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FACSIMILE IMAGE QUALITY AS CORRUPTED BY TRANSMISSION-INDUCED SCAN LINE ERRORS

ITU-T Recommendation E.453

(Previously “CCITT Recommendation”)

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation E.453 was prepared by the ITU-T Study Group 2 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 12th of August 1994.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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SUMMARY

Transmission-induced scan line errors are one of the important impairments perceived by customers in non-Error Correction Mode (see Recommendations T.4 and T.30) Group 3 facsimile. This proposed text develops a set of scan line related performance metrics that can help benchmark the performance of transmission networks with respect to Group 3 facsimile.

In this text, certain criteria are developed for declaring a received facsimile page Error-Free, Errored, and Severely-Errored. These criteria are based on the number and distribution of errored scan lines and were developed based on customer perception studies of facsimile images.

Recommendation E.453

FACSIMILE IMAGE QUALITY AS CORRUPTED BY TRANSMISSION-INDUCED SCAN LINE ERRORS

(Geneva, 1994)

1 Introduction

Transmission-induced scan line errors are one of the important impairments perceived by customers in non-Error Correction Mode (see Recommendations T.4 and T.30) Group 3 facsimile. The purpose of this Recommendation is to develop a set of scan line related metrics that can help benchmark performance of transmission networks with respect to Group 3 facsimile.

Scan line errors occur when voiceband modem data stream is corrupted during transmission, causing errors in the received facsimile image data. The receiving facsimile machine may be unable to decode the received scan line data, or the scan line data may not decode into the required number of pels, e.g. 1728.

For the purposes of image quality evaluation, an errored scan line is one which fails to produce (e.g. through printing) an identical copy of the original (transmitted) scan line.

The receiving machine may employ one of several strategies to deal with errored scan lines. These strategies include:

a) delete;

b) print previous;

c) print white;

d) combination of above in case of consecutive errored scan lines; and

e) some other form of error concealment.

The distribution of errored scan lines is the primary factor in determining the quality of the received image. The strategy used in the receiving machine is a lesser factor which is mitigated further by the points discussed below.

This Recommendation contains image transmission quality metrics that are independent of the particular strategy used for errored scan lines. Metric development was aided by knowledge of how well the various concealment strategies work and the approximate extent of each strategy's deployment. The goal was to develop a reasonable set of image quality metrics and to monitor network performance with them. These metrics have a good correlation with user quality measures, are reasonably implementable, and retain utility for the intended audience.

This Recommendation is primarily intended for a fixed network environment. Facsimile service quality metrics for PLMN are for further study.

The following points are to be noted:

– The metrics presented here are developed primarily from the customer-perceived impact of scan line errors on Roman text, Japanese text, Arabic numerical information, although a limited set of graphs such as line graphs, pie charts and other graphics were considered. Several limited studies have shown that text and numerical information are likely to be the most frequently transmitted material on international facsimile calls.

– Image quality metrics based on Recommendation T.30 HDLC messages such as RTP and RTN and also ECM messages can be developed. Certain additional complexities are known, such as the wide range of decision criteria for sending RTP and RTN. This subject is for further study.

2 Definitions

2.1 Error definitions

2.1.1 errored scan line: An errored scan line is one whose received data stream fails to produce (e.g. through the process of decoding and printing) an identical copy (pel for pel) of the original scan line.

The intent of this definition is to quantify transmission errors within the context of the facsimile page information bit stream. Some examples of errored scan lines follow:

1) A line whose encoded representation contains one or more bit errors.

2) A line whose preceding end-of-line code (EOL) contains one or more bit errors.

3) A line that cannot be correctly decoded to produce the original line, because of some corruption in a previously received line that was used as an encoding reference. This example can only occur with two-dimensional (e.g. modified READ) encoding.

This definition is not intended to include image degradation confined to the printing or display process. The subject of manipulation of fill bits is for further study.

2.1.2 consecutive scan lines in error: Scan lines errors are defined as occurring in a consecutive configuration, when two or more scan line errors are received with no intervening error-free lines. The instance of consecutive errored lines is always preceded and followed by at least one error-free line (except if the instance occurs at the beginning or end of the page).

2.1.3 single scan line error: A single scan line error is defined as one errored scan line preceded and followed by at least one error-free scan line (except if the instance occurs at the beginning or end of the page).

2.2 Standard test transactions

Standard test transactions have been defined in Recommendation E.456.

2.3 Image quality categories

This subclause defines the method to collect information on the distribution of errored scan lines within a page. It also defines the image quality categories for assignment of received pages to perform transmission performance assessment.

Given that:

– there exists a pair of transmitting and receiving test machines that operate in the standard mode and do not have any known compatibility problems;

– the speed of the initial TCF (S_i, as defined in Recommendation E.452) is known;

– the test transaction is completed (all pages are received),

the following definitions apply.

2.3.1 error-free page: A page is considered error-free if it has no errored scan lines and contains all scan lines of the transmitted original page.

Pages delivered with error-free quality will retain all of their original information content, as though the facsimile operation were a lossless encoding-transmission-decoding process. The communication service provider has not added to, nor subtracted from the original information content.

2.3.2 errored page: A page is considered errored if it has one or more scan line errors but less than the number required to declare the page severely-errored (see 2.3.3).

Pages received with this level of quality contain some degradation to the original image, but are very likely to retain their intended utility. The page contains some errors, but based on subjective studies, it remains acceptable in most applications. For example, a typical page of 10-point text will still be readable, and a page of graphics will convey the intended information.

There are some less-frequency applications of facsimile which demand error-free or near error-free image quality to retain their utility, such as very small point size text or other fine detail, or legal documents where errors could render the document useless in court. When considering the performance of these stressful facsimile applications, network planners should focus on the error-free category as a measure of useful delivery.

2.3.3 severely-errored page: The following definitions apply to the Standard Resolution (3.85 lines/mm) as defined in Recommendation T4.

A page is considered severely-errored if it has:

a) at least N4 instances of four or more consecutive scan line errors; and/or

b) at least NS total scan line errors in single consecutive instances; and/or

c) at least N23 instances of consecutive errored scan lines with two and/or three consecutive scan lines in each instance.

N4, NS and N23 define the threshold values over a range of scan line error event types. The value of expressing the distribution of scan line errors in this way has been demonstrated through subjective testing.

Pages received with this level of quality contain substantial deviation from the original image bit-map and, based on subjective studies, are considered unacceptable. It is likely that they no longer convey some part of their original information, or contain distortion that significantly detracts from their usefulness. Some small fraction of pages may retain their utility, such as when the original image contains substantial redundancy, or in the unlikely event that all degradation is confined to "white" space.

TABLE 1/E.453

Thresholds for a severely-errored page for standard resolution

Criteria	Page is severely-errored when count is at least
N4	1
NS	12
N23	3
NOTE – Thresholds for a Severely-Errored Page of Optional Higher Resolution (7.7 lines/mm) are to be added in future.	

2.4 Transaction metrics

Calls with error-free pages:

– C_{EF} is the number of completed transactions which had all error-free pages.

– Then, represented as a percentage of T_C, where T_C is the number of completed transactions in the test:

$$\%C_{EF} = (C_{EF} / T_C) \times 100$$

Calls with errored pages:

– C_E is the number of completed transactions which had one or more errored pages, but no severely-errored pages.

– Then, represented as a percentage of T_C:

$$\%C_E = (C_E / T_C) \times 100$$

Calls with severely-errored pages:

– C_{SE} is the number of completed transactions which had one or more severely-errored pages.

– Then, represented as a percentage of T_C:

$$\%C_{SE} = (C_{SE} / T_C) \times 100$$

For exchanging network performance data, there is often a need to define the percentage of calls that contain no severely-errored pages. This is defined as $\%C_{NSE}$ and is the complement of $\%C_{SE}$, i.e.:

$$\%C_{NSE} = 100 - \%C_{SE}$$

Note that the number of completed transactions (used in the denominator) determines the sample size and therefore the confidence interval for these measures. When preparing for a series of test calls, some transaction failure rate should be assumed. Failed transactions shall be excluded from the sample. The total test calls should be increased by an appropriate amount to attain the desired confidence in the measurement.

2.5 Page metrics

Page based metrics have definitions similar to transaction metrics. Let the test transaction be of N pages, where the value of N is given in Recommendation E.456.

Number of error-free pages:

– P_{EF} is the total number of error-free pages in T_C completed transactions.

– Then, represented as a percentage of the total number of pages of T_C completed transactions:

$$\%P_{EF} = [P_{EF} / (N \times T_C)] \times 100$$

Number of errored pages:

– P_E is the total number of errored pages in T_C completed transactions.

– Then, represented as a percentage of pages in T_C completed transactions:

$$\%P_E = [P_E / (N \times T_C)] \times 100$$

Number of severely-errored pages:

– P_{SE} is the total number of severely-errored pages in T_C completed transactions.

– Then, represented as a percentage of pages in T_C completed transactions:

$$\%P_{SE} = [P_{SE} / (N \times T_C)] \times 100$$

$\%P_{NSE}$, the percentage of non-severely-errored pages is defined as the complement of $\%P_{SE}$, i.e.:

$$\%P_{NSE} = 100 - \%P_{SE}$$

3 Processing the scan line error distribution

It is recognized that scan line errors affecting text (or other picture element information) are much more important than those occurring in white spaces. However, there are several points which support collection of scan line performance over the entire page.

NOTE – The “entire page” is defined as an area that closely approximates the “guaranteed reproducible area” described in ITU-T Recommendation T.4.

1) Image quality performance results reported on the basis of entire pages present a conservative view of the results, in that customers would experience performance which is better than that measured. Lower limit measurements such as this are useful in performance monitoring and network planning.

2) There is a possibility that some scaling functions could be applied to measurements to predict typical customer response. The application of any scaling functions should benefit if the initial measurements are based on entire pages. The subject of scaling functions is complex and left for further study, while entire-page measurements create a strong foundation for them if needed.

3) The evaluation of image quality is greatly simplified by measuring errored scan lines over the entire page. It will be easier to compare results conducted by different Administrations using different test architectures.

Since current ITU-T test charts have little white space, this simplification is not likely to have a great impact on the results. Uniform application of these metrics will provide accurate data that can be used to assess network performance.

4 Facility-type sensitive performance criteria

Stringent criteria based on error-free thresholds may impose heavy maintenance burden for analogue switching and transmission facilities and other facilities prone to low level random errors. Therefore, it may be necessary to vary the page quality performance objectives in such a way as to concentrate on the severely-errored category for certain facility types and network topologies. A tier structure in the table of objectives makes this possible (see Table 2).

The variables EFx, Ex, SEx represent % performance in different categories where x is the tier level. Note that:

TABLE 2/E.453

Structure for performance requirements

Page/transaction category	Tier 1	Tier 2
Error-free	EF1	EF2
Errored	E1	E2
Severely-errored	SE1	SE2

$$EFx + Ex + SEx = 100\%$$

and

$$EF1 > EF2, \quad E1 < E2, \quad SE1 \approx SE2$$

It is expected that no new facilities will be assigned to Tier 2, and that the facilities which occupy this tier will be retired when the responsible Administrations find it feasible.

Numerical values for the objectives are for further study.

5 Remarks

a) Ideally, the modem speed for page transmission should be known. This is to ensure that valid comparisons can be made of network performances as, for some impairments, lowering the facsimile modem transmission speed, will decrease scan line errors.

b) For a given network impairment condition, the modem speed used for each page, and therefore, the number of severely-errored, errored and error-free pages depend on several factors. Some of the factors are:

   – number of bits errors permitted in the TCF sequence at various Phase B negotiations;

   – the image quality decision strategy (IQDS) defined as the thresholds for the number and distribution of errored scan lines used by the receive facsimile terminal to select between MCF, RTP and RTN responses. If stringent IQDS criteria are used, there may be fewer errored pages but more modem speed drop-downs and vice versa (see Recommendation E.452).

c) Further study is required to define image evaluation methods when Error Correction Mode (ECM) is used. The determination of partial pages received in the "Error-Free" category, although apparently simple, requires some consideration. On some connections, the first HDLC frame may contain errors, yet the printed page (in non-ECM mode) may not be affected by errors in pre-page fill bits. There also appears to be some promise for converting errored-frame indications into "Errored" and "Severely-Errored" categories, but further examination is necessary.