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Boundary coverage assessment of digital terrestrial television broadcasting signals

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REPORT ITU-R BT.2143

Boundary coverage assessment of digital terrestrial television broadcasting signals*

(Question ITU-R 31/6)

(2009)

Foreword

This Report contains information gathered from Radiocommunication Study Group 6 and Radiocommunication Working Party 6A. The development of the report has been driven by the fact that the measurement and verification of the planned coverage is of the utmost importance after the planning of digital broadcasting services.

1 Coverage

The term "coverage" is typically used in this Report to represent all the points where the electromagnetic field strength is higher than the minimum theoretical required value and the interference signal level is lower to that indicated as protection ratio parameters in ITU-R Recommendations. Both wanted field strength and the potential unwanted interfering signals can be evaluated by means of theoretical calculations or by measurements. However, the extension of the coverage area for DTTB depends on several additional factors:

a) the channel model adopted as reference (i.e. Rayleigh, Rice, ANWG, etc.);

b) the modulation configuration adopted (which includes more than one hundred possibilities);

c) the kind of the network implemented (SFN vs. MFN); and

d) the reception types (fixed, portable, mobile, indoor), continuous and troposphere interferences, man made noise, and so on.

It is clear that, when the electromagnetic field strength exceeds the minimum theoretical value, evaluated at reference clutter height, it should be protected against interference through the normal frequency coordination process. However, it is also possible to have good reception also with the electromagnetic field strength lower than the minimum theoretical value.

In terms of theoretical evaluation, in the ITU-R DTTB Handbook, Edition 2002, both time and location variability of field strength have been defined. In particular for each reception condition a three-level approach has been defined:

Level 1: single point reception. A point can be considered served if the minimum field strength required to guarantee a service is exceeded for more than 99% of the time.

Level 2: small coverage area (100 × 100 m). It is necessary to introduce the level of the coverage. Coverage is defined as "good" if at least 95% of the points included in the area are covered. Coverage is defined as "acceptable" if at least 70% of the points included in the area are covered.

Level 3: coverage area of transmitter. The global "good" and "acceptable" area of transmitter coverage is given respectively by the sum of all little areas.

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* It should be noted that the findings in this Report might not be applicable to countries signatory to the GE-06 Agreement.

Coverage assessment of the transmitter is given by verification of the coverage area boundary in comparison with a theoretical one.

As mentioned above, each result obtained using the three-level approach method is valid for a specific reception condition. It is necessary to specify for which reception condition (Level 1, 2 or 3) the evaluation has been done.

2 Assessment of the coverage

The coverage of a specific area, as determined by a prediction method, should be verified by "in-field" measurements in order to assess prediction results.

The digital terrestrial television reception system works on the basis of a "threshold" and the coverage depends on three factors:

a) the access to the service,

b) the time availability,

c) the location availability.

The service can be defined available at the boundary, under Level 1 conditions, if the following two statements are true: BER (bit error rate) after Viterbi is less than 2×10^{-4} (QEF) and measured field strength is higher than the minimum needed field strength, indicated for the considered transmitter configuration and channel type (i.e. Ricean, Rayleigh).

The service "*time availability*" can be defined if the above-mentioned statements are verified for any time interval. Time availability is evaluated taking into account both transmitter status and channel conditions (interferences, reflections, propagation and so on).

The service "*spatial availability*" can be defined if the above-mentioned items are verified under level 2 conditions. In such cases the placement of receiving antennas is not critical.

The coverage assessment criteria should be based on the described factors and should also take into account practical objectives such that:

– measurements should be repeatable in the conditions and in the results;

– measurement procedures should provide results in an efficient way;

the methods do not necessarily have to be sophisticated and expensive.

3 Comparison with planned values

The field strength and BER change continuously during the antenna positioning process up to clutter height above ground level. The observed values depend on the different path combinations and also on the effects of obstruction at low height of the receive antenna.

Both wanted and unwanted interfering signal field-strength values should be calculated and used in the comparison process. As far as the measurements are made to the fixed high, the appropriate propagation prediction model is to be chosen for the comparison.

4 The different reception ways

The digital television signal can be received in different ways. The conventional method considered for planning for early DTTB service planning is based on fixed receiving antennas placed on the roof of buildings, as for analogue systems. Moreover, it needs to be considered the same antennas are used which are already in place for analogue systems. The criteria proposed herewith are based principally on fixed reception conditions. For fixed reception, the channel conditions under Rice propagation mode can be assumed quite constant in time. Reception conditions based on mobile or portable systems are related to extremely variable context and further studies are needed.

4.1 In cities and forest park areas, propagation of a digital television signal can be the multibeam. It renders essential influence on an opportunity of decoding action of a signal. Variation of value of field strength of a digital television signal due to its multibeam propagation is shown in the Appendix 1. This variation reaches essential values for terminal conditions BER = 2×10^{-4}. Appendix 2 describes the usage of a spectrum analyser for field-strength measurements.

5 Parameters to be evaluated

As reported in the current version of Recommendation ITU-R SM.1682 at § 2.6, the parameters to be evaluated are: field strength and BER after different decoding. The BER after Viterbi (VBER) is used to determine the threshold of QEF condition. One more parameter should also be recorded during measurement activities. It is MER (modulation error ratio) at the transmitting site. MER represents a synthetic form of constellation analysis. If the MER value at the transmitting site is lower than an established value, e.g. 32 dB, the measurement activities should be stopped due to possible transmission failure.

Appendix 3 provides the results on evaluation of dependence of the DVB-T signal quality on the filed strength and bit-error ratio after Viterbi decoder and after Reed-Solomon decoder.

6 The model for coverage assessment

It is well known that field strength measured at receiving sites varies with location. The variability, at fixed power flux-density, depends on amplitude and phase combination of several paths that reach the receiving antenna. Variability is more accentuated for CW signals than spread spectrum signals. The reflected paths can give either possible positive (additive or subtractive) or negative contributions. Negative contributions are connected to the intersymbol interference that happens when the delay of one or more paths is greater than the guard interval. Possible positive contributions are generated when the paths' delay is lower than the guard interval. The presence of several paths falling into the guard interval frame can result in additive or subtractive contributions depending on implementation of Viterbi soft decision, fixed or moving research window and paths phase. The intrinsic non-linearity related to Viterbi soft decision, protection levels, temporal and spatial dispersion gives as a result a low correlation between field strength and BER. Existence of a correlation law is yet to be studied.

As far as defining a planning method the coverage border line for E_{70} and E_{95}, in the coverage assessment is important to verify the real extension of border lines.

For fixed reception, it is proposed the scale reported in Table 1 is used.

TABLE 1

DTTB coverage assessment

BER / Field strength	VBER > 2×10^{-4}	VBER ≤ 2×10^{-4}
$E < E_{70}$	F	A
$E_{70} \leq E < E_{95}$	NA	A
$\geq E_{95}$	NA	G

where:

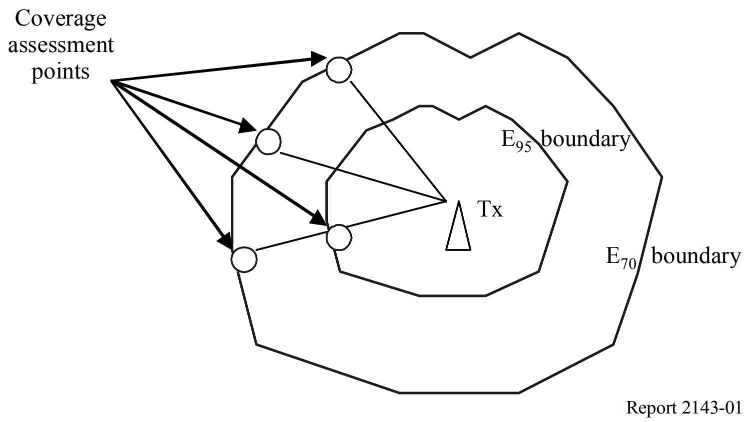
E_{70} or E_{95}[1] represents the minimum median field strength needed for location probability of 70% or 95% (DTTB Handbook Edition 2002 – Chapter 5 and Recommendation ITU-R BT.1368-4). E_{70} or E_{95} value depends on the adopted configuration. VBER of 2×10^{-4} is referred to the QEF condition. F = Failure; A = Adequate; NA = Not Adequate; G = Good.

The E_{70} or E_{95} border lines as provided by the planning system, should be chosen as the measuring points to assess the coverage. The parameters to be acquired to characterize each measurement point are described in Recommendation ITU-R SM.1682. On the base of the parameter acquired it is possible to apply the Table 1, in order to get the more appropriate qualification of the measurement point under investigation.

Starting from the first measuring point and moving along the border line in clockwise direction (or counter clockwise) it is simple to connect each point with the following ones having the same assignment (e.g. G or A) given by mean of the Table 1 scheme application. In such a way the first draft of measured envelopes of the coverage area are obtained, under the E_{70} or E_{95} planning condition.

FIGURE 1

Boundary coverage assessment



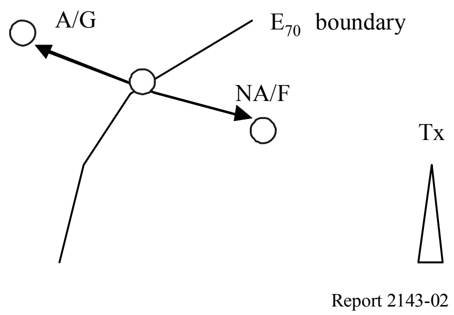
The measured envelopes can be improved/refined by two actions at each measurement point:

a) by increasing the number of measuring points;

b) by moving measurements point either toward to or far from the transmitter when the assignments fall into NA/F or in A/G part of Table 1, respectively.

FIGURE 2

Refining of the boundary coverage assessment



1 E_{70} or E_{95} may also represent the planning values chosen by administrations.

The coverage assessment for a network of transmitters is given by the envelope of the coverage border line assessed for each transmitter in the network.

Appendix 1

The results of experimental estimation of DVB-T system work stability under a multibeam signal

1 Introduction

In the planning of DVB-T networks and in the analysing of their performance such a characteristic as the strength of electromagnetic field is basically used. However, as the investigations show, this characteristic is often not sufficient for the evaluation of a digital system's operation capability.

The results of the evaluation of the signals of DVB-T decimetric range transmitter installed in St. Petersburg and adopted in four paths with different conditions of radio waves' propagation and with different irradiation field structure in test stations, are given below.

The purpose of the work is to determine the threshold value of the equivalent field strength of a signal E_{th}; the threshold value is the smallest value of the signal in which the disruption of a digital bitstream's demodulation still does not occur (picture and sound remain the same) and in which the number of mistakes after Viterbi decoder is not higher than BER = 2×10^{-4}.

2 Parameters of DVB-T transmission station

– place of installation is St. Petersburg, Russia;
– transmitter output power of 500 W;
– Tx antennas' power gain is with respect to half-wave vibrator is 9 ± 3 dB;
– height of antenna suspension 203 m;
– emission frequency band 574 … 582 MHz (34 TV channel);
– modulation: mode 8k, 64-QAM, convolutional code 2/3, guard interval 1/32, digital bit stream 24, 128 Mbit/s.

3 Parameters of experimental paths and test stations (Fig. 1)

Path 1 – An open path, supposedly a single-beam because its first part is located over a city zone and the second part – over a woodless and practically flat countryside; the receiving station "Razmetelevo" is sited on the top of the sparsely wooded hill.

Path 2 – An open path, supposedly also a single-beam because of the following reasons. Firstly, only a small part of the initial sector of the path is located over the city area. Secondly, only about half of the path is located in woodland. Finally, the receiving station "Sestrovsk" has several kilometres of flat marshland in front.

Path 3 – An open path, the first part is over the city area; the second part is over the Gulf of Finland. It is important to mention that the signal energy can be reflected from the surface of the Gulf of Finland, generating another beam, which is comparable in strength to the direct one. This phenomenon can be observed in the receiving station "Strelna".

Path 4 – Closed city multibeam path, maximum signal is from the azimuth, which is drastically different from the direct one (to the transmitter), the mobile station "Moyka" is situated in the courtyard of four- and six-storied houses.

4 Measurement equipment

You can see the measurement equipment installed on the automobile below:

– Measurement log-periodic antenna on the telescopic mast, which has a height $h_2 = 10$ m above the surface.

– Selective microvoltmeter.

– Attenuator for 50 dB with 1 dB step is switched between the exit of antenna feeder and the entrance of selective microvoltmeter.

– DVB stream tester.

5 Methods and the results of the measurement

Measurements were realized in the following way:

– A real signal field strength was measured by means of selective microvoltmeter in each of four receiving stations under attenuator's fading $S = 0$; and the amount of BER after decoder Viterbi was fixed by DVB stream's spectrograph.

– The amount of BER for each value E_{eq} was measured under step-by-step attenuation increase S (signal voltage reduction at the microvoltmeter's entrance), i.e. equivalent field intensity E_{eq} reduction.

– The reduction of E_{equ} was done before picture's fall, i.e. before the value of BER > 2×10^{-4}.

– The diagram of BER in the function E_{eq} was schemed according to the results of the measurements.

Measurement results are given in Fig. 2. At this picture the numbers of curves correspond to the numbers of the paths; points enclosed in the brackets are places conditionally – the device showed "BER < 10^{-8}" at the same time, because 10^{-8} is its lower-range value.

6 Conclusions

Path 1 – The threshold value E_{eq} comes to 38-40 dB for open single-beam paths (curves 1 and 2) whereas it amounts to 58 dB and more under multibeam (dispersed) signal E_{eq}.

Path 2 – In an open path, located, even partially (especially the end part of it), over a water surface, another beam comparable in strength to the direct one can be created by the water surface in the receiving point. Resulting from the accidentally unfavourable rate of E_{eq} phases, the summation of two antenna currents can cause a random value, which, in this case, will be slightly higher than the value of the currents on open land paths (curves 1 and 2).

Path 3 – The results show that multibeam transmission plays an important role in the DVB-T broadcasting zone. That is why when planning certain networks and estimating correction's value with respect to a minimum field strength of a signal E_{min}* in use it is better to pay attention to this fact.

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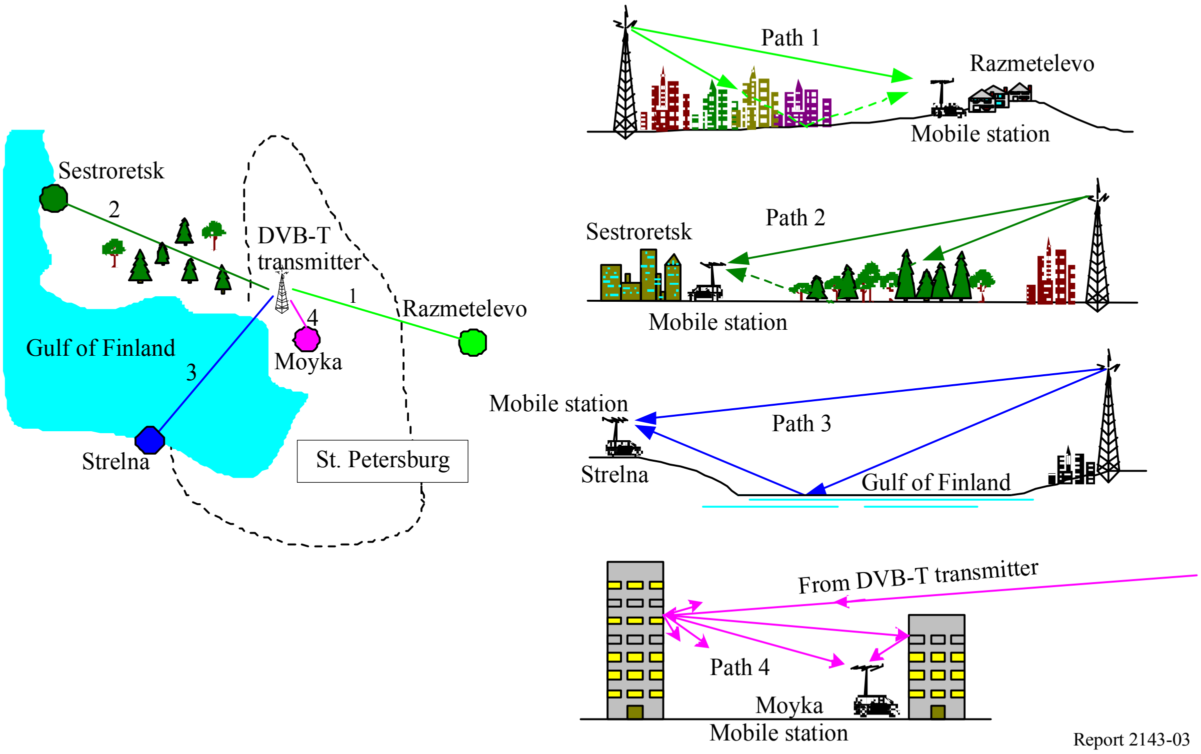
* The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T). Chester, 25 July 1997.

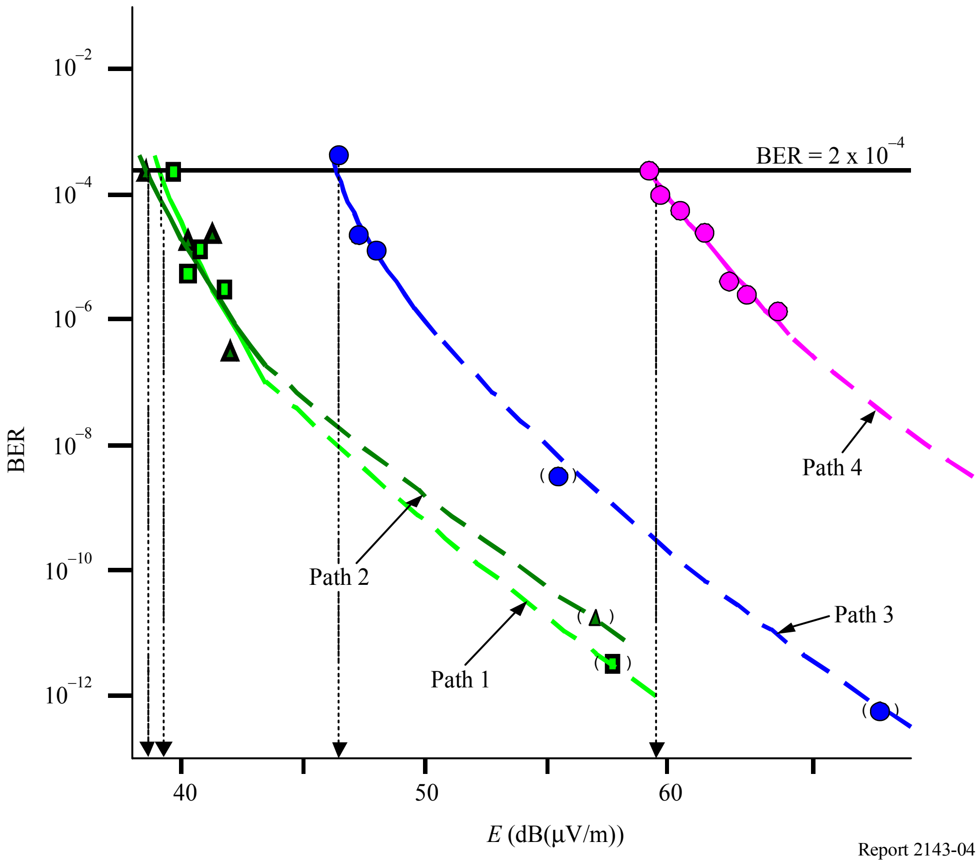
For the detailed information see Dotolev *et al.* [2002].

FIGURE 3



Report 2143-03

FIGURE 4



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References

DOTOLEV, V. G., JILTSOV, A. U., KOLESNIKOV, C. V. *et al.* [2002] Some measurement results of digital ground-based broadcasting in the experimental area. NIIR Proc., M.

Appendix 2

The usage of a spectrum analyser for field-strength measurements

1 Introduction

As a result of terrestrial digital video broadcasting introduction now there is a necessity for carrying out measurements of digital signal parameters for bringing into service new radio stations, their repairing and for performing spectrum monitoring and scientific/technical tasks.

Leading world companies have developed specialized test receivers for performance of these operations. However these test receivers have not spread yet wildly in a number of countries because of their high cost. Nevertheless, some digital signal parameters (voltage levels on a path of the transmitter, a degree of spectrum uniformity, field strength in a coverage area, etc.) can be measured by widespread conventional instruments such as spectrum analyser.

2 Digital signal voltage measurement technique

The process of field-strength value, E, determination in the test reception point by means of a spectrum analyser consists of measuring integrated voltage, U_Σ, at the output of calibrated antenna feeder and addition of calibration factor, K_A, to digital signal integrated voltage value:

$$E = U_\Sigma + k_A \tag{1}$$

The example of digital signal spectrogram on the screen of a spectrum analyser is shown on Fig. 5, with decryption of some reductions.

Such picture presents when spectrum analyser is connected through attenuator to an output of the fault-free transmitter or during off-air reception of a digital TV signal on a single-beam path without reflections from an underlying surface, nearby structures and constructions. In the presence of multibeam propagation the signal spectrum can undergo different sort of distortions (see example on Fig. 6) which complicate signal analysis.

Specialized equipment (for example, in test digital receiver EFA-40 from Rohde and Schwarz) for an estimation of an integrated level of such signal "u_Σ" uses the principle of the automated splitting of all bandwidth of a spectrum on "n" narrow equal parts, B_n, with the subsequent measurement of "u_i" with peak detector:

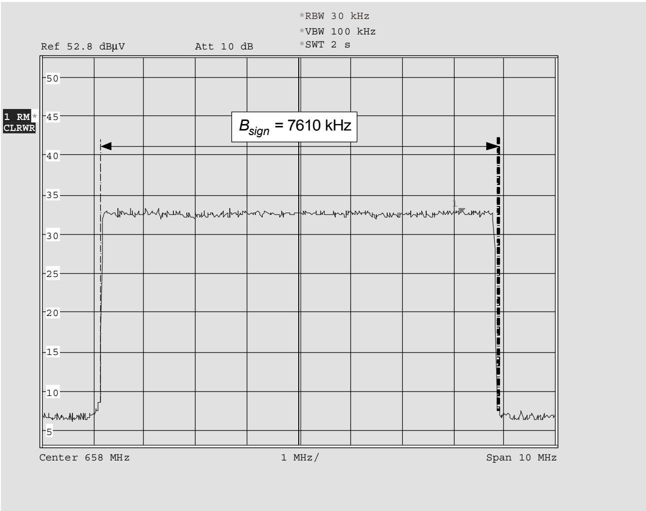
When the equipment bandwidth, B_{RBW}, is less than B_n it is necessary to add the correction factor Δu to the metered values:

$$\Delta u = 10 \log(B_n/B_{RBW}) \tag{2}$$

Then an affective voltage of each interval B_n:

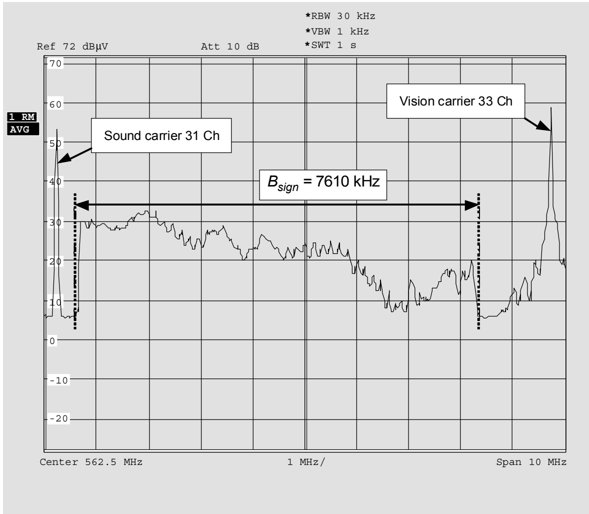
$$U_1 = u_1 + \Delta u;\;\; U_2 = u_2 + \Delta u;\;\; \ldots\; U_n = u_n + \Delta u$$

FIGURE 5



Report 2143-05

FIGURE 6



Report 2143-06

And a final equation is:

$$U_\Sigma = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2} \tag{3}$$

Value U_Σ is shown on the display of the test receiver.

In the case of absence of a specialized instruments for measuring digital signal level it is proposed to determine U_Σ of digital signal using a spectrum analyser according the method presented above (i.e. in accordance with equations (1) to (3)), but with manual processing. As a spectrum analyser gives only a picture of a signal spectral distribution it is necessary to make integration of signal level in all bandwidth of a digital television signal.

For this purpose it is necessary to break down a signal bandwidth on several frequency intervals (a large number of intervals gives more precise result). From an experience point of view, optimum quantity of intervals are 8-10; and it isn't necessary to make intervals equal.

The next step is calculation of median voltage level U_{med} for each interval.

Then it is necessary to convert median values U_{med} into linear units of measure (µV or mV) then to take a square root from the sum of squares of U_{med} (see equation (3)) and translate the result back into logarithmic units of measure. Further it is necessary to add the correction factor according to value of an equipment passband B_{RBW} according to (2).

When spectrum has a simple form (Fig. 5) it is possible not to break down it into intervals and directly determine median value in dB and add to it the correction factor for a difference between instrument and signal bandwidths.

During experimental estimation of accuracy of proposed technique for measuring digital signal integrated voltage level and comparison it with test receiver measurements it was found that the difference in results does not exceed 1 dB even in complex cases [Jiltsov *et al.*, 2007].

It is necessary to add, that a number of modern spectrum analysers already have a function with similar calculations implemented by means of built-in programs.

References

JILTSOV, A. U., PYATYSHEV, Y. A. and SHEPETKOV, N. P. [2007] Using of a spectrum analyzer in practice of Terrestrial Digital Video Broadcasting signals parameters measurements. NIIR Proc., M. (in the print).

Appendix 3

The impact of signal parameters variation on DVB-T reception quality

Dependence between the quality of DVB-T programs reception and such parameters as field strength, *S*/*N*, BER in real conditions indicates threshold effect of digital system reception. This fact has significant impact in establishing the criterion for acceptable quality reception. It may be also important to establish a clear definition of digital terrestrial broadcasting service area for planning and regulatory purposes.

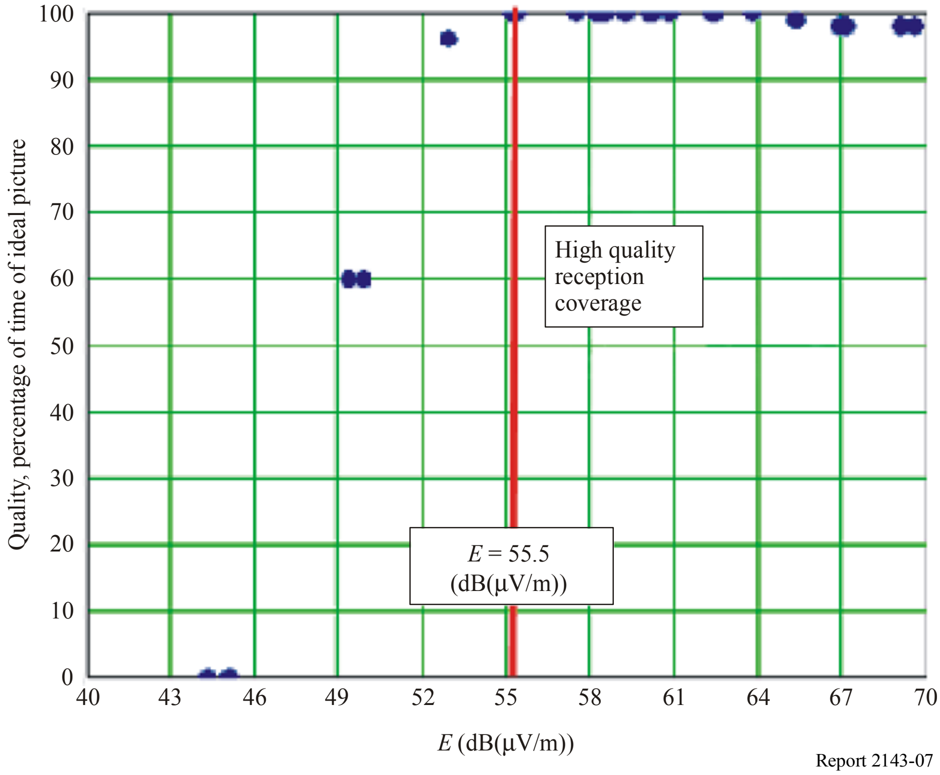
1 Low or not present external interference conditions

In case of low or not present external interference, coverage area tends to be maximum possible and limited only by performance of the digital system itself, taking into account presence of natural and human-made noise in used RF channel. Results are shown in Figs. 7-9.

E and BER used in digital terrestrial broadcasting planning are shown in the figures by red lines.

FIGURE 7

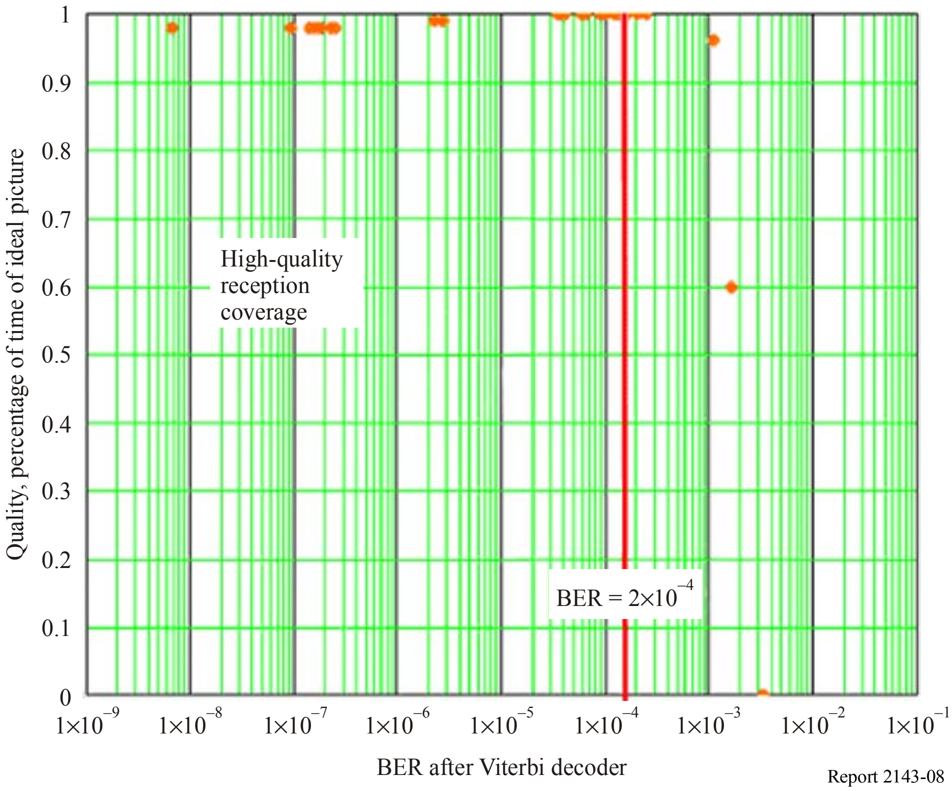
Received signal quality as function of field strength



Report 2143-07

FIGURE 8

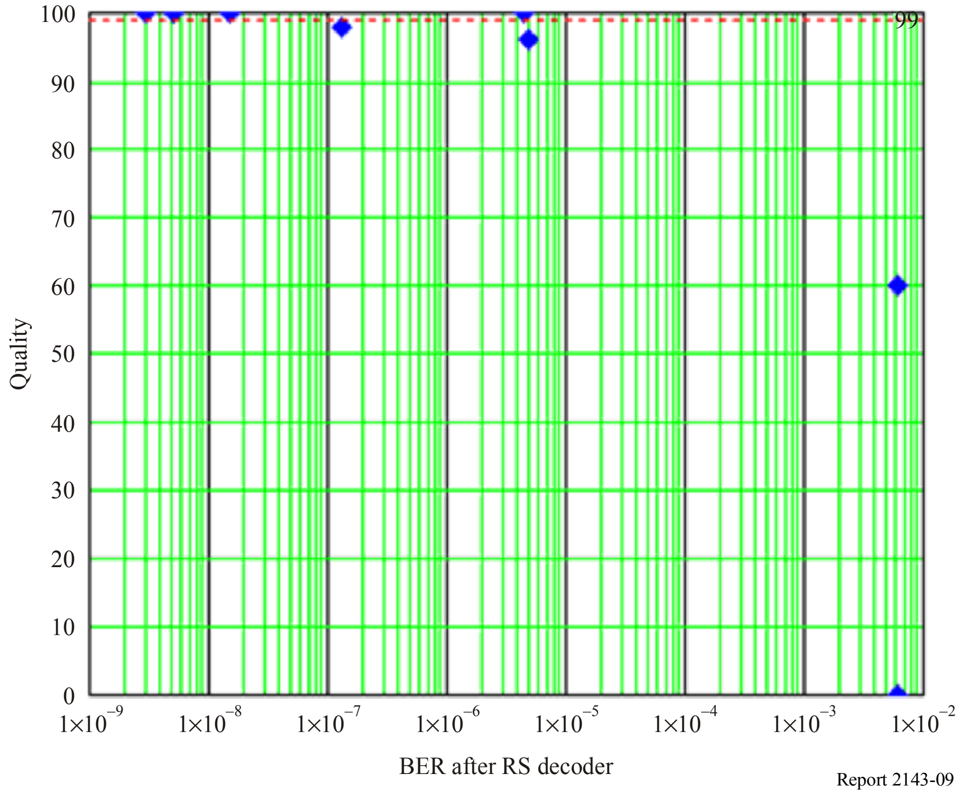
Received signal quality as function of bit-error ratio after Viterbi decoder



Report 2143-08

FIGURE 9

Received signal quality as function of bit-error ratio after RS decoder



Report 2143-09

Figures 7 to 9 clearly indicate that reception quality has a threshold nature and depends on reception/demodulation parameters. At the same time threshold values of measured parameters which provide a high-quality reception are close to the values recommended in GE-06.

Figure 7 contains data averaged on several digital receivers. Therefore the figures in the threshold area are a little bit more flat in comparison with theoretical model.

Mention should be made of the fact that measurements were carried out of the city, this provided characteristics of the channel close to Rice distribution. Further researches are necessary for determination of reception quality dependence in urban and SFN conditions.

2 Presence of external interference

In case of external interference, several (or all) sub-carriers of DVB-T signal affected by interfering signal components.

Results are shown in Figs. 10 to 11.

FIGURE 10

Received signal quality as function of bit-error ratio after Viterbi decoder

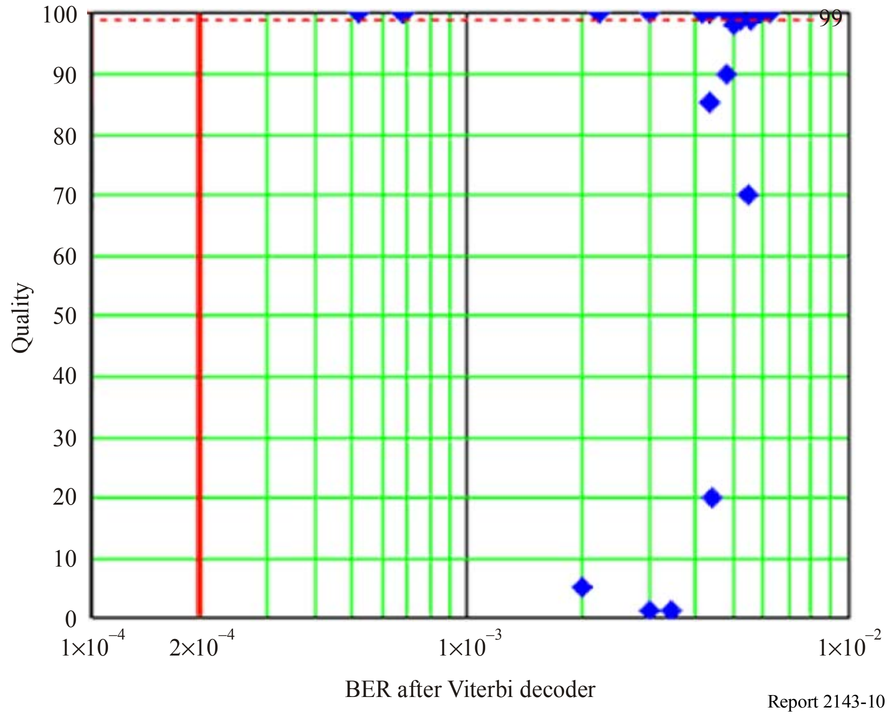


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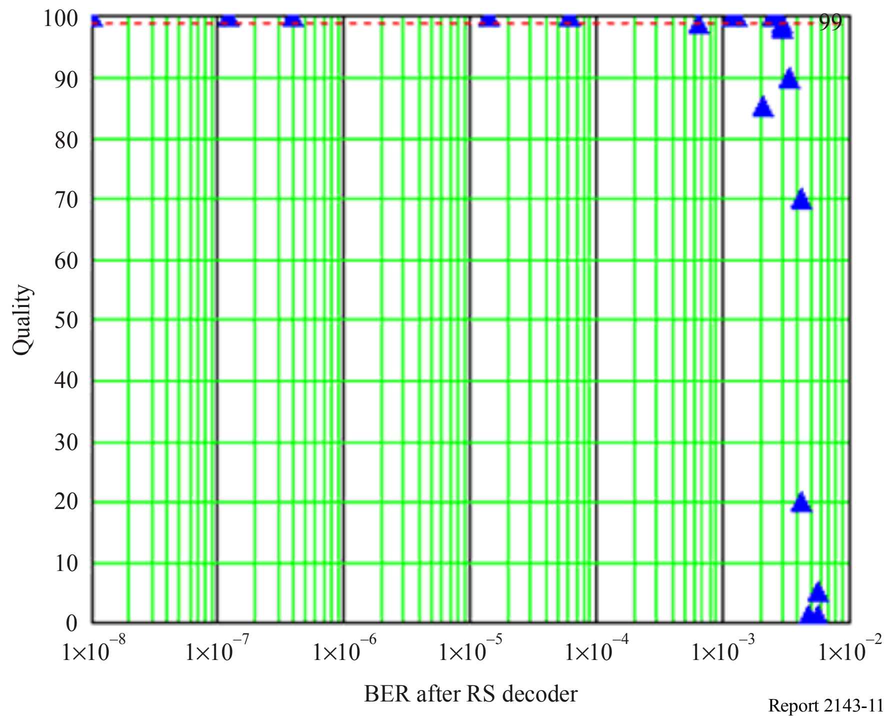
FIGURE 11

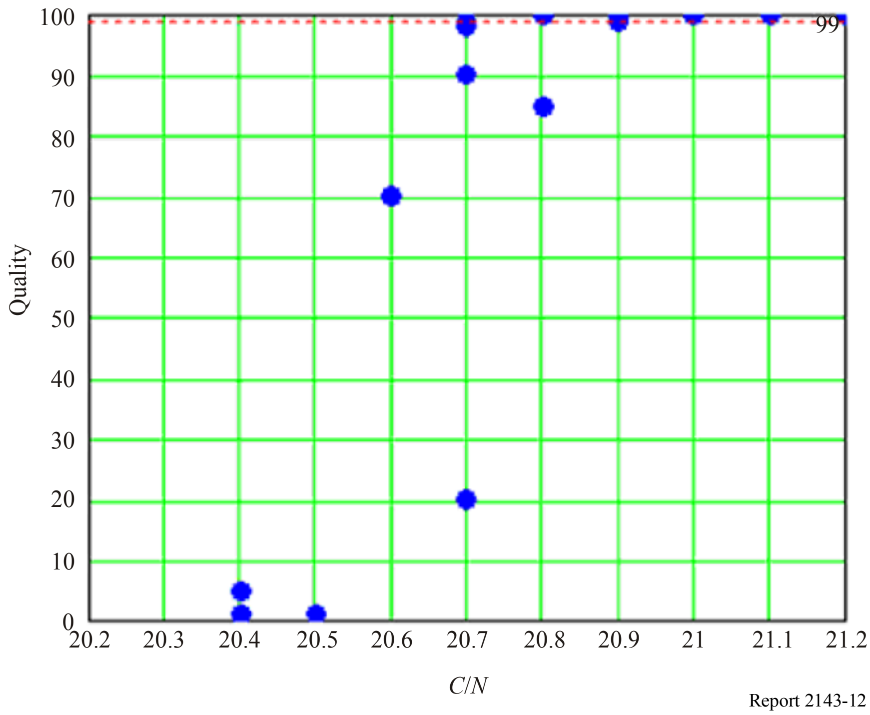
Received signal quality as function of bit-error ratio after Reed-Solomon decoder



Report 2143-11

FIGURE 12

Received signal quality as function of measured *C*/*N* ratio



Report 2143-12