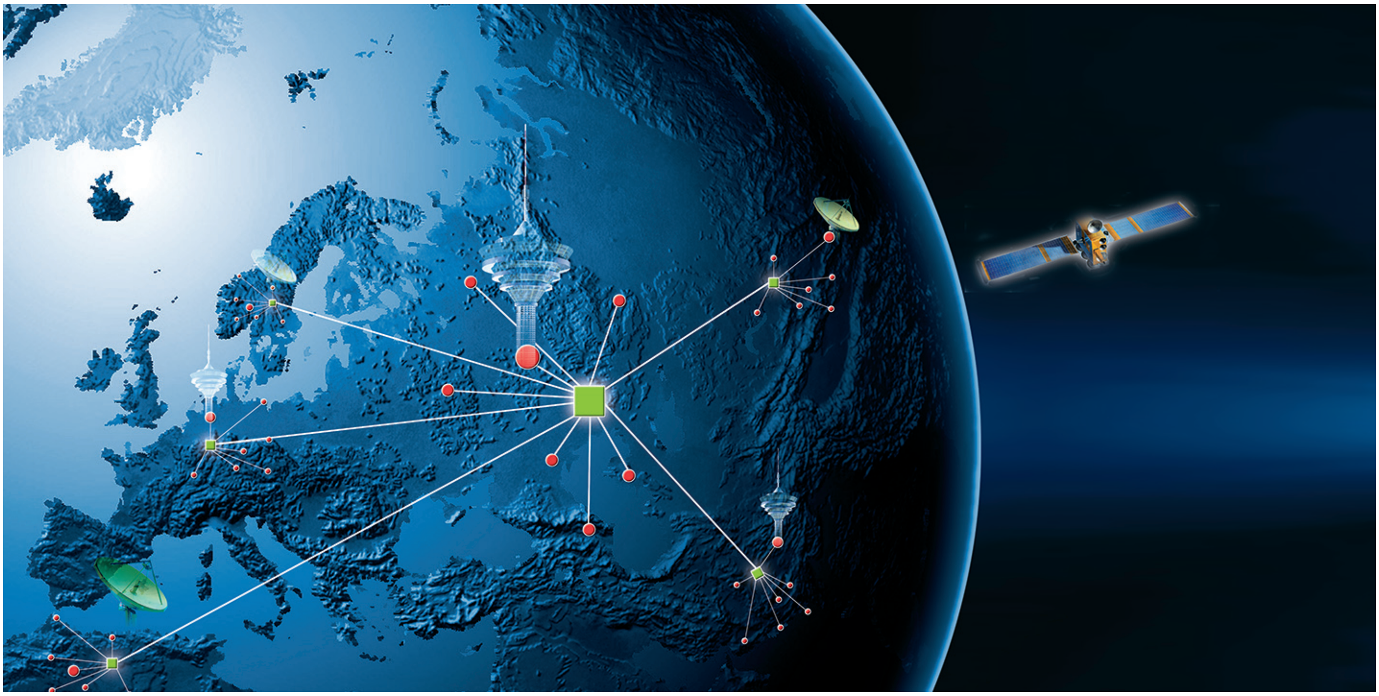
Efficient and to the point: monitoring of digital TV signals

Ensuring high signal quality and signal availability is as indispensable in digital TV networks as it is in analog TV. Signal monitoring is a key method in quality assurance, but it is getting increasingly complex – not least because of the wide variety of programs and auxiliary data services.

Which is the best concept?

Finding the ideal concept for monitoring digital TV networks depends on different criteria and needs to be established separately for each application. To identify the best possible solution, the following aspects should be taken into account:

- **Reason for monitoring –** what are the objectives involved?
- **Network structure –** at which point in the network is the monitoring to be performed?
- **The signals to be monitored and their characteristics –** which measurements need to be performed?



Why is monitoring performed – and what are the objectives?

Program providers and network operators place considerable importance on the error-free generation of digital TV signals and their correct distribution and transmission in networks, not least because of contractual obligations toward their business partners. Monitoring institutions, however, handle different tasks. For example, they check if relevant standards are complied with, including whether the coverage in a specific transmission area is adequate, or if a specific program set is correctly broadcast.

There is a wide variety of monitoring objectives, including:

- **Prevention of serious interference** by intervening early on whenever minor changes to signals or in the system are discovered
- **Immediate and efficient troubleshooting** by quickly detecting and locating signal failures or signal errors and determining their causes
- **Recording signal characteristics and system availability** for subsequent analysis or demonstration purposes toward the contracting partners
- **Enhanced quality of service** by detecting and remedying even sporadic errors

At which points in the network is monitoring to be performed?

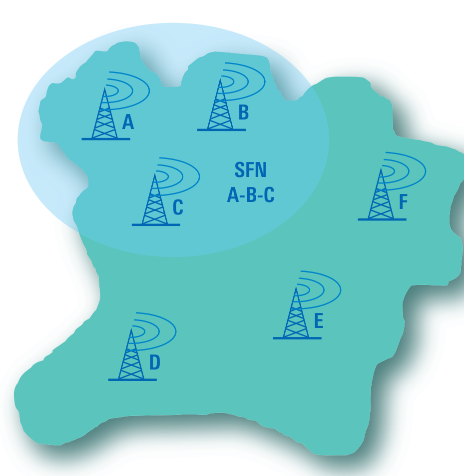
Complex structure: distribution networks for digital TV signals

Networks for distributing digital TV signals are often complex and elaborate in structure, for example because individual network sections or feeder links are frequently operated by different organizations. In these cases, there are transfer points for handing over signals and/or responsibility.

Different methods are used to physically transmit signals; cable headends, for example, can be supplied via satellites or fiber-optic links (IP or ATM), while standalone terrestrial transmitters can be connected via microwave links or off-air reception, and terrestrial MFNs may also include local SFN sections. There are thus plenty of reasons for examining the structure of these networks in more detail.

FIG 1 Example of a DVB-T network with different regional programs

	Transmitter					
Program	A	B	C	D	E	F
News channel	✓	✓	✓	✓	✓	✓
Movie channel 1	✓	✓	✓	✓	✓	✓
Movie channel 2	✓	✓	✓	✓	✓	✓
Sports channel	✓	✓	✓	✓	✓	✓
Home shopping	✓	✓	✓	✓	✓	✓
Cartoons	✓	✓	✓	✓	✓	✓
Regional channel SFN 1	✓	✓	✓			
Regional channel SFN 2	✓	✓	✓			
Regional channel D				✓		✓
Regional channel E					✓	
Regional channel F				✓	✓	✓



Network characterization based on the content of the distributed signals

One of the basic network characterizations takes into account whether all customers receive the same signal, i.e. the same content. If this is the case, the signal is usually compiled at one location and then distributed via the network. If the content varies, different signals are transmitted simultaneously, or only one signal is transmitted but is modified at specific points in the network to accommodate a limited number of customers. FIG 1 shows a typical simple example[1]: Six transmitters broadcast four programs each on two channels

Six programs are identical on all transmitters; five are only of local interest and are fed separately to the relevant regions.

[1] The SFN in this example (which is also used for FIGs 2 and 3) is only important insofar as all transmitters involved in the SFN transmit the same transport stream.

Network characterization based on sections

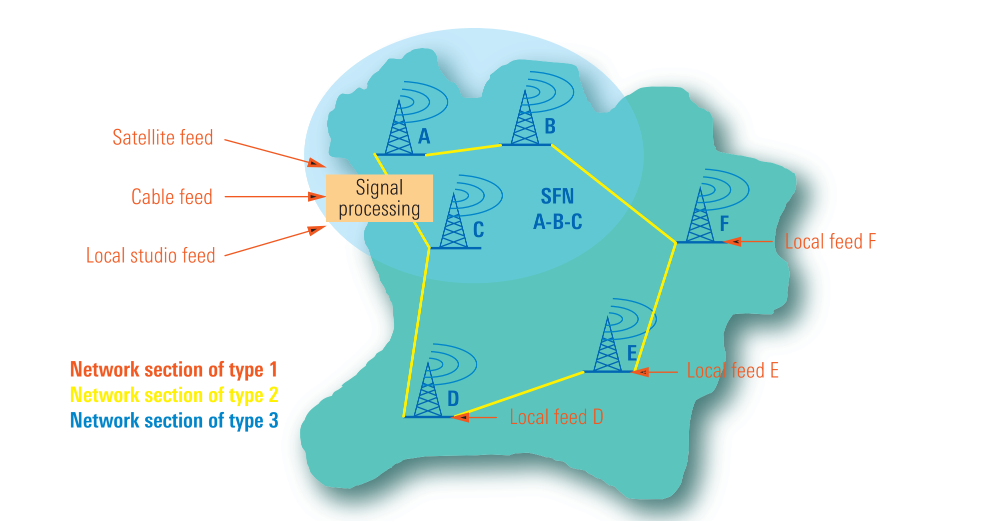
Networks with identical signals for all customers can be classified in sections of different types:

Network sections of type 1 are used to combine all programs that are ultimately intended to reach the customers. The programs are received by very different providers at home and/or abroad. A wide range of transmission standards can be used to transmit the programs; these standards may change along partial paths and do not even exclude analog transmission methods. With analog transmission methods, the received program must be digitized and compressed on-site. If the programs are received from a studio on-site or from a local server, for example, the network section can be very short, or is limited to local signal processing.

Via **network sections of type 2 (contribution),** the processed signal is transmitted to the network sections of type 3, which ultimately supply the services to the customers.

Network sections of type 3 (distribution) are used for direct customer coverage; they may be transmitter, cable, or satellite networks, for example. In special terrestrial networks, a signal received via a network section of type 3 can be distributed virtually simultaneously in additional network sections of type 3. This method is referred to as off-air reception; it is used whenever the additional network section of type 3 is difficult to access via a network section of type 2.

FIG 2 Example of the different types of network sections



Networks where not every subscriber receives the same signal can also be classified according to this pattern. In this case, however, network sections of type 1 can directly feed network sections of type 3 after the signals have been appropriately processed.

FIG 2 shows the different types of network sections. They are based on the DVB-T network shown in FIG 1, which supplies the customers with TV signals and thus corresponds to the network section of type 3 (distribution, shown in blue). The individual transmitters receive the signals from an ATM network in ring configuration (yellow), which is a network section of type 2 (contribution). In practical applications, this section is often redundant in design to ensure enhanced reliability of transmission.

The signal that is to be distributed is generated at a location between the transmitters A and C, where several programs are received in different ways. The networks used for this purpose correspond to a network section of type 1 (orange). The networks for feeding the regional programs to the transmitters D, E, and F also correspond to the network section of type 1.[2)]

[2)] Local signal processing of the locally transmitted programs to the transmitter stations D, E, and F is not included.

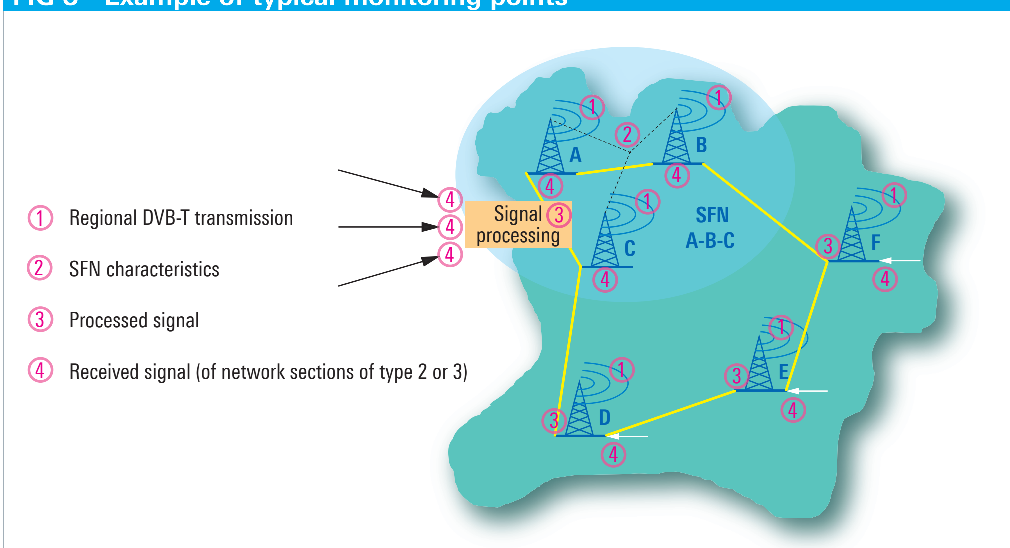
Typical monitoring points in the network

The interface to the customer is very important in monitoring: This is where the signal is checked to ensure that it is without errors. Monitoring of the transmitter modulation quality must be carried out directly on the transmitter. Otherwise, environmental influences would impair the measurement result.

The SFN characteristics must be monitored at a point where the reception of all transmitters included in the SFN is good. If transport streams are combined or modified, the newly generated transport stream should be monitored directly on-site to ensure that it is correct. If the individual network sections are in different areas of responsibility, monitoring should be performed at the transfer points between two sections.

The same applies when errors occur in order to quickly pinpoint the error source. The individual programs are usually monitored directly at the site of program provision or channel coding. FIG 3 shows an example of typical monitoring points for the different network sections.

FIG 3 Example of typical monitoring points



Which measurements need to be performed?

This question can be answered by taking into account the monitoring objective and the function of the system being monitored. If the transport stream is to be distributed without any changes, for example via a terrestrial transmitter network, monitoring will focus on the RF characteristics. If, however, the network operator modifies the transport stream, additional monitoring of the transport stream characteristics can be beneficial.

Program providers, however, mainly concentrate on the correctness of the signal to be transmitted as well as on the video and audio signal quality of the individual programs. Thus, their main focus is on checking the program quality and the correct structure of the transport stream.

Deriving measurements from the signal processing chain

FIG 4 shows the signal processing chain in digital TV in simplified form. It is based on digitized but not yet compressed signals for each program. The signals may be provided by a camera, a server, or a decoder, for example. The encoders reduce the signal data rate for transmission. The multiplexer combines the individual, compressed signals and adds additional data which the receivers need in order to correctly replay the programs. In addition to the audio and video signals, all other data such as teletext and subtitles or program information for an electronic program guide is inserted.

The signal to be transmitted – the transport stream – is provided at the multiplexer output. Depending on the transmission method, the transport stream is channel-coded, modulated, and then transmitted (e.g. terrestrial transmission, via satellite uplink, or via cable). Based on the signal processing chain described, measurement points can be identified as follows:

Program level / data level – between encoder and multiplexer ①

- Poor picture and sound quality or, in the case of data services, incorrect data structures
- Coding with syntax errors
- Incorrect time references (e.g. PCR, PTS, and DTS)
- Unnecessarily high data rate

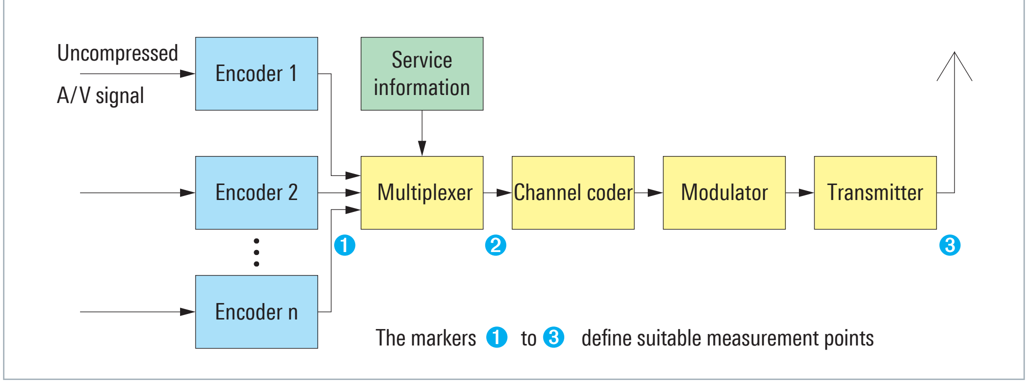
Transport stream level – between multiplexer and channel coder ②

- Incorrect or missing content (e.g. programs or their components such as audio signals)
- Data rate too high / too low
- Incorrect references
- Syntax error
- Important auxiliary data (tables) that is to be repeated periodically is transmitted too frequently / too seldom
- Incorrect modification of the time references of the individual programs

RF signal level – transmitted signal ③

- Missing channel
- Insufficient signal strength / quality, or bit error ratio too high
- Impaired transmitter synchronicity in SFNs

FIG 4 Signal processing chain for digital TV (simplified)



Recommendations of the measurement guidelines

A guideline for measurements in DVB systems was published as a Technical Report (TR) with the designation ETSI TR 101 290, "Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems", and is now available as version 1.2.1 (2001-05).

The document specifies how to perform measurements on DVB systems both with regard to RF and transport stream characteristics. It also suggests measurements especially with a view to transport stream monitoring. The measurements are classified in three groups and prioritized.

All measurements refer to the syntax and the logical structure (references in tables) of the transport stream as well as to the characteristics with time reference (PCR and buffer) and the integrity (CRC). They can be performed without having any knowledge of the specific transport stream to be measured.

Measurements in practical applications

In practical applications, the measurements focus on RF and transport stream characteristics. In some cases, the individual programs are automatically monitored in order to check their video and audio quality, and – insofar as possible – the correct structures for data services.

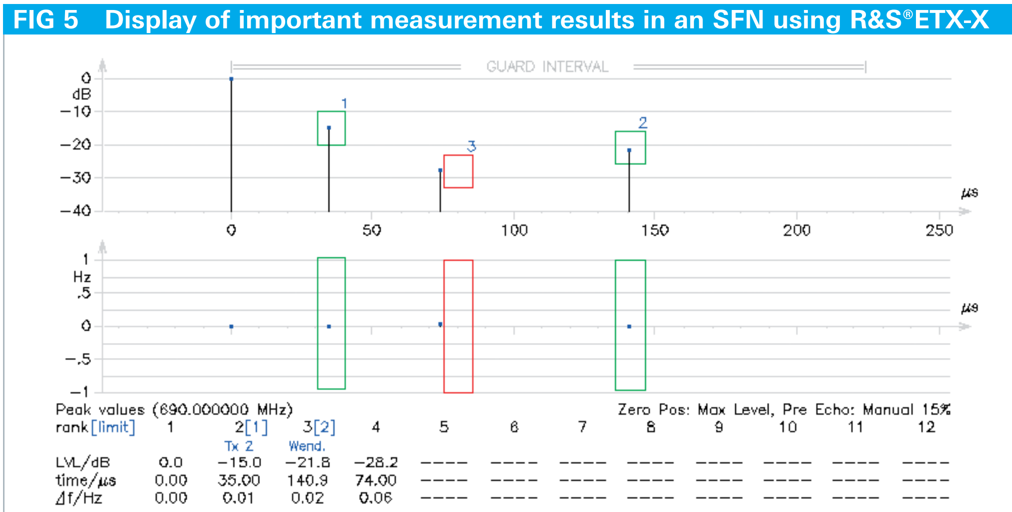
Monitoring RF characteristics

Only a few RF measurements are needed to detect the errors at the RF level as described in the section "Deriving measurements from the signal processing chain". They are part of the basic measurements in practical monitoring applications:

- RF Sync – Is there any signal that can be synchronized?
- Level – Is the signal strength sufficient?
- MER – Is the modulation quality sufficient?
- BER – Is the proportion of correctly received bits (prior to error protection) sufficient?
- PER – What is the proportion of defective transport stream packets (after error protection)?

During DVB-T transmission in SFNs, transmitter synchronicity must also be monitored – by measuring changes in frequency, level, and time reference of all transmitters included in the SFN. Thus, an individual transmitter that no longer transmits synchronously can be immediately detected and switched off. This prevents a failure of the entire network; the deactivation of the defective transmitter affects only a few customers.

FIG 5 Display of important measurement results in an SFN using R&S®ETX-X



The example of an SFN with four transmitters in FIG 5 shows how the R&S®ETX-T monitoring receiver displays the measurement results. The upper diagram includes the amplitudes of the individual signals versus the time reference of the signals to each other. The lower diagram shows the frequency errors. The colored rectangles mark the defined tolerance limits; due to the color-coding, a violation of these limits can be quickly detected.

In addition, the modulation parameters of the received signal are often checked to verify that they are correct, i.e. that they comply with the nominal values stored in the monitoring device. A constellation diagram provides a graphical display of the modulation and the signal quality. FIG 6 shows an example of the RF measurement result display.

Detecting small changes of a transmitter signal at an early stage is of vital importance in RF monitoring. By taking measures early on, extensive changes and even transmitter downtimes can be prevented. However, detecting small signal changes requires a wide dynamic range during the MER measurement.

Monitoring the transport stream

By performing the measurements of priority 1, 2, and 3 as specified in the DVB measurement guidelines, the transport stream syntax and structure can be appropriately determined. In most cases, however, further measurements need to be performed. For example, the megaframe initialization packet (MIP) is checked in SFNs; the MIP is a transport stream packet required for synchronizing the transmitters involved. A MIP inserter inserts the TS packet in a transport stream that is sent to all transmitters. Comprehensive measurements for analyzing the MIP are defined in the DVB measurement guidelines.

FIG 6
Display of the RF measurement results using the R&S®DVM MPEG-2 monitoring system.

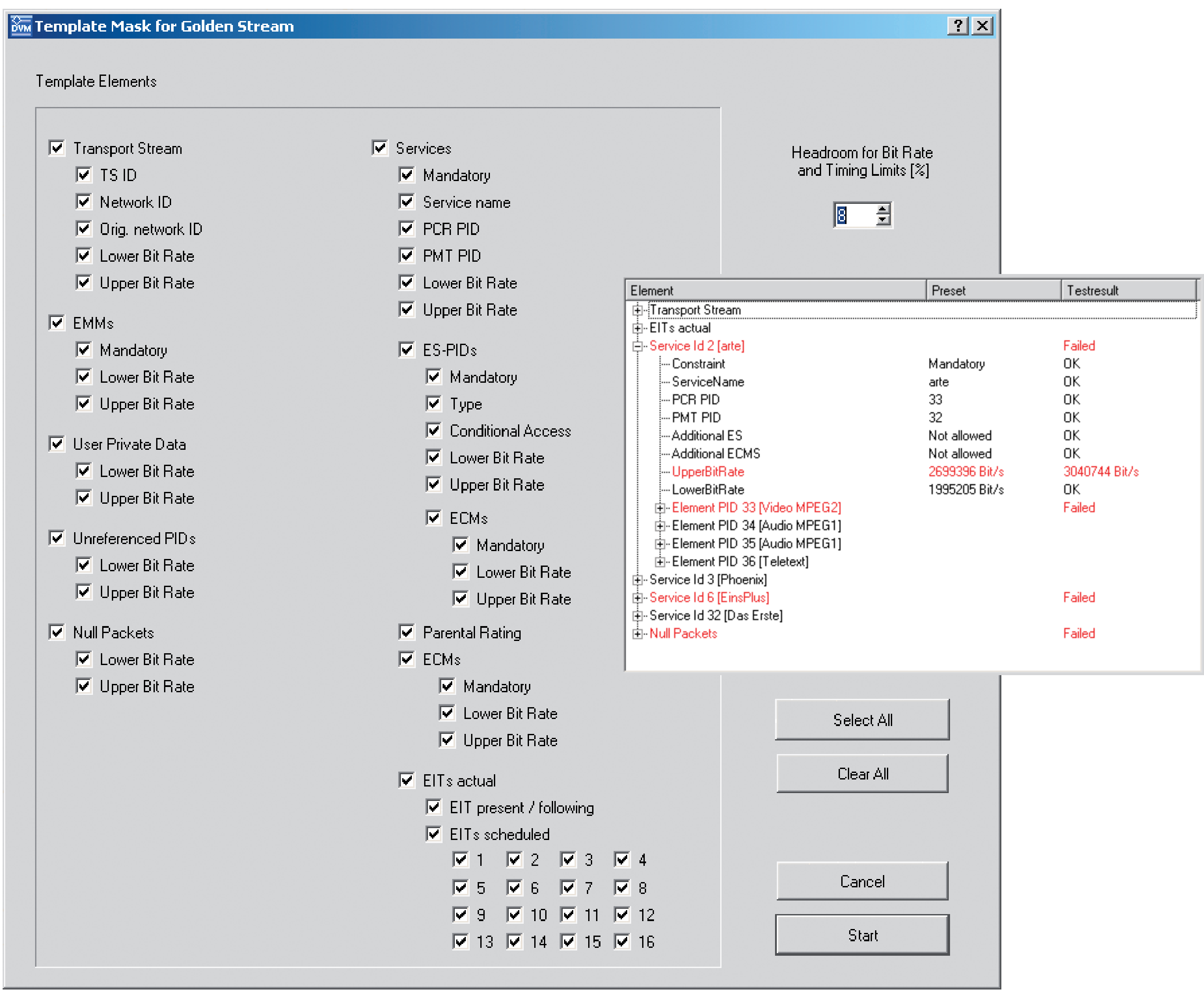
Further measurements
provide answers to the following questions:

- Are all programs available?
- Do the programs contain all desired elements?
- Does a program take up too much bandwidth?
- Are all program designations correct?
- Are pay-TV programs really encrypted?

If all these aspects are to be monitored, the monitoring equipment needs to know the nominal values so that it can compare them with the measured values. FIG 7 shows how this function has been implemented in the R&S®DVM MPEG-2 monitoring system. The configuration window (large) for automatic template generation shows the wide range of characteristics that can be specified.

The measurement result window (small) shows the template in a structured form and highlights in color the deviations from the measured signal with the appropriate measurement value.

FIG 7
Monitoring application using the R&S®DVM MPEG-2 monitoring system: configuration window for automatic template generation (large) and structured display of measurement results (small).



Monitoring of programs and services

When the quality of video and audio signals is monitored, the test equipment signals picture freeze or picture loss as well as silence or sound loss. High-end and specialized equipment additionally calculates a quality value for the video signal. Analysis functions and equipment are used to check the configuration of data services such as teletext, subtitles, or MHP applications.

However, monitoring equipment for realtime checking of all data services of a transport stream is not commercially available. To find out whether data is transmitted to the individual services, the data rate of the individual elementary streams can be monitored. This simplified way of monitoring can also be used for video and audio elementary streams if the budget does not suffice for monitoring the video and audio quality.

User-friendly: One instrument performs all tasks

The section "Measurements in practical applications" (page 6) gives a detailed overview of the measurement functions required when monitoring digital TV signals. Since these different measurements may involve the monitoring of RF characteristics, the transport stream, and perhaps even individual programs or data services, etc., it is particularly beneficial if you can perform all of them simultaneously and with only one instrument. This considerably simplifies configuration and operation since you have to become familiar with only one user interface. Moreover, it is much easier to integrate only one instrument interface into computer networks.

A clear advantage: high-end measuring equipment

Measurement values should only be compared if they were determined in compliance with standards. Especially data rate and PCR jitter measurements frequently reveal that measurement methods applied by different manufacturers are incompatible. Some manufacturers do not even indicate them. The various instruments clearly differ if you concentrate on the accuracy of RF measurements.

Any shortcoming in this respect can be disadvantageous. If you want to determine the MER, for example, this important measurement must detect the slightest change in a signal (which might indicate that a failure is about to occur) at the transmitter end as early as possible. Doing so will enable you to respond in due time and minimize downtimes. Only high-end instruments offer the dynamic range necessary for performing this sophisticated measurement.

Configuration: maximum flexibility and capability

Monitoring is considered to be efficient if all true errors are detected and no false alarms are triggered. However, monitoring tasks vary greatly and the definitions of errors or false alarms are not necessarily standardized. A precondition for efficient monitoring is that you can configure monitoring functions to meet individual requirements and adapt them to each signal.

Monitoring instruments should allow you to activate each measurement individually and to adapt the limit values for alarm generation. To make the interpretation of measurement results easier, it is useful to be able to classify the individual measurements, e.g. in "Alarm", "Warning", or "Info". This classification can then be used by the monitoring instrument or the external software for all further signaling options, e.g. for class-specific icons on the graphical user interface, filter criteria in SNMP traps, and explanations in reports.

Indispensable: in-depth configurability

In-depth configurability is required particularly at the transport stream level, e.g. when a network operator transmits additional data in unreferenced transport stream packets with known PIDs. These PIDs are of course not supposed to provoke the error message "unreferenced PID". But the monitoring instrument must indicate other unreferenced PIDs in the transport stream as erroneous. The situation is similar when the transport streams transmitted by a network operator include known, sporadic errors that are to be ignored as long as they only last for a specified period of time. Otherwise, too many alarms would be triggered.

State-of-the-art monitoring systems such as the R&S®DVM digital video measurement system from Rohde&Schwarz allow you to define a period of time for a measurement during which detected errors are to be "hidden". The PIDs of the transport stream packets concerned can also be entered. FIG 8 shows the configuration of the "Hiding of Events" function provided by the R&S®DVM for such cases.

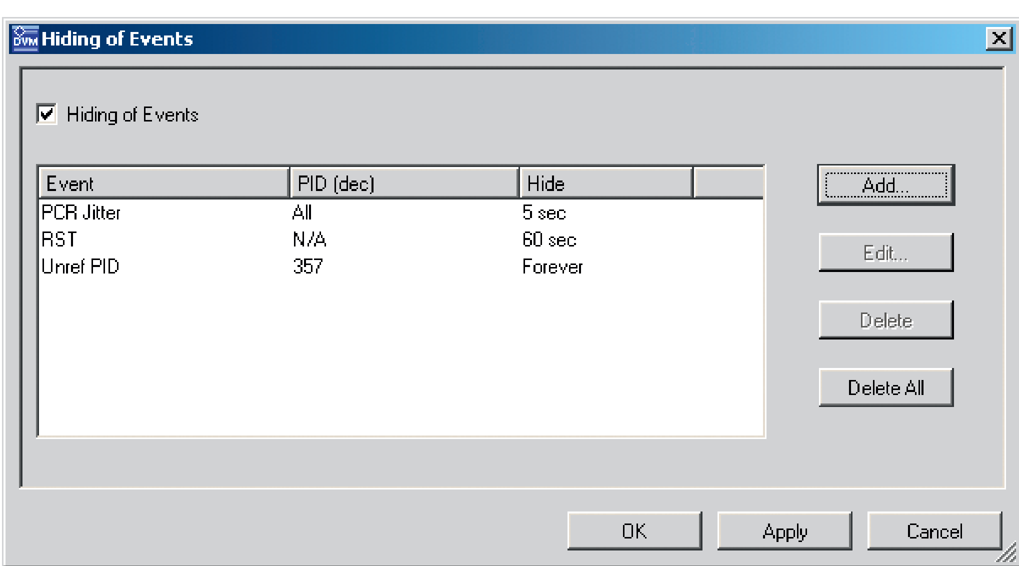


FIG 8
Configuration of the "Hiding of Events" function in the R&S® DVM digital video measurement system from Rohde&Schwarz.

Template monitoring

When using the template monitoring function you have to store numerous characteristics of the signals to be monitored. Since template creation is very time-consuming, things should best be kept simple and easy. The most convenient way would be to let the monitoring instrument do this. The signal is fed to the monitoring instrument for analysis purposes and the template is automatically created based on the data obtained. An additional editing function is required for manual modifications. FIG 9 shows the editor of the R&S®DVM with an open template. The automatic template creation function can directly be accessed from the editor. It is started with the "Create Template from current TS "Golden Stream" …" key.

Since the time-specific structure of transport streams may vary, the monitoring instrument must be able to automatically switch between different templates. This should be supported by the remote-control interface and a Scan mode provided by the instrument.

Scan mode

If you do not have a budget to buy monitoring systems that are able to monitor all signals at the same time, you can monitor the signals one after the other using one measurement and demodulator unit. The unit must be equipped with a function to allow the time-based switchover of modulation parameters and of the complete measurement configuration. This mode, which is referred to as the Scan mode, calls for options for setting a time-specific sequence and for defining multiple measurement configurations. This mode can also be used if the transport stream structure of the same channel changes on a time basis.

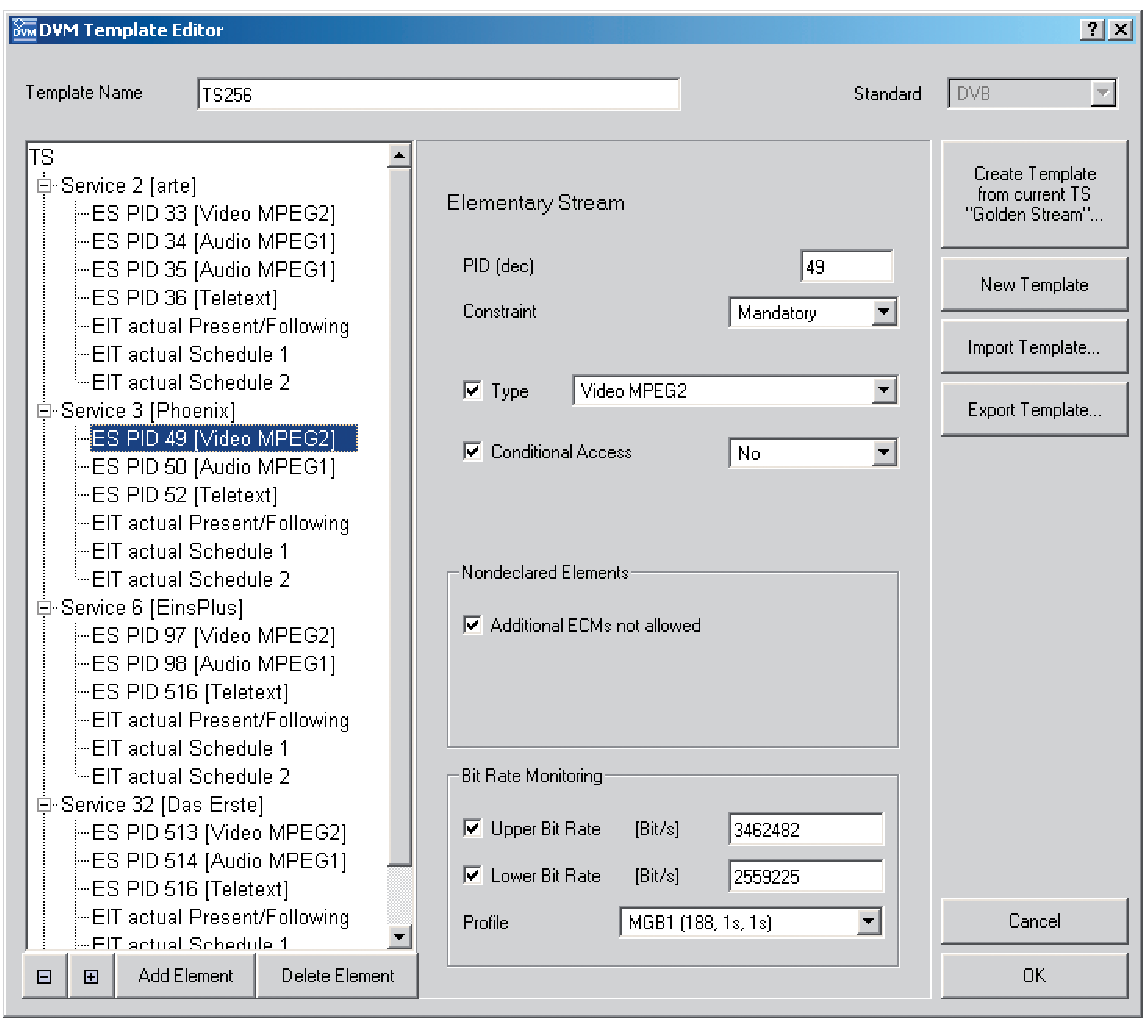


FIG 9 Template editor of the R&S®DVM.

State-of-the-art interface reduces effort

When you have such a large number of functions and related configuration options, you need a perfectly intuitive operating concept. This includes context-sensitive menus and convenient help functions which make operation easier. The user interface should be similar to conventional standard software so that no extra effort is required in order to become familiar with the instrument. Information must be clearly displayed in one window at a defined screen position and should not be spread over several windows. Another important aspect is that the overall status of each measured signal is permanently displayed even if detailed results are being displayed or in-depth analyses are being performed.

Alarm generation over any distance

If errors occur in signals, you have to be informed immediately and in complete detail. This allows you to quickly respond in case of emergency. An alarm can be indicated, for example, by a clearly visible graphical display on the screen. If alarms should be triggered in another room, e.g. via acoustic or optical signaling devices, the monitoring instrument must be equipped with relay contacts. If the monitoring instrument is at a remote location, it must be equipped with a network interface including the corresponding protocol to trigger alarms. The SNMP protocol is used as standard.

Wide variety of report functions facilitate operation

All errors detected by the monitoring instrument must be recorded and automatically archived to help ensure a detailed analysis or in order to provide proof for contracting partners. In combination with advertising contracts, for example, you can thus prove the availability of a system. Sorting and filtering functions for report entries facilitate the analysis. Statistics, e.g. in the form of counters for the individual error types, are also convenient.

In addition to solely documentating measurement results, the recording of a transport stream segment at the occurrence of the error is also important. It may prove helpful during error analysis or serve as relevant proof for third parties. The essential aspect about this recording function is that the error is part of the recorded segment and that the recording is archived automatically.

Indispensable: Monitoring instruments must be communicative

Monitoring instruments must be operable by remote control and they must be able to report errors themselves. That's because users who need access to the monitoring results or have to perform in-depth signal analyses are not always present at the site of the monitoring instrument. And in some cases, monitoring instruments may be located at unattended stations or stations that are difficult to access. If multiple, spatially separated monitoring points are involved, the best solution is to route all measurement results to a central PC. For this reason, monitoring instruments must be equipped with a network interface that supports a corresponding protocol. Ethernet with 10, 100, or 1000 Mbit/s is regarded as standard.

Manual remote control and query of measurement results

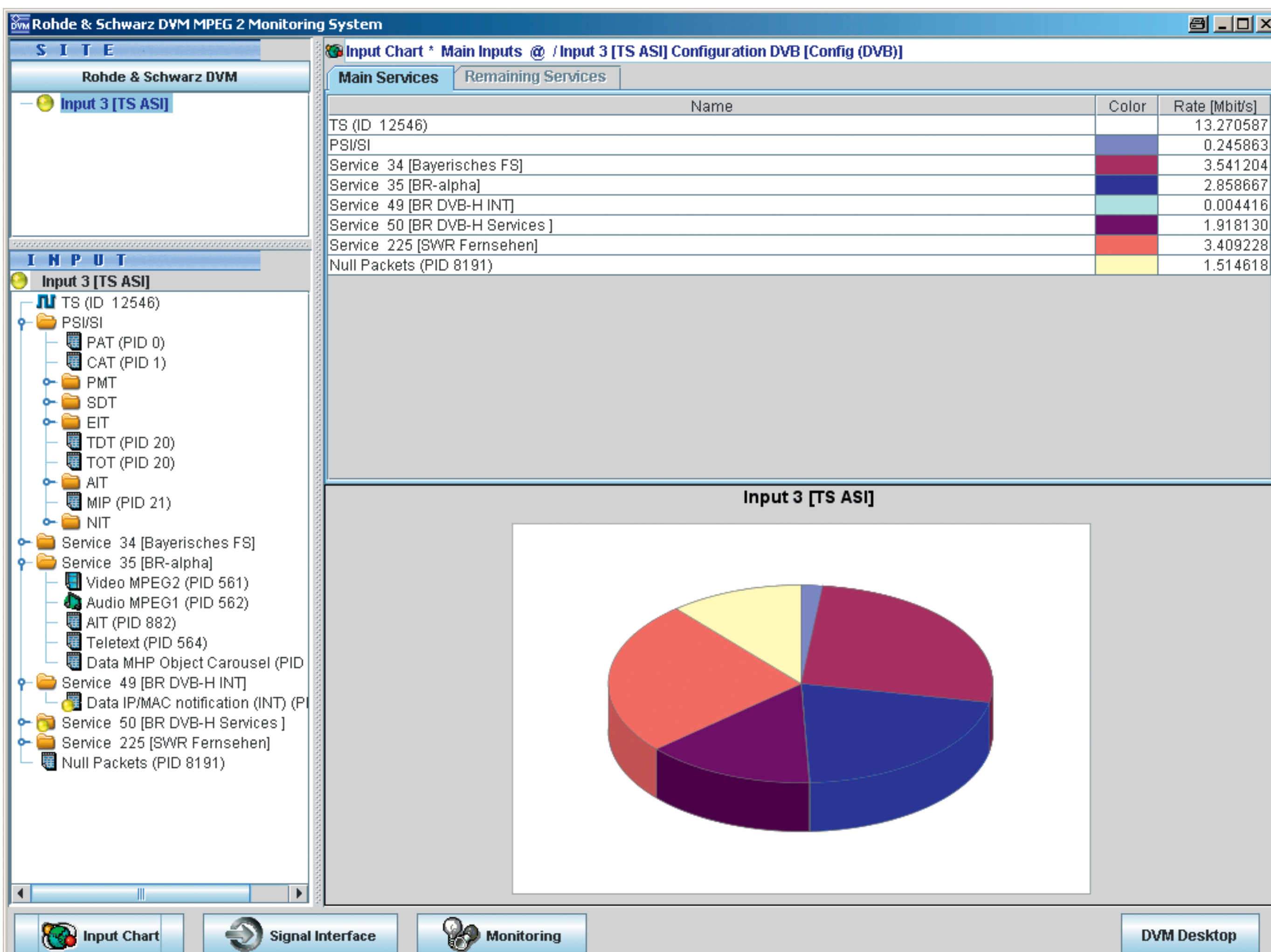
State-of-the-art monitoring instruments are equipped with an integrated web server allowing you to conveniently access the instrument via a conventional browser. If the web server is configured in such a way that, on access, a Java application is downloaded from the monitoring instrument to the client PC and then started, operation is particularly convenient and the graphical display on the client PC is optimized.

FIG 10 shows the Java-based display of measurement results of the R&S®DVM digital video measurement system on the client PC as an example – with the data rate displayed in a graphical form.

Moreover, the display on the client PC should correspond to that of the monitoring instrument so that you do not have to familiarize yourself with two different forms of displays and operating concepts.

Of course, the remote-control interface must be protected against unauthorized access. This can be implemented via passwords and different user rights. For example, a user with a low authorization level may only have read access to measurement results. In the next-higher level, you are authorized to change configurations, and as a fully authorized user, you are authorized to modify the entire system. The remote-control interface must also support the simultaneous access to the monitoring instrument by multiple users.

FIG 10
Display of R&S® DVM measurement results on the client PC.



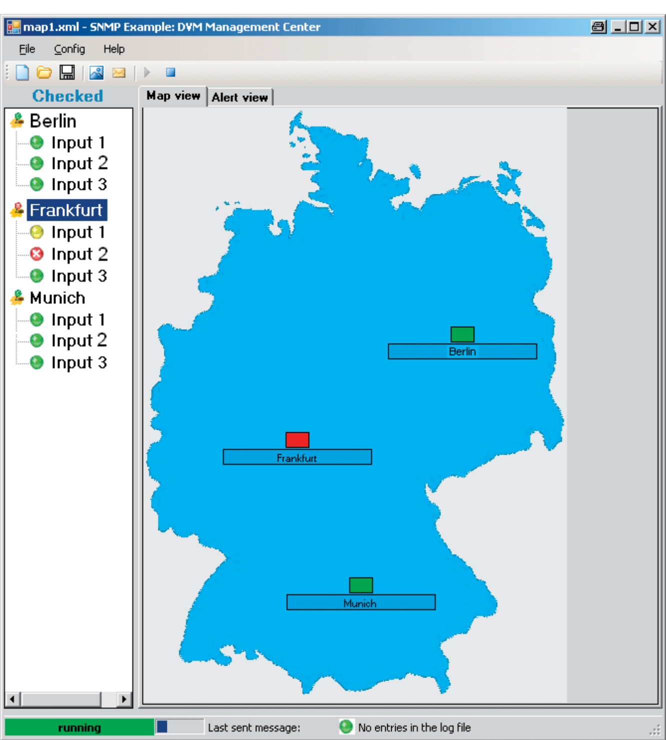
Integration into network management systems

SNMP is used as standard to integrate the monitoring instrument into network management systems. This protocol enables you to read and write individual variables in the monitoring instrument, and thus query measurement results and modify configurations. If monitoring instruments are equipped this way, errors detected by the instrument can be sent as traps, i.e. information units describing an error, to previously specified client PCs in the network. This function is used to notify you at a remote location and to trigger an alarm, if required.

The functionality of an SNMP interface is described by a file, the management information base (MIB). The MIB should cover all relevant device functions as only these functions are supported by the remote control interface.

FIG 11 shows how all monitoring results from multiple instruments are displayed on a single monitor. This application is fully based on SNMP. You can click one of the location symbols to connect to the web server of the corresponding monitoring instrument.

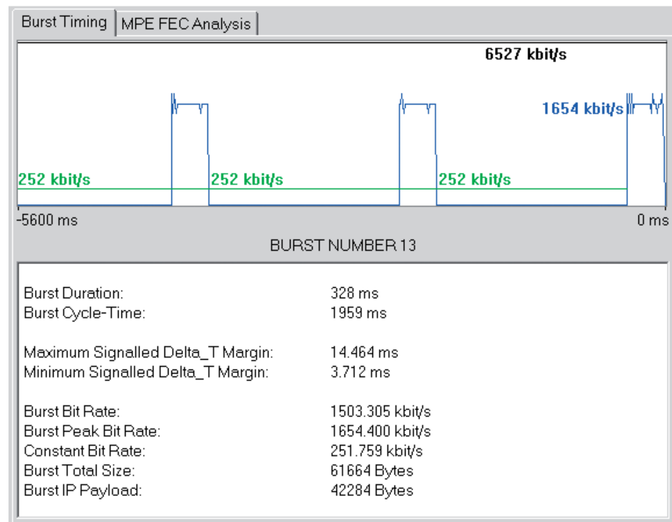
FIG 11
Example showing the measurement results of multiple monitoring instruments displayed in a single window.



Analysis functions are convenient

It is often convenient if the monitoring instrument allows you to graphically display the measurement results and to perform in-depth analyses, like the R&S®DVM (FIG 12) does. In this case, the monitoring functions must not be interrupted.

FIG 12
Time slicing analysis of a DVB-H service.



Same program display as on TV set

It is convenient to display the picture contents of the program in the same way as on the TV set, i.e. as watched by the television viewer. At a mere glance, you can thus see whether the transmission system fulfills its major task. The programs can directly be displayed on the instrument itself or – via a physical interface – on an external monitor. If you want to display the programs on an external monitor, you need a hardware decoder. The picture quality can also be evaluated far better than with a software decoder. Either you select the program, or the monitoring instrument automatically switches from one program to the next. The "Thumbnail Display" function simultaneously displays multiple programs in a very small format and cyclically refreshes the display.

When a monitoring instrument is operated via the remote-control interface, it would be convenient to have a function for streaming all program-specific data to the client PC on which the program is visualized.

Wide scope of functions at minimum space requirements

The space for monitoring instruments is frequently limited, i. e. the instruments have to be quite small. If an instrument can simultaneously monitor multiple signals and standards, operation and integration is further optimized since you only have to work with one operating and one remote-control interface. If a network has to be subsequently expanded to broadcast further programs, it should be easy to upgrade the monitoring instrument accordingly.

Summary

This article shows that monitoring the transmission and distribution of digital TV signals is a complex task. When the specifications for a monitoring system are being defined, the monitoring objectives as well as the function and structure of the network to be monitored are the key aspects. Measurement functions and measurement points can be derived from them. The higher the number of measurement points and the more complex and detailed the measurements, the better the information about signal characteristics, signal errors, and their cause – and – likewise, the more specific and faster the response to alarms. The installation and configuration effort as well as the required budget are opposed to the number of measurement points, the measurement effort, and the measurement depth.

A monitoring system is considered to be good if you can strike the best compromise among the above and select the correct monitoring instruments. The monitoring instrument must provide the required monitoring functions as well as simple and flexible configuration options to meet the specific requirements of the signals to be monitored. The effort and flexibility required for integration and operation depend to a great extent on the additional functions and characteristics provided by the monitoring instruments.

Thomas Tobergte

Abbreviations

ATM	Asynchronous transfer mode
BER	Bit error ratio
CRC	Cyclic redundancy check
DTS	Decoding time stamp
DVB-C/S/T	Digital video broadcasting – cable / satellite / terrestrial
IP	Internet protocol
MER	Modulation error ratio
MFN	Multifrequency network
MIB	Management information base
PCR	Program clock reference
PER	(MPEG TS) packet error ratio
PID	Packet identifier
PTS	Presentation time stamp
SFN	Single frequency network
SNMP	Simple network management protocol

More information and data sheets at
www.rohde-schwarz.com
(search term: DVM)

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