ

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1 Introduction

Ultra high definition TV (UHDTV) is gaining more and more attention in the broadcasting industry. With major sports events coming up, such as the XXXI Olympic Games in Rio de Janeiro, Brazil, UHDTV technology has been given a major push by broadcasters, and by manufacturers of test and measurement (T&M) equipment, and consumer electronics (TV and set-top box).

The increase in picture (spatial) resolution (3840x2160) for 4K and (7680x4320) for 8K compared with current HDTV (1920x1080), as well as the need to deliver these services at higher frame rates (50/60 fps up to 100/120 fps) translate into a major challenge when it comes to delivering UHDTV content to households over terrestrial transmission, due to much higher data rates.

DVB-T2 has been favored by many countries throughout the world, because it has proven to give the best spectral efficiency for terrestrial broadcasting. Yet MPEG-4 appears to be the bottleneck for UHDTV, since a much higher data rate is needed to deliver such services. Therefore HEVC becomes mandatory for UHDTV delivery over DVB-T2.

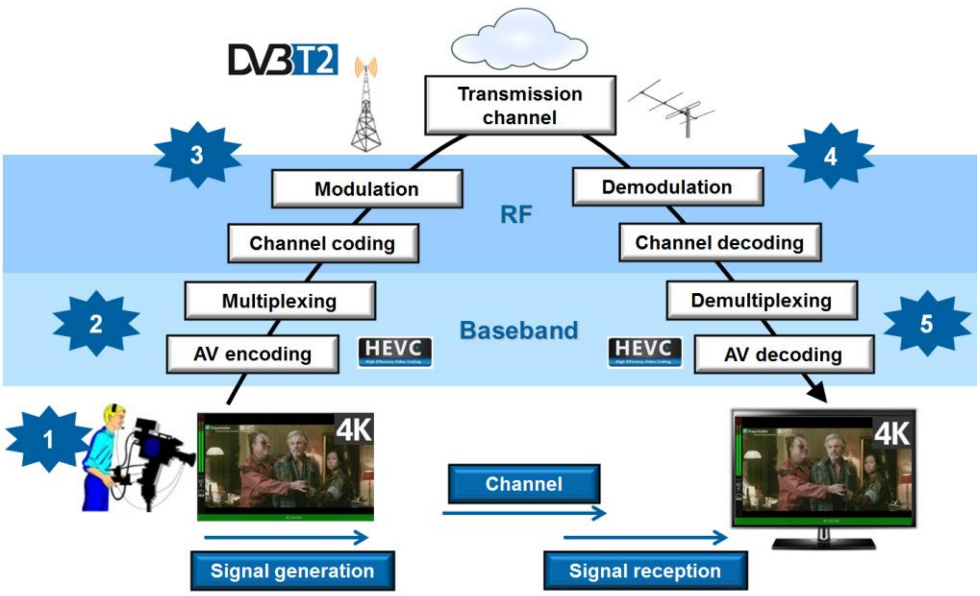

Fig. 1-1: Illustration of the broadcasting chain showing UHD 4K content acquisition and delivery from post production to households over terrestrial network in five steps.

This paper gives an overview of a complete end-to-end solution for UHDTV delivery over DVB-T2 in five steps, based on a realistic scenario. Each step of the UHDTV signal processing along the transmission chain will be described in detail. Step 1 starts from the acquisition stage in the post-production environment. Step 2 describes the real time HEVC encoding of the UHDTV signal and multiplexing into a T2-MI stream. Step 3 describes the RF transmission of the UHDTV signal under SFN conditions using DVB-T2, and step 4 describes the reception of the UHDTV signal and RF demodulation. Finally, the HEVC decoding and presentation to a 4K TV display (household) is discussed in step 5. Fig. 1-1 depicts the broadcasting chain from signal generation (acquisition) to presentation on a household UHD-TV in the five steps mentioned above.

2 4K ingest and playout (post-production environment)

UHDTV content is most commonly generated by the use of 4K cameras. The UHDTV content is stored internally in the camera memory or, in case of live broadcasting, is transferred in real-time to an ingest system via 4 x 3G-SDI cables. Table 2-1 below describes different data rates required for different color sampling formats and bit depth levels based on UHDTV resolution of 3840x2160 with 60fps [video bitrate calculator reference].

UHD resolution: 3840x2160 with 60 fps				
Color sampling	**4:4:4**	**4:2:2**	**4:2:0**	**12 bit**
Bit rate (Gbps)	17.92	11.94	8.96	
Color sampling	**4:4:4**	**4:2:2**	**4:2:0**	**10 bit**
Bit rate (Gbps)	14.93	9.95	7.46	
Color sampling	**4:4:4**	**4:2:2**	**4:2:0**	**8 bit**
Bit rate (Gbps)	11.94	7.96	5.97	

Table 2-1: Raw data rates for UHTV 4K with 60 fps.

A typical 4K camera nowadays can either output 4K raw video content at 50 fps or 60 fps using 10 or 12 bits with 4:2:2 [Sony ref] or save the 4K content internally in a compressed high resolution format (XAVC, AVC Ultra, ProRes etc.) with the use of memory cards. In the first case, the challenge is to ingest the 4K content by combining the incoming 4x 3G-SDI signals into one 4K image (stitching). In the second case the data can be ingested by file copy into the storage of the processing system which should be compatible with all different 4K camera file formats. In both cases it is necessary for the UHDTV 4K signal to reduce its color sampling to 4:2:0 and bit depth to 8-bit or 10-bit in line with UHD-1 broadcasting requirements [ITU-R BT.2020].

R&S®Clipster not only offers that but also can support any resolutions from SD up to 8K and can convert files of different formats (XAVC, ProRes etc.) to any color sampling (RGB, YUV) and bit depth (Fig. 2-1).

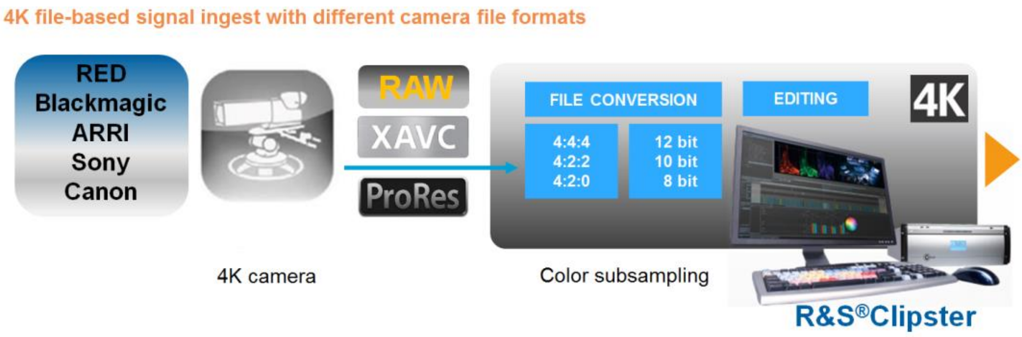

Fig. 2-1: R&S®Clipster – 4K camera file-based ingest supporting various formats and file conversion using different chroma samplings.

R&S®Clipster automatically synchronizes the incoming signals (stitching) and compiles one 4K image before processing. This methodology is important to get rid of any artifacts often appearing near the borders of the four quadrants from the incoming signals. From this point, the signal is in a file-based format and it can be further processed (transcoding using HEVC, JPEG2000 etc.) or transferred to a playout center or central storage (Fig. 2-2).

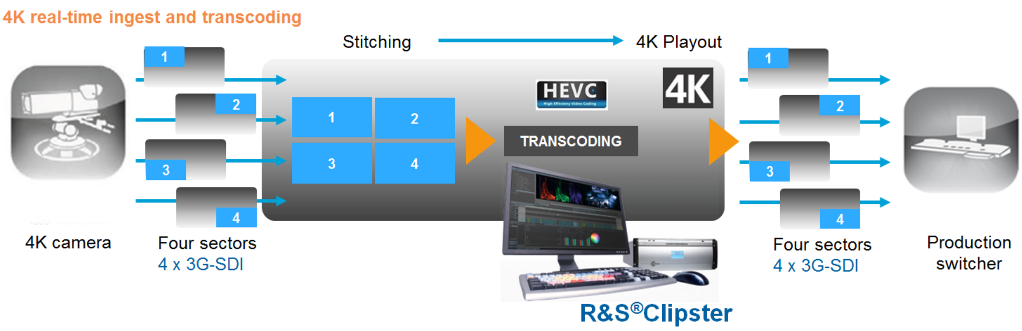

Fig. 2-2: R&S®Clipster – 4K real-time signal ingest via 4 x 3G-SDI, transcoding and playout. This feature will be available in 2014.

3 HEVC realtime encoding and multiplexing

Step 2 describes a realistic broadcasting scenario where the UHDTV 4K content needs to be processed in real time. Therefore let us assume a live broadcast of a sports event where high resolution (UHDTV) and high frame rate (50 fps or 60 fps) is needed.

The challenge here appears to be a lot more complicated because the broadcaster needs to:

- Synchronize the 4 x 3G-SDI signals into a single 4K image (stitching).
- Encode the 4K signal in real time using HEVC.
- Generate the UHDTV multiplex and load the PSI/SI information.
- Generate the timestamps from the GPS signal into the T2-MI packets (SFN synchronization).
- Deliver the MPEG-2 transport stream (T2-MI) via IP or ASI to the transmitter network.

To meet this challenge, Rohde & Schwarz proposes the R&S®AVHE100, a modular system that provides the entire functionality of a headend in an extremely compact size. The R&S®AVHE100 utilizes state-of-the-art IT technologies offering the highest possible processing power necessary for HEVC encoding and signal processing. The signal flows within the headend are fully IP-based, providing the high flexibility required to fulfill a wide range of customer needs.

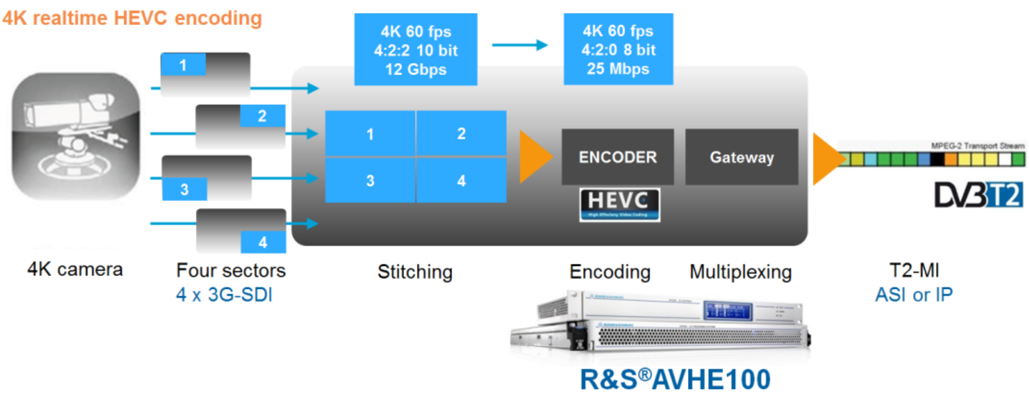

Fig. 3-1: R&S®AVHE100 headend system from Rohde & Schwarz with realtime HEVC encoding

The incoming 3G-SDI signals are initially synchronized inside the R&S®AVHE100 (muxing) to form a single 4K image. The HEVC encoders are then processing the whole 4K data and generate the MPEG-2 transport stream in line with the DVB standards. The output from the headend can be either via ASI or IP; it can therefore be used for unicast or multicast purposes and be delivered over terrestrial, satellite, cable or IP network (Fig. 3-1).

Note: Initial development of realtime HEVC encoding requires multiple servers (depending on resolution and frame rate). This is expected to be simplified in the coming years. Alternatively a single rack encoder unit can be used that can reach 30 % to 40 % encoding efficiency compared with H.264.

4 UHDTV delivery over DVB-T2 SFN network

DVB-T2 has proven to provide the highest data rate capacity for digital TV terrestrial broadcasting. Here we assume a realistic DVB-T2 SFN network based on a trial setup in the Seoul metropolitan area (South Korea), and the following limitations were considered from the start:

- The RF DVB-T2 bandwidth is fixed to 6 MHz.
- Due to the geostatic profile of the Seoul metropolitan area, a relatively large guard interval must be taken into account for SFN planning, which reduces the data capacity of DVB-T2. The choice of guard interval to 1/16 is based on reference DVB-T2 SFN networks that are currently on air in South Africa, Germany and Russia as well as on the Nordig specification focusing on SFN DVB-T2 networks in the Scandinavian countries [Nordig link] and primarily targeting rooftop reception.
- Initial experiments on real time HEVC encoding have shown that at least 25 Mbps are needed to achieve satisfactory results (based on 3840x2160 with 4:2:0, 8-bit and 60 fps).
- UHDTV 4K delivery should target both rooftop and indoor reception.

Based on all the above limitations, some possible DVB-T2 configurations are shown in Table 4-1 below:

Constellation	FEC	GI	FFT	Pilot	T2 frame	Num of blocks	C/N	Data Rate	
(Mode 1) 256 QAM	2/3					153	20.8 dB	27.1 Mbps	6 MHz bandwidth
(Mode 2) 64 QAM	5/6	1/16		PP4	47	114	19.4 dB	25.2 Mbps	
(Mode 3) 64 QAM	2/3		32K			114	16.2 dB	20.2 Mbps	
(Mode 4) 64 QAM	2/3	1/8		PP2	45	105	16.2 dB	18.3 Mbps	

Table 4-1: Recommended transmission modes for UHDTV terrestrial broadcasting in Seoul metropolitan area using DVB-T2 SFN scenario for rooftop (modes 1 and 2) and indoor reception (modes 3 and 4).

- Mode 1 (256QAM) is the preferred DVB-T2 configuration for rooftop reception since this allows the highest possible data rate (26.6 Mbps) with a good noise protection.
- Mode 2 offers a slightly improved noise protection compared with mode 1 with a small reduction of data rate.
- Modes 3 and 4 are designed for indoor reception, with the latter having a larger guard interval. Although these modes have a better noise immunity, their data rate is limited, which makes UHDTV delivery very challenging at high frame rates (possible with 3840x2160 at 30 fps).

However, this SFN approach needs to be validated with real field trials in the Seoul metropolitan area based on the transmitter topology and emission of RF power for DVB-T2.

The R&S®AVHE100 headend feeds the MPEG-2 transport stream to all the transmitters located in the SFN via microwave link. These transmitters support both ASI and IP inputs. The synchronization time stamps are included in the T2-MI stream and the transmitter network is synchronized by using NTP and 1 pps GPS signaling for the time reference and 10 MHz for the frequency reference (Fig. 4-1).

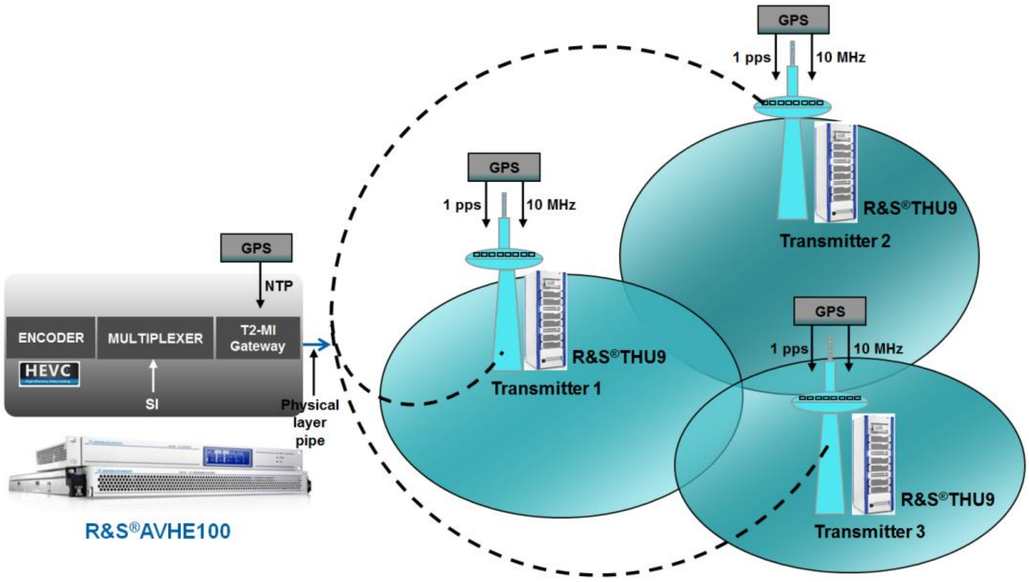

Fig. 4-1: DVB-T2 SFN configuration of three transmitter sites using the R&S®AVHE100 encoder/multiplexer/gateway and the R&S®THU9 high-power DVB-T2 transmitter from Rohde & Schwarz.

For the transmitter part, Rohde & Schwarz proposes the R&S®Tx9 generation of transmitters. The R&S®THU9/R&S®THV9 for high-power requirements with liquid cooling and the R&S®TMU9/R&S®TMV9 for medium-power and air-cooled applications.

The R&S®Tx9 generation offers the highest power efficiency in the market (up to 38 % in Doherty mode, including the cooling system). Some of the different transmitter power classes are described in Table 4-2 below:

	R&S® Transmitter type	Efficiency	Min. power	Max. power
UHF	THU9 standard	28 %	1.3 kW	36 kW
	THU9 Doherty	38 %	1.15 kW	50 kW
	TMU9 standard	25 %	0.3 kW	2.85 kW
	TMU9 Doherty	38 %	0.3 kW	2.85 kW
VHF	THV9 standard	33 %	1.3 kW	30 kW
	THV9 Doherty	46 %	1.3 kW	30 kW
	TMV9 standard	33 %	0.35 kW	4.3 kW
	TMV9 Doherty	46 %	0.35 kW	4.3 kW

Table 4-2: R&S® Tx9 generation of DVB-T2 medium and high power transmitters from Rohde & Schwarz.

5 RF demodulation and HEVC decoding

The final part of the UHDTV transmission takes place at the customer premises. Typically for roof-top reception, a Yagi antenna captures the DVB-T2 RF signal and delivers it to the UHD television via a 75 ohm cable. The RF demodulator and HEVC decoder are implemented on the TV receiver or set-top-box (Fig. 5-1). However, in an experimental environment where network operators are looking for in-depth RF and baseband analysis of the DVB-T2 signal carrying the UHDTV content, Rohde & Schwarz proposes the R&S®ETL TV analyzer. The analyzer receives the DVB-T2 RF signal which contains the UHDTV service and demodulates it down to baseband level. The demodulated signal, which has the form of an MPEG-2 transport stream, can then be fed into the GMIT®BMM-810 via ASI. The GMIT®BMM-810 is a server-based solution for monitoring and visualization of broadcast video and audio services, it is able to decode multiple UHD services (compressed or uncompressed) and output the signal to a TV monitor via HDMI™, DisplayPort™ or quad 3G-SDI connection. The GMIT®BMM-810 can provide real time PSNR and SSIM measurements between an uncompressed (3G-SDI) and a compressed (HEVC) signal (Fig. 5-1).

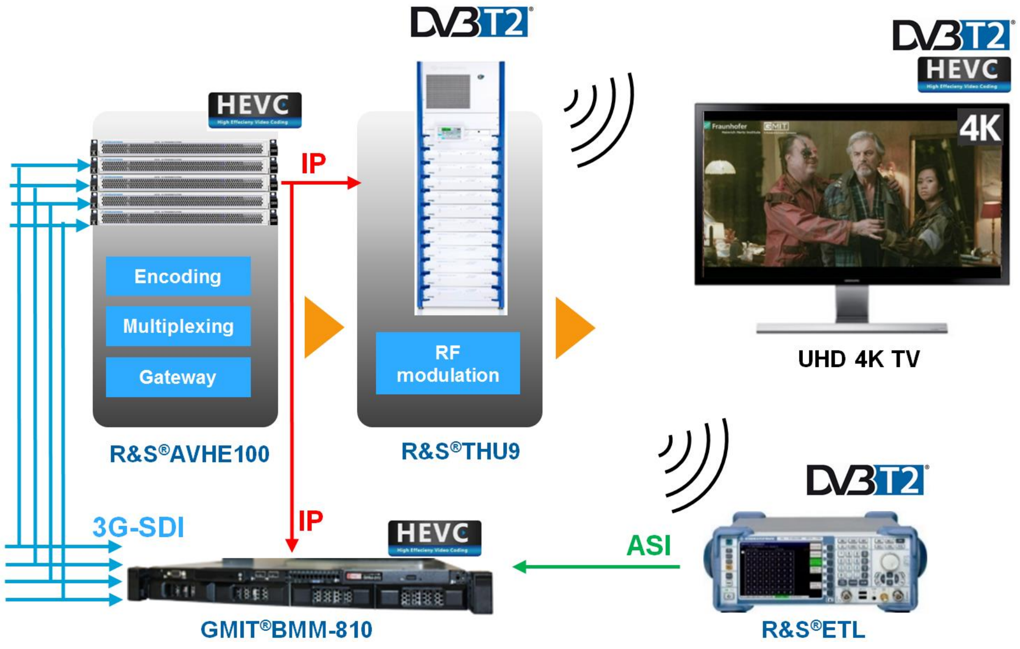

Fig. 5-1: DVB-T2 RF demodulation by the R&S®ETL TV analyzer and real time HEVC decoding and comparison (uncompressed and compressed UHD) using the GMIT®BMM-810.

6 Summary

With major sports events coming up and a trend to increase TV screen sizes, UHD 4K content delivery is becoming reality. The increase in both spatial and temporal resolution creates new challenges for broadcasters, since a much higher data rate handling and processing is now required. UHDTV content delivery becomes even more challenging when this data needs to be transformed and transmitted over terrestrial networks due to channel capacity limitations. In this paper, a UHD 4K end-to-end solution utilizing products from Rohde & Schwarz was demonstrated from the point at which 4K content is captured until its delivery to households via a DVB-T2 SFN network. This work is based on a real test case scenario reflecting the technical requirements of the major Korean broadcasters.

7 Abbreviations

3G-SDI	3 GHz serial digital interface
HDMI	High definition multimedia interface
HEVC	High efficiency video coding
MPEG	Moving picture experts group
SFN	Single frequency network
NTP	Network time protocol
T2-MI	T2 modulator interface
UHDTV	Ultra high definition TV

8 References

[Sony reference] http://pro.sony.com/bbsccms/assets/files/show/highend/pdf/Sony_Cinealta_Family_Brochure.pdf

[ITU-R BT.2020] http://www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC-BT.2020-0-201208-I!!PDF-E.pdf

[Nordig reference] http://www.nordig.org/pdf/NorDig-Unified_Test_Specification_ver_2.2.2.pdf

[Video bitrate calculator reference] web.forret.com/tools/video_fps.asp

9 Additional Information

Our application notes are regularly revised and updated. Check for any changes at http://www.rohde-schwarz.com.

Please send any comments or suggestions about this application note to

Broadcasting-TM-Applications@rohde-schwarz.com.

10 Ordering information

Designation	Type	Order No.
4K Ingest & Playout with XAVC support	R&S®Clipster	2900.8560.00
Headend Solution for Encoding and Multiplexing	R&S®AVHE100	5301.8000K12
High-Power DVB-T2 Transmitter	R&S®THU9	2109.9010K02
TV Analyzer	R&S®ETL	2112.0004.13
Multiviewer & Content Monitoring	GMIT®BMM-810	BMMHWSYS4K

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 more than 80 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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