Communications Research Centre

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by
Bernard Caron

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DIGITAL TRANSMISSION OVER VIDEO CHANNELS: TELETEXT FIELD MEASUREMENTS

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ABSTRACT

This document presents results from field measurements made to evaluate the performance of digital transmission over television channels (teletext) and to identify possible means of improvement.

The document begins with a review of television and teletext signal parameters and test signals used in measuring system performance.

The results of the measurements, performed across Canada, are used to indicate the teletext reception conditions for different situations. Over-the-air teletext reception is estimated to be very good (BER=10^{-5}) for 90% of the sites in urban areas, but for only 50% of the sites in hilly regions. In plains, reception is very good up to 80 km from a typical transmitter. On cable networks, very good teletext reception could always be obtained if some precautions were taken.

Different factors and parameters affecting teletext performance are also studied. Image grade and eye diagrams are shown to give indications about the teletext service quality to be expected. VHF and UHF transmission of the teletext signal offered similar performances. Small bidirectional antennas are a poor choice for teletext reception. Quasi-synchronous demodulators result in performances close to those obtained with synchronous models. The study of teletext error statistics shows that a code correcting 2 single errors per line would be sufficient for the majority of cases.

Possible improvements are suggested. Adjustments of the equipment, based on video test signals, improved the teletext signal. The teletext decoder used in the tests can be improved by making its clock recovery circuit adaptive and by increasing its precapture capabilities.

Finally two ways are proposed to estimate the bit error rate.

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DIGITAL TRANSMISSION OVER VIDEO CHANNELS: TELETEXT FIELD MEASUREMENTS

1.0 INTRODUCTION

In recent years there has been an increased interest in the use of broadcast television channels to carry digital information services. One such service is the teletext system, whereby textual and graphical information is transmitted onto otherwise unused portions of a television signal, typically during the Vertical Blanking Interval (VBI).

A good knowledge of the analog characteristics of the television channels is thus needed to support the design and development of such digital information systems.

To this end, the Communications Research Centre (CRC) of the Department of Communications started, in 1983, a series of field measurements on the performance of the Canadian teletext system. The goals of these field measurements were to characterize the performance of teletext transmission and to identify possible means of improvement.

This document first presents a short review of television and teletext system parameters. Then the measurement procedure and the equipment used to perform these measurements are described. The results obtained are presented and analyzed for the different situations found under normal operation of television systems. No attempt was made to improve the teletext performance by modifying or adjusting television transmission equipment. However, suggestions are given for possible improvements to the teletext and television systems.

2.0 CHARACTERISTICS OF THE TELEVISION AND TELETEXT SIGNALS

The basic characteristics of the television and teletext signals are presented in this section along with the test signals used.

2.1 Television Signal Parameters

Table 2.1 presents the relevant parameters from the National Television Standard Committee (NTSC) system M standard which is used for television transmission in Canada.

TABLE 2.1: Basic Television Parameters.

VHF band I.................	54-88 MHz (Channel 2-6)
band III...............	174-216 MHz (Channel 7-13)
UHF........................	470-890 MHz (Channel 14-83)
Channel Bandwidth..........	6 MHz
Number of Lines............	525
Field-repetition Frequency.	59.94 Hz
Line Frequency.............	15,734 Hz
Video Bandwidth............	4.2 MHz
Line Duration..............	63.5 microseconds
Active Line Duration.......	53.3 microseconds
Number of Picture Elements Per Line...................	426
Picture Element Duration (T)	125 nanoseconds
Color Subcarrier Frequency.	3,579,545 Hz
Video Signal Amplitude.....	-0.286 volt to +.714 volt (-40 IRE to +100 IRE) (synch tip to white)

The 525-line image is composed of two interlaced fields. Each field started with the Vertical Blanking Interval (VBI) containing 21 lines. The first 10 lines are used for vertical synchronization. The next 11 lines were left blank in the early days of television to give the first receivers enough time to bring their beam from the bottom to the top of the screen at the end of each field. Because modern receivers can do this operation faster, those 11 lines are free today. They can be used to transmit vertical interval test signal (VITS) or teletext signal.

2.2 Teletext Signal Parameters

The Canadian teletext signal characteristics are described in the North American Broadcast Teletext Specification (NABTS) [1]. This is a two-level non-return-to-zero signal with a data rate equal to 8/5 of the color subcarrier frequency (5.727272 Mb/second). The pulse shape should produce a spectrum such as a Raised Cosine with a 55% to 100% roll-off. It is limited by a phase-corrected 4.2 MHz low-pass filter. The nominal data amplitude should be 70 ± 2 IRE units and 0 ± 2 IRE units for a logical "1" and "0" respectively, and maximum allowed amplitude of the overshoots is 8 IRE.

This signal is inserted in the active portion of one of the video lines from the VBI, then transmitted in the conventional way. The teletext signal begins 10.48 ± 0.34 microseconds after the mid-amplitude point of the leading edge of the horizontal synchronization pulse. The data format, which is depicted in Figure 2.1, starts with 16 bits of alternating 0s and 1s used for clock synchronization. The next 8 bits form a framing code for byte synchronization. This is followed by a 5-byte address identification prefix. The next 27 bytes form the data block. The last byte is used for error detection and correction. It is also possible to increase the number of error correction bytes to 2.

When 1 parity byte is used for error protection, each video line provides an effective data rate of 6,480 bits/second for each field (12,760 bits/second for each frame). Normally from 3 to 4 lines of the vertical blanking interval (VBI) on each field will be used for teletext signal transmission. This translates into effective data rates of 38,880 bits/sec. and 51,840 bits/sec. respectively. It is also possible to use a full TV channel to transmit teletext. In this case the effective data rate is 3.4 megabits/sec.

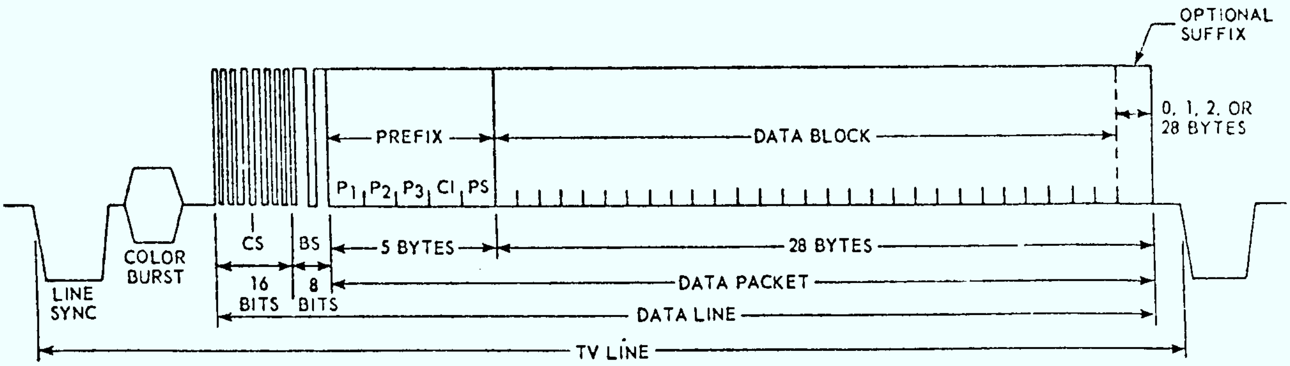


FIGURE 2.1: The Teletext Line.

The teletext signal will be sensible to the frequency response of the equipment used to transmit the video signal and to the interference present on the television channel. For example, short echoes and group delay inequalities affect the teletext signal even if their effect is often not noticeable on the television image.

Echoes of one of the symbols will be superimposed on part of the following symbol, thus causing distortions of the teletext signal. Group delay inequalities will distort some symbols whose sign could then be wrongly identified. A description of the teletext decoder functioning will explain how.

In the decoder, the slicer level is established and the phase of the bit clock is recuperated. Both operations are executed at the beginning of each line using the clock run-in sequence as a reference.

To establish the slicer level, the clock run-in sequence passes through a low-pass filter (270 khz) whose response is stable after approximately 12 bits. This voltage value is then frozen and used as the slicer level for the rest of the line. If high frequency response of the television channel is bad or if there are echoes, the teletext signal may be distorted, thus causing the slicer level to establish incorrectly for some of the symbols in the line.

The bit clock phase is established by adjusting the internal clock oscillator in phase with the run-in sequence. If group delay inequalities are present they will change the phase relationship between the clock run-in sequence and some of the symbols. The sampling moment will not be at the center of these symbols, thus increasing the probability of errors.

These two degradations will be particularly important because they happen when the signal received is distorted and would be difficult to decode correctly even if a perfect slicer level and a correct bit clock phase were available.

2.3 Test Signals

To measure the degradation affecting the television and the teletext signals, different test signals were inserted on some lines of the VBI. Two regular video VITS, the composite and the multiburst test signals, were used to evaluate the analog characteristics of the channel.

The 2T Sine Squared Pulse and the bar, included in the composite test signal, can be used to estimate the frequency response of the channel. The pulse-to-bar ratio is the value obtained by dividing the peak amplitude of the pulse by the mid-point amplitude of the bar. The 2T pulse can also be used to measure the echo rating using a mask described by Goody [2]. The asymmetry of the pulse is an indication of phase distortion. The width of the pulse at mid-amplitude (50 IRE) is an indication of non-linear distortion when it is not equal to 250 nsec. The 12.5 T modulated Sine Squared Pulse and the staircase, also part of the composite test signal, can be used to measure the Chrominance-to-Luminance gain and delay, and nonlinear distortion respectively.

The multiburst test signal consists of 6 frequency bursts, at 0.5, 1.25, 2, 3, 3.58 and 4.1 MHz. Their amplitudes are between 10 and 70 IRE for the 50% amplitude version of this signal and between 0 and 100 IRE for the full amplitude version. This signal helps to estimate the amplitude response of the channel at each frequency.

In order to characterize the performance of teletext transmission, teletext test signals were also inserted in the VBI. These signals had a 100% raise cosine pulse shape and were bandlimited to 4.2 MHz. The first line was a teletext sequence in which all the bits in the data block were equal to zero except for one bit. This pulse was useful in isolating shorter echoes and gives a good idea of the shape of the channel impulse response.

The second teletext test signal was a fixed pseudo-random sequence which was repeated on each field. It was useful if a quick estimation of the quality of the received signal was required. The digitization of this sequence was used to make a computer-generated eye diagram and to calculate the channel impulse response.

The third signal was formed by a 65,535 bit pseudo-random sequence which was transmitted in a continuous cycle of 273 lines, with each line containing a packet of 240 bits. This sequence was generated by the polynomial:

$$C(X) = X^{16}+X^{14}+X^{5}+X+1$$

It was used to calculate the various error statistics of teletext transmissions which are described later.

The video and the teletext signals were inserted on selected VBI lines of a regular TV program, using a video test generator with an external input for Vertical Interval Test Signals (VITS). This input was fed by a teletext signal generator which was synchronized with the composite synchronization signal from the test generator. This set-up is illustrated in Fig. 2.2.

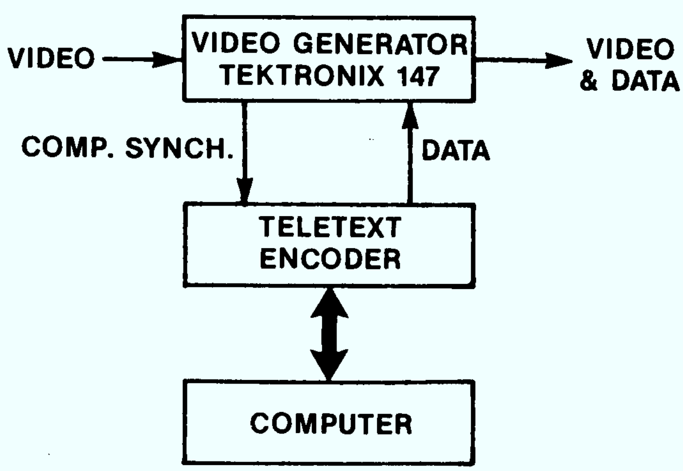


FIGURE 2.2: Teletext Signal Insertion on a Video Program.

The teletext signal generator used was developed at CRC. It is composed of a video interface and a microcomputer. Data were generated by the computer and then transferred to the memory buffer of the video interface. This buffer sent the teletext signal to the video test generator during each appropriate line.

The photograph of Figure 2.3 illustrates a portion of the VBI of the video signal obtained at the output of the video test generator. The four lines shown there contain the short teletext test sequence, the long teletext test sequence, the composite video test signal and the multiburst video test signal.

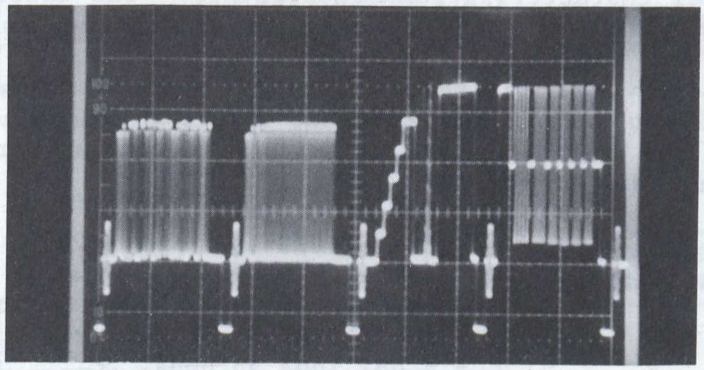


FIGURE 2.3: Portion of the VBI: Short Teletext Test, Long Teletext Test, Composite Video Test and Multiburst Video Test Signals.

The measurements performed using the different test signals just described, are discussed next.

3.0 DESCRIPTION OF MEASUREMENTS

3.1 Review of the Parameters

The measurements performed can be divided in three categories: the analog video measurements, the teletext measurements and the channel characterization measurements. The latter ones were based on a digitization of the teletext short sequence test signal.

At each site visited, a complete set of measurements was performed at least once. More than one set of measurements were done when one of the following pieces of equipment or parameters was changed to study its effect:

-- Types of Antenna:
  - a VHF-UHF Jerrold V-283-X directional antenna with a 7 dB gain. (An antenna booster was used for some tests.)
  - a VHF rabbit-ear antenna.
  - a UHF loop antenna.

  These were mounted on a mast 10 meters high.

-- Type of Demodulator:
  - a Tektronix 1450 synchronous demodulator. This is a professional demodulator with an in-phase (I) and a quadrature (Q) output.
  - a Rhodes and Schwartz (R&S) EKF2 demodulator used in its synchronous mode.
  - a Sony VTX-1000R quasi-synchronous demodulator representative of new high- quality consumer products.
  - a Zenith quasi-synchronous demodulator which was included in one of the models of a teletext decoder.

-- Television Channels:
  - television channels in the UHF and VHF bands and cable channels were measured.

-- Teletext Decoders:
  - a Norpak Mark IV teletext decoder.
  - a Norpak Mark V teletext decoder.

This equipment was installed in a mobile van which has its own electrical power sources. Fig. 3.1 shows the block diagram of the measurement system and a photograph of the van interior. This vehicle was used to perform the measurements described next.

3.2 Analog Measurements

The analog measurements performed were similar to those made when monitoring normal television reception.

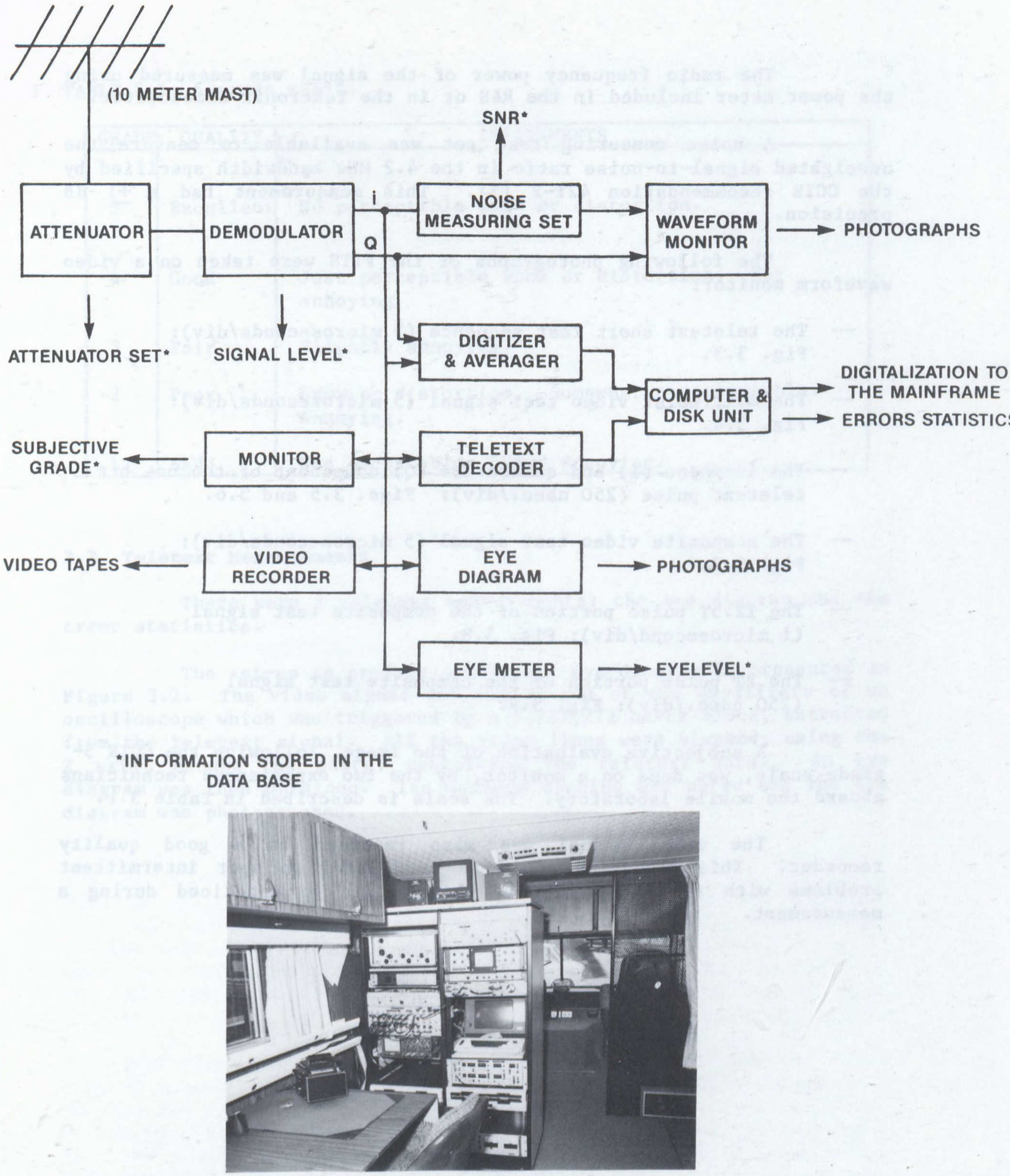


FIGURE 3.1: Block Diagram and Photograph of the Receiving and Measurement Equipment Installed in the Mobile Van.

The radio frequency power of the signal was measured using the power meter included in the R&S or in the Tektronix demodulator.

A noise measuring test set was available to measure the unweighted signal-to-noise ratio in the 4.2 MHz bandwidth specified by the CCIR recommendation 421-2 [3]. This measurement had a ± 1 dB precision.

The following photographs of the VITS were taken on a video waveform monitor:

-- The teletext short test sequence (5 microseconds/div): Fig. 3.3.

-- The multiburst video test signal (5 microseconds/div): Fig. 3.4.

-- The in-phase (I) and quadrature (Q) component of the one bit teletext pulse (250 nsec./div): Figs. 3.5 and 3.6.

-- The composite video test signal (5 microseconds/div): Fig. 3.7.

-- The 12.5T pulse portion of the composite test signal (1 microsecond/div): Fig. 3.8.

-- The 2T pulse portion of the composite test signal (250 nsec./div): Fig. 3.9.

A subjective evaluation of the image, following the CCIR 5-grade scale, was done on a monitor, by the two experienced technicians aboard the mobile laboratory. The scale is described in Table 3.1.

The video signal was also recorded on a good quality recorder. This recording could be used later to spot intermittent problems with the video signal, which could go unnoticed during a measurement.

TABLE 3.1: 5-grade Scale.

GRADE	QUALITY	IMPAIRMENTS
5	Excellent	No perceptible snow or distortion.
4	Good	Just perceptible snow or distortion. Not annoying.
3	Fair	Slightly annoying.
2	Poor	Snow or distortion. Somewhat objectionable. Annoying.
1	Bad	Non acceptable. Very annoying.

3.3 Teletext Measurements

There were 2 teletext measurements: the eye diagram and the error statistics.

The set-up to produce a teletext eye diagram is presented in Figure 3.2. The video signal was fed to one of the amplifiers of an oscilloscope which was triggered by a 5,727,272 hertz clock, extracted from the teletext signal. All the video lines were blanked, using the Z axis, except the one(s) containing the teletext data. An eye diagram was then obtained. Its maximum opening was noted and the eye diagram was photographed.

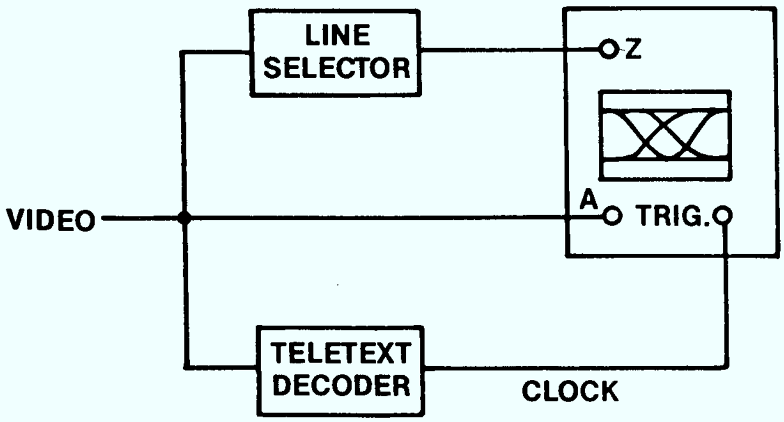


FIGURE 3.2: Teletext Eye Diagram Set-up.

The measurement of the height of the eye diagram was also made with an eye meter developed at CRC [4] and based on an analog-to-digital converter. The data produced was processed in real-time by a microcomputer which calculates the average of the minimum eye height over 120 teletext lines. This device could also measure the bit error rate, the line loss rate, the worst case eye height, the peak-to-peak signal level, the average 1 and 0 signal levels and the slicing level. During the tests, these values were calculated from the digitized version of the short teletext sequence or the error distribution of the long sequence, as will be explained.

The error statistics were calculated by a computer. The computer program first compared the decoded teletext sequence with a copy of the original sequence. The distribution of the errors was then printed and stored on a floppy disk. Each test lasted until about 100 errors occurred. When the number of errors was very low the test was stopped after 20 minutes. When it was very high, the test was stopped when more than 1000 errors were detected. Normally between 10,000 and 40,000 packets would be received, i.e., between 2.4 million and 9.6 million bits. This is sufficient data to ensure, with a confidence level between 90% and 99%, that the measured value was within 20% of the real value.

The distribution of errors was used to calculate the following statistics:

-- The bit error rate (BER): which is the ratio between the number of bits in error and the number of bits in all the detected packets (or teletext lines). It is shown in [5] that a bit error rate of $5x10^{-5}$ or less ensures the teletext user a satisfactory service, as the incidence of retransmission requests and of adverse ratings become relatively small. Based on practical considerations, a very good teletext reception was defined to be one with a bit error rate less than $1x10^{-5}$. Teletext reception problems will begin when the BER is greater than 10^{-4}. An essentially perfect reception will be assured when the bit error rate is less than 10^{-6}.

-- The packet error rate: which is the ratio of the number of packets containing one or more errors to the number of packets detected.

-- The packet loss rate: which is the ratio between the number of undetected packets and the number of packets transmitted. A packet is undetected when the byte synchronization word or one of its address 3 bytes contains more than one error.

-- The percentages of packets with 1, 2, 3, 4 or 5 and more bits in error.

-- The percentages of packets with 1, 2, 3, 4 or 5 and more consecutive bits in error.

-- The average number of packets between errors.

-- The average number of bytes in error per packet in error.

These statistics were not calculated when teletext reception was impossible. A synchronization loss was then recorded and the site was classified as a No Reception case. This means that the decoder had not detected the byte synchronization because it contained more than 1 bit in error.

3.4 Channel Characterization

The television channels were characterized by measurement of the channel complex impulse response, from which the amplitude and phase (group delay) response of the channel were derived. This was accomplished by using a digitalization of the short fixed pseudo-random teletext sequence, done at a frequency equal to 2 times the bit rate (2 x 5.72 MHz) with an 8 bit analog to digital converter.

To reduce the effect of noise, sample averaging was taken over 2048 such sequences. The SNR is thus improved by 10 log 2048 = 33 dB. The averaged samples were then stored on a floppy disk.

When the Tektronix demodulator was used, the quadrature (Q) component of the short sequence was also sampled, averaged and stored.

The analysis of the measured sequence was done back at the CRC laboratory. The stored data was first transferred to a mainframe computer and then a program, developed at the CRC, calculated and plotted the following items:

-- The average of the short teletext test sequence: Fig. 3.14.

-- The eye diagram obtained from the short sequence and its different characteristics (Fig. 3.14), specifically:
    - Maximum level
    - Minimum level
    - Average zeros level
    - Average ones level
    - Slicing level
    - Maximum eye height value
    - Time when the eye is at its maximum
    - Eye height at the sampling time
    - Maximum eye width and the level at which it occurs
    - Eye width at slicer level.

-- The real impulse response of the overall teletext channel which includes the transmitter, the television channel and the receiver: Fig. 3.15.

-- The quadrature impulse response of the teletext channel: Fig. 3.16.

-- The envelope of the impulse response: Fig. 3.16.

-- The frequency response of the teletext channel: Fig. 3.15.

-- The group delay of the teletext channel: Fig. 3.15.

The estimates of the channel response were based on a least-squares analysis technique as described in [6].

3.5 Example of Measurements at a Site

The following pages present an example of all the different information gathered during one group of measurements: the different photographs, the parameters for this sequence of measurements, the error distribution printout, the calculated error statistics, the parameters for I and Q components of the digitized received waveform, a reconstruction of the short test sequence, an eye diagram and its characteristics, and the estimates of the channel parameters are all included. The way some of this information was stored in a microcomputer database, for some sites in the same region, is shown in Fig. 3.17.

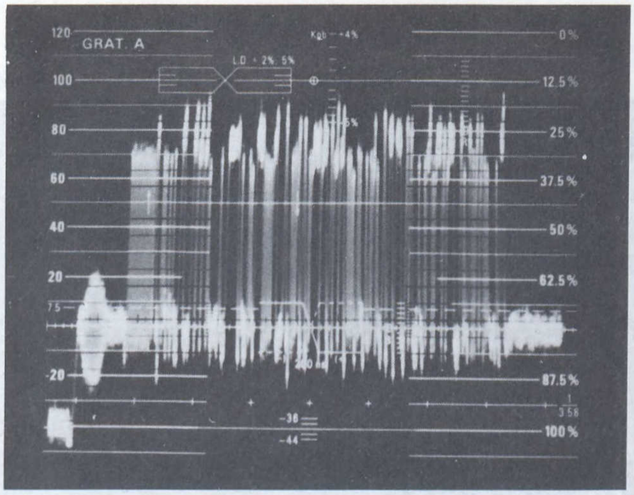


FIGURE 3.3: The Teletext Short Test Sequence.

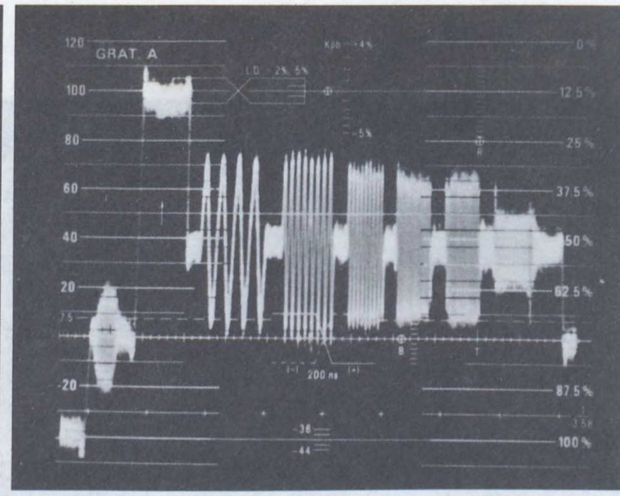


FIGURE 3.4: The Multiburst Video Test Signal.

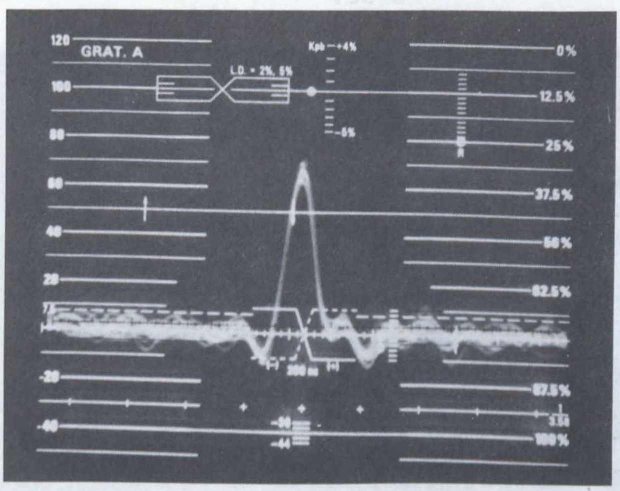


FIGURE 3.5: The In-Phase (I) Component of the 1 Bit Teletext Pulse.

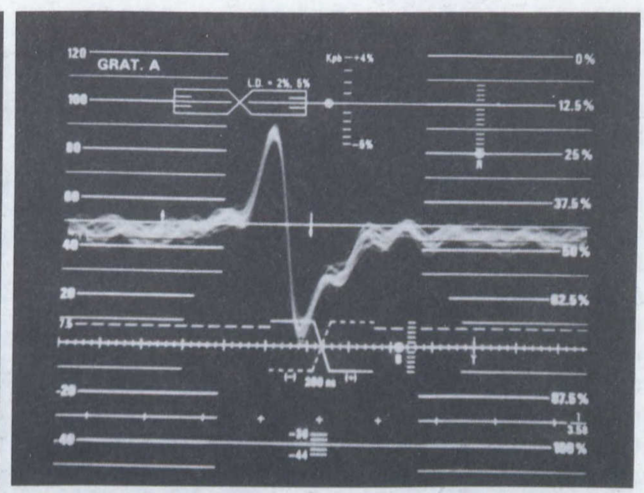


FIGURE 3.6: The Quadrature (Q) Component of the 1 Bit Teletext Pulse.

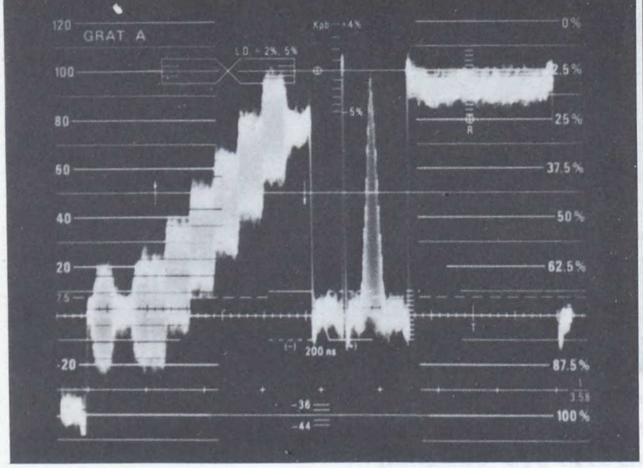


FIGURE 3.7: The Composite Video Test Signal.

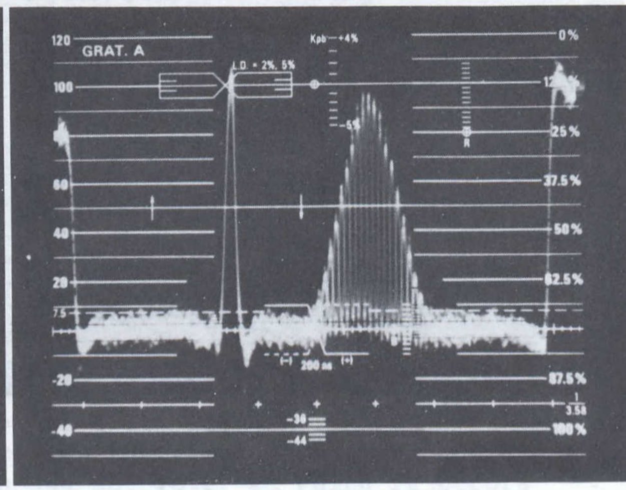


FIGURE 3.8: An Expanded View of the Composite Test Signal: The 12.5T Sine Squared Pulse.

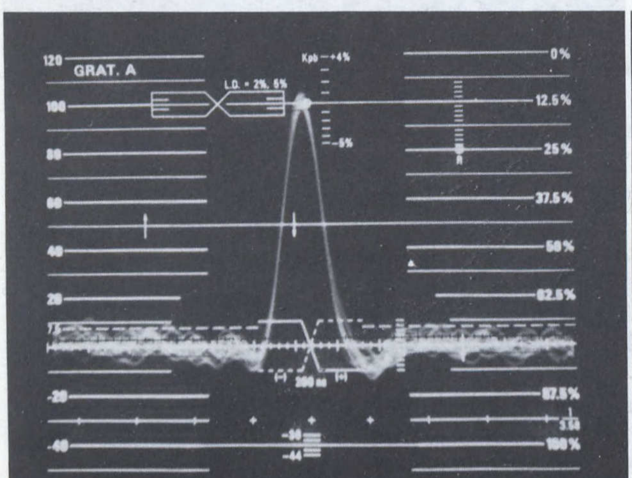


FIGURE 3.9: An Expanded View of the Composite Test Signal: The 2T Sine Squared Pulse.

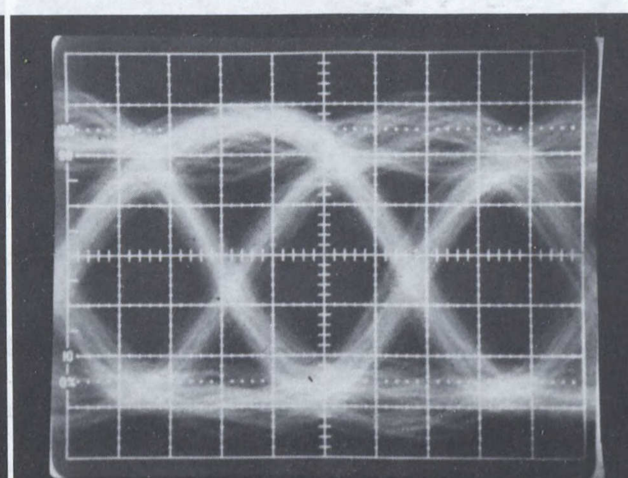


FIGURE 3.10: The Eye Diagram of the Teletext Signal.

```
                    R TELIDON Version 6.0
                    04 FEB 86   19:07:36

ENTER FILE NAME  >SA0454.211
CREATING FILE DK  :SA0454.211

*/SA0454

-- Enter ? to get the menu --

>WWSTART

-- Enter  :? for help on comment commands --
-- Enter   ? for help on  edit   commands --

COMMENTS? *:3
COMMENTS? *OFF AIR;LINE 16 LING;MK V DECODER TEST A/N 87778;
COMMENTS? *TEK DEMOD.1450-1/TDC-1 VHF A/N 24850/851;
COMMENTS? *ANT.JERROLD J-283 X;FRAME WINDOW 2.OuS;
COMMENTS? *SITE;DISTANCE;CHANNEL;ATTENUATOR;RF LEVEL;
COMMENTS? *SNR;EYE;PICTURE GRADE;VCR TAPE NUMBER / MARK(MM:SS);
COMMENTS? *WILLIAMSBURG,FIRE STATION,77KM.SOUTHCH40,+BOOSTER,2DB,-40.ODBM
COMMENTS? *32DB,55%,3.0,10/35:44
COMMENTS? *

 SYNC
> 00000    00001    00000    00000    00000    00000   -00001    00000
> 00000    00000    00000    00000    00000    00000    00000    00001
> 00001    00000    00001    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00001    00000    00001    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00001
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00001
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000    00000    00000    00000    00000    00000    00000
> 00000    00000  S 00000  TO 00000  P 00000    00000    00000    00000
>
TOTAL MISSED FRAMES = 0000000011
TOTAL BIT ERRORS    = 0000000015
TOTAL BITS RECVD.   = 0004643520
>
```

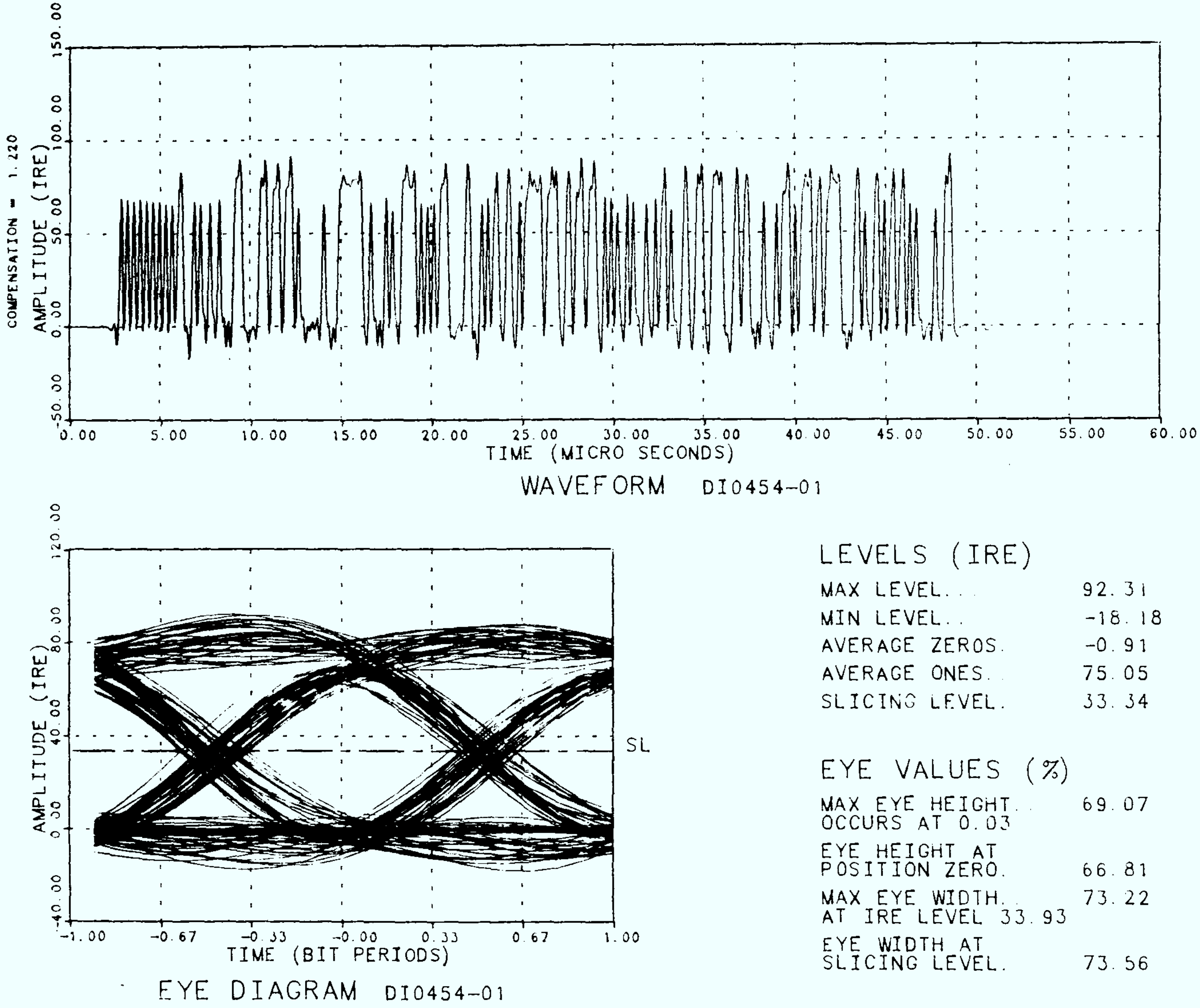
FIGURE 3.11: The Measurement Parameters and the Error Distribution of the Long Teletext Test Sequence.

```
                         R STAT Version 3.0
                        04 FEB 86 . 19:20:01

ENTER FILE NAME  SA0454.211

*** SEARCHING FILE: DK>:SA0454.211
--------------------------------

SITE NAME : /SA0454                            4 FEB 86  19:07:36

/SA0454
OFF AIR;LINE 16 LONG;MK V DECODER TEST A/N 8778;
TEK DEMOD.1450-1/TDC-1 VHF A/N 24850/851;
ANT.JERROLD J-283 X;FRAME WINDOW 2.OuS;
SITE;DISTANCE;CHANNEL;ATTENUATOR;RF LEVEL;
SNR;EYE;PICTURE GRADE;VCR TAPE NUMBER / MARK(MM:SS);
WILLIAMSBURG,FIRE STATION,77KM.SOUTH,CH40+BOOSTER,2DB,-46.ODBM
32DB,55%,3.0,10/35:44

***Final Statistics ***
   Packets received                   :    19348.
   Packets in error                   :       15
   Packets lost                       :       11
   Packets rejected                   :        0
   Packet error rate                  :  0.7753E-03
   Packet lost rate                   :  0.5682E-03
   Bit error rate                     :  0.3230E-05
   Avg. # pkts between errs.          :    658.37
   Avg. # byte errs per pkt. in err.  :      1.00 Not incl. rej. pckts.

   % of N consec. bits error prob.    :     1      2      3      4     5&+
                                        100.0    0.0    0.0    0.0    0.0

   % of packets with N bit errors     :     1      2      3      4     5&+
                                        100.0    0.0    0.0    0.0    0.0

DO YOU WANT DECODER DATA ANALYSIS (Y/N)?
N

*** END OF TEST -- NO MORE DATA ***
```

FIGURE 3.12: The Measurement Parameters and the Calculated Error Statistics.

```
 QUIT
>
                         R TELIDON Version 6.0
                         04 FEB 86   19:15:35

ENTER FILE NAME >DI0454.211
CREATING FILE DK :DI0454.211

*/DI0454

-- Enter ? to get the menu --

>WD ON

-- Enter :? for help on comment commands --
-- Enter  ? for help on  edit   commands --

COMMENTS? *NUMBER OF SAMPLES         =   600
COMMENTS? *POSITION OF FIRST SAMPLE =     1
COMMENTS? *NUMBER OF AVERAGING       =     1
COMMENTS? *:1
COMMENTS? *I OUTPUT;OFF AIR;LINE 15 SHORT;DIGITIZER 8100 A/N 18667;
COMMENTS? *DC COUPLING;INPUT RANGE .2V;INPUT OFFSET -.56;ARM DELAY 0.00 &
COMMENTS? *LEVEL -.00;TRIGG.DELAY 0.06 & LEVEL +.25;TIME BASE-EXT.2X CLK.
COMMENTS? *(11.4545MHz);REGENERATED STROBE & SUBCARRIER;ANT.JERR.J-283 X;
COMMENTS? *TEK DEMOD.1450-1/TDC-1 VHF A/N 24850/851;
COMMENTS? *INPUT OFFSET:-.45
COMMENTS? *

-- READY TO START.  PRESS DIGITIZER 'ARM' BUTTON. --

>
--    SAMPLING BEGINS.    --
----- END OF SAMPLING.  ----
>WD OFF
>
```

FIGURE 3.13: The Parameters for the In-Phase (I) Components of the Digitized Received Signal.



WAVEFORM AND EYE DIAGRAM FOR FILE # DI0454-01

FIGURE 3.14: The Short Teletext Test Sequence and its Eye Diagram with its Characteristics Produced from the Digitized Waveform.

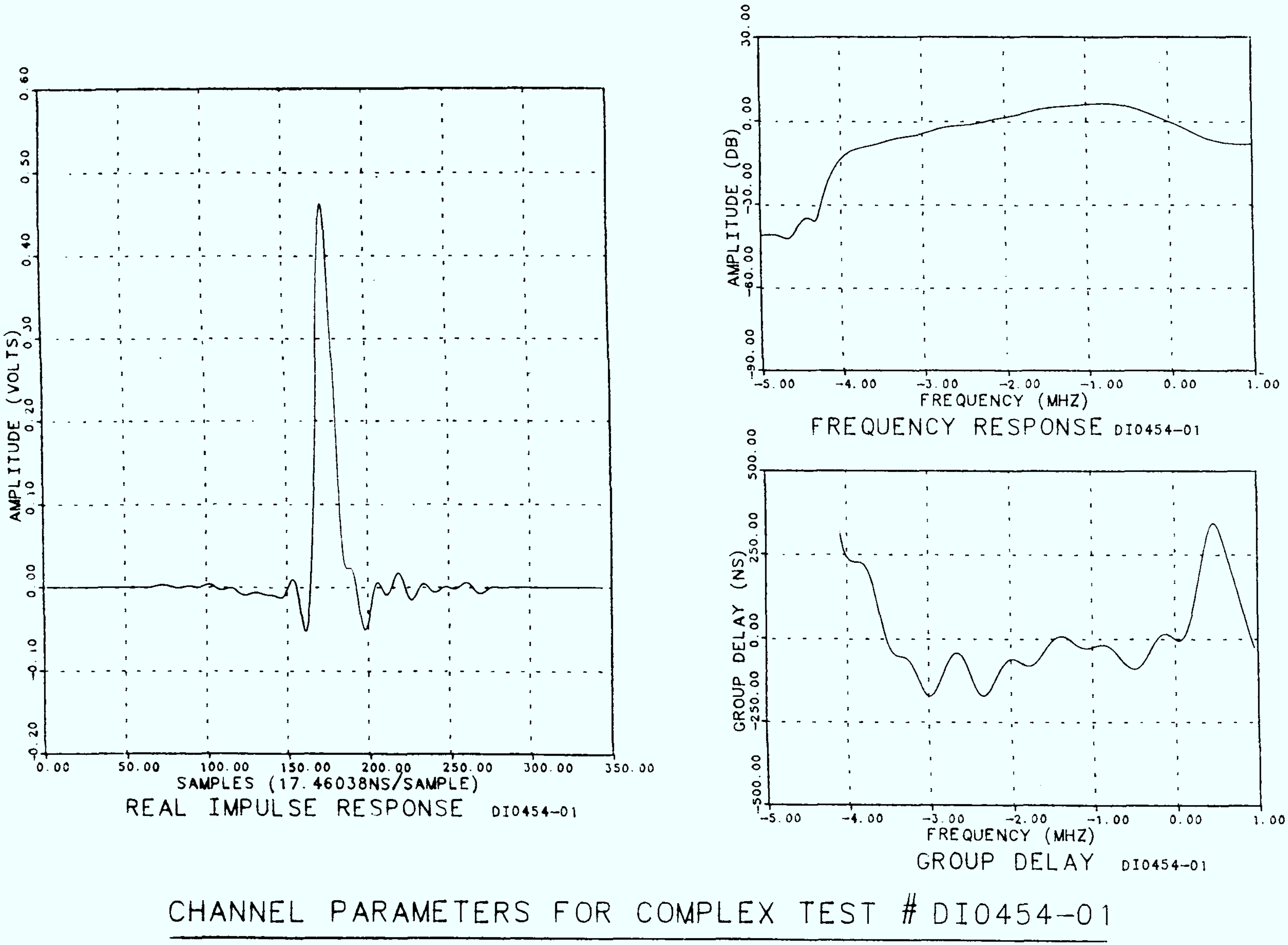


FIGURE 3.15: Some Parameters of the Channel as Estimated from the Digitized Short Sequences: In-Phase Impulse Response, Channel Frequency Response and Channel Group Delay.

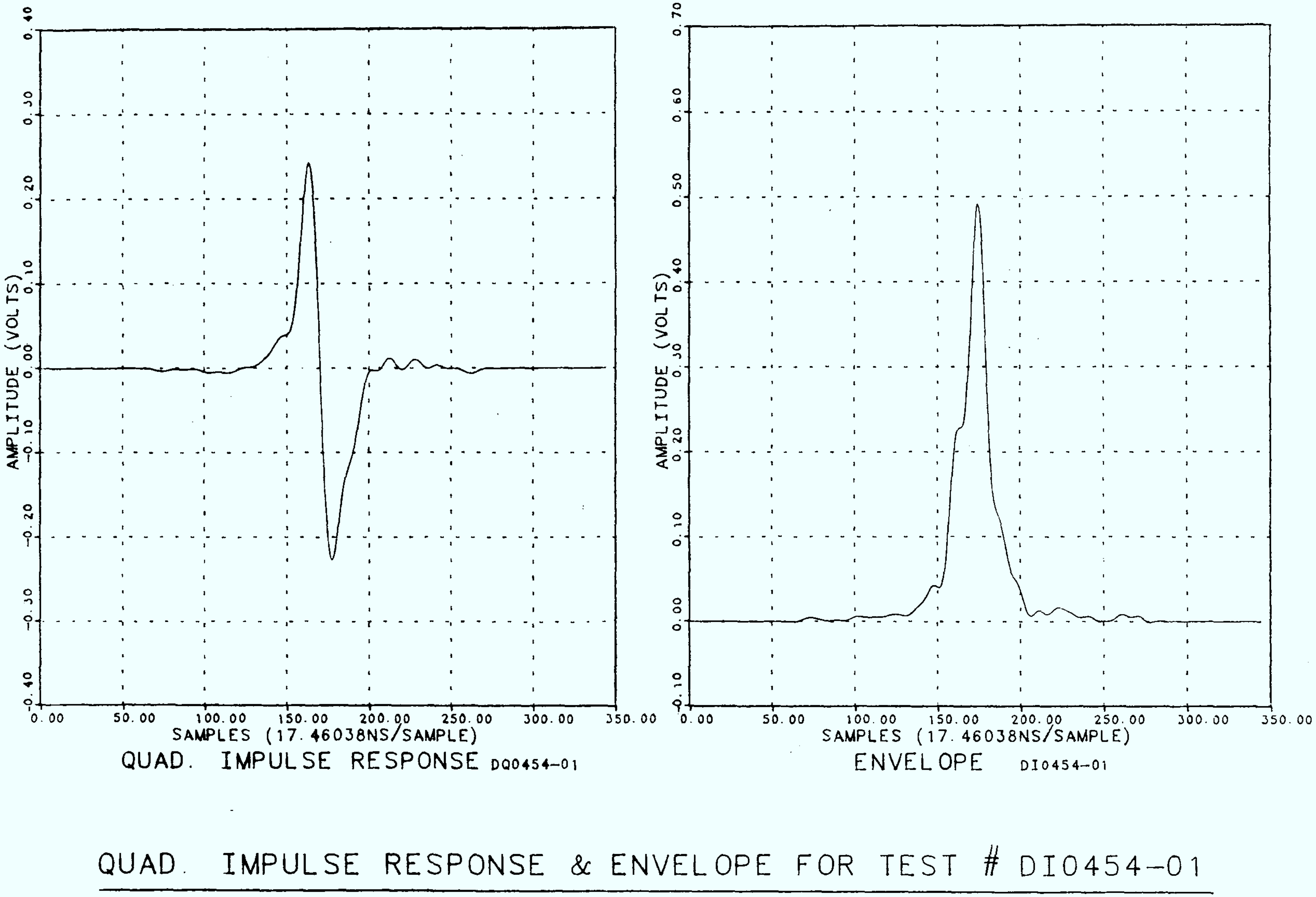


FIGURE 3.16: Some Parameters of the Channel as Estimated from the Digitized Short Sequences: The Quadrature Impulse Response and the Impulse Response Envelope.

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RECNUM	FILENAME	SNR	SIGLEVEL	ATTENSET	DISTANCE	GRADE	EYELEVEL	PERC1	BERC1	PKTERROR	PKTLOSS	BITERROR	B.1	B.2	B.3	B.4	B.5	P.1	P.2	P.3	P.4	P.5	RECEIVER
103	SA0451.211	42	-43.0	2	77 KM S	3.5	50%	0.000E+00	0.000E+00	0.000E+00	4.610E-05	0.000E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TEK
104	SA0454.211	32	-46.0	2	77 KM S	3.0	55%	0.000E+00	-4.167E-10	7.753E-04	5.682E-04	3.230E-06	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	TEK
107	SA0461.211	44	-43.0	2	80 KM S	3.5	40%	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TEK
108	SA0462.211	39	-46.3	2	80 KM S	3.5	15%	7.503E-01	1.632E-02	9.583E-01	0.000E+00	1.719E-02	100.0	0.0	0.0	0.0	0.0	21.7	26.1	8.7	8.7	34.8	TEK
109	SA0464.211	36	-43.5	2	80 KM S	4.0	70%	0.000E+00	0.000E+00	0.000E+00	3.845E-03	0.000E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TEK
111	SA0471.211	25	-61.7	2	88 KM S	2.0	25%	4.939E-02	5.799E-04	1.843E-01	0.000E+00	1.142E-03	99.9	0.1	0.0	0.0	0.0	73.2	16.4	6.0	1.6	2.7	TEK
112	SA0473.211	24	-55.00	2	88 KM S	2.5	35%	1.741E-02	1.933E-04	7.284E-02	4.424E-03	4.243E-04	100.00	0.0	0.0	0.0	0.0	76.1	15.4	4.4	2.1	2.0	TEK

RECNUM	FILENAME	CHANNEL	SITELOC1	SITELOC2	REMARKS
103	SA0451.211	CH 13	WILLIAMSBURG	FIRE STATION PARKING LOT	RESIDENTIAL AREA; SMALL TOWN; FLAT LAND
104	SA0454.211	CH 40	WILLIAMSBURG	FIRE STATION PARKING LOT	BOOSTER PS7070; RESIDENTIAL AREA; SMALL TOWN; FLAT LAND
107	SA0461.211	CH 13	WILLIAMSBURG	2ND. RD. S; PASSED WILLIAMSBURG	STRAIGHT LINE SOUTH OF TRANS.; OPEN FIELD AREA; FEW HOUSES; FLAT LAND
108	SA0462.21	CH 08	WILLIAMSBURG	2ND. RD. S; PASSED WILLIAMSBURG	WARNING; STRAIGHT LINE SOUTH OF TRANS.; WENT OUT OF SYNC.; OPEN FIELD AREA; FEW HOUSES; FLAT LAND
109	SA0464.211	CH 40	WILLIAMSBURG	2ND. RD. S; PASSED WILLIAMSBURG	STRAIGHT LINE SOUTH OF TRANSMITTER; BOOSTER PS7070; OPEN FIELD; FEW HOUSES; FLAT LAND
111	SA0471.211	CH 13	MORRISBURG	WATERFRONT PARK; END OF HWY. 31	STRAIGHT LINE SOUTH OF TRANSMITTER; RESIDENTIAL AREA
112	SA0473.211	CH 40	MORRISBURG	WATERFRONT PARK; END OF HWY. 31	STRAIGHT LINE SOUTH OF TRANSMITTER; BOOSTER PS7070; RESIDENTIAL AREA

FIGURE 3.17: Example of the Information Stored in the Microcomputer Database.

4.0 LABORATORY MEASUREMENTS OF THE TELETEXT SIGNAL

Some measurements were performed in the laboratory to evaluate the equipment and to correct any anomalies. They are presented in this section.

To evaluate the performance of the teletext decoder, bit error rates were measured in the presence of white gaussian noise. To perform this measurement, a teletext signal was inserted into the VBI of a video signal which was modulated by a VHF Scientific-Atlanta Modulator. The television signal was attenuated until the desired signal-to-noise ratio was obtained. The signal was then demodulated and decoded by the teletext decoder. The data received was compared with the reference sequence and the bit error rate was calculated. The graph of Fig. 4.1 presents the results obtained for two Norpak teletext decoders: the Mark IV and the Mark V.

These results can be taken as upper limits for the performance of those decoders. In a field transmission, the received signal will be more affected by various other distortions, such as echoes and impulsive noise, and the bit error rates obtained will be higher.

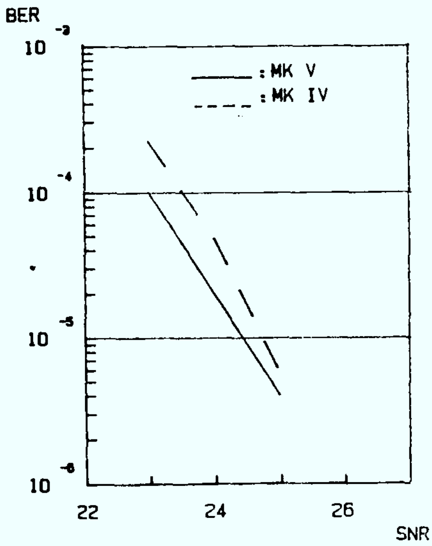


FIGURE 4.1: Bit Error Rates in Laboratory Transmissions for Two Teletext Decoders.

The 3 ways in which the eye height could be measured were compared. These were visual measurements on an oscilloscope, measurements with the eye height meter and off-line calculation in a computer mainframe. It was found that the three values were not significantly different. For this reason it was decided to use the value of the average minimum eye height measured with the eye meter because this was the easiest to do.

A test, presented in detail in [6], was made to validate the channel parameter estimation. A video signal with a line of teletext data was passed through a 4 MHz low-pass filter. The digitized teletext line was used to calculate the channel response, i.e., the output of the low-pass filter. Fig. 4.2 (a) and (b) show that the estimated impulse response of the filter is very similar to the photograph of the 1 bit teletext pulse at the output of the filter.

The complete measurement system was installed in the mobile laboratory. It was checked from time to time with video and teletext test signals, which could be generated in the van.

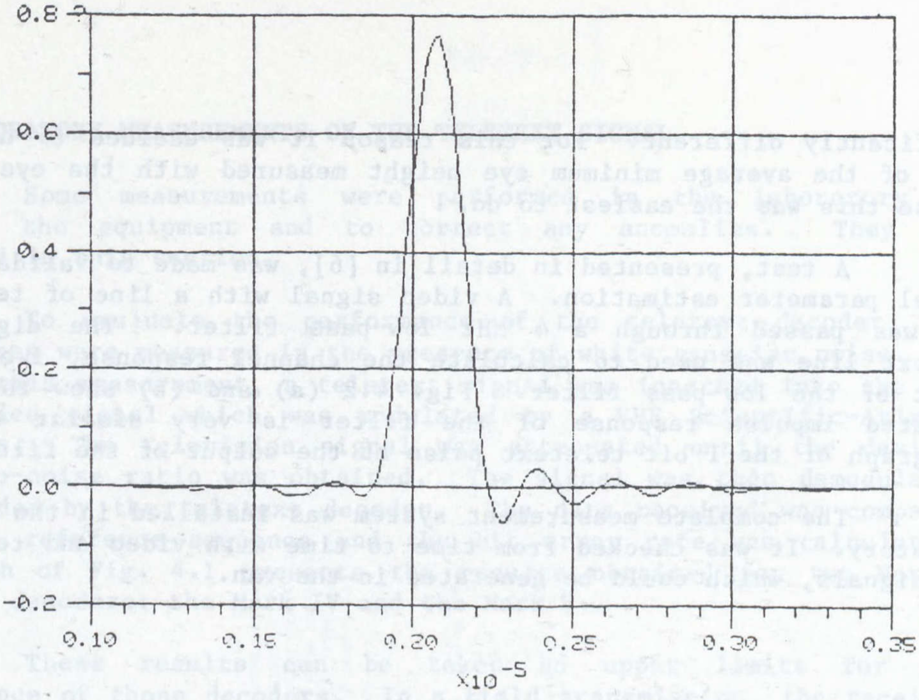


FIGURE 4.2(a): Estimated Response of the Lowpass Filter.

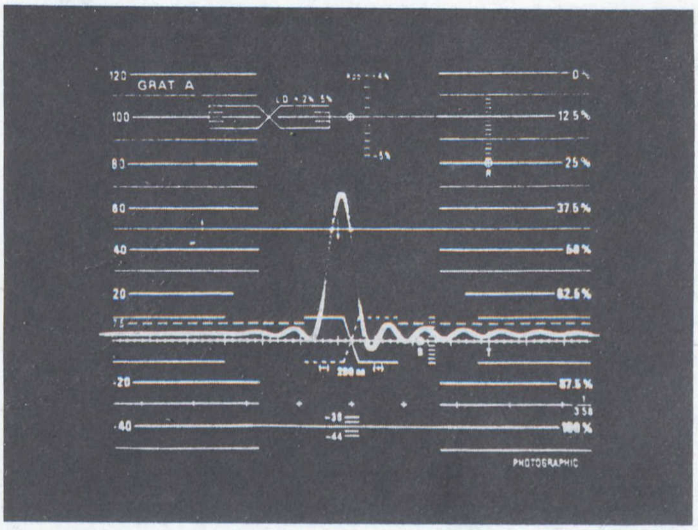


FIGURE 4.2(b): Photograph of the 1 Bit Teletext Pulse at Output of the Lowpass Filter.

5.0 MEASUREMENT OF TELETEXT SIGNALS TRANSMITTED OVER THE AIR

5.1 Over-the-air Reception

The most common way to transmit a television signal is over the air using vestigal side-band amplitude modulation. In this section the performance of over-the-air reception of teletext signals will be examined, using field test results.

Thanks to the collaboration of broadcasters all over Canada, it was possible to add teletext test signals to their regular video transmission. More than 450 measurements were performed at about 300 different sites using 10 different transmitters. These transmitters are listed in Table 5.1 along with some of their characteristics. They were used without any particular adjustments so that the teletext performance measured is the one obtained under normal operation. These transmitters are thought to be typical of those used across Canada.

TABLE 5.1: Characteristics of the Television Transmitters Used During the Tests.

LOCATION	CHANNEL	VIDEO POWER (KW)	ANTENNA HEIGHT ABOVE AVERAGE TERRAIN (FT)
Ottawa	40	185	1184
Ottawa	30	713	1184
Ottawa	13	178	1150
Sudbury	5	1000	1057
Timmins	3	55	N.A.
Saskatoon	8	325	866
Calgary	2	1000	700
Calgary	4	1000	989
Kelowna	5	4	N.A.
Vancouver	8	194	2315

No problems were of enough significance to prevent teletext transmission at any television station. In each case, checks were made to ensure that no equipment between the teletext encoder and the transmitter was disturbing the signal in the VBI, particularly the teletext data. It was also checked that no data sent in the VBI was affecting remote-controlled equipment. For example, a reset on the teletext encoder could generate random data which might be interpreted as a command by some pieces of equipment.

All the results presented in this section were obtained with a synchronous demodulator and the 7 dB gain antenna. The performance of other types of equipment will be discussed later.

5.2 Reception in Urban Areas

The majority of the over-the-air teletext reception measurements were done in urban areas because of the population concentration and the particular problems of transmission to be found in the city. The sites were generally selected at random but no measurements were performed in the heart of the city, where there are mainly high-rise office buildings and a few residental buildings. Many sites in Ottawa were selected close to the center of the city because of the presence of multiple signal reflections, causing echoes which were identified as a potential source of problem for teletext reception.

In general, the results showed that television reception was good in urban centers. The SNR had large variations among sites but it was normally close to 40 dB. The eye height was affected by echoes which were caused by multiple reflections on various obstacles found in urban areas. In addition to creating distortion, echoes may affect the positioning of the slicing level and the bit timing recovery in the decoder. The resulting effect is a degradation of reception quality. However, an eye height greater than 50% and a bit error rate better than 10^{-5} was found at almost all of the urban sites. At some unusual sites, where the echoes were important because of the proximity of many high buildings, the teletext reception was difficult and sometimes impossible. Often the television image reception on these sites was quoted grade 3, which is just passable.

It was estimated that at 90% of the urban sites the bit error rate obtained was better than 10^{-5}, which translates into a very good teletext service to the users. Reception was impossible for about 5% of the sites. Those results were obtained with a 7 dB gain antenna. A lower gain antenna would pick up more reflections which might result in a poorer performance. This will be discussed again in section 7.4.

It can be concluded that teletext reception in urban areas can be without problems for the majority of users. At poor sites, where problems are encountered, reception could be improved by connection to a cable network, which is now almost always available in cities.

5.3 Reception in Hilly Areas

Problems were encountered for television reception in hilly areas because of the many obstacles which can exist between transmitter and receiver antennas.

It was found that, as in the city, received signals suffer from echoes. Unlike the reception in a city however, the level of signal-to-noise ratio can be very low in the 20 dB range, which causes many errors. The combination of these two causes explains why it was possible to receive teletext signals with a bit error better than 10^{-5} for only 50% of the sites in hilly regions. Teletext reception was impossible for about one quarter of the sites.

It is sometimes difficult to predict the location of any particular sites likely to give problems. For example, no error reception was observed at a site 60 km from the transmitter, but reception was impossible at another site which was only 40 km from the same transmitter. In general, a problem will appear when the SNR is less than 30 dB.

The solution to this problem is to use a better antenna, to place it higher or to add an antenna booster. People from these areas are accustomed to this kind of solution because they already have problems receiving normal television programs.

5.4 Reception in Flat Areas

Flat areas are the ideal environment for over-the-air transmission. In these areas teletext reception is easy. The distance from the transmitter which reduces the signal-to-noise ratio is the only important factor affecting the quality of reception.

Errors start to appear when the SNR is worse than 30 dB. This situation will typically be encountered when the site is more than 80 km away from the transmitter. This distance will vary, depending on the transmitter power and the antenna's height and gain.

Measurements showed that, in a plain, the majority of the sites situated within the grade A contour, as defined in [7], will receive a teletext signal without error. Within a grade B contour, half of the sites will have a bit error rate less than 10^{-5}.

5.5 Reception in the Ottawa Region

Because of its proximity to the Communications Research Centre, the teletext reception in the Ottawa region had been studied in more detail.

It was thus possible to create the two graphics of the following figures. However those results are based on a relatively small number of sites and should not be used to generalize.

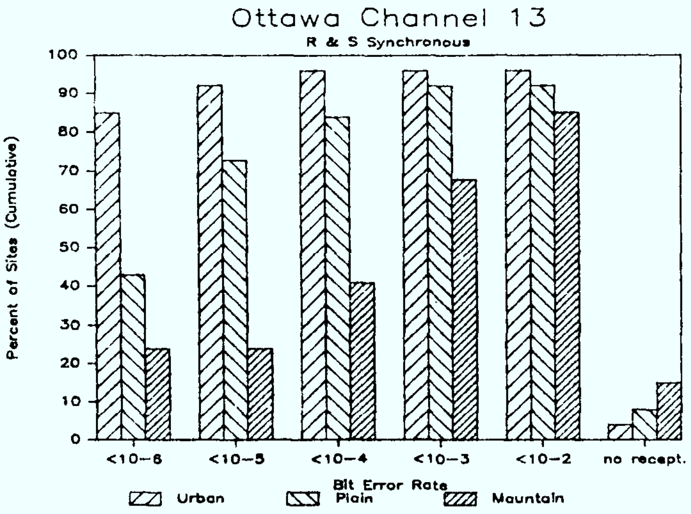


FIGURE 5.1: Distribution of the Bit Error Rate for Different Environments. Channel 13 Synchronous Demodulator.

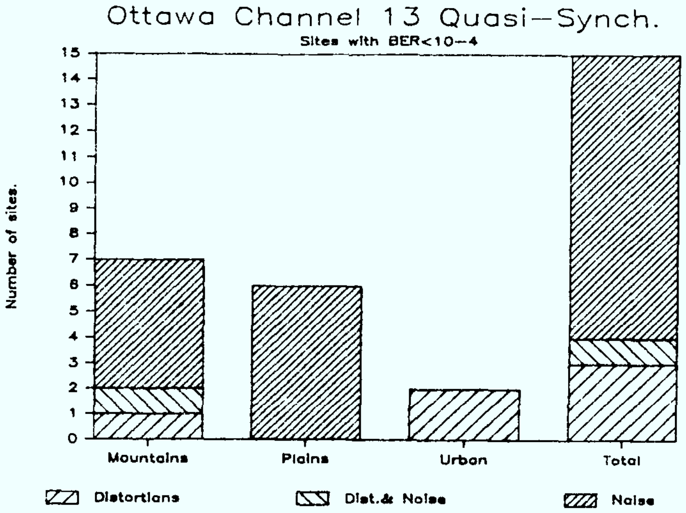


FIGURE 5.2: Probable Causes of the Errors for Sites with Bit Error Rates Higher than 10^{-4}. Channel 13 Tektronix and R&S Demodulators.

Figure 5.1 presents the distribution of the bit error rate for sites in three different environments. Those results are similar to the general ones presented before, except for the hilly regions where reception in the Ottawa Region was not as good as elsewhere in Canada.

Figure 5.2 gives an idea about the probable cause of the errors for the sites where a bit error rate higher than 10^{-4} was recorded. It is clear that, except in urban areas, the noise is the main source of errors.

5.6 Reception from a Repeater

Television repeaters are often used to serve small communities. They usually receive a signal from a television station via a microwave link. This signal is then modulated and transmitted.

Teletext performances were measured at 8 different repeater sites. In general the results were poor. At the majority of the sites the bit error rate was worse than 10^{-5}.

It was checked at one of the repeaters that the microwave link was not responsible for the deterioration of the signal. The signal received at the repeater was of high quality. However it was observed that the processing amplifier used at the repeater distorted the signal. As seen in Fig. 5.3, the eye diagram for the signal before the processing amplifier was almost perfect, but it became non-symmetric at its output.

It is also suspected that the high frequency response of these repeaters was not always very good, because it was observed that the amplitude of the 2T pulse was often lower than 70 IRE. A bad high-frequency response distorted the teletext signal and caused errors.

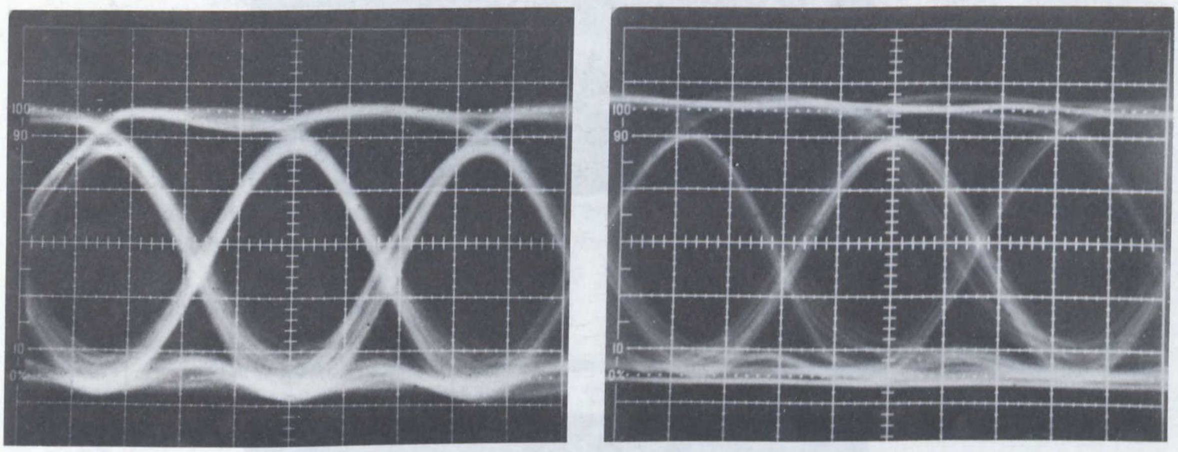


FIGURE 5.3: The Eye Diagram Before and After the Processing Amplifier of a Repeater Station.

5.7 Reception from a Satellite

No tests were performed to estimate the quality of the transmission of television and teletext signal by satellite. However, one of the stations that was used during the tests in Ottawa received its signal from Montreal via the Anik C-3 satellite. It was found that the teletext signal was not affected by this transmission, as can be seen from Fig. 5.4.

No problems are expected due to satellite transmission of teletext signals.

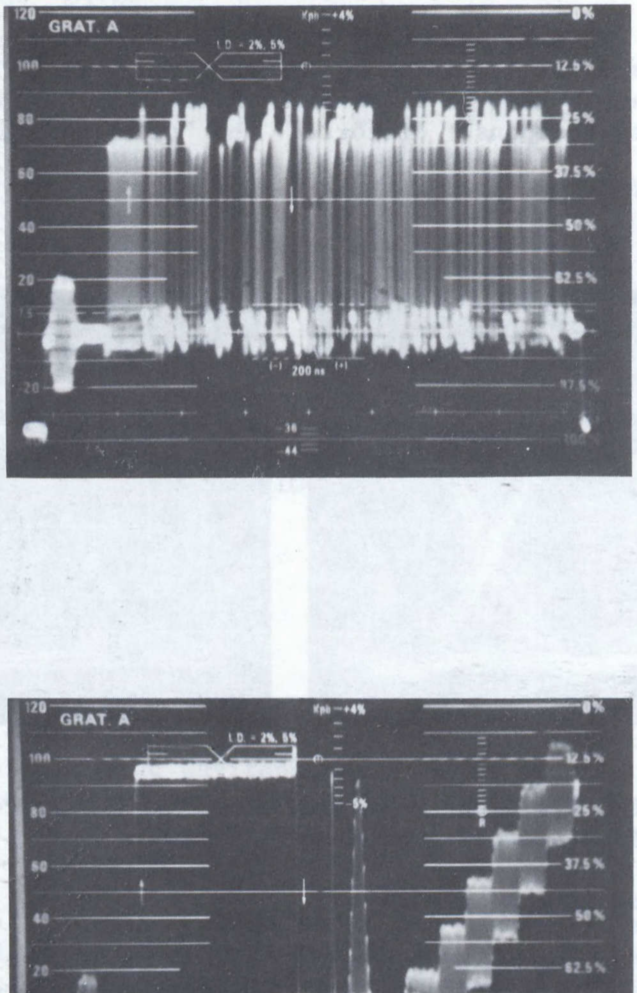


FIGURE 5.4: Test Signals Received from a Satellite Transmission.

6.0 RECEPTION OF TELETEXT SIGNAL TRANSMITTED OVER TELEVISION CABLE NETWORKS

Cable television services are now available to a large portion of the Canadian population. The cable transmission of television signals is regulated to assure a minimum signal quality. In Canada these rules are contained in Broadcast Procedure 23 [8].

Some of the rules are of interest for teletext transmission over cable. A minimum carrier-to-noise ratio of 40 dB must be available at each cable connection. This corresponds to a SNR of about 36 dB. The 2T pulse echo rating must be less than 7%.

These two limits were met at almost all the sites measured during the tests. The exceptions occurred at some sites where the echo rating was higher than 7%.

An example of cable network measurements is illustrated in Fig. 6.1. The teletext signal transmitted by a local station is picked up by the cable network antenna. It is frequency translated to a new television channel and transmitted to the beginning of a trunk using microwave links. A measurement is taken after the last amplifier of the trunk. There can be up to 35 amplifiers on a trunk; less than 30 being more common.

The tests were performed on 6 different networks. In general, results were excellent. The eye height was higher than 50%, the SNR was better than 36 dB and the bit error rate was lower than 10^{-5}.

At some sites, however, results were not as good, which is probably due to three main reasons. First, the performance can be affected by the quality of the signal received over the air at the cable antenna. If the signal was already distorted at this point, the cable network degraded it further, and after the signal passed through some amplifiers, the bit error rate increased to an unacceptable value. An example of this degradation is shown in Table 6.1 which gives the bit error rates measured after different numbers of amplifiers on one trunk of a network. The SNR was about 36 dB at the 3 sites.

TABLE 6.1: Example of Bit Error Rates Measured on a Cable Network Trunk.

NUMBER OF AMPLIFIERS	BIT ERROR RATE
13	6.8×10^{-7}
23	1.6×10^{-6}
26	1.9×10^{-5}

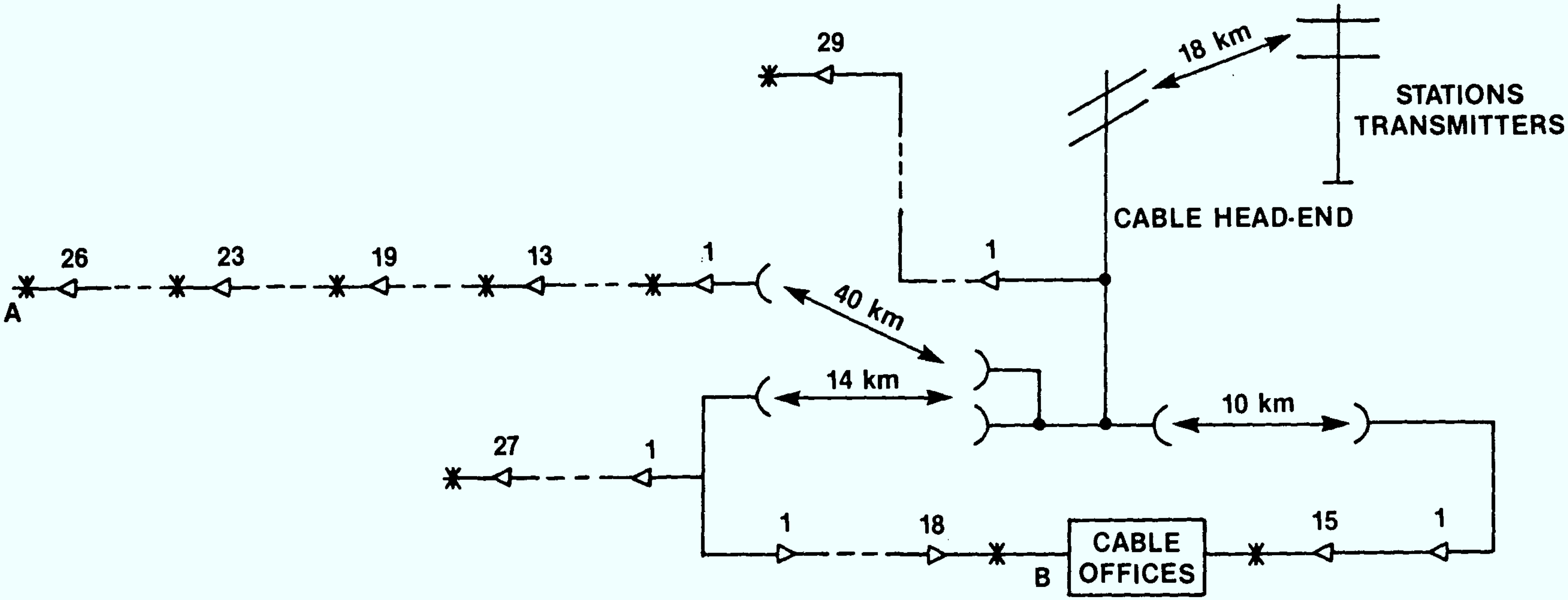


FIGURE 6.1: Example of the Measurements (*) Taken on a Cable Network.

Another problem is caused by older types of converters that translate television channels using one of the channel's carriers as a reference frequency. This seemed to affect the signal in an intermittent fashion. This effect appeared to be more of a problem with a synchronous demodulator than with a quasi-synchronous one. It was not possible at the time to investigate this problem further.

Third, some difficulties were encountered with measurements performed when the cable network personnel were doing sweep frequency tests on the cable network. This interferred with the teletext signal.

It may be concluded that, if precautions are taken to avoid the problems described above, teletext reception on cable systems can be very good.

7.0 TELETEXT RECEPTION FACTORS AND PARAMETERS

In this section factors and parameters that could affect the quality of the teletext service will be reviewed.

7.1 Video Image Quality

Image rating is one way to evaluate the quality of a video signal. It is useful to explore a possible relation between image rating and teletext quality.

The quality of the image was evaluated at each measurement site. However, the standard 5-grade CCIR scale was used only for the last series of tests.

The relation between image quality and bit error rate did not always exist. There were many cases of a site with a good or fair image with very poor teletext reception. However, measurements showed that 85% of the sites with a grade equal to or greater than 3 had a bit error rate less than 10^{-4}. It was also found that at all sites, where a grade equal to or less than 2 was observed, the teletext bit error rate was always worse than 10^{-4}.

A rough relation between image grade and bit error rate is given in Table 7.1. It should be used as an approximate estimate.

TABLE 7.1: Rough Estimate of Relation Between the Subjective Image Quality and the Teletext Bit Error Rate.

GRADE	BIT ERROR RATE
4.5	0
4.0	10^{-6}
3.5	10^{-5}
3.0	10^{-4}
2.0	10^{-3}

Sometimes it was observed that a signal carrying an image which is subjectively graded high did not provide a good teletext signal. This is because some types of distortion, such as short echoes or group delay, do not affect the quality of the image, but may deteriorate the teletext signal. It is, however, generally true that at a site where a really distorted image is received the teletext signal will be unacceptable.

Based on these remarks it can be concluded that the image quality provides an indication on the quality of a teletext signal. Complemented by other observations and good experience of teletext reception, fairly reliable conclusions about the potential of a site for teletext reception can be reached.

7.2 Eye Diagram

The eye diagram is one of the most useful means to evaluate the quality of a digital signal. For a teletext signal, a competent interpretation of the characteristics of the eye diagram can be a very powerful way to predict performance. In this sub-section, some characteristics of the eye diagrams measured during the tests are presented and discussed.

The eye height is the easiest eye parameter to measure and to interpret. The eye height measured during the tests was the minimum eye height at the estimated sampling instant. It is the ratio between the height of the minimum eye opening and the amplitude between the average 0 and 1 levels. The eye height is a good indication of the signal's resistance to noise. In practice the measured eye height ranges from 0 to 75%. A value superior to 40% is desirable. The diagram in Fig. 7.1 shows the eye height distribution for a series of 100 measurements done in Ottawa with the Tektronix demodulator. The average eye height was 39.6%. This is pessimistic because some sites were selected for their potentially bad teletext reception.

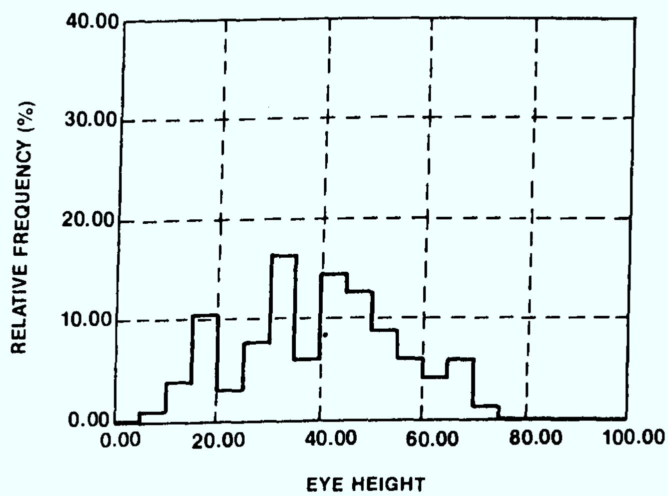


FIGURE 7.1: The Eye Height Distribution for 100 Measurements Done in Ottawa.

The eye height is not sufficient to estimate the bit error rate for a given signal-to-noise ratio. The width and the symmetry of the eye must also be considered.

The width of the eye diagram at the slicing level gives an indication of the amount of phase jitter which can be tolerated by the recovered sampling clock.

Ideally the eye diagram will be symmetric about its two axes. When the eye is not symmetric vertically, it indicates non-linear amplitude distortion. This will cause the slicing level to be set away from its ideal location in the middle of the eye. An example of this situation is presented in Fig. 7.2 where the slicing level is superimposed on the eye diagram.

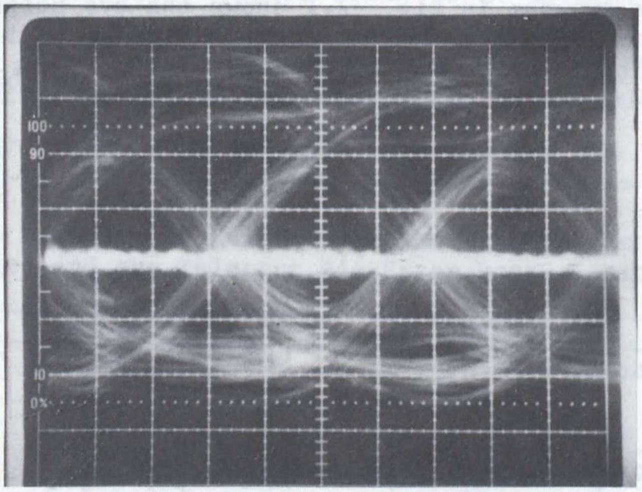


FIGURE 7.2: Example of a Vertically Distorted Eye Diagram. The Slicer Level Does Not Set in the Middle of the Eye.

An eye that is not horizontally symmetrical will cause the actual sampling point to occur away from the ideal sampling point, where the eye height is maximum. This asymmetry is due to group delay or to linear phase distortion. Using the eye analysis program presented earlier, it was calculated that at about 20% of the test sites in the Ottawa region, the sampling occurs at more than ±.1 of a bit period (17.5 nsec.) from the ideal sampling instant. The maximum error found was .21 bit periods (36.7 nsec.). This problem might be solved by having a recovered clock whose phase could be automatically adjusted until it reaches the phase giving the minimum number of detected errors.

Even though the eye height alone is not sufficient to estimate the bit error rate, it can often help establish an estimate of its range. This is due to the fact that the factors affecting the eye height will often deteriorate the eye symmetry or the eye width. For example, when the eye height was higher than 40%, all the sites studied had a bit error rate better than 10^{-4} and more than 85% of the sites had a rate better than 10^{-6}. On the other hand, when the eye height is less than 30% a bit error rate worse than 10^{-4} is almost certain to be obtained. These results are valid for the particular teletext decoders used: the Mark IV and Mark V from Norpak.

It can be concluded that the eye diagram is one of the best tools available to the experienced person wishing to estimate the teletext bit error rate.

7.3 VHF and UHF Transmissions

Teletext signals can be transmitted using a conventional VHF or UHF television transmitter. Some tests were made to see whether teletext transmission were similar on both VHF and UHF channels.

Tests made in the Ottawa region compared channel 13 and channel 40. It was found that the eye diagram and the bit error rate obtained on the UHF channel became similar to the ones obtained on the VHF channel after the UHF channel was amplified by an antenna booster. This booster compensated for the 10 dB difference observed between the signal-to-noise ratio on the VHF and UHF channels. The bit error rates measured were identical or similar for 85% of the 34 sites where teletext reception on VHF and UHF were compared. The antenna booster was not necessary for the VHF signal. However, it improved the weaker UHF signal by 8 to 14 dB.

7.4 Antenna Types

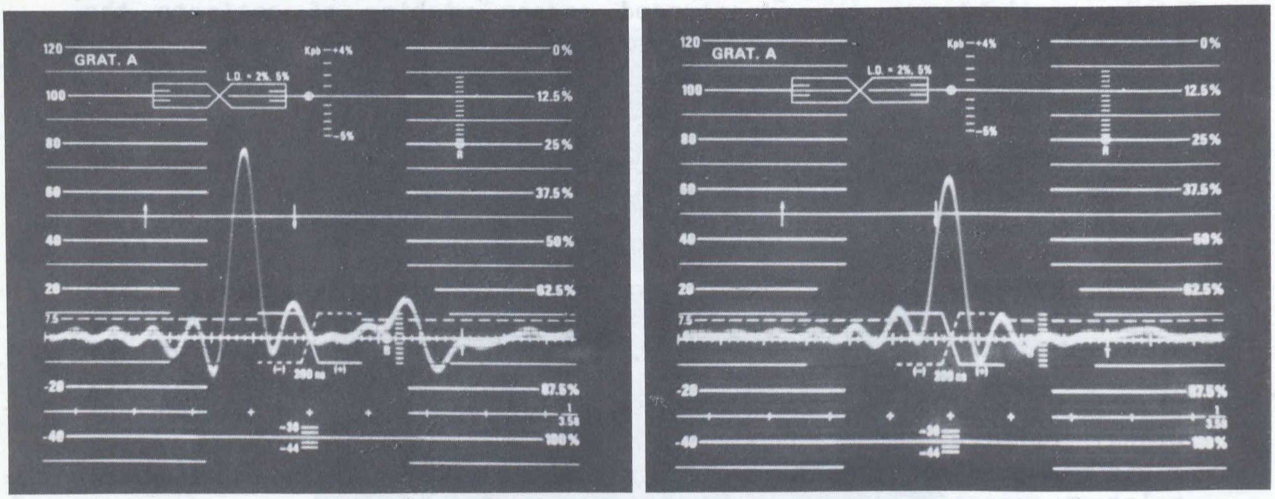
Two types of antennas were used during the tests. One type was a high gain directional Jerrold antenna and the other type included two bidirectional antennas. One of the latter was a VHF rabbit-ear antenna and the other one was a UHF loop antenna.

These lower gain antennas are more likely to pick up long echoes of higher amplitude. The signals received often looked like those shown in Fig. 7.3(a). At the same site, the directional antenna greatly reduced the echoes, as can be seen from Fig. 7.3(b).

In Figure 7.4 the maximum, minimum and average of the impulse responses measured in the Ottawa region using the lower gain antenna are shown. They can be compared with the smaller echoes presented in Fig. 8.2, which were obtained with a high gain antenna.

The eye diagram obtained when the low gain antennas are used will be affected by echoes and, consequently, the bit error rate will be worse than with the directional antenna, even if the level of noise is not much different when using each type of antenna.

It is concluded that a small set top antenna will assure a good teletext reception only at sites where the signal is not affected by echoes or distortions. Highly directional antennas are clearly superior because they tend to discriminate against long echoes.



(a) (b)

FIGURE 7.3: Example of a 1 Bit Period Pulse Received in the Presence of Echoes with (a) a Rabbit-Ear Antenna and (b) with a Highly Directional Antenna.

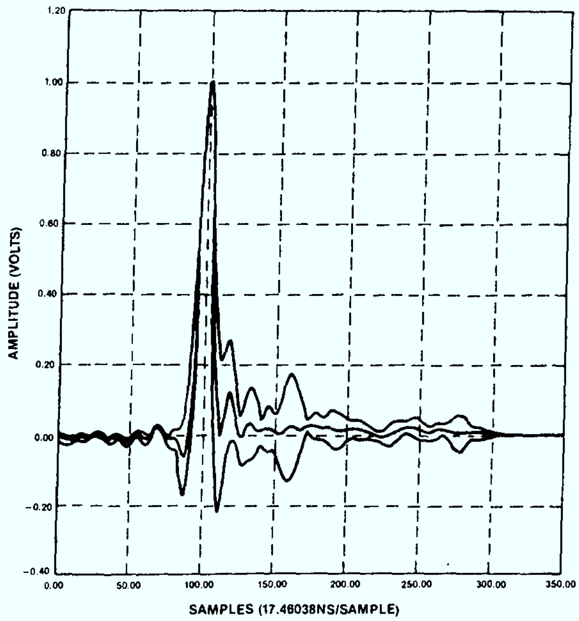


FIGURE 7.4: Maximum, Minimum and Average of the Impulse Responses Measured in the Ottawa Region with Low Gain Antennas.

7.5 Types of Demodulators

Four different demodulators were used during the tests. Two were synchronous models and the two others were quasi-synchronous. Envelope demodulators were not tested because they have been found to be inferior to synchronous types [9]. They are unlikely to be used in teletext decoder tuners or included in television sets with built-in teletext decoders.

The two synchronous demodulators, the Tektronix (TEK) and the Rhodes and Schwartz (R&S) provide similar teletext performance. The first quasi-synchronous model, the Zenith, was not as good and its use resulted in greater bit error rates. An error rate better than 10^{-5} was obtained at only 56% of the sites, compared with 92% of the sites for the R&S. The bit error rates obtained with the Zenith demodulator were 10 to 100 times worse than the ones measured with the R&S demodulator.

The second quasi-synchronous demodulator, the Sony, gave better results and were sometimes superior to those obtained with the 2 synchronous ones. This is because the synchronous models have a wider bandwidth IF filter with a steeper attenuation slope at cut-off frequencies. At sites where noise and distortion are low, this filter will permit very low bit error rates. However, when noise or distortion are present, the Sony demodulator can be superior, because its narrower and smoother transition slope will decrease the noise level and will not distort the signal. These conditions, under which the quasi-synchronous demodulator might be superior, are more common on cable networks.

It can be concluded that some quasi-synchronous demodulators give very good performance, but that a synchronous model is necessary to obtain top performance.

7.6 Error Statistics

During the tests, all the errors detected were recorded and some of their statistics were calculated. These statistics are useful in designing or selecting error-correcting-and-detecting codes.

7.6.1 Number of Errors Per Packet

The number of errors per packet (per teletext line) is a useful parameter to determine the error correcting code needed to protect teletext transmissions.

Table 7.2 shows the percent of the sites across Canada where some of the packets received contained more than 2 errors for each range of bit error rate.

TABLE 7.2: Percent of Sites Where Some of the Packets Received Contained More than 2 Errors.

BER Range	Percent of Sites with Some Packets Containing More Than 2 Errors
Less than 10^{-6}	0%
10^{-5} to 10^{-6}	17%
10^{-4} to 10^{-5}	50%
10^{-3} to 10^{-4}	100%
Greater than 10^{-3}	100%

For the sites with bit error rate between 10^{-3} and 10^{-4}, 85% of the packets received contained 1 error, 12% had 2 errors, 2% had 3 errors and 1% had 4 errors or more. The values given for this bit error rate range by a French study [10] are similar: 85% of the packet had 1 error, 10% had 2 errors and 4% had 3 or more errors.

For error rates greater than 10^{-3} the number of errors per packet varied greatly from one site to another. For example, from one site to another, between 0% and 29% of the packets may have 5 errors or more.

It can be concluded that for sites with a bit error rate better than 10^{-3} the vast majority of packets in error contain a maximum of 2 errors.

7.6.2 Number of Consecutive Errors Per Packet

The number of consecutive errors per packet can be useful for determining the type of error correction needed. The measurements showed that for teletext transmission, more than 99% of the errors were isolated. Less than 10% of the sites had more than 1% of the errors which were consecutive.

It appears that codes capable of correcting burst of errors are not necessary to improve the teletext service at the majority of the sites but could be useful in some cases.

7.6.3 Packet Error Rate

The packet error rate measured was compared with the theoretical value given by

$$PER = 1-(1-BER)^{240}$$

which gives the packet error rate (PER) to be expected for a given bit error rate (BER) if the errors are independent. The two values were close for all the valid tests. The curve of Fig. 7.5 shows some measured values and the theoretical curve.

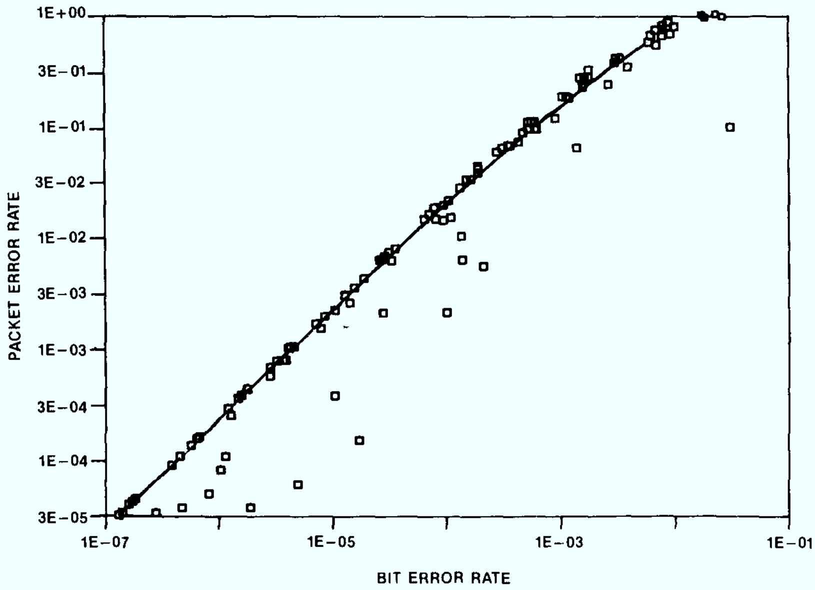


FIGURE 7.5: Packet Error Rates Against Bit Error Rate.

7.6.4 Error Correcting Codes

The error statistics just presented showed that we can generally expect a maximum of 2 isolated errors per packet. However, there are also some less common situations where the errors occurred in increased number and may be consecutive. Which error correcting code could be appropriate for those cases?

The present Canadian teletext implementation includes a one byte parity check and a product code which can correct 1 error per packet and detect at least 2 errors. The NABTS specification [1] allows more bytes for error detection or correction. It is then possible to consider much more powerful error correcting-and-detecting codes. The improvement which could be gained with more powerful codes can be estimated by exercising them with recorded error sequences.

This kind of analysis was done in [11] for 38 sites with 2 types of codes. The first one, the C code, has an effective rate equal to 96% of the present implementation. This code used 2 parity checks at the end of each packet and will correct any single byte error or any double byte errors when both erroneous bytes have a parity failure, or any double bit-error. The second code, the Bundle code, used 1 or 2 complete packets at the end of a predefined number of packets as parity check bytes for vertical codewords, which are elements of code C, forming an interleaved code. Many sets of errors will be corrected with this very powerful code. Its effective rate is equal to 85% of the present implementation.

The results obtained with those 2 codes showed that a powerful code such as the Bundle Code was too powerful for 90% of the sites studied and that code C would meet the requirement at these sites.

An estimate of the gain that can be expected from improved error correction was also done. Table 7.3 gives examples of packet error rate after correction of 1 (present implementation) and 2 (code C) bits per packet. These results were calculated using the average values of errors per packet presented previously for a bit error ratio between 10^{-4} and 10^{-3}: P1=85%, P2=12%, P3=2%, P4=0.5%, P5=0.5%.

TABLE 7.3: Packet Error Rate After Correction for a Bit Error Rate Between 10^{-4} and 10^{-3}.

PACKET ERROR RATE		
No Correction	1 Bit Correction	2 Bits Correction
4×10^{-2}	6×10^{-3}	1.2×10^{-3}
6×10^{-2}	9×10^{-3}	1.8×10^{-3}
1×10^{-1}	1.5×10^{-2}	3×10^{-3}

The above table can give an indication of the necessary error correcting power to obtain the packet error rate after correction necessary for a particular application. A more powerful code increases the redundancy, which reduces the effective data rate but may improve the throughput.

In conclusion, the present error correcting code seems sufficient for the majority of cases. A code capable of correcting 2 single errors per line would improve the performance at many sites. More powerful codes may be appropriate for specific teletext applications where a higher degree of protection is required.

8.0 RECOMMENDATIONS ON POSSIBLE IMPROVEMENTS

The observations that have been presented show that the present teletext system would provide an acceptable service at the majority of the sites. Some of the problems which have been discussed could be solved by means which are presented next.

8.1 Television System Improvements

A television system can be improved for teletext transmission by proper adjustment of the transmit equipment to obtain good reception for the two commonly used video test signals.

It was observed that a teletext signal is often difficult to decode if the high frequency response of the transmitter is distorted. This distortion is indicated by the low amplitude of the 2T Sine Squared pulse. It will degrade the high frequency content of the teletext signal. The clock run-in sequence will be attenuated, thus causing a poor bit synchronization. Also, some fast transitions in the teletext sequence will be degraded, thus creating errors.

Adjustments should be made at the transmitter to have, at a line-of-sight reception site, the amplitude of the 2T pulse higher than 70 IRE. Best results will be obtained when the amplitude is equal to or slightly greater than 100 IRE.

A multiburst test signal received at a line-of-sight site, which is smooth and not affected by overshoots, is also an excellent indication of good teletext service.

The two remarks above also apply to the quality of the signal picked up at the head-end of a cable network. Antennas and demodulators should be adjusted to obtain maximum 2T pulse amplitude and a smooth multiburst as illustrated in Fig. 8.1.

Those simple adjustments shall not only improve teletext reception but also the quality of the television image.

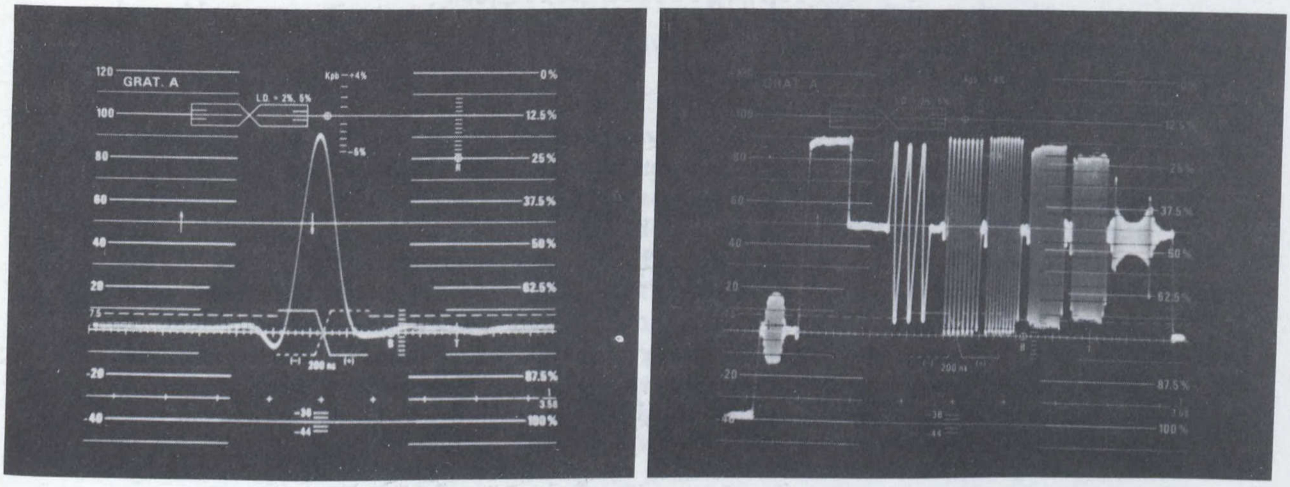


FIGURE 8.1: Example of the 2T Sine Squared and Multiburst Test Signals Received at a Line-of-sight Site from a Good Transmitter.

8.2 Teletext System Improvements

Some improvements to the teletext system are possible.

As discussed earlier, a more powerful error correcting code may be necessary for special applications to provide increased protection. To implement it, the software at both the teletext encoder and decoder must be modified.

For improvements of teletext signal on a cable network, a data regenerator can be installed at the head end. It is a teletext decoder and encoder combination. It decodes the teletext data at the beginning of the cable network where it should not be sufficiently distorted to cause incorrectable errors. The data are then corrected and encoded again and this new signal, now without distortion, is sent over the cable network.

Finally, the pulse shape recommended for teletext, a raised cosine pulse, was shown by simulation and analysis [12] to be about 1 dB less effective than the optimum pulse shape. This difference is probably too small to justify a change to the present pulse shape.

8.3 Teletext Decoder Improvements

The two teletext decoders used during the test are believed to be representative of what is available on the market now. Four possible improvements are discussed below.

First, the slicer level was investigated. In the decoders used, the level was set at the beginning of each line. The clock run-in sequence passes through a low-pass filter (270 khz) whose response is stable after approximately 12 bits. This voltage value is then frozen and used as the slicer level for the rest of the line. This procedure was modelled on a computer. The slicer level obtained with the model was compared with the slicer level which was found, also by simulation, to give the best bit error rate. For the 25 sites tested, the maximum difference between the two slicer levels was less than 3%. The present slicer setting technique is thus judged to be satisfactory for most signal conditions.

Second, the clock recovery circuit performance was examined. In many tests it was easy to see on the eye diagram that the sampling instant chosen by the decoder was not optimum. The sampling instant chosen is based on the clock run-in sequence. If the data is distorted by linear phase distortion then the phase of the data will be offset relative to that of the clock sequence. A solution to this problem is to implement an adaptive clock whose phase would be automatically adjusted to give the best bit error rate. It was noted earlier that a difference of up to 36.7 nsec. (.21 bit period) was once observed between the real sampling moment and the ideal one, i.e., at the moment when the eye is open at its maximum. The difference is greater than ±17.5 nsec. (±0.1 bit period) at about 20% of the sites measured in the Ottawa area.

Third, adaptive equalization would improve teletext signal reception. It would help solve the problems due to echoes found at some sites close to the center of cities or in the hills. Some echo characteristics observed during the tests could be useful for the design of such an equalizer. For example, when echoes are present, they typically have an amplitude between plus and minus 20 IRE and are less than .9 microseconds (5 bit periods) away from the main pulse. This can be observed in Fig. 8.2 which shows the maximum, the minimum and the average of all the impulse responses measured in the Ottawa region. The maximum values observed for all tests were -35 IRE and 1.3 microseconds (7.5 bit periods). These values do not change much between the different channels tested. In [9] a signal equalization of between -0.5 and +1.5 microseconds was judged to give an improvement.

Implementation of an equalizer may necessitate the addition of a training sequence to the teletext data. Or it may be possible to use the prefix as a training sequence if the equalizer is short. Self-training may also be a possibility.

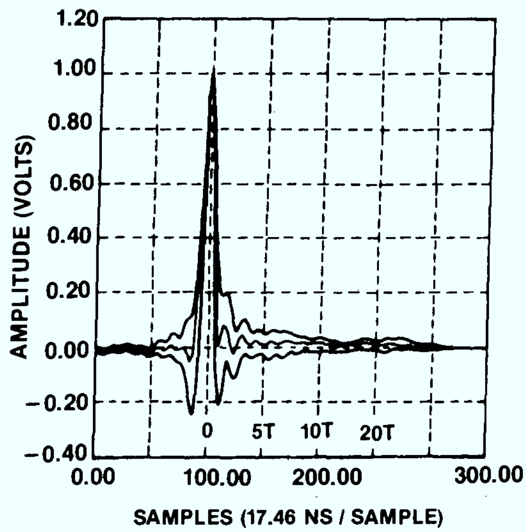


FIGURE 8.2: Maximum, Minimum and Average of all the Impulse Responses Measured in the Ottawa Region.

Finally, precapture is another technique which can improve teletext performance. Present teletext decoders can precapture one or two pages of information. This means that the decoder stores in its memory the pages which are the most probable next choices of the user. In this way a page can be processed and, if errors are detected, recalled again during the time that the user is viewing their present selection. The viewers will then get their next choice very quickly if it is among the pages precaptured. Ideally, all the teletext pages transmitted in a cycle could be stored in the decoder. In practice, a compromise should be reached between the size of the memory and the price of the decoder.

In conclusion, some improvements to television or teletext systems may be possible but not all are necessary. For example, adaptive equalization and extended precapture capabilities may be included in top-end models. Other improvements, such as adjustment to the transmitters, should be made to improve teletext service for all users.

9.0 ESTIMATION OF THE TELETEXT RECEPTION QUALITY

Based on observations made and on the experience gained during the field tests, two ways to estimate the teletext reception quality, based on the bit error rate, are suggested here.

9.1 First Method

The first procedure is a heuristic approach and should be adapted, by every person using it, to correspond to each particular situation and to their own experience.

Table 9.1 lists the suggested parameters which can be used. If more than 3 conditions in the same column are met, the bit error rate estimate given in this column can be expected.

TABLE 9.1: Estimation of the Bit Error Rate.

PARAMETER	VALUES			
2T Amplitude	<70 IRE	>90 IRE	>90 IRE	>90 IRE
SNR	<40 dB	>40 dB	>30 dB	>50 dB
Multiburst	Distorted	Smooth	Smooth	Distorted
CCIR Grade	<3.5	>3.5	>3.5	>3.5
Eye Height	<40%	>40%	>60%	>50%
Eye Symmetry	No	Yes	Yes	No
Estimated BER	10^{-4}	10^{-6}	10^{-6}	10^{-6}

Time did not permit checking this procedure against actual results. It is believed to provide a useful rough estimate for a fairly large proportion of the sites.

9.2 Second Method

A second way to predict error rate is based only on the data amplitude, the minimum eye height and the unweighted video SNR. This method is valid because all the factors that may affect the teletext signal will very often affect the eye height, and because white noise can be expected in the majority of cases. From [10] and [13] the bit error rate can be calculated:

$$BER = 1/2 \text{ erfc } (x)$$

where

$$\text{erfc}(x) \cong \frac{e^{-x^2}}{\sqrt{\pi}\, x} \left(1 - \frac{1}{2x^2} + \frac{1.3}{(2x^2)^2} + \frac{1.3.5}{(2x^2)^3}\right)$$

and $$x = \frac{h \times A}{2\sqrt{2}\sigma}$$

with $$h = \frac{\text{Minimum eye height in percent}}{100}$$

$$A = \frac{\text{Data amplitude in IRE ('1' average level)}}{100}$$

$$\sigma = \frac{1}{10^{\left(\frac{SNR}{20}\right)}} \qquad \text{(SNR in dB)}$$

The above calculation was done for 17 representative sites. For the sites where a bit error rate less than 10^{-5} was measured, the calculation predicted no error at all. The errors observed are then probably caused by impulsive noise and not only by gaussian noise.

When the measured bit error rate is greater than 10^{-4}, the calculations give a result which is 10 times greater than the measured value. This is because the calculation is based on the minimum eye height. In reality the eye is, for the majority of the time, greater than this minimum value, and so the bit error rate measured is better than the calculated one.

The calculated and the measured values do not correspond when a particular problem, such as very low 2T pulse amplitude, affect the signal at a site. This is because this kind of distortion probably affects the signal in a way that is not reflected in the eye height, but may affect the eye width or the overshoot levels, which are not taken into account in the calculation.

Even though it is not very precise, the calculation can be used to obtain a rough estimate of a bit error rate.

An intelligent use of the two methods given above should give a good estimate of the teletext reception quality to be expected at a site and, where necessary, an indication about the steps necessary to get better reception.

10.0 CONCLUSIONS

After a review of the basics of television and teletext signal parameters, the series of measurements taken across Canada on the characteristics of teletext channels were presented. These results showed that a very good teletext service can be expected at a majority of the sites. Based on observations made during the tests, some improvements were suggested and two ways to estimate the teletext bit error rate were proposed.

In conclusion, the teletext system used in Canada was shown to perform very well in the majority of the areas visited. The proposed improvements should solve most of the remaining problems.

All the data collected during the tests are still available to persons interested in studying the performance of television or teletext systems.

11.0 ACKNOWLEDGEMENTS

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The technician, Andre Martinelli, did almost all the measurements across Canada in the mobile laboratory. In the Ottawa region he was helped by Jean-Pierre Raymond who, with Tom Green, also contributed to the implementation of the measurement system. Tom was also responsible for the teletext data base development.

The engineers, Mario Bruneau, Gilles Gagnon, Lynton Hutchison and Ron Morley, contributed to this project by designing the equipment and the system software. Some Co-op students from universities and community colleges helped them in those tasks.

Some software was also developed, under contract, by the personnel of Miller Communications Systems. Some error statistics studied by Brian Mortimer and Michael Moore from Carleton University helped improve the measurement system. Discussions with Mike Sablatash, scientific adviser for Information Processing, helped define the goals and means of this project.

The project was initiated by J.R. Storey, now consultant in Broadcast Systems; directed by Andre Vincent, manager of Video Systems; and supported by E.A. Walker, formerly director of Radio Research, by R.G. Fujaros, acting director of Information Processing and by W. Sawchuk, deputy director-general of Informatics Systems.

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This document was proofread and reviewed by G. Gagnon, M. Sablatash, J.R. Storey and A. Vincent. It was typed by K.A. Kennedy.

Many thanks to everybody.

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