Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

PD8401E

PROJECT IRIS: EVALUATION OF TELETEXT SIGNAL RECEPTION ON CABLE TELEVISION SYSTEMS

LOUIS THIBAULT

JULY 1984

PLANNING AND DEVELOPMENT SECTION
CABLE TV ENGINEERING DIVISION

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1. INTRODUCTION

Project IRIS (Information Relayed Instantly from the Source) is the result of an agreement between the Department of Communications and CBC whereby CBC undertook to perform certain tests aimed at the possible introduction of national broadcast teletext services. The goals of Project IRIS are the following:

- to evaluate the degree of public receptivity to this new communications medium: teletext
- to demonstrate the feasibility of this new technology for the transmission of information
- to contribute to the development of the Canadian high technology industry

From the start of the project, significant variations in the quality of service have been reported by the different participants. Teletext signal decoders operated satisfactorily at certain locations, marginally at others and not at all at certain critical sites.

As in the case of field tests performed in the past by the Department of Communications, the Montreal program was organized with the following primary overall objectives:

1 - To evaluate the capacity of the network in question for distributing signals in keeping with Specification BS-14 (Ref. 1).
2 - To identify the components as well as the limiting factors that cause the deterioration of the teletext signal, or that affect the quality of its reception.

Secondary objectives particular to Project IRIS were also established:

3 - To identify the exact causes of reception problems at those locations which are considered critical.
4 - To make recommendations aimed at solving these problems.

The tests and measurements described in this report were carried out during the months of August and September 1983. A mobile unit was specially equipped for the purpose.

2. EQUIPMENT SET-UP AND PROCEDURES

2.1 Measurements

The quality of reception of a 5.72 Mbits/sec teletext signal was evaluated by means of the two following series of measurements:

a) Analog measurements

Photographs of pertinent signals were taken at various test points allowing the evaluation of the analog characteristics of the transmission channel. These signals were:

- teletext line
- expanded teletext line (synchronization burst)
- "Multiburst"
- 2T and 12.5T pulses
- expanded 2T pulse
- eye diagram
- amplitude vs frequency response
- group delay vs frequency response
- signal-to-noise ratio (S/N)
- maximum eye height (MEH)
- over and undershoots (OVS)

b) Digital measurements

- Bit Error Rate (BER)
- Line Loss Rate (LLR)

2.2 Bit error rate (BER) and line loss rate (LLR)

The equipment set-ups used to measure the bit error rate and the line loss rate are shown in Figure 2.1. The set-ups shown in Figures 2.1.a and 2.1.b were used at test points where the signal was RF and the set-up in Figure 2.1.c at test points where the signal was video. It is to be noted that the first two set-ups (a and b) yield similar results when fed with the same RF signal.

A Norpak MKIV decoder, identical to those used by Project IRIS subscribers, was used to measure the BER and the LLR. This model was equipped with a tunable demodulator (quasi-synchronous) which allowed it to work from an RF signal. In addition, the unit used in this study was modified to also accept a video signal at its input.

The MKIV decoder is equipped with a circuit capable of detecting a test sequence periodically inserted in the teletext signal carrying the visual information, and of counting various types of errors. Estimated BER and LLR values may be calculated from these error measurements. (Appendix A).

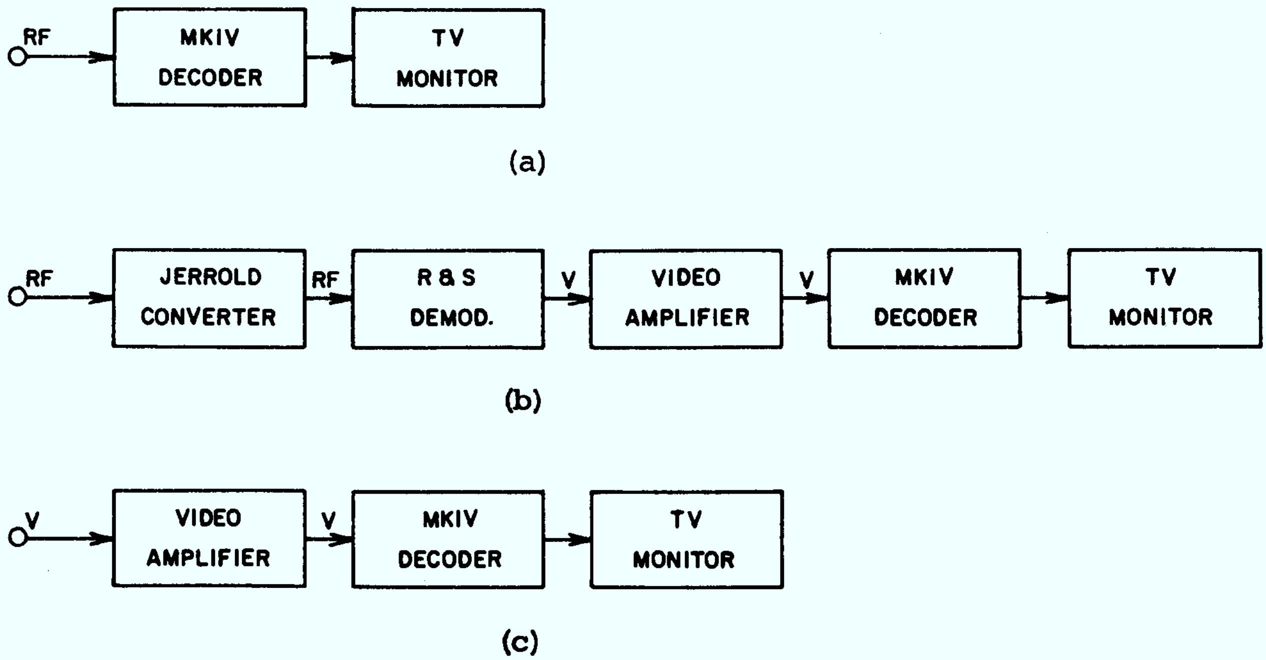


Figure 2.1: Equipment set-up for the measurement of bit error rate and line loss rate.

The bit error rate and the line loss rate are defined as follows:

$$\text{BER} = \frac{\text{no. of erroneous bits}}{\text{no. of decoded lines x no. of bits/line}}$$

$$\text{LLR} = \frac{\text{no. of lines transmitted - no. of lines decoded}}{\text{no. of lines transmitted}}$$

It should be noted from these definitions that lost lines do not enter into the bit error rate calculation.

2.3 **Signal-to-noise (S/N) and carrier-to-noise (C/N) ratios**

The video signal-to-noise ratio was measured using the set-up shown in Figure 2.2. The ratio (measured with an error of ± 2 dB) is obtained by dividing the level of the video reference signal (714 mvolts) by the rms value of the noise contained in a weighted 4 MHz band ("CCIR Weighting Filter" (Ref. 4)). The video S/N values thus obtained are, within 0.2 dB (Ref. 4), equal to the carrier-to-noise (C/N) ratio as defined in standard BP-23 (Ref. 5). In the remainder ot the text, the expression "carrier-to-noise" (C/N) will be used.

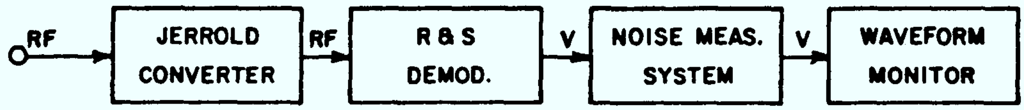


Figure 2.2: Equipment set-up for measuring signal-to-noise and carrier-to-noise ratios.

2.4 **Maximum eye height (MEH) and overshoots (OVS)**

Maximum eye height is calculated from photographs of the eye diagram obtained by using the set-up shown in Figure 2.3.a (for RF signal test points) or 2.3.b (for video signal test points). In these set-ups, the MKIV decoder was used to generate a 5.72 MHz clock synchronized with the teletext signal. The Jerrold cable converter (Figure 2.3.a) was used at test points presenting several RF channels.

The E.D.S. (Eye Diagram Synchronizer) is a device designed by the Department of Communications. When used in conjunction with a digital storage oscilloscope, it can produce eye diagrams of a clarity that is impossible to obtain by conventional methods.

Maximum eye height (MEH) is defined as:

$$\text{MEH} = \frac{(\text{lowest level of "1" - highest level of "0"}) \times 100}{(\text{"1" constant level - "0" constant level})}$$

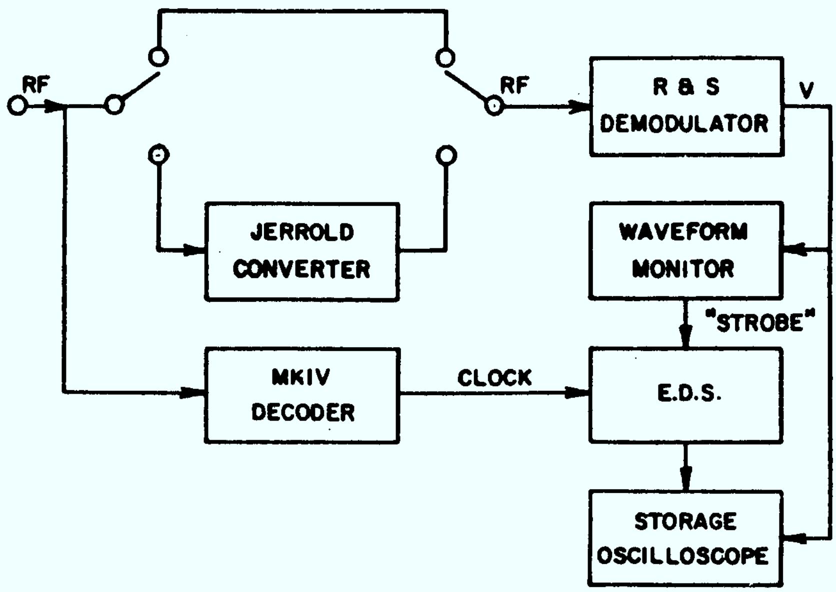
It is important to note the following limiting factors:

1) Estimating eye height from photographs introduces an error of ±3%.

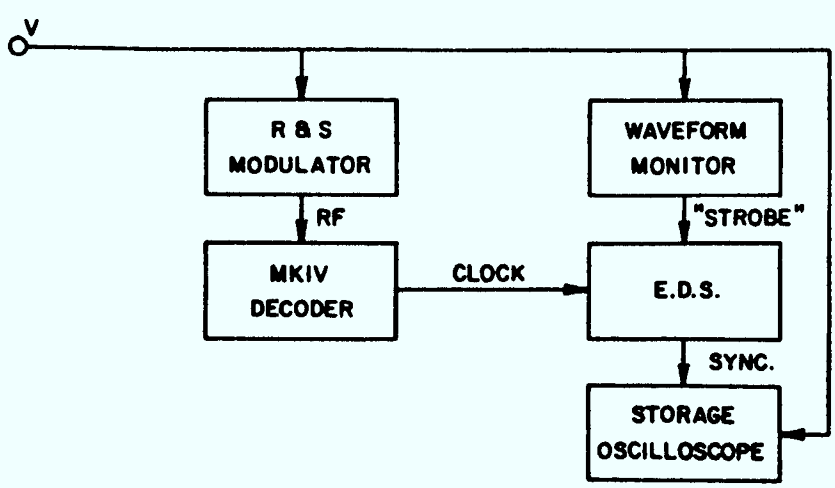
2) The eye height obtained in this manner can differ appreciably from the heights seen by the MKIV decoder at its sampling time. This is particularly true when the frequency content of the synchronization burst is subject to a significant group delay compared to the remainder of the frequency content of the teletext signal.

Maximum eye height is still a useful tool, however, for analysing distortion of teletext signals introduced by a transmission system.

The overshoots of the teletext signal which concern us most are those occurring under the "0 IRE unit" level and which are called undershoots. The decoder can confuse important undershoots with horizontal synchronization pulses, giving rise to data synchronization problems. The undershoots were therefore measured (in IRE units) from photographs of a complete teletext line.



a) RF signal test points



b) Video signal test points

Figure 2.3: Equipment set-up for eye diagram measurements

2.5 Amplitude response and group delay

The equipment set-up used for measuring amplitude response and group delay of various segments of the network under test is shown in Figure 2.4. Two types of apparatus were used depending on whether the input and output of the system being tested were physically separated (open loop measurement with a Wandel & Goltermann generator and receiver set) or physically close (closed loop measurement with a Shibasoku generator/receiver). A reference modulator and/or demodulator were used when the system to be tested had an RF input and/or output. The photographs of the frequency response curves were digitized and drawn by computer in order to make them easier to read.

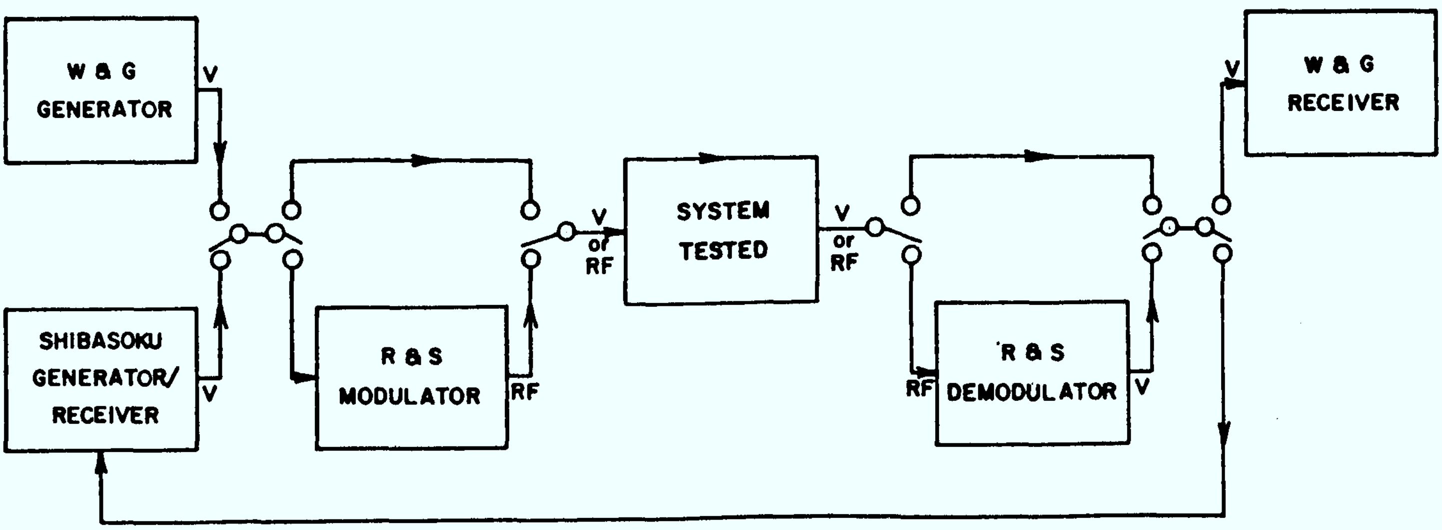


Figure 2.4: Equipment set-up for measuring amplitude response and group delay

2.6 Photographs of video signals

The equipment set-up used to obtain photographs of the various signals of interest (listed in section 2.1) is shown in Figure 2.5. The signals from baseband test points (V) were routed directly to the waveform monitor. A cable converter was used at test points giving access to several RF channels (N Channels) in order to prevent saturation of the reference demodulator input stage.

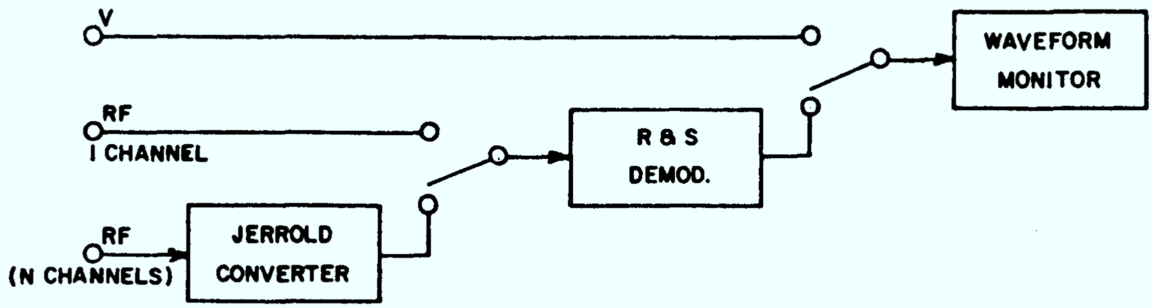


Figure 2.5: Equipment set-up used to photograph pertinent baseband signals

It is important to keep in mind that the results presented in this report represent the performance of the network as seen by the various measuring instruments used. Ideally, these instruments should be as transparent as possible so that any degradation of the teletext signal is only due to the network itself.

Figure 2.6 shows the equivalent baseband transfer function (amplitude response and group delay) of the reference demodulator utilized. The deviations of ±0.5 dB in amplitude and of ±10 nsec in group delay observed in the 0-3.5 MHz band (which contains most of the teletext signal energy) are representative of a very good quality demodulator.

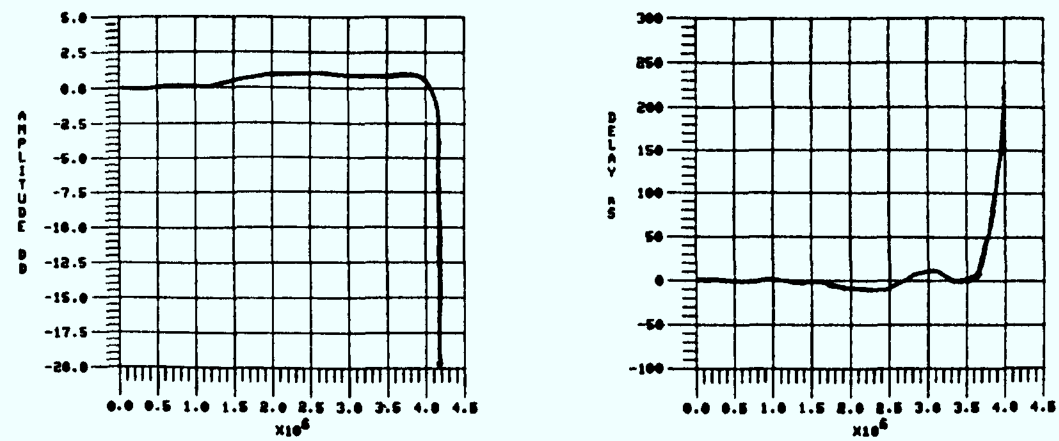


Figure 2.6: Transfer function of the R&S reference demodulator

Figure 2.7 shows eye diagrams for a computer simulated test-sequence. Figure 2.7.a shows the eye diagram of the sequence shaped by a Nyquist filter (100% roll-off) followed by a linear phase low-pass filter with a 4.0 MHz cutoff frequency. This sequence is filtered by the transfer function of Figure 2.6 and the result is shown in Figure 2.7.b. The maximum calculated eye height is 82% for Figures 2.7.a and 2.7.b: overshoots increase from 11% at the input to 15% at the output. Therefore, the distortion introduced by the reference demodulator is minimal.

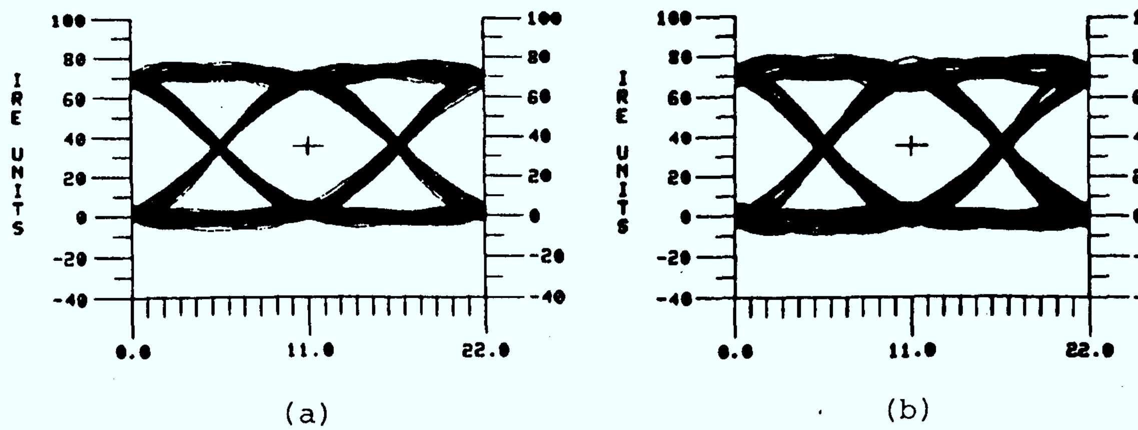


Figure 2.7: Eye diagram of a teletext test-sequence (computer simulated) at the input (a) and at the output (b) of an R&S reference demodulator.

Figure 2.8 shows the baseband equivalent transfer function of a Jerrold cable converter-R&S demodulator combination used to view the teletext signal at test points having several RF channels (i.e. on cable network distribution lines).

Figure 2.9 shows the distortion effect of this combination (Figure 2.9.b) on the eye diagram of a test-sequence filtered at 4.0 MHz applied to the input (Figure 2.9.a). The maximum eye height increases from 82% at the input to 85% at the output. Overshoots increase from 11% to 20%. Therefore, this combination tends to slightly increase the maximum eye height, and to a greater degree, the overshoots.

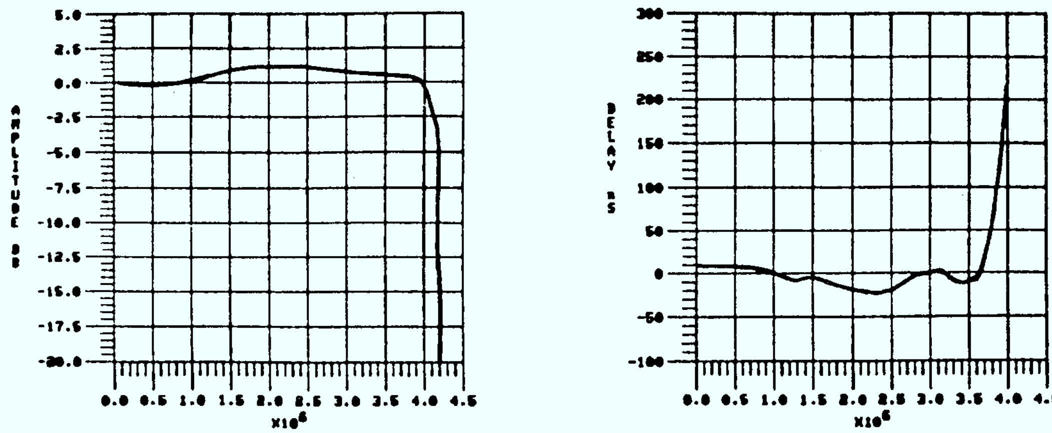


Figure 2.8: Transfer function of the Jerrold cable converter-R&S demodulator combination.

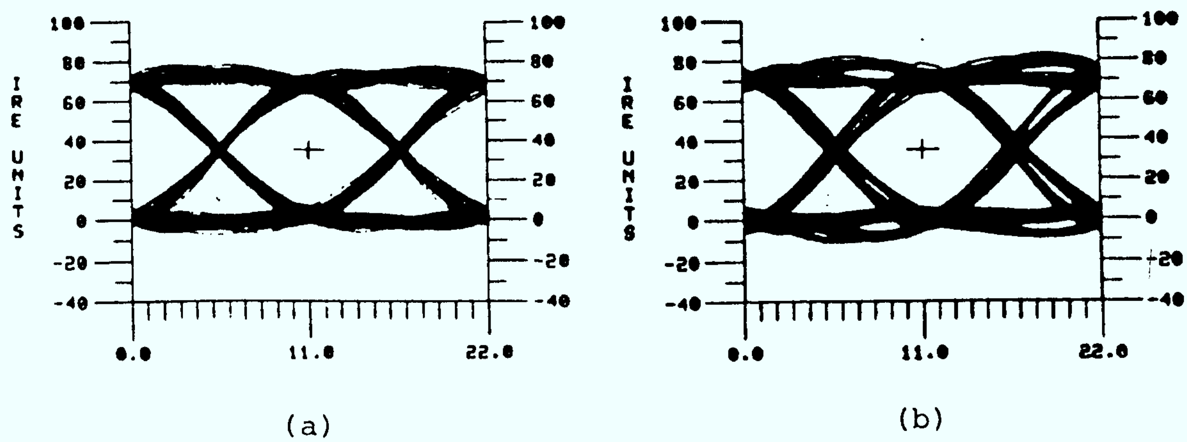


Figure 2.9: Eye diagram of a teletext test-sequence (computer simulated) at the input (a) and at the output (b) of a Jerrold cable converter-R&S demodulator combination.

2.7 List of Instruments Used

INSTRUMENT	MANUFACTURER	MODEL
modulator	Rohde & Schwarz	SBUF-E1
demodulator	Rohde & Schwarz	EKF2
eye height counter	Rohde & Schwarz	DZF
teletext decoder	Norpak	MKIV
waveform monitor	Tektronix	1480
digital oscilloscope	Tektronix	468
noise measuring system	Tektronix	1430
TV monitor	Tektronix	650HR
cable converter	Jerrold	400
sweep signal generator	Wandel & Goltermann	CDS-1 TFPS-42
sweep signal receiver	Wandel & Goltermann	LDE-1 SG-1
sweep signal generator/receiver	Shibasoku	201/1
video amplifier	DOC	-
eye diagram synchronizer (EDS)	DOC	-

3. DESCRIPTION OF THE NETWORK

This chapter describes the configuration of the network visited in Montreal. The installations of three organizations involved in Project IRIS were examined:

- CBC (The broadcaster)
  The organization responsible for the production of the information and the generation of the teletext signal. Measurements were taken at CBC's headquarters as well as at their Mount Royal transmitter site.

- Cablevision Nationale Ltée (Cable system no. 1)
  Cable distributer serving the eastern part of Montreal. Measurements were taken at the headend (split between two sites: Beaubien Street and Pie IX Street) as well as on two distribution lines.

- Cable TV (Cable system no. 2)
  Cable distributer serving the western part of Montreal. Measurements were taken at the headend only for reasons that will be given below.

The teletext signals of the French network (CBFT) and of the English network (CBMT) were evaluated at all test points.

3.1 Network Configuration

The plan of the network visited is shown in Figure 3.1. The paths followed by the teletext signal of the French (CBFT) and English (CBMT) signals are essentially the same except:

- the CBFT signal is generated at CBC's Montreal headquarters while the CBMT signal is generated in Toronto and transmitted to Montreal via a high quality link

- the CBFT signal is regenerated at the headend of cable system no. 1 while the CBMT signal is not.

After having been generated (or received), the teletext signal is inserted in lines 15, 16, 18 and 20 of the vertical blanking interval of the video program signal. This insertion is accomplished by a Tektronix model 149 (TP-2) generator/inserter. The resulting signal is then routed to the Mount-Royal transmitter via an FM (frequency modulated) link and broadcast on channel 2 for CBFT and channel 6 for CBMT.

These broadcast signals are received on antennas by the cable distributors. In the case of cable system no. 1, the RF (radio frequency) signal is first demodulated at headend site A; the CBFT teletext signal is then regenerated. After being transmitted to site B via an FM link, the baseband signal is remodulated on cable channel 4 for CBFT and on cable channel 13 for CBMT. Two distribution lines were visited: the first starts off right at site B via a combiner while the second is put on a

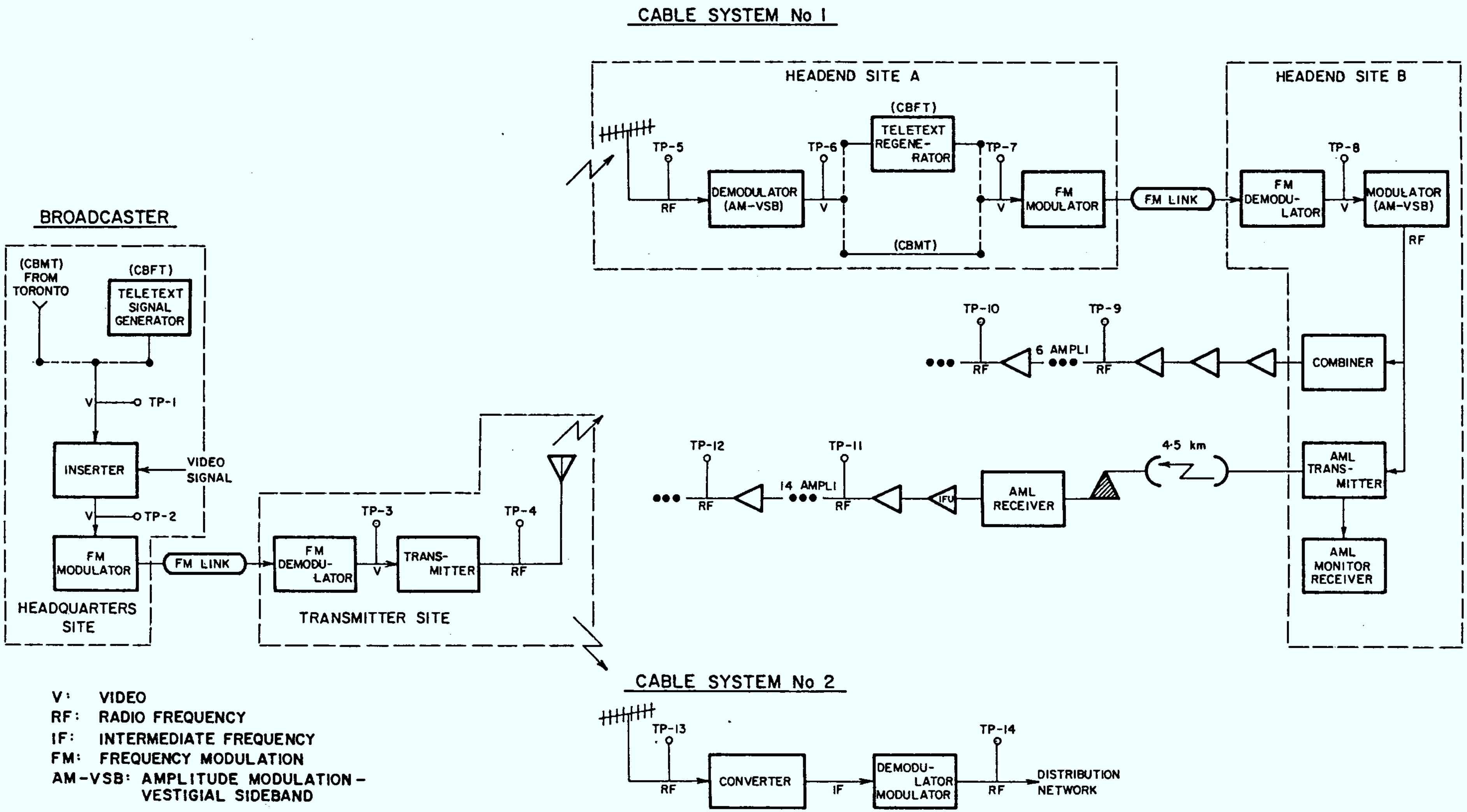


Figure 3.1: Network visited in Montreal

microwave link (AML). Two sites were chosen on each of these distribution lines: the first at the beginning of the line and another further down.

In the case of Cable TV (Cable system no. 2), measurements were taken only at the headend. The broadcast signal is first picked up by an antenna and then converted to IF (Intermediate Frequency) by a converter before being demodulated and remodulated on cable channel 4 for CBFT and on cable channel 13 for CBMT.

3.2 Description of the Test Points

The different measurement test points are identified on the network plan in Figure 3.1 by the letters TP (Test Point) followed by the number of the test point.

CBC

TP-1 :	Norpak generator output (CBFT) Toronto link output (CBMT)
TP-2 :	Tektronix 149 generator/inserter output
TP-3 :	Output of the FM demodulator on the Headquarters/Mount Royal link
TP-4 :	Transmitter output

Cablevision Nationale

TP-5 :	Receiving antenna output
TP-6 :	Output of the cable system demodulator
TP-7 :	Regenerator output (CBFT only)
TP-8 :	Output of the FM demodulator of the Beaubien-Pie IX link
TP-9 :	Output of the 3rd amplifier on the line starting at Pie IX
TP-10:	Output of the 10th amplifier on the line starting at Pie IX
TP-11:	Output of the first amplifier after the AML receiver
TP-12:	Output of the 16th amplifier after the AML receiver

Cable TV

TP-13:	Receiving antenna output
TP-14:	Output of the cable system modulator

4. <u>RESULTS</u>

4.1 Results of Digital Measurements

The results of the digital measurements taken at various test points are summarized in Table 4.1. The only two parameters evaluated at the broadcaster (TP-1 to TP-4) were maximum eye height (MEH) and overshoots (OVS) of the teletext signal.

The carrier/noise (C/N) ratio was measured only on distribution lines (TP-9 to TP-12) and all the test points located on these lines had an RF signal level higher than 0 dBmV. All numbers preceded by the symbol "<" in Table 4.1 indicate that no errors were detected during reception of a quantity of bits or lines equal to the inverse of the number.

The results appearing in this table will be commented on in chapter 5.

TEST POINT	CBFT					CBMT				
	C/N dB	MEH %	OVS IRE units	BER	LLR	C/N dB	MEH %	OVS IRE units	BER	LLR
TP-1 TP-2 TP-3	-	67	5	-	-	-	64	5	-	-
TP-4	-	65	10	-	-	-	66	10	-	-
TP-5	-	60	20	3E-4	1E-3	-	52	8	3E-4	1E-3
TP-6	-	60	10	-	-	-	47	5	6E-4	1E-3
TP-7	-	86	2	<1E-5	<3E-4	-	-	-	-	-
TP-9	42	67	15	3E-4	1E-3	41	60	10	4E-4	2E-3
TP-10	40	65	15	6E-4	3E-3	40	58	15	7E-4	3E-3
TP-11	44	67	20	3E-4	<3E-4	42	49	15	-	-
TP-12	42	64	22	6E-4	3E-3	40	51	18	7E-4	3E-3
TP-13	-	61	10	2E-4	1E-3	-	33	5	1E-4	6E-4
TP-14	-	49	15	1E-3	9E-4	-	16	2	2E-4	<1E-4

Accuracy: C/N = ±2, MEH = ±3, OVS = ±3 <u>N.B.</u> 1E-4 = 1×10^{-4}

Tableau 4.1 Results of digital measurements

4.2 **Performance objectives**

The overall quality of a service such as teletext can be evaluated from the time interval required to capture a page of given information. Unduly long intervals are caused by transmission errors and are highly dependent upon the quality of the decoder used (i.e. the degree of sophistication of its decoding strategy and the efficiency of the circuitry chosen to achieve that strategy).

By means of appropriate probability calculations, it is possible to translate these teletext service quality objectives into performance objectives related to data transmission, namely the bit error rate (BER) and the line loss rate (LLR). Appendix B contains the calculations which were used to evaluate the BER and LLR objectives taking into account the particular nature of the long bursts of errors produced by the decoder used in Montreal. These objectives, which apply only to this type of decoder, are:

$$BER < 10^{-3}$$
$$LLR < 10^{-3}$$

When met, these objectives guarantee excellent reception quality. They ensure, among other things, that a user will be successful in obtaining the page of information requested on the first try (i.e. with a waiting time less than the data base cycle time) 93 times out of 100, or more. These objectives are related to the decoder, which, however, must be fed with a sufficiently high quality teletext signal in order to meet them. The quality of the signal available to the subscriber is the responsibility of the cable distributor. This fact requires the determination of a set of performance objectives for the teletext signal at the subscriber's terminal.

The quality of signal required is also closely tied to the overall quality of the decoder used. In order to set down realistic specifications for the signal, it would be necessary to do a complete and systematic study to define limiting characteristics of the eye diagram (overshoots, height and width of eye, dissymetry) within which decoders generally available on the market would "feel comfortable". To the author's knowledge, such a study has not yet been done.

There is information available, however, (Ref. 2), which makes it possible to formulate partial objectives for the moment in terms of maximum eye height (MEH) and overshoots (OVS). It has been shown, (Ref. 2), that undershoots below -20 IRE units could affect the synchronization of the Norpak MKIII decoder (the MKIV is a more recent version) and that its operational limit is situated at about 30% eye height.

Considering the fact that the eye height seen by a decoder at the sampling time may be considerably lower than the MEH for unsymmetrical eye diagrams, the following performance objectives have been established for the teletext signal at the subscriber's terminal, once demodulated with the reference equipment described in chapter 2:

MEH : > 50%
OVS : < 20 IRE units
C/N : > 40 dB

The objective for C/N comes from BP-23 (Ref. 5) which specifies that the carrier/noise ratio for each of the received television channels must not be lower than 40 dB at any subscriber terminal.

5. DISCUSSION

This chapter is devoted to a discussion of the results obtained during the field trial. The approach taken in this chapter is to analyse the network in question, component by component, in order to highlight its strong and weak points. The network plan is shown in Figure 5.1 together with the eye diagrams measured at each test point. This Figure in itself summarizes the essential measurements. Frequent reference will be made to it in the discussion that follows.

5.1 The Broadcaster CBC

- Teletext signal generator

CBFT's teletext signal is unsymmetrical at the output of the generator (TP-1) as shown by Figure 5.1: the constant level of "1" deviates more from the eye's pupil than does the constant level of "0". This anomaly is produced within the generator by the shaping filter whose output is shown in Figure 5.2.b before filtering at 4.2 MHz (Figure 5.2.c). The effect of this lack of symmetry is to reduce the MEH measured at TP-1 to 67%: this is a low value for the output of a generator.

The same comments can be made about the CBMT teletext signal received from Toronto which has a MEH of only 64% at TP-1 (Figure 5.1). A height of 80% or more is desirable at this location.

Another anomaly at TP-1 is highlighted by Figure 5.3. The CBMT teletext signal level (Figure 5.3.b) has a nominal amplitude less than that of CBFT by 15 IRE units (Figure 5.3.a). CBMT's signal is thus more susceptible to detection errors caused by the additive noise of the transmission channel.

- FM link

The FM link between CBC headquarters and the Mount Royal transmitter is transparent for both channels as shown by the test signals of Figures 5.4 and 5.5 which were photographed at the output of the link (TP-3). These test signals were generated at headquarters by a Tektronix 149 inserter for each of the two channels. Since no distortion was produced from TP-1 to TP-3, the same eye diagram was used for these three points in Figure 5.1.

- Transmitters

The eye diagram measured at the output of the channel 2 (CBFT) transmitter (TP-4) is shown in Figure 5.1, after demodulation by the R&S reference demodulator. The eye diagram does not suffer any significant distortion between TP-3 and TP-4: the eye height remains approximately constant (67% at TP-3 and 65% at TP-4) and the symmetry of the eye is maintained. Figure 5.6, which shows the transfer function (amplitude response and group delay) of the channel 2 transmitter-demodulator combination, justifies this observation. In fact, the amplitude response curve hardly deviates more than ±0.5 dB from a constant average value and

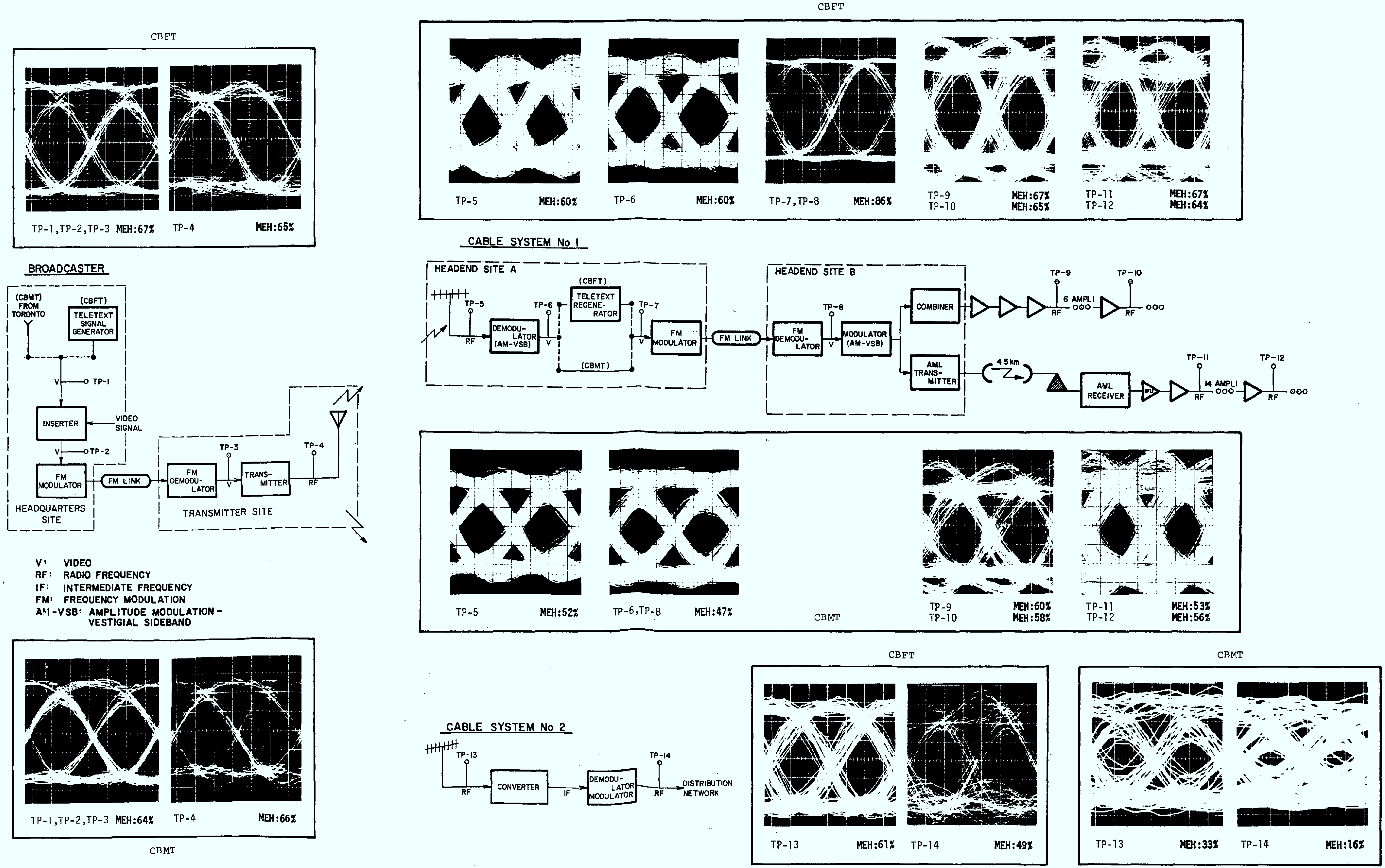


Figure 5.1 Eye diagrams measured on the Montréal network

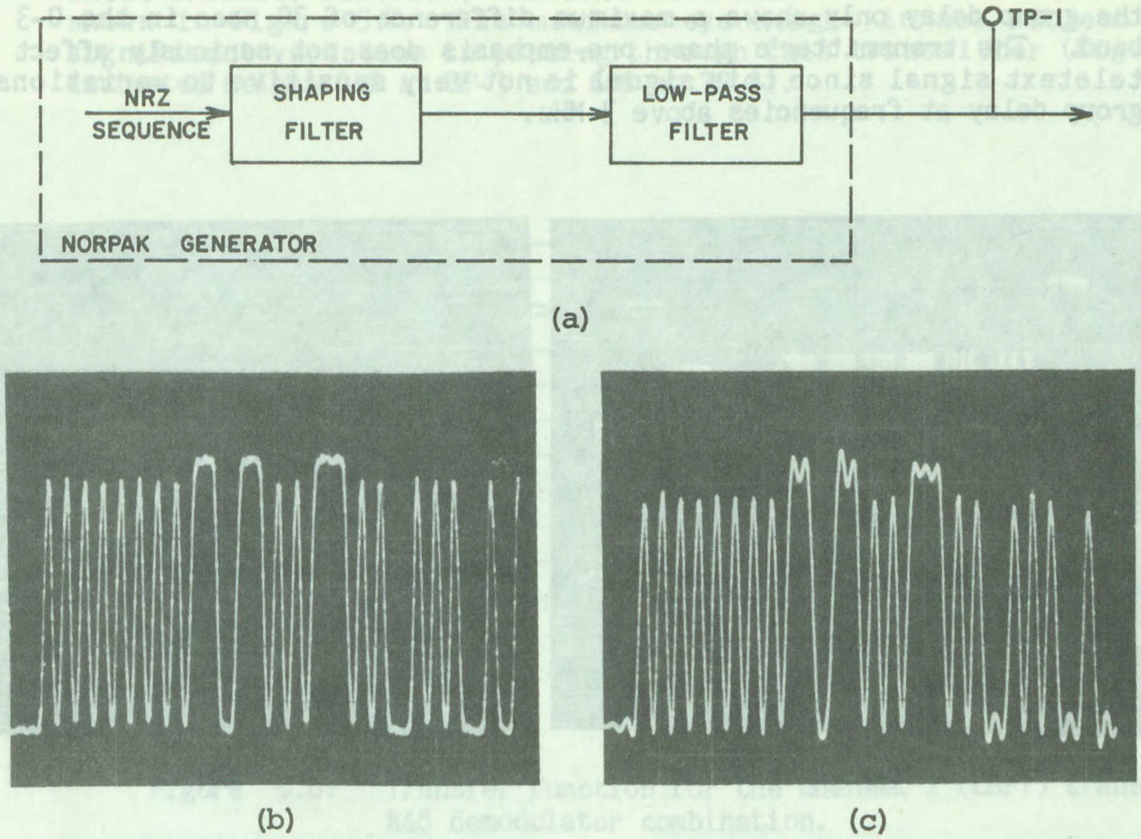


Figure 5.2: Output of the Norpak generator (CBFT) shaping filter (b) and low pass filter (c).

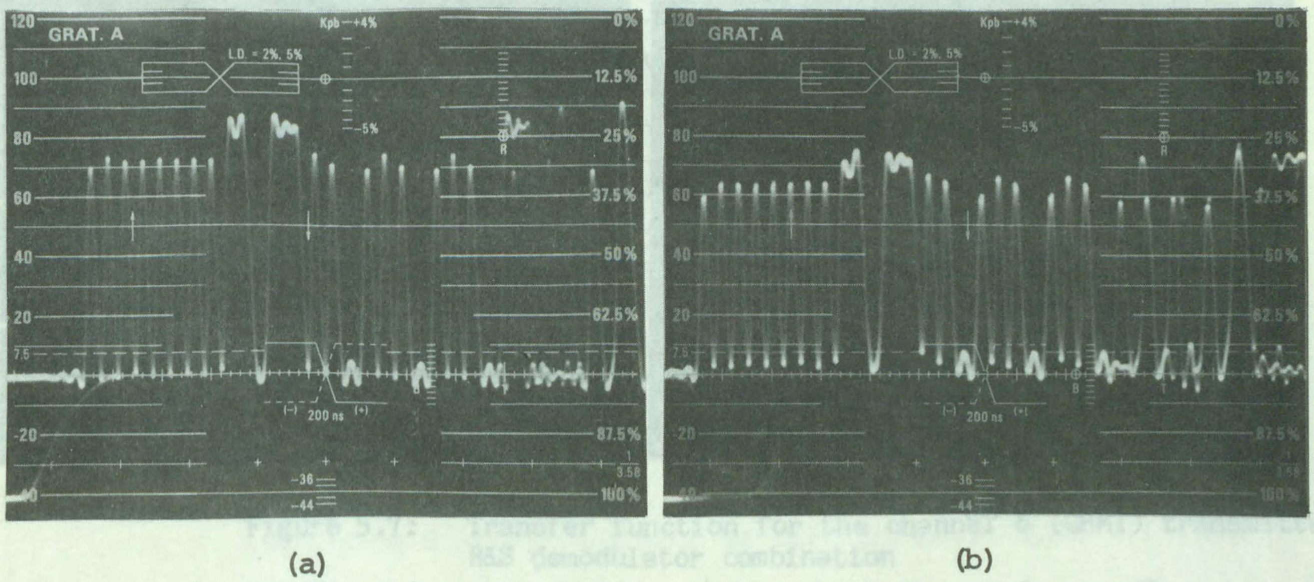
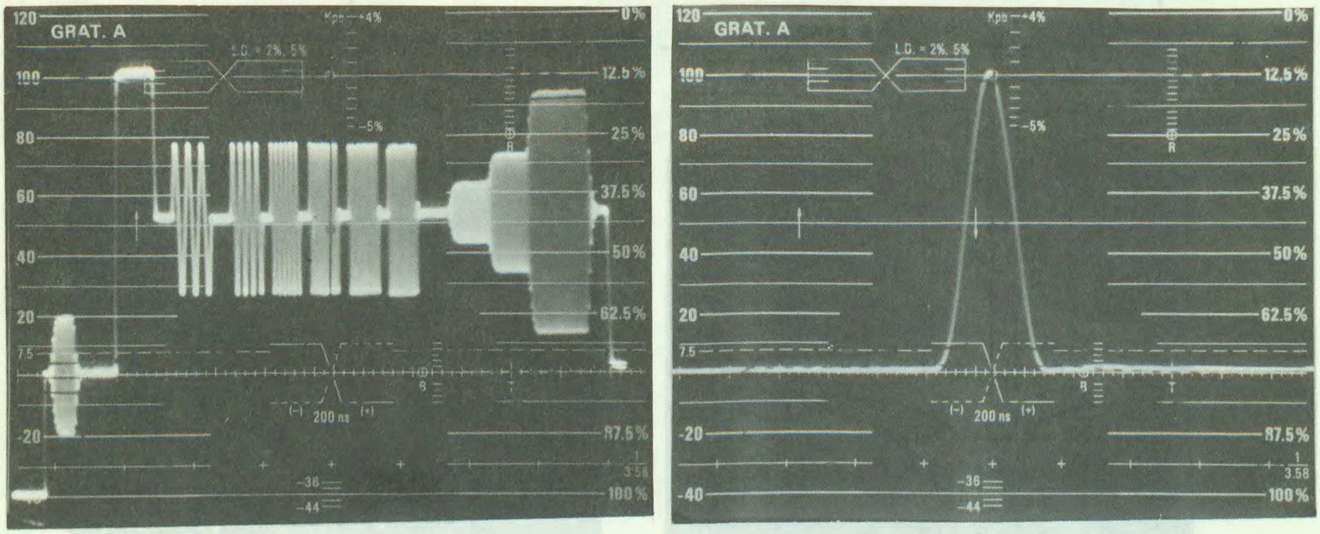


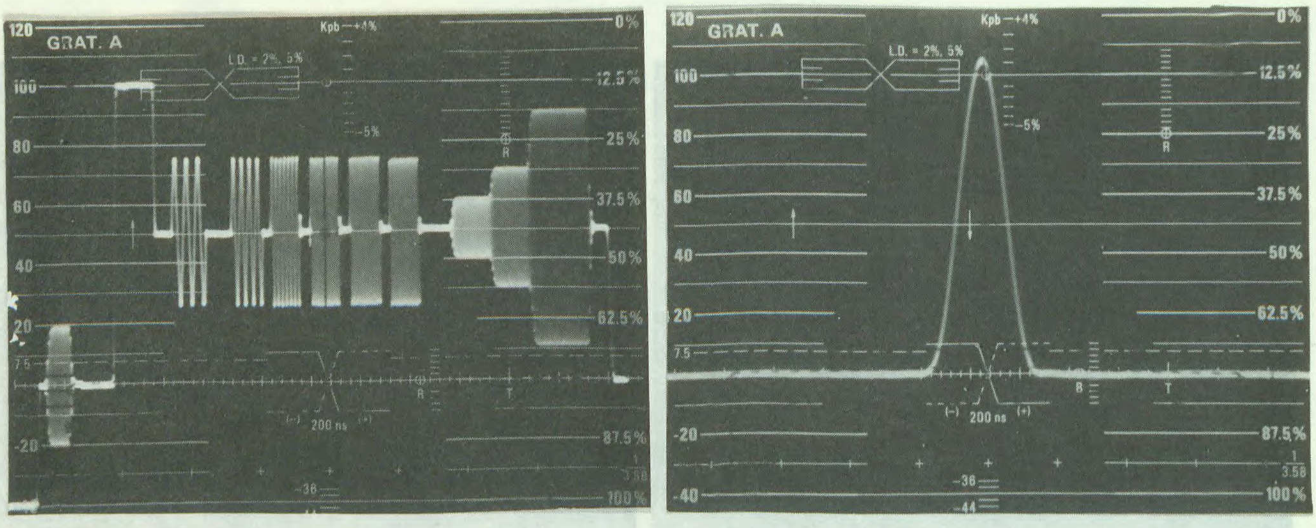
Figure 5.3: Beginning of a CBFT (a) and a CBMT (b) teletext line at TP-1.

the group delay only shows a maximum difference of 30 nsec in the 0-3 MHz band. The transmitter's phase pre-emphasis does not seriously affect the teletext signal since this signal is not very sensitive to variations in group delay at frequencies above 3 MHz.



(a) (b)

Figure 5.4: Test signals (a: Multiburst and b: 2T pulse) measured at the output of the FM link (TP-3) for CBFT



(a) (b)

Figure 5.5: Test signals (a: Multiburst and b: 2T pulse) measured at the output of the FM link (TP-3) for CBMT

The same observations apply to the transmitter for channel 6 (CBMT), whose transfer function, combined with that of the R&S demodulator, is shown in Figure 5.7. The maximum eye height is not subject to any significant variation in passing through this transmitter (Figure 5.1, estimated height 64% at TP-3 and 66% at TP-4).

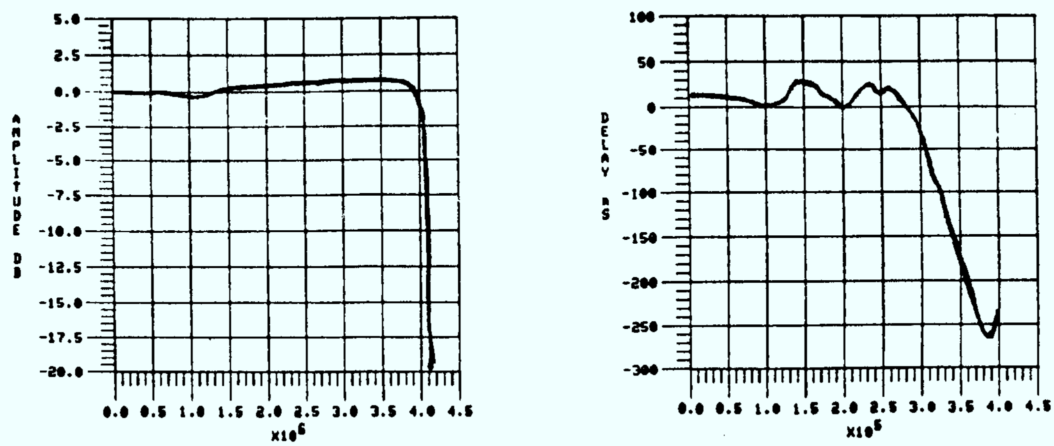


Figure 5.6: Transfer function for the channel 2 (CBFT) transmitter-R&S demodulator combination.

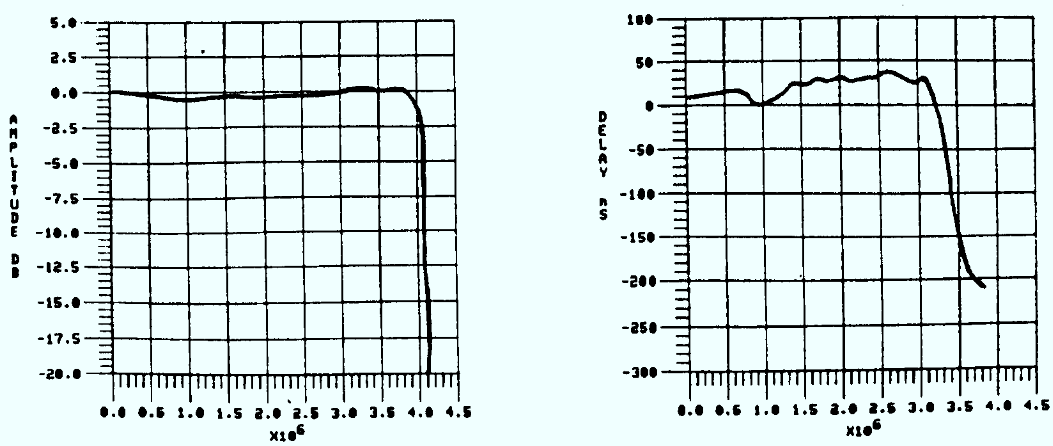


Figure 5.7: Transfer function for the channel 6 (CBMT) transmitter-R&S demodulator combination

5.2 **Cable System No. 1 (Cablevision Nationale)**

- Broadcast signal reception

The first test point (TP-5) on this cable distribution network enables us to evaluate the quality of the broadcast link by comparing the test signals measured at TP-4 and TP-5 with the same reference demodulator.

In the case of CBFT, the eye diagram obtained at TP-5 (Figure 5.1) is unsymmetrical and shows more pronounced overshoots than at TP-4. The maximum eye height of 60% indicates an acceptable decrease of 5% in MEH between the antennas. A significant undershoot of the 2T trailing edge at TP-5 (Figure 5.8.b) is characteristic of a delay of the high frequencies with respect to the low frequencies, that is of a group delay curve that increases in value with frequency. A comparison of the Multiburst signal at TP-4 and TP-5 (Figure 5.8) indicates an appreciable gain at high frequencies (> 2MHz).

In the case of CBMT, a considerable drop of 14% in the MEH occurred in the brodcast link resulting in an eye diagram with a height of 52% at TP-5 (Figure 5.1). A comparison of the 2T pulses at TP-4 and TP-5 indicates no anomaly in the group delay between these two points (Figure 5.9). However, the Multiburst signal at TP-5 (Figure 5.9) indicates attenuation of the high frequencies (> 2 MHz) in the broadcast link which has the effect of closing the pupil of the eye and of reducing the MEH as well as the overshoots.

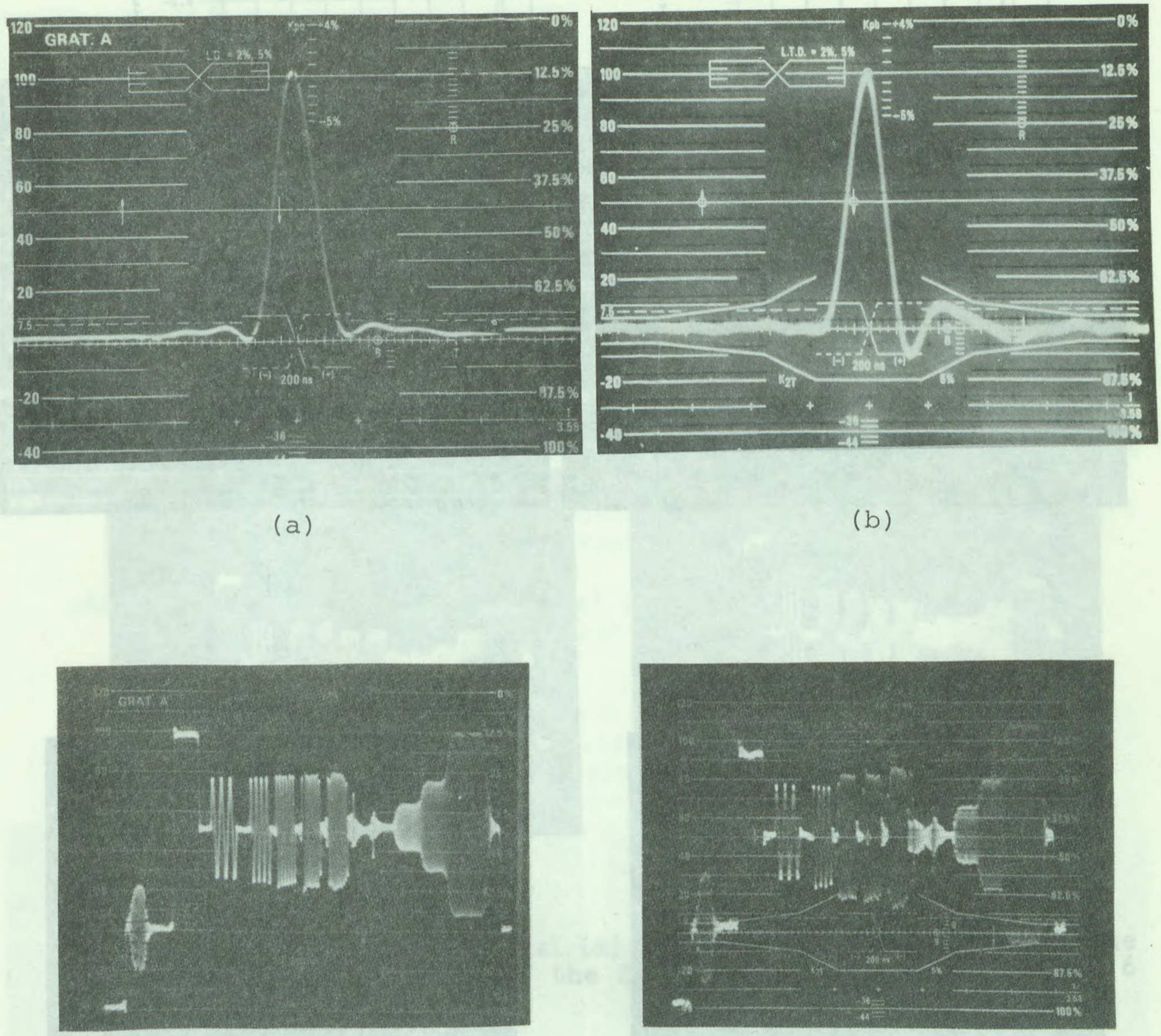
- Cable distribution network demodulators

At TP-6, the cable distribution network demodulator for CBFT (RCA model CTD-1 with synchronous detection) produced a symmetrical eye diagram with an MEH of 60% (Figure 5.1). This value is acceptable at this point since the teletext signal will be regenerated at site A. The demodulator group delay shown in Figure 5.10 compensated for the eye dissymetry observed at TP-5 and produced by the antennas.

The CBMT demodulator (identical model to CBFT's) for its part added 5% to the 14% decrease of MEH observed at TP-5: the resulting eye height of 47% at TP-6 (Figure 5.1) is considered too low for a non-regenerated signal at the headend. The Multiburst signal measured at the input and the output of this demodulator (Figure 5.11) indicates that it slightly attenuated the high frequencies and closed the pupil of the eye by the above mentioned 5%.

- CBFT teletext signal regenerator

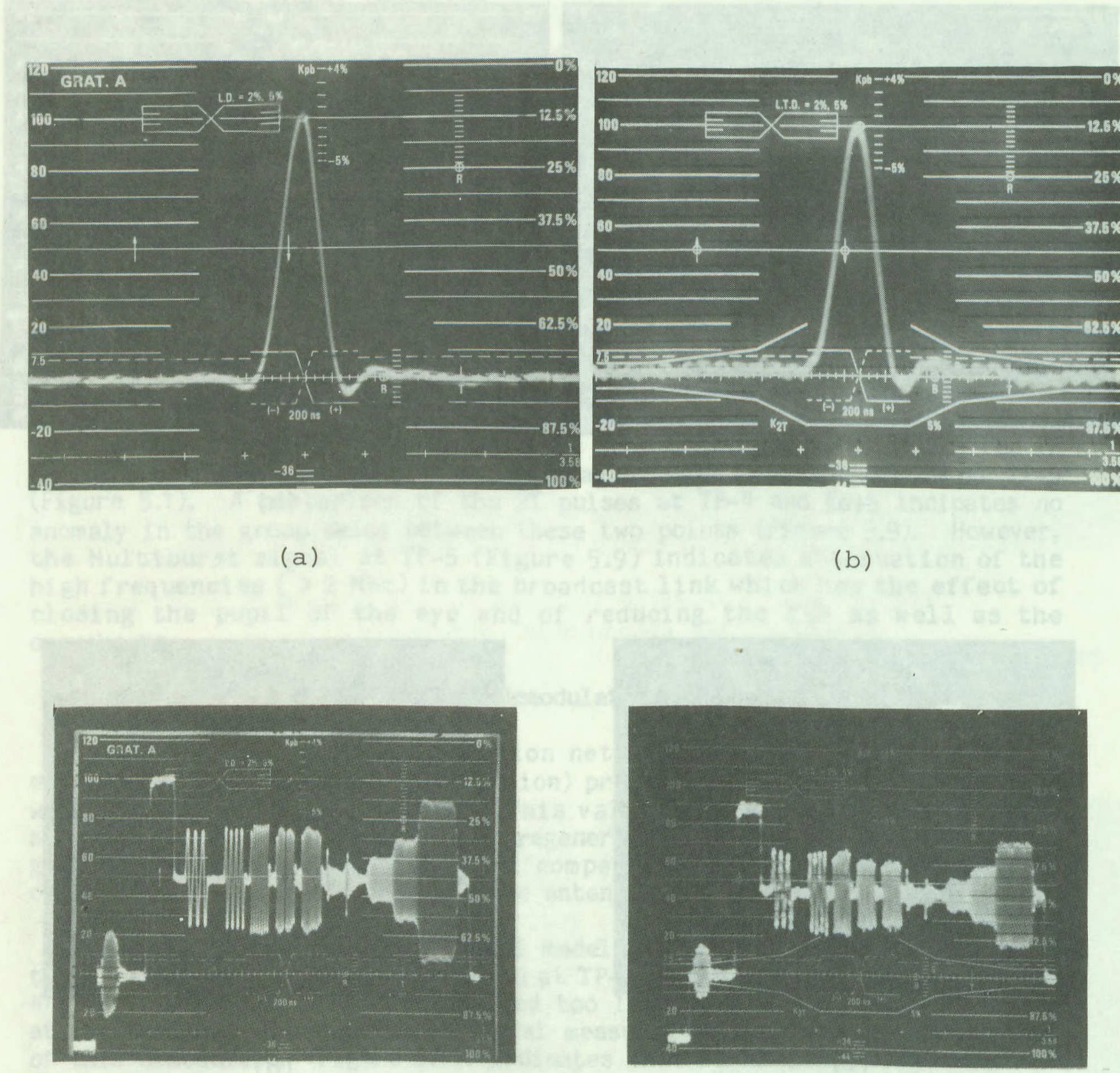
The French network teletext signal is regenerated at TP-7. The resulting eye diagram is shown in Figure 5.1 and has an MEH of 86%, which is an acceptable value at the output of a regenerator. However, it must be mentioned that this signal is not filtered at 4.2 MHz as recommended in BS-14 (Ref. 1). This filtering will be done by the site B modulator.



(a) (b)

(c) (d)

Figure 5.8: Test signals measured at TP-4 and TP-5 for CBFT (a: 2T at TP-4, b: 2T at TP-5, c: Multiburst at TP-4 and d: Multiburst at TP-5)



(a) (b)

(c) (d)

Figure 5.9: Test signals measured at TP-4 and TP-5 for CBMT (a: 2T at TP-4, b: 2T at TP-5, c: Multiburst at TP-4 and d: Multiburst at TP-5).

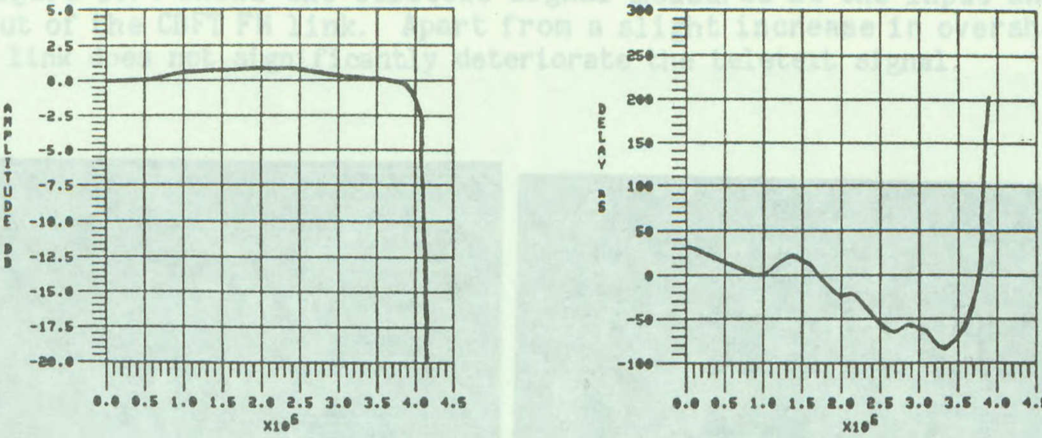
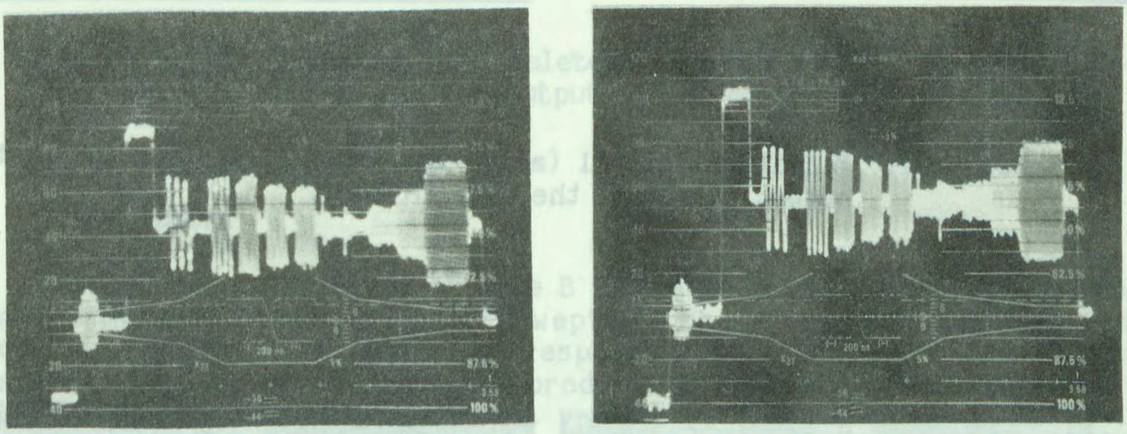


Figure 5.10: Amplitude response and group delay for RCA CTD-1 demodulator on channel 2 (CBFT).

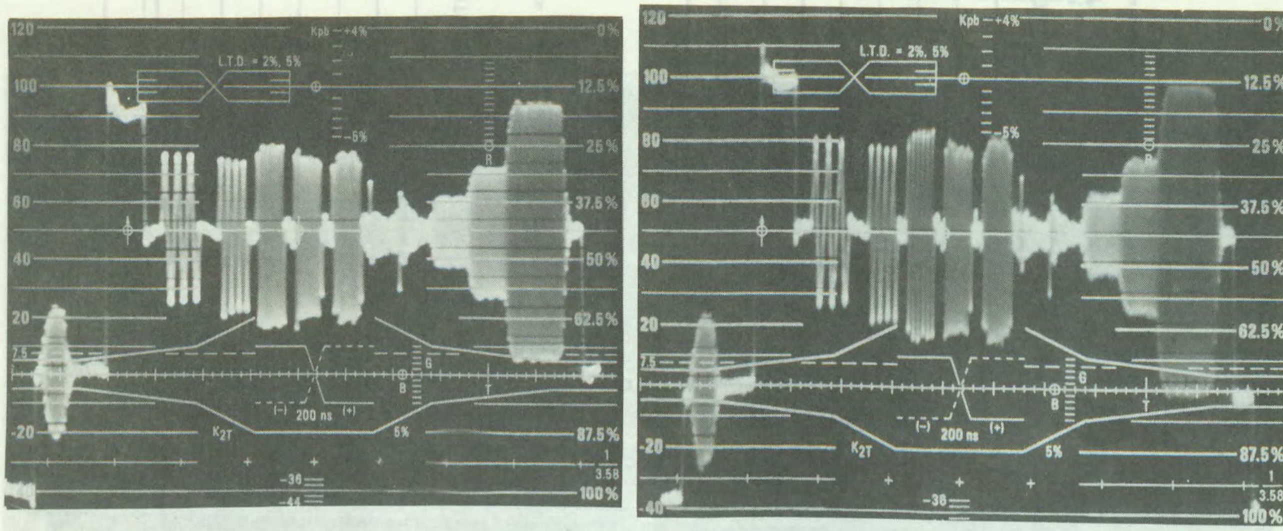


(a) (b)

Figure 5.11: Multiburst signal (a) at the input (TP-5) and (b) at the ouput (TP-6) of the RCA CTD-1 modulator on channel 6 (CBMT).

- FM link (between sites A and B)

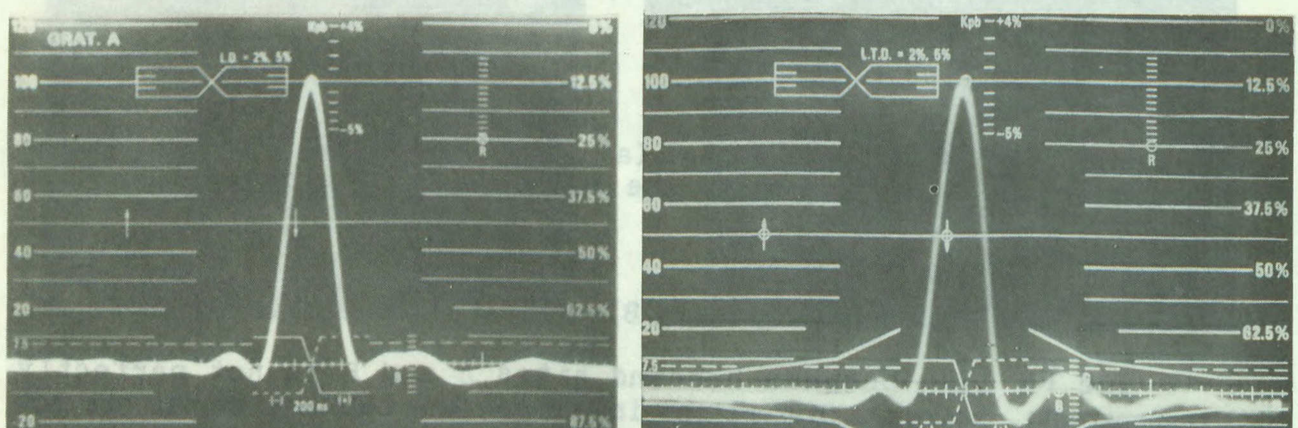
The FM link between headend sites A and B is not perfectly transparent: however, distortions induced on the teletext signal are not significant. Examination of the photographs of Figure 5.12, which shows a Multiburst signal at the input and at the output of the FM link, indicates that the amplitude response of this link is relatively flat in the video band. However, an examination of Figure 5.13 shows that this is not the case for group delay: the presence of undershoot at the end of the 2T trailing edge at TP-8 indicates a delay of the high frequencies.



(a)

(b)

Figure 5.12: Multiburst signal (a) at the input (TP-7) and (b) at the output (TP-8) of the CBFT FM link.

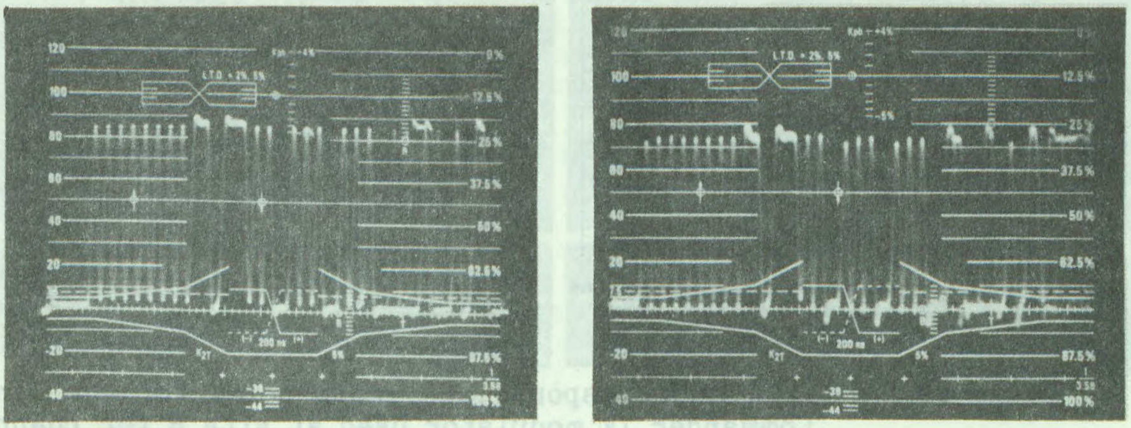


(a)

(b)

Figure 5.13: 2T pulse (a) at the input (TP-7) and (b) at the output (TP-8) of the CBFT FM link.

Figure 5.14 shows the teletext signal measured at the input and the output of the CBFT FM link. Apart from a slight increase in overshoots, this link does not significantly deteriorate the teletext signal.



(a) (b)

Figure 5.14: Beginning of a teletext sequence (a) at the input (TP-7) and (b) at the output (TP-8) of the CBFT FM link.

- Modulators

Jerrold modulators used at site B for cable channel 4 (CBFT) and cable channel 13 (CBMT) were frequency swept and their transfer functions are shown in Figure 5.15 and 5.16 respectively. The most significant distortion of the teletext signal produced by these modulators is due to group delay which shows significant variations (in the order of 80 to 120 nsec) in the 0-3 MHz band where the teletext energy is concentrated. Amplitude response, however, is relatively flat in the same band for both modulators. In spite of these variations, the frequency response of both modulators meets the requirements of BP-23 (Ref. 5).

The CBFT modulator, whose output (TP-9) was demodulated using the reference equipment, introduced a significant increase in overshoots and a decrease of 19% in eye height from TP-8 to TP-9 (Figure 5.1). However, part of this decrease (5 to 10%) must be attributed to the low pass filtering effect (at 4.2 MHz) of the modulator on the regenerated teletext signal; the remainder is attributable to the less-than-ideal characteristics of the modulator's transfer function.

In the case of CBMT, the combined effect of the modulator and the reference demodulation equipment was to increase both the overshoots and the MEH which went from 47% at TP-8 to 60% at TP-9 (Figure 5.1). In this case, the less-than-ideal characteristics of the modulator had a beneficial effect on the eye height.

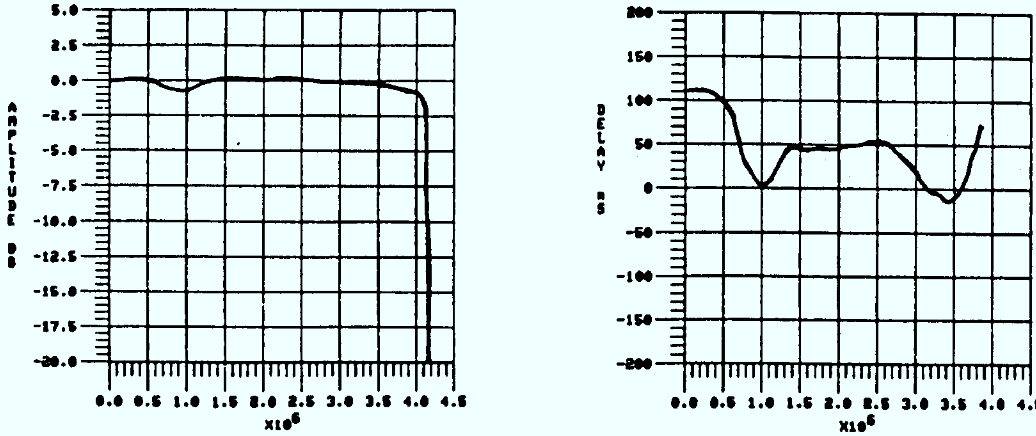


Figure 5.15: Amplitude response and group delay for the Jerrold Commander IV modulator used at site B for channel 4 (CBFT).

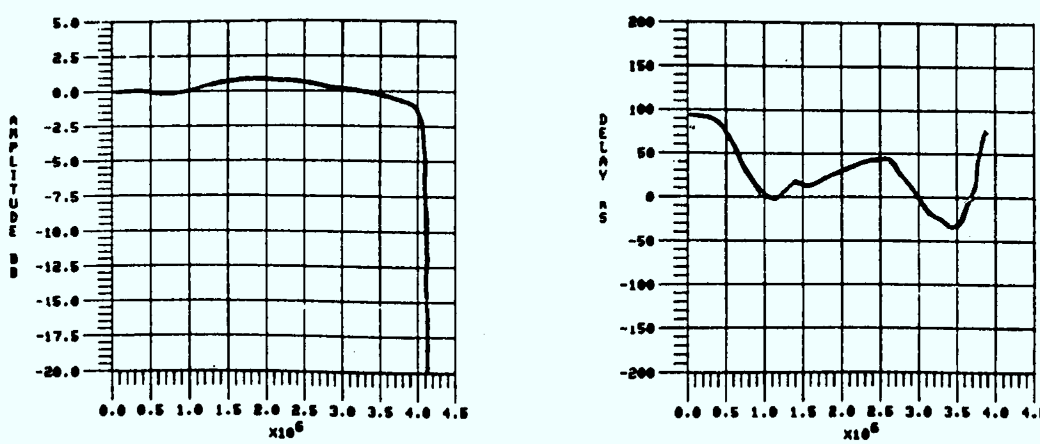
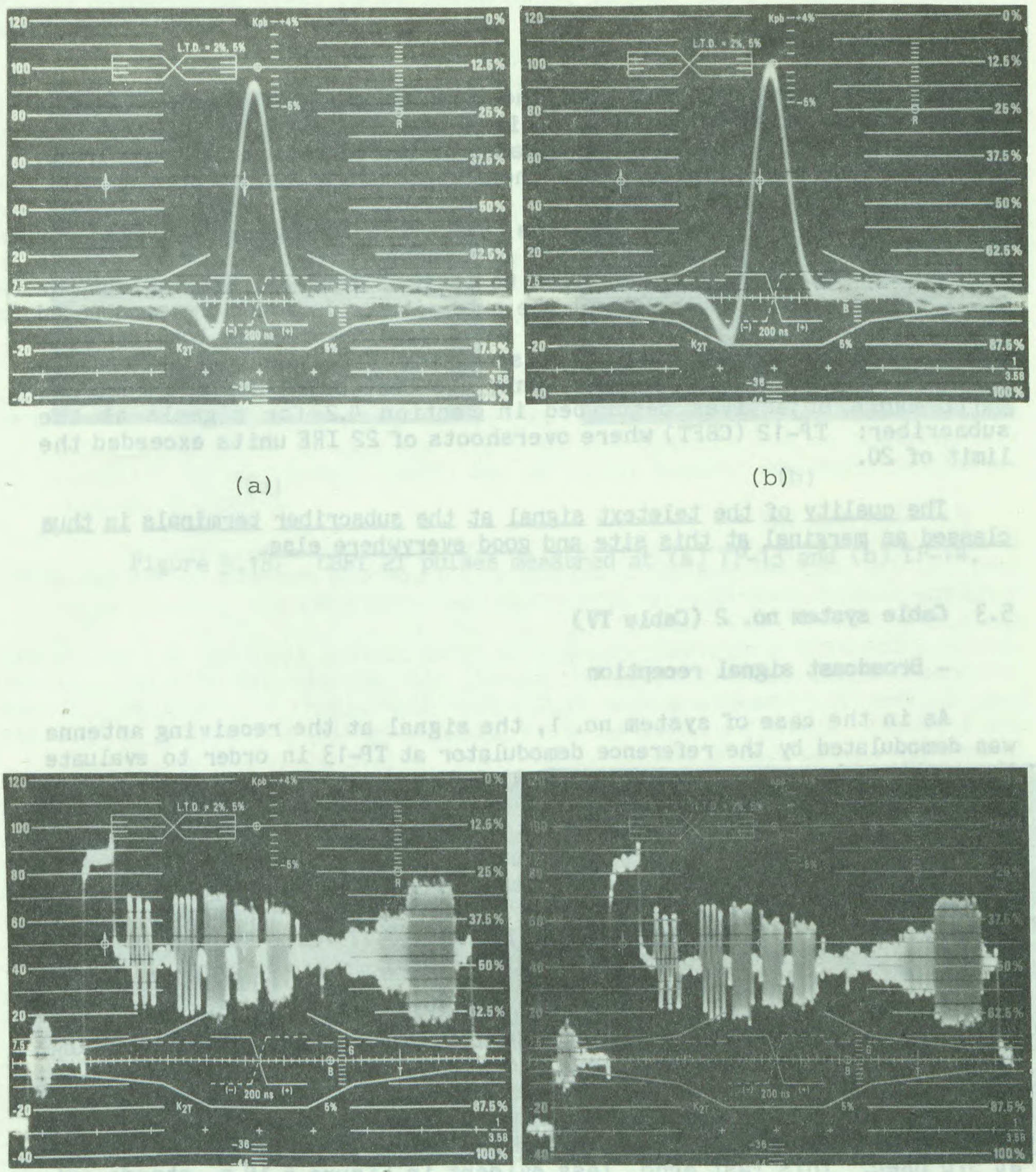


Figure 5.16: Amplitude response and group delay for the Jerrold Commander IIIA modulator used at site B for channel 13 (CBMT).

- AML Link

The AML link is considered transparent for both CBFT and CBMT. The similarity of the eye diagrams measured at TP-9 and TP-11 (Figure 5.1) shows that the AML link is transparent to these two channels. However, it should be noted that in the case of CBMT, there is a difference of 7% between the MEH measured at TP-9 (60%) and that measured at TP-11 (53%). This difference is a result of the fact that the time and intensity of exposure of the eye diagram were greater at TP-11 than TP-9. The longer the exposure time the more the eye diagram tends to close. The transparency of the CBMT AML link is confirmed by the similarity of the 2T and Multiburst test signals measured at TP-9 and TP-11 (Figure 5.17)



(a) (b)

(c) (d)

Figure 5.17: Test signals measured at TP-9 and TP-11 for CBMT (a: 2T at TP-9, b: 2T at TP-11, c: Multiburst at TP-9 and d: Multiburst at TP-11).

- Distribution lines

No significant degradation of the teletext signal is produced by the transmission lines. This fact is highlighted by Figure 5.1, where the differences in MEH between points located on the same line (TP-9 and TP-10, TP-11 and TP-12) are only 2 to 3%: these differences are not significant.

Because it was regenerated, the CBFT teletext signal displayed MEH values (64-67%) higher than its CBMT counterpart (53-60%) at test points located on distribution lines (TP-9 to TP-12). These points reflect the quality of the signal available at the subscriber. In addition, pronounced overshoots varying from 10 to 22 IRE units were observed on both channels (see table 4.1). All the carrier/noise ratios (C/N) measured met or even exceeded the 40 dB requirement. Only one test point did not meet the performance objectives described in section 4.2 for signals at the subscriber: TP-12 (CBFT) where overshoots of 22 IRE units exceeded the limit of 20.

The quality of the teletext signal at the subscriber terminals is thus classed as marginal at this site and good everywhere else.

5.3 Cable system no. 2 (Cable TV)

- Broadcast signal reception

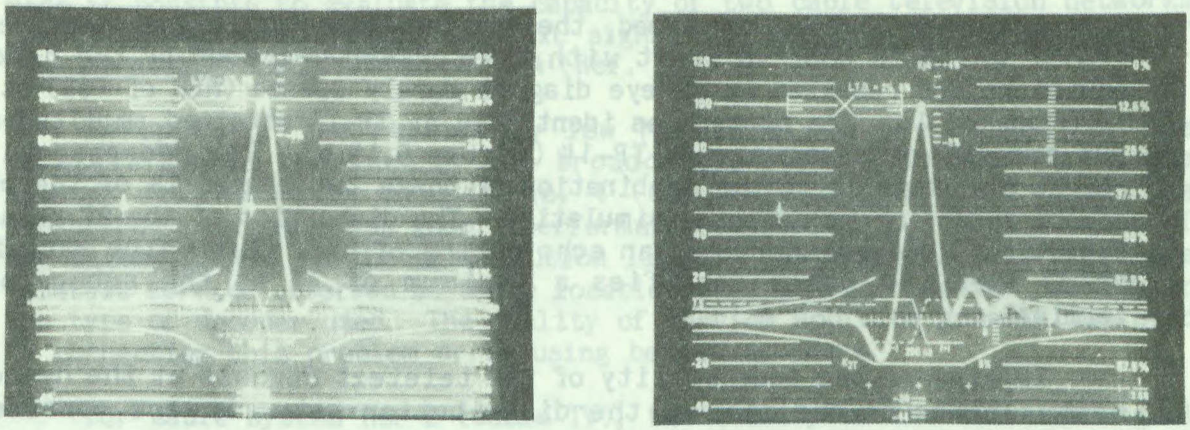
As in the case of system no. 1, the signal at the receiving antenna was demodulated by the reference demodulator at TP-13 in order to evaluate the quality of the broadcast link (TP-4 to TP-13).

The eye diagram generated at TP-13 in the case of CBFT is shown in Figure 5.1: its MEH of 61% (compared to 65% at TP-4) as well as its shape, which is very similar to that measured at TP-4, indicate good broadcast signal reception for this channel. This is also confirmed by the appearance of the 2T pulse at TP-13 (Figure 5.18.a) which is very similar to that of the 2T measured at TP-4 (Figure 5.8.a).

The eye diagram produced by the reference demodulator at TP-13 for CBMT (Figure 5.1) suffered severe degradation (MEH of only 33%) indicating very poor quality broadcast signal reception for teletext. The 2T pulse measured at this test point is shown in Figure 5.19.a. Two positive echoes appear: the first one situated at 325 nsec after the centre of the 2T and having an amplitude of 10% (-20 dB) and the second of 5% amplitude (-26 dB) at 570 nsec. This last echo, less evident in Figure 5.19.a, stands out more in Figure 5.19.b where its effect has been amplified. By computer simulation, we were able to evaluate the decrease in eye height caused by the cumulative effect of these two echoes as being close to 20%.

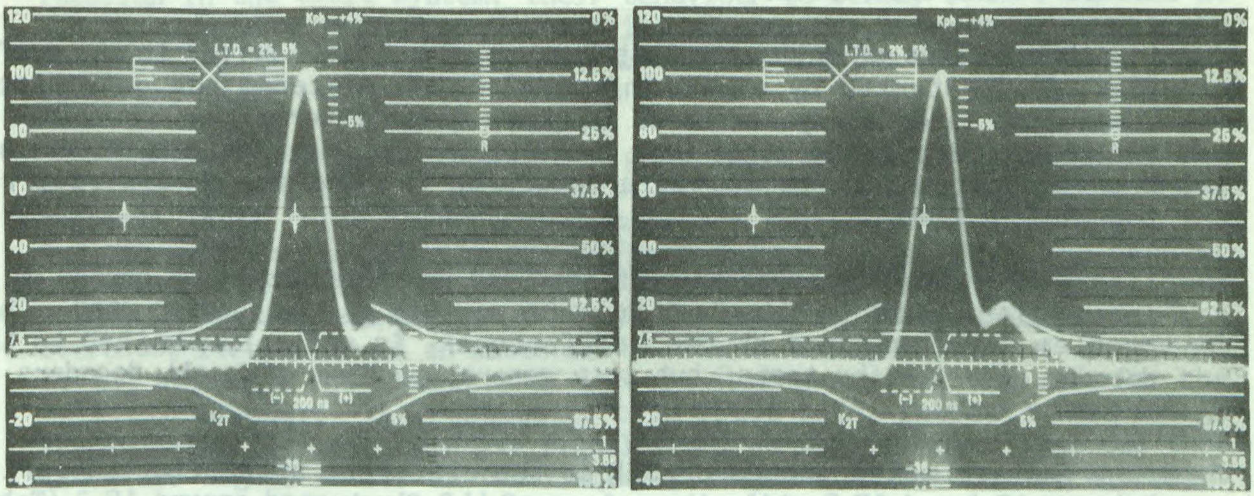
- Headend equipment

In spite of a good signal at the antenna output, CBFT's signal processing equipment (converter-demodulator-modulator) produced an eye diagram with a height of only 49% and whose symmetry was seriously affected



(a) (b)

Figure 5.18: CBFT 2T pulses measured at (a) TP-13 and (b) TP-14.



(a) (b)

Figure 5.19: CBMT 2T pulses measured at (a) TP-13 and (b) TP-14.

(TP-14, Figure 5.1). The 2T pulse measured at TP-14 is shown in Figure 5.18.b and indicates significant group delay distortion generated by this equipment.

As far as CBMT is concerned, the received broadcast signal measured at TP-13, which is poor to start with, is further degraded by the headend equipment and resulted in an eye diagram barely opened (MEH of 16%) at TP-14 (Figure 5.1). The two echoes identified at TP-13 attained amplitudes of 20% and 10% respectively at TP-14 (Figure 5.19.b). The decrease in eye height attributable to the combination of these two echoes is of the order of 35% according to computer simulation. The distortion of the 2T pulse in Figure 5.19.b corresponds to an echo rating of 5%: this value satisfies BP-23 (Ref. 5) which specifies a maximum of 7% at the subscriber's terminal.

In view of the poor quality of the teletext signals at the headend, measurements on the rest of the distribution network were considered useless.

5.4 BER and LLR

The present section is devoted to an overall analysis of the bit error rate (BER) and of the line loss rate (LLR) measured.

The errors observed during this study always occurred in long bursts. When a burst of errors occurred, a whole line of data was affected: almost all the 28 bytes which make up the data block (Ref. 1) contained 3 errors or more. Such a line was therefore unusable by the decoder due to multiple errors in the data block.

Other lines of data were lost because of multiple errors in the prefix (Ref. 1) (protected by a Hamming code) which precedes the data block. These lost lines always occurred in pairs in an intermittent fashion. In addition, the unusable lines (due to multiple errors in the data block) and the lost lines (due to multiple errors in the prefix) always occurred together in time.

This systematic appearance of lost and unusable lines was caused by an intermittent fault in the clock recovery circuit of the decoder used. This problem, acknowledged by the manufacturer, is not only limited to the decoder used for the tests, but is a general problem with all decoders of the same model.

The estimated values of BER at the different sites visited varied between 1E-4 and 1E-3 while the values of LLR fluctuated around 1E-3 (Table 4.1). Of all the test points located on the distribution lines (TP-9 to TP-12), only one (TP-11, CBFT) met the performance objectives of 1E-3 for the BER and the LLR as set down in section 4.2. In spite of a teletext signal of relatively good quality at the subscriber's terminal, the decoder used yielded marginal performance.

6. CONCLUSIONS

The series of measurements made in Montreal as part of Project IRIS made it possible to evaluate the capacity of two cable television networks for distributing broadcast teletext signals in keeping with Department of Communications Specification BS-14 (Ref. 1).

In spite of the relatively low MEH (Maximum Eye Height) of the teletext signal provided by the broadcaster (CBC), the quality of the signal delivered by system no. 1 (Cablevision Nationale) at the subscriber's terminal was good: performance objectives were met at most of the sites visited on the distribution lines. The marginal quality of the teletext service observed at these locations was due to a design problem in the type of decoder used. The quality of service would be greatly improved by correcting this problem or by using better decoders.

For cable system no. 2 (Cable TV), the quality of the teletext signal was judged to be inadequate right at the headend due to poor off-air reception on one channel (CBMT) and deficient headend equipment on the two channels evaluated.

In addition to the broadcaster's generators which produced a teletext signal with a rather low maximum eye height (67% and 64% for CBFT and CBMT respectively), the components of the network in question which contributed most to the degradation of the teletext signal were: single channel receiving antennas (directional), headend modulators and demodulators. These and similar devices all belong to one particular class of network components, namely those that manipulate a single channel or perform band limiting in the 6 MHz TV channel. Due to their strategic position and function in the cable system, their behaviour is likely to be reflected at all subscriber terminals. Less critical are the broadband components manipulating serveral channels such as microwave links and receivers, trunk lines and amplifiers.

Single channel amplitude and group delay responses are among the limiting factors for the provision of good teletext service. Group delay response is of prime importance because any significant inequality in the 0-3 MHz band can affect the eye diagram symmetry and shift the decoder sampling time away from optimal MEH position. As for the amplitude response, an important gain at high (video) frequencies increases the overshoot level whereas an attenuation reduces the eye aperture. Overshoot level, aperture and symmetry of the eye diagram are what counts for the teletext decoder. The results of this field trial incidate that a high transmission bit rate teletext signal requires tighter specifications than the video signal as far as the frequency response of the headend equipment is concerned.

This work highlighted the importantce of echo as a limiting factor. This factor is particularly critical at the output of a receiving antenna in an urban area: this type of environment is susceptible to reflections and multiple paths are frequent occurrence. Positive echoes are harmful because they tend to close the eye of the teletext signal; in addition, the effect of multiple echoes is cumulative. Such a case was observed in Montreal where a drastic decrease of 20% in the eye height was caused by the cumulative effect of two echoes at one receiving antenna. The Department of Communications has produced an excellent study on the effect of echo on teletext signals (Ref. 3). The maximum echo rating of 7% permitted in BP-23 (Ref. 5) for video signals is not stringent enough for teletext signals.

The RF signal level available at the subscriber's terminal is another limiting factor. Certain sites visited were rejected due to signal levels that were too low; the sites that were chosen for this study all had signal levels higher than 0 dBmV. Levels lower than this value generally result in low C/N ratios and marginal teletext reception.

It is undeniable that subscriber equipment plays a dominant role in determining the quality of teletext service. Tuning of the cable converter and of the demodulator is more critical for teletext than for video. Synchronous or quasi-synchronous detection is superior to envelope detection.

The quality and the level of sophistication of the teletext decoder are unquestionably the most important factors affecting the quality of teletext service. This study has proven this fact by identifying a design problem in the type of decoder used which significantly affected the quality of service. Performance standards for a "typical BS-14 decoder" are yet to be defined and only then will it be possible to derive a firm and comprehensive set of performance objectives for the cable network.

7. RECOMMENDATIONS

A certain number of problems particular to the network visited in Montreal were identified and discussed in chapters 5 and 6 of this report. The purpose of the following recommendations is to rectify these problems and improve the quality of teletext service on this network.

The Broadcaster (CBC)

1. That the unsymmetrical amplitude of CBFT and CBMT teletext signals generated by CBC be corrected. An eye height of 80% or more should be attained following this correction.

2. That the nominal basic amplitude of the CBMT teletext signal be increased to 80 IRE units.

3. That the synchronization problem of the Norpak MKIV decoders utilized in Project IRIS be corrected or that better decoders be utilized.

Cable System No. 1 (Cablevision Nationale)

4. That the off-air reception of the CBMT teletext signal be improved. A 60% or better eye height should be achieved at the output of the cable system demodulator (TP-6); otherwise, the use of a regenerator should be considered at this point.

5. That the group delay curve of the CBFT and CBMT modulators used at site B (Pie IX) be corrected and equalized. This correction should reduce over and undershoots and improve the symmetry of eye diagrams measured on distribution lines.

Cable System No. 2 (Cable TV)

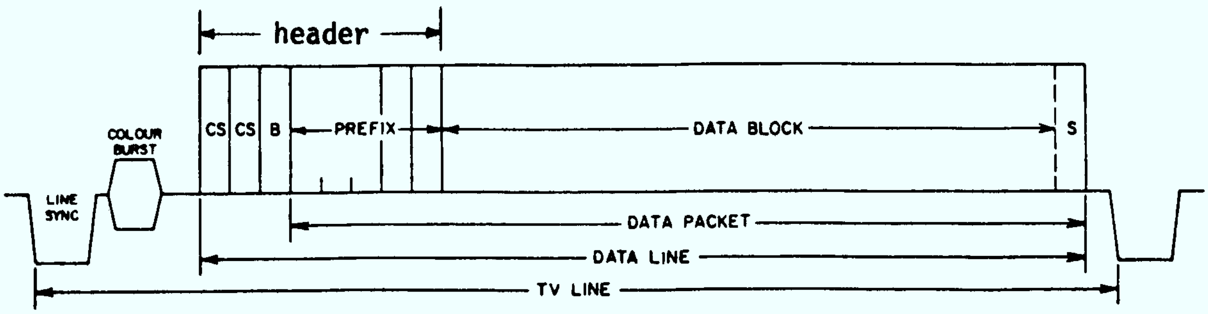
6. That the off-air reception of the CBMT teletext signal be improved. A symmetrical eye diagram with an eye height of 60% or more should be obtained at the output of the antenna (TP-13) with a good quality synchronous demodulator.

7. That the headend equipment for the two channels (CBFT and CBMT) be replaced by better quality instruments. (This replacement was already under study when the tests were done and has since been carried out).

APPENDIX A

ESTIMATED BER AND LLR

The teletext data lines inserted in the vertical blanking interval consist of a series of 288 bits with the following format:



The data line header is composed of the first eight bytes:

- Clock Run In (CS, CS) (bit synchronization)

The first 16 bits of the line are composed of alternating 1's and 0's starting with a 1. This series enables the decoder to synchronize its clock and to initialize its data slicer.

- Framing Code (B) (byte synchronization)

This byte is used to define the byte structure in order to break up the information that follows byte per byte. The code of this byte was specifically chosen to tolerate a single error.

The synchronization bytes are followed by a prefix of 5 bytes protected by a Hamming code which allows correction of single bit errors and detection of most multiple bit errors (> 2) in each byte.

- Packet Addresses (P1, P2, P3)

These three bytes allow the time division multiplexing of 4096 different data channels on one television channel.

- Continuity Index (CI)

This byte is used to detect the loss of a data packet following transmission errors. The value of this index varies from 0 to 15 and increases by 1 with each transmission of a data packet on a given data channel.

- Packet Structure (PS)

This byte specifies the nature and the structure of the data block that follows.

The data block that follows the prefix includes the visual information data encoded according to the Telidon format. This block is followed by a suffix of 1 redundant byte which allows the decoder to correct any single bit error in the data block and to detect all double errors as well as most multiple errors.

Depending on whether the line header (clock run in, framing code and prefix) or the data block contains errors, the consequences are different. The consequences of errors in a data line are summarized in Table A.1 which is partly extracted from Reference 6.

The consequences listed in this table are desirable consequences. Since no standard exists for decoders, their behaviour in the presence of multiple errors (> 2) in the prefix or the data block can differ from the content of Table A.1.

It can be seen from this table that in most cases, multiple errors (> 2) in the framing code as well as in the prefix cause information loss in the form of loss of complete lines. This loss can generally be estimated by means of the LLR parameter (Line Loss Rate). A precise estimation of the LLR must therefore take into account multiple errors occurring in the framing code as well as in the prefix.

The Norpak MKIV teletext decoder used during the field trial is capable of detecting and of counting a certain number of errors and transmission parameters by means of a test sequence inserted periodically in the teletext signal carrying the visual information:

LI : Total number of lines received

LG : Number of lines received without any errors

CE : Number of lines lost due to multiple errors in the prefix (Hamming code protected)

PU : Number of lines received containing multiple errors in the data block (product code protected)

PC : Number of lines received containing an erroneous bit (correctable) in the data block

HC : Number of bytes containing one errorr

HU : Number of bytes containing two errors

HB : Number of bytes containing three errors or more.

Bytes affected	Number of errors	Consequences
clock run in	1 or several	Generally without effect. However, certain configurations (rare) can lead to premature byte synchronization (especially when the framing code also contains an error) and therefore the loss of a line and eventually the assigning of the line to another data channel.
framing code	1	Without effect, except in the exceptional case above.
	2 or more	Framing code not recognized: loss of the line. Eventual assignment of the line to another data channel.
packet address	1	Without effect (since it is corrected).
	2 or more	Line lost. In certain rare cases, possible assignment of the line to another data channel.
continuity index	1	Without effect (since it is corrected).
	2 or more	Line Lost. In certain rare cases, the continuity counter may be perturbed.
packet structure	1	Without effect (since it is corrected).
	2 or more	Line lost. In certain rare cases, loss of part of the data in the block or sampling of part of the data block containing no data.
data block	1	Without effect (since it is corrected).
	2 or more	Unusable line. The line is received, but its data block cannot correctly be interpreted by the decoder due to multiple errors.

Tableau A.1 Effect of errors in the data lines.

The contents of these various counters may be displayed on a TV screen by placing the decoder in a particular mode. An estimate of the bit error rate (BER) and the line loss rate (LLR) may be calculated from the contents of these counters.

Note that a line is lost when the framing code or the bytes of the prefix contain two or more errors. The CE counter of the MKIV decoder counts those lines that are lost due to multiple errors in the prefix only: this decoder was not equipped to detect multiple errors in the framing code. Therefore, this leads to an "optimistic" estimate of the LLR by dividing CE by the total number of lines received (LI), i.e.

$$LLR = \frac{CE}{LI} \qquad (A.1)$$

These lost lines are simply ignored and do not enter into the BER calculation. When the prefix of a data line is received without errors or with errors that are correctable by Hamming code, the line in question is accepted and its data block is interpreted. The errors that can occur in this entire data line are then counted in HC, HU and HB.

It is possible to calculate an estimate of the BER from LI, HC, HU and HB. The HB counter contains an uncertainty factor in that it is impossible to tell if the bytes in question contain 3, 4, 5, 6, 7 or 8 erroneous bits. We therefore propose two boundary estimates of the BER, within which the true BER should be located. A first "optimistic" estimate (BER_3) is otbained by assuming that 3 errors are contained in the bytes indicated by HB and a second "pessimistic" estimate (BER_8) assuming 8 errors per byte.

Thus,

$$BER_3 = \frac{HC + (2 \times HU) + (3 \times HB)}{(288 \times LI)} \qquad (A.2)$$

$$BER_8 = \frac{HC + (2 \times HU) + (8 \times HB)}{(288 \times LI)} \qquad (A.3)$$

where 288 represents the total number of bits per received line (LI).

The values in Table 4.1 were calculated with BER_8 and are therefore a pessimistic estimate of the true situation.

APPENDIX B

BER AND LLR PERFORMANCE OBJECTIVES

- **Performance objectives in the presence of random and independent errors**

Unless otherwise specified, the decoding strategy implicitly used for measuring the bit error rate (BER) at the end of a data transmission channel is generally the simplest one: a sample of the data signal (filtered) is taken at the proper instant (generally at the centre of a bit interval) and its amplitude is compared to a decision threshold. If the amplitude of the sample is greater than the threshold, the decoder's decision is a binary "1", otherwise the decoder's decision is a binary "0". A simple decoder of this nature is often called a detector (Figure B.1).

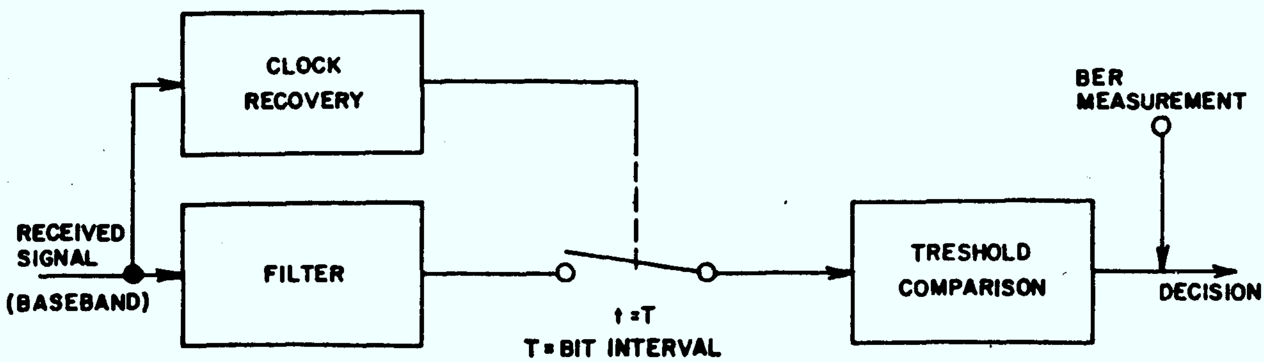


Figure B.1 Simple detector for measuring the BER

The erroneous bits obtained at the output of a detector are generally the result of distortion of the signal caused by the non-ideal frequency response (amplitude and phase) of the transmission channel as well as by the additive noise of this channel. The type of noise generally assumed is gaussian and white (i.e. non-correlated): noise of this nature causes random and independent errors. In the case of broadcast teletext data, most of these errors are single and isolated (Ref. 7).

This fact suggested the addition of a code to the transmitted data that allows the correction of single errors and the detection of double errors in the data block of the teletext line (Ref. 8). A decoder equipped with such an error correction scheme (Figure B.2) can reduce considerably the BER values obtained with the detector of Figure B.1.

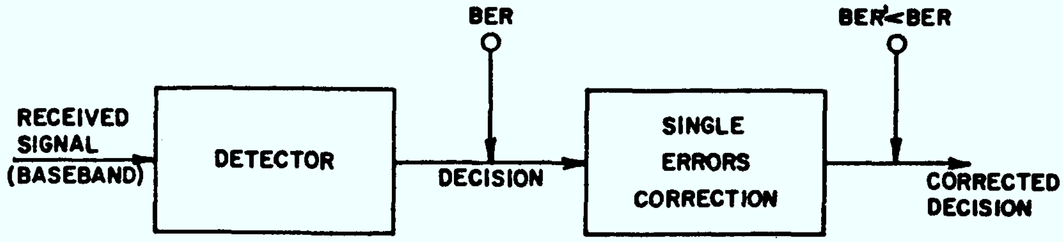


Figure B.2 Decoder equipped with a circuit for correcting single errors in the data block

Certain authors (Ref. 9) have estimated the quality of teletext service provided by a sophisticated decoder of this nature as a function of the BER (before error correction) and of the line loss rate (LLR) values. The results suggested by this analysis are that, to ensure good quality service, the LLR and the BER must be less than 1E-4, i.e.

$$\text{BER} < 10^{-4} \qquad \text{(B.1)}$$

$$\text{LLR} < 10^{-4} \qquad \text{(B.2)}$$

The quality of service is judged to be "good" when the time required to capture a desired page of information on the first try does not exceed the cycle time of the teletext data base. Typically, this cycle interval is in the order of fifteen seconds. When conditions B.1 and B.2 are met, a decoder such as the one in Figure B.2 should enable a requested page to be captured on the first try (i.e. with a waiting time smaller than the cycle time) at least 99 times out of 100.

The decoder used in the Montreal field trial (Norpak MKIV) was of the type shown in Figure B.2. Therefore, in theory, the performance objectives stated above of 1E-4 for the LLR and the BER should be used. Unfortunately, this particular decoder (not only the unit used in the Montreal study but also all those used by CBC in Project IRIS) suffered from an operational problem. The data clock recovery circuit failed intermittently thus causing poor synchronization between the clock and the data. A flurry of errors resulted and a few successive lines were lost.

This operational problem, although it certainly affected reception quality, was not serious to the point of making the decoder unusable. It is however impossible to use the performance objectives mentioned in B.1 and B.2 which, as stated, only apply in the presence of random and independent errors. Therefore, other performance objectives must be developed which also take into account bursts of errors produced by the decoder. In spite of decoder malfunction, it would be interesting to be able to judge the quality of service that it can provide.

- **Performance objectives in the presence of bursts of errors**

Intuitively, and as will be demonstrated by the analysis below, good quality service is to be expected in spite of a new BER objective higher than in B.1. Most of the errors are produced in long bursts and are concentrated in a few successive data lines. Whether there are 2 errors or 200 errors in each of these lines, the result is the same in both cases: a single line is unusable by the decoder. Still, in one case, the number of errors is 100 times greater than in the other!

Two types of errors were observed during the field trial:

Type 1 — Random and independent errors (for the most part single and isolated) produced by transmission channel noise (presumably gaussian and white) during periods of good decoder synchronization. The probability of this first type of error depends only on the carrier/noise ratio (C/N).

Type 2 — Bursts of errors in a few consecutive lines occurring during periods of poor decoder synchronization. Since these errors are due to an operational problem, they do not depend on the carrier/noise ratio (C/N) of the transmission channel.

The bit error rates (BER) estimated in Montreal and appearing in Table 4.1 include both types of errors: however, as shall be seen, the number of type 2 errors predominated to a large extent.

Laboratory tests (Ref. 10) with an MKIV decoder (with no operational problem) showed that with a C/N ratio of 32 dB and an eye height of 70%, this type of decoder produces a random bit error rate (type 1) which varies between 6E-6 and 1E-5. With a C/N ratio of 40 dB, the error rate decreases below 1E-6. Since the error rates (type 1 and type 2) estimated at Montreal were in the order of 5E-4 (Table 4.1) for C/N ratios of 40 dB and higher, we can conclude that the errors counted during the field trial were practically all of type 2. A considerable improvement in BER and in the quality of servide would therefore result from correcting the operational problem of the decoders used or from using better decoders.

Most of the errors observed appeared in long bursts affecting an entire data line: practically all the 28 bytes of the data block contained 3 or more errors. A line of this nature, classed as unusable, was ignored by the decoder because of multiple errors in the data block. Other lines, classed as lost, were also ignored by the decoder because of multiple errors in the prefix which precedes the data block.

The probability of lines ignored by the decoder is therefore given by

$$P(\text{ignored line}) = P(\text{lost line}) + P(\text{unusable line}) \quad (B.3)$$

The probablity of lost lines is identical to the line loss rate (LLR)

$$P(\text{lost line}) = LLR \quad (B.4)$$

The probability of unusable lines will be evaluated as a function of the bit error rate (BER) taking into account the particular manner in which the errors occurred. The error rates of Table 4.1 were estimated by means of the following formula (A.3 of Appendix A)

$$\text{BER} = \frac{\text{HC} + (2 \times \text{HU}) + (8 \times \text{HB})}{(288 \times \text{LI})} \qquad \text{(B.5)}$$

where HB is much greater than HC and HU indicating, as we have said, that practically all the bytes of the data block of an affected line contained 3 or more errors (in fact, we assumed 8 errors per byte). Typically, the results obtained were HC = 1, HU = 1 and HB = 26 per unusable line. We can therefore approximate the BER as follows

$$\text{BER} \approx \frac{8 \times \text{HB}}{288 \times \text{LI}} \qquad \text{(B.6)}$$

Each time an unusable line was received, the HB counter increased by 26 on average. The ratio HB/26 should therefore give an estimate of the <u>number</u> of unusable lines. The <u>rate</u> or probability of unusable lines is obtained by dividing this ratio by LI (the number of lines received). The preceding equation therefore becomes (by dividing both sides by 26)

$$\frac{\text{BER}}{26} \approx \frac{8}{288} \times \frac{\text{HB}}{26} \times \frac{1}{\text{LI}} \qquad \text{(B.7)}$$

from which can be extracted the probability of unusable lines

$$\text{P(unusable line)} \approx \frac{(\text{HB}/26)}{\text{LI}} \approx \frac{288 \times \text{BER}}{8 \times 26} \qquad \text{(B.8)}$$

$$\text{P(unusable line)} \approx 1.4 \times \text{BER} \qquad \text{(B.9)}$$

The factor of 1.4 relating the BER to P(unusable line) was checked in another way. The PU counter (Appendix A) of the MKIV decoder counts the number of lines containing multiple errors in the data block. An estimate of P(unusable line) can also be obtained by dividing PU by LI (the total number of lines received). In this way we have estimated P(unusable line) from 21 measurements made in Montreal and Ottawa: for each measurement, we divided the estimate of P(unusable line) by an estimated BER calculated according to equation B.5. The average of the 21 ratios obtained in this way was 1.42, confirming the factor 1.4 calculated using B.9.

The probability of a teletext line being ignored by the decoder, expressed as a function of the BER and LLR, therefore becomes (B.4 and B.9 in B.3).

$$P(\text{ignored line}) = LLR + (1.4 \times BER) \quad (B.10)$$

The probability of <u>capturing</u> a teletext line on the first try is given by

$$P(\text{captured line}) = 1 - P(\text{ignored line}) = 1 - LLR - (1.4 \times BER) \quad (B.11)$$

Assuming that a teletext page contains an average of 896 bytes of data or 32 lines, the probability of capturing a page on the first try is

$$P(\text{captured page}) = (P(\text{captured line}))^{32} \quad (B.12)$$

BER	LLR	P(captured page)	Quality of service
10^{-2}	10^{-2}	0.46	46%
10^{-2}	10^{-3}	0.616	61.6%
10^{-3}	10^{-2}	0.693	69.3%
10^{-3}	10^{-3}	0.926	92.6%
10^{-4}	10^{-4}	0.99235	99.235%
10^{-5}	10^{-5}	0.99923	99.923%
10^{-6}	10^{-6}	0.99992	99.992%

Table B.1: Quality of teletext service for different orders of magnitude of BER (composed of bursts of errors) and of LLR.

Table B.1 gives the quality of service equivalent to different values of LLR and BER (composed of bursts of errors). This table indicates that the probability of capturing the requested page on the first try (i.e. with a waiting time less than the cycle time of the data base) decreases slowly when the BER and the LLR vary from 1E-6 to 1E-3: below 1E-3, the quality of service deteriorates rapidly.

Performance objectives for the BER and LLR values measured in Montreal with the Norpak MKIV decoder (affected by an intermittent synchronization problem which generated bursts of errors) are therefore set at

$$BER < 10^{-3} \tag{B.13}$$

$$LLR < 10^{-3} \tag{B.14}$$

Once met, these objectives guarantee that a page of 32 lines will be captured on the first try at least 92.6 times in 100.

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