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Boundary coverage assessment of digital terrestrial television broadcasting signals

BT Series

Broadcasting service (television)

International Telecommunication Union

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REPORT ITU-R BT.2143-1

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.

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

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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.

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 $BER = 2 \times 10^{-4}$. 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 BER 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 path's 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
$E_{70} \le E < E_{95}$	NA	A
$\ge E_{95}$	NA	G

where:

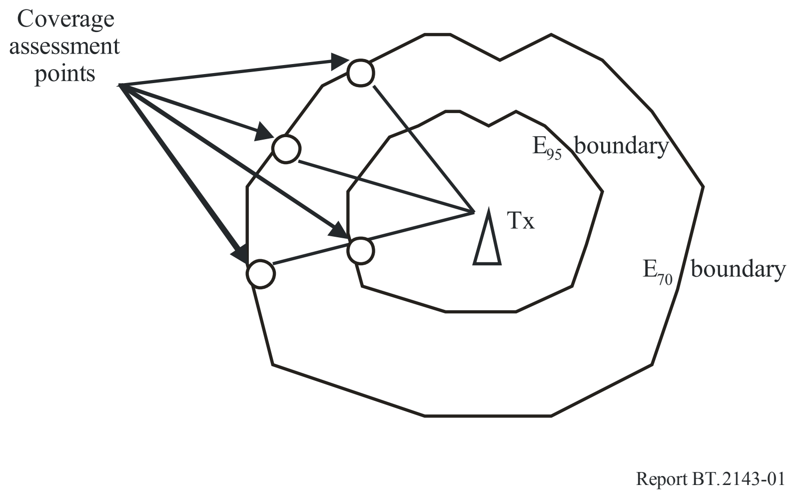
E_{70} or E_{95}[1] represents the minimum median field strength needed for location probability of 70% or 95% (DTTB Handbook Edition 2002 – Chapter 5 and Recommendation ITU-R BT.1368-4). E_{70} or E_{95} value depends on the adopted configuration. VBER of 2×10^{-4} is referred to the QEF condition. 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.

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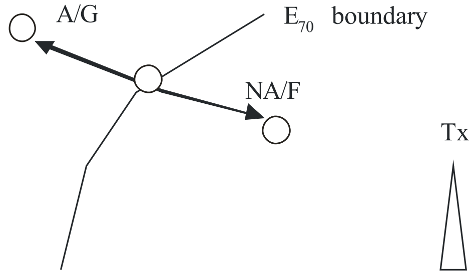
[1] E_{70} or E_{95} may also represent the planning values chosen by administrations.

FIGURE 2

Refining of the boundary coverage assessment



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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 antenna's 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 $> 2 \times 10^{-4}$.

– 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

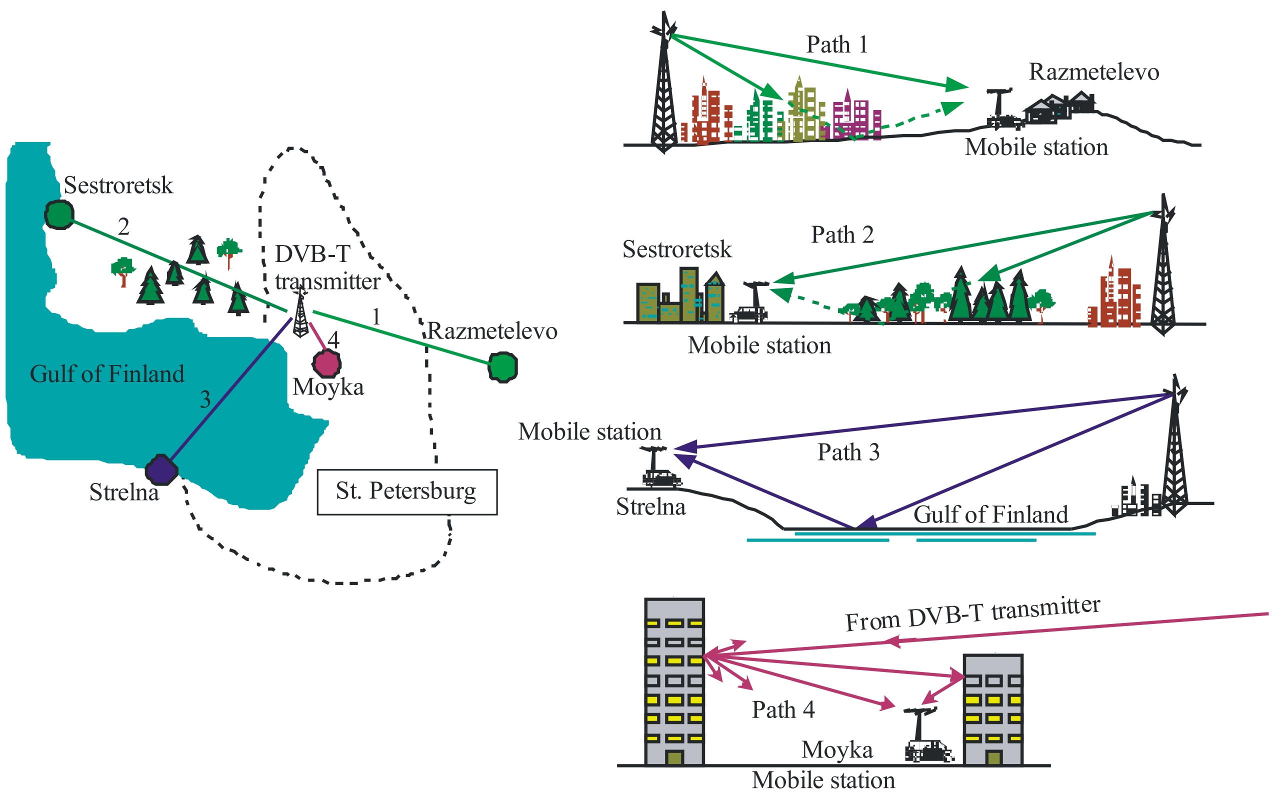
Path 1 – The threshold value E_{eq} comes to 38-40 dB for open single-beam paths (curves 1 and 2) whereas it amounts to 58 dB and more under multibeam (dispersed) signal E_{eq}.

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}[2] in use it is better to pay attention to this fact.

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

FIGURE 3



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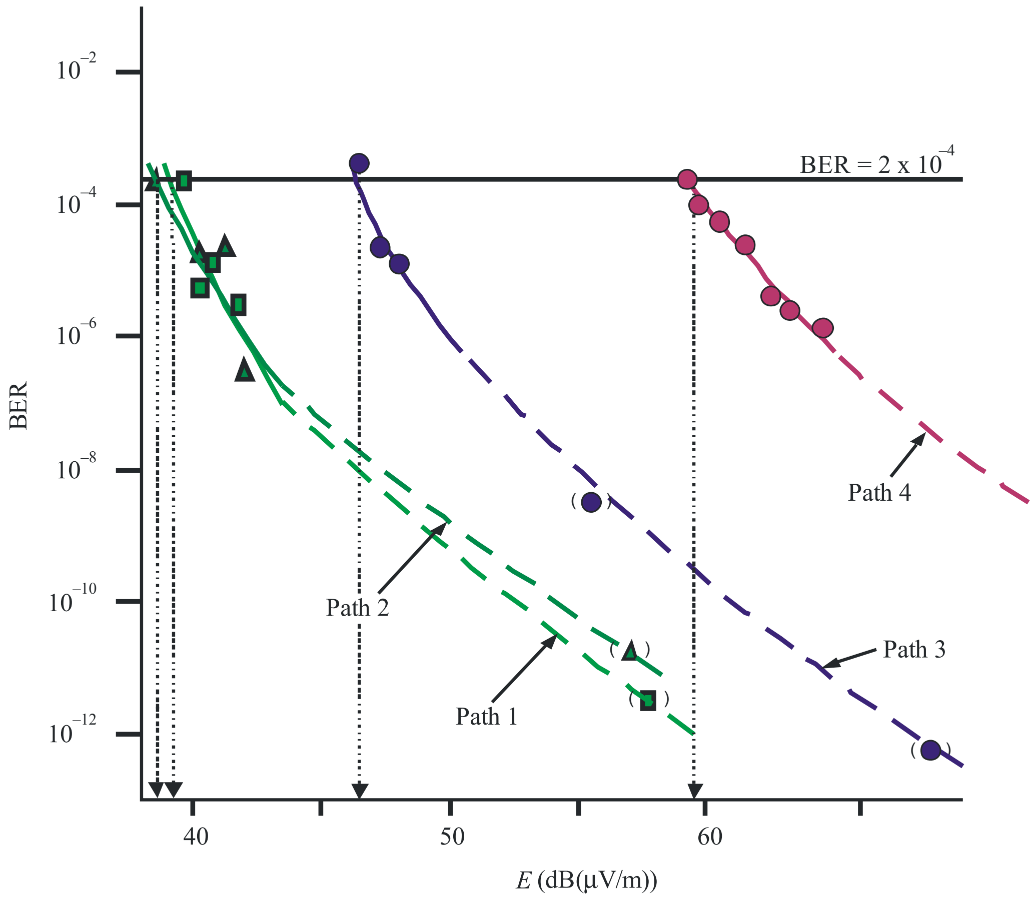
2 The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T). Chester, 25 July 1997.

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:

$$E = U_\Sigma + k_A \qquad (1)$$

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:

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

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

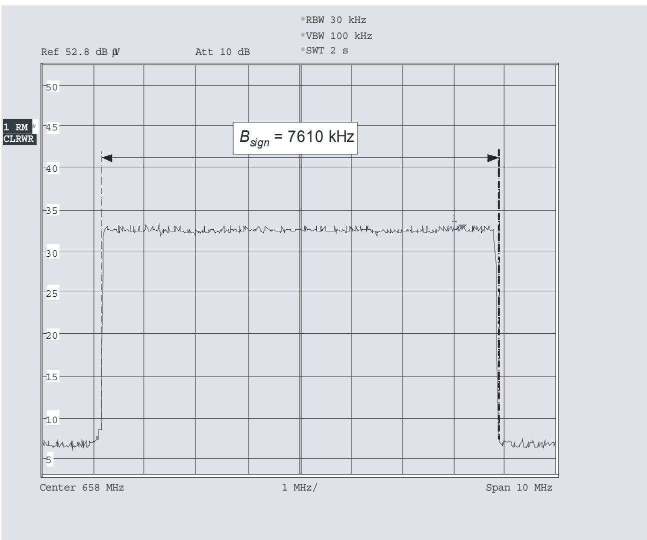

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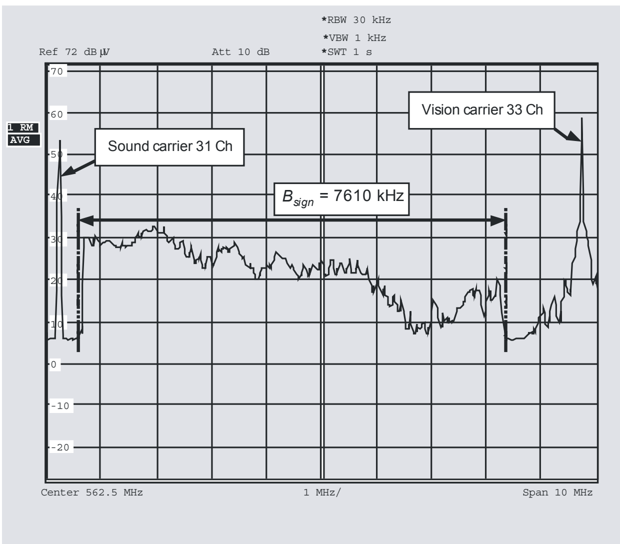
FIGURE 6



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And a final equation is:

$$U_{\Sigma} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2} \qquad (3)$$

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 to 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

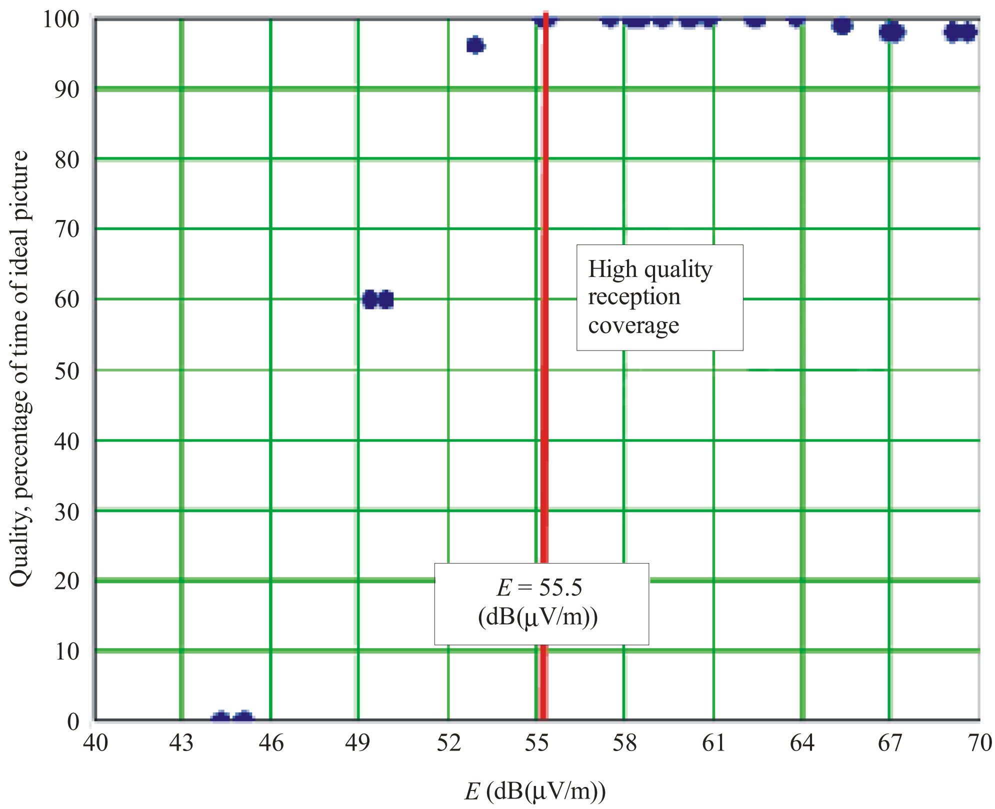

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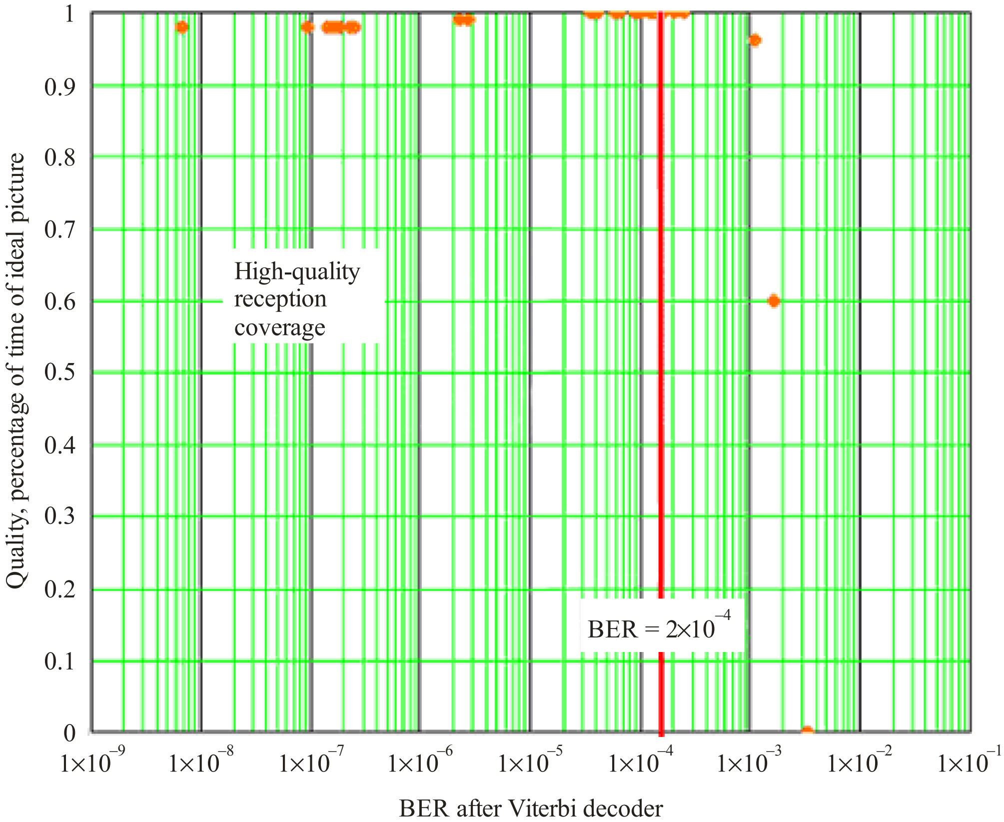
FIGURE 8

Received signal quality as function of BER after Viterbi decoder



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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 9

Received signal quality as function of BER after RS decoder

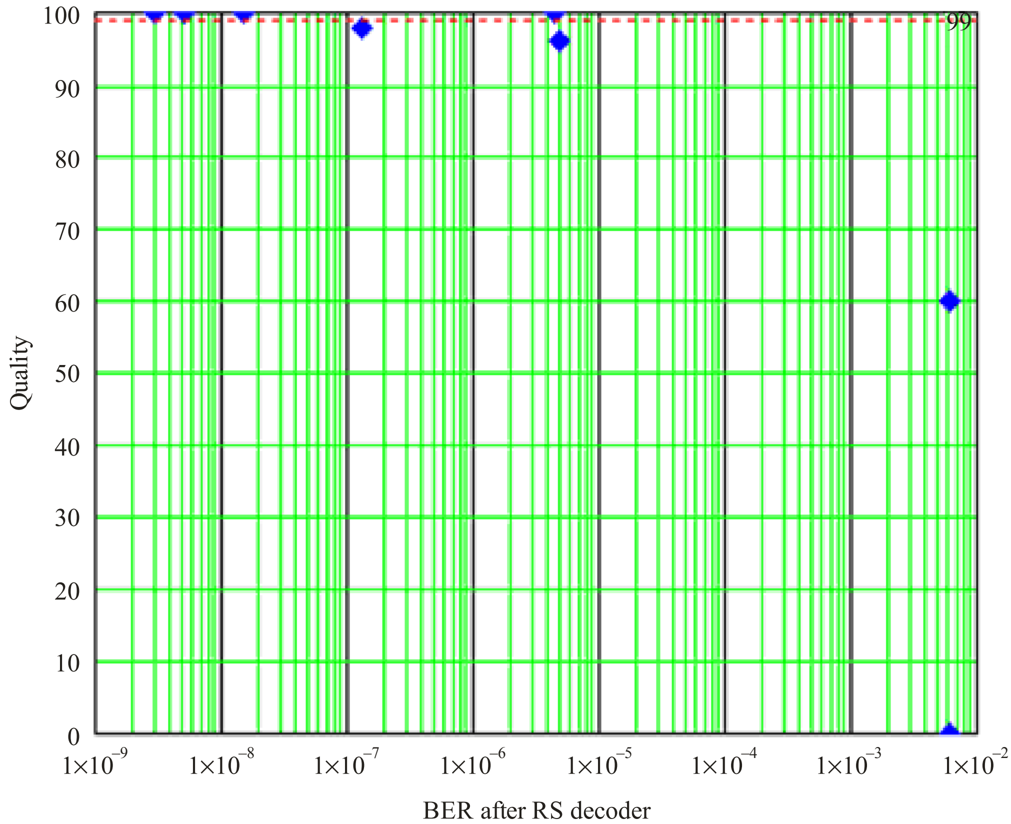

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FIGURE 10

Received signal quality as function of BER after Viterbi decoder

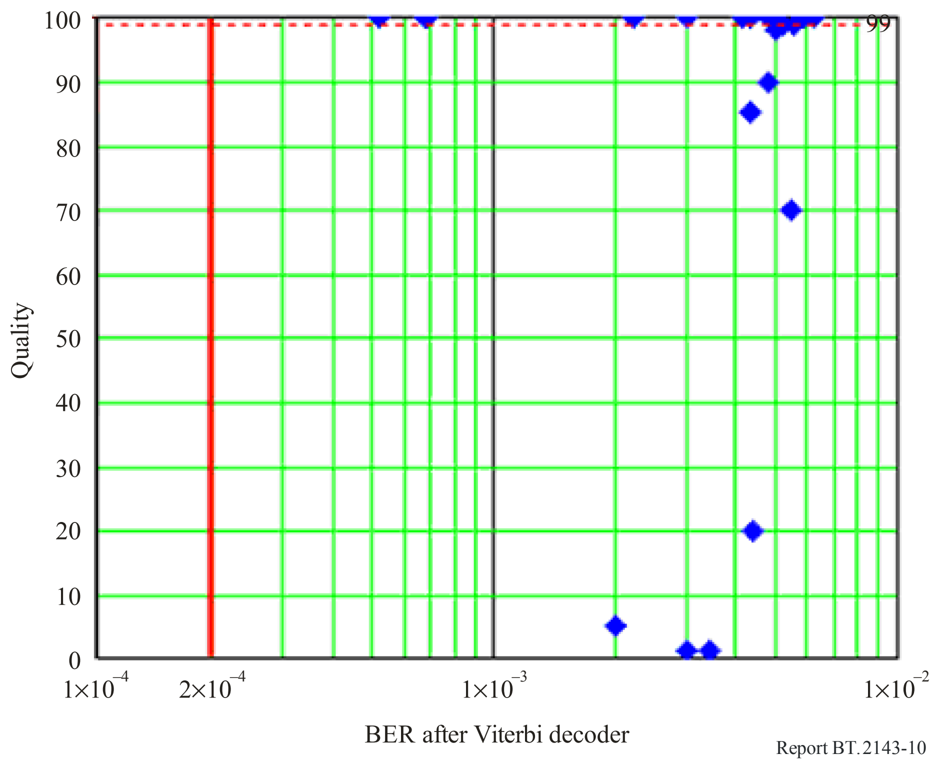

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FIGURE 11

Received signal quality as function of BER after Reed-Solomon decoder

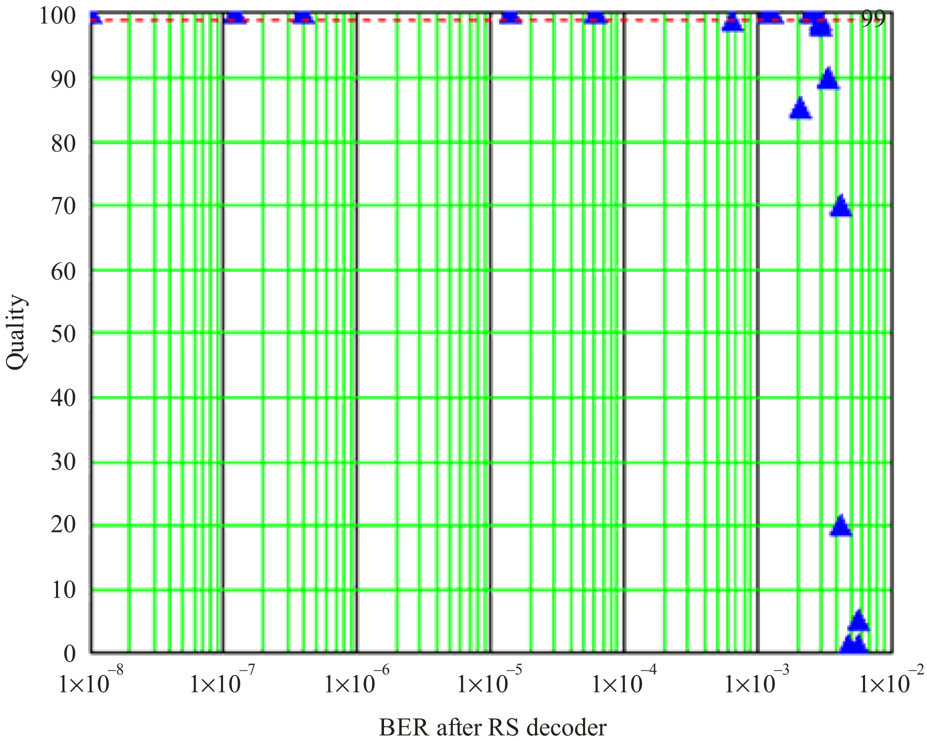

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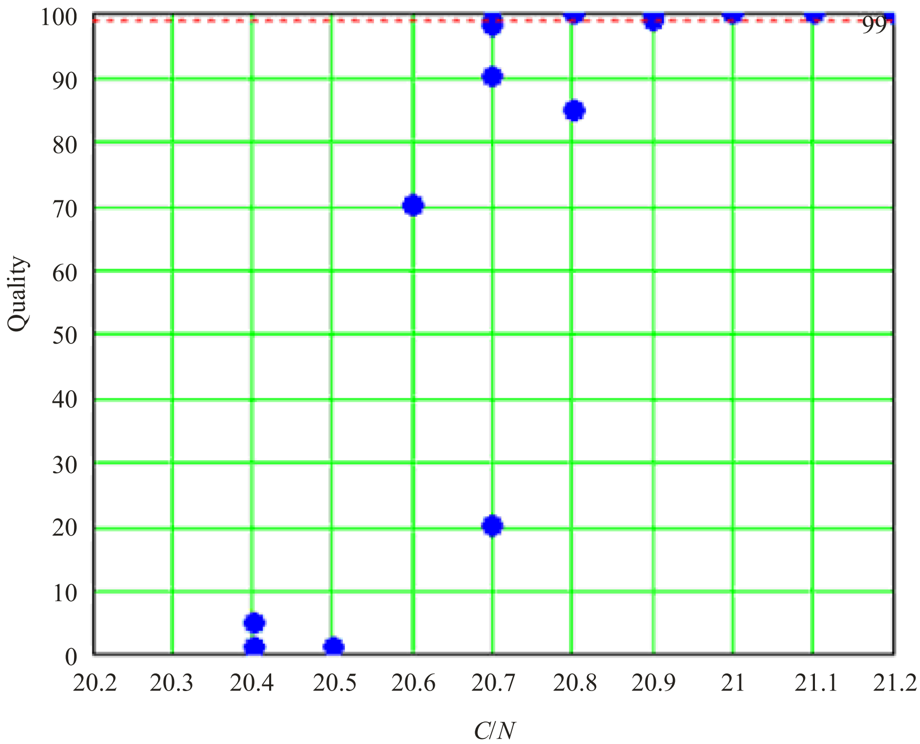
FIGURE 12

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



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Appendix 4

The impact of mountainous area conditions on reception quality of digital TV broadcasting

1 The impact of propagation path on useful signal field strength

Dependence between useful signal field strength and propagation path has a complex character due to several factors:

– reduction of useful signal field strength due to loss conditioned by natural barriers;

– diffraction at the edges of ground relsief obstacles;

– presence of additional beams reflected from barriers situated out of straight path from transmitter to receiving end.

For mathematical modeling of field strength the following methods were used:

– Recommendation ITU-R P.1546-3;

– Recommendation ITU-R P.1812.

Results of modeling were compared with results of measurements.

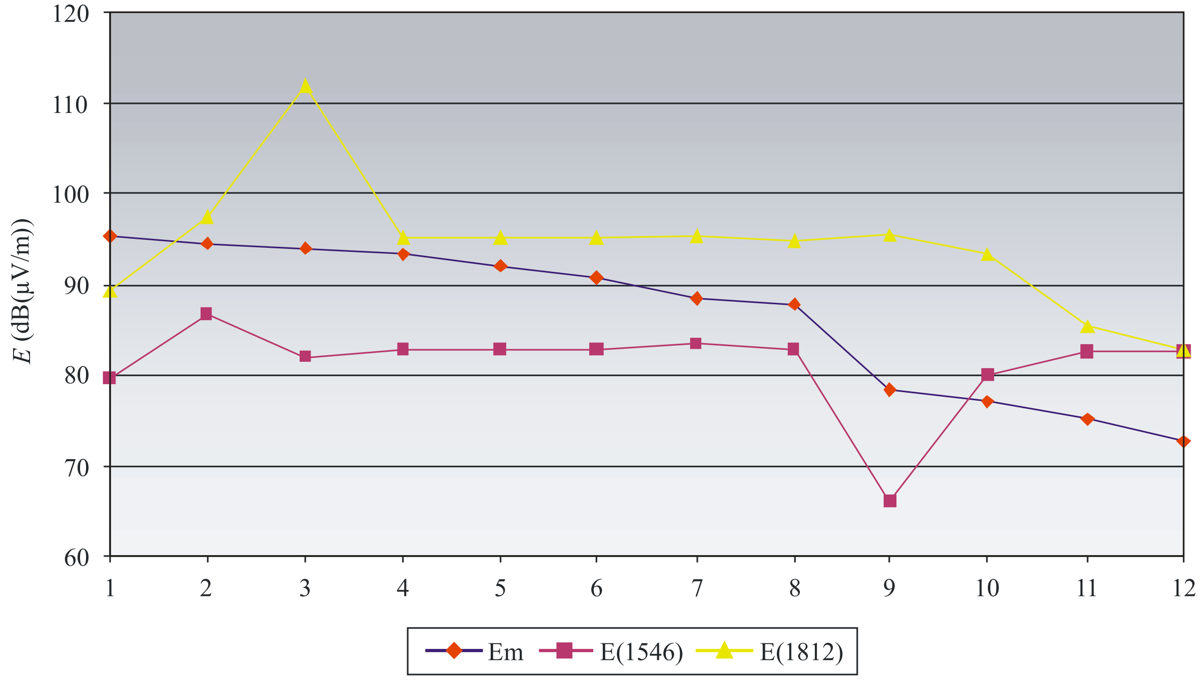
Measurements of field strength from different transmitting stations in different environmental conditions were made during the research of test SFN near the city of Sochi in March 2009. The results of signal level measurements were combined for the analysis by the type of propagation paths. The results of signal level measurements were combined for the analysis by the type of propagation paths.

Three diagrams (for line of sight, semi-line-of-sight and non-line-of-sight paths) are presented in Figs 13, 14 and 15. These diagrams will help analyse differences in the process of signal levels prediction for different propagation paths.

Figure 13 shows the comparison of measured field-strength values (marked as Em) for line of sight propagation paths with predicted values based on Recommendations ITU-R P.1812 and ITU-R P.1546. For line of sight paths both propagation prediction methods give the results close to measured values.

FIGURE 13

Line-of-sight propagation paths



Example of line of sight path:

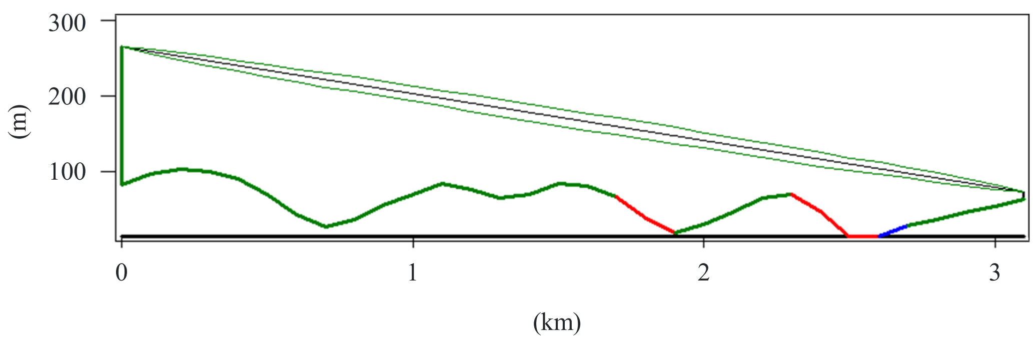


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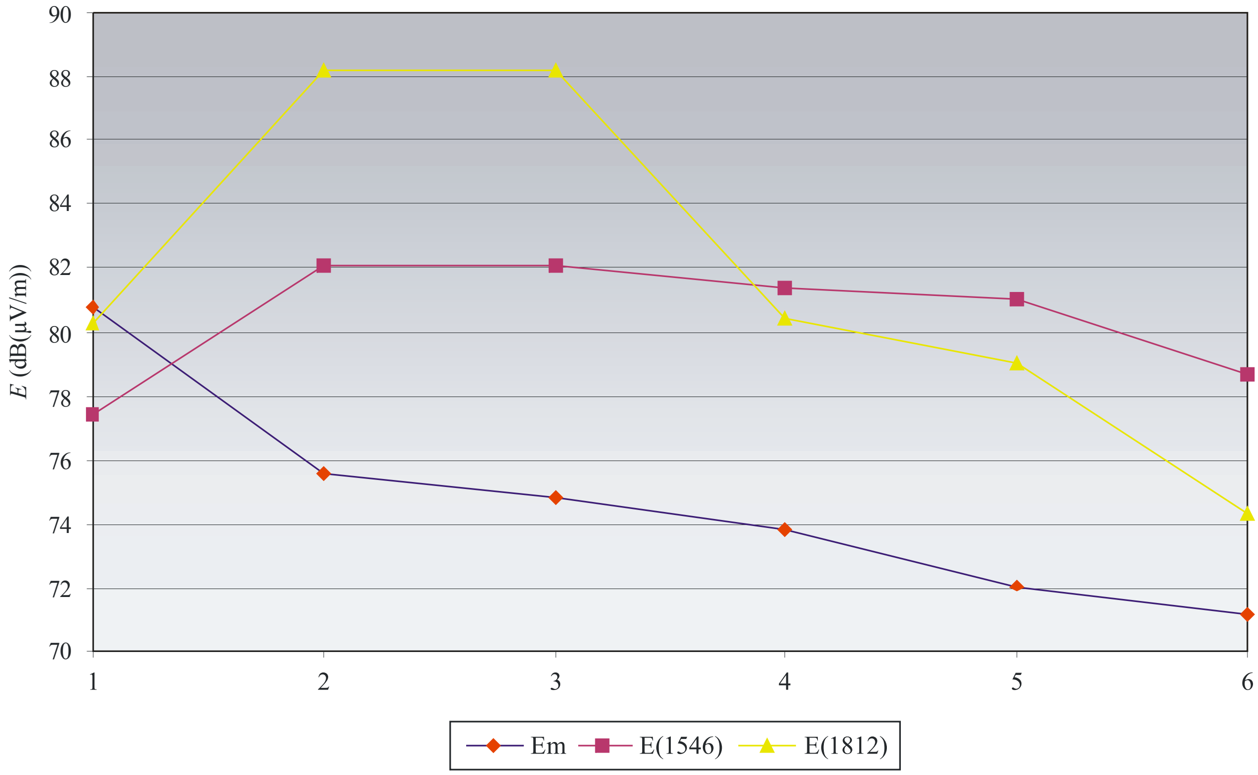
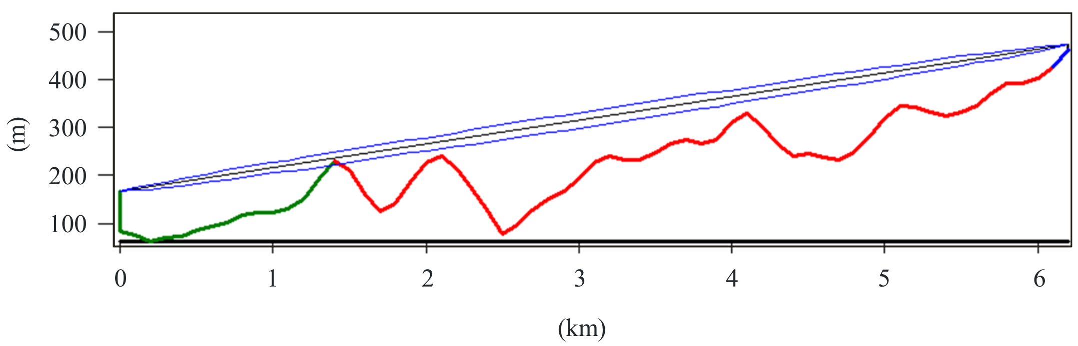
Figure 14 shows the comparison of measured field-strength values for semi-line-of-sight propagation paths.

FIGURE 14

Semi-line-of-sight propagation paths



Example of semi-line-of-sight path:



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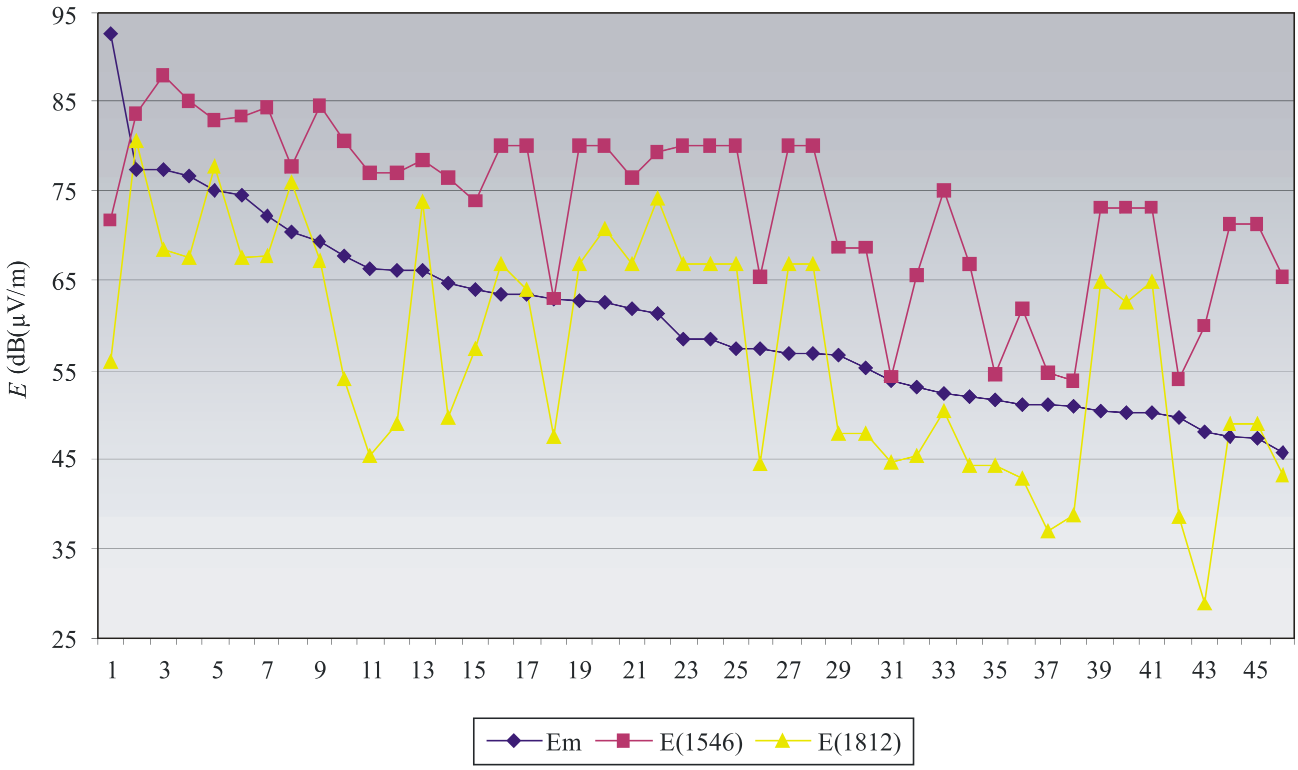
It is seen that calculated values based on both Recommendations in general give results more or less similar to measured ones.

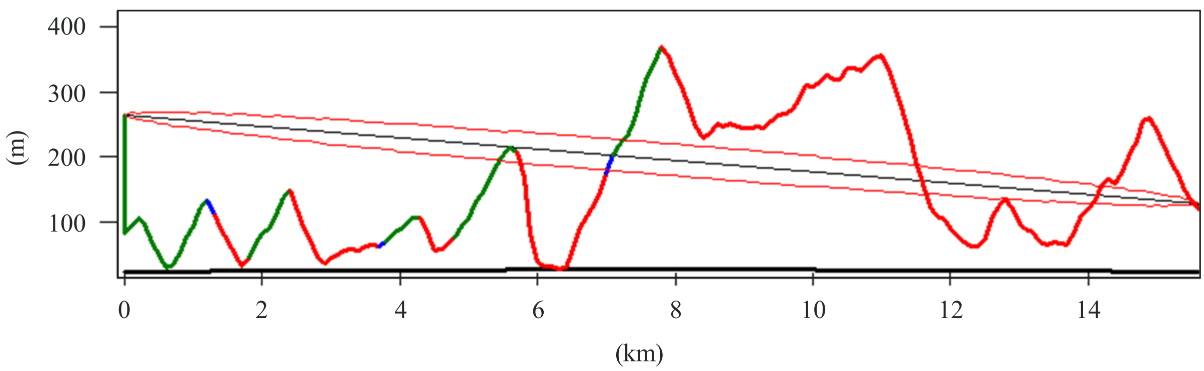
Figure 15 shows the comparison of measured field-strength values for non-line-of-sight propagation paths.

FIGURE 15

Non-line-of-sight propagation paths



Example of non-line-of-sight path:



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It is seen that both methods do not give correct predictions on non-line-of-sight paths. Model based on Recommendation ITU-R P.1546 in most cases give overstated values while model based on Recommendation ITU-R P.1812 in many cases predict smaller values in comparison with ones which were really received. But it can't be stated what last method can be used as "worse case" prediction estimation for mountains areas conditions, because sometimes estimation exceed measured values. Of course, it is worth while to say that model based on Recommendation ITU-R P.1546 gives more correct predictions.

Conclusions

Prediction of useful and interference field strength at reception point is the basis for terrestrial broadcasting network planning. Analysing diagrams for different types of propagation paths mentioned above it is not safe to say that model based on Recommendation ITU-R P.1812 can be used for predicting of coverage area as "pessimistic" estimation, taking into account that in some cases predicted field strength exceeds real ones. Model based on Recommendation ITU-R P.1546 in mountainous area conditions as a rule gives slightly overstated values for semi-line-of-sight and non-line-of-sight paths. This model can be used as an upper estimate of field strength except for fully line of sight paths because it frequently gives understated values for such paths in mountainous areas. The conclusion is what in mountainous areas it's may be right thing when planning broadcasting network, to combine measurements with prediction estimation at least for some specific paths. Another option may be development of deterministic propagation model, what takes into account specific of local conditions. In latter case a set of measurements also required to "calibrate" deterministic propagation model for typical propagation paths.

It's important to say what examples in this chapter deals only with main beam, coming directly from transmitter site. In mountainous at most reception places "multi-beam" conditions detected, when a set of signals coming to receiving site from different directions, even if only one transmitter in network at operation. This happens because of presence of beams, reflected from surfaces of the mountains and hills.

2 The impact of reflected signals on reception quality

In mountainous area conditions DVB-T programme reception quality depends not only on field strength but also on other signal characteristics, such as MER, BER and frequency-selective interference of signal spectrum. Many reflected and multiple-reflected signals having impact on all listed characteristics were found during test works at transmitting networks in mountainous areas. Appearance of reflected signal depends on physical characteristics of underlying terrain and relief features. In this section it was attempted to determine conditions leading to reflected signals appearance and draw a conclusion on the impact of reflected signals on digital broadcasting programmes reception.

Measurements were carried out in winter (snow) and spring periods (trees began to send out leaves) at average and high ground humidity.

The example of conditions under which measurements of reflected signal in mountainous area are carried out is given in Fig. 16.

FIGURE 16

Measurements of reflected signal

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FIGURE 17

Location features and conditions for reflected signals appearance

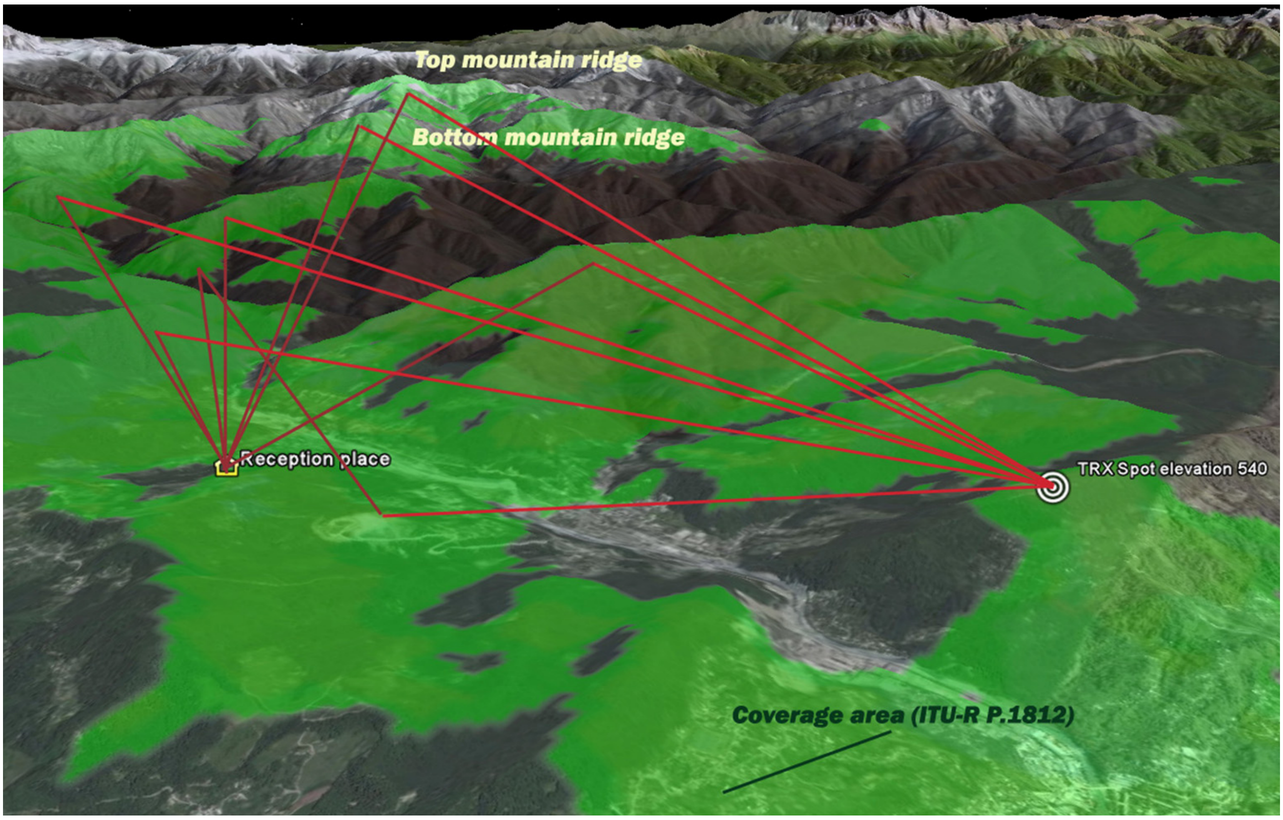

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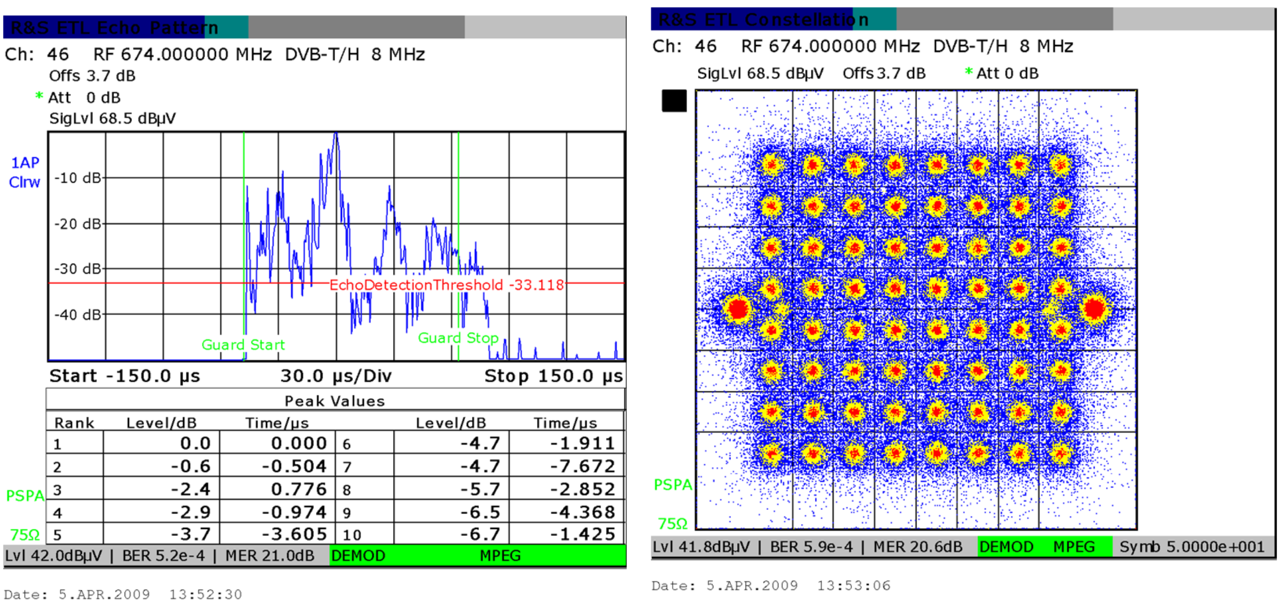
FIGURE 18

Time diagram and constellation of received signal



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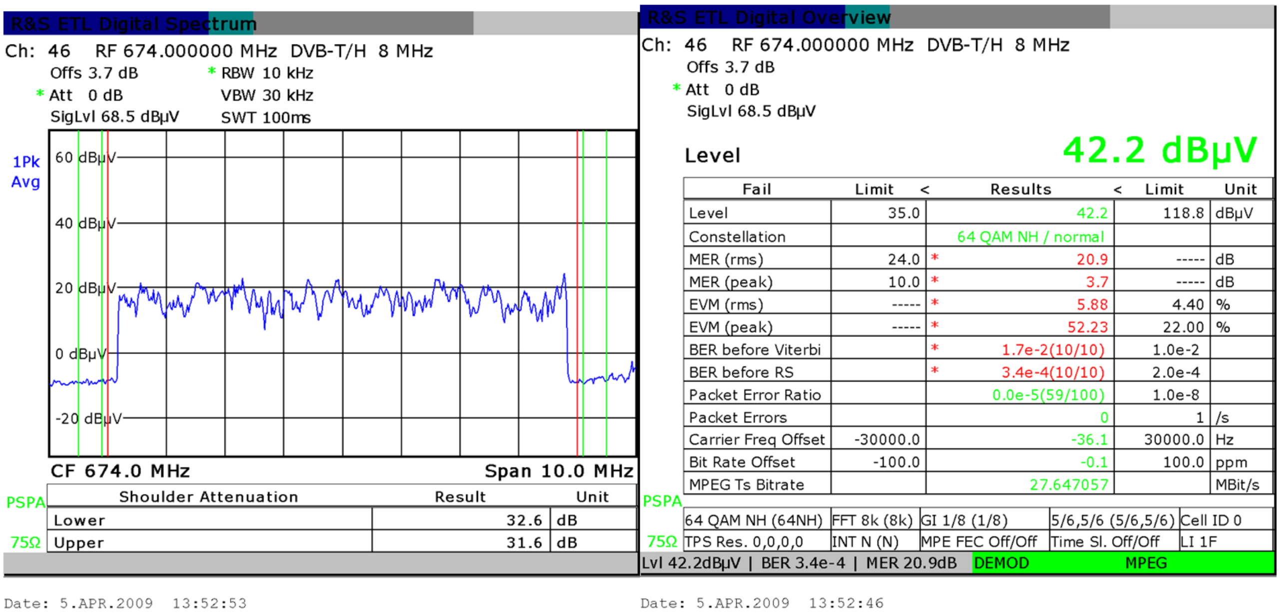
According to the time diagram maximum delays correspond to signal run distance of about 38 km that corresponds to distance to the top mountain ridge.

FIGURE 19

Spectrum and received signal characteristics



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Received signal can be demodulated by the receiver though low signal level and spectrum interference of received signal as it is seen from Fig. 19. The example of more difficult reception conditions at the boundary of coverage area is given below.

FIGURE 20

Reception of reflected signals at the boundary of coverage area

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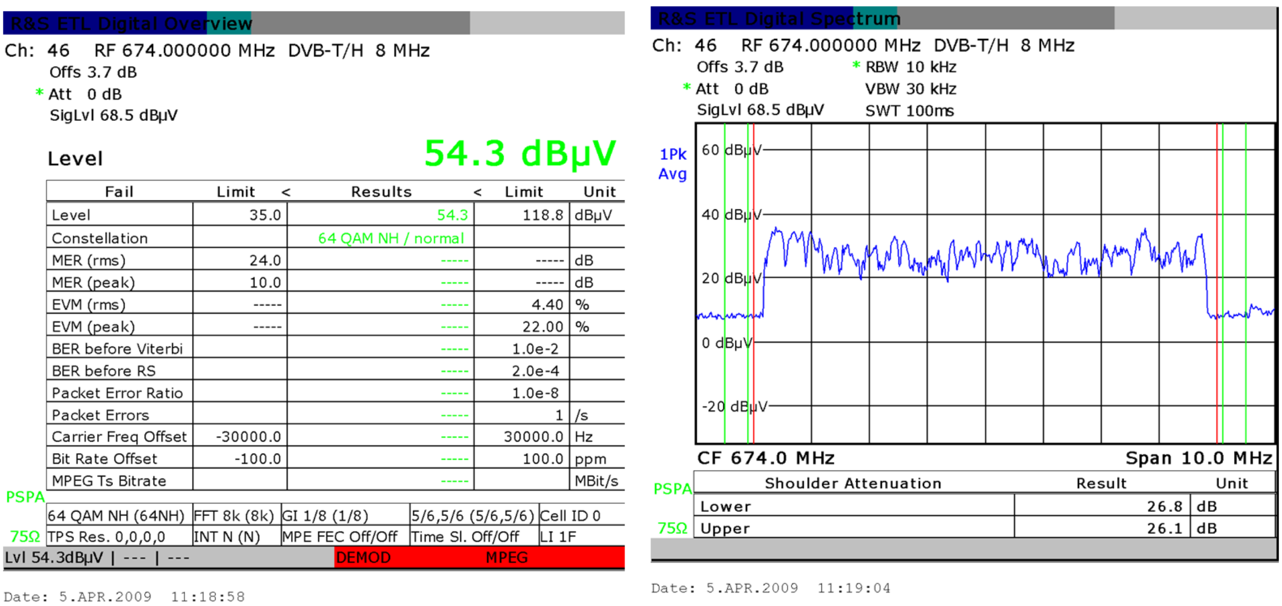
FIGURE 21

Characteristics and spectrum of received signal



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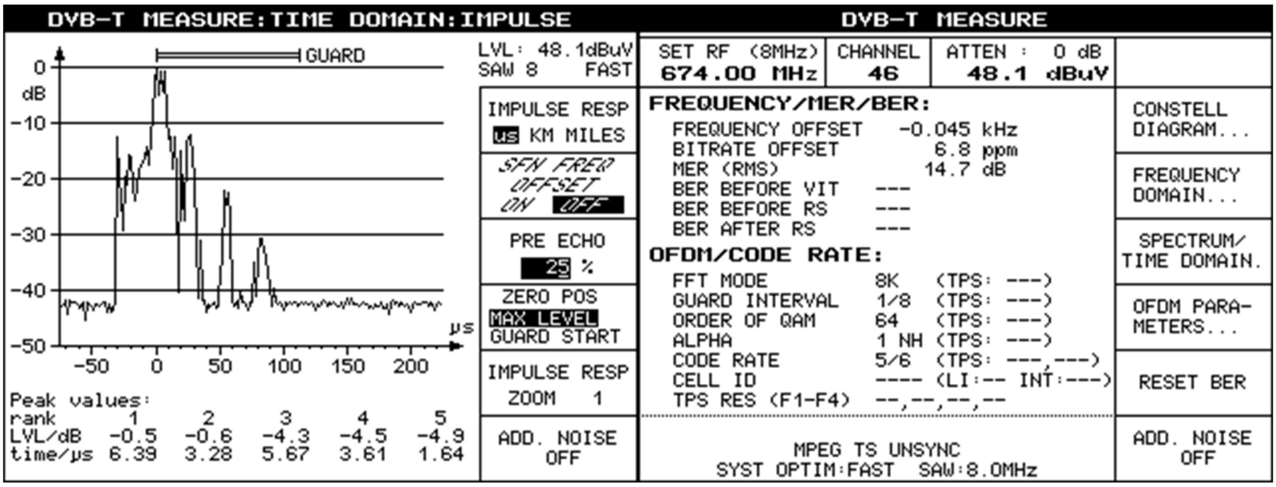
In these conditions good reception is failed because settings of receiver work window correspond to the most powerful signal (see Fig. 21).

FIGURE 22

Time diagram and characteristics of received signal



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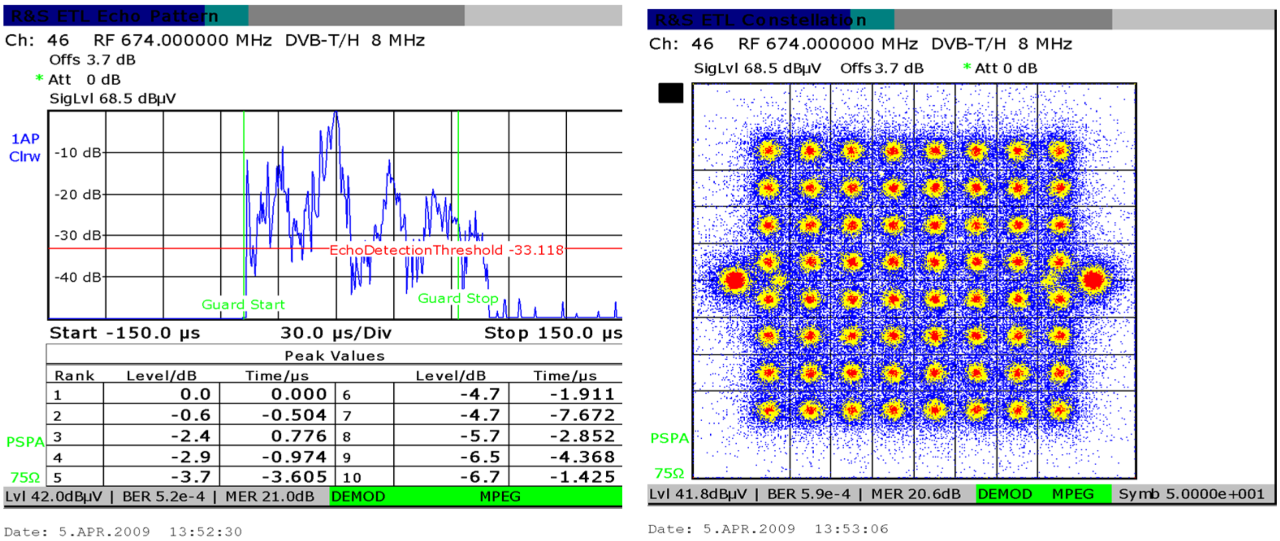
In such conditions signal demodulation by one of test receivers was impossible.

By changing receiving antenna position the direction which gives an opportunity to demodulate signal by all receivers was found. But this direction was different from the maximum signal level one.

FIGURE 23

Time diagram and constellation of received signal after changing of receiving antenna direction



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Other typical conditions of reflected signal reception in mountainous area are river-valleys located in ground folds.

FIGURE 24

Conditions of reflected signal reception in river-valleys

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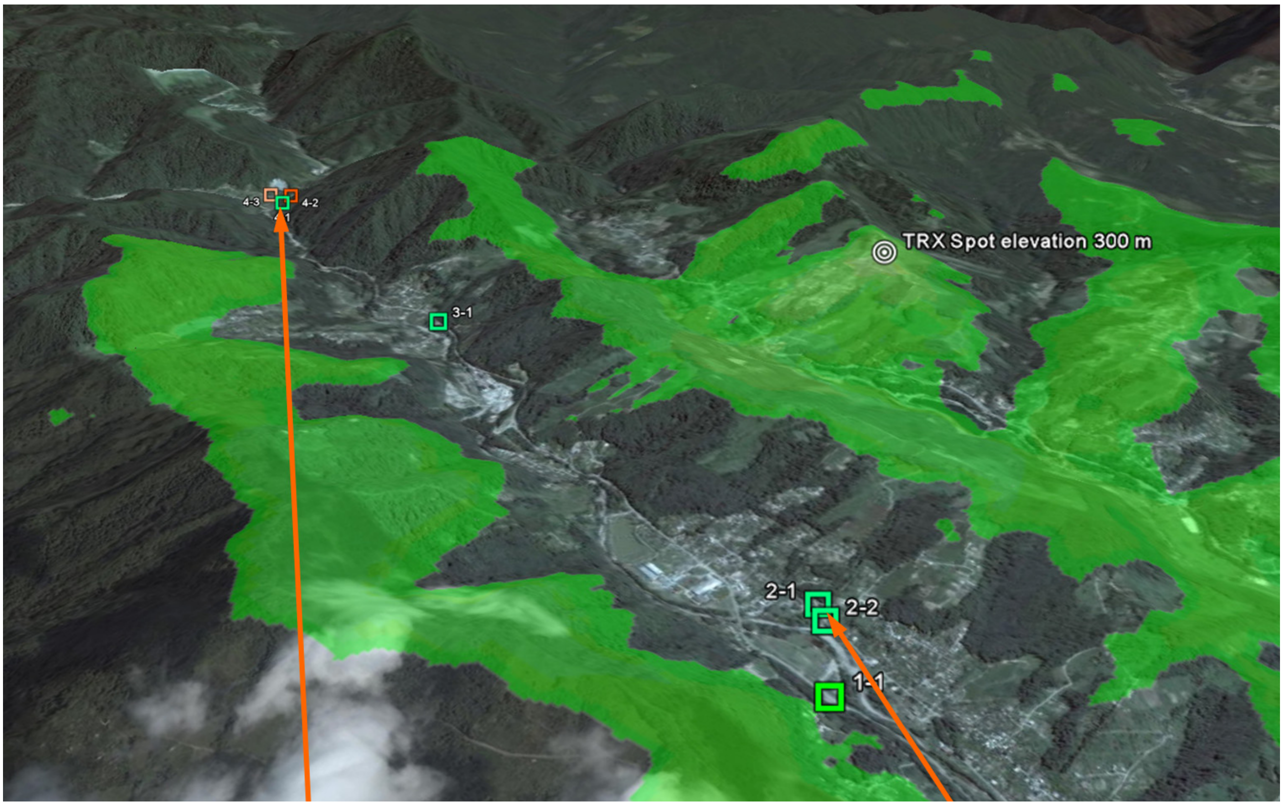
FIGURE 25

Reception of reflected signals in ground folds



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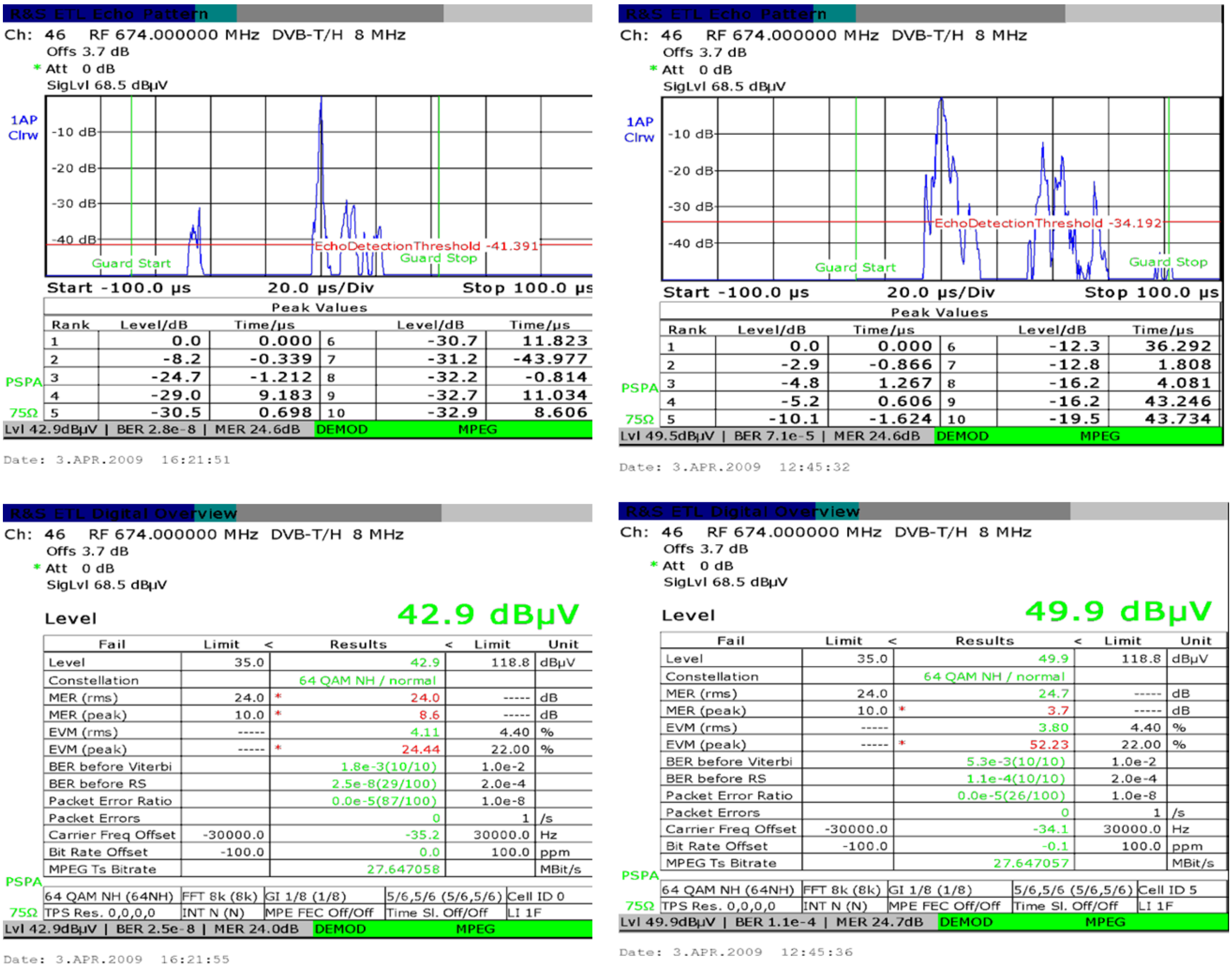

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In the process of measurements directional antenna was used. It was placed at 10 m height in blind zone of useful station in the direct beam and was directed to the maximum of reflected signal (against direction to transmitter).

Reception places where best results were received in the process of receiving antenna orientation towards reflected signal rather than towards transmitting station (2-1, 2-2, 3-1, 4-1) are marked with light-green colour. Coverage area calculated according to Recommendation ITU-R P.1812 is marked with green colour.

In all cases directional receiving antenna is oriented towards receiving signal maximum. Reception place was in a low ground therefore signal attenuated due to natural barriers. Thus, maximum level of received signal can be achieved when receiving antenna is oriented towards reflected beam.

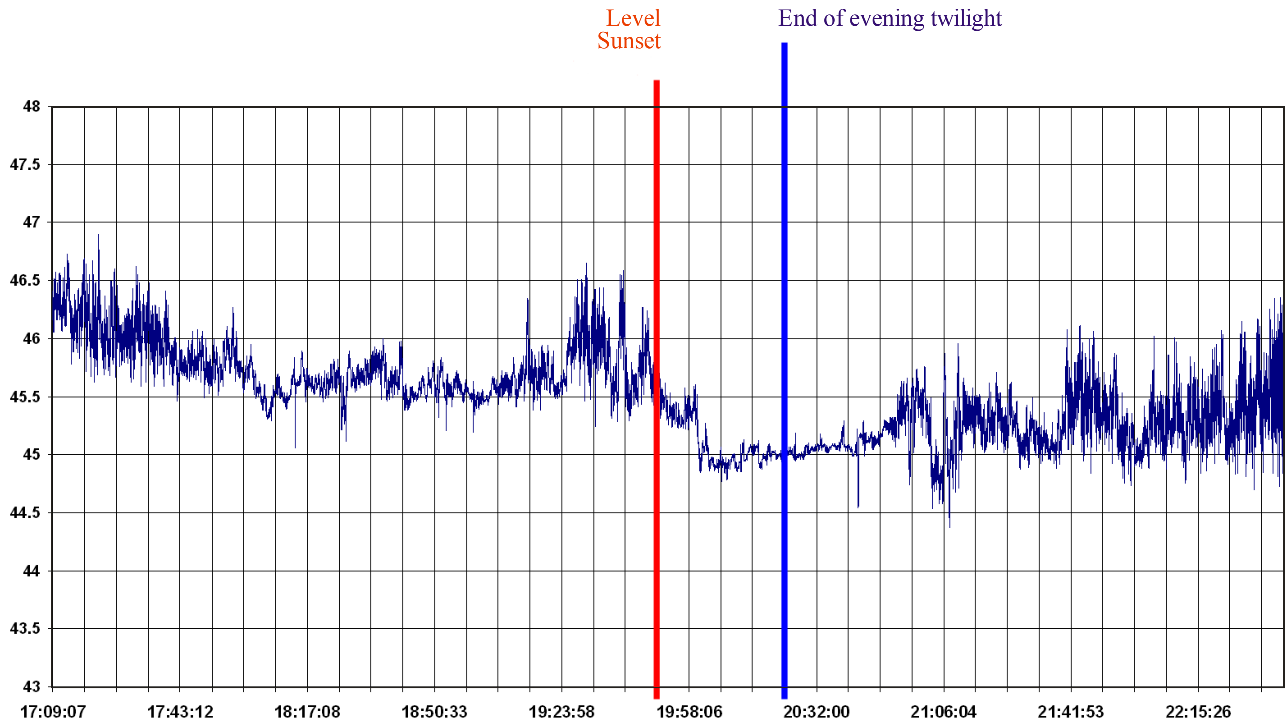
Time variations of reflected signals

Field-strength instability of reflected signals is well-known. At same time, correlation of level changes between different COFDM sub-carriers is not large. As far as COFDM signal is broadband, changes at some frequencies partly compensate each other leading to reduction of general signal level changes at receiver input and less impact on the reception. During measurements short-term (less than one minute) variations of measured DVB-T signal level of reflected beam in any cases do not exceed 5.5 dB.

Within the limits of diurnal cycle time changes of reflected signal level are not large. The example of time variations measurements of signal reflected from breast of a hill covered with young spring forest (without leaves) at average ground humidity is shown in Fig. 26.

FIGURE 26

Time variations of reflected signal field in reception place



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In the process of measurements directional antenna was used. It was placed at 10 m height in blind zone of useful station in the direct beam and was directed to the maximum of reflected signal (against direction to transmitter).

The sunset and the end of evening twilight are given in accordance with astronomical calendar. Due to shadow of mountains a real sunset in reception place came about 20 min earlier.

Conclusions

Depending on conditions and network operation mode, reflected signals can be both useful and interfering. When the choice of SFN characteristics is right (first of all guard interval) reflected signals from network stations can improve reception conditions. In MFN by contrast reflected signals can lead to interference. For exact estimation of coverage area in mountainous area conditions it makes sense to take into account reflected signals and their impact on digital TV broadcasting reception quality.

Mention should be made of the fact that none of propagation models mentioned above take into account the presence and the impact of reflected signals. Under development of such model it is necessary to take into account the following:

– errors of reflective surfaces modeling, first of all – ground surface;

– reflective surfaces characteristics;

– changes of reflective surface characteristics depending on weather and climate conditions;
– distortion (error) of phase and polarization of reflected signals.

3 Estimation of digital set-top boxes work in multipath conditions

Results of measurements of necessary *C*/*I* ratio for different reception conditions and receivers are shown in Figs 27 to 29. Graphics of digital set-top boxes (labels "Signal", TP-5, "NIIR") reaction under conditions of one main signal reception and another signal with time delay are given below. Delay time of another signal in μs corresponds to axis of abscissas. Relation of measured protection ratio to theoretical value for appropriate modulation mode corresponds to axis of ordinates. Recommended *C*/*I* correspond to values of co-channel protection ratios given in Table 14 of Recommendation ITU-R BT.1368 for Rice channel.

FIGURE 27

Set-top box 1 ("Signal")

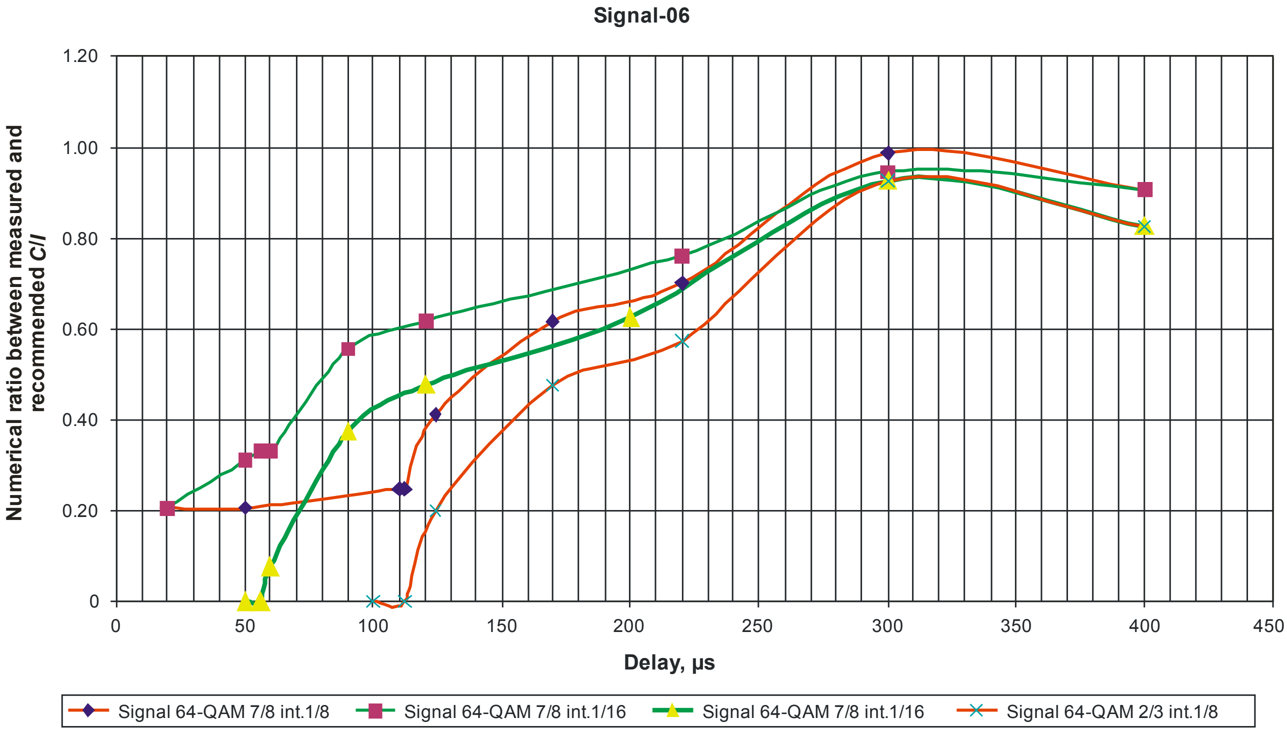

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FIGURE 28

Set-top box 2 ("TP-5")

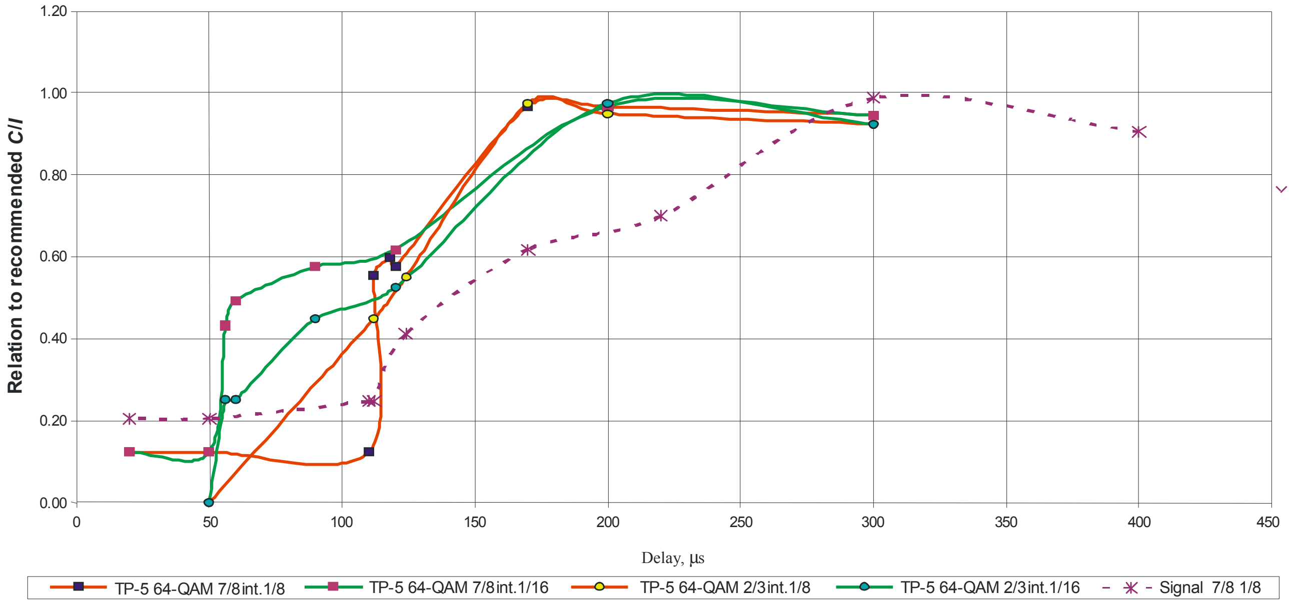

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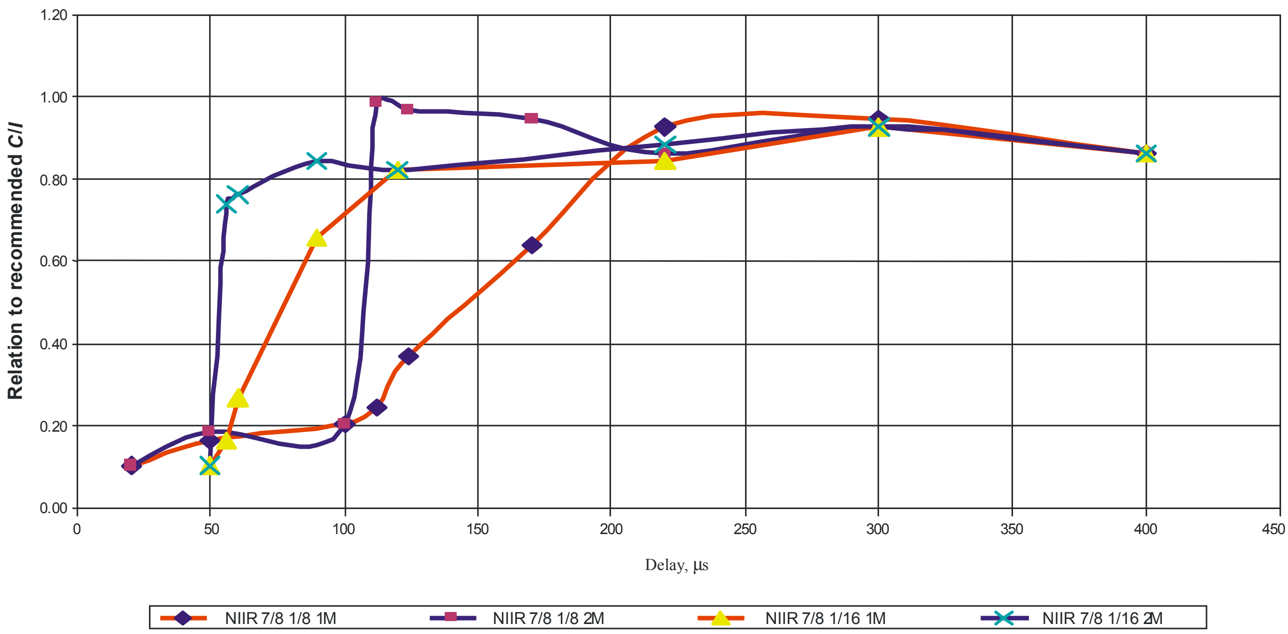
FIGURE 29

Set-top box 3 ("NIIR")



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Measurements carried out by means of set-top box 3 for one modulation mode: 64-QAM 7/8 are shown in Fig. 29. Different conditions were: guard interval (1/8 and 1/16), difference between levels of main and delayed signals ("1M" – means that main signal is more powerful, "2M" – means that delayed signal is more powerful).

Conclusion

Measurements show that set-top boxes of different manufactures have different characteristics. In general set-top boxes characteristics are better than reference model, because reception is possible even when protection ratio between useful and delayed signals is failed. At the same time further changes of set-top box constructive features may require new measurements.

Attachment 1
to Appendix 4

Detailed information on measurements

1 Measurement location

Measurements were carried out in North Caucasus near populated areas Sochi-Lazarevskoe (seashore and mountainous parts of Bolshoi Sochi), Krasnaya Polyana.

Mountain-hilly relief of middle or low height with rich forest flora without ascents and existence of sea signal propagation paths is typical for this location. Populated areas are located both in lows and in down-hills and at tops of hills.

2 Measurement technique

2.1 Measurement of received signal level

This parameter is measured by test DVB-T receiver or spectrum analyser on arbitrary frequency inside a received channel. Levels of carriers are practically identical because frequency spectrum is more or less flat. Possible number of spectrum interference has to be assessed by spectrum analyser connected to input signal in parallel to test receiver (see Figs 33 and 34).

2.2 Measurement of *S*/*N*

Test DVB-T receiver can be used for *S*/*N* measuring. But the results of these measurements are not usually accurate with regard to the use of frequency filtering (separation) of carrier power and interference. Spectrum analyser with RMS detector can be used for more successful *S*/*N* measurement.

2.3 Measurement of BER

There are four BER (before and after Viterbi decoding, before and after Reed Solomon decoding). BER before Viterbi decoding provides information on transmitted signals. BER after Viterbi can be compared with a limit value mentioned in DVB specification ($2*10^{-4}$), this value provides information on receiver work. From theoretical point of view BER after Reed Solomon decoding can impact on reception quality. BER can be measured by test DVB-T receiver (measurement range of BER is usually 1.10^{-8}–1.10^{-2}).

2.4 Determination of reception quality

To estimate the impact of conditions changes and measured characteristics on reception quality a set of 3 different digital receivers (set top boxes) was used. These receivers were connected to monitor equipped with recording device consequently one after another, reception quality was determined for each set-top box. Later, during the analysis received results were processed to find an average value among these receivers.

Due to complex nature of digital modulation, coding and compression techniques it isn't easy to give a subjective quality mark ("1" - "5"), especially intermediate ones ("2"…"4"), for digital TV/sound reception as it was with analogue TV. Taking into account a need in simple and clear criterion for carrying out tests, "percentage of time 100% quality reception" criterion was chosen.

Reception quality was featured by percent of time during which DVB-T programme picture and sound displayed without any interference ("ideal reception"). The presence of "ideal" reception not less than 99% of observation time considered as acceptable reception quality. This criterion closely corresponds to planning method (99% of time) at a particular measurement point.

3 Description of transmitting network

Test network with transmitters of average power was created for carrying out measurements. These transmitters have the following characteristics:

– Power: 0.1-1.2 kW.
– Antenna suspension high: from 10-180 m.
– Antenna directivity: changeable (1 and 2 panels)
– Modulation mode: 8K, 16-QAM 2/3, 3/4, 5/6, 64-QAM 2/3, 3/4, 5/6.
– Radio frequency channel: 46.
– Work mode: MFN and SFN.

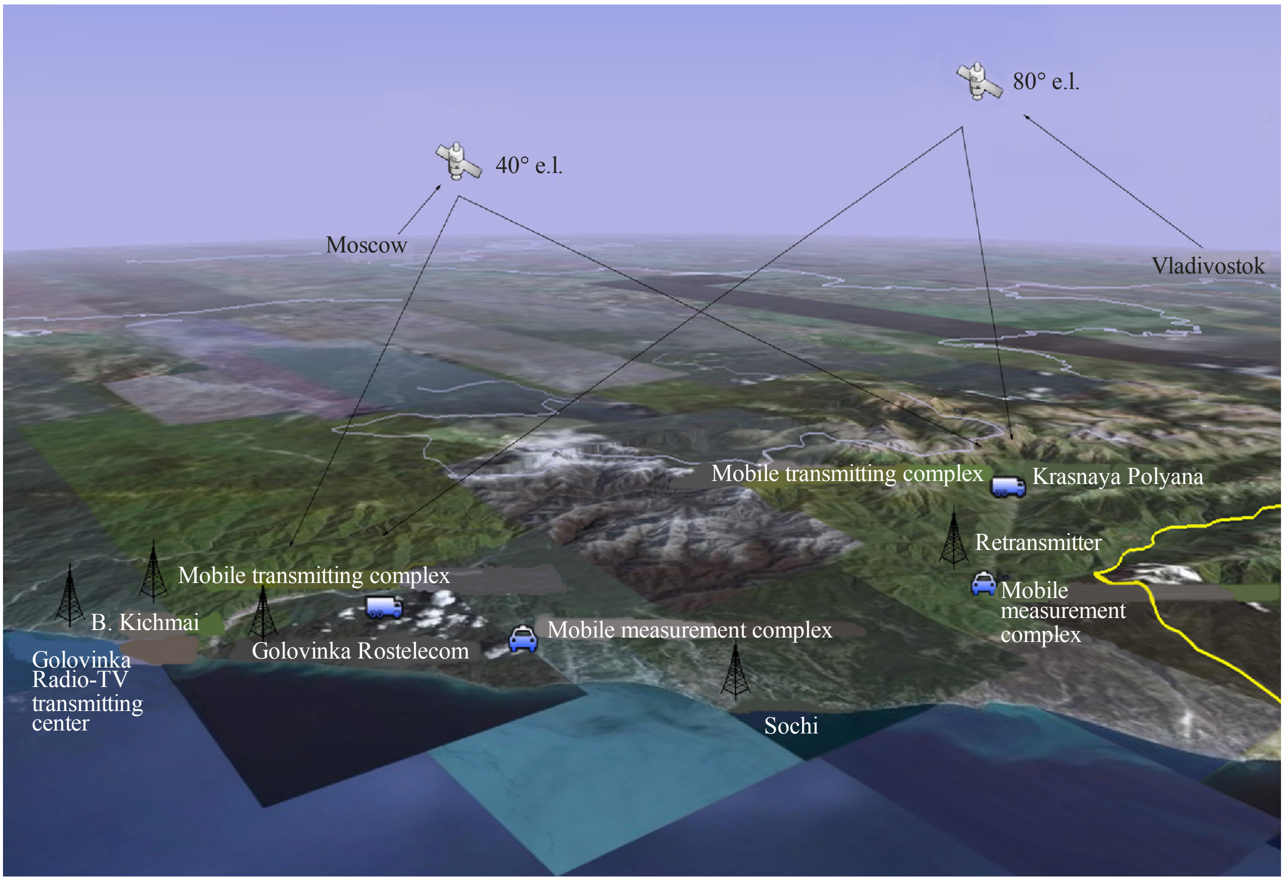
Measurements were carried out for fixed reception at 10 m high above ground level.

Places of measurements were chosen in the distance of 10-90 km from transmitting side, not far from boundary coverage area, in different directions. Some changes were made in Moscow, 32 channel, QPSK 1/2.

Organization of measurements at transmitting network is shown on Fig. 30.

FIGURE 30

Organization of programmes delivery to transmitting stations



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Stationary segment of network consisted of two small transmitting stations of 100 W power and two stations of average power 50 W to 1.2 kW.

Characteristics of transmitting stations emissions and modulation modes were changed for studying of different possible work conditions of transmitting stations of designed DTTB network and imitation of possible scenarios of internal interference appearance and multipath effect on signal propagation paths. Main types of stationary transmitting stations are shown in Figs 31 and 32.

Mobile transmitting stations were placed on preliminary chosen ground points. Their transmitting antennas were directed according to measurement task (see Fig. 33).

FIGURE 31

Small transmitting stations and main transmitting station of test network

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FIGURE 32

Transmitting station at radio-relay line mast

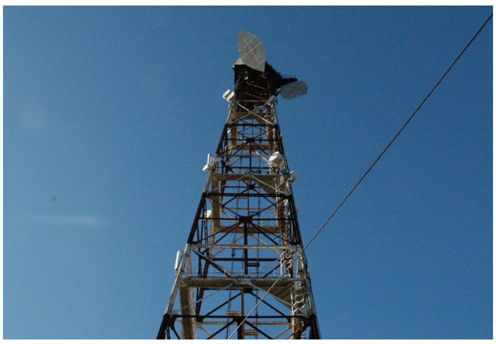

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FIGURE 33

Mobile transmitting station at site

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4 Measuring equipment

Measurements were carried out by means of two mobile measurement complexes. Each of them was equipped with identical set of special receiving equipment, measurement and common (meet the requirements of all Union State Standard) receiving antennas and set-top boxes of different producers. In each measurement not less than 3 different digital set-top boxes were used.

Measurement complexes were equipped with computers having special software used for automated documentation of measurement results. They were also equipped with satellite navigation system used for fixing of measurement point coordinates to the location and displaying them on digital map.

FIGURE 34

Mobile measurement laboratory structure

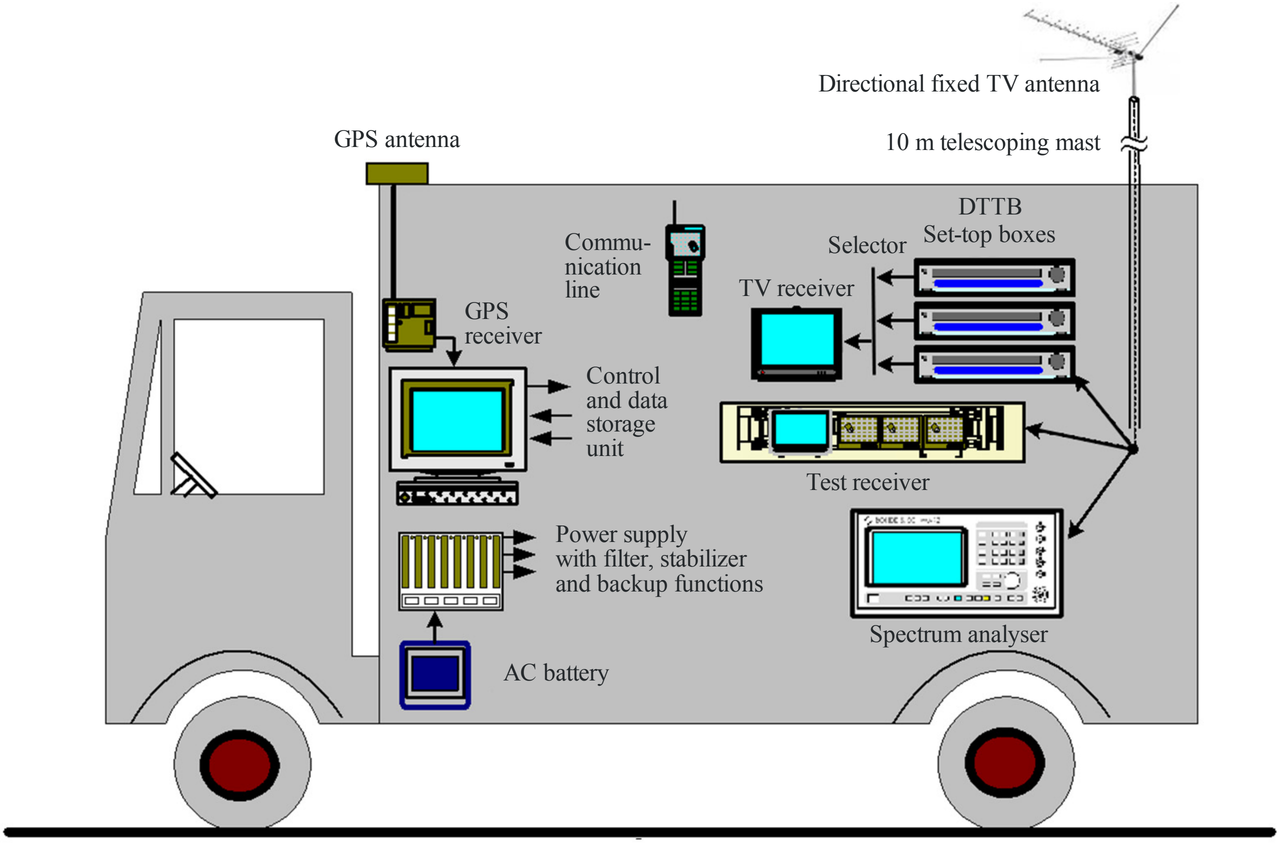

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TABLE 2

Measuring equipment

	Equipment	Producer	Model
1	Test receiver	Rohde & Schwarz	ETL
1	Test receiver	Rohde & Schwarz	EFA-40
2	Spectrum analyser	Rohde & Schwarz	FSQ
3	Decoder	Radio manufacturing plant “Signal”	TLS2006TFTA
4		Telecom-project 5 Ltd.	TP5-3800TSD
5		NIIR FSUE	NIIR Terminal multifunctional
6		General satellite (assembled in Saint-Petersburg)	TE-8310
7	Receiving antenna	NIIR FSUE	21/69
8	Measurement antenna	Rohde & Schwarz	HL223
9	TV receiver	Philips	19PFL4322

Mobile measurement laboratory was equipped with telescoping mast of 10 m height and calibrated receiving antenna for fixed reception. At the beginning of measurement campaign receiving antennas were checked for meeting the requirements of Recommendation ITU-R BT.419-3 for fixed receiving antennas.

In the process of measurements receiving antenna was oriented in horizontal plane in direction to maximum receiving signal level, then – in direction to transmitters.