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(02/2014)

Methods for objective reception quality assessment of digital terrestrial television broadcasting signals of System B specified in Recommendation ITU-R BT.1306

BT Series

Broadcasting service (television)

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R BT.1735-2

Methods for objective reception quality assessment of digital terrestrial television broadcasting signals of System B specified in Recommendation ITU-R BT.1306

(Question ITU-R 100/6)

(2005-2012-2014)

Scope

The purpose of this Recommendation is to make available methods to assist in quality assessment of the reception of digital terrestrial television broadcasting services for digital television broadcasting in System B. This Recommendation takes into account relevant ITU-R Recommendations. For the stated purpose, two methods are available, one for multi-frequency network (MFN) and one for single frequency network (SFN).

The ITU Radiocommunication Assembly,

considering

a) that Recommendation ITU-R SM.1682 – Methods for measurements on digital broadcasting signals, specifies in § 2.6 the parameters to be measured for coverage evaluation;

b) that in Recommendation ITU-R BT.1368 planning parameters such as minimum field strength, protection ratio and relation between minimum field strength and receiver voltage input are defined and widely used by administrations;

c) that in Recommendation ITU-R P.1546 field strength prediction methods and clutter height for field evaluation are indicated and widely used by administrations;

d) that ITU-R established Recommendation ITU-R BT.500 as a methodology for the subjective assessment of the quality of television pictures;

e) that, with the introduction of digital television services, it has been observed that subjective assessment of digital television pictures is considered less relevant in quality assessment, as the performance of digital technologies do not provide the tolerances experienced with analogue;

f) that with the assessment of digital television systems, a critical requirement is that the system is above the threshold;

g) that subjective analysis of the picture quality cannot be used as a measure of the interference level or required protection ratio of digital systems;

h) that satisfactory planning of digital systems requires a determination of operation with a sufficient margin above the threshold point of quasi error free (QEF) signal, taking into account time and location variability;

j) that BER after Viterbi decoding (vBER) is used to determine the threshold of QEF condition;

k) that the SFP method is used to determine the threshold of visible errors;

l) that there is a need for in-field methodologies to assist administrations and Sector Members to assess the reception quality of digital terrestrial television broadcasting (DTTB) coverage,

recommends

1 that the model to describe the objective reception quality of digital signals based on measured bit error rates (BER) and measured field strength, in accordance with § 3 of Annex 1 should be used;

2 that for MFN the quality scale presented in Tables 1 and 2 of § 3.1 of Annex 1 should be used;

3 that for SFN the quality scale presented in Table 3 of § 3.2 and Table 2 of § 3.1 of Annex 1 should be used;

4 that the methods of measurement described in §§ 5, 6 and 7 of Annex 1 should be used.

Annex 1

Standard method for objective reception quality assessment for digital television broadcasting signals for System B

1 Objective quality assessment of reception

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. In terms of quality, by means of a prediction method, it is possible to identify the coverage area using "location probability". In the same way, the "perceived quality" concept, related to the end user, could be evaluated by means of measurement methods. The digital terrestrial television reception system works on the basis of a "threshold" and the perceived quality depends on three factors: the access to the service, the time availability and the location availability.

Signal level assessment and quality assessment are two different processes within the application of this method.

Application of the reception environment is not relevant in the quality assessment process[1]. It is assumed that the quality assessment process is based upon the minimum signal level applied for a specific environment within an administration's DTTB planning regime where the derivation of minimum signal level would take into account the relevant reception environments. It is also assumed that the DTTB planning regime takes into consideration location availability.

If the field strength in a particular reception environment is not achieved according to the planning regime, then the service automatically fails to meet the quality assessment requirement.

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[1] The main application is for fixed reception and steady receiving conditions. Caution should be taken for tropospheric propagation when detectable contributions fall closed or outside GI.

For fixed reception and time variable receiving conditions, a statistical method has to be applied. Several samples of field strengh and BER have to be taken over a significative period of time and Q values have to be calculated for each sample. A Q value exceeded for more than a specific percentage of time (e.g. 90%) of the samples is the value of the Quality coverage.

2 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 bit error ratio (BER) after different decoding stages (here it is suggested to get the BER before and after Viterbi decoding – (cBER and vBER)). The BER after Viterbi decoding (vBER) is used to determine the threshold of quasi error free (QEF) condition. One more parameter should also be recorded during measurement activities. It is the modulation error ratio (MER) 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[2], the measurement activities should be stopped due to possible transmission failure. It has been noted that within some administrations there can be distinct classes of MER performance where there appear to be three distinct classes of MER performance corresponding to *tiers of services* for different types of transmission services as follows:

Type of service	Service performance target (MER)
Primary transmission service which may feed secondary transmission services, requires a reference quality suitable for coverage of urban, suburban and rural areas.	> 35 dB
Secondary re-transmission service which is RF fed from the primary transmitter service and reconstituted or re-modulated for re-transmission on a different output channel to the input.	> 33 dB
Tertiary translator or on channel repeater service which is RF fed off-air from the primary transmitter service and is IF processed only to transmit on either a different channel or the same channel in the case of on-channel repeater (OCR), is intrinsically a lower power service and has a relatively smaller coverage area and may be fed from a secondary re-transmitter service.	> 30 dB

3 The objective quality scale for System B

It is well known that field strength measured at receiving sites varies with location and receiving antenna height. The variability, at fixed power flux-density (pfd), depends on amplitude and phase combination of several paths that reach the receiving antenna. Variability is more accentuated for continuous wave (CW) signals than wideband signals. The reflected paths can give either possible positive 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 path 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-linear relationship among Viterbi decoding, protection levels, temporal and spatial dispersion gives as a result a low correlation between field strength and BER, as shown by analysis of thousands of field survey data reported in Report ITU-R BT.2252.

[2] Minimum MER values are typically included in transmitter specifications and operational performance contracts.

The quality evaluation system for an analogue signal has been based on both field strength and the five quality (Q) grades subjective assessment scale. Q5 grade corresponds to "excellent", Q1 grade corresponds to "very bad". The acceptance threshold is fixed to Q3 grade. In a digital environment the situation is quite different and it is important to note the difference between compression video quality evaluation methods and broadcasting coverage quality evaluation. For the compression methods evaluation, such as MPEG, the five-grade assessment scale has been maintained. For the objective of broadcasting reception quality evaluation, it would seem more difficult to maintain a method based on the five-grade scale because of rapid transition from a service to a no service condition. Nevertheless, it is possible again to maintain a five-grade scale if, at each grade, the meaning of distance from the transition point is attributed. For a deeper analysis of transition zone, a three-grade scale can be used. Evaluation of the distance from the transition point is very important because the measurement equipment is usually placed before the end user's reception system, usually composed of an antenna, distribution system and set-top box. Interpretation of digital objective quality reception assessment *is not to be confused* with interpretation of the analogue quality assessment.

Therefore, this Recommendation defines the following reception quality grades in terms of the margin to failure of the received signal.

Grade Q1 – Signal level is below minimum planning target.

Grade Q2 – Signal level is below minimum planning target or margin to failure is too low (reception may be possible but signal is very susceptible to failure).

Grade Q3 – Signal level and margin to failure have some margin above minimum planning targets.

Grade Q4 – Signal level and margin to failure above planning targets.

Grade Q5 – No measurable defects can be reasonably detected.

3.1 Multi-frequency network (MFN)

For MFN fixed reception, Table 1 should be used.

TABLE 1[3]

DTTB MFN signal quality scale

BER / **Field strength**	**vBER > SFP**	**QEF < vBER ≤ SFP**	**vBER ≤ QEF and cBER ratio ≤ 10**	**vBER ≤ QEF and cBER ratio between 10 and 100**	**vBER ≤ QEF and cBER ratio > 100**
$E < E_{xx}$[4]	Q1	Q2	Q2	Q2	Q2
$E \geq E_{xx}$	Q1	Q2	Q3	Q4	Q5

For those Administrations or Sector Members which prefer to use a simplified system for signal quality scale, the grades Q5, Q4 and Q3 could be collapsed into one figure as reported in Table 2.

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[3] For acronyms, fixed values and tables scale interpretation see § 4.

[4] $\mathbf{E_{xx}}$ may also represent the planning values chosen by administrations (e.g.: E_{95}).

TABLE 2

DTTB MFN simplified signal quality scale

BER / Field strength	vBER > SFP	QEF < vBER ≤ SFP	VBER ≤ QEF
$E < E_{xx}$	Q1	Q2	Q2
$E \geq E_{xx}$	Q1	Q2	Q3

3.2 Channel impulse response (CIR) considerations for SFN

Thanks to the experience gained by the constant application of Recommendation ITU-R BT.1735 for the evaluation of large scale SFN quality coverage, it has been discovered that, in presence of particular combinations of SFN signals, field strength level and BER parameters, as used in MFN case, are not able to indicate border line conditions with a minimum margin with respect to the possibility of losing the service. Such situations are critical not only in relation to the fluctuations of the SFN signal received within the guard interval but also in consideration of possible signals that could be out of GI.

For this last case, windows position strategy could change in relation to field strength variability and consequently, for certain percentages of time, some SFN contributions could fall inside or outside reception window or GI. It could also happen that the field strength level of SFN contributions falling outside GI could increase for certain percentages of time and approach the protection level decreasing the possibility of having a stable reception. Another case could happen when one or more SFN contributions fall very close to GI edge and, depending on the measuring point, they could fall inside or outside GI itself, giving location variability on reception. It is important to note that the distance between these points could be sometimes very small.

It is also necessary to consider the reduction of noise margin level of the received signal due to the rise of noise generated by SFN signals when they are received with very low levels ratio (< 7 dB) and their delays are close to maximum admitted value or very near to the main signal or synchronous to pilots repetition positions.

Based on the above considerations, a new quality reception assessment model is proposed for large scale SFN. It takes into account the following items: QEF, SFP, cBER and vBER relationship in Gaussian channel and lack of Viterbi correction ability.

For SFN fixed reception, if $vBER < 5 \times 10^{-11}$, Table 1 should be used, otherwise Table 3 should be used.

TABLE 3

DTTB SFN signal quality scale

BER / Field strength	vBER > SFP	QEF < vBER ≤ SFP	vBER ≤ QEF and vBER > Q_4 curve	vBER ≤ Q_4 curve and vBER > Q_5 curve	vBER ≤ Q_5 curve
$E < E_{xx}$	Q1	Q2	Q2	Q2	Q2
$E \geq E_{xx}$	Q1	Q2	Q3	Q4	Q5

For those Administrations or Sector Members which prefer to use a simplified system for signal quality scale, the grades Q5, Q4 and Q3 could be collapsed into one figure as reported in Table 2.

4 Acronyms, fixed values and tables scale interpretation

Acronyms

cBER: Channel BER or BER before Viterbi

vBER: BER after Viterbi

cBER ratio = $cBER_{min}/cBER$

QEF: Quasi error free

SFP: Subjective failure point

E^5_{xx}: Minimum median field strength needed for location probability of xx%. It has not to be confused with the equivalent minimum field strength at the receiving place above which protection against interference has to be granted (see Recommendation ITU-R BT.1368 for minimum field strength calculation).

RRC-06 or GE06 and Recommendation ITU-R BT.1368 adopted for (xx) a value of 95%. The E_{xx} value depends on the adopted configuration.

cBER ratio is a parameter introduced to give an indication of the performance of the channel in terms of the measured *cBER*, relative to $cBER_{min}$. $cBER_{min}$ is the value presented when vBER is equal to QEF and it depends on the adopted code rate.

$cBER_{min}$ values for the most used configurations are listed below in Table 4. It should be noted that these values do not change with frequency and modulation scheme.

TABLE 4

Values of $cBER_{min}$ for different code rates

Code rate	$cBER_{min}$
2/3	4×10^{-2}
3/4	2×10^{-2}

[5] E_{xx} may also represent the planning value chosen by Administrations.

Fixed values

$$\text{SFP} = 6.4 \times 10^{-3}$$

$$\text{QEF} = 2 \times 10^{-4}$$

$$\text{Q4 curve} = a \cdot e^{-b \cdot cBER}$$

$$\text{Q5 curve} = c \cdot e^{-d \cdot cBER}$$

and the constant a, b, c, d being given by laboratory and in-field test as:

$$a = 10^{-5}$$

$$b = 6 \times 10^{3}$$

$$c = 5 \times 10^{-7}$$

$$d = 4 \times 10^{4}$$

4.1 Table 1 scale interpretation

The quality scale represents the distance from the transition point. The transition point starts at QEF and ends at the so called "cliff effect" point (SFP). Each Q value is a function of E and BER.

Q2 read on the first horizontal line of Table 1 means that the field strength is lower than the minimum value assigned in the planning procedure. In such cases, no protection against interference can be guaranteed. Its interpretation is given in Fig. 1A.

Q2 read on the second horizontal line of Table 1 means that QEF threshold is reached and the "cliff effect" could appear. Its interpretation is given in Fig. 1B.

For the case of Fig. 1A, it is possible to move to Q3 by increasing transmitted power or by modification of the antenna pattern. For the case of Fig. 1B, it is possible to move to Q3 by reducing interference or the level of multipath interference.

The problem with this is that monitoring of DTTB reception indicates that at any particular reception point, temporal fading of wanted signals (or enhancement of interfering signals) causes transitions between "adequate" and "inadequate" instantaneous received signals. As such, it is considered that Grade 2 presents a transition region during which the reception quality is "unreliable", but may or may not present a watchable picture at any instant.

FIGURE 1A

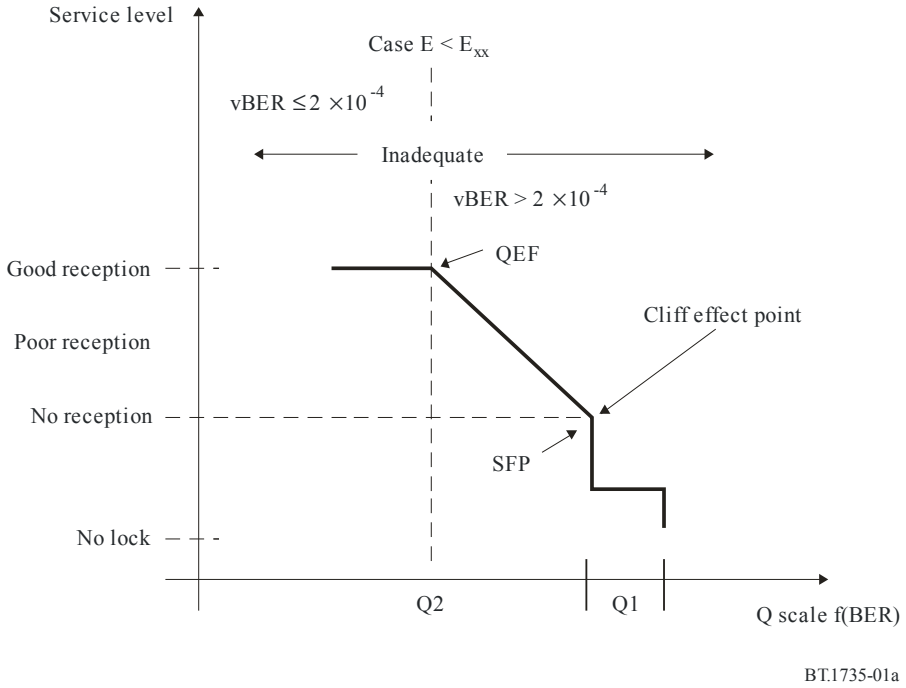
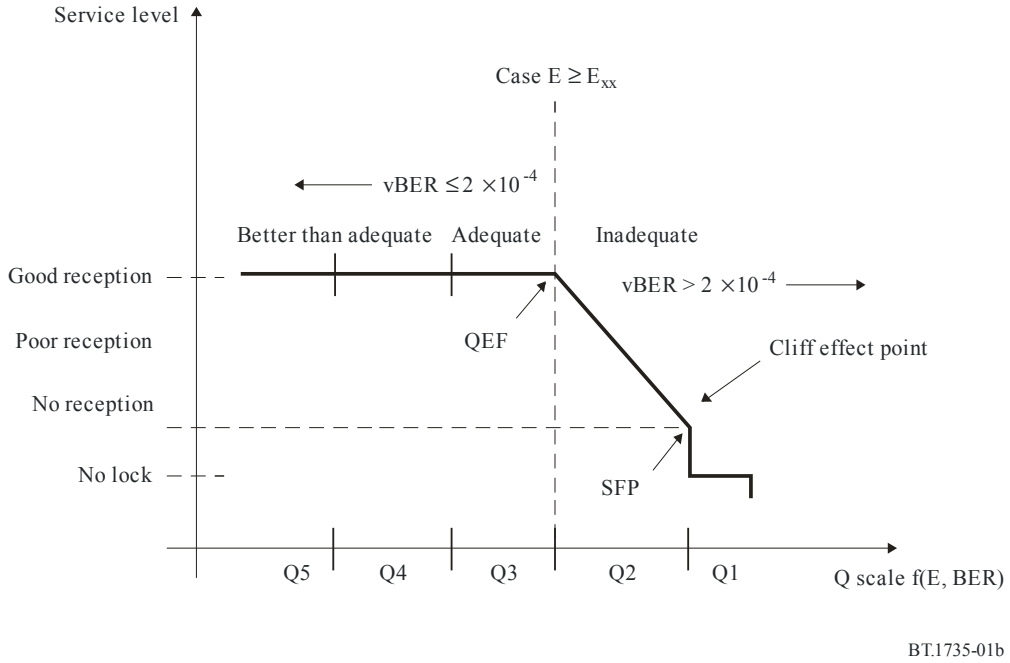


FIGURE 1B



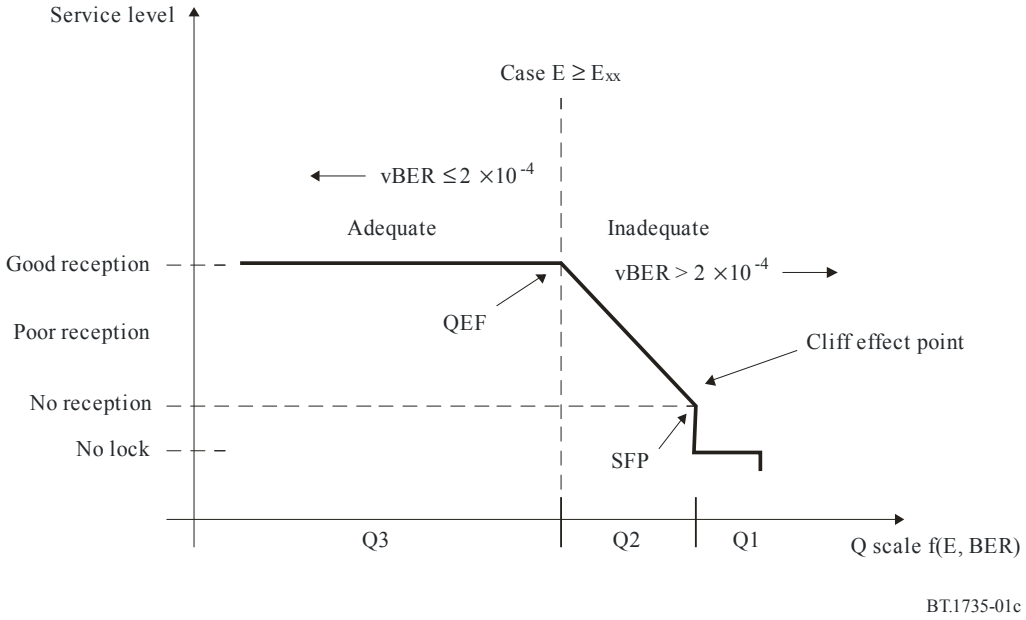
4.2 Table 2 scale interpretation

Q2 read on the first horizontal line of Table 2 means that the field strength is lower than the minimum value assigned in the planning procedure. In such cases, no protection against interference can be guaranteed. Its interpretation is given in Fig. 1A above.

Q2 read on the second horizontal line of Table 2 means that QEF threshold is reached and the "cliff effect" could appear. Its interpretation is given in Fig. 1C.

For the case of Fig. 1A, it is possible to move to Q3 by increasing transmitted power or by modification of the antenna pattern. For the case of Fig. 1C, it is possible to move to Q3 by reducing interference or the level of multipath interference.

FIGURE 1C



4.3 Table 3 scale interpretation

It is possible to represent the five grades of Table 3 in a cBER vs. vBER frame.

In the chart are plotted six reference curves: QEF, SFP, Gaussian channel, cBER = vBER, Q4 and Q5.

QEF and SFP curves are based on vBER and visible errors threshold.

Q4 and Q5 curves are exponential functions where vBER depends on cBER:

Q4 curve: $vBER = 10^{-5} e^{-6 \cdot 10^{3} \cdot cBER}$

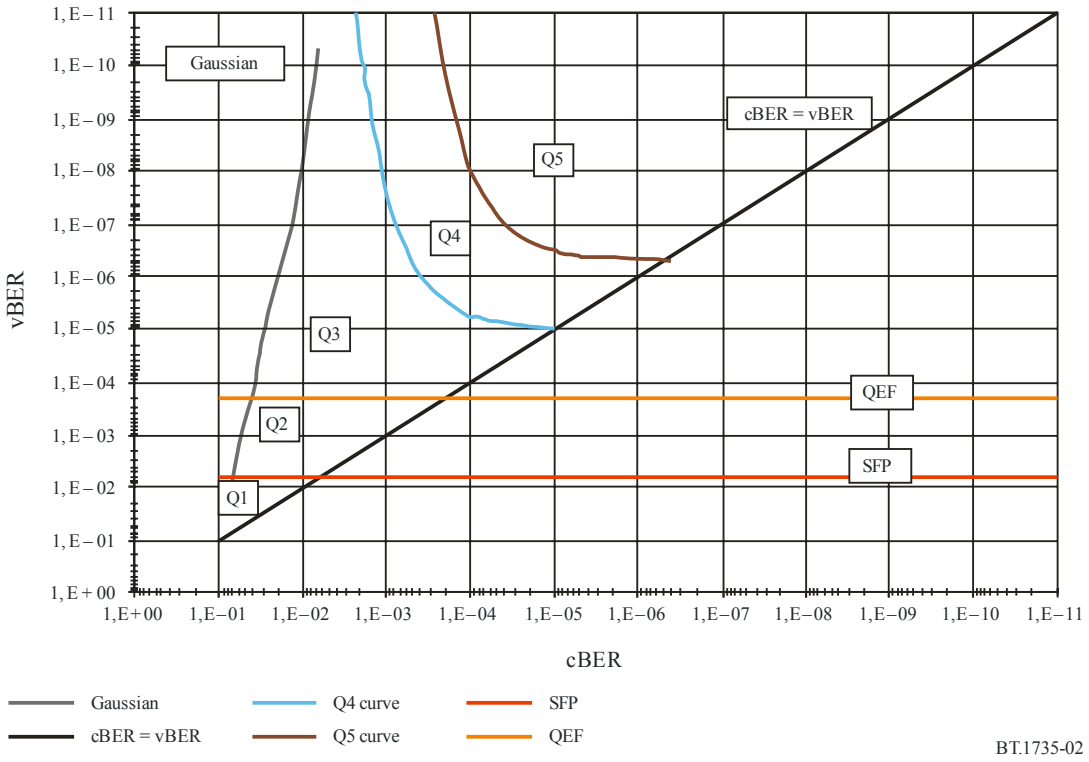
Q5 curve: $vBER = 5 \cdot 10^{-7} e^{-4 \cdot 10^{4} \cdot cBER}$

Q1 area is under SFP line; Q2 area is between SFP and QEF line; Q3 area is above QEF line and under Q4 curves; Q4 area is between Q4 and Q5 curves and Q5 area is above Q5 curve.

FIGURE 2

Gaussian, QEF, SFP, cBER = vBER, Q4 and Q5 curves

64 QAM and CR = 2/3



5 Measurements at fixed height

In this kind of measurement the receiving antenna is placed on the mast and raised to approximately 10 m height above the ground level such that the antenna is above local clutter or obstruction. The measurement results can be reproduced at any time just adopting a fixed reception system, usually found at monitoring stations. Fixed height measurements can be useful only for formal evaluation, conventionally made at 10 m high above the ground level (the height is the same as is used in the propagation the prediction method adopted for planning purposes).

In real situations the measured field strength depends on phase composition of the several received paths. Therefore, the final result depends on both: receiving antenna location and vertical variation of field strength. Using half wavelength receiving antennas, three specific situations can be identified where:

– the difference between the maxima of the vertical variation in field strength is less than half the wavelength: measured field strength is equivalent to the direct path field;

– the difference between the maxima of the vertical variation in field strength is greater than half the wavelength: measured field strength could be higher or lower than the direct path field;

– the first maximum value is higher than 10 m: measured field strength increases with height.

The fixed height measurement can be used to characterize the service area only if the result falls in evaluation class Q4 and Q5: it means field strength higher than E_{min} and absence of perturbation in the transmission channel. In such cases, it is possible to associate the measured value to an “area of validity”. The extent of the area of validity must be determined on the basis of the environment, distance from transmitter, vertical variation of the field strength and height of the first field strength

maxima. Experience in MFN analogue signal evaluation indicates the radius of the area of validity is up to a maximum of 10 km.

The objective reception quality results Q5 and Q4 indicate that "better than adequate" coverage has been achieved by the service being evaluated.

If objective reception quality results are less than Q4 it is necessary to evaluate the vertical variation of field strength and then eventually the horizontal variation of field strength.

In such a case or when the simplified method is used, the extent of the area of validity has to be reduced.

In SFN, the extent of the area of validity depends on CIR evaluation. For SFN having contributions falling inside 50% of the GI, and objective reception quality Q5 or Q4 are achieved, a maximum of 10 km can be also taken.

For SFN having contributions falling closed GI edge or beside of it or objective reception quality results are less than Q4, shorter radius of validity than above have to be taken into account.

6 Vertical variation of field strength

The field strength and BER change continuously during the antenna positioning process up to 10 m above ground level. Values depend on the different path combinations and eventually on the obstruction at the low height. If the evaluated objective quality is less than Q4 at an antenna position of approximately 10 m, it is necessary to verify if the objective quality grade Q3 has been exceeded during the antenna positioning process. An antenna position suitable for reception should be identified. The objective quality grade evaluated in such cases is reported as significant and the recorded VV (Vertical Variation) is included in the measurement results. It has been found that the radius of the area of validity is up to a maximum of 2 km.

The objective quality result Q3 is similar to coverage level grade adopted in the planned system.

7 Horizontal variation of field strength

When using a vertical variation of field strength method the objective quality evaluation remains always lower than Q3, it is necessary to verify if that result depends on a bad choice of the measurement point or if it is related to the area under investigation.

In such cases it is necessary to select other measurement points near to the first one selected. If the results related to the new points give objective quality evaluation again lower than Q3, it should be reported as most significant the best result obtained and the relative range of validity. The range of validity should be as wider as greater is the distance between measurement points.