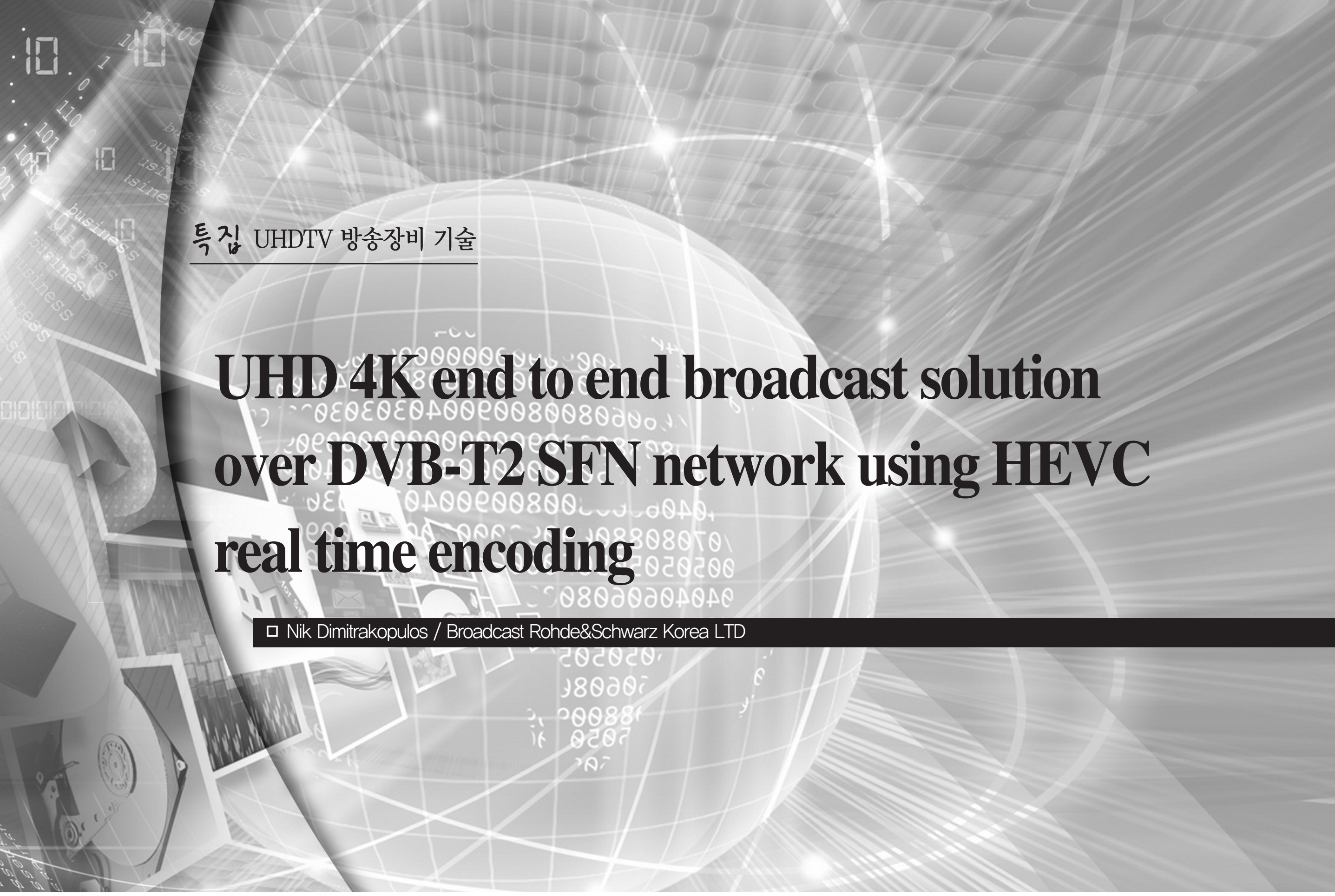


UHD 4K end to end broadcast solution over DVB-T2 SFN network using HEVC real time encoding

□ Nik Dimitrakopulos / Broadcast Rohde&Schwarz Korea LTD

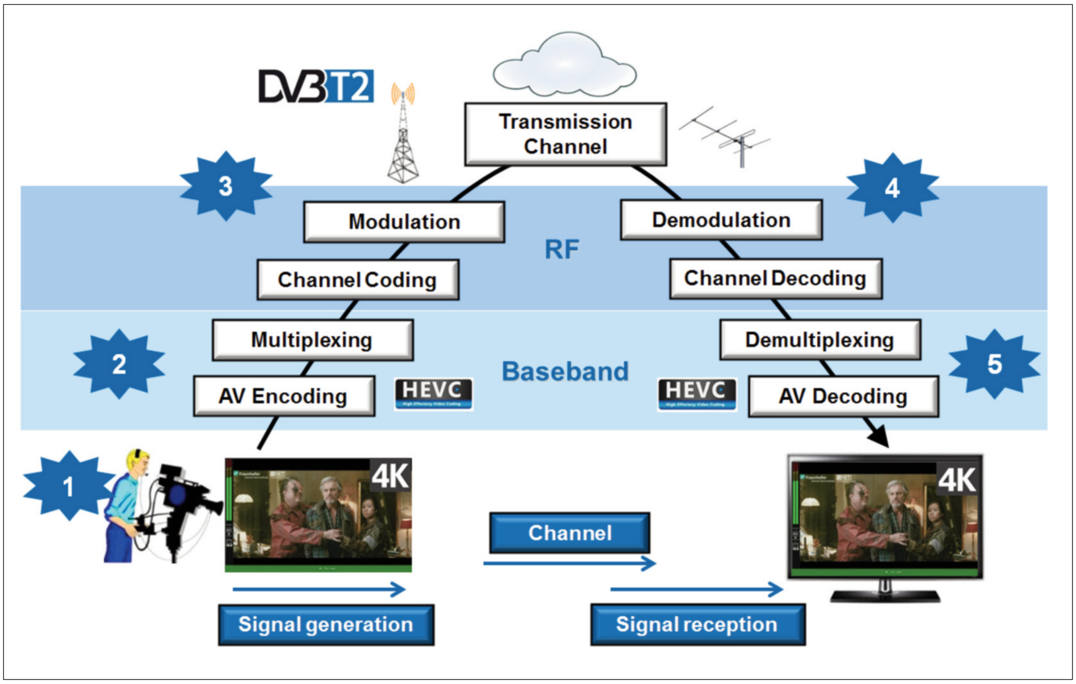
Abstract

With major sports events such as FIFA World Cup and The Olympic Games coming up, UHDTV technology has been given a major push by broadcasters, test and measurement (T&M), and consumer electronics (TV and set-top box) manufacturers. The increase in picture resolution (3840x2160) for 4K and (7680x4320) for 8K compared to current HDTV (1920x1080), as well as the need to deliver these services in higher frame rates (50/60 up to 100/120fps) translate to a big challenge in UHDTV content delivery to households over terrestrial transmission due to higher data rates. DVB-T2 has been favored by many countries across the world as it is proven to give the best spectral efficiency for terrestrial broadcasting. On the other hand 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. In this paper, we will give an overview about a complete end-to-end solution for UHDTV delivery over DVB-T2 based on a realistic SFN scenario in Seoul metropolitan area.

Ⅰ. Introduction

Ultra High Definition TV (UHDTV) is becoming more and more a hot topic in the broadcasting industry. With major sports events such as FIFA World Cup 2014 and The XXXI Olympic Games in Rio Brazil coming up, UHDTV technology has been given a major push by broadcasters, test and measurement (T&M), and consumer electronics (TV and set-top box) manufacturers.

The increase in picture (spatial) resolution (3840x2160) for 4K and (7680x4320) for 8K compared to current HDTV (1920x1080), as well as the need to deliver these services at higher frame rates (50/60 up to 100/120fps) translate to a big challenge in UHDTV content delivery to



〈Figure 1〉 *Illustration of the broadcasting chain showing UHD 4K content acquisition and delivery from post production to households over terrestrial network in 5 steps.*

households over terrestrial transmission due to much higher data rates.

DVB-T2 has been favored by many countries across the world as it is proven to give the best spectral efficiency for terrestrial broadcasting. On the other hand 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.

This paper gives an overview about a complete end-to-end solution for UHDTV delivery over DVB-T2 in 5 steps, based on a realistic scenario. Every 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. <Figure 1> depicts the broadcasting chain from signal generation (acquisition) to presentation on a household UHD-TV in the 5 steps discussed above.

Ⅱ. 4K Ingest and Playout (Post Production Environment)

UHDTV content is most commonly generated by use of 4K cameras. The UHDTV content is stored internally in the camera memory or in case of live broadcasting it is transferred in real time to an ingest system via 4 x 3G-SDI cables. The table 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].

A typical 4K camera nowadays can either output 4K raw video content at 50 or 60fps using 10 or 12bits with 4:2:2 [Sony ref] in the first case 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 file (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 cameras 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 according to UHD-1 broadcasting requirements [ITU-R BT.2020].

R&S®Clipster not only offers that but in fact 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 (<figure 2>).

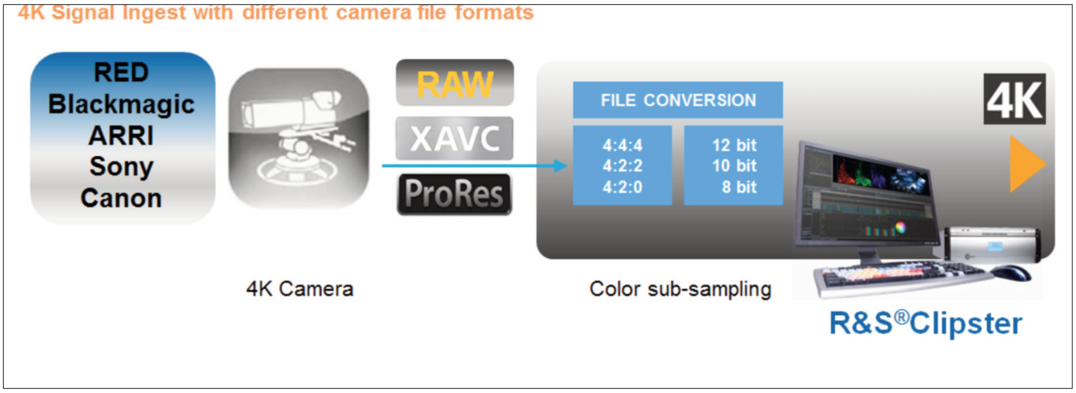
R&S®Clipster automatically synchronizes the incoming signals (stitching) and compiles one 4K file before processing (<figure 3>). This

〈Table 1〉 Raw data rates for UHTV 4K with 60fps

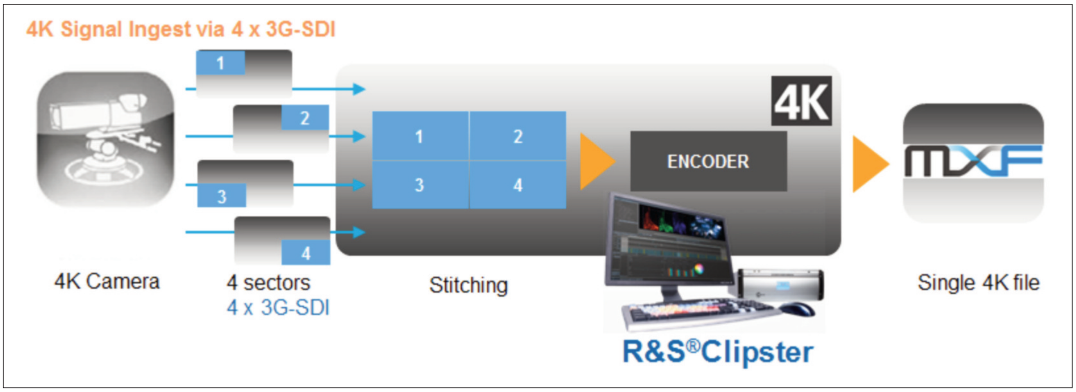
UHD resolution: 3840x2160 with 60fps				
Color sampling	4:4:4	4:2:2	4:2:0	12bit
Bit rate (Gbps)	17.92	11.94	8.96	
Color sampling	4:4:4	4:2:2	4:2:0	10bit
Bit rate (Gbps)	14.93	9.95	7.46	
Color sampling	4:4:4	4:2:2	4:2:0	8bit
Bit rate (Gbps)	11.94	7.96	5.97	

4:4:4 → 4:2:0 -50%

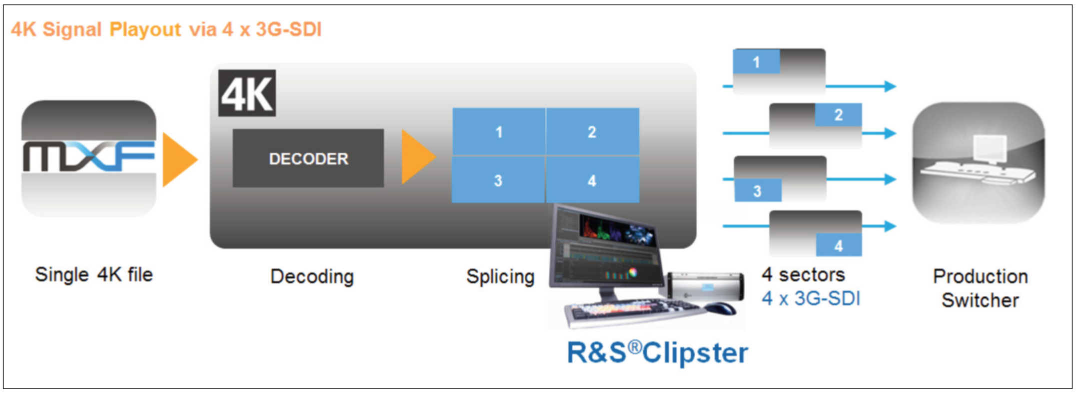
12bit → 8bit -33%



〈Figure 2〉 R&S®Clipster-4K camera ingest supporting various formats and file conversion using different chroma samplings.



〈Figure 3〉 R&S®Clipster-4K signal ingest via 4 x 3G-SDI. *This feature will be available in 2014.



〈Figure 4〉 R&S®Clipster-4K signal decoding, splicing and playout via 4 x 3G-SDI.

methodology is important to get rid of any artefacts often appearing near the borders of the 4 quadrants from the incoming signals. From this point the signal is in a file based format and it can be furthermore processed (encoding with HEVC, JPEG2000) or transferred to a playout center or central storage (<figure 4>).

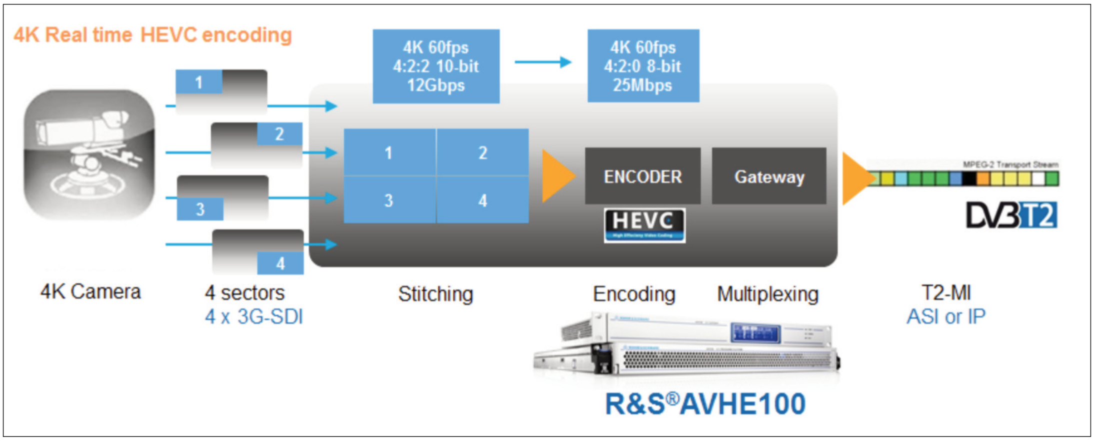
Ⅲ. HEVC Real time encoding and multiplexing

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 (50fps or 60fps) 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.

For this challenge Rohde&Schwarz proposes the R&S® AVHE100 which is 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



〈Figure 5〉 R&S®AVHE100 headend system from Rohde&Schwarz with real time HEVC encoding.

processing. The signal flows within the headend are fully IP-based, providing the high flexibility required to meet a wide range of customer needs.

The incoming 3G-SDI signals are initially synchronized inside the R&S®AVHE100 (muxing) to form a single 4K image. This is achieved by the incoming signals getting genlocked together in frequency as well as in phase (with a maximum offset of 512 pixels). The HEVC encoders are then processing the whole 4K data and generating the MPEG-2 transport stream or MPEG-DASH according to the DVB standards. The output from the headend can be either via ASI or IP and therefore it can be used for unicast or multicast purposes and it can be delivered over terrestrial, satellite, cable or IP network (<figure 5>).

Initial development of the real time HEVC encoding requires multiple servers (4 servers), due to the high processing power required for higher resolutions (UHD) and frame rates. This is expected to be simplified in the following years. Alternatively a single rack encoder unit can be used that can reach 30-40% encoding efficiency compared to H.264.

Ⅳ. UHDTV delivery over DVB–T2 SFN network

DVB-T2 is 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). In order to come up with some possible DVB-T2 configurations, the following limitations were firstly considered:

- The RF DVB-T2 bandwidth is fixed to 6MHz.
- Due to the geostatic profile of Seoul Metropolitan area, a relatively large guard interval must be taken into account for SFN planning - as a result this will reduce the data capacity of the 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 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 25Mbps are needed to achieve satisfactory results (based on 3840x2160 with 4:2:0, 8-bit 60fps*)
- 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 2 below:

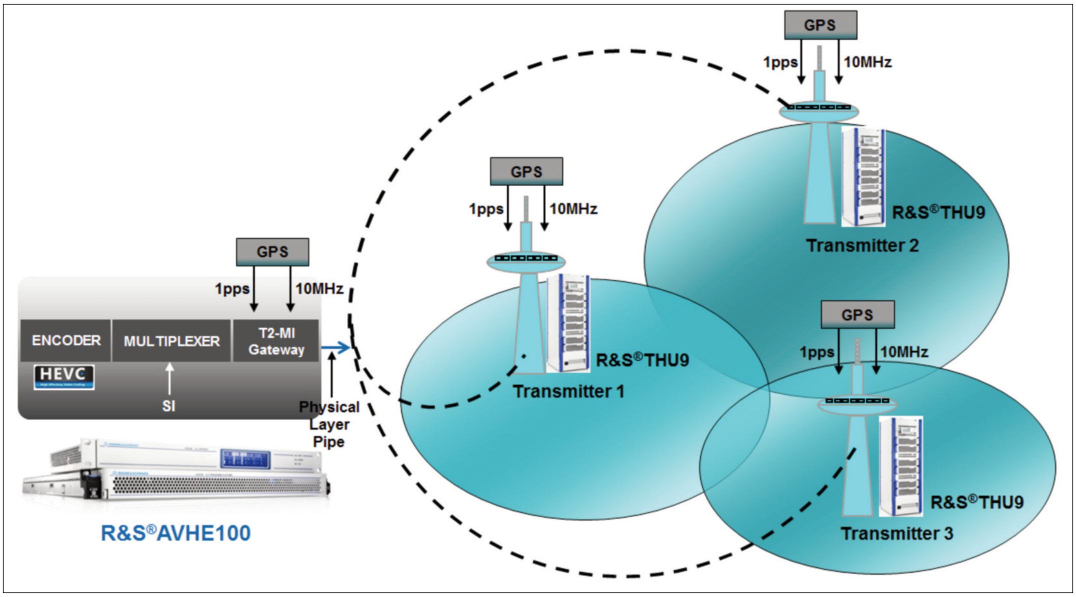
〈Table 2〉 Recommended transmission modes for UHDTV terrestrial broadcasting in Seoul metropolitan area using DVB-T2 SFN scenario for rooftop (Modes 1&2) and indoor reception (Modes 3&4).

DVB T2	Constellation	FEC	GI	FFT	Pilot	T2 frame	Num of blocks	C/N	Data Rate	
	(Mode 1) 256 QAM	2/3					150	20.8 dB	26.5 Mbps	
	(Mode 2) 64 QAM	5/6	1/16	32K	PP4	47	116	19.4 dB	25.7 Mbps	BW 6 MHz
	(Mode 3) 64 QAM	2/3					116	16.2 dB	20.5 Mbps	
	(Mode 4) 64 QAM	2/3	1/8		PP2	45	107	16.2 dB	18.7 Mbps	
	Note* These data rates are calculated with the T2-MI interface activated.									

• 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 to mode 1 with a small reduction of data rate.

• Modes 3&4 are designed for indoor reception with the latter having a larger guard interval. These modes although have a better noise immunity, they are limited to data rate which makes UHDTV delivery very challenging at



〈Figure 6〉 DVB-T2 SFN configuration of 3 transmitter sites using the R&S®AVHE100 encoder/multiplexer/gateway and the high power R&S®THU9 DVB-T2 transmitter from Rohde&Schwarz.

〈Table 3〉 Generation Tx9 DVB-T2 medium and high power transmitters from Rohde&Schwarz.

R&S®THU9

	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

high frame rates (possible with 3840x2160 at 30fps)

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.

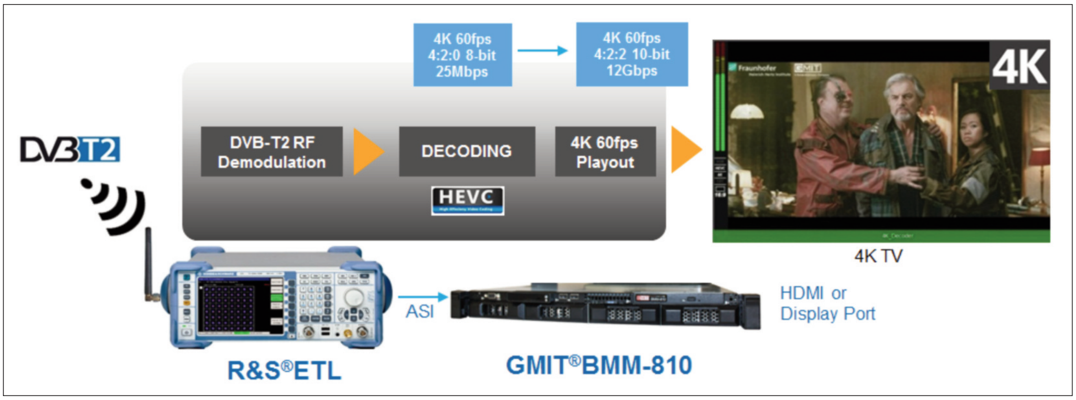
The R&S®AVHE100 headend feeds the MPEG-2 transport stream to all the transmitters located in the SFN. These transmitters support both ASI and IP inputs. The synchronization time stamps are included in the T2-MI stream and the transmitter network is synchronized by using 1pps GPS signaling for the time reference and 10 MHz for the frequency reference (<figure 6>).

For the transmitter part, Rohde&Schwarz proposes the 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 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 the table 3 below:

Ⅴ. RF demodulation & HEVC decoding

The final part of the UHDTV transmission is located at the customer premises. Typically for a roof top reception a Yagi antenna captures the DVB-T2 RF signal and delivers it to the UHD-TV via a 75 Ohm cable. The RF demodulator and HEVC decoder are implemented on the TV receiver or Set Top Box. However in an



⟨Figure 7⟩ DVB–T2 RF demodulation by the R&S®ETL TV analyzer and real time HEVC decoding and presentation on a 4K monitor screen using the GMIT®BMM–810.

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 is then 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 and it is able to decode the HEVC UHD service and output the signal into a TV monitor or a 4K projector via HDMI or DVI connection (<figure 7>). This unit supports simultaneous decoding of up to 4 HEVC streams in 4K resolution.

Ⅵ. 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 sets new challenges for the 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 capturing 4K content throughout to deliver it to households via DVB-T2 SFN network. This work is based on a real test case scenario reflecting the technical requirements of the major Korean broadcasters.

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필 자 소 개

Dr Nik Dimitrakopoulos Ph.D, MSc (Eng)

Currently based in Rohde & Schwarz' subsidiary in Korea, Dr Dimitrakopoulos is the Regional Business Development Manager for T&M solutions in Broadcast and is responsible for the Asian market. He was involved in the first UHDTV trial over DVB-T2 in Asia with KBS and at the moment, he is assisting with the next phase of the trials that involve an end to end broadcasting solution for delivery of UHDTV content via DVB-T2 SFN.

Prior to joining Rohde & Schwarz, Dr Dimitrakopoulos spent two years with Digital TV Labs and was responsible for all RF conformance testing of TV receivers and STBs (D-Book, Nordig etc), as well as DVB-T2 trials taking place across Europe and Asia.

In 2008, he was with Amplifier Technology in the UK working on power amplifier systems for VHF/UHF, as well as C-Band and X-Band frequency projects to support the Aerospace & Defence industries.

Dr Dimitrakopoulos graduated from the University of Leeds with a Ph.D in Electronic Engineering and MSc (Eng). In addition, he is an active member of the DTG RF group and HDMI forum.