Zeitschrift: Technische Mitteilungen / Schweizerische Post-, Telefon- und Telegrafenbetriebe = Bulletin technique / Entreprise des postes, téléphones et télégraphes suisses = Bollettino tecnico / Azienda delle poste, dei telefoni e dei telegrafi svizzeri

Herausgeber: Schweizerische Post-, Telefon- und Telegrafenbetriebe

Band: 58 (1980)

Heft: 1

Artikel: Experiments on data broadcasting in a television channel

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DOI: https://doi.org/10.5169/seals-875864

Experiments on Data Broadcasting in a Television Channel

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070.48:621:397.13.037.37:621.397.62

1 Preamble

Broadcast teleinformation systems have been developed for some years and mark the beginning of a new evolution in the field of social communication. The special feature of these systems is the public use of digital data transmitted within the unused capacity of the television broadcasting network.

Two teletext systems were developed in Europe: UK teletext (Ceefax/Oracle) and French Antiope. The latter is a special application of the universal DIDON data broadcasting system.

The introduction of these new services is faced with the problem of compatibility with the existing television system. An investigation of the performances of UK teletext and DIDON thus constitutes the aim of the trials undertaken by the research and development division of the Swiss PTT. This work is to be considered as a contribution to the standardization efforts being made in the field of data broadcasting.

2 Introduction

Broadcast transmission of digital data inserted in the field blanking interval of a TV signal is the subject of numerous studies in various countries. The insertion of data into the field blanking intervals is already an old technique. The innovation resides in the use of such data signals for a public service.

The appearance of cheap integrated logic circuits enabled digital techniques to be used. The methods of broadcasting graphic and alphanumerical data are based on these principles and allow for a new service to be broadcast by better utilization of the video channel. It is also important to note that teletext is not simply a matter of extending the service offered by television, but of a new means of communication.

However, taking the existing television network into account, it is imperative not to impose more stringent requirements on the transmission and reception material than those necessary for the transmission of TV signals. The aim of the field trials is to assess the influence of all the parameters of the transmission chain on the quality of the digital signal. Measurements are made at each reception point, so as to characterize the analog and the digital signal. The non-interactive teletext system should be designed in such a way that good quality reception is possible wherever the reception quality of the TV signal is satisfactory. The generally very mountainous topography of Switzerland and the dense network of transposer stations will scarcely facilitate the choice of an optimum system which is a compromise between a high data transmission speed and a low susceptibility to transmission impairments.

After a brief description of the data broadcasting systems, the equipment and the measurement zones, the measuring techniques and field trials with UK teletext and DIDON will be discussed. The most significant results, valid in the precise context of the experiments, and conclusions of a more general range will be drawn in this report.

3 Aim of the tests

Experience has shown that there is no possible substitute for the field trials under actual service conditions, for evaluating the quality of new communication services.

The tests carried out by the research and development division of the PTT were primarily intended to provide a knowledge of the special features of data broadcasting systems. An assessment of the performances of UK teletext and DIDON in the field was then the next logical step. However, it has to be stressed that the available equipment is still subject to improvements and that the results found are only valid for the particular equipment used for the tests.

The radio transmission and broadcasting network introduces linear and nonlinear distortions and the effects of these on the digital signal ought to be studied. The strategy chosen consists in carrying out a search for measuring points as close as possible to the actual reception conditions in television. We are not interested, in the first instance, to evaluate the service coverage of teletext, but rather to study the influence of phenomenological criteria (noise, echoes, interference patterns, etc.) affecting the teletext transmission. As a next step, the performances of the data broadcasting systems are compared with those of the television services. This comparison enables us to form a rough idea of the possible coverage of a teletext service compared with the existing television coverage.

4 Data broadcasting systems

This chapter is devoted to a few comments on the teletext and data broadcasting systems. The non-interactive teletext service distributes graphic and alphanumerical information which is organized on to pages and displayed on the screen of domestic television sets. An unit, added to the ordinary TV receiver, makes it possible

- to extract the data from the video signal (demultiplexing)

- to select the pages of a magazine by means of a keyboard
- to store the data in a digital form and to read it cyclically
- to display the data by means of a character generator

A magazine consists of a number of cyclically broadcast pages, containing rows of characters. This involves a certain access time to a selected page, which is the longer the more voluminous the magazine, the lower the transmission speed (bit-rate) and the fewer the number of lines per frame are. Conversely, the teletext signal may be received by an unlimited number of users due to its insertion into the TV signal. The detailed characteristics of UK teletext and Antiope, and their respective advantages and disadvantages have already been dealt with [1, 2, 3, 4 and 5] and we shall not revert back to this. However, it should be mentioned that UK teletext, designed and tested in Great Britain since 1972, is based on the Television System I with a nominal video bandwidth of 5.5 MHz. In Switzerland, the teletext tests are being made on the TV network based on the B/G System with a nominal bandwidth of only 5 MHz.

The name DIDON [6, 7] is applied to a data broadcasting system which makes use of the television channel and which is characterized by the possibility of choosing the bit frequency within a wide range. The data is broadcast by means of packets occupying the active part of television lines. DIDON is therefore a data transmission system from the information provider to the public consumer, irrespective of the special nature of the application envisaged. The advantages of this broadcasting system make it possible to choose the optimum transmission speed with regards to the characteristics of the transmission channel, regardless of the teletext system, i. e. the data transmission and the display of the information are independent.

5 Digital data broadcasting

First of all, the characteristics of the broadcasting network and the digital sources used will be briefly described.

51 Television network

The data signal was injected into the video channel at the Bantiger transmitter station, near Berne, and emitted alternately on channels C2, C10, C40 and C53. The radiated powers of the main transmitters in use range from 1.15 kW (C53) to 100 kW (C2 and C10) to 300 kW (C40). Chains of no more than three transposers serving part of Emmental (Canton Berne) and of Val-de-Travers (Canton Neuchâtel) are fed by these main transmitters. The channels used on these chains are distributed in bands III, IV/V with power-ratings from 2 W to 300 W. All the measurements were made during the PTT test pattern transmission.

52 The UK teletext page generator

The teletext pages were stored in a programmable read-only memory (EPROM) and cyclically transmitted according to the UK teletext standard.

53 Pseudo-random generator

The digital channel must be capable of conveying information with minimum loss and error. To evaluate the channel performance, a known pseudo-random data structure is transmitted and analyzed at the end of the chain [8, 9].

The properties of the pseudo-random sequences make it possible to assess the performances of a digital path in the television channel. The characteristics of the digital signal (bit-rate, amplitude) are identical with those of UK teletext. In addition to the bit-frequency of *6.937 MHz (UK teletext Standard),* two additional frequencies were used for the trials: *4.296 MHz and 6.203 MHz (provisory ANTIOPE Standard).*

54 Comments

A non-return-to-zero code (NRZ) is used for the transmission of the binary data signal. This signal is passed through a pulse-shaping filter (sine-squared data pulses) before transmission in order to meet the spectrum requirements of the channel.

The structure of the data packets used for UK teletext is different from that of DIDON. In the latter, the prefix consists of 8 bytes (1 byte = 8 bit word; synchronization, addressing, continuity, format), whereas the number of bytes of the data block depends on the bit-repetition frequency f_{eb}:

- f_{eb} = 4.296 MHz: 19 bytes
- f_{eb} = 6.203 MHz: 32 bytes
- f_{eb} = 6.937 MHz: 37 bytes

The prefix used for UK teletext consists of 5 bytes (synchronization, addressing) and the data block of 40 bytes.

The television lines 19 (332) and 20 (333) were used for UK teletext. The error rate measurements carried out with DIDON were made on line 16 (329).

6 Reception of analog and digital signals

A measuring vehicle, equipped with a power generator, a 10 m telescopic mast and the following instruments were used for the field trials:

- semi-professional receiver with quasi-synchronous detection
- domestic TV set with quasi-synchronous detection and teletext decoder (UK teletext)
- semi-professional receiver with envelope detection
- professional receiver with synchronous detection
- line selector and oscilloscope
- colour monitor
- counter for bit-errors and block-losses (DIDON)

The RF receiver input voltage was determined by means of the quasi-synchronous detection receiver. The TV picture quality was evaluated using the domestic TV set.

The UK teletext data was extracted by means of the built-in teletext decoder and displayed on the screen of the domestic television receiver. The DIDON data was received with a separate receiver. Two counters were used to evaluate the number of bit-errors and data-block-losses within a given time interval. The essential characteristics of the antennas, used for the field trials, are summarized in *Table I.* The field strength at the reception sites was calculated from the measured receiver input voltage.

Table I. Characteristics of the receiving antennas

Band	Gain G_d in relation to the half-wave dipole [dB]	Horizontal half-power aperture [°]	Forward/backward ratio [dB]
I III IV/V	3 7...8.5 5.5...10	~60 ~80 ~60	~14 ~27 ~24
I II IV/V	1 5...7.5 8...11	80 50...60 22...35	3...7 15...25 22...26

7 Measuring zones and sites

The choice of the Bantiger station (Canton Berne) as the main transmitter site determined the test zones. The zones are numbered from 1 to 5 *(Fig. 1)* and some sites are shown on the map. The sites were selected on phenomenological criteria *(Tab. II).*

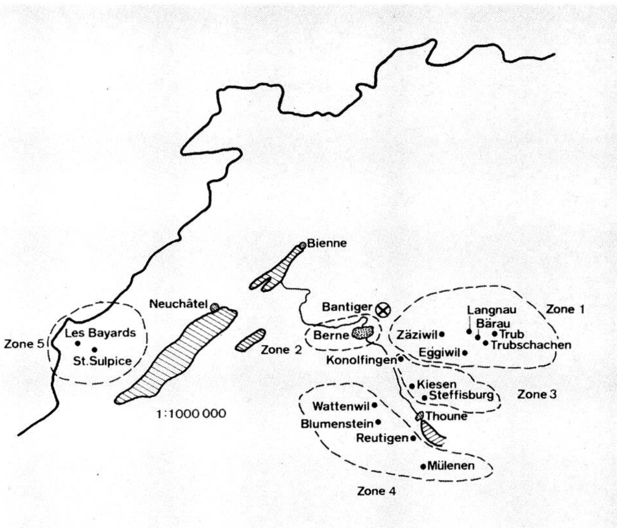

Fig. 1
Measuring sites and zones
⊗ Transmitter
• Test site

Table III. The CCIR 5-point quality scale (Recommendation 500)

5-point quality (grade Q_I)	
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

Table II. Number of sites and observations for each trial

Number of trial	Number of sites	Total number of samples (sites x measured channels)	Number of samples				Remarks
			Direct reception of the main transmitter	Reception via			
				1 transposer	2 transposers	3 transposers	
1	13	40	21	6	5	3	5 points on community antenna system
2	33	92	60	14	6	3	9 points on community antenna system
3	16	45	29	6	5	5	

8 Measurement methods

The following measurements were made on the *television signal:*

- RF receiver input voltage (maximum level for a reception antenna height of 10 m)
- subjective evaluation of the TV picture quality
- classification of the main picture degrading interference sources (discrete echoes, diffuse echoes, noise, impulsive interference, etc.)
- photographs of lines 17 and 18 (insertion test signals) for further evaluation

The CCIR quality scale *(Tab. III)* was used for the subjective evaluation of the television picture. The observations were made by two technical experts and in accordance with CCIR Recommendation 500 [10].

The following measurements were made on the *data signal* [11, 12]:

- subjective evaluation of the digital transmission quality by means of the teletext page and the following three quality criteria:
  - quality grade Q_T: after the first acquisition, the errors and losses are counted and a grade is given according to *Table IV.* In each case, the most unfavourable grade is considered. This very simple

Table IV. Teletext service quality scale

Quality grade Q_T	Number of character losses	Number of character errors
5	0	0
4.5	1	1
4	2	2
3.5	3	3
3	4	4
2.5	5...6	5
2	7...8	6
1.5	9...12	7
1	over 12	over 7

subjective method was used during the first trial. In the second, it was only introduced for some comparative tests
  - criterion B: no losses or errors in three successive acquisitions of a teletext page
  - criterion C: no errors or losses in the second acquisition of one and the same teletext page
- objective evaluation of the quality of the digital path by means of pseudo-random sequences (error and loss rates)
- S/N ratio by means of the following equation [17]:

$$S/N = 20 \log BA/U_{pp} + 17 \text{ [dB]}$$

with

BA Nominal amplitude of the luminance signal (0.7 V)
U_{pp} Peak-to-peak amplitude of the noise on line 22 (observation on the oscilloscope)

The methods described above made it possible to evaluate the performances of UK teletext and of the DIDON data broadcasting system under actual service conditions.

The subjective assessment criteria (Q_T, B, C) refer to a particular test page. It was found that, for certain interference sources (mainly short echoes), the results can be dependent on the test page in use (pattern dependent errors). The pseudo-random sequences, on the other hand, cover the whole range of information to be transmitted. They make it possible to calculate the performances of a digital path in terms of error and loss rates. The error rate is associated to faults within the data block, while the loss rate results from interference affecting the prefix of the data packets.

9 Field trials

91 Parameters and objectives

The first trial [13] was carried out in May 1977 in zones 1 and 2 (Fig. 1). It included 13 sites subdivided into 40 sample points (Tab. II). A domestic TV receiver, equipped with one of the first LSI teletext decoders[1], was used. The service quality of the teletext was subjectively evaluated by means of the assessment grade Q_T (Tab. IV).

It should be remembered that this procedure is based on a comparison of the known test page, and its display on the television screen, following the first acquisition. The primary aim of these tests was to familiarize ourselves with a new system and to carry out experiments in different topographical areas from those of Great Britain and Germany [14, 15].

The second trial [16], conducted in August and September 1977, differed from the preceding ones by:

- improved teletext decoder[2]
- assessment criteria B and C
- substantial increase in the number of sites and observations, ranging from 13 to 33 and from 40 to 92 (zones 1 to 4) respectively
- modification of the programmable read-only memory at the source, thus permitting the displayed page to be updated without prior erasement

The aim of this trial was to evaluate the advantages of the new decoder by a comparison of the results of the two trials at the same sites using criteria B and C. Criterion C could possibly be used as a definition of the degree of coverage for a teletext service.

In the above trials, the quality of the digital path was subjectively evaluated for a given bit-frequency, page content and receiver unit. Owing to the use of the DIDON data broadcasting system and of the pseudo-random sequences, these constraints could be overcome during the third trial [17]. Using DIDON, it is possible to calculate the performances of the digital channel [18]. The influence of the receiver (RF part + intermediate frequency [IF] + detection) and of the bit-frequency can thus be demonstrated. This trial took place from mid-April to the end of May 1978. The 16 sites and the 45 individual samples were distributed in zones, 1, 2 and 5.

92 Results

921 First trial

The quality Q_I of the TV picture is represented by the histogram in *Figure 2*. The statistical distribution function is almost normal which gives, for the mean value and the standard deviation

$$\bar{Q}_I = 3.5, \quad \sigma = 0.7$$

The quality of the TV picture is satisfactory ($Q_I \geq 3$) in 92 % of the cases.

Figure 3 shows the picture quality as a function of the RF receiver input voltage. The correlation between these two parameters (close to 0.8) is remarkably high.

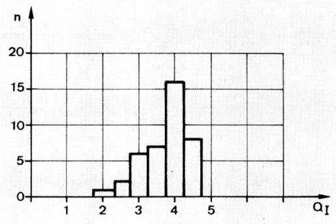

Fig. 2
Histogram of the TV picture quality
Q_I Quality grade (TV)
n Number of samples

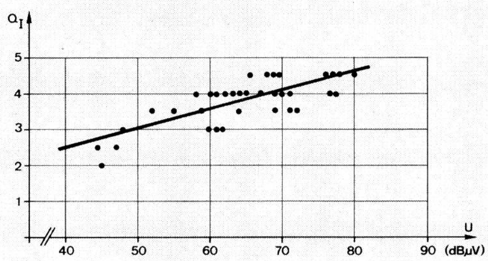

Fig. 3
Quality of the TV picture as a function of the RF receiver input voltage
Q_I Quality grade (TV)
U RF receiver input voltage

[1] Tifax-decoder
[2] Mullard-decoder

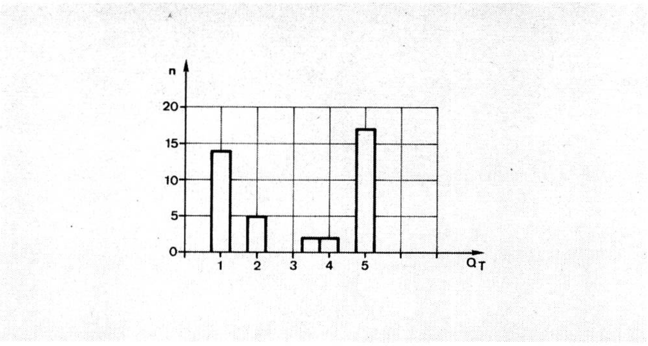

Fig. 4
Histogram of the teletext page quality
Q_T Quality grade (teletext; Tab. IV)
n Number of samples

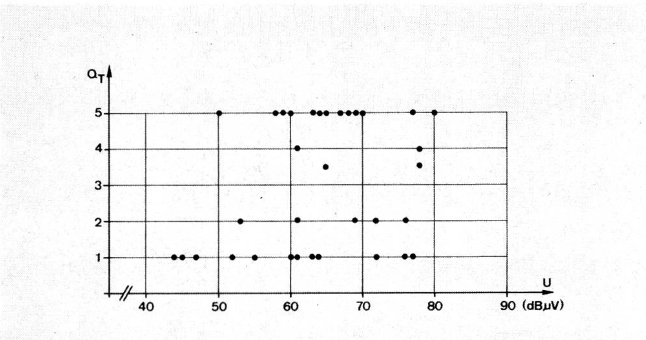

Fig. 5
Quality of the teletext page as a function of the RF receiver input voltage
U RF receiver input voltage
Q_T Quality grade (teletext)

The results are clearly less favourable for the teletext signal, which is shown in *Figure 4*. Error- or loss-free teletext reception was obtained in 43 % of the cases only, which is very low as compared with the 92 % score for satisfactory television reception ($Q_I \geq 3$).

The scatter diagram *(Fig. 5)* indicates a very loose correlation between the RF receiver input voltage and the grade Q_T. The same applies for the quality of the two services (teletext and television; *Fig. 6)*.

Echoes were found to be one of the main reasons for the degradation of the teletext signal. They affect the television picture and the data signal in different ways *(Tab. V)*.

Table V. Favourable cases for the TV and teletext services as a function of the interference source

Interference source	Number of samples	$Q_I \geq 3$	$Q_T \geq 3$
Echo	25	23	12
Noise	13	12	8
Impulsive interference	2	2	1

Q_I Quality grade (TV)
Q_T Quality grade (teletext)

These results are only valid within the precise scope of the tests conducted and for the equipment used. As we shall see later, the evolution of the reception and decoding material is such that these values have only a temporary significance. Nevertheless, the knowledge gained from the first measurements is interesting in many ways not the least by the fact that they demonstrated that short echoes affect the quality of the services in a different way.

922 Second trial

The results common to the two trials are presented at first in order to permit the comparison of the new teletext decoder with the previous one.

Figure 7 shows, in the form of histograms, the television picture quality Q_I. A slight difference, probably due to different test conditions and a more severe grading of the pictures, can be observed.

The mean value and the standard deviation appear as

$$\bar{Q}_I = 3.2, \quad \sigma = 0.6$$

This seems to be confirmed by the diagrams of *Figure 8* in which, for a high signal level, the grades are lower.

The teletext reception was clearly better in the second trial, as *Figure 9* shows. This improvement is due to the introduction of a more performant decoder. The percentage of *error- or loss-free pages increases from 43 to 70 %*. In *Figure 10*, the cases of favourable teletext reception ($Q_T \geq 3$) have again been represented with respect to the quality of the TV picture (to be compared with Fig. 6).

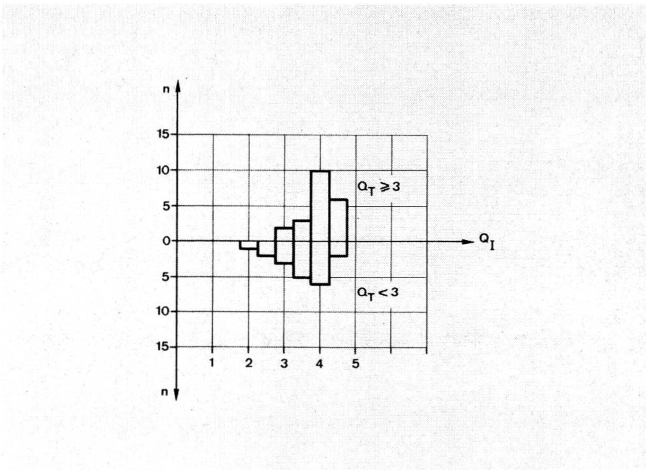

Fig. 6
Distribution of the teletext page quality as a function of the TV picture quality
Q_T Quality grade (teletext)
Q_I Quality grade (TV)
n Number of samples

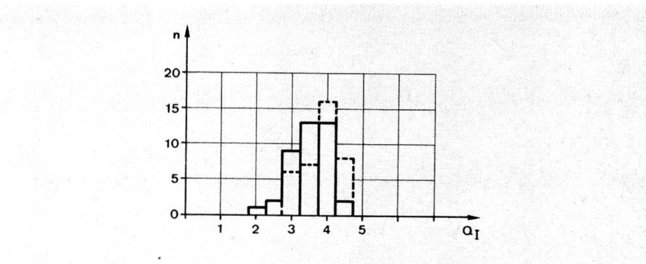

Fig. 7
Histogram of the TV picture quality (points common to the two trials)
Q_I Quality grade (TV)
n Number of samples
--- 1st trial
— 2nd trial

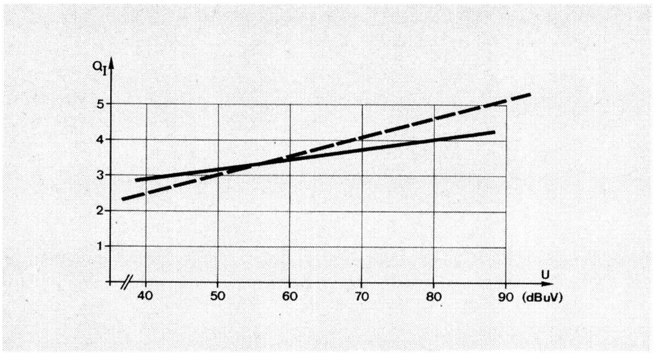

Fig. 8
Quality of the TV picture as a function of the RF receiver input voltage (points common to the two trials)
U RF receiver input voltage
Q_I Quality grade (TV)
– – – 1st trial
—— 2nd trial

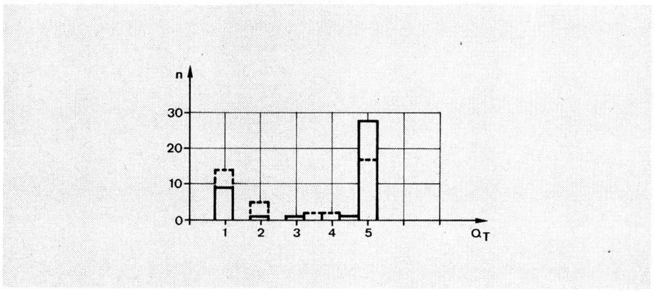

Fig. 9
Histograms of the teletext page quality (common to the two trials)
Q_T Quality grade (teletext)
n Number of samples
– – – 1st trial
—— 2nd trial

It can be seen that, in general, the errors and losses in the teletext service decrease with increasing TV picture quality.

The histogram in *Figure 11* shows the distribution of the TV picture quality for some fifteen channels (bands I, III, IV and V). Mean value and standard deviation are

$$\bar{Q}_I = 3.7, \quad \sigma = 0.7$$

The television picture quality is slightly better than that of the previous trial. The proportion of pictures with $Q_I \geq 3$ is 86 %. The correlation between the RF level and the quality Q_I is looser; it is in the vicinity of 0.6 *(Fig. 12)*.

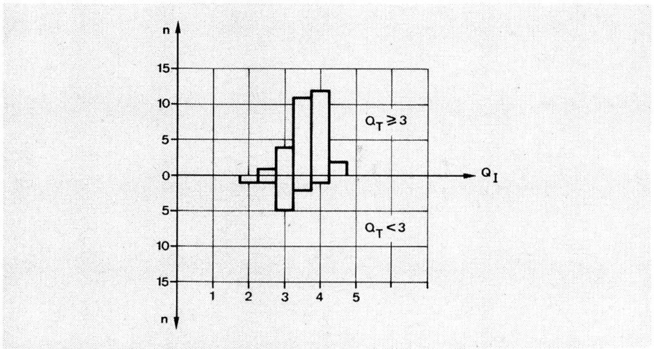

Fig. 10
Distribution of the teletext page quality as a function of the TV picture quality (points common to the two trials)
Q_I Quality grade (TV)
Q_T Quality grade (teletext)
n Number of samples

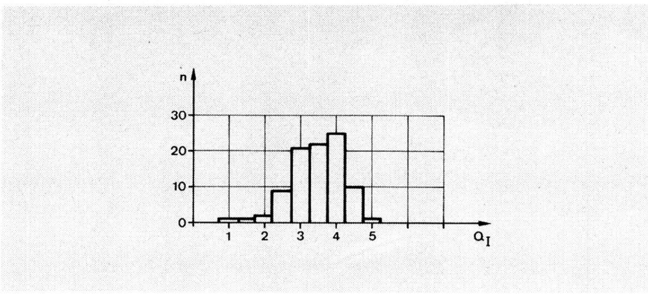

Fig. 11
Histogram of the TV picture quality
Q_I Quality grade (TV)
n Number of samples

For teletext, criteria B and C were used for the first time. Provided the teletext page is received without errors during the first acquisition, the receiver input voltage is reduced until the mentioned criteria are just met. The value of the attenuation thus found is called the noise margin or reserve. *Figure 13* shows the number of favourable cases (margin ≥0 dB). The low correlation between receiver input voltage, TV picture quality and the assessment criteria for teletext should be noted.

Criterion B is satisfied in 65 % and C in 75 % of the cases.

The diagrams of *Figure 14* illustrates the distribution of the two criteria as a function of the overall TV picture quality. It should again be noted that the number of cases with favourable teletext reception increases with the picture quality. For a grade equal to 3, the probability of meeting one of the criteria is about 0.5, which is comparatively low, considering that this grade appears frequently under actual reception conditions.

A distinction is made between weak, strong and diffuse echoes. *Table VI* illustrates the influence of the

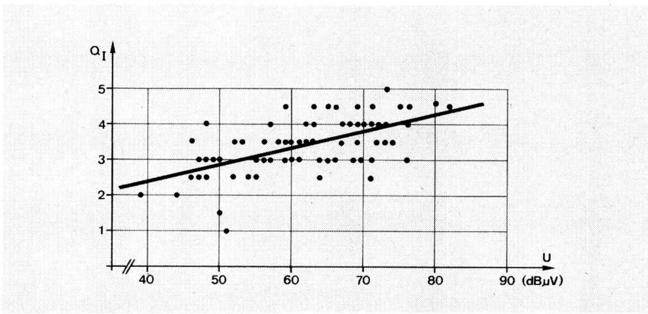

Fig. 12
TV picture quality as a function of the RF receiver input voltage
Q_I Quality grade (TV)
U RF receiver input voltage

Table VI. Favourable cases for the TV and teletext services as a function of the interference source

Interference source	Number of samples	$Q_I \geq 3$	Teletext: cases where criterion B or C were met	
			B	C
Weak echo (discrete)	32	32	29	31
Strong echo (discrete)	16	9	4	6
Diffuse echoes	20	15	9	10
Noise	18	18	16	17
Impulsive interference	6	5	2	5

Q_I Quality grade (TV)
Criteria Band C: Definition see Chapter 8

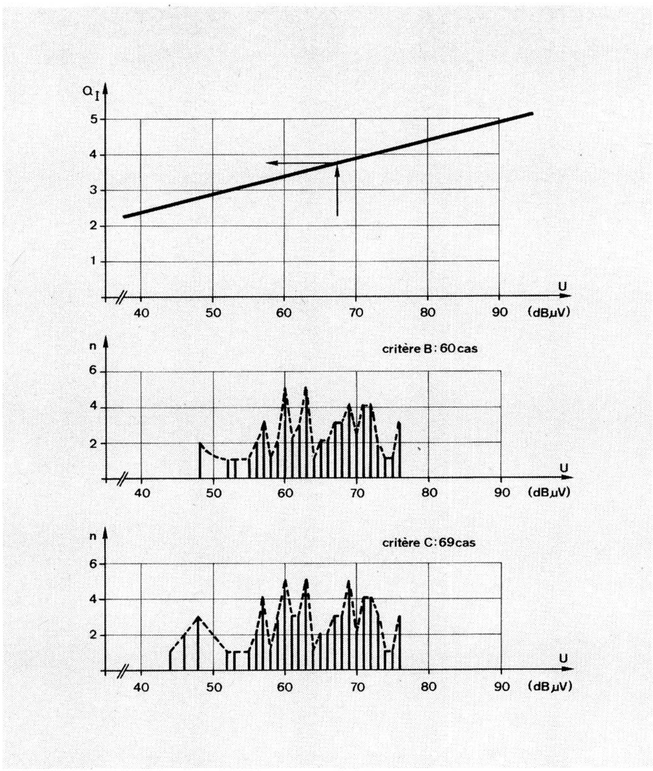

Fig. 13
Stick diagrams of criteria B and C as a function of the RF receiver input voltage and of the TV picture quality
Q_I Quality grade (TV)
U RF receiver input voltage
Criterion B / Criterion C } See definition in Chapter 8
n Number of samples
Critère – Criterion
Cas – Case

various sources of interference. The strong and diffuse echoes seem to be largely responsible for the degradation of the teletext service.

923 Third trial

First of all, the results concerning the television service are analyzed. To facilitate the notation, we introduce the codes QS, E and S, referring to the quasi-synchronous (QS), envelope (E) and synchronous (S) receivers. The histograms of the TV picture are shown in *Figure 15* as a function of the type of receiver. The statistical distribution functions are more or less normal:

- quasi-synchronous detection $\bar{Q}_I = 3.4$, $\sigma = 0.45$
- envelope detection $\bar{Q}_I = 3.45$, $\sigma = 0.55$
- synchronous detection $\bar{Q}_I = 3.7$, $\sigma = 0.5$

These few results underline the *weak influence of the receiver type and performance on the quality of the TV picture.* The subjective grades obtained with the synchronous detection receiver, being of a more up-to-date technology, were slightly higher. The following values reveal the teletext coverage degree P obtained from the field trials carried out within the mentioned test areas. The percentages P obtained for $Q_I \geq 3$ are:

QS P = 80 %
E P = 80 %
S P = 92 %

The objective tests on the DIDON data signal are summarized in *Figure 16*. It is assumed, that an error rate P_e of *equal to or less than 10^{-4}*, is satisfactory for a future broadcasting teletext service operating between criteria B and C [15, 17, 19].

The following remarks apply to Figure 16:

- At the lowest bit-rate, the characteristics and performances of the receivers play practically no role. *The percentages for satisfactory data reception are between 84.5 and 90.9 %: they are very close to those found for television.* The coverage area for television and data is about the same. Unfortunately, this bit-rate is too low to meet the requirements of the present UK teletext system without an undesirable reduction of the number of characters per row.
- At 6.203 MHz, a certain disparity appears between the receivers. Whereas the results are fairly similar for E and S, a low percentage of successful reception cases is observed for QS. This seems to be due to a misalignment of the IF stages of this receiver.
- At 6.937 MHz, the QS receiver becomes unusable for the reason mentioned above. Similar results can be observed again in the case E and S.

It is important to note, that the *perfomance tolerances of the receivers, sufficient for TV, become in general insufficient when used for teletext reception*, especially at 6.937 Mbit/s. This points needs to be stressed, as it im-

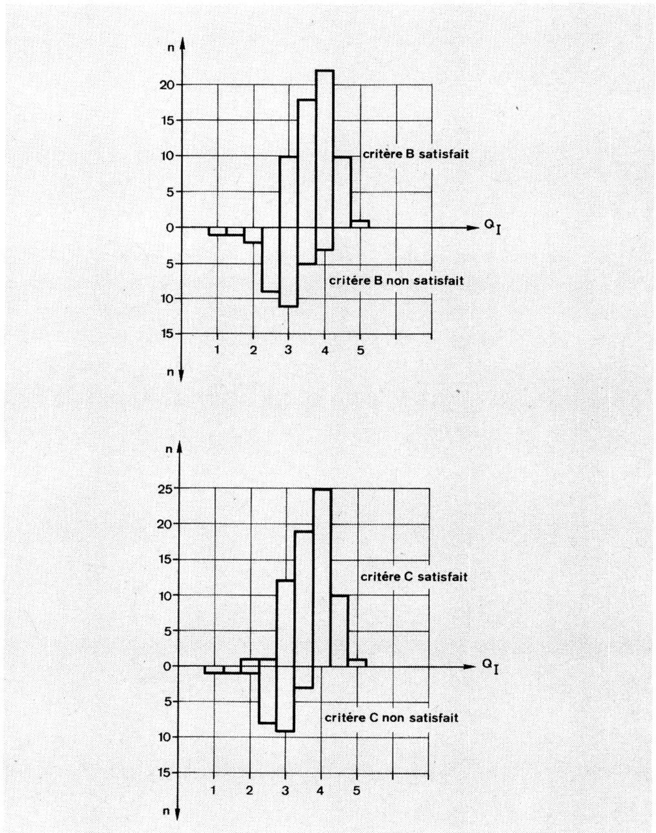

Fig. 14
Distribution of the teletext page quality (criteria Band C) as a function of the TV picture quality
Q_I Quality grade (TV)
Criterion B / Criterion C } See definition in Chapter 8
n Number of samples
Critère B (C) (non) satisfait – Criterion B (C) (not) satisfied

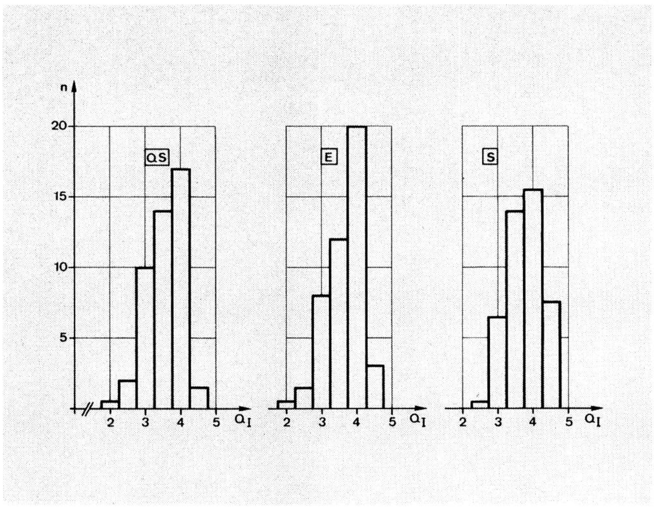

Fig. 15
Histograms of the TV picture quality
Q_I Quality grade (TV)
QS Quasi-synchronous detection receiver
E Envelope detection receiver
S Synchronous detection receiver
n Number of samples

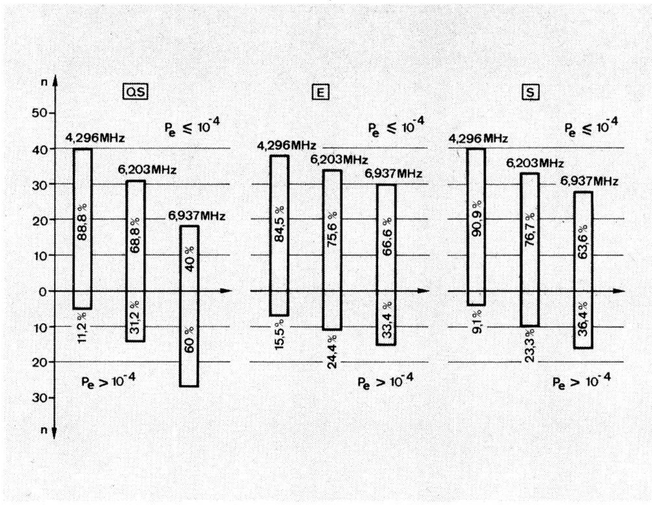

Fig. 16
Distribution of the DIDON data signal samples as a function of the bit-error rate P_e (the frequencies correspond to f_{eb})
P_e Bit-error rate
QS Quasi-synchronous receiver
E Envelope detection receiver
S Synchronous receiver
n Number of samples

poses more stringent requirements on the receiving equipment used for data reception.

In *Figure 17,* the distribution of the favourable (error rate $\leq 10^{-4}$) and unfavourable cases (error rate $\geq 10^{-4}$) has been drawn as a function of the TV picture quality, type of receiver and bit-rate.

Once again it can be seen that the probability of receiving the data signal without error or loss is the higher the lower the bit-rate and the higher the TV picture quality are. The correlation between the overall quality of the television picture and the bite-error rate depends on the equipment and on the bit-rate and lies between -0.4 and -0.7. *Table VII* shows the values obtained. It can be seen that the mean signal-to-noise ratio ($\overline{S/N}$), determined with the relation given in Chapter 8, is slightly reduced for a decreasing bit-rate: only the noise in the channel disturbs the reception of the data (limit of the system). This is confirmed by a study of the CCETT [20] in which some S/N ratios were calculated for different error rates in the presence of noise alone.

The interference sources were again divided into five classes and then distributed as functions of the receivers and bit-frequencies *(Tab. VIII).* Once again it can be seen that the echoes are the primary interference source.

Table VII. Signal-to-noise ratio for a bit-error rate of 10^{-4}

f_{eb} [MHz]	QS		E		S	
	$\overline{S/N} \pm \sigma$ [dB]	n	$\overline{S/N} \pm \sigma$ [dB]	n	$\overline{S/N} \pm \sigma$ [dB]	n
4.296	26.5±3	37	25±2	36	24±3	35
6.203	28±3	29	27.5±2.5	32	25.5±3	32
6.937	28.5±3	18	27.5±3	28	26±3	28

f_{eb} Bit frequency
$\overline{S/N}$ Mean video S/N ratio
σ Standard deviation
n Number of samples
QS Quasi-synchronous detection receiver
E Envelope detection receiver
S Synchronous detection receiver

10 Trials with biphase-coded data signals

UK teletext and the DIDON data broadcasting system make use of the NRZ code. For a given transmission channel, NRZ coding enables the highest bit-rate, thus making optimal use of the available bandwidth. However, due to the structure of the coded signal, the spectral component carrying the clock frequency remains low. At the receiving end, fairly complex devices are required for restoring the data clock. This disadvantage does not exist with the biphase system, each bit of which consists of two complementary binary elements.

Table VIII. Favourable cases for the data broadcasting service as a function of the interference source

Interference source	Number of samples	Criterion $P_e \leq 10^{-4}$ satisfied								
		f_{eb} = 4.296 MHz			f_{eb} = 6.203 MHz			f_{eb} = 6.937 MHz		
		QS	E	S	QS	E	S	QS	E	S
Discrete echo	20	20	18	19	13	17	17	6	13	13
Diffuse echo	9	5	5	7	4	5	5	3	4	4
Noise	12	12	12	12	12	10	11	12	11	11
Moiré	3	2	2	2	2	1	1	1	1	1
Impulsive interference	1	1	1	1	1	1	1	0	1	1

f_{eb} Bit-repetition frequency
QS Quasi-synchronous receiver
E Envelope detection receiver
S Synchronous receiver
P_e Error rate

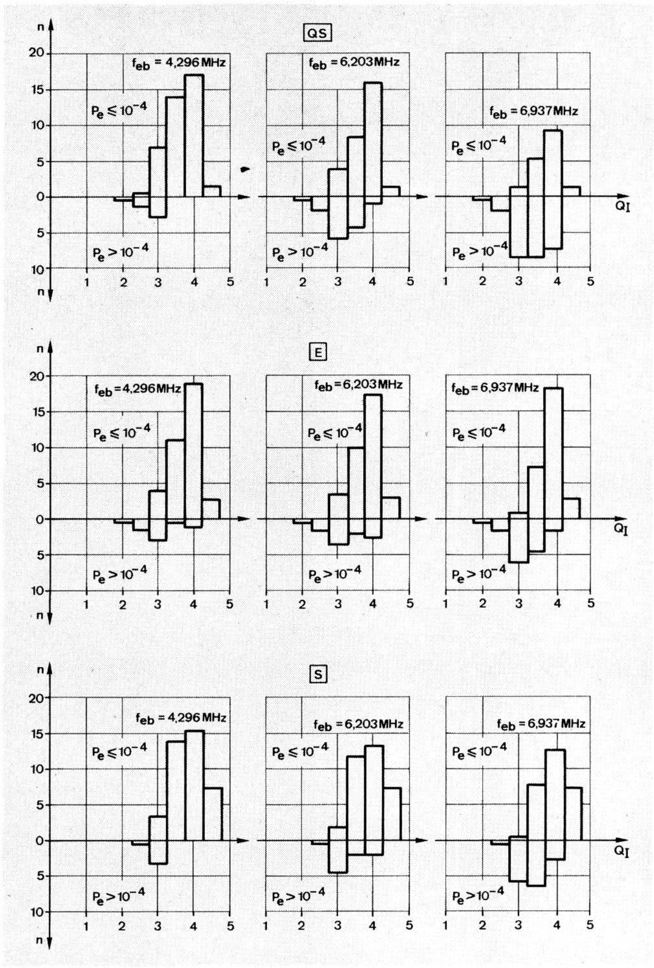

Fig. 17
Distribution of the DIDON data signal samples as a function of the television picture quality
f_{eb} Bit frequency
Q_I Quality grade (TV)
QS Quasi-synchronous receiver
E Envelope detection receiver
S Synchronous receiver
n Number of samples

This biphase signal contains a steady component of the clock frequency which is independent of the transmitted information. However, the *effective bit-rate is only one half compared with NRZ coding.* Moreover, it is easy to detect and, in conjunction with the word parity-check, to correct single transmission errors[1]. Tests were made using this code in Italy [21] and in Switzerland [22] where they were carried out in zones 1, 2 and 5, comprising 47 observations, 26 on teledistribution networks. It emerges from this trial that, in the course of a teletext transmission in NRZ (6.9 Mbit/s) the criterion C could not be met for 3 samples on a transposer chain and for 2 samples on community antenna systems. With biphase coded signals (3.45 Mbit/s), however, teletext reception was no problem. The Italian and Swiss experiences suggest that the biphase system offers some advantages as regards to protection against phase and non-linear distortion [5].

Some aspects peculiar to radio propagation are developed in a document quoted in reference [23] in the case of the Swiss trials.

In the light of the experiments carried out with DIDON, it appears that a signal coded in NRZ and at the bit-rate of about 5 Mbit/s would provide a good compromise regarding system capacity and security of data reception. A biphase coded system with an effective bit-rate of 3.5 Mbit/s does not seem to have a great advantage over a NRZ-system at the same bit-rate [5]. However, biphase coding could be considered for special critical situations (e. g. strong phase degradation) where NRZ coded signals are excessively degraded.

11 Comments

It is a consequence of the properties of the radio broadcasting network that every signal transmitted is degraded in the course of transmission and that the receiver obtains a deformed signal, instead of the emitted signal [20]. The TV signal and the data signal are thus disturbed by linear and non-linear distortion from the studio to the TV receiver. The degradation of the quality of the digital paths can occur at different levels of the transmission chain, namely

- at the transmitting end
- during propagation
- at the receiving end

111 Transmitting end

The transmitting equipment degrades the quality of the digital signals due to its peculiar modulation characteristics [24]. This degradation can be expressed as the decrease in the eye-opening or eye-height[2]. An eye-height of 68 to 75 % was measured at the transmitter output using a bit-rate of 6.9 Mbit/s and a synchronous receiver. The eye-height increases with a reduced bit-rate.

A study carried out by the BBC [25] has shown that the eye-opening is a priori reduced by about 6 % on transmission of the UK teletext signal, intended for television system I, via a B/G system.

The transposer network also adds degradation to the signal. We are referring here to the degradations caused by the intrinsic properties of the transposer. However it seems, and this will be seen further on, that the signal received, then processed and retransmitted, is more likely to be disturbed by the propagation conditions than by the transposer itself.

In addition, the problem of antenna matching has to be considered. It is often the cause for short echoes interfering with the data signal.

112 Propagation

The problem of propagation, both important and complex, is often underestimated in radio broadcasting [23, 26].

The main sources of degradation likely to impair the quality of the broadcast signal are

- noise
- impulsive interference
- echo phenomena by multipath propagation

[1] RAI-patent

[2] This eye-height or eye-opening measurement is based on a statistical measurement of the frequencies of passage through level 1 and level 0 at a given heighth [12].

The trouble caused by these sources of interference is only experienced at the reception level. Taking into consideration the fact that the reception equipment also introduces distortions, it is sometimes difficult to categorize the causes as the effects observed are often very similar.

Man-made noise (vehicles, electric household appliances, etc.) are very troublesome. They can have disturbing effects at the level of the prefix (losses of packets or rows) and of the data packet (errors or losses of characters) [5].

The distortions due to the peculiar topography of Switzerland and to the concept of the networks of transmitter and transposer stations can be critical in data broadcasting. The particular position of the transmission and reception sites, the short distance between these points and the presence of neighbouring obstacles are the elements which favour the phenomena of multi-path propagation. The receiving antenna then receives a direct and one or more reflected signals, the delays of which may be brief. The resulting deformations of the video spectrum depend on the height of the transmitting and receiving antennas, on their proximity and on the zones of reflection. The characteristics of the latter undergo seasonal changes and depend on the weather conditions, particularly at UHF which means that, for fixed antenna heights, the deformation of the spectrum will not remain stable in time. On-site tests have shown that the optimum qualities of the TV and teletext services are not obtained with identical antenna heights. Providing a coverage area with a teletext service of constant quality thus seems to be a compromise under these conditions.

113 Receiving end

The receiving equipment can be defined on the basis of two functional blocks

- RF-IF-demodulation (integral part of a domestic TV receiver)
- processing and display of the digital data [5]

The receiver brings, besides background noise, amplitude, phase, composition and quadrature distortion [20]. These distortions are connected with the television modulation characteristics requiring asymmetrical filters. Some of these defects can be more or less neutralized. Quadrature distortion, occurring mainly in envelope detection receivers, cannot be compensated. It is avoidable by using synchronous detection. It is important to remember that the RF-IF-demodulation part of the receiver is primarily designed for television and not for data-reception. The data extraction circuit can thus also play a significant role in the degradation of the digital signal quality. The performances of this device can be analysed by means of the eye-opening, which characterizes the digital signals before decoding, and the error rate, which specifies the data signal quality after decoding.

The overall degradation caused by the whole transmission chain is evaluated by means of the various measurement methods mentioned in Chapter 8 and the results are represented in Chapter 9. It is proposed, in what follows, to mention various items of information gathered in the field:

- the inspection of TV line 17, in particular the 2T and 20T pulses, is interesting for trying to characterize the nature of the distortion. The presence of echoes at the receiving end, due to the particular topography of a service area, can be demonstrated by altering the height of the receiving antenna: the amplitudes of pulses 2T and 20T then vary within large proportions [23]
- short reflections (delay less than 1 microsecond), created by the transmission and reception conditions inherent to Switzerland, degrade the quality of the digital signals, but have, in general, little effect on the TV service. The opposite seems to be true for delays longer than 1 microsecond
- the influence of the phase and of the echo delay on the quality of the digital transmission seems to depend on the bit-rate and on the receivers in use [19, 27]
- attenuation of higher video frequencies only slightly affects the reception of the TV signal due to the presence of an automatic chrominance gain control. However, its influence on the data signal may be serious
- the quality of the TV picture is proportional to the video S/N ratio. In data transmission, there is a rapid transition from a usable to a non-usable state
- it is apparent from Tables V, VI and VIII that noise alone only appears rarely (20 to 30 % of the cases). Conversely, the echoes are the most frequently encountered sources of interference (64 to 75 % of the cases)
- the quality of the sound channel was not evaluated
- the tuning of the television receiver is an important parameter which has an immense effect on the degradation of the digital signal. Without automatic frequency control, a TV set seems not usable because of the local oscillator drift and of inaccurate tuning by the user. The result may be, depending on the direction of the mistuning, an accentuation of the high or low frequencies of the spectrum which interferes with both television and data reception. All the receivers used in the trials, without exception, were equipped with an automatic frequency control
- the antenna should be carefully matched to the receiver (source of echoes)
- the tests were carried out on the bands III, IV and V, and partly on band I. Thus, the effects of the different picture carrier frequencies on propagation and on the receiver performance were broadly taken into account
- during the measurements with the UK teletext system, the acquisition time for a page was relatively high (of the order of 24 s). A modification of the page generator (reduction of the number of pages) and the introduction of a new assessment criterion (error threshold) accelerated the field trials considerably [28]. Unfortunately, no standardized criteria for the evaluation of a teletext service quality exist as yet
- transmission via a community antenna system does not, in principle, pose problems, provided that the installation complies with certain quality requirements and the signal received at the station is not already degraded
- the subjective evaluation of the television picture qua-

lity by means of the Post Office test pattern results in a more severe judgment of the service quality than with live programs. The percentages indicated for $Q_I \geq 3$ are to be considered as minimum values because, in practice, the picture contents are generally less critical

12 Conclusions

The experiments carried out with data signals in a TV channel (CCIR-B/G System) highlight the importance of the equipment, the influence of the bit-rate in use and the propagation effects.

A certain degradation of the digital signal is already observed at the level of the transmitting equipment. The RF-IF-demodulation part of the receiver also contributes to the digital signal distortions, although its performances have less effect on the quality of the TV picture.

Echo is one of the main causes of the data signal degradation. Its characterization and the search for its origin pose certain problems. Echoes may be caused by multipath propagation, by poor antenna matching or by distortions introduced by the transmitter, transposer or receiver. This type of interference affects the quality of the TV and data broadcasting services in a very different way.

Short echoes tend to interfere with the data signal but have little effect on the television signal. Noise acts as an aggravating factor.

Table IX shows all the principal results from the trials. These results have to be considered in specific contexts: available equipment, measuring areas, objective and subjective methods of quality assessment.

The service quality of the received data only partially coincides with that of ordinary television. The probability of a digital transmission being without error or loss is higher the lower the bit-rate and the higher the quality of the TV picture are. This observation applies in a special way to the results of the last trial.

The foregoing considerations suggest that the choice of a NRZ code and of a bit repetition frequency around 5 MHz would provide a good compromise between transmission speed and robustness in the case of a data broadcast system in Switzerland.

The teletext or generally data broadcasting systems are comparatively new systems. This being so, they are open to improvement and it would be possible, by successive improvements, to increase the reception quality (tolerances of the transmitting equipment, matching of antennas, coding standard, bit-rate, higher-duty decoder, etc.). The foreseeable developments of the RF-IF-demodulation part of receivers will most likely not only improve data reception but also, to a certain extent, the reception of television pictures.

Some more recent knowledge

Further laboratory and field trials [29, 30] were carried out during 1979. The main purpose of these trials was to compare the performances of UK teletext and French Antiope, especially with respect to the different decoders used for these systems. The same transmitter site, measuring areas and transposer chains as described in the present report were used for these further trials. The data signals used for UK teletext and DIDON/Antiope were simultaneously transmitted in the field blanking interval. The same professional receivers (synchronous, quasi-synchronous, envelope detection) were used and the identical video signal was simultaneously fed into the UK teletext- and DIDON-decoder. The methods used for clock recovery and for determining the slicing level were different for these decoders: in the case of UK teletext, the data clock was recovered by means of a resonant circuit and the threshold was determined with peak amplitude detectors, thus making use of all the bytes within the data blocks. The DIDON-decoder employed a digitally phased quartz oscillator for clock recovery and a filter with a sample and hold circuit for the threshold determination. Both the data clock and the threshold were fixed during the run-in sequence of the

Table IX. Percentages of the favourable cases for the TV and teletext or data broadcasting services

Number of the trial	Number of sites	Number of samples	Type of receiver	Number of samples with television picture quality $Q_I \geqslant 3$ [%]	% of cases for which the following criteria are met						Remarks
					Teletext page			DIDON (pseudo-random) $P_e < 10^{-4}$			
					$Q_T \geqslant 3$	B	C	f_{eb} = 4.296 MHz	f_{eb} = 6.203 MHz	f_{eb} = 6.937 MHz	
1 (May 1977)	13	40	domestic	92	53	—	—	—	—	—	First trial
2 (August–September 1977)	13	40	domestic	92	75	—	—	—	—	—	Decoder with better performance than the one used in the first trial
	33	92	domestic	86	—	65	75	—	—	—	
3 (Mid-April to May 1978)	16	45	Quasi-synchronous	80	—	—	—	89	69	40	$P_e \leqslant 10^{-4}$ (between criteria B and C)
			Envelope	80	—	—	—	85	76	67	
			Synchronous	92	—	—	—	91	77	64	

the data prefix and were not influenced by the remaining bytes of the data block.

The following results were found from the additional laboratory and field trials:

- in the presence of noise, the performance of both UK teletext and DIDON/Antiope, operating at the same transmission speed, was very similar. Criterion C (no remaining errors or blanks after one repetition of the teletext page) was met at an error rate between 1×10^{-3} and 3×10^{-3}
- in the case of Antiope, control characters affecting the display format seemed to be sufficiently protected. Format distortion due to control character errors was never noticed during the trials
- the performance of the two decoders was considerably different in the presence of echoes. It was noticed that the optimal sampling instants of the data signal, determined during the run-in signal, and during the active portion of the data block, can be offset by echoes (especially by preceding negative echoes). In such cases the resonant circuit decoder used for UK teletext revealed an adaptive behaviour leading to a performance superior to the DIDON decoder
- bit errors obtained with the resonant circuit decoder were generally less numerous, but more dependent on certain bit patterns than with the DIDON decoder. This led to fixed errors on the display screen which were often not corrected by subsequent repetitions of the same teletext page
- nonlinear distortion, which occurred frequently in the presence of negative echoes, especially with the envelope detection receiver, can lead to asymmetrical overshoots of the data signal. Under such circumstances the DIDON decoder was found to be superior to the UK teletext decoder
- it was found that the quality of the data signal was strongly influenced by receiver imperfections (misalignment, mistuning, etc.) if higher transmission speeds (6.9 and 6.2 Mbit/s) were used. This influence became negligible at the reduced bit-rate of 4.3 Mbit/s. The strong influence of the receiver on the occurrence of transmission errors was observed when professional equipment was used. It can be assumed that this influence will be even more pronounced when television receivers with teletext are in domestic use

Therefore, from our experience, it must be concluded that the use of bit-rates above 6 Mbit/s will be critical with our reception conditions. On the other hand, a reduced bit-rate implies fewer pages per magazine or the use of additional lines of the field blanking interval. Once again, it seems that a *bit-rate around 5 Mbit/s* could be a good compromise between a reasonable capacity of the teletext system and an adequate security against transmission impairments.

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