Easy Analysis and Precise Optimization of ATSC or ATSC Mobile DTV Single-Frequency Networks
Application Note

Products:

- R&S®ETL

Keeping an ATSC (or ATSC Mobile DTV) single-frequency network (SFN) running smoothly not only requires that every single TV transmitter functions properly – the RF performance criteria echo pattern and frequency deviation also have to be strictly complied with.

The R&S®ETL TV analyzer enables operators to check these crucial RF parameters at a glance with unmatched precision.

The patented implementation achieves an echo delay resolution of one nanosecond, which is nearly a hundred times higher than in conventional approaches.

This allows more precise control and adjustments of the several transmitters within the ATSC (or ATSC Mobile DTV) SFN and thus helps to ensure excellent coverage for the receivers.

Application Note

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ROHDE&SCHWARZ

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1 Overview

By June 12, 2009, the transition from terrestrial analog (ATV) to digital (DTV) television broadcasting has to be completed in the United States. However, network operators trying to use their old radio tower infrastructure also for the new digital signals will likely face the so called "cliff effect": Regions of poor but still operational ATV reception will no longer be covered, since digital video quality does not degrade smoothly like on analog channels, but abruptly (the "cliff"). Increasing the transmitter's power mainly brings about additional costs, but not the intended amount of coverage enhancement. Introducing translators as gap fillers also results in an inefficient cost increase, as additional TV channels have to be allocated.

Interestingly, the new digital technology permits a solution that was not possible during analog times: Single-frequency networks (SFNs) caused annoying ghosting in ATV, but thanks to training sequences and equalizers, DTV multi-path reception can be handled error free.

The importance of SFN solutions was recently attested to by the Federal Communications Commission (FCC) in its report and order document 08-256 [1], easing authorization for the major subclass of SFNs, the distributed transmitter systems (DTS). In the past, a special temporal authority (STA) was required.

In the case of ATSC Mobile DTV networks, SFNs are more or less mandatory, since multi-path reception significantly eases reception for mobile devices, which suffer from small, low-gain antennas and sudden shadowing due to movement.

This section first describes the SFN concept. Next, the important measurements for failure-free operation are derived. Finally, the easy and precise solution using the R&S®ETL TV analyzer is presented.

1.1 Single-Frequency Network

Due to the limited coverage area of a single radio tower, TV broadcast networks are structured in cells. Two different approaches exist:

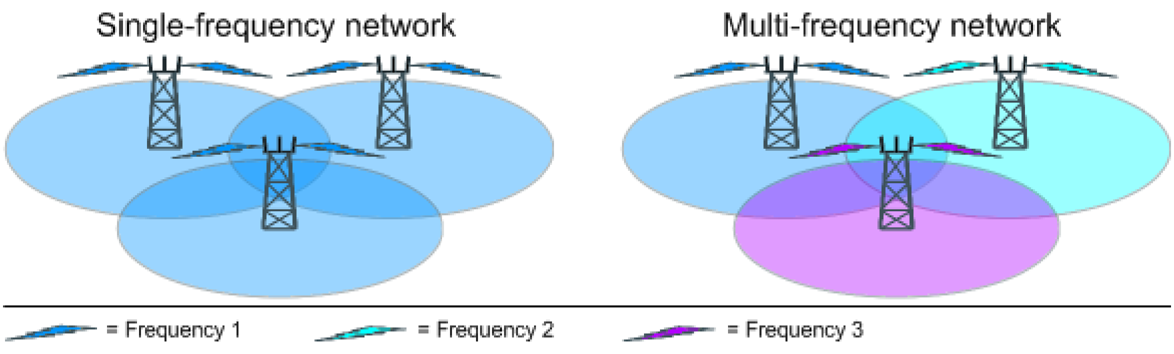


Fig 1: Single-frequency and multi-frequency approach for a cell structured network

1.1.1 Mode of Operation

ATSC (or ATSC Mobile DTV) transmitters can be run as a single-frequency network (SFN), in which all towers send the same program content at exactly the same frequency and same time. This makes efficient use of the scarce frequency resource, leaves more room for frequency planning, allows far more accurate coverage planning and, last but not least, contributes to cost-efficient operation, particularly in areas with difficult geographic conditions.

At the receiver, ATSC (or ATSC Mobile DTV) SFN signals arrive at different times due to distance-dependent path delays. To optimize SFNs – e.g. to take special ranges of individual transmitters into account – an individual delay can additionally be set for each transmitter.

As an additional reception path distance of 91.45 feet already causes a delay equal to the symbol time, intersymbol interference is inevitable and tolerated to a certain extent. That is why in ATSC (or ATSC Mobile DTV) systems, known training data is periodically inserted by the transmitters to allow the use of a symbol restoring equalizer in the receiver.

1.1.2 Crucial Measurements

To ensure that all SFN transmitters comply with the time-specific synchronization and the transmit frequency, they are linked to a reference time standard. Global positioning system (GPS) information is provided for this purpose. But if GPS fails, for example, an intact transmitter may soon become the source of a failure. In this case, the transmit frequency and the set delay time of the transmitter will slowly drift, which finally leads to co-channel interference. This will also happen if the delay time or even the transmit frequency is incorrectly set due to an operator error on site. A frequency deviation of only a single hertz already significantly cuts down the system's security margin.

In both cases, the resulting co-channel interference may cause reduced radio coverage, a loss of synchronization at a receiver, or even the complete failure of the TV broadcast service. This is why precise echo pattern and frequency deviation measurements are vital for efficient installation and operation of an SFN.

1.2 R&S®ETL TV Analyzer

Fig 2: R&S®ETL TV analyzer

This multistandard instrument 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.

Another highlight is its easy and comprehensive ATSC SFN measurement solution of unmatched precision, which covers the analysis of the different signal levels, delay spread and frequency deviation. It 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.

1.2.1 Unmatched SFN Measurement Precision

Temporal delay
The R&S®ETL measures the delay between the certain signals of the participating SFN towers with a resolution of a single nanosecond, which is almost only one hundredth of the symbol time. This allows even earlier and more precise detection of slight temporal drifts at a single transmitter site. The horizontal scale can be changed from the time domain (μs) to the distance domain (miles, km).

Frequency deviation
To verify whether all transmitters actually transmit at the same frequency, it was previously necessary to measure the frequency at each and every transmitter location – a time-consuming method. The test receiver used for this purpose was itself required to be locked to a precision reference frequency to ensure that measurements were performed with the stipulated accuracy.

A patented method developed by Rohde & Schwarz now provides the solution to this problem. The R&S®ETL-K221 ATSC SFN frequency offset option indicates, for each signal, the frequency deviation relative to the main signal with an accuracy of <0.3 Hz. Since the frequency deviation is determined as a relative value, a reference frequency is not necessary, which greatly facilitates measurements. The R&S®ETL immediately indicates whether the frequency of one or more transmitters in the network deviates from that of the main transmitter.

1.2.2 ATSC (or ATSC Mobile DTV) SFN Measurement Range

In order to perform this kind of measurements, the R&S®ETL has to synchronize on the desired RF signal first. This requires the following conditions to be met:

1. Main signal power condition

- The power of the main (strongest) signal received has to be in the range of -70 dBm to +20 dBm

2. Delay conditions

- The relative delay of an echo received has to be in the range of -10 µs to +40 µs
- The delay spacing between each signal received has to exceed 1 µs

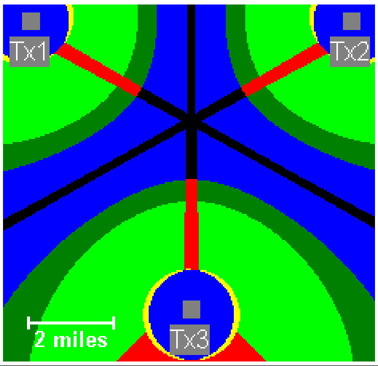
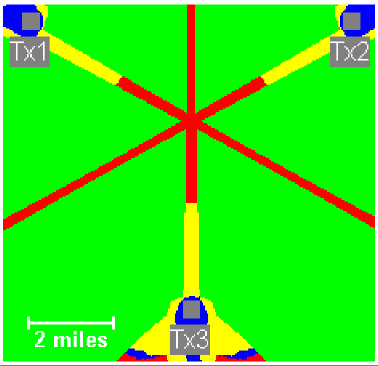
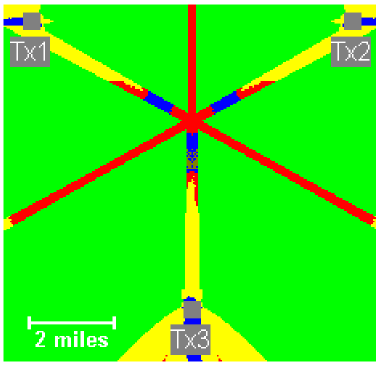
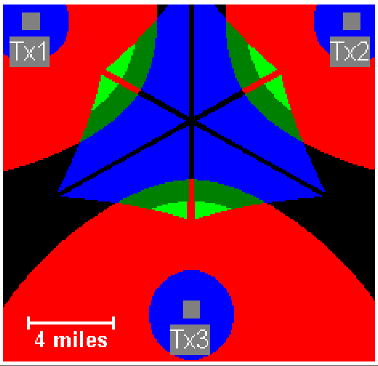
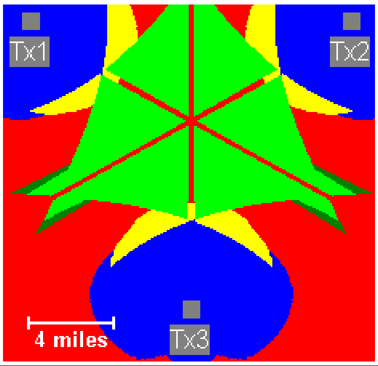
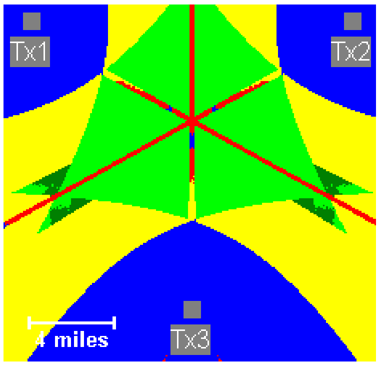
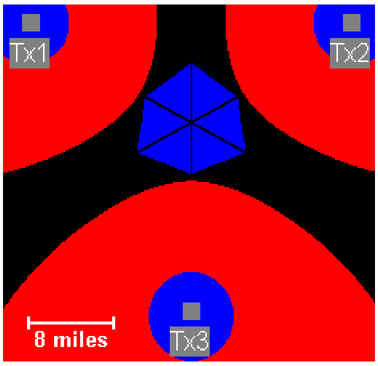
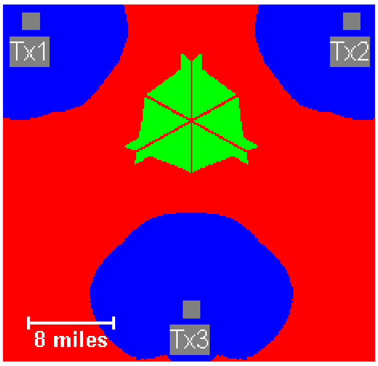
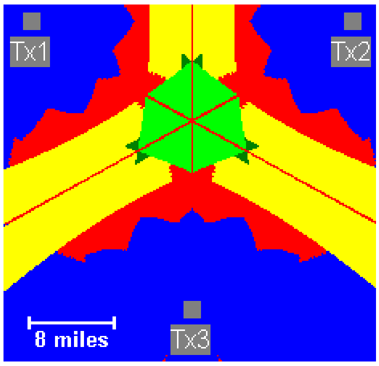
3a. Power conditions for measuring up to 1 Hz maximal frequency deviation

- The relative power sum of all trailing echoes may not exceed -8 dB
- The relative power sum of all leading echoes may not exceed -16 dB

3b. Power conditions for measuring up to 5 Hz maximal frequency deviation

- The relative power sum of all trailing echoes may not exceed -13 dB
- The relative power sum of all leading echoes may not exceed -20 dB

The impact of these conditions on the measurement range is illustrated in the following table, where the case of three SFN transmitters radiating with equal powers in an equilateral triangle constellation is analyzed:

Isotropic antenna	Directional antenna, 90°/270°: -16 dB, 180°: -24 dB	Directional antenna, 90°/270°: -45 dB, 180°: -25 dB
7.5 airline miles transmitter distance		
		
15 airline miles transmitter distance		
		
30 airline miles transmitter distance		
		

Legend		
No synchronization, because…	Measurements possible up to 1 Hz maximal frequency deviation of…	Measurements possible up to 5 Hz maximal frequency deviation of…
…delay conditions violated	…two transmitters	…two transmitters
…power conditions violated	…three transmitters	…three transmitters
…delay and power conditions violated		

Table 1: Illustration of the ETL® ATSC (or ATSC Mobile DTV) SFN measurement range

The interpretation of table 1 leads to the following results:

- The delay conditions only allow the measurement to take place roughly within the radius of 7.5 miles around the circumcenter of the triangle formed by the transmitters.
- The power conditions, however, force quite the opposite situation, since the transmitters reach the circumcenter with almost the same power, violating the differences in power required.
- But this last issue can be overcome by the use of a directional antenna with a high front-to-back ratio (e.g. YAGI). In addition, an even stronger suppression of the 90°/270° sidelobes can mask out a certain transmitter to such an extent that the two remaining ones can be measured in an enlarged range, shown in yellow. Finally, directional antennas solve the problem of assigning the several transmitters to the particular signals detected, as the transmitter within their beam is significantly emphasized over the others.

This simple simulation does not account for different transmitter powers, transmitter delays or terrain topology, so the illustration given can only serve as a first approximation.

Especially in the case of other transmitter constellations/numbers or heavy terrain shielding/reflections, suitable measurement positions have to be derived by meeting the stated distance and power conditions with the aid of the SFN planning software used.

2 Configuration

This section describes how the R&S®ETL TV analyzer has to be configured for the ATSC (or ATSC Mobile DTV) SFN measurements.

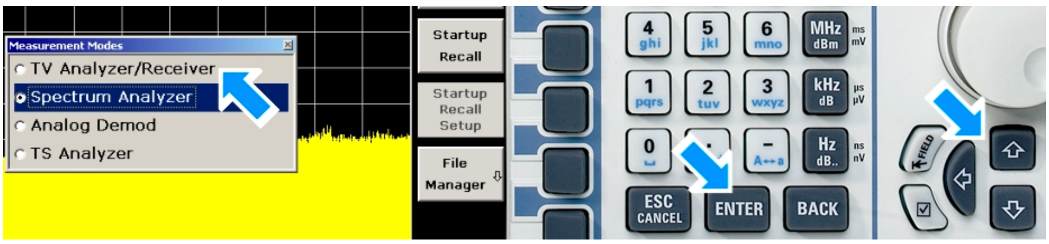
2.1 Options Required

- R&S®ETL-K220: "ATSC/8VSB firmware"
- R&S®ETL-K221: "ATSC/8VSB SFN frequency offset"
- R&S®ETL-B203: "RF preselector"

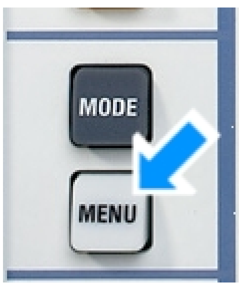
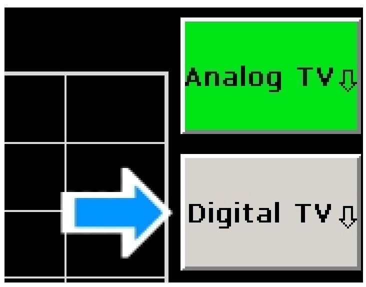
Please see section seven "Ordering Information" for details.

2.2 Device Setup

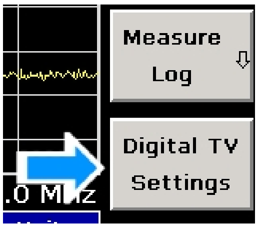
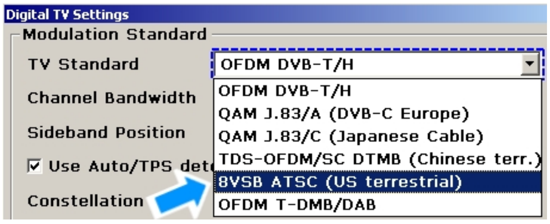
1. TV application selection

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>a) Press the "MODE" button located to the left of the screen.</td><td>b) Then use the cursor buttons on the right to select "TV Analyzer/Receiver".
c) Finally confirm with the "Enter" button.</td></tr>
</table>

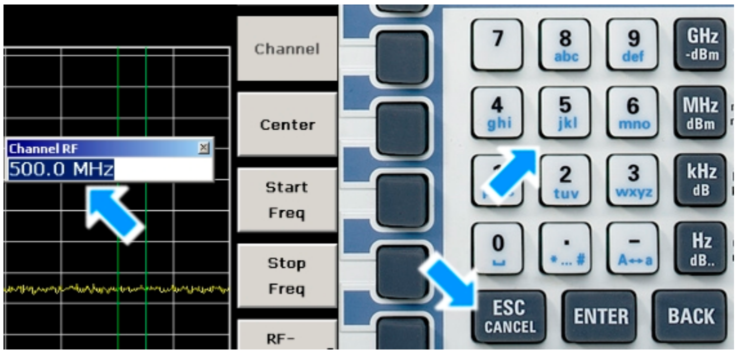
2. Digital TV mode selection

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>a) Press the "MENU" button located to the left of the screen.</td><td>b) Then press the "Digital TV" soft-key at the right of the screen if it is not highlighted green already.</td></tr>
</table>

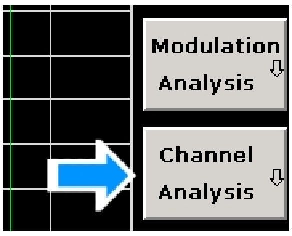
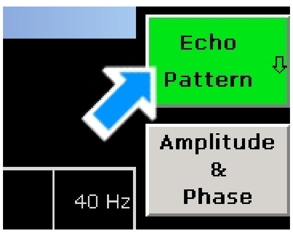
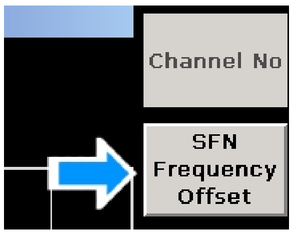
3. ATSC mode selection

		
a) Press the "Digital TV Settings" softkey at the right of the screen.	b) Then select "8VSB ATSC" in the "TV Standard" list.	c) Finally close the popup window by pressing the "ESC" button.

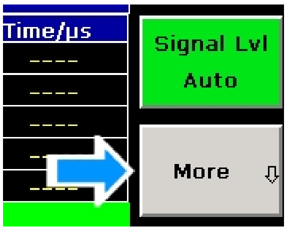
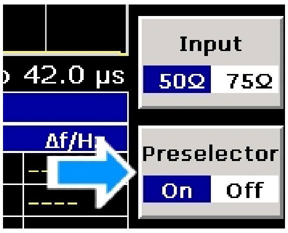
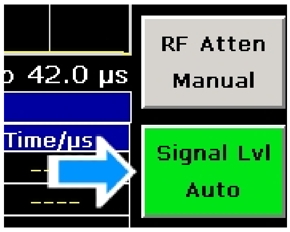
4. RF frequency selection

	
a) Press the "FREQ" button located to the top right of the screen.	b) Then enter the desired frequency by using the keypad and the unit key (MHz). c) Finally close the popup window by pressing the "ESC" key.

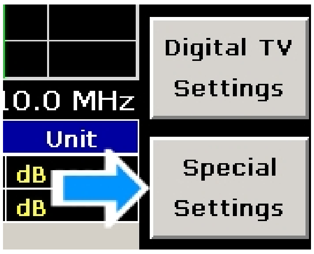
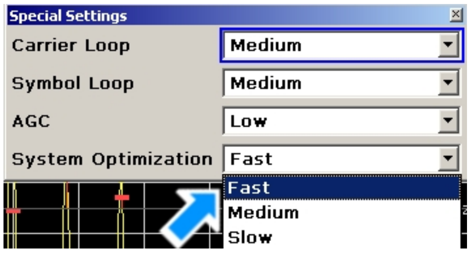
5. SFN measurement mode selection

		
a) Press the "Channel Analysis" softkey lat the right of the screen.	b) Then select "Echo Pattern", even if already highlighted green.	c) Finally enable the "SFN Frequency Offset" softkey so that it is highlighted green.

6. Signal power & preselector settings

			
a) Press the "AMPT" button located to the top right of the screen.	b) Continue by pressing the "More" softkey...	c) ...and make sure the "Preselector" softkey is activated.	d) Then press the "AMPT" button again and select "Signal Lvl Auto", if not already highlighted green.

7. System optimization configuration

			
a) Press the "MEAS" button located to the top right of the screen.	b) Then press the "Special Settings" softkey.	c) Choose "Fast" in the "System Optimization" list.	d) Finally close the popup window by pressing the "ESC" button.

3 Measurement

The R&S®ETL offers precise analysis functions for each of the three criteria – transmitter frequency, differences in delay and receive level – and presents results at a glance in a single measurement window:

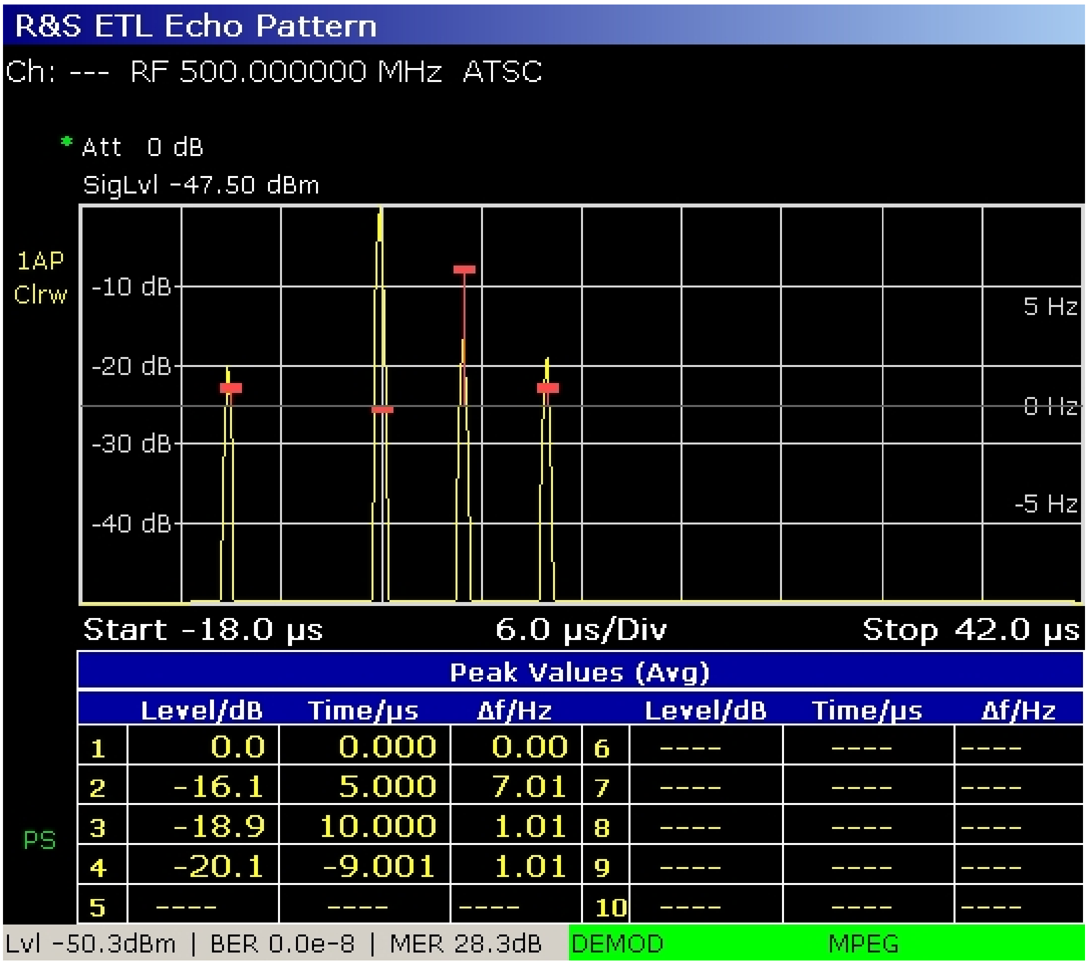


Fig 3: R&S®ETL ATSC (or ATSC Mobile DTV) SFN measurement screen

The upper part of the screen provides a graphical presentation in the time domain. For each transmitter, the detected level [dB, absolute or relative] (left y-axis, yellow plot), delay [seconds or miles] (x-axis) and frequency offset [Hz] (right y-axis, red plot) are shown, while the strongest signal serves as the reference on the x-axis. A zoom and center function facilitates navigation within a trace, allowing even extremely narrow pulses and pulses located closely together to be analyzed in detail.

A particularly valuable aid is the result table displayed at the bottom of the screen, which directly refers to its graphical counterpart. It lists up to ten signals according to level or delay/distance. Level values are displayed as relative values referenced to the main signal. As the absolute levels of echo signals at the site of reception are also of interest, especially in the case of coverage measurements, the R&S®ETL allows you to choose between relative or absolute level display.

4 Abbreviations

ATSC	Advanced Television Systems Committee
ATV	Analog television
DTS	Distributed transmitter system
DTV	Digital television
FCC	Federal Communications Commission
GPS	Global positioning system
RF	Radio frequency
R&S	Rohde & Schwarz
SFN	Single-frequency network
STA	Special temporal authority

5 Literature

[1] FCC Report and order 08-256,
"Re: Digital Television Distributed System Technologies",
http://www.fcc.gov/Daily_Releases/Daily_Business/2008/db1107/FCC-08-256A5.pdf

6 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.

7 Ordering Information

Designation	Type	Order No.
Base unit		
TV Analyzer, 500 kHz to 3 GHz, with tracking generator	R&S®ETL	2112.0004.13
Required options		
ATSC/8VSB Firmware	R&S®ETL-K220	2112.0456.02
ATSC/8VSB SFN Frequency Offset	R&S®ETL-K221	2112.0462.02
RF Preselector	R&S®ETL-B203	2112.0327.02
Recommended options		
Measurements on ATSC (or ATSC Mobile DTV) transmitters		
OCXO Reference Frequency	R&S®FSL-B4	1300.6008.02
Power Sensor Support	R&S®FSL-K9	1301.9530.02
Measurement Log	R&S®ETL-K208	2112.0579.02
Hard Disk 80 Gbyte	R&S®ETL-B209	2112.0291.02
MPEG analysis and A/V decoding		
MPEG Processing Board	R&S®ETL-B280	2112.0362.02
Video and Audio Hardware Decoder	R&S®ETL-B281	2112.0356.02
HDTV and Dolby Upgrade	R&S®ETL-K281	2112.0604.02
MPEG Analysis/Monitoring	R&S®ETL-K282	2112.0610.02
In-Depth Analysis	R&S®ETL-K283	2112.0627.02
Data Broadcast Analysis	R&S®ETL-K284	2112.0633.02
DC and battery operation		
DC Power Supply 11 V to 19 V	R&S®ETL-B230	2112.0256.02
Li-Ion Battery Pack 10 Ah	R&S®ETL-B235	2112.0262.02
Miscellaneous		
Documentation of R&S®ETL Calibration Values	R&S®ETL-DCV	2082.0490.31

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.

Environmental commitment

- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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