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Recommendation ITU-R SM.1875-4

(09/2022)

DVB-T/T2 coverage measurements and verification of planning criteria

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Spectrum management

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RECOMMENDATION ITU-R SM.1875-4

DVB-T/T2 coverage measurements and verification of planning criteria

(2010-2013-2014-2019-2022)

Scope

This Recommendation describes measurement methods for the coverage of DVB-T and DVB-T2 transmitters and networks and their evaluation. Most of the principles described are also applicable for other digital broadcasting systems, especially those using OFDM modulation (e.g. DAB), but the example values used in this Recommendation are taken only from DVB-T/T2 systems.

Keywords

Measurement, coverage, service, DVB-T, DVB-T2, monitoring, coverage predictions

Abbreviations/Glossary

BER – Bit error ratio

C/*N* – Carrier-to-noise ratio

C/*I* – Carrier-to-interference ratio also referred to as protection ratio in this Recommendation

FEC – Forward error correction

DVB-T/T2 – Terrestrial Digital Video Broadcasting

FX – Fixed reception

GE06 Agreement – Regional Agreement and its annexes together with its associated Plans as drawn up by the Regional Radiocommunication Conference 2006 for the planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 situated to the west of meridian 170° E and to the north of parallel 40° S, except the territories of Mongolia) and in the Islamic Republic of Iran, in the frequency bands 174-230 MHz and 470-862 MHz (Geneva, 2006).

LDPC – Low Density Parity Check-code

MFN – Multi-frequency network

PI – Portable indoor reception

PO – Portable outdoor reception

QEF – Quasi-error-free

QoS – Quality of service

RF – Radio frequency

SFN – Single frequency network

Related ITU-R Recommendations and Reports

Recommendation ITU-R BT.419

Recommendation ITU-R P.1546

Recommendation ITU-R BT.1735

Recommendation ITU-R P.1812

Report ITU-R BT.2254

Report ITU-R BT.2265

NOTE – In every case the latest edition of the Recommendation/Reports in force should be used.

The ITU Radiocommunication Assembly,

considering

a) that the GE06 Agreement defines the receiving conditions, necessary signal-to-noise ratios and minimum field strength values for the reception of DVB-T;

b) that monitoring services have to measure the coverage of DVB-T/T2 transmitters and networks to verify compliance with coverage predictions used in the planning process or to assess the receiving condition at a location where interference is reported,

recognizing

a) that Report ITU-R BT.2254 defines the receiving conditions, necessary signal-to-noise ratios and minimum field strength values for the reception of DVB-T2;

b) that Recommendation ITU-R BT.1735 makes available methods to assist in quality assessment of the reception of digital terrestrial television broadcasting services in System B (DVB-T),

recommends

that the methods described in Attachments 1, 2, 3 and 4 to the Annex should be used for DVB-T/T2 coverage assessment and comparison with coverage predictions.

NOTE – Section 3 of the Annex to this Recommendation provides guidance on which method should be applied, depending on the DVB-T/T2 network design, terrain and aim of the measurement.

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1 Introduction

Monitoring services have to assess the coverage of broadcast networks for different purposes:

– To verify predictions of computerized tools used for the planning of the network.

– To verify compliance with license conditions if part of the broadcast license is that a certain area, percentage of an area or percentage of the population is covered by the broadcast service.

– To assess the receiving conditions at certain locations where interference is reported.

Due to certain circumstances and principles inherent in the reception of digitally modulated systems, the coverage of digital terrestrial television networks has to be measured different from analogue networks.

This Recommendation describes the measurement principles, procedure and necessary equipment for fixed and mobile coverage assessment of DVB-T/T2 transmitters and networks. It is aimed for Monitoring Services. Broadcasters that want to ensure that their service can be received with commercially available equipment inside their aimed coverage area may have to include additional quality of service criteria.

Although specifically tailored to DVB-T/T2, much of the information provided in this Recommendation is also valid for other digital terrestrial broadcasting systems.

Measurements to verify technical transmitter and network parameters are not covered in this Recommendation.

2 Terms and definitions for the purpose of this Recommendation

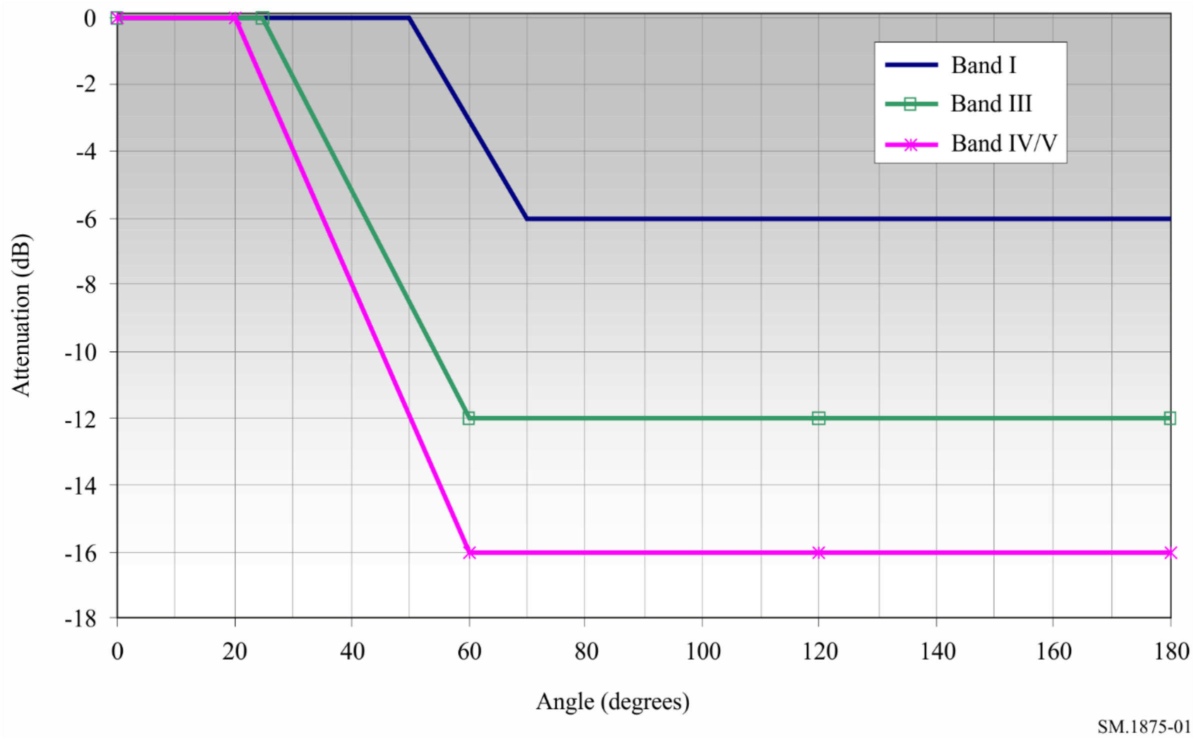
The following terms and definitions are used throughout this Recommendation. In case of generally known terms, their definitions are interpreted and specialized only to coverage issues related to the DVB-T/T2 system throughout this Recommendation.

2.1 Antenna diagram for fixed reception

The antenna diagram characterizes the relative output level of an antenna when the signal is received under different angles. Recommendation ITU-R BT.419 defines the directivity of a reference antenna used for fixed broadcast reception as in Fig. 1. This antenna is used in the coverage prediction tools. It should be noted that the reference antenna is idealized and actual antennas will not have exactly the same characteristics. Measurements for fixed coverage should be made with a measurement antenna having at least the same directivity and gain as the reference antenna.

FIGURE 1

Relative directivity of the reference antenna for fixed broadcast reception



Idealized omnidirectional antennas are used for portable and mobile reception in ITU-R Recommendations and in the GE06 Agreement as well as in planning tools, but do not exist in reality. The maximum relative loss of a measurement antenna used for mobile coverage measurements should be ±3 dB in any direction.

2.2 Antenna factor

The antenna factor is used to calculate the field strength from the antenna output level. Because it is usually specified in dB, the calculation formula is as follows:

$$E = U + K \qquad \text{dB}(\mu\text{V/m})$$

where:

E: electrical field strength at the antenna (dB(μV/m))

U: measured antenna output voltage (dB(μV))

K: antenna factor (dB(1/m)).

The antenna factor depends on frequency and gain according to the following formula:

$$K = 20\log(f) - G_i - 29.774 \qquad (for\ 50\ Ohm\ systems)$$

where:

f: frequency (MHz)

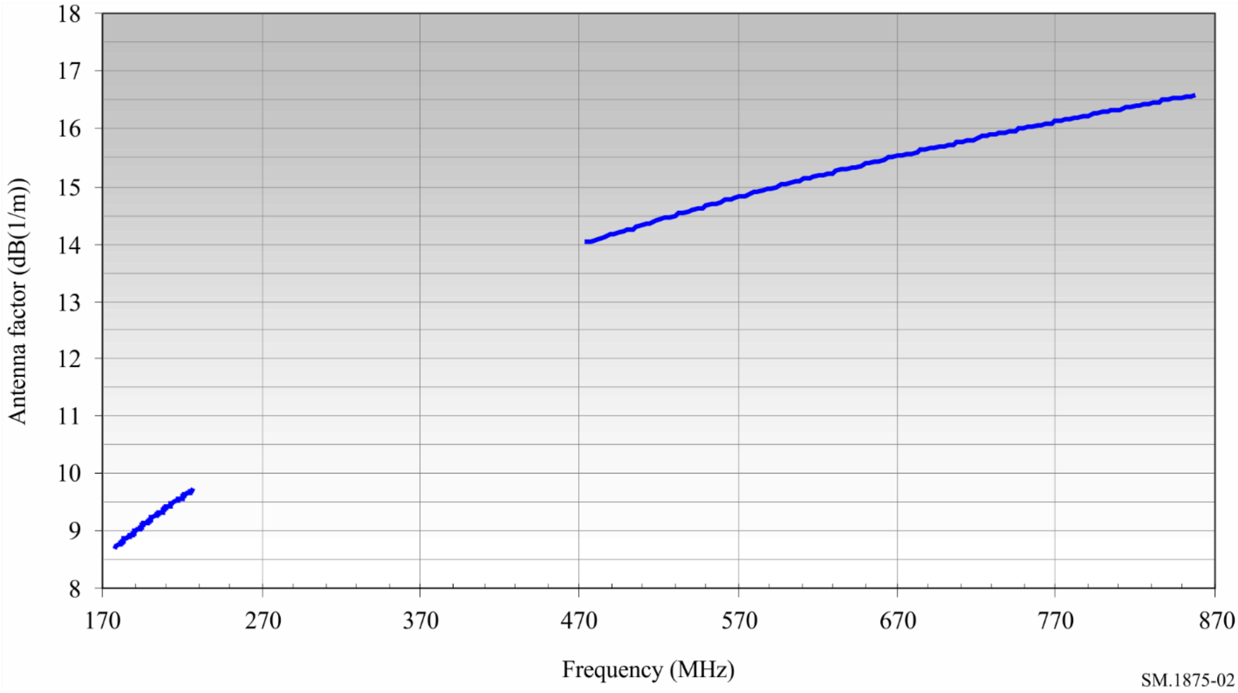
G_i: antenna gain relative to an isotropic radiator (dB)

K: antenna factor (dB(1/m)).

Figure 2 shows the antenna factor of the reference antenna used for fixed broadcast reception according to Recommendation ITU-R BT.419 in the direction of the main beam.

FIGURE 2

Antenna factor for fixed broadcast reception



2.3 Bit error ratio

Generally, the bit error ratio (BER) is the number of false bits divided by the total number of bits transmitted during a given time. It is a measure of the receiving quality of a digital signal. Because DVB-T uses inner and outer error protection, it is possible to determine the BER after the Viterbi and after the Reed-Solomon decoder off the air.

A BER of 10^{-4} after the Viterbi decoder is regarded sufficient for DVB-T reception.

In DVB-T2, a different error correction principle is used. The relevant parameter in this system is BER after LDPC (inner) decoder. A BER after LDPC (LBER) of 10^{-7} is regarded sufficient for quasi error-free DVB-T2 reception.

2.4 Cell

A grid of squares or triangles, within this area the standard deviation of field strength is equal to 5.5 dB. In accordance with Recommendation ITU-R P.1546, the standard grid size of a cell is 500 m.

2.5 *C*/*N*

See protection ratio.

2.6 Coverage area

A certain area is regarded as being 'covered' by DVB-T/T2, when the median field strength for the particular receiving situation in a specified height above ground (often 10 m) and the protection ratio reach or exceed the values given in relevant planning documents (e.g. the GE06 Agreement for DVB-T and Report ITU-R BT.2254 for DVB-T2).

The fact of a certain area to be covered or not is a result of the calculation process done with a coverage prediction tool that assumes defined conditions and/or values for:

– the receiving condition (e.g. fixed or portable reception);

– the field strength loss with distance due to topography and morphology;
– the field strength loss due to height loss and/or building entry loss (if appropriate);
– the receiver model (e.g. sensitivity and selectivity);
– the receiving antenna (height, polarisation, gain and directivity);
– the reception channel (Gaussian, Rice or Rayleigh).

Attached to the attribute ‘covered’ is also a certain probability in time and location. Using planning tools, the coverage area is calculated for this probability (typically 99% of the time and 95% of the locations).

It can therefore not be assumed that DVB-T/T2 reception with a standard receiver and a reference antenna is possible at every single location inside the area defined as being covered.

Verification of coverage cannot be done with a standard DVB-T/T2 receiver by simply checking whether it works at a certain location since coverage is defined with a high likelihood of reception, both in terms of time and of location. Ideally measurements would be made in a number of locations throughout a pixel, and over a time period, long enough to capture anomalous propagation events – typically over a year. As this is not practical, technical parameters such as field strength have to be measured, preferably under the same receiving conditions with equally performing equipment as assumed in the planning tool alongside values from computer prediction models.

For the purpose of this Recommendation, the definition of coverage is similar to the term “nominal coverage” in the ITU Terms and Definitions Database.

2.7 Service area

The DVB-T/T2 reception is regarded possible if at a certain location a standard receiver can correct (nearly) all errors in 99% of the time and produce a picture. In DVB-T networks, the BER after the Viterbi decoder should be below $2*10^{-4}$. In DVB-T2 networks, the BER after LDPC should be below 10^{-7}.

The actual necessary field strength for a successful DVB-T/T2 reception depends on:
– the DVB-T/T2 system variant;
– the receiver performance (noise figure, synchronization strategy, etc.);
– the receiving antenna system gain and characteristics;
– the type of reception channel (Gaussian, Rice or Rayleigh).

Verification of a general reception possibility can be done by measurement of the following parameters:
– receiving field strength;
– interfering field strength;
– type of reception channel.

The interfering field strength or the presence of a sufficient *C*/*I* can be indirectly determined by measuring BER or MER for Gaussian interferers.

Alternatively, a reception test with a standard DVB-T/T2 receiver can be done. Experience from such tests shows that, for portable reception, sometimes higher field strengths than median values given in the relevant agreements are necessary.

For the purpose of this Recommendation, the service area as defined in the ITU Terms and Definitions Database corresponds to the area where the above conditions for possible reception are fulfilled.

2.8 Coverage prediction

Coverage prediction is a procedure to calculate the geographical area inside which reception of the service is possible. It is based on transmitter parameters, terrain and propagation models, certain reception models/parameters and is done with computerized tools. The results are provided for a specific location and time probability.

In the GE06 Agreement and in Report ITU-R BT.2254, the minimum field strength values for DVB-T/T2 to be reached at the coverage border are valid in 10 m height above ground and assume fixed reception with a directional antenna according to Figs 1 and 2 or portable reception with an omnidirectional antenna. They are medians of the minimum equivalent field strength values and depend on the system variant and the reception channel.

2.9 Crest factor

The crest factor is the ratio between the peak and r.m.s. level value of an RF emission. Usually, it is given in dB and is then the difference between peak and r.m.s. levels (dB).

2.10 Directional discrimination

The directional discrimination is the relative, angle-dependent loss of the received level of a signal arriving at the measurement antenna under a different angle than the main direction.

In case of mixed polarized SFNs, signals from a transmitter being orthogonal to the polarization of the receiving antenna are subject to an additional polarization discrimination. In this case, according with Note 3 of Recommendation ITU-R BT.419, the combined discrimination is as follows:

TABLE 1

Combined discrimination provided by directivity and polarization orthogonality in Band III

Offset angle relative to main direction (α) (degrees)	Combined discrimination of reference antenna (dB)
0 to 26.5	10
26.5 to 43.25	16 * (α – 26.5) / 16.75
43.25 to 180	16

TABLE 2

Combined discrimination provided by directivity and polarization orthogonality in Band IV/V

Offset angle relative to main direction (α) (degrees)	Combined discrimination of reference antenna (dB)
0 to 20	9
20 to 37.5	16 * (α – 20) / 17.5
37.5 to 180	16

2.11 Guard interval

To make use of all incoming signal components from co-channel transmissions and reflections within an SFN that arrive at different times at the receiver, and to prevent interference of two subsequent symbols, each symbol is transmitted longer as would be necessary to decode the signal. The additional time is called guard interval. The actual decoding process inside the receiver can start after the guard interval has passed. The length of the guard interval depends on the system variant which is chosen based on the maximum distance between neighbouring transmitters in a single frequency network (SFN). Signals that arrive within the guard interval contribute fully to the wanted signal level. When the arrival time of a signal exceeds the guard interval, the wanted contribution of that signal decreases and the interference potential of that signal increases. At a certain arrival time beyond the guard interval, the signal contributes fully to the interfering signal level.

2.12 Height loss

This is the field strength difference at 10 m above ground (reference for DVB-T/T2 planning) and the receiving field strength at an antenna being closer to the ground (e.g. 1.5 m for portable reception).

2.13 Interfering field strength

The interfering field strength is produced by signals from transmitters on the same frequency that are not part of the investigated SFN or transmitter, by signals from adjacent channel transmitters and by the relevant proportion of signals from transmitters of the investigated SFN that are received outside the guard interval (self-interference). It is formed by the addition of the directly received signal component from the interferer and reflections due to obstructions in the field. It varies with the location of the receiver, because reflecting obstacles may not be stationary, and because of tropospheric effects, it also varies with time. The actual interfering field strength inside a certain area can therefore only be described statistically by a median value and a standard deviation. Interfering signals need to be considered at 1% of probability in time.

Practical measurement of the interfering field strength can be difficult, especially if its level is well below the wanted signal level and both interferer and wanted transmitter are received from the same direction. Possible ways of improving the measurement conditions for the interfering field strength are:

– Use of a measurement antenna with a high directivity to separate wanted and interfering signals by changing the azimuth.

– Measurement of a signal on a different frequency that is emitted from the same location as the interfering transmitter. In this case, corrections for different attenuation loss from the frequency difference and for different transmission characteristics on the measurement frequency may have to be applied.

– Switch off the wanted transmitter or SFN during the measurement.

Alternatively, measurement of BER or MER at receiving points where synchronization is possible can be performed as an indirect assessment of the ratio between wanted and interfering field strength (C/I).

When the interfering signal is more than 30 dB below the wanted field strength, its influence on the reception of the wanted transmitter or SFN can be neglected.

2.14 Median

The median is calculated from a total of many samples (e.g. a series of measured field strengths) so that 50% of all samples exceed the median value, the other 50% of the samples are lower. The median is a statistical value and specifies a 50% confidence or probability.

Example: The field strength is measured at 100 locations inside a certain area. The median of all measurement values is 42 dB(µV/m). This means that the probability of the actual field strength at **any** location in this area being at least 42 dB(µV/m) is 50%.

The advantage of using the median when specifying field strength statistically is that single values far off do not influence the result as much as the average or mean.

2.15 Minimum median field strength (E_{med})

This is the median field strength required for reception of a certain system variant based on calculations at a certain percentage of the locations inside a receiving area. In relevant planning texts such as the GE06 Agreement for DVB-T and Report ITU-R BT.2254 for DVB-T2, its values are given at 10 m height above ground and for 50% location probability.

Network planning ensures that the minimum wanted field strength is at least theoretically reached for the whole coverage area, depending e.g. on radiated transmitter power, transmitter antenna height, topography of the terrain, morphology (if applicable, e.g. for portable reception) and assumptions on building entry loss (portable indoor reception).

2.16 MFN

MFN is the abbreviation for multi-frequency network. This is a network where, inside the coverage area, transmitters use a number of different frequencies.

2.17 Minimum equivalent signal level

The minimum level at the receiver input necessary to decode the wanted signal is the minimum system-dependant signal-to-noise ratio (*S/N*) plus the receiver noise figure. The minimum *S*/*N* enables the receiver to decode the signal quasi-error-free (QEF). It depends on the system variant and the reception channel. The receiver noise figure assumes a certain receiver performance and is defined to be 7 dB for a standard DVB-T receiver (see GE06) and 6 dB for a standard DVB-T2 receiver (see Report ITU-R BT.2254).

2.18 Minimum wanted (equivalent) field strength (E_{min})

This is the minimum field strength of a single wanted signal necessary for a standard receiver to decode the signal QEF, in the absence of any interfering signals. It is the minimum equivalent signal level at the input of the receiver plus antenna factor and is valid for a certain receiving location, i.e. without corrections for location and time probability.

2.19 Network gain

If signals from multiple wanted transmitters inside an SFN can be received within the guard interval, the reception quality can be improved, and the minimum wanted field strength from each transmitter can be lower. The network gain, however, is not just the sum of the wanted field strengths from all receivable transmitters. It is also the increased probability to receive a signal from an additional direction than from a single transmitter alone.

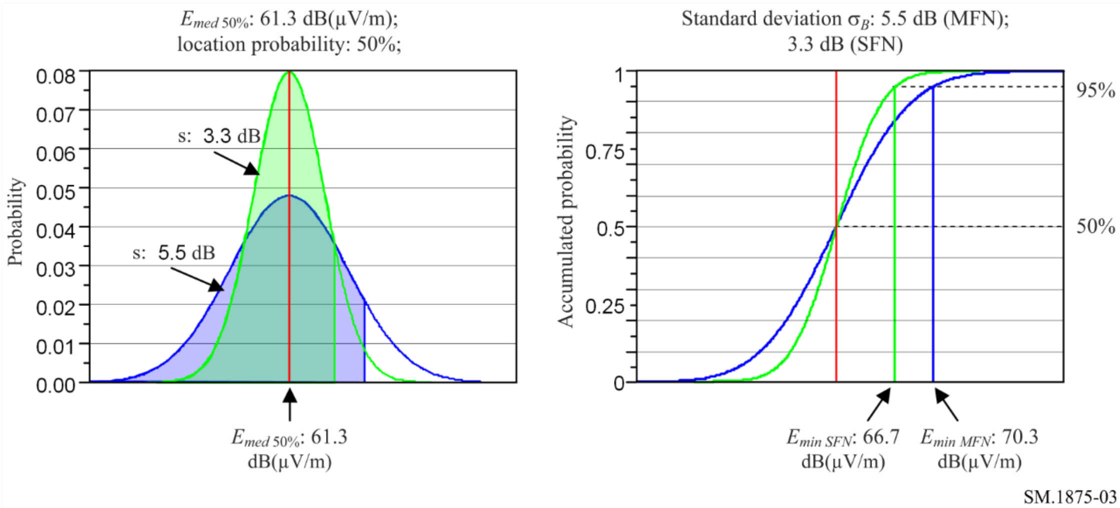
The network gain is the difference of the receiving field strengths inside SFNs and MFNs necessary for the same location probability.

In an SFN, usually the increased number of co-channel transmitters leads to a more homogeneous distribution of the field strength in the coverage area. The standard deviation σ of the field strength values is lower.

Example (hypothetical, just to explain the procedure): The minimum median field strength E_{med} for a certain system variant according to international agreements may be 61.3 dB(µV/m). This, per definition, applies to 50% location probability. In an SFN, the minimum wanted field strength E_{min} for 95% location probability may be 66.7 dB(µV/m), for an MFN it is 70.3 dB(µV/m). The network gain is then 3.6 dB (see Fig. 3).

FIGURE 3

Network gain



2.20 Protection ratio

The protection ratio (*C*/*I*) is the difference between the wanted signal level and the total of all unwanted signal levels, given in dB, needed for the receiver to correctly decode the signal. For DVB-T, the required protection ratios are given in the GE06 Agreement. For DVB-T2, they are given in Report ITU-R BT.2254. They depend e.g. on the system variant.

In the absence of interfering signals, the only 'interferer' is the noise and *C*/*I* becomes the same as the carrier-to-noise ratio (*C*/*N*).

2.21 Quasi error-free reception

As in many digital systems involving FEC, quasi error-free reception is defined at the point where only one uncorrected error per hour occurs (see the ITU-R Terms and Definitions database). For DVB-T systems, the corresponding BER are:

– $1 * 10^{-11}$ after the Reed-Solomon decoder;

– $2 * 10^{-4}$ after the Viterbi decoder.

For DVB-T2, the corresponding BER after LDPC is 10^{-7}.

These values are commonly used in ITU-R documentation (e.g. the GE06 Agreement).

2.22 Receiving field strength

The receiving field strength is formed by the addition of the directly received signal components and reflections due to obstructions in the field. It varies with the location of the receiver, and because the reflecting obstacles may not be stationary, it also varies with time. The actual receiving field strength inside a certain area can therefore only be described statistically by a median value and a standard deviation.

2.23 Receiving scenario

The following receiving scenarios have been defined:

– Fixed reception (FX)

– Portable reception outdoor (PO or "portable class A")

– Portable reception indoor (PI or "portable class B")

– Mobile reception (MO).

Table 3 lists some of the main characteristics and parameters used for these receiving scenarios.

TABLE 3

DVB-T/T2 receiving scenarios and parameters

	FX	**PO**	**PI**	**MO**
Receiver location	Outside buildings	Outside buildings	Inside buildings	Car roofs, moving
Antenna, gain	Directional, 7 dBd at 200 MHz 10 dBd at 500 MHz 12 dBd at 800 MHz	Omnidirectional, −2.0 dBd at 200 MHz 0 dBd in UHF	Omnidirectional, −2.0 dBd at 200 MHz 0 dBd in UHF	Omnidirectional, −2.0 dBd at 200 MHz 0 dBd in UHF
Antenna height	10 m above ground(1)	1.5 m above ground	1.5 m above ground	1.5 m above ground
Polarization	Horizontal/vertical	No polarization decoupling	No polarization decoupling	No polarization decoupling
Cable loss	2 … 5 dB	0 dB	0 dB	0 dB
Building entry loss	0 dB	0 dB	VHF: 9 dB UHF: 8 dB Standard deviation: VHF 3 dB UHF 5.5 dB	0 dB

(1) Planning tools always assume an antenna height of 10 m above ground for fixed reception. In order to achieve realistic assessments of the reception probability at locations with average roof heights above 10 m, measurements can also be done 1.5 m above the average roof level.

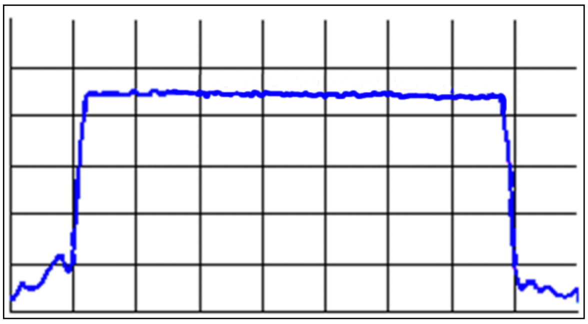
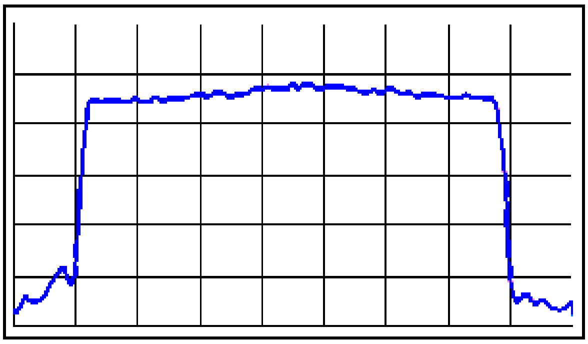
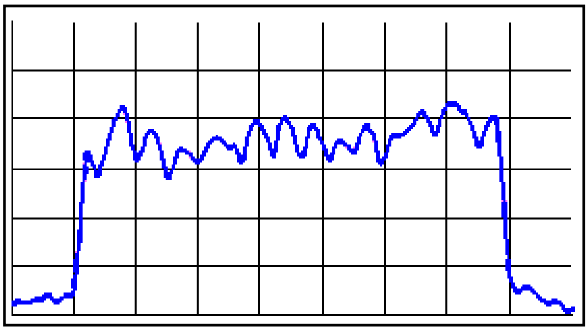
2.24 Reception channel

The ideal reception channel is a Gaussian channel (see Table 4 below). Due to reflections, shading and reception of signals from multiple transmitters of an SFN, the received spectrum can be degraded compared to Gaussian channel. The order of this degradation determines the reception channel which is specified in Table 4.

The standard deviation of the spectral amplitudes σ_{sp} has an influence on the minimum receiver input level necessary to decode the DVB-T/T2 signal.

TABLE 4

DVB-T/T2 reception channels

Gauss channel: Only the direct signal from a transmitter within line-of-sight is received. No reflections and co-channel emissions are received. As a result, the OFDM spectrum is rectangular. The standard deviation of the spectral amplitudes over the channel bandwidth σ_{sp} is between 0 and 1 dB.	
Rice channel: In addition to the direct signal, several smaller co-channel signals and reflections are received. The OFDM spectrum shows slight variations in amplitude over frequency. The standard deviation of the spectral amplitudes over the channel bandwidth σ_{sp} is between 1 and 3 dB.	
Rayleigh channel: The received signal is composed only of reflections and components from various co-channel transmitters. No dominant direct signal is received. The OFDM spectrum shows heavy distortion. The standard deviation of the spectral amplitudes over the channel bandwidth σ_{sp} is higher than 3 dB.	

It is important to determine the type of reception channel when measuring DVB-T/T2 field strength because the minimum required field strength according to planning standards depends on the reception channel. Rayleigh channels require the highest field strength, Gauss channels the lowest.

Experience shows that the vast majority of practical receiving situations will show Rice and Rayleigh channels. Gauss channels are very rare.

2.25 The GE06 Agreement

The Regional Agreement and its annexes together with its associated *Plans* as drawn up by the Regional Radiocommunication Conference 2006 for the planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 situated to the west of meridian 170° E and to the north of parallel 40° S, except the territories of Mongolia) and in the Islamic Republic of Iran, in the frequency bands 174-230 MHz and 470-862 MHz (Geneva, 2006) (the GE06 Agreement).

2.26 Self-interference inside an SFN

In this context, self-interference inside SFNs is the distortion of the received signal due to the combination of the directly received signal component and:

– signals from other co-channel transmitters belonging to the same SFN;

– reflections of the signal from the same transmitter,

that are received **outside** the guard interval.

2.27 Single-frequency network

An SFN consists of two or more transmitters that are time-synchronized and transmit the same programme content. The network planning has to ensure that at all receiving locations inside the target coverage area of the SFN, the signals of all receivable transmitters participating in the SFN which have the level > *C/I* arrive at the receiver with the correct timing with respect to the guard interval (see § 2.11). This is done e.g. by:

– selection of the system variant;

– selection of a guard interval length which fits to the maximum distance between any two neighbouring transmitters inside the SFN, or to choose transmitters for which the maximum distance fits within the maximum or the intended guard interval length;

– adjustment of ERP and/or antenna diagram for one or more transmitters (if needed), and

– proper time delay, also called static delay, for one or more transmitters (if needed).

2.28 Standard deviation

The standard deviation is the square root of the variance in a series of samples. It is the average deviation of all samples from the arithmetical average and can be calculated as follows:

Arithmetical average: $$\mu = \frac{P_1 + P_2 + P_3 + \dots P_n}{n}$$

Standard deviation: $$\sigma = \sqrt{\frac{(P_1 - \mu)^2 + (P_2 - \mu)^2 + \dots (P_n - \mu)^2}{n - 1}}$$

where:

$P_1 \dots P_n$: sample values.

2.29 Standard deviation of the spectral amplitudes (σ_{sp})

It was established experimentally that the standard deviation levels of the spectral amplitudes (see § 2.27), measured in logarithmic units (dB(μV) or dBm), correspond to σ_{sp} values, given in § 2.24 Reception channel.

2.30 σ_{sp}-correction (C_σ)

The necessary *C*/*N* given in relevant international documents such as the GE06 Agreement and Report ITU-R BT.2254 depends on the reception channel: Rayleigh channels require a high *C*/*N*, Rice channels a medium and Gauss channels the lowest *C*/*N*. A typical value specifying the reception channel is the standard deviation of the spectral amplitudes over the whole DVB-T/T2 bandwidth (σ_{sp}). With regard to the international texts, it is assumed here that σ_{sp} has the following values:

TABLE 5

Standard deviation of the spectral amplitudes (σ_{sp})

Reception channel	σ_{sp}
Gauss	$\sigma_{sp} \leq 1$ dB
Rice	1 dB < σ_{sp} < 3 dB
Rayleigh	$\sigma_{sp} \geq 3$ dB

However, the true value of σ_{sp} at real measurement points will most often be different from these extremes. They usually lie between 1 and 5 dB. To compare the measured field strength with the international texts, it is necessary to determine the reception channel and σ_{sp} for each measurement. A correction value *C* is subtracted from each measured value according to the following formula:

$$C_\sigma = \frac{{}^{C}/_{N_{Rayleigh}} - {}^{C}/_{N_{Gauss}}}{2} \cdot (\sigma_{sp} - 3)$$

where $C/N_{Rayleigh}$ and C/N_{Gauss} are taken from the relevant international texts, such as the GE06 Agreement, for the system variant used. This process is called σ_{sp}-correction.

The formula establishes a linear interpolation between and beyond the σ_{sp} values at the borders between Gauss/Rice (1 dB) and Rice/Rayleigh channels (3 dB). Depending on the reception channel, the value for C_σ can also be negative.

The graphs in Attachment 2 show some examples for σ_{sp}-correction values.

2.31 Small area

A ‘small area’ is an area within which the field strength and receiving situation is assumed to be equal (e.g. location variation is not considered and instead the median value is used). It is used to convert measurements done at specific locations into an assessment of a situation inside an area. Measurements of field strength, reception channel and BER are done at one or more locations inside the small area. If measurements are taken at multiple locations, the median values are calculated. The results are assumed to be valid for the whole small area.

2.32 Substitution transmitter

This is a transmitter that is operating at the same location using an antenna which has the same polarisation and has almost the same height as the transmitter that has to be measured, but operating on a different frequency. The substitution transmitter can be used for the measurement if the original transmitter has not been set up yet or if its signal is too heavily interfered by other, unwanted signals. If no substitution transmitter exists, it is possible to use a test transmitter that is set-up only for the measurements.

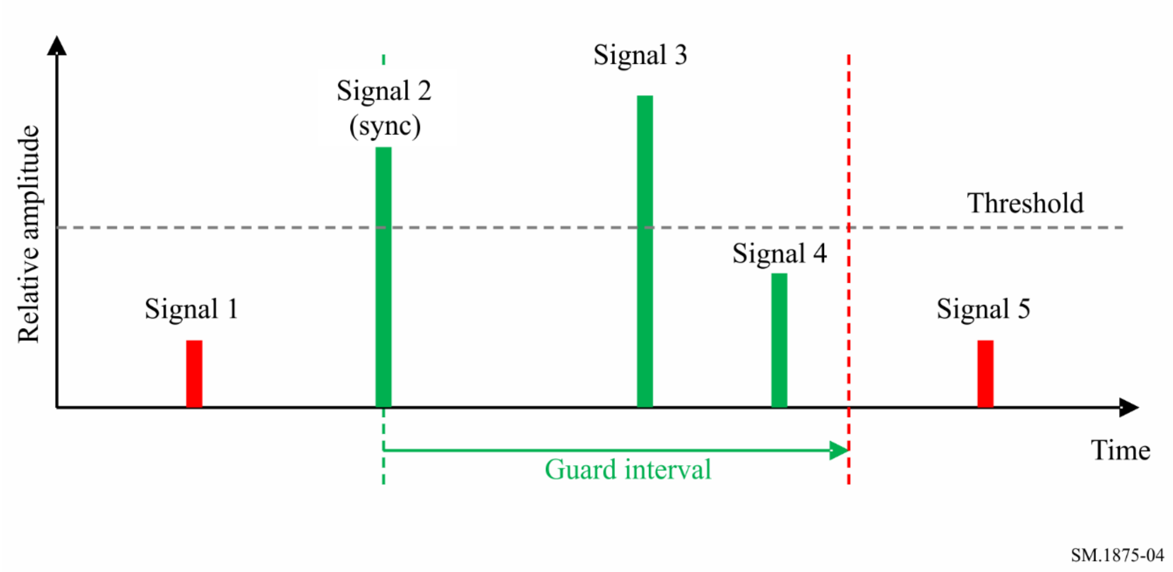
2.33 Synchronisation

Due to different distances, a symbol from different transmitters in an SFN arrives at the receiver with different time delays and different levels. This effect can also occur in MFNs due to reflections.

For demodulation, the receiver synchronizes to one of these signals. Different strategies are possible. For the purpose of this Recommendation, it is assumed that the receiver synchronizes to the first signal that is received above a certain threshold. An example is shown below.

FIGURE 4

Synchronisation to the first signal received above the threshold



The signal used for synchronisation is Signal 2. This signal also determines the position of the guard interval. Signals 2, 3 and 4 are treated as wanted signals and contribute to the decoding capability. Signals 1 and 5 arrive outside the guard interval and are treated as interfering signals.

2.34 System variant

Several parameters of the DVB-T/T2 system can be selected according to the needs of the service to be provided (e.g. data rate, reception mode, etc). The selected set of parameters determines the system variant (with the exception of the RF bandwidth. The main variable parameters are shown in the following table:

TABLE 6

Main parameters used to define the DVB-T/T2 system variant

Parameters	DVB-T	DVB-T2
RF bandwidth*	6 MHz, 7 MHz, 8 MHz	1.7 MHz, 5 MHz, 6 MHz, 7 MHz, 8 MHz
Number of subcarriers	2k, 8k	1k, 2k, 4k, 8k, 16k, 32k
Subcarrier modulation	QPSK, 16-QAM, 64-QAM	QPSK, 16-QAM, 64-QAM, 256-QAM
Code rate	1/2, 2/3, 3/4	1/2, 3/5, 2/3, 3/4, 4/5, 5/6
Guard interval	1/8, 1/4, 1/16, 1/32	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4
Rotation of constellation diagram	No	Yes
Extended carrier mode	No	No/Yes
Pilot pattern	Fixed	Variable (PP1 to PP8)

* RF bandwidth is not always regarded as part of the system variant.

2.35 Wanted field strength

This is the total received field strength of a wanted transmitter or network at any receiving location. When comparing measured field strength values of an SFN with necessary field strength values, the wanted field strength can be increased by the network gain.

3 Measurement methods

Attachments 1 to 4 describe different methods to measure and evaluate DVB-T/T2 service coverage.

Attachment 1 describes a method to verify predicted coverage areas for fixed reception. It is based on the principle that actual measurements are taken only in certain test areas. These test areas are placed at villages or cities located at the border of the predicted coverage. By evaluating field strength measurements made at a number of locations inside the test areas, the actual coverage situation is compared with the predicted coverage area. If the measured coverage matches or exceeds the prediction in the test areas, it may be assumed that this is the case for the whole service area of the DVB-T/T2 transmitter or network.

Attachment 2 describes a method to verify predicted coverage areas for portable reception. It is based on the principle that a large amount of field strength samples are taken while driving along most of the roads inside certain test areas. The test areas are placed at villages or cities located at areas where reception conditions are changing i.e. from "(good) reception" to "no reception" (border of the predicted coverage). After applying several corrections (e.g. for the reception path and the fact that portable reception was measured mobile), the percentage of measured field strength samples exceeding the minimum required field strength is compared with the predicted percentage of coverage inside the test area. If the measured coverage matches or exceeds predictions for the test areas, it may be assumed that this is the case for the whole service area of the DVB-T/T2 transmitter or network.

Attachment 3 describes a simplified method to determine the coverage border of a DVB-T/T2 transmitter or network for fixed reception. It is based on the principle that field strength measurements are taken at a number of locations along routes leading away from or towards the transmitter(s). A field strength curve versus distance is calculated that best matches the measurement results. The distance where this field strength curve reaches the minimum required field strength according to the planning criteria determines the coverage border of the DVB-T/T2 transmitter or network. This method is most effective when coverage predictions are available because the measurement points can be selected only around the predicted coverage border. However, in principle it works also if no a priori knowledge of the coverage area is available.

Attachment 4 describes a method to verify actual coverage in specific areas of interest. These areas can for example be districts with inhomogeneous terrain where propagation models are not reliable, or settlements where problems with DVB-T/T2 reception have been reported. It is based on the principle that field strength and BER measurements are taken in a number of small areas on a measurement grid that is placed over the area of interest. Where the minimum required field strength is reached or exceeded and the relevant BER is sufficiently low, the small area is regarded as covered. If this method is used to investigate areas where interference is reported, it does not require knowledge of coverage predictions.

In case of fixed reception there is not a single method for coverage measurement being optimal for all possible measurement conditions. Depending on the type of DVB-T/T2 network (SFN or MFN), the size of the coverage area, the terrain, the presence or absence of interferences and the purpose of the measurement, one of the methods from Attachments 1, 3 and 4 could be considered as more suitable for the DVB-T/T2 coverage measurement and comparison with coverage predictions compared to the other two methods. The following table contains information to provide guidance on the applicability of the different measurement methods.

TABLE 7

Comparison of measurement methods for fixed reception

Topic/Issue	Method in Attachment 1	Method in Attachment 3	Method in Attachment 4
Coverage prediction	Necessary	Not necessary, but eases measurements considerably	Not always necessary, depending on aim of measurement
Applicable in SFNs	Yes	Principally yes, but measurement effort increases with number of transmitters in SFN	Yes
Measurement effort	High for good accuracy, depends on number of test areas	Low, especially if coverage prediction is available	High
Terrain of coverage area	Any	Preferably flat	Any

The following issues associated with the recommended measurement methods have to be considered.

a) Degradation of the reception due to self-interference may not be assessed correctly by methods in Attachment 3 because separation between wanted and unwanted field strength is not always possible. The method in Attachment 4 indirectly measures interfering field strengths by assessing the BER. If at locations with sufficient wanted field strength reception is not possible or BER is too high, it can only be because of interfering signals, either external or from self-interference.

b) The network gain in an SFN that is calculated from the distribution of measured field strengths in methods in Attachment 1 and Attachment 3 may be different from the network gain assumed by planning tools.

c) BER measurements are inherently dependent on the DVB-T/T2 receiver used, especially on its noise figure. To minimize this influence, measures have to be taken to achieve a maximum total receiver noise figure of 6-7 dB as assumed by planning. This can for example be done by inserting an external low-noise amplifier in front of the measurement receiver.

d) Reflections of the wanted signal at the measurement points are not predicted by planning tools but are included in the measurement result. Their effects can be constructive or destructive, depending on the delay relative to the direct signal or other reflections.

For the above reasons, the results of the measured coverage at certain reception points or areas may differ from the predicted coverage area, although the prediction can be regarded realistic.

Attachment 1
to the Annex

Verifying the coverage prediction for fixed reception

A1.1 Selection of measurement locations

To exactly verify the true coverage area, measurements at virtually all locations inside the area would have to be made. In the procedure described in this Attachment, measurements are limited to a certain number of test areas close to the border of the predicted coverage area of the DVB-T/T2 transmitter or SFN network in order to keep the amount of measurements at a practical level. The measured coverage inside the test areas is extrapolated to verify the predicted coverage for the whole network. To obtain the required accuracy of the extrapolation the number of test areas should be sufficient.

Test areas should preferably be placed:

– at the border of the predicted coverage area;
– in regions with high population density, leaving out regions where no reception is required;
– in regions with different terrain (hilly and flat);
– in different directions from the DVB-T/T2 transmitter or network.

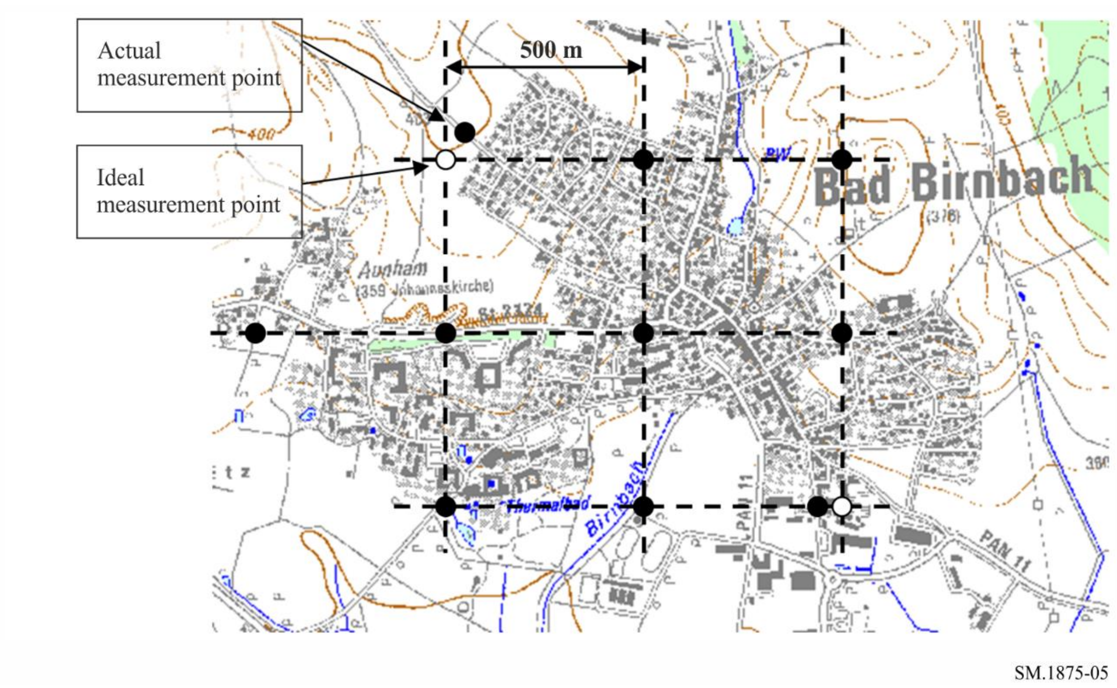
The number of selected test areas depends on:

– the difference in terrain in and around the planned coverage area;
– the required accuracy of the coverage assessment;
– the maximum feasible measurement effort.

To find measurement locations, a grid of squares or triangles with a side length of 500 m is placed over each test area (see Fig. 5).

FIGURE 5

Measurement points (fixed reception)



Sometimes the ideal measurement point will not be accessible due to buildings, non-existing roads and other problems. In this case, the nearest accessible measurement point has to be chosen, preferably within a distance of 50 m around the ideal measurement point. If possible, actual measurement points should not be obstructed by buildings that are higher than 10 m. If this is not realizable (especially in big cities) and more than 30 other locations have been measured for the area, the measurement point can be discarded. Otherwise, the best compromise between distance to ideal measurement point and obstruction-free reception has to be chosen. The result may be that the measurement point is not covered but this situation reflects the reality that would also be experienced by the user.

A1.2 Necessary measurement equipment

For the verification of coverage predictions for fixed DVB-T/T2 reception, the following equipment is needed:

TABLE 8

Necessary equipment for verification of fixed DVB-T/T2 reception

	Equipment type	Required functions, remarks
General setup	Measurement vehicle	Rotatable antenna mast that can be lifted up to 10 m height above ground, Positioning system (e.g. GPS)
Receiver 1	Spectrum analyser	Data interface to computers (e.g. LAN, IEEE488.2) Channel power measurement capability r.m.s. detector
Receiver 2	DVB-T/T2 measurement receiver	Noise Figure 6 to 7 dB* Capable of measuring levels from impulse response diagram
Antenna	LogPer or Yagi	Mounted on the mast of the measurement vehicle Characteristic as closely as possible to ITU-R BT.419 Horizontal and vertical polarization must be possible Antenna factor must be known (calibrated)
Measurement control	Computer program	Store trace data from spectrum analyser Store channel power measurement results Store data from positioning system Preferred function: Automatically adjust the analyser and perform the measurements

* If the noise figure of the measurement receiver exceeds 6 to 7 dB, a low noise amplifier must be applied in front of the receiver, so that the total noise figure of the measurement system is in this range.

A1.3 Required information

The following technical information about the DVB-T/T2 transmitter must be known prior to the measurement. In case of an SFN, the information is required for each of the transmitters in the network.

– Centre frequency

– Geographical coordinates of the transmitter(s)

– Polarization

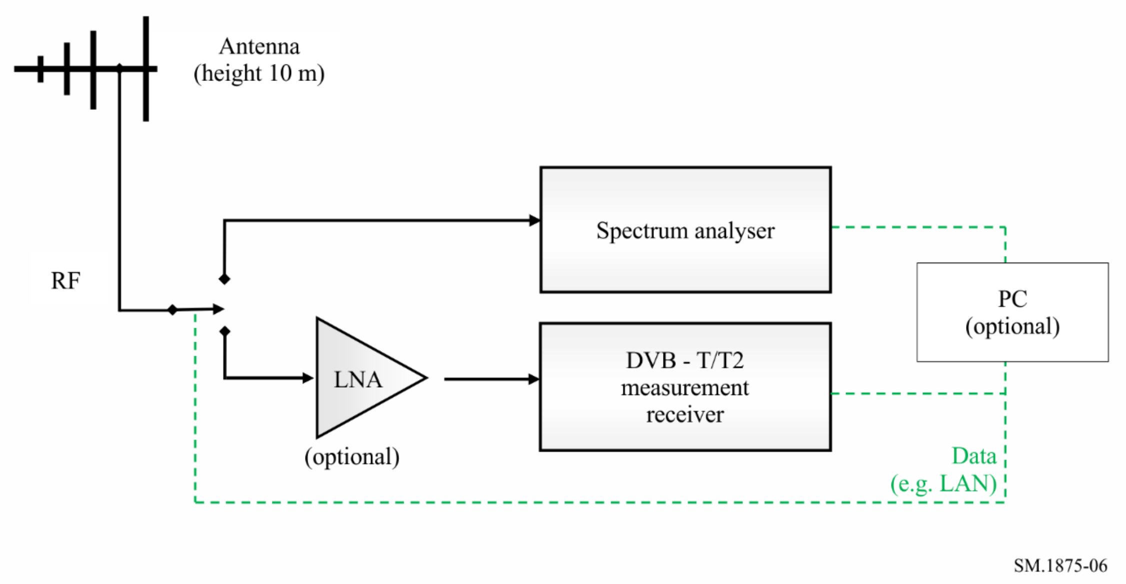
– System variant
– Relative time offset.

A1.4 Measurement setup

The following setup is used for the measurement.

FIGURE 6

Principle measurement setup (fixed reception)



A1.5 Measurement procedure

At the measurement location, the antenna is pointed in the nominal direction to the transmitter in 10 m height with the same polarisation as the transmitter. In an SFN, this should be the transmitter providing the highest signal level at the measurement location.

The first measurement is done using the DVB-T/T2 measurement receiver with the following settings:

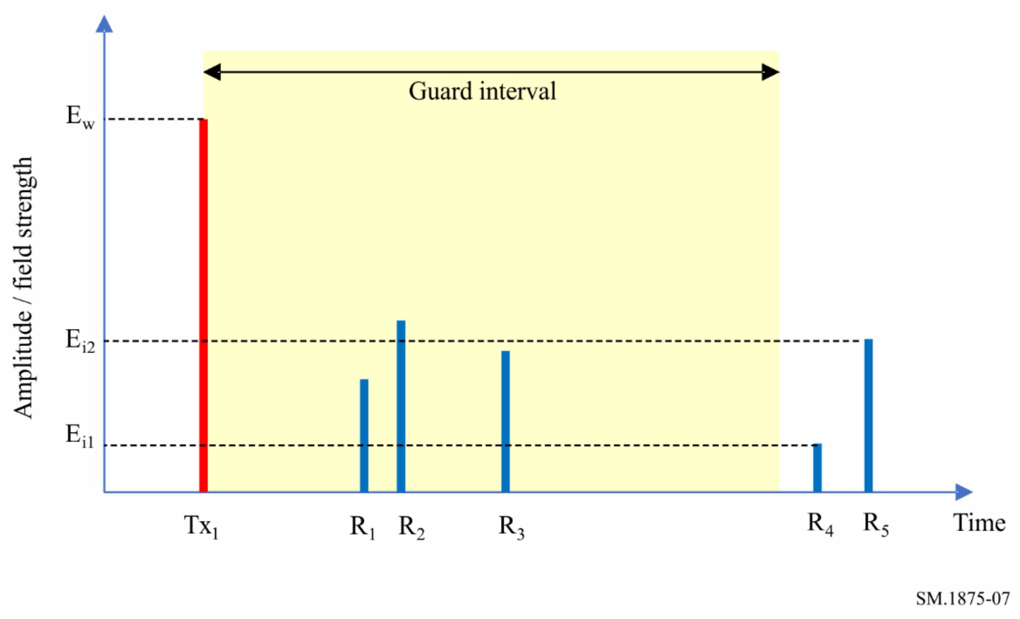
– frequency: centre frequency of the DVB-T/T2 channel;
– measurement mode: channel impulse response.

If synchronization is possible, it can be assumed that the strongest peak refers to the direct signal of the wanted transmitter. The field strength of this peak is measured as the wanted field strength E_w.

The field strengths of each peak outside the guard interval are measured as E_{i1} to E_{in}.

FIGURE 7

Example of a channel impulse response measurement



The peaks inside the guard interval that result from reflections are not added to the wanted field strength because they are not assumed to be reliable and stable.

If the DVB-T/T2 receiver is not able to synchronize for any antenna direction/SFN transmitter, the measurement location is not covered. If further information about the reason is needed, additional measurements are described in § A1.4.

Because the minimum field strength values for DVB-T/T2 are different for Gaussian, Rice and Rayleigh channels, the reception channel has to be determined at each measurement location. This is done by recording one trace of the signal spectrum with a small RBW and calculating the standard deviation σ_{sp} of the resulting spectral densities.

This measurement is done with the following spectrum analyser settings:

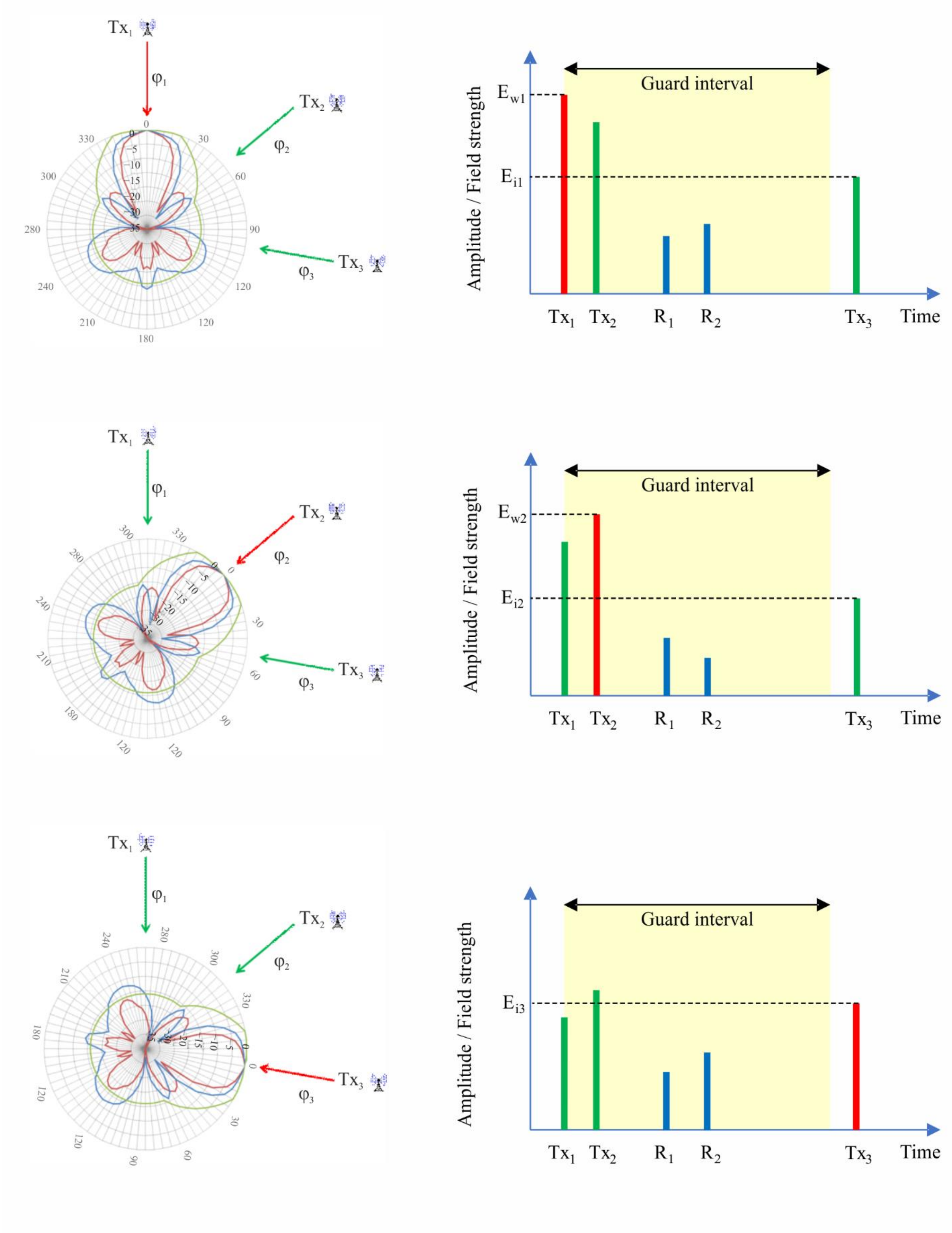
– Span: exact bandwidth of the DVB-T/T2 system
– RBW: 30 kHz
– Detector: r.m.s.
– Trace mode: ClearWrite
– Sweep time: ≥200 ms
– Unit: dB(μV) or dBm.

The slow sweep time (or long averaging time) is needed to ensure that the resulting spectral levels are not influenced by the modulation of the signal.

In case of an SFN, the measurement has to be repeated after pointing the antenna in the direction of every transmitter in the network. The nominal directions to these transmitters are calculated from their known coordinates and the coordinates of the measurement location. The (possibly weaker) signal peaks from the various transmitters in the SFN can be identified by calculating the differences in distance relative to the distance to the first transmitter, also considering the known time offset of each transmitter in the network. Figure 8 shows an example with three SFN transmitters.

FIGURE 8

Example field strength measurement in an SFN with three transmitters



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In the example, the receiver always synchronizes on the first peak. The signal from Tx3 arrives outside the guard interval and therefore is always regarded as an interfering signal. This may be possible if the measurement location is outside the planned coverage area of the SFN. As a consequence, the measurement in the direction of Tx_3 does not provide any wanted field strength.

Determination of the reception channel has to be done for each direction separately.

Depending on the measured wanted field strength and reception channel, the distance to the next measurement point can vary according to Table 9.

TABLE 9

Distance between neighbouring measurement points

Reception channel	**Measured wanted field strength (dB)**	**Distance to next measurement point (m)**
Gauss or Rice	$e \geq E_{med} + 10$	1 000
Gauss or Rice	$e < E_{med} + 10$	500 (standard)
Rayleigh	(any)	250

A1.6 External interference

The measurement with the DVB-T/T2 receiver can only detect interfering signals from the wanted transmitter or network (self-interference). The relative received field strength of signals from adjacent transmitters (in MFNs) or other SFN networks is normally lower than the discrimination of the measurement antenna, in which case they cannot be measured separately. However, they are assessed indirectly by the fact that the DVB-T/T2 receiver has to be able to synchronize for the measurement. If synchronisation is not possible, it can either be because the wanted signal level is not sufficient, or because the interfering level is too high. In both cases, the measurement point is regarded not covered.

If it is necessary to determine the cause of the inability to synchronize, the following alternative measurement procedure may be applied.

With the measurement antenna pointed to the direction of the wanted transmitter (in case of SFN all wanted transmitters separately), the total field strength of the wanted transmitter(s) is measured with the spectrum analyser using the following settings:

– Span: channel width of the DVB-T/T2 system
– RBW: 30 kHz
– Detector: r.m.s.
– Trace mode: ClearWrite
– Sweep time: ≥ 200 ms
– Measurement mode: Channel Power.

If the σ_{sp}-corrected value exceeds the minimum required field strength for the DVB-T/T2 system, the cause of the failure to synchronize (and hence for the measurement location not being covered), is assumed to be to high external interference, or too strong levels from adjacent channels. In some situations, the interfering level from a co-channel transmitter may be measurable by turning the antenna away from the wanted transmitter(s) and searching for another local maximum. If necessary, a measurement antenna with higher directivity may be used for this measurement.

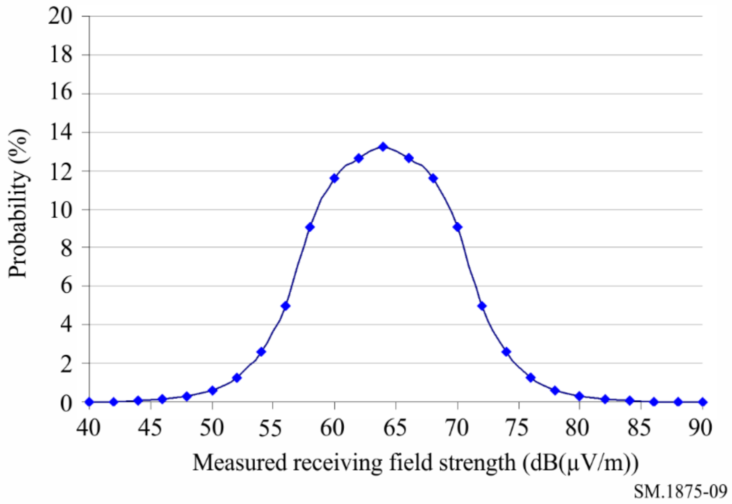
A1.7 Evaluation of the results

A1.7.1 Verifying homogeneous field strength distribution

To verify that the field strength inside the measurement area is homogeneous and that, depending on the reception channels, enough measurement samples have been taken, it is helpful to plot the statistical distribution of the measured field strength values as shown in Fig. 9. The plot shows the percentage of measurement samples having a certain field strength value (on the y-axis) against that value (on the x-axis).

FIGURE 9

Receiving field strength distribution (fixed reception)



In the example shown, 13% of all measured receiving field strength values are 64 dB(µV/m). The curve is relatively narrow and Gaussian. In this case, it can be assumed that the field is relatively homogeneous inside the measurement area. If the curve is flat, broad or does not resemble a Gaussian distribution, the field is cluttered and disturbed. In this case, further measurements with a 250 m grid are necessary.

It must be emphasized that the requirement on field strength distribution given in this section can be used only for study areas located far enough away from the transmitting station and with boundary shapes close to a square or a circle, in other cases this requirement may not be met.

A1.7.2 Correction for the reception channel

As said in § 2.24, the international agreements such as the GE06 Agreement for DVB-T show different *C*/*N* and/or minimum required field strengths depending on the reception channel. These reception channels are idealized in that way that for example, the Rayleigh channel is assumed to have a standard deviation of σ_{sp} of 3 dB. Typically signals of different reception channels are received. To correctly combine the field strengths of these signals, a correction (C_σ) is added to all measurement values according to § 2.29 and Attachment 5 (σ_{sp}-correction). This correction can be positive or negative. It normalizes all measured field strengths to a σ_{sp} of 3 dB. The result is then only compared with the *C*/*N* and/or minimum median field strength values for Rayleigh channels available in ITU-R documentation.

In case of an SFN, the same value for the σ_{sp}-correction applies to all signal peaks measured in one direction φ.

A1.7.3 Correction for time probability of interfering signals

If significant interference was received, including the self-interferences of an SFN, the measurement values for the interfering field strength made at a random time are regarded to have a 50% time probability. Usually DVB-T/T2 coverage is planned for a time probability of 1% for interfering signals. In case of external interference (signals from another transmitter in MFNs or other SFN networks), no correction is necessary because they have only been assessed indirectly by the requirement of synchronisation during the measurement. If synchronisation was not possible due to excessive external interference, the measurement location is not regarded covered anyway. For self-interference, the measurement values have to be corrected to 99% time probability.

In an SFN, the distance to the interfering signal source can be calculated by the time offset measured in the impulse response diagram. The necessary correction value can then be determined using Recommendation ITU-R P.1546.

In MFNs, interference can be caused by improper network planning and reflections. In these cases, the distance to the interfering signal source is unknown and exact correction from Recommendation ITU-R P.1546 is not possible. For this situation, a standard correction of 10 dB is suggested which has to be added to the measured field strengths. This value corresponds to the average difference for 50% and 1% time probability at 600 MHz land paths in Recommendation ITU-R P.1546.

A1.7.4 Calculation of the total field strength

In case of SFNs, for each measurement direction φ, the peaks from the different transmitters (received inside the guard interval), are corrected by the directivity attenuation of the reference antenna in the angle offset under which the signal arrives.

Example from Fig. 8 for an SFN with three transmitters in the UHF Band IV: It is assumed that the signal from Tx_1 is the strongest, so φ_1 would be the preferred direction of a customer's antenna. The signal from Tx_1 arrives in the main lobe of the antenna and its field strength E_1 is not corrected. The signal from Tx_2 arrives under a relative angle of 50 degrees. The attenuation of the reference antenna for this angle is 12 dB (see Fig. 1). The field strength E_2 is derived from the signal peak of Tx_2, measured in the direction of φ_2, and reduced by 12 dB. The field strength E_3 is the peak from Tx_3, measured in the direction of φ_3, and reduced by 16 dB.

If any of the transmitters in the SFN have a different polarisation than the main transmitter, their field strengths are reduced by the combined directivity and orthogonality discrimination values in Tables 1 and 2 instead.

In case of MFNs, measurements were only done in one direction, and reflections were not included since it cannot be assumed that they are reliable and stable in time. Therefore, the total wanted field strength is the main peak of the signal measured inside the guard interval, and the total interfering field strength is the sum of all peaks measured outside the guard interval.

The sum of multiple measured field strengths E_{sum} is the linear addition according to the following equation:

$$E_{Sum} = 10 \log \left(10^{E_1/10} + 10^{E_2/10} + \ldots + 10^{E_n/10} \right)$$

The interfering signals are corrected and added equally.

A1.7.5 Decision whether a measurement point is covered

If the DVB-T/T2 receiver was not able synchronize (in SFNs if no synchronisation was possible in any direction), the measurement location is not covered.

In case synchronisation was possible, the corrected result of the measurement has to be evaluated for each measurement location (in case of SFNs also for each direction φ) separately.

To determine whether successful reception of the service is possible with a sufficient confidence level, the following three components have to be compared:

– The measured wanted field strength E_{sum} including σ_{sp}-correction (Blocks A in Fig. 10).

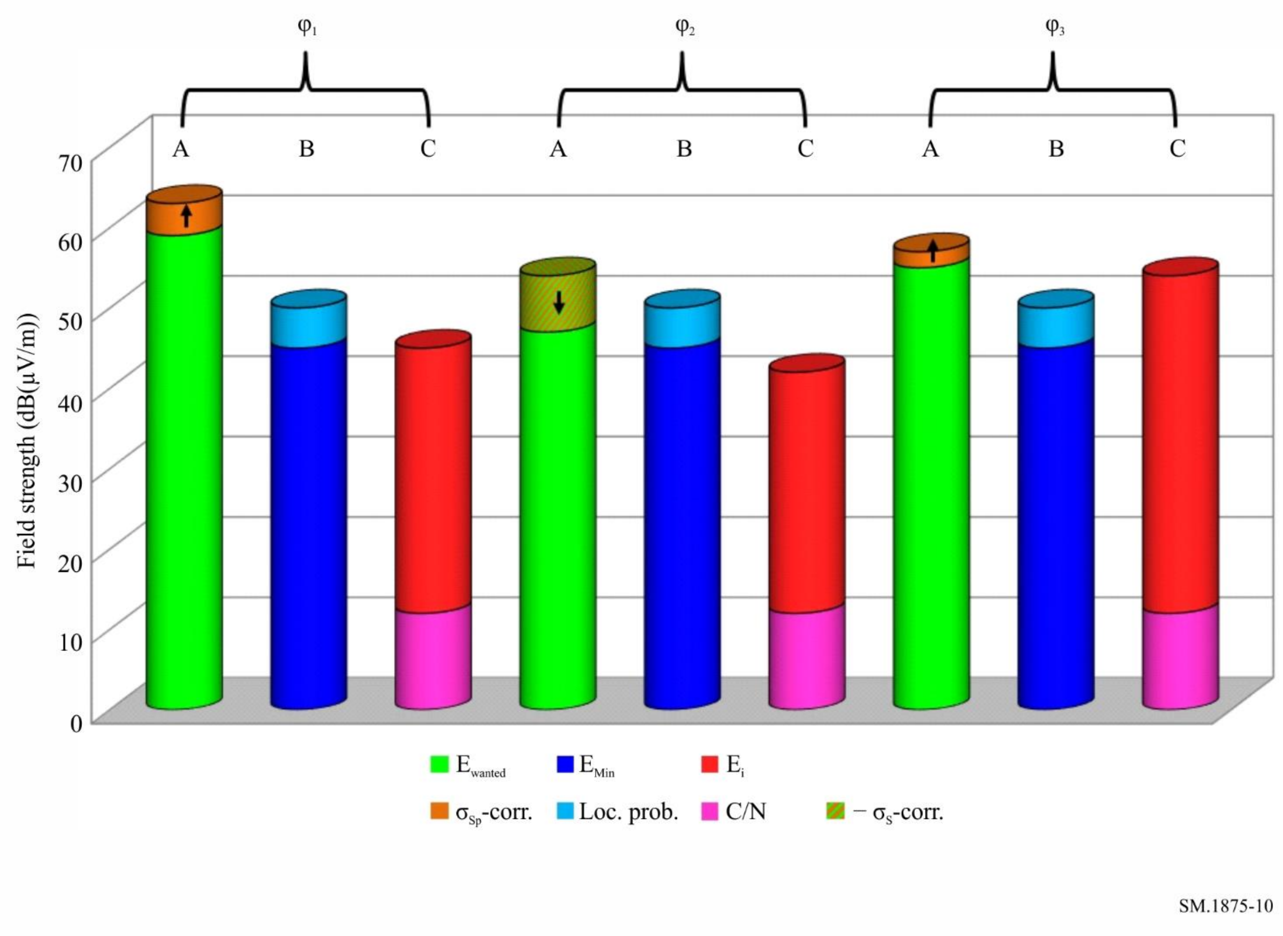
– The sum of minimum wanted field strength (E_{min}) and correction for required location probability according to Attachment 5 (Blocks B in Fig. 10).

– The sum of measured interfering field strength and required protection ratio for the service (Blocks C in Fig. 10).

These components are shown in Fig. 10 using the example of an SFN with three transmitters.

FIGURE 10

Measurement evaluation (fixed reception)



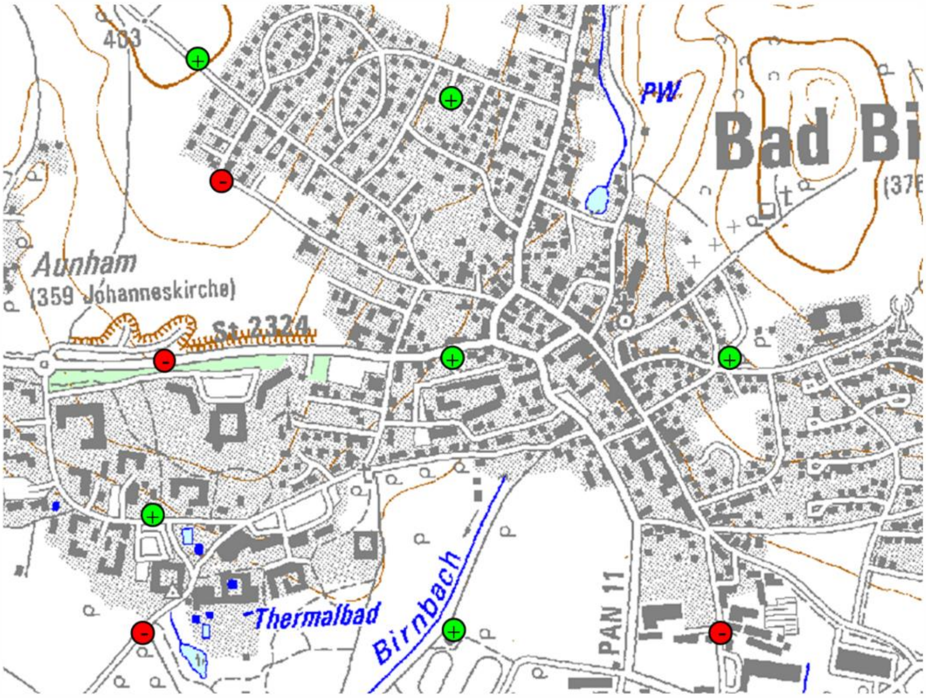
If the wanted signal block exceeds the other two blocks, fixed reception is possible with 95% probability. In the example above, this is true for the directions φ_1.and φ_3. For the direction φ_1 no reception can be assumed, although the measured wanted field strength exceeds both other blocks, because in this direction the σ_{sp}-correction is negative. In case coverage is to be assessed for other location probabilities, the correction from 50 to 95% has to be replaced by the equivalent value for the required probability.

A1.8 Result presentation

An evident way of displaying the results is to draw them in a map as shown in Fig. 11. Here, measurement locations where reception is possible are shown as green (bright) dots whereas measurement points where no reception is possible are shown in red (dark). Also to be seen is that between some original measurement locations, additional points were inserted that roughly follow a 250 m grid.

FIGURE 11

Measurement results (fixed reception)



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Provided enough measurements have been made, it is also possible to determine the location probability with which reception of the service is possible inside the measurement area. This is done by plotting the percentage of σ_{sp}-corrected measurement values exceeding a certain field strength against the value of that field strength. An example is shown in Fig. 12.

The coverage threshold is the higher of:

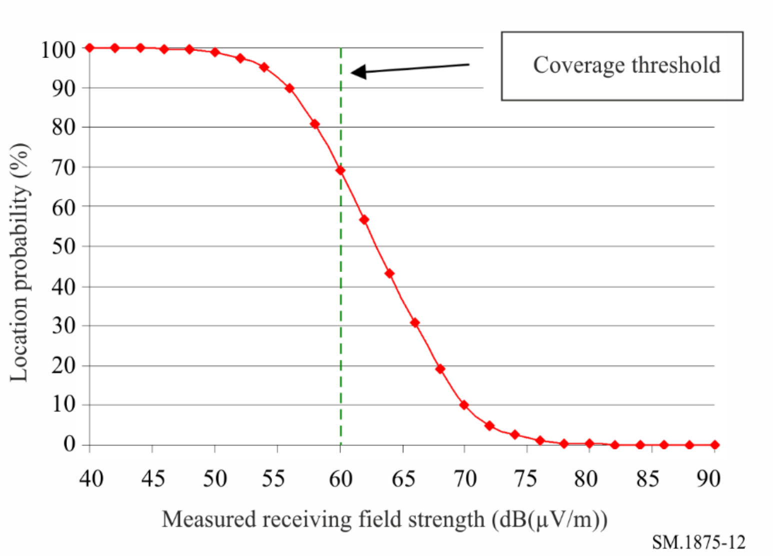
– the sum of measured interfering field strength plus required protection ratio for the service (this is the ‘interferer’ block C in Fig. 10);

– the sum of minimum wanted field strength (E_{min}) and correction for required location probability (C_1) according to Attachment 5 (this is the ‘calculated’ block A in Fig. 10).

In the example in Fig. 12, the coverage threshold is 60 dB(µV/m) which is reached or exceeded by 70% of the measurement samples. This means that reception will be possible at 70% of the locations inside the measurement area, or, in other words, the measurement area is covered with a probability of 70%.

FIGURE 12

Measured location probability (fixed reception)



A1.9 Verification of planned coverage

Comparison between measured and planned coverage is done as follows:

1 Calculate the percentage of coverage according to the planning tools A_p in each test area.

2 Calculate the percentage of small areas in the original measurement grid (see Fig. 5) of each test area that have been measured as covered (A_c = green dots in Fig. 11 relative to the total number of small areas in the measurement grid).

3 Compare A_p and A_c for each test area. If $A_c \geq A_p$, the respective test area is covered at least to the extent that was predicted by planning.

If the number of test areas is assumed to be sufficient and their location is regarded as being representative for the terrain in which coverage is to be granted, and if the majority of test areas reach or exceed the planned coverage percentage, it is assumed that the total coverage area of the DVB-T/T2 station or network is at least as large as the planned coverage area.

Attachment 2
to the Annex

Verifying the coverage prediction for portable reception

A2.1 Measurement principle

To exactly verify the true coverage area, measurements at virtually all locations inside the area would have to be made. To keep the amount of measurements at a practical level, their number has to be limited.

Portable reception is usually defined in a height of 1.5 m above ground. Being so close to the ground, a line-of-sight to the transmitter dominated by the direct signal will be rare, especially in urban surroundings. Most of the reception channels will be Rayleigh. It is therefore necessary to perform mobile measurements in order to gather enough measurement samples for a statistically relevant result.

The measurement method focuses on measurement of the wanted signal only. Interfering signals from other transmitters or networks can be neglected for the following reasons:

– The required field strength for portable reception is much higher than for fixed reception. The border of the coverage area for portable reception will therefore normally be determined by the minimum required field strength rather than by insufficient *C*/*I*.
– The measurements are performed at an antenna height of only 1.5 m which makes it unlikely that signals from far away (interfering) transmitters are received with sufficient field strength to influence the result.

However, strong signals on adjacent channels may be included in the planning process and certain areas may then be predicted as not covered. These rare cases may lead to areas where the measurement shows coverage, but successful reception with commercial DVB-T/T2 receivers is not possible.

It is important to note that there are different requirements for portable and mobile reception. Since the measurement method described here focuses on field strength values only, it is still possible to draw conclusions about portable reception when in fact the measurement itself is mobile.

For DVB-T the relevant documentation (e.g. the GE06 Agreement) only specifies minimum median field strengths in 10 m height above ground. To calculate necessary field strengths for portable reception in 1.5 m height, several corrections have to be applied. They are calculated according to Attachment 5.

Example:

For DVB-T, the GE06 Agreement specifies a minimum equivalent field strength (E_{min}) of 47.3 dB(μV/m) for portable outdoor reception with a standard deviation for the spectral amplitude distribution of $\sigma_{sp} = 3$ at 500 MHz (TV channel 24). This value is clear of all margins and represents the lowest field strength for a successful reception. To calculate the necessary field strength for portable indoor reception, corrections for the building penetration loss and different location probability inside buildings have to be added. For our example, 10.9 dB have to be added for portable indoor reception with a location probability of 70% (see Attachment 5), so that the minimum median field strength at 10 m is 58.2 dB(μV/m).

For DVB-T2, Report ITU-R BT.2254 also specifies minimum median field strengths (E_{med}) for portable outdoor reception (indoor and outdoor) for one example system variant. The respective figures for other system variants can be calculated by exchanging the *C*/*I* values.

The measurement is performed while driving along most of the roads inside a measurement area that represents a village or city at the outer rim (or border) of the predicted coverage area. The results can directly be compared to the calculated minimum median field strength for portable reception.

A2.2 Necessary measurement equipment

For the verification of coverage predictions for portable DVB-T/T2 reception, the following equipment is needed:

TABLE 10

Necessary equipment for verification of portable DVB-T/T2 reception

	Equipment type	Required functions, remarks
General setup	Measurement vehicle	Multiple antennas can be attached to the roof in about 1.5 m above ground Positioning system (e.g. GPS)
Receiver (standard)	Spectrum analyser	Data interface to computers (e.g. LAN, IEEE488.2) Channel power measurement mode r.m.s. detector
Receiver (optional)(1)	Broadband receiver/analyser performing FFT	Min. capture bandwidth: 10 MHz Data interface to computers (e.g. LAN, IEEE488.2) Channel power measurement mode
Antenna	2 omnidirectional antennas(2)	Mounted on the roof top of the measurement vehicle One antenna with horizontal and one with vertical polarization Antenna factor must be known (calibrated)
Antenna switch(2)	Computer controllable RF switch	Switching speed: ≥ 40/s
Measurement control	Computer program	Automatically adjustment of the analyser, position the antenna switch, perform the measurements and display live results on screen Store trace data from spectrum analyser Store channel power measurement results Store data from positioning system Live display of the actual standard deviation σ of the spectral levels on a digital map

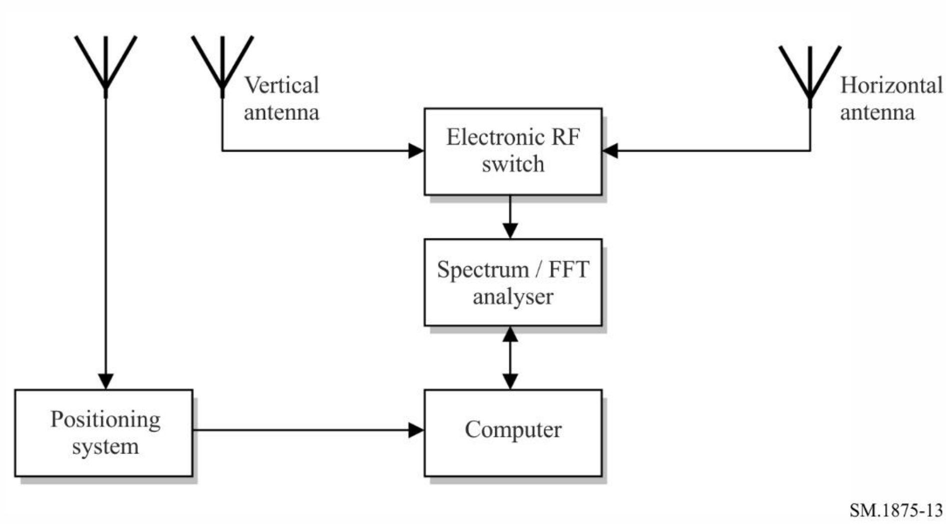
(1) Because a broadband FFT receiver/analyser captures the whole signal bandwidth at once it allows faster measurements which gives more accurate results, especially in the determination of the reception channel (see § 2.24).

(2) For measurements in networks with only one transmitter (MFN) or SFNs using only one polarization, only one omnidirectional antenna and no antenna switch is needed.

The setup for measurements inside SFNs with both polarizations is shown in Fig. 13.

FIGURE 13

Measurement setup (portable reception inside SFNs)



It is important that interferences from the measurement equipment and vehicle are kept to a level that is below the system sensitivity.

A2.3 Measurement procedure

All measurements are taken while driving along the major roads inside the measurement area which is a city or village at the border of the predicted coverage area.

The measurement is triggered once every second (roughly the time a GPS positioning system delivers a new/different coordinate). Then, in a time of 500 ms, 10 samples of the received signal level are taken, converted into field strengths using the antenna factor of the measurement antenna, and the median of the 10 samples is stored together with the geographical coordinate.

The following settings for the spectrum analyser have to be used for the measurement:

– Measurement mode: Channel power
– Channel bandwidth: 6 MHz, 7 MHz or 8 MHz
– RBW: 30 kHz or "Auto" (not higher than 100 kHz)
– Detector: r.m.s.
– Trace mode: ClearWrite
– Sweep time: 20 … 25 ms.

If a broadband receiver or analyser performing FFT is used, the following settings apply:

– Capture bandwidth: ≥ 6 MHz, 7 MHz or ≥ 8 MHz (channel bandwidth)
– Acquisition time: 1 ms
– Measurement mode: Channel power.

Especially when performing mobile measurements in urban areas and only 1.5 m above ground, the reception channel will often be Rayleigh with fast and significant variations of the receiving conditions. Despite the fact that continuous mobile registration will deliver many measurement values, the number of samples may not be enough to draw conclusions on the coverage situation with reasonable confidence. To get information about the distribution of the field strength in the measurement area, it is necessary to determine the reception channel. This has to be done in each measurement cycle, i.e. once every second, directly after the field strength measurement.

The reception channel is determined by recording the average spectrum over a time of at least 200 ms to level out influences of the DVB modulation.

If this measurement is done with a swept spectrum analyser, the following settings have to be used:

– Span: exact bandwidth of the DVB-T/T2 system
– RBW: ≤ 30 kHz
– Detector: r.m.s. (preferred) or sample (if r.m.s. is not available)
– Trace mode: ClearWrite
– Sweep time: 200 ms
– Unit: dB(μV) or dBm.

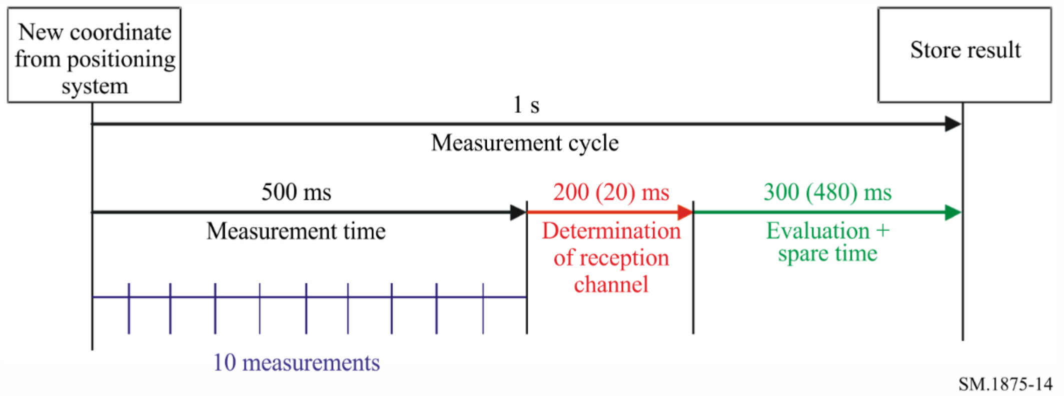
Especially in mobile measurements with fast changing receiving conditions, it is important to have the determination of the reception channel as close to the field strength measurement as possible. A broadband receiver/analyser performing FFT can record the whole DVB-T/T2 spectrum at once requiring far less measurement time and is therefore recommended. The following settings have to be used:

– Capture bandwidth: ≥ 6 MHz, 7 MHz or ≥ 8 MHz (channel bandwidth)
– Used span: exact bandwidth of the DVB-T/T2 system
– RBW: ≤ 30 kHz
– Acquisition time: 20 ms.

For each of the captured spectra, the standard deviation of the spectral amplitudes σ_{sp} is calculated and stored together with the channel power level and geographical coordinates. Figure 14 shows the basic timing for one measurement cycle.

FIGURE 14

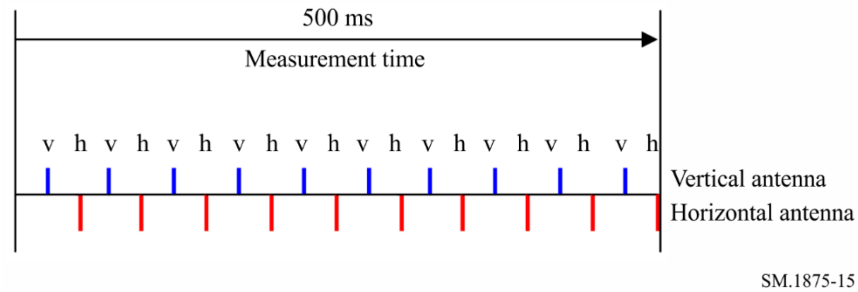
Basic timing for transmitters/networks with only one polarization (portable reception)



In SFNs with mixed polarization, both polarization planes must be measured at the same time. This requires taking 20 measurement samples in 500 ms measurement time. The antenna is switched from vertical to horizontal between each sample. This is necessary to acquire median field strength values for both polarizations referring to the same location. Figure 15 shows the necessary timing (only for the field strength measurement).

FIGURE 15

Measurement timing for SFNs with mixed polarization (portable reception)



In SFNs with mixed polarization, the reception channels also have to be measured in both planes separately. This leaves only 100 ms spare and processing time if a swept spectrum analyser is used, and 460 ms if a broadband FFT receiver/analyser is used.

The equivalent field strength is calculated from the ten samples of each polarization plane separately. The σ_{sp}-correction from the reception channel determination is applied to each of the two medians. The higher of both values is stored as the result.

A2.4 Evaluation of the results

A live evaluation of the measurements is possible by displaying the current value of σ_{sp} on a digital map during the measurement: If in a certain region the value of σ_{sp} frequently is above 3 dB, it is an indication of dominant Rayleigh reception channels. In this case, more measurements are needed which can be achieved by driving more side roads along the route. Figure 16 shows an example of such a live display where green (bright) dots mark Rice channels and red (dark) dots are Rayleigh channels.

FIGURE 16

Live display of the reception channel during measurement

To determine whether portable reception is possible inside the measurement area, it is necessary to compare all measured field strength values with the minimum median field strength for portable reception calculated from the relevant ITU-R documentation (e.g. the GE06 Agreement). Care should be taken to apply the corrections to the measurement results according to the required reception conditions:

– For portable outdoor reception, only σ_{sp}-correction has to be applied. No additional corrections for location probability are necessary since the measurement was taken under the correct reception conditions and enough samples have been taken. The location probability can directly be derived from the measurement results (see § A2.5).

– For portable indoor reception, additional corrections for building penetration loss and the different location probability according to Attachment 5 have to be applied.

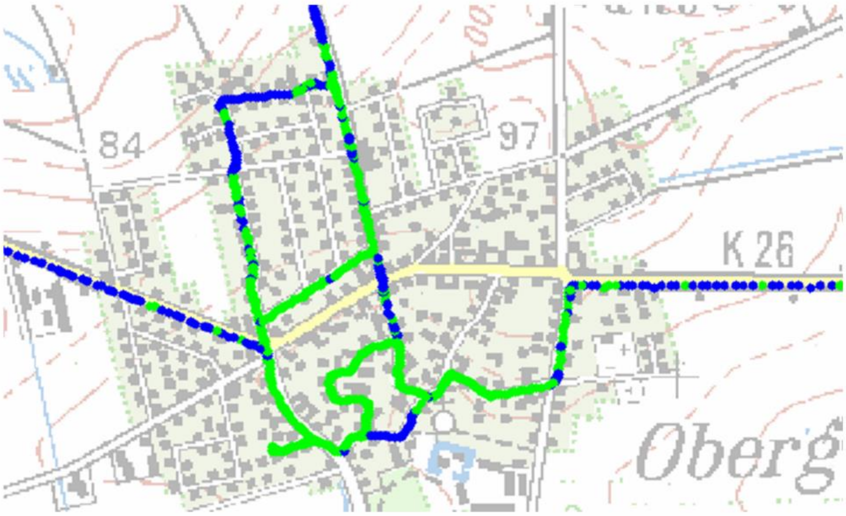
– Fixed reception cannot be calculated from these mobile coverage measurements at all. Instead, the measurement procedure described in other attachments should be used.

A2.5 Result presentation

The direct way of displaying the coverage situation is to draw the result of the comparison described above on a map in different colours (see Fig. 17): A green (bright) dot shows measured values plus additional margins exceed the minimum median field strength (reception possible) for portable outdoor situation, blue (dark) dots show points where portable indoor reception is possible.

FIGURE 17

Measurement results (portable reception)



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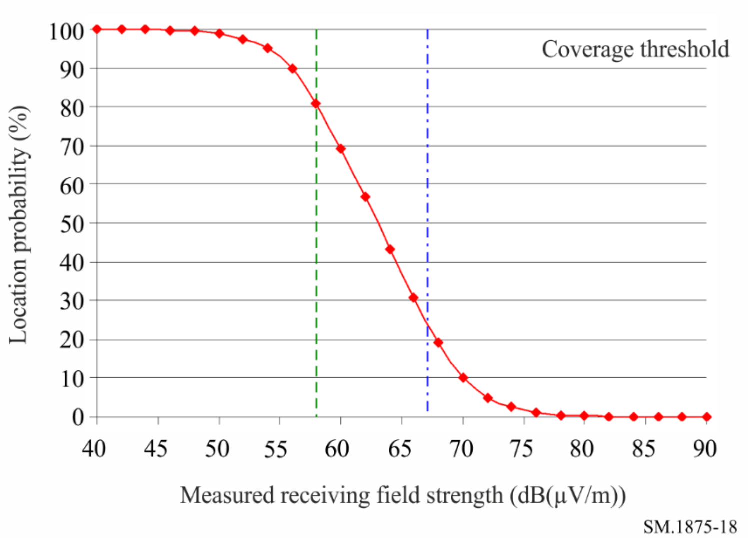
If no live display of the reception channel during measurements was possible, it can still be determined afterwards whether the field strength distribution was homogeneous inside the measurement area. This is done by drawing the distribution of the σ_{sp}–corrected measurement results like in Fig. 9. If the curve is Gaussian and relatively narrow, like in the example, the field strength distribution is sufficiently homogeneous. If not, more measurement values are needed by driving along more different roads inside the measurement area.

The disadvantage of the method described here is that this conclusion can only be drawn off-line and may require repeating the measurement. A live display of the reception channel, however, already reveals this result during the measurement when immediate reaction is possible.

From the σ_{sp}-corrected measurement results, it is possible to draw a conclusion about the probability of portable reception inside the measurement area. This is done by plotting the percentage of σ_{sp}-corrected measurement values exceeding a certain field strength against the value of that field strength. An example is shown in Fig. 18.

FIGURE 18

Measured location probability (portable reception)



In the example, the calculated minimum median field strength for portable outdoor reception is 58 dB(µV/m) (green dashed line) and for portable indoor reception 67 dB(µV/m) (blue dotted line). The measurement shows that portable outdoor reception is possible in at least 80% of the measurement area and portable indoor reception is possible in at least 25% of the measurement area.

Attachment 3
to the Annex

Alternative method to determine the coverage border of DVB-T/T2 transmitters and networks for specific cases

A3.1 Introduction

The method covered in this Attachment defines a procedure for defining the coverage area of DVB-T/T2 station for fixed reception based on the measurement of field strength in selected directions from the transmitter. The method can be regarded as simplified because it requires fewer measurements than the method described in Attachment 1, especially under the following conditions:

– The DVB-T/T2 network is an MFN.

– The transmitter(s) have omnidirectional antennas.

– The terrain in the coverage area is relatively flat (no hills providing large shading areas).

Availability of a priori knowledge of the predicted coverage area would be helpful to support the method.

The advantage of requiring little measurement effort exists especially when data from coverage predictions are available.

A3.2 Measured parameters of the signal

In determining the service area of a transmitting station of a terrestrial digital broadcasting standard DVB-T/T2 fixed reception in receiving location is carried out measurement of the following signal parameters:

– electromagnetic field strength;

– the standard deviation of the spectral amplitudes σ_{sp} DVB-T/T2 signal.

A3.3 Equipment requirements

Measurements are carried out using a mobile or transportable measurement system, which includes the following equipment:

– antenna mast with height of 10 m;

– antenna tripod with height of 1.5 m or more (see further explanation in § A3.5);

– directional receiving antenna;

– calibrated antenna cable;

– measuring receiver/analyser;

– navigation receiver;

– computer.

Equipment characteristics are given in Table 11.

TABLE 11

Characteristics of equipment

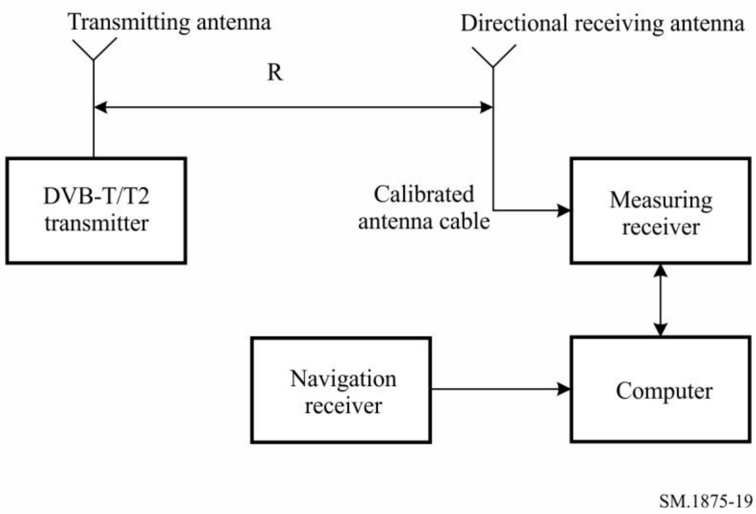
Equipment	Characteristics
Measuring device(s)	Spectrum analysis capability. Channel power measurement. “Echo pattern” function. Data interface to the computer.
Directional receiving antenna	Polarization: linear [2]. Antenna gain, at least * [3]: 200 MHz: 7 dBd; 500 MHz: 10 dBd; 800 MHz: 12 dBd.
Calibrated antenna cable	Maximum feeder loss *: 200 MHz: 2 dB; 500 MHz: 3 dB; 800 MHz: 5 dB.

* These values are taken from ITU-R BT.1368 and reflect the values assumed by planning tools.

The equipment connection diagram is shown in Fig. 19.

FIGURE 19

Equipment connection diagram



A3.4 Measurement planning

Initially a radio wave propagation model might be used to determine the coverage boundaries for a selected DVB-T/T2 station (e.g. Rec. ITU-R P.1546 or Rec. ITU-R P.1812).

Then, taking into account the presence of roads and highways, a number of radial directions from the DVB-T/DVB-T2 station is selected to be measured. The number of radial directions shall be at least 4 to draw the measured coverage area boundary curve on a digital map.

For each radial direction the location of small areas is defined (areas of approximately 100 m × 100 m).

The location of the first small area shall meet the following requirements:

– the small area shall be within the DVB-T/T2 station line-of-sight;

– the small area shall be within the main vertical lobe of the transmitting antenna.

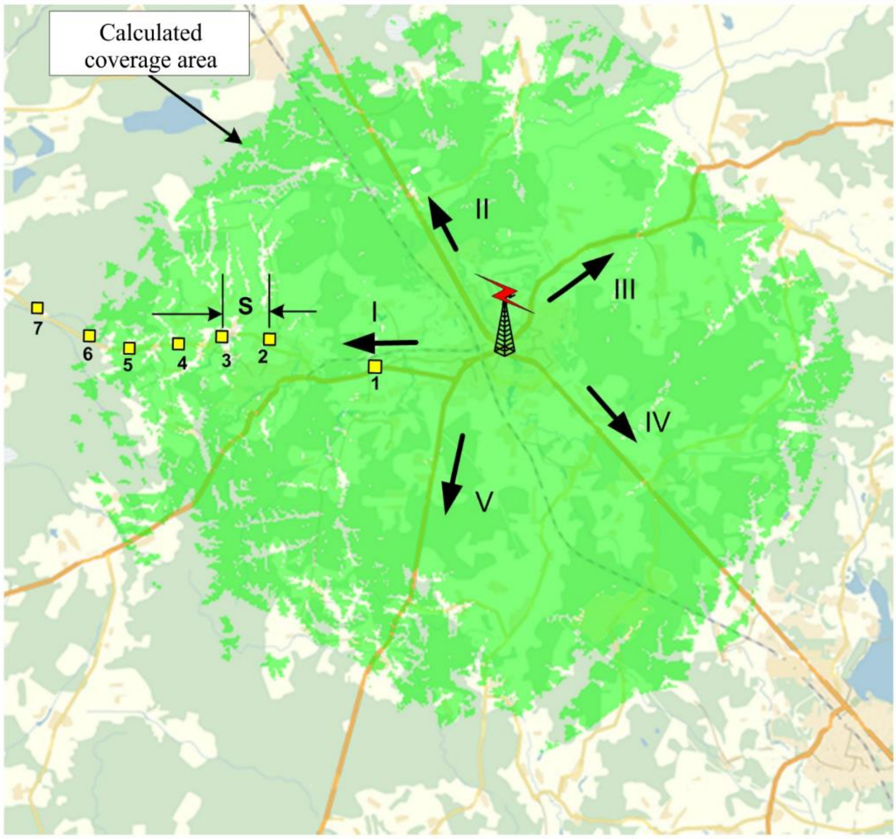
Other small areas are located closer to the calculated coverage boundary with approximately equal distances S. It is advisable to choose small areas within or near settlements. If settlements are located both on hilltops and in lowlands, then the measurements should also be carried out on hilltops and in lowlands.

The number of small areas should be at least seven (Fig. 20). With fewer small areas, the accuracy of the coverage boundary determination is reduced.

If necessary, the locations of small areas are confirmed by satellite images (e.g. Google Earth) or by their preliminary visitations. In each small area at least three measurement points ($N \geq 3$) are planned. One measurement point should be in the centre of the small area.

FIGURE 20

Example of measurement planning



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A3.5 Measurement procedure

At each receiving location the following parameters should be measured:

– electrical field strength;

– standard deviation σ_{sp} of the DVB-T/T2 signal spectral amplitudes.

In rural areas the receiving antenna is mounted at a height of 10 m. If it is not possible to find a measurement location without obstructions in the direction of the transmitter, such as in many urban areas with roof heights above 10 m, the measurement is conducted on the roofs of buildings with the receiving antenna installed on a tripod.

The antenna is pointed in the direction of maximum received field strength. If this maximum is received from the direction of the relevant DVB-T/T2 station and external disturbance from electrical or electronic equipment is not present, the measurement location is regarded suitable.

The absence of external disturbance can be assumed if the following conditions are met:

– There are no emissions visible in the spectrum that are higher than the level of the wanted DVB-T/T2 signal.

– The noise level between the wanted and adjacent DVB-T/T2 channels (the ‘gaps’ in the spectrum) is less than 3 dB above the receiver noise level (measured with the antenna being disconnected).

In other cases, an alternative measurement location inside the small area should be used instead.

The measurements are carried out with the following settings of the measuring receiver (mode ‘Spectrum analyser’):

– Centre frequency (FREQ): equal to the nominal centre frequency of the TV-channel;
– Channel bandwidth (Span): 8 to 10 MHz;
– Resolution bandwidth (RBW): 30 kHz;
– Video filter bandwidth (VBW): from 100 to 300 kHz (VBW ≥ 3 RBW);
– Sweep time: 2 s;
– Detector: RMS;
– Trace mode: Clear/Write.

During a measurement time of at least 1 min, 30 measurements of field strength and 30 standard deviations of spectral amplitudes σ_{sp} shall be taken. The values σ_{sp} are calculated according to Attachment 5. Thus 30 measurements of field strength, including σ_{sp}-correction, are used to define the median (over time) field strength (E^{loc}_{med}) in each receiving location.

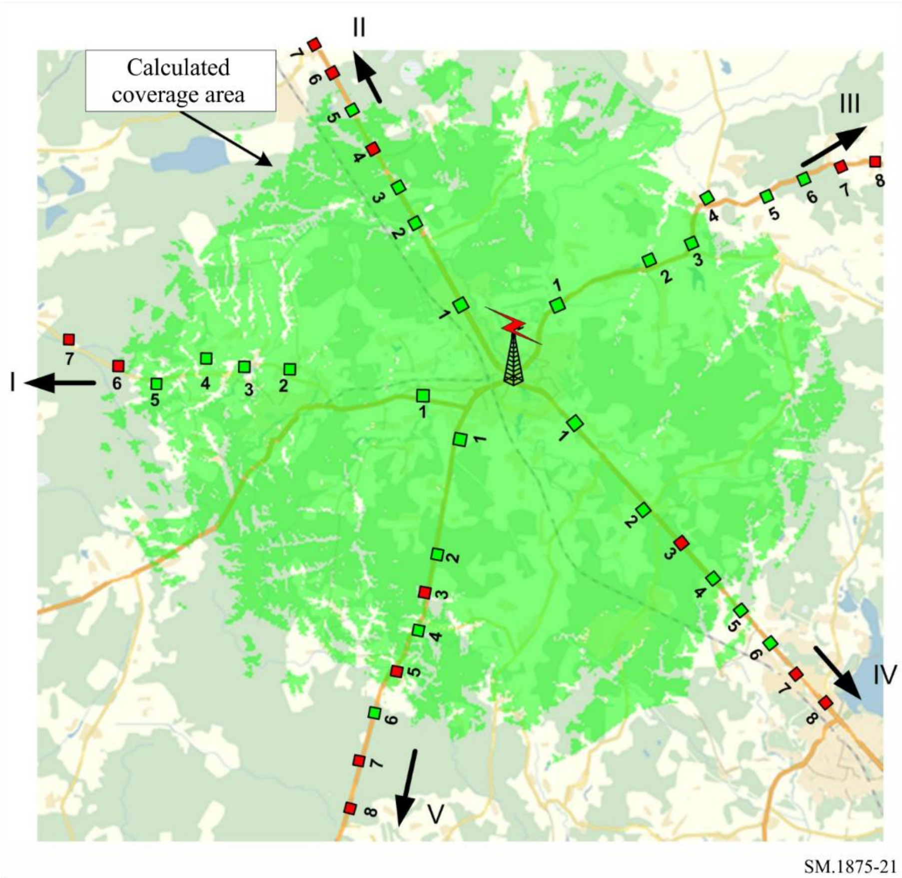
The values for σ_{sp} are calculated each time when field strength is measured. This is done with the intention to cancel out fast fading that can affect the shape of signal spectrum.

If the resulting field strength (E^{loc}_{med}) is lower than the required minimum field strength, measurements at additional planned locations inside the small area have to be performed. For each small area a median field strength $E^{small\_area}{}_{med}$ is calculated.

A small area is considered "covered" if the value of $E^{small\_area}{}_{med}$ exceeds the required value of minimum median equivalent field strength E_{med}. In this case the small area is marked with green colour, otherwise – with red colour. Typically, if two or three adjacent small areas satisfy the condition $E^{small\_area}{}_{med} < E_{med}$, then the measurements in this radial direction can be considered as completed (Fig. 21).

FIGURE 21

Example of measurement results in small areas



A3.6 Processing of measurement results

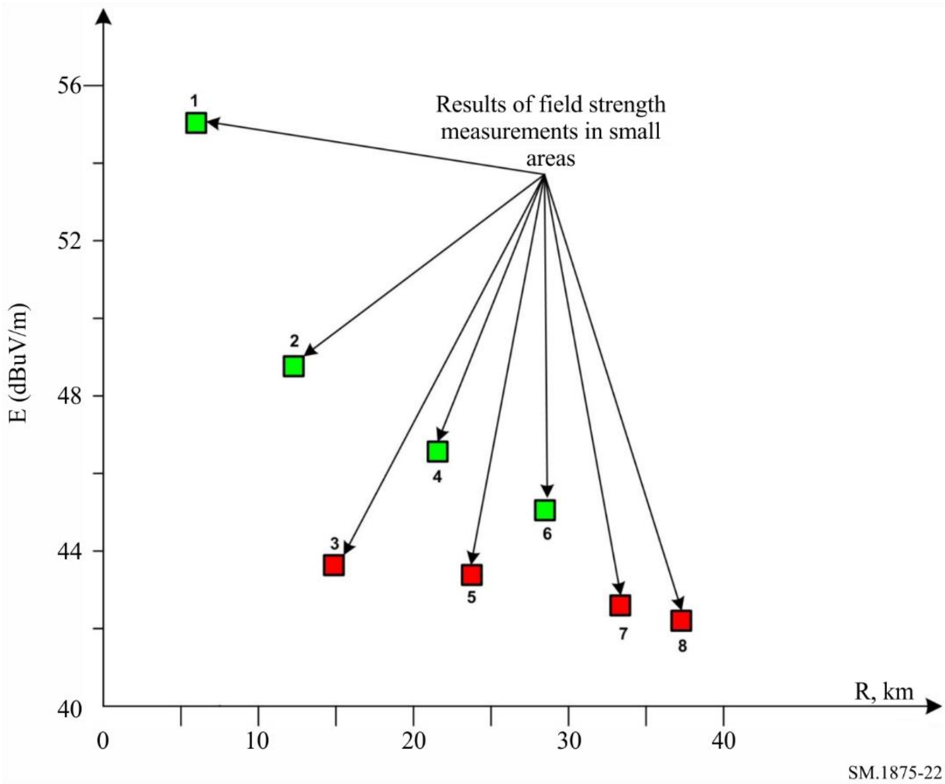
For each radial direction the following steps are performed:

– the final azimuth of radial direction is defined as a mean arithmetic value of azimuths of small areas in this direction;

– the median field strength values in the small areas are plotted in a diagram versus distance to transmitter $E^{small\_area}{}_{med}$ (R) as in Fig. 22.

FIGURE 22

Example of obtained measurement results in a single radial direction



1) a curve approximating the obtained values of field strength is defined as:

$$E(d_i) = E(d_1) - 10 \cdot n \cdot \log_{10}(d_i / d_1) \tag{1}$$

where $E(d_1)$ and $E(d_i)$ are field strength values (in dBuV/m) at distances d_1 and d_i.

The value of n in the above formula is determined according to the Least Squares of Approximation error (LSA) method:

$$n = \frac{\sum_i [E(d_1) - E(d_i)] \times 10lg\frac{d_i}{d_1}}{\sum_i \left[10lg\frac{d_i}{d_1}\right]^2} \tag{2}$$

For free space, the value of n is equal to 2. In presence of obstacles, the value of n increases and typically ranges from 2 to 5.

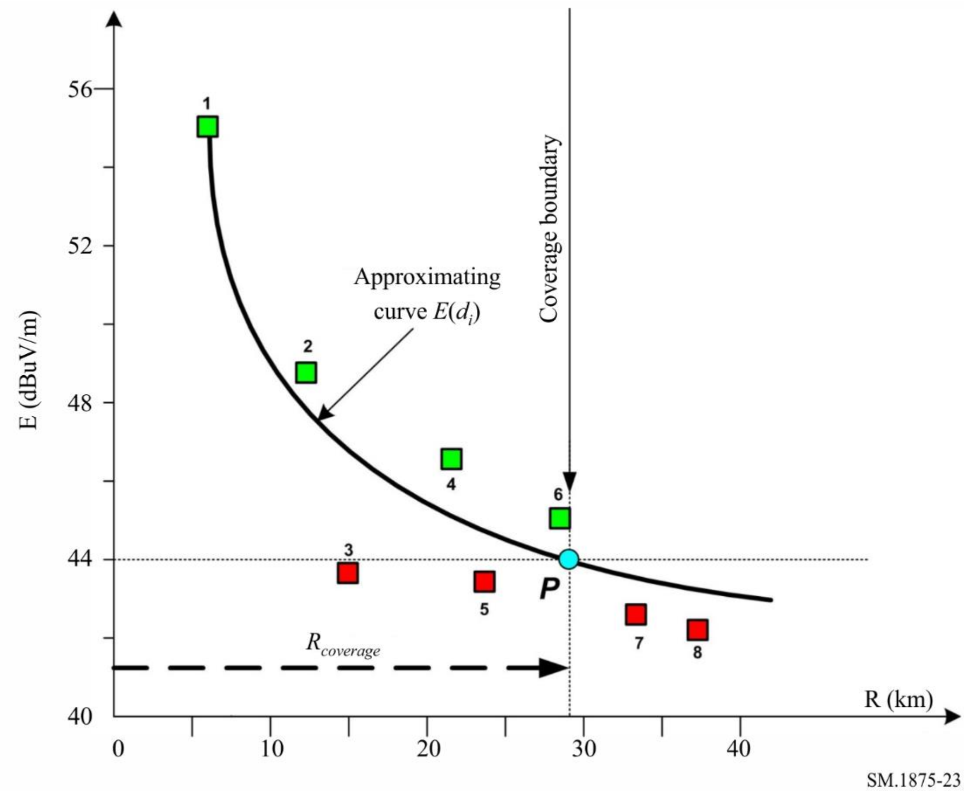
2) the intersection of the horizontal line, corresponding to the minimum median field strength, with the approximating curve determines the estimated location of the coverage boundary in this direction (see Fig. 23):

$$R_{Coverage} = d_1 \times 10^{\frac{E(d_1) - E_{med}}{10n}} \tag{3}$$

3) steps 1 through 4 are performed for all other radial directions that have been measured.

FIGURE 23

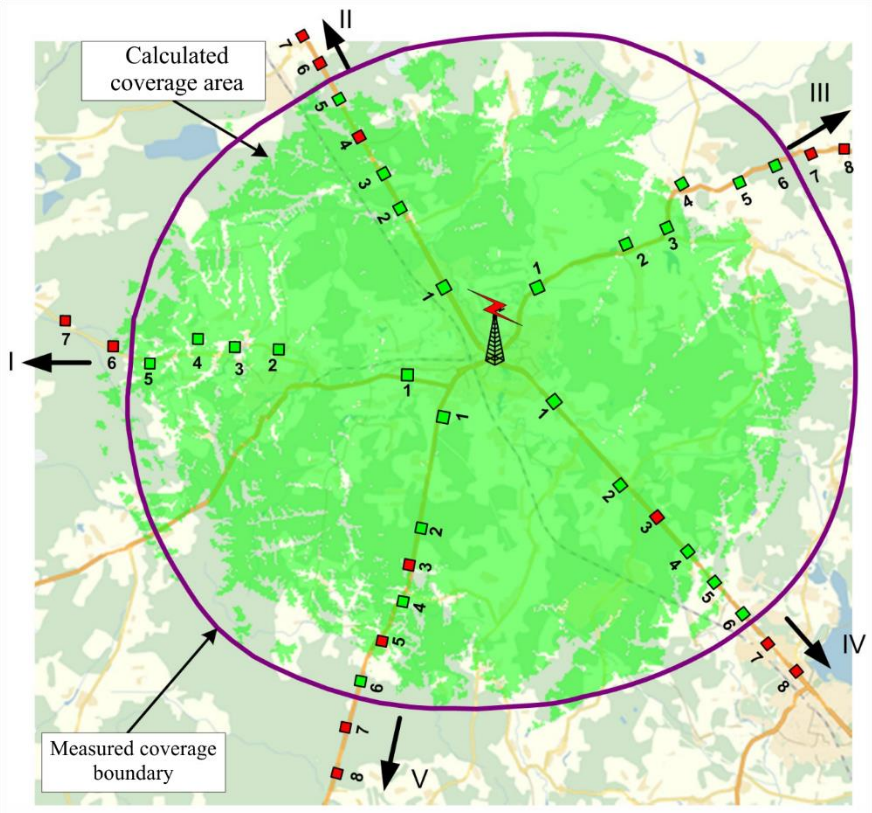
Example of measurement results processing in a single radial direction



Finally, the radial points of coverage boundary determined above are interconnected by a smooth curve, which follows the shape of the calculated coverage boundary. The resulting measured coverage boundary line is plotted on the map (see Fig. 24). As in the example in Fig. 24, the measured coverage boundary may not coincide with the calculated coverage boundary in all directions.

FIGURE 24

Example display of measured coverage boundary



A3.7 Measurements in SFN

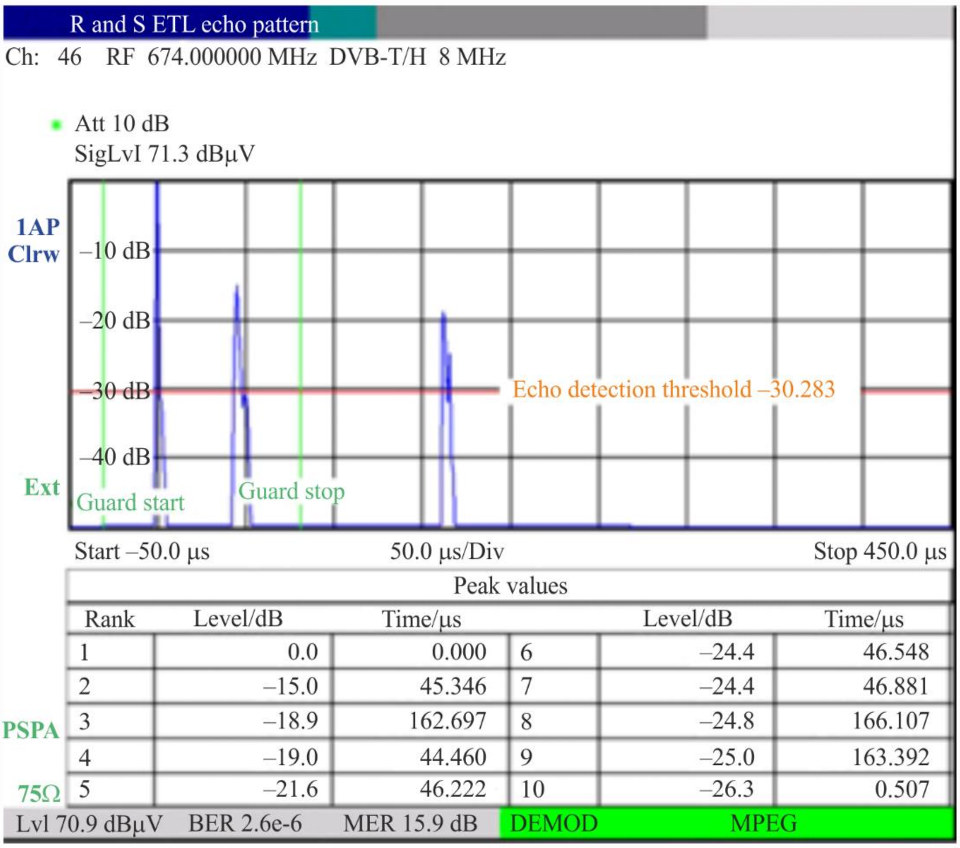
In SFN the coverage boundary is defined as an aggregate of boundaries of all DVB-T/T2 stations forming this single frequency network.

For the method described in this Attachment to be applied in SFNs, the border of each of the SFN transmitters has to be measured separately.

For each measurement location to be reliable, the signal level from the station under test shall be more than 10 dB above the signal levels from other stations of the same SFN. This can be verified by using an echo pattern measurement as in Fig. 25. In the displayed example, the echoes from other transmitters are suppressed by 15 and 18 dB which is regarded sufficient for the measurement location to be suitable.

FIGURE 25

Screenshot from a measuring receiver display (Function "Echo pattern")



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If necessary, an antenna with a narrower directional diagram can be used.

Attachment 4
to the Annex

Method to measure the coverage of DVB-T/T2 service for fixed reception in defined areas

A4.1 Introduction

The method described in this Attachment defines a procedure for DVB-T/T2 coverage area measurement of a DVB-T/T2 transmitter or network to verify compliance with coverage predictions used in the planning process or to assess the receiving condition at locations where interference is reported. In this case the method provides a tool to determine the service area as quality of service parameters are also measured.

A4.2 Equipment requirements

Measurements are carried out using a mobile or transportable measurement system, which includes the following equipment:

– antenna mast with height of 10 m;
– antenna tripod with height of 1.5 m or more (see further explanation in § A4.4);
– directional receiving antenna;
– calibrated antenna cable;
– measuring receiver/analyser;
– navigation receiver;
– computer.

Equipment characteristics are given in Table 12.

TABLE 12

Characteristics of equipment

Equipment	Characteristics
Measuring receiver	Spectrum analysis function. Channel power measurement. VBER measurement for DVB-T. LBER measurement for DVB-T2. "Echo pattern" function. Data interface to the computer.
Low-noise amplifier	Minimum frequency range 174-862 MHz Amplification and noise figure suitable to provide a total noise figure of not more than 6-7 dB
Directional receiving antenna	Polarization: vertical or horizontal, depending on transmitter Antenna gain, at least(1): 200 MHz: 7 dBd; 500 MHz: 10 dBd; 800 MHz: 12 dBd.
Calibrated antenna cable	Feeder loss(1): 200 MHz: 2 dB; 500 MHz: 3 dB; 800 MHz: 5 dB.

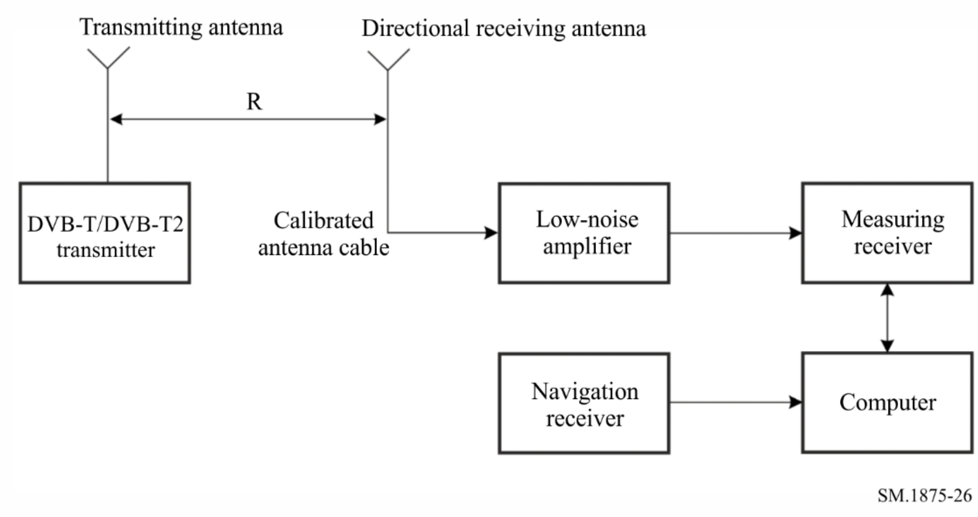
(1) These values are taken from ITU-R BT.1368 and reflect the values assumed by planning tools.

NOTE – A low-noise amplifier should be used when the noise figure of a measuring receiver is higher than the noise figure of a reference receiver (6 to 7 dB according to Rec. ITU-R BT.2036-2).

The equipment connection diagram is shown in Fig. 26.

FIGURE 26

Equipment connection diagram



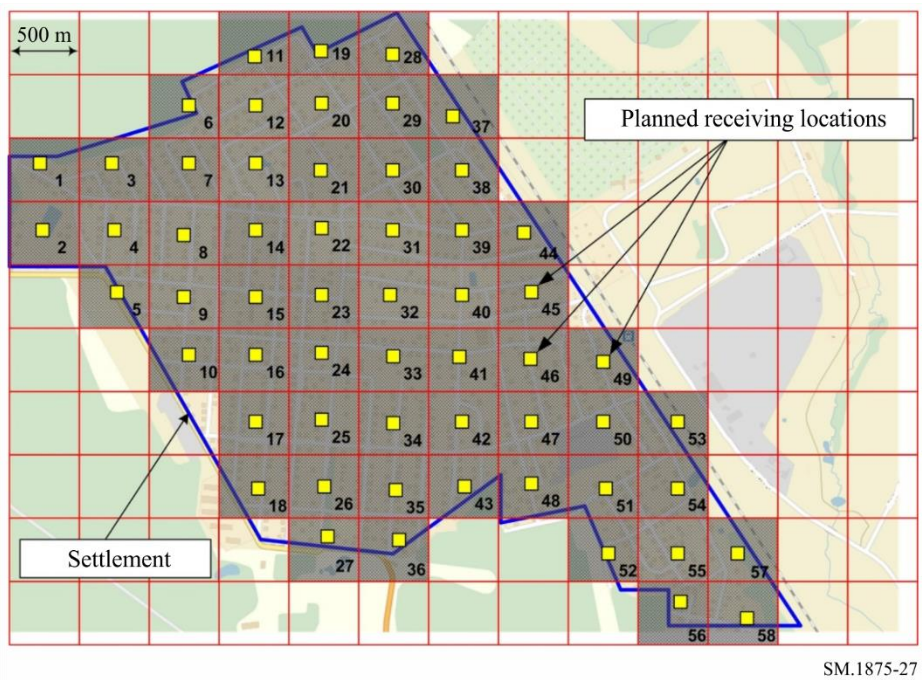
A4.3 Measurement planning

A grid of squares ("cells") of 500 m length is placed over the test area (so-called "test grid") and is plotted on the map.

The test grid shall completely cover the test area. The points of measurement or receiving locations are marked as shown in Fig. 27. The number of receiving locations in different cells of the test grid may vary.

FIGURE 27

Example of test grid plotting



If necessary, the measurement locations could be verified with regard to the possibility to place measurement equipment through satellite images (e.g. Google Earth) or by visiting these points before starting the measurement.

A4.4 Measurement procedure

The following parameters of the signal should be measured at each measurement location:

– electromagnetic field strength;

– the standard deviation of the spectral amplitudes σ_{sp} DVB-T/T2 signal;

– Bit error rate after the Viterbi decoder VBER for DVB-T or bit error rate after the LBER decoder LDPC for DVB-T2.

In rural areas the receiving antenna is mounted at a height of 10 m. If it is not possible to find a measurement location without obstructions in the direction of the transmitter, such as in many urban areas with roof heights above 10 m, the measurement is conducted on the roofs of buildings with the receiving antenna installed on a tripod.

The antenna is pointed in the direction of maximum received field strength. If this maximum is received from the direction of the relevant DVB-T/T2 station and external disturbance from electrical or electronic equipment is not present, the measurement location is regarded suitable.

The absence of external disturbance can be assumed if the following conditions are met:

– There are no narrowband or CW carriers visible in the spectrum that are higher than the level of the wanted DVB-T/T2 signal.

– The noise level between the wanted and adjacent DVB-T/T2 channels (the "gaps" in the spectrum) is less than 3 dB above the receiver noise level (measured with the antenna being disconnected).

In other cases, an alternative measurement location inside the cell area should be used.

The measurements are carried out with the following settings of the measuring receiver (mode "Spectrum analyser"):

– Centre frequency (FREQ): equal to the nominal centre frequency of the TV-channel;

– Channel bandwidth (Span): 8 to 10 MHz;

– Resolution bandwidth (RBW): 30 kHz;

– Video filter bandwidth (VBW): from 100 to 300 kHz (VBW ≥ 3 RBW);

– Sweep time: 2 s;

– Detector: RMS;

– Trace mode: Clear/Write.

During a measurement time of at least 1 min, 30 measurements of field strength and 30 standard deviations of spectral amplitudes σ_{sp} shall be taken. The values of σ_{sp} are calculated according to Attachment 5. Thus 30 measurements of field strength, including σ_{sp}-correction, are used to define the median (over time) field strength ($E^{\text{loc}}_{\text{med}}$) in each receiving location.

The values for σ_{sp} are calculated each time when field strength is measured. This is done with the intention to cancel out fast fading that can affect the shape of the signal spectrum.

If the resulting field strength ($E^{\text{loc}}_{\text{med}}$) is lower than the required minimum field strength, measurements at a maximum of 4 additional locations inside the cell area have to be performed. For each cell a median field strength $E^{\text{cell}}_{\text{med}}$ is calculated.

A4.5 Processing of the measurements

The successful reception of the DVB-T/T2 signal is possible, and cell is considered 'covered' if the following conditions are met:

– $E^{\text{loc}}_{\text{med}} \geq E_{med}$

– VBER$^{loc} \leq 2\times10^{-4}$ for DVB-T or LBER$^{loc} \leq 10^{-7}$ for DVB-T2
– no interruptions during the VBER/LBER measurement process occurred for at least 60 s.

The cell is marked with green colour if the majority of measurement points inside this cell fulfil the above-mentioned conditions. Otherwise, the cell is marked with red colour.

A4.6 Display of measurement results

The results of the measurements are plotted on a map as in Fig. 28. The percentage of covered cells in the test area is calculated as:

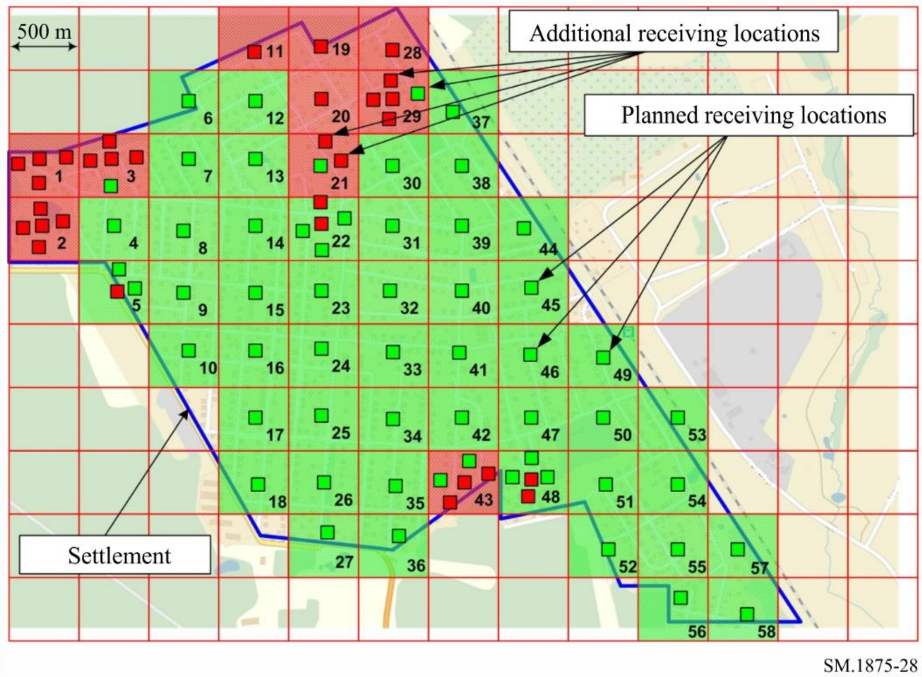
$$P(\%) = (m/n) \times 100\% \tag{4}$$

where:

m: the number of cells, where the signal parameters meet the criteria of coverage
n: the total number of cells within the test area.

For the example in Fig. 28: *P(%)* =(48/58)*100% = 82.8%.

FIGURE 28
Example display of measurement results



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Attachment 5
to the Annex

Required corrections of measurement results

A5.1 Reception channel correction (σ_{sp}-correction)

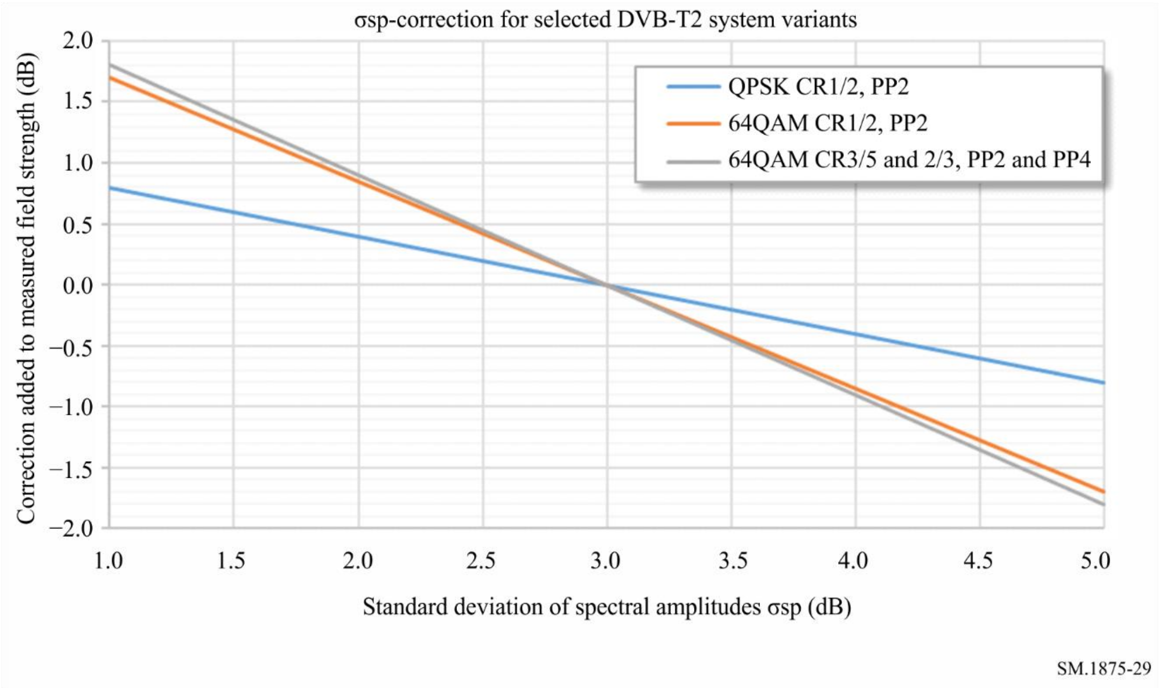
The tables with minimum signal-to-noise ratios (*C*/*N*) in the GE06 Agreement assume Rice reception channels with a standard deviation σ_{sp} of the spectral amplitudes of 1 dB or Rayleigh channels with a standard deviation of 3 dB. Real measurement results, however, will have standard deviations different from 1 or 3 dB. In these cases, a correction value has to be subtracted from the median of the measured field strength values before comparing them with the relevant tables in the GE06 Agreement according to the following formula:

$$C_{\sigma} = \frac{C/N_{Rayleigh} - C/N_{Gauss}}{2} * (\sigma_{sp} - 3)$$

Figure 29 has examples of the resulting correction for 8k-DVB-T systems with 2/3 and 3/4 code rate.

FIGURE 29

Corrections due to non-standard reception channels



A5.2 Location probability correction

Calculation of the correction for location probabilities C_l other than 50% assumes a log-normal distribution of the receiving signal samples.

$$C_l = \mu * \sigma \qquad \text{dB}$$

where:

- μ : distribution factor
- σ : standard deviation of the measurement samples.

For broadband signals such as DVB-T, the GE06 Agreement specifies the standard deviation inside large areas σ_1 as 5.5 dB. With this assumption, the correction for different location probabilities can be calculated according to the values in Table 13.

TABLE 13

Corrections for different location probabilities

Wanted location probability (%)	μ	C_l (dB)
50	0	0
70	0.52	2.9
95	1.64	9
99	2.33	12.8

For assessment of the indoor coverage, the building entry loss has to be subtracted from measurement values made outside. This building entry loss, however, also has a standard deviation σ_2 that has to be added to the standard deviation for broadband signals σ_1 as follows:

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$$

For DVB-T indoor coverage, using the example of GE06, which specifies the following values for the building entry loss and σ_2:

TABLE 14

Standard deviation and building entry loss for DVB-T indoor coverage

Frequency range (MHz)	Building attenuation (dB)	σ_2 (dB)
VHF	9	3
UHF	8	5.5

NOTE – The values are based on GE06.

A5.3 Total correction for indoor coverage

The total correction to be added to field strength values measured at certain fixed locations when indoor coverage is to be assessed is the sum of location probability correction C_l, the standard deviation σ_1 for broadband signal measurements, the building entry loss and its standard deviation σ_2.

TABLE 15

Total correction for DVB-T indoor coverage when measured at fixed points

Frequency range (MHz)	Wanted location probability (%)	μ	σ_1 (dB)	σ_2 (dB)	σ (dB)	C_l (dB)	Building entry loss (dB)	Total correction (dB)
VHF	70	0.52	5.5	3	6.3	3.3	9	12.3
	95	1.64				10.3		19.3
	99	2.33				14.7		23.7
UHF	70	0.52	5.5	5.5	7.8	4.0	8	12.0
	95	1.64				12.8		20.8
	99	2.33				18.2		26.2

NOTE – The values are based on GE06.

If, as recommended, the measurement is done mobile, the standard deviation σ_1 for broadband signals does not apply for the following reasons:

– the measurement was actually taken where reception is to be assessed;

– the measurement method provides so many samples that the calculated median of all measurement samples already represents the actual median field strength inside the measurement area.

The total correction to be applied to these measurement values are summarized in Table 16.

TABLE 16

Total correction for DVB-T indoor coverage when measured mobile

Frequency range (MHz)	Wanted location probability (%)	μ	σ (dB)	C_l (dB)	Building entry loss (dB)	Total correction (dB)
VHF	70	0.52	3	1.6	9	10.6
	95	1.64		4.9		13.9
	99	2.33		7.0		16.0
UHF	70	0.52	5.5	2.9	8	10.9
	95	1.64		9.0		17.0
	99	2.33		12.8		20.8

The values of the minimum equivalent field strength used by planning are given for a reception antenna height of 10 m. To compare the measured values with planning values, a height correction has to be applied which can be calculated according to Section 2.1.9 of the GE06 agreement.