ROHDE&SCHWARZ

BROADCASTING DIVISION

Application Note

Fading
Channel Simulation in DVB

Products:

TV Test Transmitter	*SFQ*
Option Fading Simulator	*SFQ-B11*

7BM05_1E

Contents

Fading, Channel Simulation in DVB

1 Introduction **3**

2 Basic Elements of Fading **3**
2.1 CONSTANT PHASE **3**
2.2 PURE DOPPLER **4**
2.3 RICE Fading **5**
2.4 RAYLEIGH Fading **7**
2.5 LOG NORMAL Fading **7**
2.6 Gaussian Channel **8**

3. Channel Simulation with SFQ Fading Simulator Option B11 ..... **9**
3.1 Definition of Real Conditions **9**
3.2 RF Levels of Fading Profiles **10**
3.3 VALIDATE 100 .... **10**
3.4 EASY 3 EASY, 3 km/h **10**
3.5 REGULAR TU50 REGULAR REDUCED TYPICAL URBAN, 50 km/h **11**
3.6 RED HT100 REDUCED HILLY TERRAIN, 100 km/h **11**
3.7 RED6 DVB-T REDUCED DVB-T ANNEX B, 6 PATHS **11**
3.8 ET 50 EQUALIZATION TEST, 50 km/h **12**
3.9 DIFFICULT RA250 DIFFICULT RURAL AREA, 250 km/h **12**

4 Outlook **13**

Fading, Channel Simulation in DVB

1 Introduction

Fading is known from shortwave transmission, where the received field strength level may strongly vary due to atmospheric disturbances. In analog TV, the term "fading" is practically unknown. Rather, one talks of "antenna shadows" or "ghost images". The effect in question, however, is fading, ie constant reflection of the eletromagnetic waves emitted by the TV transmitter by walls of buildings, mountain slopes and similar reflecting natural or artificial obstacles. In analog TV, fading is of minor importance since the effects thereof can be eliminated almost completely through the directivity and exact orientation of the Yagi roof antenna for stationary TV reception at home.

Fading effects can also be observed in analog cable TV, for example in a block of flats linked to the cable network with one or several antenna sockets in every flat. If the taps for the sockets are not match-terminated, reflections with constant level and constant phase arise which may cause level reductions of several dB at exactly calculable points in the cable.

Moreover, the reception of TV signals broadcast via satellite can be impaired by fading. A known phenomenon is flickering of the received picture, produced by planes flying past or a drop in receive field strength caused by an approaching thunderstorm.
All the above receive conditions have one thing in common: reception is stationary with a direct line of sight to the TV transmitter.

Looking at receive conditions in DVB, the effects in cable and satellite reception (DVB-C and DVB-S) are found to be similar as in analog reception. In these two modes reception is stationary, too.
Terrestrial transmission (DVB-T) not only provides for stationary operation but also for portable and mobile reception. This considerably accentuates the effects of fading.

In this application note we investigate fading effects in DVB, with the emphasis on those in DVB-T signals.

2 Basic Elements of Fading

2.1 CONSTANT PHASE

The first basic element of fading is reflection. Reflections or echoes occur at all obstacles in the propagation path of waves. Echoes are described by the reflected level and the phase shift caused by reflection. The level and phase shift depend on the reflecting material.
Example:
Reflection of a wave at a plane metallic surface will produce no level loss but a phase shift of 180°.
Reflection at the wall of a building, however, will produce a large level loss and an undefined phase shift.

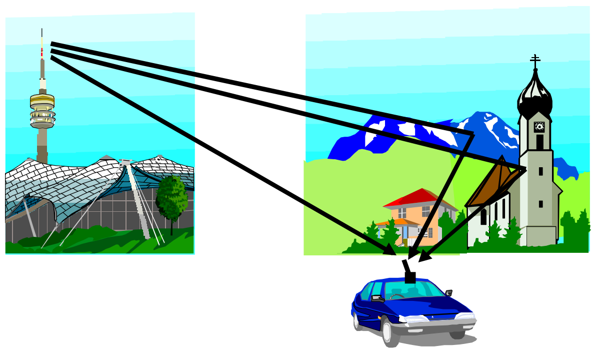


Fig. 1 Echoes

The determining parameters are:
- path loss (dB),
- delay relative to direct path (ns),
- phase angle (deg).

This type of fading is referred to as "constant phase".
Looking at a single carrier of the COFDM signal, the effects on the receive signal can be seen only from the resulting amplitude. Examining the full spectrum of a DVB signal, however, reveals valleys in the spectrum depending on the number of paths with path loss, delay and phase.

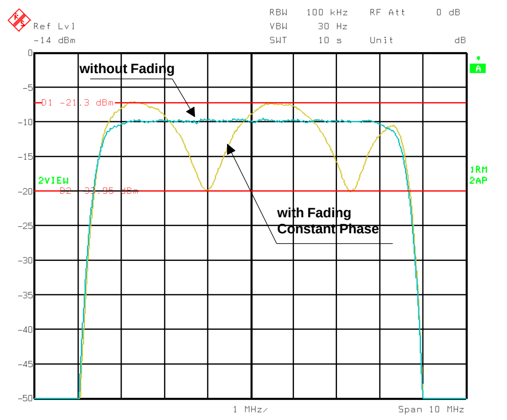


Fig. 2 Constant phase

The blue line in Fig. 2 shows the original spectrum without fading, whereas the yellow line represents the spectrum for CONSTANT PHASE with a second path. The parameter values are as follows:

	Path 1	Path 2
Path loss	2 dB	6 dB
Delay	0 ns	300 ns
Phase	0°	70°

The valleys in the spectrum occur at intervals of Δf = 3.3 MHz, which corresponds to the reciprocal of the path delay (Δf = 1/ delay).
The depth L in dB of the valleys is obtained as follows:

$$L = 20 * \left[\log(10^{\frac{|L1-L2|}{20}} - 1) - \log(10^{\frac{|L1-L2|}{20}} + 1) \right] \mathrm{dB}$$

(1)
where L = depth of valleys
L_1 = loss of path 1
L_2 = loss of path 2
$L_1 \neq L_2$. If $L_1 = L_2$, the depth $L = \infty$.
With more than 2 paths, calculation of the depth is very complex.
Example with 2 paths:

L_1 = 2 dB, loss of path 1
L_2 = 6 dB, loss of path 2
L = 12.91 dB

The reflection phase determines where cancellations occur in the spectrum.
An adaptive equalizer (also referred to as channel estimation) in the receiver compensates for spectral valleys within its dynamic range to ensure undisturbed demodulation even for multipath reception.

The carrier phase further determines the rotation of the demodulated constellation diagram. The constellation diagram of path 2 is rotated 70° compared with that of path 1. This rotation, too, should be compensated by the channel estimation.

2.2 PURE DOPPLER

The second basic element is the Doppler effect, ie the frequency shift resulting from the movement of the receiver relative to the site of a DVB-T transmitter.

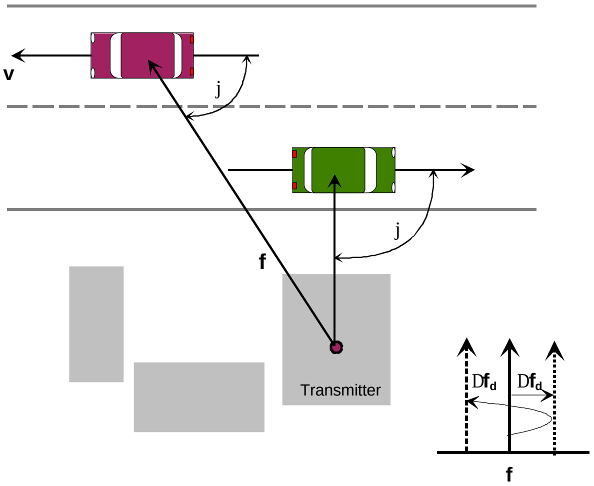


Fig. 3 Doppler effect

The frequency shift Δf_D caused by the Doppler effect is obtained by means of the following formula:

$$\Delta f_{DOPPLER} = v * \frac{f}{c} * \cos(j) \qquad (2)$$

where
v = vehicle velocity
f = carrier frequency of transmitter
c = speed of light (300 000 km/s)
φ = angle between direction of motion and line of sight to transmitter
$0 < \varphi < \pi$

There are three cases:

1. The vehicle is moving towards the transmitter:
$\varphi = 0°$, ie $\cos\varphi = 1$:
the transmit frequency increases by Δf_D.

2. The vehicle is moving away from the transmitter:
$\varphi = 180°$, ie $\cos\varphi = -1$:
the transmit frequency decreases by Δf_D.

3. The vehicle is driving around the transmitter in circles: $\varphi = 90°$, ie $\cos\varphi = 0$:
the transmit frequency remains unchanged, ie $\Delta f_D = 0$.

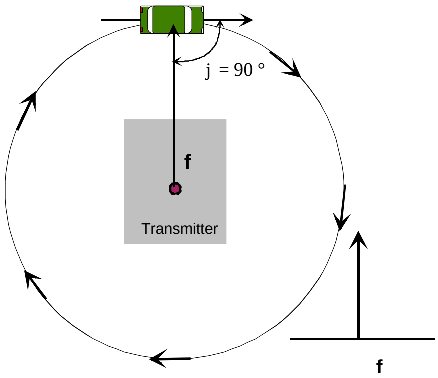


Fig. 4 Case with constant $\varphi = 90°$

If the vehicle moves towards the transmitter from a long distance, passes the transmitter and then moves away from it, the carrier frequency f is Doppler-shifted through the range $f - \Delta f_D \le f \le f + \Delta f_D$, as illustrated by Fig. 3. The shift from f to $f + \Delta f_D$ takes place when the vehicle is moving towards the transmitter.

From (2), the following can be seen:
The Doppler shift $\Delta f_{Doppler}$ is directly proportional to the carrier frequency f of the transmitter. The lower the frequency f, the smaller the Doppler effect in DVB-T, since the OFDM carrier offset remains constant. This is to be demonstrated by two examples:

The vehicle is driving towards the transmitter at a constant velocity of v = 140 km/h.

Example 1:
Carrier frequency f = 50.5 MHz (first DVB-T channel in band I VHF, 7 MHz bandwidth)

v = 140 km/h
= 140 / 3.6 = 38.9 m/s
φ = 0°

The Doppler shift in this case is:

$$\Delta f_{DOPPLER} = 38.9 * \frac{50.5 * 10^6}{300 * 10^6} * 1 = 6.54817 \text{ Hz}$$

Despite the high velocity, the frequency shift is very small relative to the carrier offset of 1116 Hz in the 8k mode.

Example 2
Carrier frequency f = 858 MHz (currently last DVB-T channel in band V UHF, 8 MHz bandwidth)

v = 140 km/h
= 140 / 3.6 = 38.9 m/s
φ = 0°

Here the Doppler shift is:

$$\Delta f_{DOPPLER} = 38.9 * \frac{858 * 10^6}{300 * 10^6} * 1 = 111.254 \text{ Hz}$$

In this case a significant shift is obtained, which is however of little importance in PURE DOPPLER as the frequency shift in the DVB-T channel is

$$\Delta f_{Doppler} * 854/858 = \Delta f_{Doppler} * 0.995$$

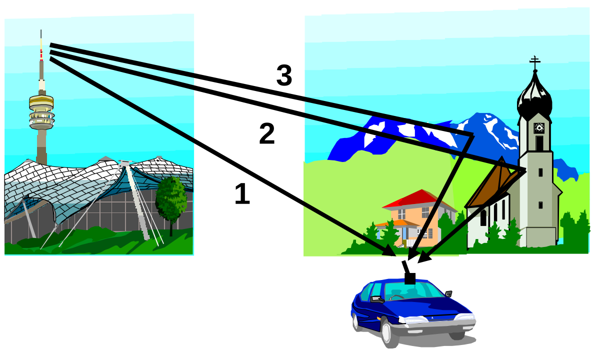
at the lower end of the channel and

$$\Delta f_{Doppler} * 862/858 = \Delta f_{Doppler} * 1.005$$

at the higher end of the channel, and the receiver PLL should have no problems handling such a small offset by means of the channel estimation.

2.3 RICE Fading

The third basic element is Rice fading.
Rice fading is caused by Doppler-shifted echoes with a Gaussian distribution, but in addition there is always a direct path from the Tx antenna to the



Rx antenna. Accordingly, figures 1 and 5 illustrate Rice fading.

Fig. 5 Rice fading

The direct path 1 between the antennas considerably boosts the received field strength level. This path can in mobile reception only be influenced by the Doppler effect. In addition to the direct path, many echoes are received. Since the echoes arrive from different directions, the angle φ for calculation of the Doppler shift is not constant in mobile reception. So the spectrum of Rice fading is obtained:

The angle with the lowest probability is at $\varphi = 90°$, because a vehicle will only in rare cases move around a transmitter in circles. Consequently, the lowest level is found at the frequency f.

High levels are obtained at frequencies $f \pm \Delta f_D$ since the vehicle will with great probability move towards or away from the transmitter for a long time with $\varphi = 0°$ or $\varphi = 180°$ both at large and short distances from the transmitter. Between these two angles, the level distribution is in the form of a bell-shaped curve. It results from Doppler-shifted echoes produced by random reflection at the surrounding buildings, mountains and other natural and artificial obstacles. The level curve represents the sum of all these echoes.

The same spectrum is obtained if the vehicle moves around the transmitter and changes its direction at random. The spectral bandwidth results from the maximum Doppler shift of the single echoes, the Rice peak from the Doppler shift in the direct path. The maximum Doppler shift of the echoes and the shift of the Rice peak are not correlated to each other, since the angles φ of the receive paths hardly ever coincide.
The following spectrum is obtained:

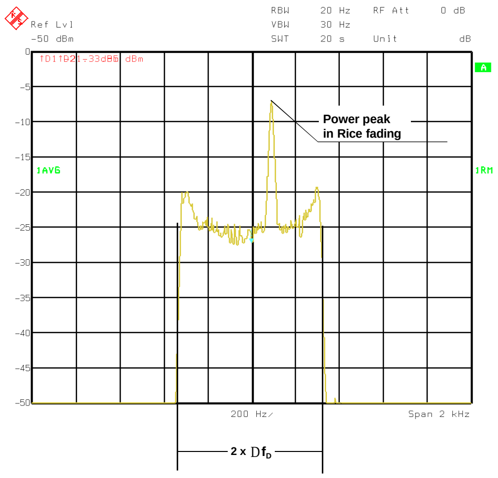


Fig. 6 Rice spectrum of single carrier

Depending on the direction of movement relative to the transmitter, the level peak is shifted towards higher or lower frequencies as a result of the Doppler effect. In Fig. 6, the level peak is at a frequency above f, ie the vehicle moves towards the transmitter but with a transverse component, because the shift is only about $\Delta f_D/3$. The angle of direction φ is calculated as follows:

$$\varphi = \arccos (0.333) = 70°$$

The parameters relevant for Rice fading are:
- Parameters of Doppler effect
- Echo parameters path loss and delay
- Additional parameters for direct receive path (DISCRETE COMPONENT):
  - Power ratio (dB), determines the height of the power peak
  - Frequency ratio, determines the frequency shift relative to Δf_D

LOG NORMAL may be activated in addition (see 2.5, LOG NORMAL Fading).

The received power as a function of time shows level dips that result from the superposition of all echoes with different levels and phases and from the direct path at the receive antenna.

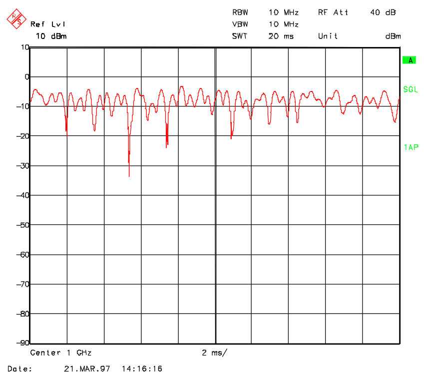


Fig. 7 Rice fading
Level versus time

The level dips have a maximum depth of 25 dB, which is not very large, because the direct path always makes a major contribution to the received power.

2.4 RAYLEIGH Fading

The fourth basic element is Rayleigh fading. Rayleigh fading, same as Rice fading, is caused by Doppler-shifted echoes with a Gaussian distribution, but there exists no direct path from the Tx antenna to the Rx antenna.

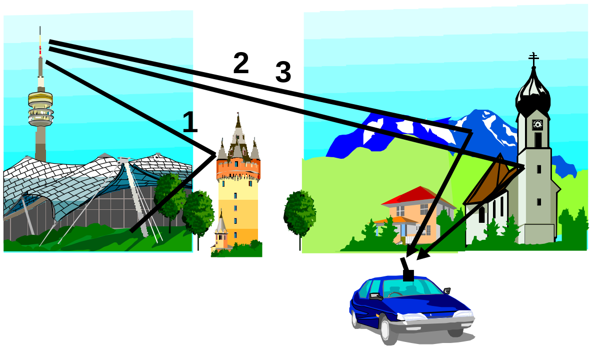


Fig. 8 Rayleigh fading

The parameters relevant for Rayleigh fading are:
    Parameters of Doppler effect
    Echo parameters path loss and delay
Here, too, LOG NORMAL may be activated in addition (see 2.5, LOG NORMAL Fading).
The received power as a function of time shows level dips produced in this case only by the superposition of all echoes with different levels and phases at the receive antenna.

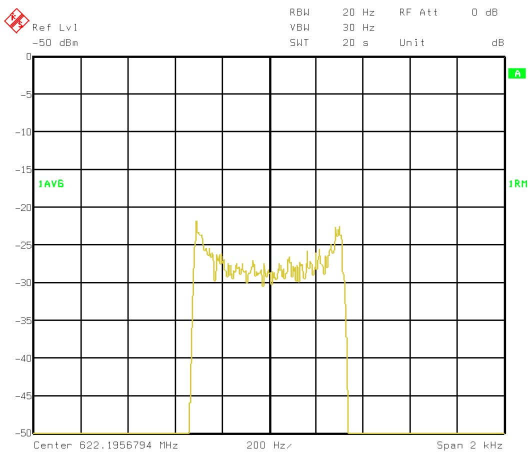


Fig. 9 Rayleigh spectrum of single carrier

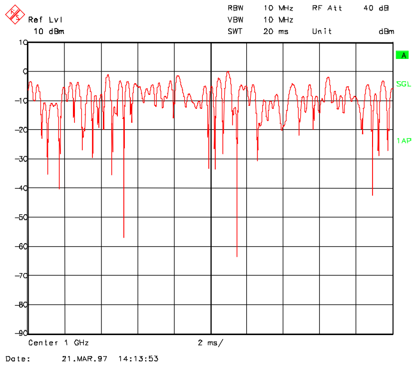


Fig. 10 Rayleigh fading
Level versus time

The level dips have a depth of 60 dB and more because the continuous power component contributed by the direct path in Rice fading is missing here.

2.5 LOG NORMAL Fading

Another standard basic element is log normal fading. The term is derived from "normal distribution of a logarithmic value". This value expresses the signal level variation in dB.

Log normal describes slow changes in the fading path. The fading profiles discussed above are, in contrast to log normal, "fast" profiles, where level changes take place after distances as short as the wavelength of the received signal, ie in the order of milliseconds. Variations in log normal fading are caused by the vehicle moving in different environments, for instance in built-up urban areas, in flat, open terrain, or hilly terrain. The distances over which the relevant parameter values change are correspondingly large.

The relevant parameters for log normal fading are:
    Local constant in meters:
        Defines the distance over which fading conditions do not change.
        In strongly structured areas, the local constant will assume low values (eg 50 m in street canyons in cities), whereas on broad plains without vegetation high values (>300 m) are to be expected.
    Standard deviation:
        Describes the interval ($\pm 1\ \sigma$) within which 66% of all level changes occur (with Gaussian distribution).

The variations of fading conditions as a function of time further depend on the vehicle velocity. For a tour in the city with v = 50 km/h = 50 / 3.6 m/s and a local constant of 50 m, a time constant of

$$\tau = 50 / (50/3.6) = 3.6 \text{ s}$$

will be obtained, whereas in an open plain with v = 120 km/h = 120 / 3.6 m/s and a local constant of 300 m, the time constant will be

$$\tau = 300 / (120/3.6) = 9 \text{ s}$$

Accordingly, the time axis for the received power will be scaled in seconds and not in milliseconds as with Rice fading and Rayleigh fading.

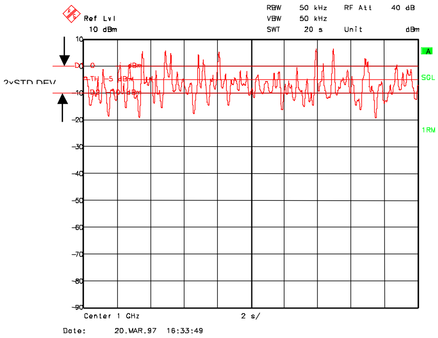


Fig. 11 Log normal
Level versus time

Fig. 11 shows log normal fading with:

Local constant	200 m
Standard deviation	5 dB
Signal level	-5 dBm

The time axis is scaled 2 s/div. Level changes are slow compared with Rice or Rayleigh fading. In mobile reception, ie in a car, bus or train, log normal fading is encountered, since this type of fading always involves the reception of Doppler-shifted echoes (Rayleigh fading), sometimes also with a direct line of sight to the transmitter (Rice fading).
Log normal fading with Rayleigh fading is also referred to as Suzuki fading.

2.6 Gaussian Channel

Noise is an important quality parameter in any kind of signal transmission. Whenever fading is described, therefore, the Gaussian channel is included. It contains none of the above-described elements for channel simulation. The quality of the transmission channel is determined only by white noise superimposed on the signal, this being referred to as C/N ratio.

In measurements for determining the quality of a transmission path, compliance with the bit error ratio BER $\leq 2 * 10^{-4}$ according to Viterbi is applied as limit criterion. If this limit is not attained by means of the predefined profiles of channel simulation, additive white noise is superimposed on the signal to reach the BER limit value. Fading profile parameters are important factors in channel simulation, but also the Gaussian channel, which is defined by the C/N ratio.

3. Channel Simulation with SFQ Fading Simulator Option B11

3.1 Definition of Real Conditions

The SFQ Fading Simulator option simulates all the above-described simple fading profiles. Real profiles however result from more than a single path; they are the sum of at least 5 to 10 single profiles. In GSM (mobile radio), profiles with up to 20 single profiles are defined. The most well-known are the COST 207 profiles with up to 20 fading paths. For DVB-T, however, it has shown that 6 paths are absolutely sufficient to simulate fading conditions in all of the three receive modes:
-
stationary: reception with fixed, directional Yagi antenna with defined gain,
portable: reception with rod antenna or "rabbit ear" antenna set up at a fixed position (eg park bench) and
mobile: reception with rod antenna in a moving vehicle, eg a car, bus
or
train.

The optional SFQ Fading Simulator B11, therefore, is capable of generating fading profiles with up to 6 paths. For applications requiring more paths, a second option B11 can be installed in SFQ for the generation of up to 12 paths.
In the MOTIVATE and VALIDATE working groups for DVB-T, some profiles have been recommended to cater for special receive conditions:

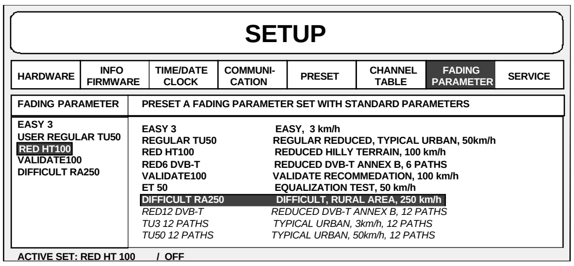


Fig. 12 Fading profiles

Up to 5 of n proposed fading profiles can be stored in SFQ under FADING PARAMETER. With currently 10 profiles developed by the working groups, n = 10 is valid at present. The proposed fading profiles can be called directly from the SETUP menu MODULATION / FADING / PARAMETERSET.

Example:

EASY 3
USER REGULAR TU50
RED HT100
VALIDATE100
DIFFICULT RA250

The settings valid for the individual profiles are briefly explained under
"PRESET A FADING PARAMETER SET WITH STANDARD PARAMETERS":

1 EASY 3:
EASY, 3 km/h
2 REGULAR TU50:
REGULAR REDUCED,
TYPICAL URBAN, 50 km/h
3 RED HT100:
REDUCED HILLY TERRAIN, 100 km/h
4 VALIDATE100:
VALIDATE RECOMMENDATION,
100 km/h
5 RED6 DVB-T:
REDUCED DVB-T ANNEX B, 6 PATHS
6 ET 50:
EQUALIZATION TEST, 50 km/h
7 DIFFICULT RA250:
DIFFICULT, RURAL AREA, 250 km/h

If only 6 paths are available in SFQ for fading simulation, the profiles including up to 12 paths are displayed in italics:

8 RED12 DVB-T:
REDUCED DVB-T ANNEX B, 12 PATHS
9 TU3 12 PATHS:
TYPICAL URBAN, 3 km/h, 12 PATHS
10 TU50 12 PATHS:
TYPICAL URBAN, 50 km/h, 12 PATHS

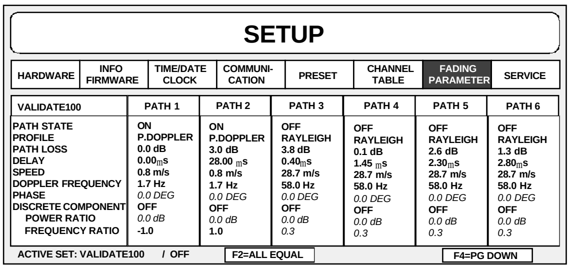
The single parameters of the profiles are displayed on opening the predefined fading profiles. TV Test Transmitter SFQ allows all single parameters to be optimized for the measurements to be performed.

3.2 RF Levels of Fading Profiles

Each path of a fading profile contributes towards the total RF output power of SFQ. The level should however remain constant to simplify fading measurements. If the level C at the input of a receiver changes, the C/N ratio also changes because the noise N remains constant. This means that there are no constant conditions at the input of the DVB-T receiver. Constant conditions are necessary however for obtaining comparable results in measurements with different fading conditions.
SFQ therefore takes into account the levels of all paths defined by the PATH LOSS parameter, and corrects the sum level to yield a constant output level, which is displayed.
Special cases are the sum levels of profiles with CONSTANT PHASE paths and PURE DOPPLER paths with identical Doppler shift. Here the nominal value is displayed although the sum level may deviate from this value because of the fixed phase relationships in the paths.
Despite this, the displayed sum level is correct in accordance with DVB-T specifications, which define the following: the level with multipath reception is the sum level of the individual paths, the effects of CONSTANT PHASE and PURE DOPPLER being left out of account. TV Test Transmitter SFQ simulates the real conditions of mobile reception, where the level of C changes, resulting from the varying superposition of paths as the receiver is moving, while the noise N remains constant. Still, the receiver must be able to demodulate such signals correctly. The movement of the receiver is simulated by varying the phase with CONSTANT PHASE and the speed with PURE DOPPLER. The current state is frozen and the new receive conditions are evaluated.
For such profiles, the level and thus the C/N ratio for the simulated current position of the receiver should be measured with a spectrum analyzer with frequency markers, or with thermal power meters at the output of SFQ with the noise switched off.
The displayed sum value of C according to specifications is obtained for the above profiles by measuring the level of C at many points located close together and forming the average of the results.

For CONSTANT PHASE, for example, the value of C displayed on TV Test Transmitter SFQ can be checked as follows:
measurement of C at various phases (eg at increments of 5°) and calculation of average value. The measured average agrees with the displayed value of C.

3.3 VALIDATE 100


SETUP

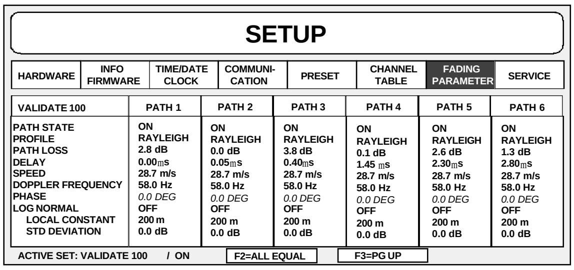
HARDWARE	INFO FIRMWARE	TIME/DATE CLOCK	COMMUNI-CATION	PRESET	CHANNEL TABLE	FADING PARAMETER	SERVICE

VALIDATE100	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	OFF	OFF	OFF	OFF
PROFILE	P.DOPPLER	P.DOPPLER	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	3.0 dB	3.8 dB	0.1 dB	2.6 dB	1.3 dB
DELAY	0.00µs	28.00 µs	0.40µs	1.45 µs	2.30µs	2.80µs
SPEED	0.8 m/s	0.8 m/s	28.7 m/s	28.7 m/s	28.7 m/s	28.7 m/s
DOPPLER FREQUENCY	1.7 Hz	1.7 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB
FREQUENCY RATIO	-1.0	1.0	0.3	0.3	0.3	0.3

ACTIVE SET: VALIDATE100 / OFF F2=ALL EQUAL F4=PG DOWN

Fig. 13 VALIDATE 100 profile

This fading profile, which was proposed by the VALIDATE working group, simulates mobile reception with the vehicle moving in hilly terrain at 100 km/h without a direct line of sight to the transmitter in an MFN (multifrequency network) or towards a transmitter in an SFN (single-frequency network). Six Rayleigh paths are sufficient to simulate the receive conditions. Log normal is switched off, which can be seen when scrolling down with the Page Down key F4.


SETUP

HARDWARE	INFO FIRMWARE	TIME/DATE CLOCK	COMMUNI-CATION	PRESET	CHANNEL TABLE	FADING PARAMETER	SERVICE

VALIDATE 100	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	2.8 dB	0.0 dB	3.8 dB	0.1 dB	2.6 dB	1.3 dB
DELAY	0.00µs	0.05µs	0.40µs	1.45 µs	2.30µs	2.80µs
SPEED	28.7 m/s	28.7 m/s	28.7 m/s	28.7 m/s	28.7 m/s	28.7 m/s
DOPPLER FREQUENCY	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
LOG NORMAL	OFF	OFF	OFF	OFF	OFF	OFF
LOCAL CONSTANT	200 m	200 m	200 m	200 m	200 m	200 m
STD DEVIATION	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: VALIDATE 100 / ON F2=ALL EQUAL F3=PG UP

Fig. 14 VALIDATE 100 profile LOG NORMAL OFF

3.4 EASY 3

EASY, 3 km/h

This profile was defined by the participants in the MOTIVATE group and is derived from the DVB-T Mobile Profile (SFN) developed by this group. Only two paths with PURE DOPPLER are active. LOG NORMAL is switched off. The user should adapt the vehicle speed, the echo delay and the

level of the second path to match his measurement conditions.
MOTIVATE has in part defined these values:

Speed	Not defined
Delay	$\frac{1}{2} * T_{guard}$
Level	0 dB

Table 1

SETUP

HARDWARE | INFO FIRMWARE | TIME/DATE CLOCK | COMMUNI-CATION | PRESET | CHANNEL TABLE | FADING PARAMETER | SERVICE

EASY 3	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	OFF	OFF	OFF	OFF
PROFILE	P.DOPPLER	P.DOPPLER	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	3.0 dB	3.8 dB	0.1 dB	2.6 dB	1.3 dB
DELAY	0.00 µs	28.00 µs	0.40 µs	1.45 µs	2.30 µs	2.80 µs
SPEED	0.8 m/s	0.8 m/s	28.7 m/s	28.7 m/s	28.7 m/s	28.7 m/s
DOPPLER FREQUENCY	1.7 Hz	1.7 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB
FREQUENCY RATIO	-1.0	1.0	0.3	0.3	0.3	0.3

ACTIVE SET: EASY 3 / OFF | F2=ALL EQUAL | F4=PG DOWN

Fig. 15 EASY 3 profile

This profile did not place any special demands on the receiver during measurements. It allows however conclusions to be drawn as to "normal" operation in areas of average structure. Extreme conditions are not covered.

3.5 REGULAR TU50

REGULAR REDUCED TYPICAL URBAN, 50 km/h

SETUP

HARDWARE | INFO FIRMWARE | TIME/DATE CLOCK | COMMUNI-CATION | PRESET | CHANNEL TABLE | FADING PARAMETER | SERVICE

REGULAR TU50	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	3.0 dB	0.0 dB	2.0 dB	6.0 dB	8.0 dB	10.0 dB
DELAY	0.00 µs	0.20 µs	0.50 µs	1.60 µs	2.30 µs	5.00 µs
SPEED	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s
DOPPLER FREQUENCY	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	200 m	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: VALIDATE100 / OFF | F2=ALL EQUAL | F4=PG DOWN

Fig. 16 REGULAR TU 50 profile

This profile was defined by COST 207 to simulate typical terrestrial wave propagation in an urban environment. The originally 12 paths were reduced to 6. The echo delays in the paths cover a wide range, and the echo levels are relatively high. The vehicle velocity corresponds to the 50 km/h allowed in built-up areas. This profile, which places average demands on the demodulator, is already used in DAB and GSM.
Experience has shown that, if receivers can handle this profile without problems, reception in an urban environment in general is (almost) ensured.

3.6 RED HT100:

REDUCED HILLY TERRAIN, 100 km/h

Fig. 17 REDUCED HILLY TERRAIN 100 profile

SETUP

HARDWARE | INFO FIRMWARE | TIME/DATE CLOCK | COMMUNI-CATION | PRESET | CHANNEL TABLE | FADING PARAMETER | SERVICE

RED HT 100	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	1.5 dB	4.5 dB	7.5 dB	8.0 dB	17.7 dB
DELAY	0.00 µs	0.10 µs	0.30 µs	0.50 µs	15.00 µs	17.20 µs
SPEED	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s
DOPPLER FREQUENCY	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	200 m	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: RED HT100 / OFF | F2=ALL EQUAL | F4=PG DOWN

This profile too was defined by COST 207. It has only 6 paths, and simulates conditions for a vehicle moving at 100 km/h in hilly terrain. In addition to shortterm echoes with low loss, there are two paths with long reflection times and lower levels. All paths have Rayleigh characteristic, and the LOG NORMAL function is switched off.

3.7 RED6 DVB-T

REDUCED DVB-T ANNEX B, 6 PATHS

In Annex B of the EN 300 744 DVB-T standard, a fading profile for stationary reception with 20 paths is described. This profile was adopted by COST 207. A selection of 6 of the 20 paths yields the REDUCED DVB-T profile.

SETUP

HARDWARE | INFO FIRMWARE | TIME/DATE CLOCK | COMMUNI-CATION | PRESET | CHANNEL TABLE | FADING PARAMETER | SERVICE

RED6 DVB-T	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	C.PHASE	C.PHASE	C.PHASE	C.PHASE	C.PHASE	C.PHASE
PATH LOSS	3.9 dB	4.0 dB	4.5 dB	5.2 dB	5.3 dB	5.8 dB
DELAY	0.50 µs	1.95 µs	3.25 µs	2.75 µs	0.45 µs	0.85 µs
SPEED	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s	27.8 m/s
DOPPLER FREQUENCY	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz	58.0 Hz
PHASE	336.0 DEG	8.9 DEG	175.0 DEG	127.0 DEG	340.0 DEG	36.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	200 m	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: RED6 DVB-T / OFF | F2=ALL EQUAL | F4=PG DOWN

Fig. 18 REDUCED DVB-T (6 paths) profile

This profile contains the 6 most important paths of the 20-path profile defined in EN 300 744 so that there is no major difference with respect to the original profile.

All of the six paths are defined as CONSTANT PHASE with average path loss between 3.9 dB and 5.8 dB. The reflection angles are distributed over a wide range, simulating omnidirectional reception. The resulting spectrum at the site of reception is shown by Fig. 19.

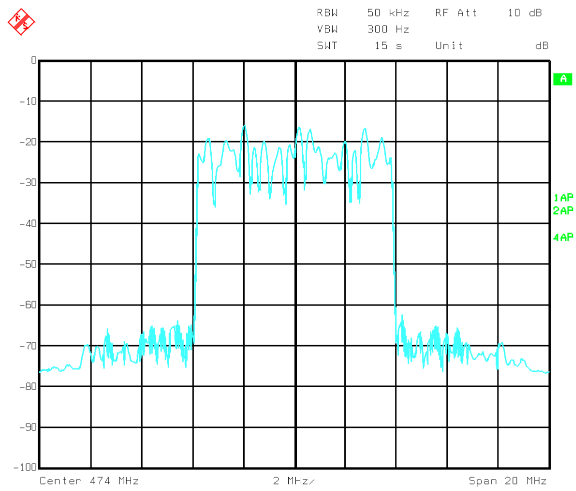


Fig. 19 Spectrum of
REDUCED DVB-T ANNEX B, 6 PATHS

A static fading profile is obtained, which is compensated by channel correction in the receiver. So, there is only the requirement of sufficient dynamic range, ie $\Delta \approx 15$ dB, of the equalizer, but no requirement as to the speed of equalization in dB/s.

This profile has only CONSTANT PHASE paths. It therefore describes, among other things, the typical case of constant reflections in cables in the event of mismatch. An important application, therefore, is simulation of cabling in DVB-C. This profile makes it easy to test set top boxes for DVB-C in the real environment of a domestic cabling system with numerous antenna sockets on each floor, each of which is more or less distorting the characteristic impedance of 75 Ω. In this case, 6 faulty sockets are simulated by the 6 paths. The reflection losses and associated delays represent the change of characteristic impedance and the spatial separation of the antenna outlets.

3.8 ET 50

EQUALIZATION TEST, 50 km/h

This test profile too was defined by COST 207 and adopted for DVB-T.

SETUP

HARDWARE	INFO FIRMWARE	TIME/DATE CLOCK	COMMUNI-CATION	PRESET	CHANNEL TABLE	FADING PARAMETER	SERVICE

ET 50	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB
DELAY	0.00 µs	3.20 µs	6.40 µs	9.60 µs	12.80 µs	16.00 µs
SPEED	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s	13.9 m/s
DOPPLER FREQUENCY	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz	29.0 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	OFF	OFF	OFF	OFF	OFF	OFF
POWER RATIO	200 m	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: ET 50 / OFF F2=ALL EQUAL F4=PG DOWN

Fig. 20 ET 50 profile

The profile simulates reception in Rayleigh mode with 0 dB echoes with a delay of $t = n * 3.2$ µs, with n = 0 to 5 and at 50 km/h driving speed. At a carrier frequency of 626 MHz, for example, this corresponds to a Doppler shift of 29 Hz. The channel estimation in the DVB-T receiver should be able to handle this profile without any problems.

3.9 DIFFICULT RA250

DIFFICULT RURAL AREA, 250 km/hFig. 21
DIFFICULT RURAL AREA, 250 km/h
profile

SETUP

HARDWARE	INFO FIRMWARE	TIME/DATE CLOCK	COMMUNI-CATION	PRESET	CHANNEL TABLE	FADING PARAMETER	SERVICE

DIFFICULT RA 250	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RICE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB
DELAY	0.00 µs	0.10 µs	0.20 µs	0.30 µs	0.40 µs	0.40 µs
SPEED	69.4 m/s	69.4 m/s	69.4 m/s	69.4 m/s	69.4 m/s	69.4 m/s
DOPPLER FREQUENCY	198.7 Hz	198.7 Hz	198.7 Hz	198.7 Hz	198.7 Hz	198.7 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	ON	OFF	OFF	OFF	OFF	OFF
POWER RATIO	6.6 dB	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	1.0	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: DIFFICULT RA 250 / OFF F2=ALL EQUAL F4=PG DOWN

This profile is bound to place great demands on channel correction because of the high velocity. At a carrier frequency of 858 MHz (UHF channel with the currently highest carrier frequency), this velocity results in a Doppler shift of 197.8 Hz. Channel correction is facilitated by the RICE path with 0 dB level loss at 0 µs, and a power ratio of the Rice level peak to the Doppler-shifted Rayleigh paths of 6.5 dB at a frequency ratio of 1. This means that the Rice peak is at the upper end of a Doppler-shifted Rayleigh path, but is visible in the spectrum only in a single-carrier measurement.

Looking at the spectrum of all COFDM carriers, the Rice peak will not be visible since the resolution bandwidth and the span of the spectrum analyzer do not allow this.

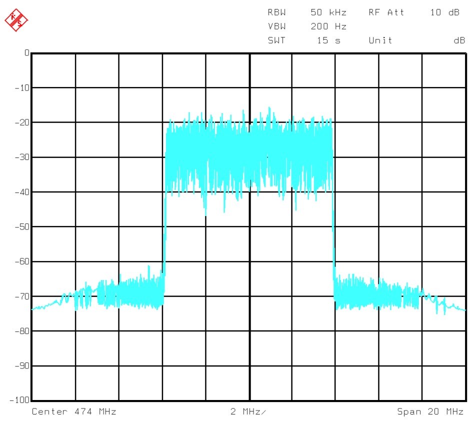


Fig. 22 Spectrum of DIFFICULT RURAL AREA 250 km/h fading profile

The effect of Rice and Rayleigh fading can be seen clearly. The spectrum appears to be very noisy compared with the same spectrum without fading.

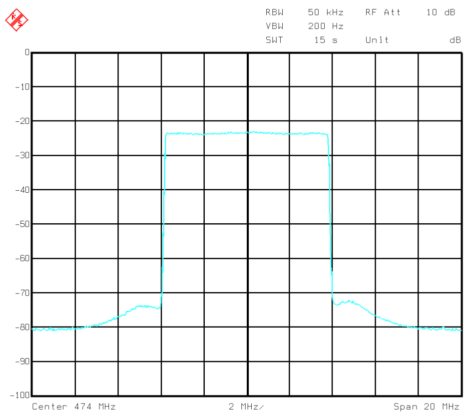


Fig. 23 DVB-T 8k UHF 8 MHz spectrum without fading

The DIFFICULT RURAL AREA, 250 km/h profile constitutes an extreme case of fading. Mobile reception at a velocity as high as 250 km/h, which corresponds to 69.4 m/s, is probably possible only in high-speed trains such as the ICE or TGV, whereas the simulated conditions will hardly ever be fulfilled by cars on motorways.
At a carrier offset of $\Delta f = 1/224{*}10^{-6} = 4\,464$ Hz in 2k mode with QPSK modulation or possibly even with 16 QAM and a code rate of 2/3, a QEF transport stream with this profile could just be demodulated. At higher rates and with 64 QAM, however, demodulation will be errored to a considerable extent.
8k mode with a carrier offset of $\Delta f = 1/896{*}10^{-6} = 1116$ Hz is certainly not appropriate for QEF reception with this profile.

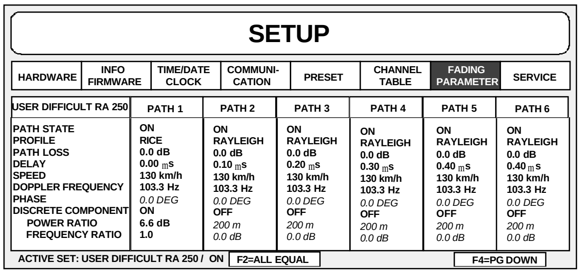
The profile can easily be adapted for testing mobile reception in a car at a velocity of approx. 130 km/h common today on motorways. To this effect, the DIFFICULT RURAL AREA, 250 km/h profile is opened and the velocity changed to 130 km/h. The new Doppler shift Δf_D for the selected carrier frequency is automatically calculated and displayed.
The profile designation is changed from

DIFFICULT RURAL AREA, 250 km/h

to

USER DIFFICULT RURAL AREA, 250 km/h.

The actual values of the fading parameters are stated in the SETUP menu.
The instrument is immediately ready for measurement after this modification.



SETUP

HARDWARE	INFO FIRMWARE	TIME/DATE CLOCK	COMMUNI-CATION	PRESET	CHANNEL TABLE	FADING PARAMETER	SERVICE

USER DIFFICULT RA 250	PATH 1	PATH 2	PATH 3	PATH 4	PATH 5	PATH 6
PATH STATE	ON	ON	ON	ON	ON	ON
PROFILE	RICE	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH	RAYLEIGH
PATH LOSS	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB
DELAY	0.00 µs	0.10 µs	0.20 µs	0.30 µs	0.40 µs	0.40 µs
SPEED	130 km/h	130 km/h	130 km/h	130 km/h	130 km/h	130 km/h
DOPPLER FREQUENCY	103.3 Hz	103.3 Hz	103.3 Hz	103.3 Hz	103.3 Hz	103.3 Hz
PHASE	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG	0.0 DEG
DISCRETE COMPONENT	ON	OFF	OFF	OFF	OFF	OFF
POWER RATIO	6.6 dB	200 m	200 m	200 m	200 m	200 m
FREQUENCY RATIO	1.0	0.0 dB	0.0 dB	0.0 dB	0.0 dB	0.0 dB

ACTIVE SET: USER DIFFICULT RA 250 / ON | F2=ALL EQUAL | F4=PG DOWN

Fig. 24
USER DIFFICULT RURAL AREA, 250 km/h profile

4 Outlook

Fading profiles are needed to test receivers for immunity to interference encountered in stationary, portable and mobile reception. Proposals to this effect have been developed by various working groups, and their current version fully integrated in TV Test Transmitter SFQ. To suit a given application, the fading profiles can easily be modified on SFQ directly in the profile description. SFQ has been designed to cope with all future settings and changes. Any further channel simulation profiles for important measurements developed by the working groups will be added to the SFQ profile list. Specifications laid down by the known standard committees of ETSI, ITU or DVB are however still outstanding.