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OF ITU

**J.142**

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SERIES J: TRANSMISSION OF TELEVISION, SOUND  
PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Measurement of the quality of service

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**Methods for the measurement of parameters  
in the transmission of digital cable television  
signals**

ITU-T Recommendation J.142

(Formerly CCITT Recommendation)

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*For further details, please refer to the list of ITU-T Recommendations.*

## **ITU-T Recommendation J.142**

### **Methods for the measurement of parameters in the transmission of digital cable television signals**

#### **Summary**

This Recommendation specifies objective methods for the measurement of parameters in the transmission of digital cable television signals. The Recommendation is applicable for Digital Cable Television Signals using PSK, QAM and OFDM modulation. Measurement of mutual interference between analogue and digital television signals is also described in the Appendices.

#### **Source**

ITU-T Recommendation J.142 was prepared by ITU-T Study Group 9 (1997-2000) and approved under the WTSC Resolution 1 procedure on 18 May 2000.

## FOREWORD

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

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSC Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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## **Introduction**

Digital television produces new impairments which have an influence on received picture quality. Objective measurements of parameters in the transmission are required in order to assure optimum quality of service.

## ITU-T Recommendation J.142

### Methods for the measurement of parameters in the transmission of digital cable television signals

#### 1 Scope

This Recommendation specifies objective methods for the measurement of parameters in the transmission of digital cable television signals. It concerns the end-to-end performance measurement of digital cable television signals from the signal source to the user's receiver. Measurement of OFDM modulated TV signals over cable networks is also specified in Annex A. This transmission chain contains the cable distribution system, consisting of full-coaxial or hybrid fibre and coaxial (HFC) cables, and may also contain the satellite links, terrestrial links and/or broadband network links that may provide sources for the cable head-end.

As there are several and very distinct measurements specific for satellite, microwaves and for terrestrial systems, it seems this is not the appropriate place to define each of them.

It is suggested that any measurement of the performance of signals being supplied through a CATV system without trans-modulation, where the original source is taken from satellite (QPSK, BPSK, etc.), terrestrial sources (8-VSB or COFDM) or microwave multi-point distribution systems, be referred to the appropriate ITU-T documents on such systems which are or may be made available.

#### 2 Informative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

- ITU-T J.82 (1996), *Transport of MPEG-2 constant bit rate television signals in B-ISDN*.
- ITU-T J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution*.
- ITU-T J.131 (1998), *Transport of MPEG-2 signals in PDH networks*.
- ITU-T J.132 (1998), *Transport of MPEG-2 signals in SDH networks*.
- ITU-T J.140 (1998), *Subjective picture quality assessment for digital cable television systems*.
- ITU-T P.910 (1999), *Subjective video quality assessment methods for multimedia applications*.

#### 3 Terms and definitions

This Recommendation defines the following terms:

**3.1 cable television:** Communications systems distributes broadcast and non-broadcast signals, as well as a multiplicity of satellite signals originating programming and other signals by means of coaxial cable and/or optical fibre.

**3.2 MPEG-2:** Coding system of video and audio signals defined in ISO/IEC Standard 13818, ITU-T H.222 and H.262.

**3.3 multiplex:** A stream of all the digital data carrying one or more services within a single physical channel.

**3.4 service information (SI):** Digital data describing the delivery system, content and scheduling/timing to broadcast data streams etc. It includes MPEG-2 Program Specific Information (PSI) together with independently defined extensions.

**3.5 transport stream (TS):** TS is a Transport Stream.

**3.6 mutual isolation:** The attenuation between specified system outlets at any frequency within the range of the system under investigation. It is always specified, for any particular installation, as the minimum value obtained within specified frequency limits.

## 4 Abbreviations

This Recommendation uses the following abbreviations:

8-VSB	Eight Vestigial SideBand
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BW	BandWidth
C/N	Carrier to Noise ratio
CATV	Cable Television
COFDM	Coded Orthogonal Frequency Division Multiplex
CSO	Composite Second Order beat
CTB	Composite Triple beat
CW	Continuous Wave
dB	Decibels
dBc	Decibels below a Carrier used as reference
dBm	Decibels referred to a 1 mW power
dBmV	Decibels referred to a 1 milliVolt rms signal level
dBuV	Decibels referred to a 1 microVolt rms signal level
DVB	Digital Video Broadcasting
DVB-SI	Digital Video Broadcasting – Service Information
E <sub>b</sub>	Energy per bit
EB	Errored Block
ES	Errored Second
FEC	Forward Error Correction
GHz	Giga Hertz (10 <sup>9</sup> Hertz)
Hz	Hertz (1 cycle per second)
I/Q	In-Phase/Quadrature-Phase
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
kHz	kilo Hertz (1000 Hz)

MATV	Master Antenna TeleVision
MER	Modulation Error Ratio
MHz	Mega Hertz ( $10^6$ Hz)
MMDS	Multichannel Multipoint Distribution System
MPEG	Motion Picture Experts Group
MVDS	Multichannel Video Distribution System
mW	Milliwatt
NM	Noise Margin
No	Noise power normalized to 1 Hz
°	Degrees Celsius
OFDM	Orthogonal Frequency Division Multiplex
PRBS	Pseudo Random Binary Sequence
PSI	Program Specific Information
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free
QPSK	Quaternary Phase-Shift Keying
RF	Radio Frequency
RMS	Root Mean Square
R-S	Reed-Solomon
S/N	Signal to Noise ratio
SDP	Severely Disturbed Period
SES	Severely Errored Second
SHF	Super High Frequency
SI	Service Information
SMATV	Satellite Master Antenna TeleVision
TC8PSK	Trellis Coded 8 Phase Shift Keying
TCM	Trellis Coded Modulation
TEV	Target Error Vector
TS	Transport Stream
Ut	Unavailable time
XM	Cross Modulation

## **5 Objective methods for measurements of parameters in the transmission of digital cable television signals**

Overview of cabled distribution system is shown in Figure 5-1. Regardless of system complexity, the method for measurement of parameters shall be specified uniquely for end to end measurement. As a sub-system of cabled distribution system, the SMATV/MATV system is shown in Figure 5-2. This Recommendation is applicable to any digital cabled distribution system (including individual receiving systems) having a coaxial cable output and primarily intended for television and sound signals operating between about 30 MHz and 2150 MHz.

An extension of the frequency range to that from 5 MHz to 3000 MHz will be considered for future work.

This Recommendation lays down the basic methods of measurement of the operational characteristics of digital cabled distribution systems having coaxial cable outputs in order to assess the performance of those systems and their performance limits.

### **5.1 End to end measurement of PSK, QAM modulated television signals**

The methods of measurement listed below are applicable to PSK and QAM digitally modulated signals. Specific measurement methods may be required for the transmission of VSB signals on cable; these are under study.

- Mutual isolation between system outlets;
- Amplitude response within a channel;
- RF Carrier power;
- RF Noise power;
- Carrier to Noise ratio (C/N);
- Bit Error Rate (BER);
- BER versus  $E_b/N_0$ ;
- Noise Margin;
- Modulation Error Ratio (MER);
- Signal to noise ratio (S/N);
- RF Phase Jitter;
- Echoes.

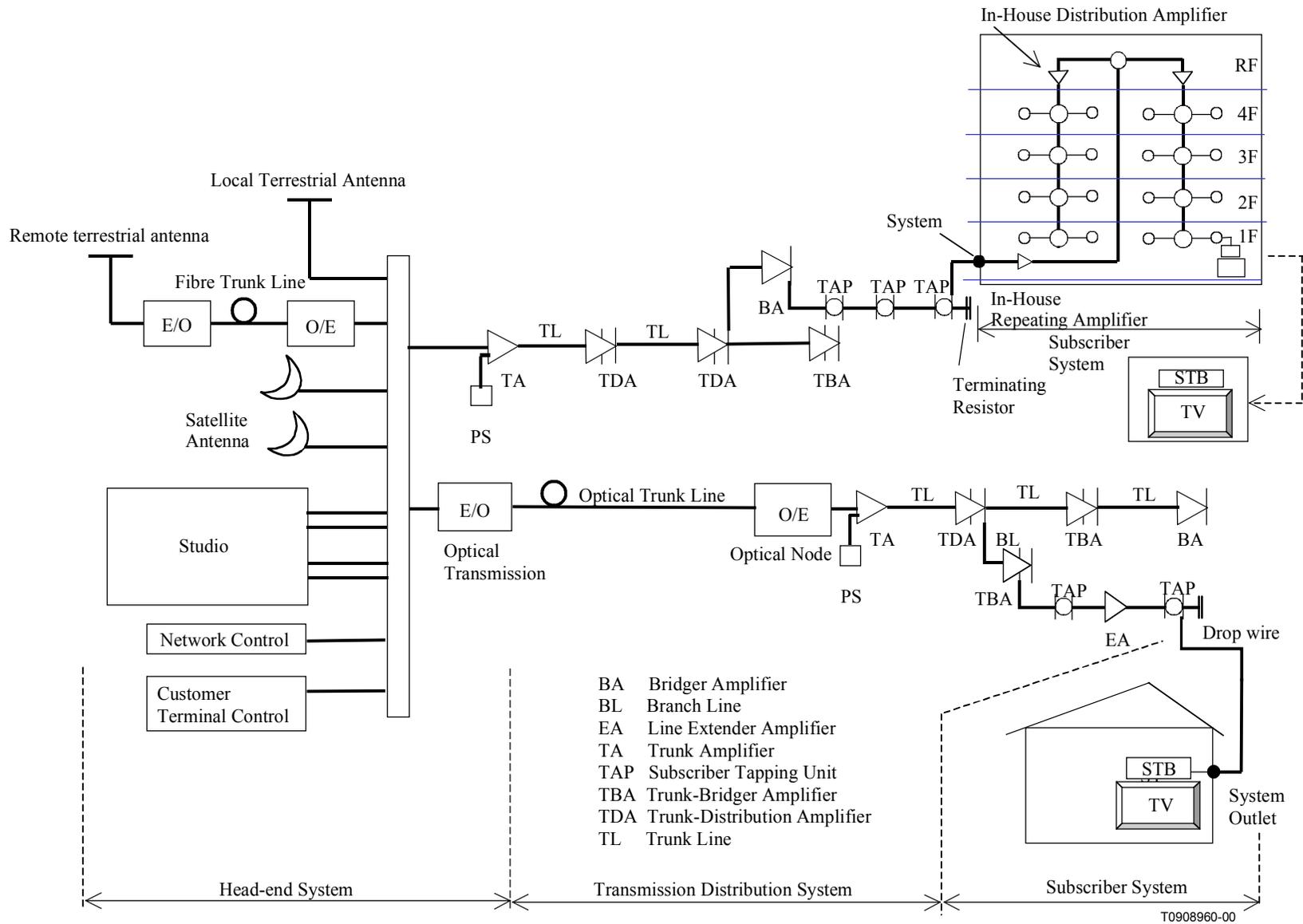
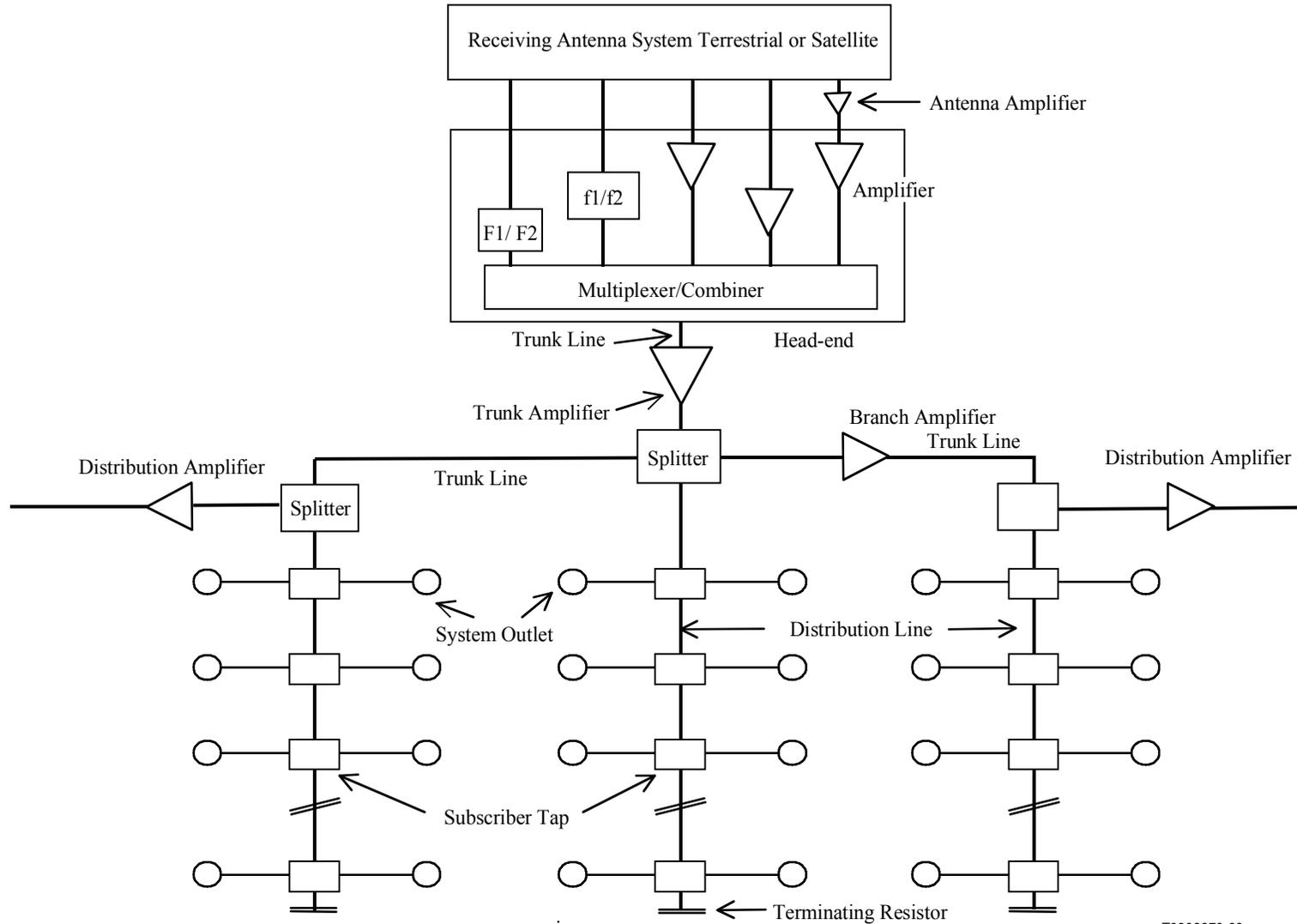


Figure 5-1/J.142 – An example of cable distribution system for television and sound signals



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Figure 5-2/J.142 – An example of Master Antenna Television System for Terrestrial (MATV) or Satellite

The methods of measurement for digitally modulated signals differ from those for analogue modulation for several reasons:

- a) except in the case of VSB transmission, the carrier is either not present in the modulated signal and therefore cannot be measured (i.e. systems using PSK or QAM modulation as in ITU-T J.83), or there are thousands of modulated carriers (i.e. systems using OFDM including pilots and BPSK, QPSK and QAM modulation);
- b) the modulated signal has a spectrum that is flat in the bandwidth and is similar to noise;
- c) the parameters that affect the quality of the received signal are related to the bit and word errors introduced by the channel (noise, amplitude and phase response inequalities, echoes, etc.) before demodulation and error correction.

The methods of measurement for digitally modulated signals are based on the assumption that:

- a) the MPEG-2 Transport Stream (TS) is the specified input and output signal for all the baseline systems, i.e. for satellite, cable, SMATV/MATV, MMDS/MVDS and terrestrial distribution;
- b) the digitally modulated signals received by satellite are modulated in the PSK format, i.e. for the QPSK format, and can be distributed in the same format in cable systems (SMATV/MATV Systems);
- c) the digitally modulated signals received by satellite are distributed in CATV systems in the QAM format;
- d) the digitally modulated signals received from terrestrial broadcasting in the OFDM format are distributed in SMATV/CATV systems in the same OFDM format;
- e) an I/Q baseband signal source for PSK or QAM or OFDM format is available, appropriate interfaces are accessible and are consistent with the relevant SI documents;
- f) a reference receiver for PSK or QAM or OFDM format is available where appropriate interfaces are indicated;
- g) the decoder implementation will not affect the consistency of the results.

### **5.1.1 Mutual isolation between system outlets**

Isolation will usually be measured between:

- a) system outlets connected to adjacent subscribers' taps;
- b) system outlets connected to the same multiple subscribers' tap;
- c) adjacent looped system outlets.

The method of measurement is based on the use of a sweep generator as for analogue modulated signals.

### **5.1.2 Amplitude response within a channel**

The method described is applicable to the measurement of the amplitude response of cabled distribution systems over the frequency range of an individual channel between two specified points within the system.

However, where input signals to the system are demodulated to baseband, and subsequently modulated onto the system carrier frequencies, the response of any demodulator and modulator shall not be included. If it is required to include the characteristics of these items, a separate assessment shall be made using test techniques applicable to such equipment.

Where the system contains frequency changing equipment between the antenna input and the system outlet at which the tests are to be made, the calibration of the equipment shall be carried out at the output frequencies, having first checked that the output of the frequency generator is also flat over the input channel.

The method of measurement is based on the use of a sweep generator as for analogue modulated signals.

### **5.1.3 RF carrier power<sup>1</sup>**

The RF power for digitally modulated carriers (wanted power) is defined by the mean power as measured by a thermal power meter. It can also be measured with a spectrum analyser by integrating the spectrum power in the nominal bandwidth of the channel. (This facility is available in several models of spectrum analysers)

The bandwidth of the channel (BW) for PSK, QPSK and QAM signals is defined as the symbol rate times  $(1 + \alpha)$ . Where  $\alpha$  (alpha), the excess bandwidth of the filter, is defined in each application. The bandwidth for OFDM signals is the band contained between the two outermost carriers.

The RF Carrier power is expressed in dBm (dB relative to 1 mW of power).

A vector signal analyser, or any other suitable device designed and calibrated for measurement of the RF power of digitally modulated signals can also be used.

Some precautions have to be taken into account when measuring the RF carrier power, see I.2.

The measurement can be performed at the system outlet, at the outlet of distribution equipment (passive or active), at the outlet of the headend or at the outlet of an outdoor unit (SHF receiver) for satellite reception.

### **5.1.4 RF noise power**

Noise is always present in any transmission system and causes important impairments on the transmitted signals.

The noise power (or unwanted power) is defined by the mean power as a thermal power meter measures it. It can also be measured with a spectrum analyser by integrating the spectrum power in the nominal bandwidth of the channel.

For the measurement, the carrier of the channel under test should be switched off (out of service). The bandwidth for the measurement of RF noise power should be the same as used for the RF carrier power (see above).

The RF noise power is expressed in dBm (dB relative to 1 mW of power).

A vector signal analyser can also be used for measurement of RF noise power.

The measurement can be performed at the system outlet, at the outlet of distribution equipment (passive or active), at the outlet of the headend or at the outlet of an outdoor unit (SHF receiver) for satellite reception.

Some precautions have to be taken into account when measuring the RF noise power, see I.3.

The bandwidth of the channel (BW) for PSK, QPSK and QAM signals is defined as the symbol rate.

### **5.1.5 Carrier to Noise Ratio (C/N)**

The carrier to noise ratio is defined as the dB difference between the RF carrier power and the RF noise power, both measured as described above.

An approximate procedure is explained in I.5.

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<sup>1</sup> This term is used for convenience although suppressed carrier may be employed.

### 5.1.6 Bit Error Ratio (BER)

BER is the primary parameter, which describes the quality of the digital transmission. It is defined as the ratio between erroneous bits and the total number of received bits.

Out-of-service BER measurements are done before the FEC decoder and measure the total number of errors received. The measurement is done by feeding a PRBS to the modulator at the headend.

In-service measurements are possible with real data using the error detection capabilities of the R-S error correction portion of the FEC decoder. This method provides a statistical measure of the performance of the received signal.

In both types of measurements, if the measured BER is referred to, the gross bit rate or the net bit rate shall be stated with the results. The point where the measurement of BER has been performed shall be indicated with the results.

#### 5.1.6.1 Out of service measurement of gross BER before FEC

If BER measurements before the FEC decoder are ranging between  $10^{-2}$  and  $10^{-4}$ , the measurement can be done in a reasonable amount of time.

This measuring method must be performed under out of service conditions.

The measuring set-up for BER measurement is shown in Figure 5-3.

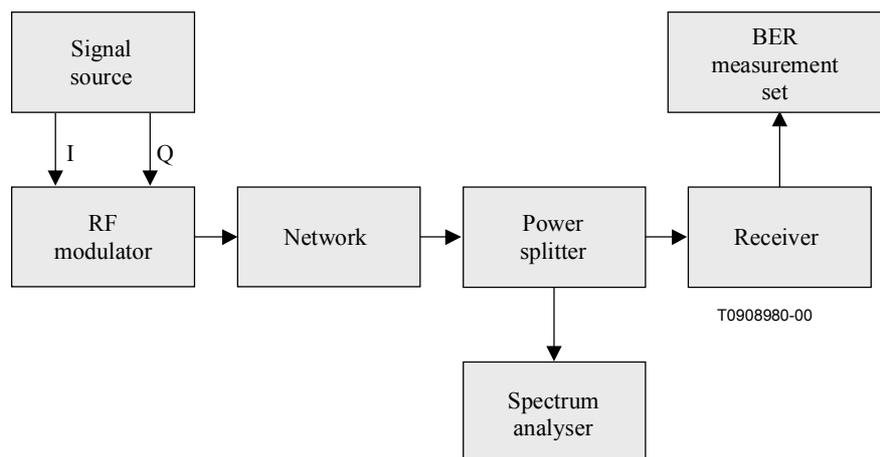


Figure 5-3/J.142 – Test set-up for BER measurement

Switch on the modulation and measure the BER, counting the error bits for a sufficiently long time to count at least 100 error bits. Refer this number to the total number of transmitted bits in that time (gross bit rate). See I.7 for notes on gross and net bit rates.

#### 5.1.6.2 In-Service measurement before FEC

The text below refers to gross BER measurement done before the FEC decoder.

It is accepted that if the errors entering the FEC decoder are random (no burst errors) and below a level of  $2 \times 10^{-4}$  then the output of the R-S decoder is considered quasi error free (QEF). QEF means less than one uncorrected error-event per transmission hour, corresponding to a Bit Error Ratio (BER) =  $10^{-10}$  to  $10^{-11}$  at the output of the R-S decoder. In this situation, error rate cannot be measured after error correction.

For the measurement the output of the FEC decoder (assumed error free) is backwards FEC encoded and fed back for comparison with a delayed and buffered version of the TS at the input of the FEC

decoder. The number of erroneous bits is counted as the difference between the two TS's, (gross BER accounting for synchronization, framing and coding overhead).

This procedure is considered valid where there are no uncorrected errors in the Transport Stream.

### **5.1.6.3 In-Service measurement after FEC**

The text below refers to measurements made after the FEC decoder.

In the case of severe error-bursts, the error correction algorithm may be overloaded and be unable to correct the errors in the TS packet. In this case the `transport_error_indicator` bit of the transport packet affected shall be set.

Counting the number of packets in error and relating them to the time allows definition of the following error measurement types:

#### **Errored Block (EB)**

A Transport Stream packet with at least one uncorrectable error, which is indicated by the `transport_error_indicator` flag set.

#### **Sync loss**

The occurrence of two or more consecutive corrupted sync bytes.

#### **Severely disturbed period (SDP)**

The duration of sync loss or signal loss.

#### **Errored second (ES)**

A one-second period with one or more errored blocks.

#### **Severely errored second (SES)**

A one-second period which contains greater than a specified percentage of errored blocks, or at least one SDP.

This percentage should be the subject of agreement between those interchanging the Transport Stream.

#### **Unavailable time (Ut)**

A period of Unavailable time begins at the onset of 10 consecutive SES events. These 10 events are considered to be part of the Unavailable time.

A period of Available Time begins at the onset of 10 consecutive non-SES events. These 10 events are considered to be part of the Available Time.

### **5.1.7 BER versus $E_b/N_0$**

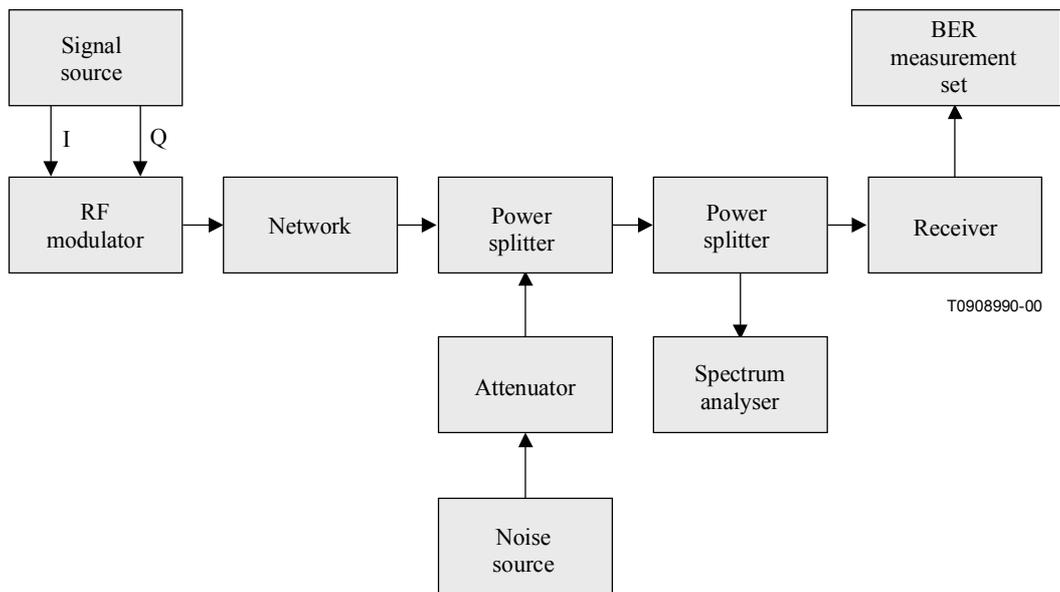
This method applies to the measurement of Bit Error Ratio (BER) of digitally modulated signals using PSK or QAM formats. The measurement of BER versus  $E_b/N_0$  enables a graph to be drawn and compared with a theoretical graph, which shows the implementation loss of the system over a range of bit error rates as the difference in  $E_b/N_0$  between the two graphs at a desired BER. The residual BER at high  $E_b/N_0$  values is an indicator of possible network problems. The BER range of interest is  $10^{-7}$  to  $10^{-3}$ .

The measurement is performed at the system outlet of a cabled distribution network while the modulated signal with the appropriate format is applied at the input of the headend or at the input of the distribution network, depending which part of the system is to be measured.

The headend can include modulation converters (e.g. from PSK to QAM format).

This measuring method must be performed under out of service conditions.

The measurement set-up for BER versus  $E_b/N_0$  measurement is shown in Figure 5-4.



**Figure 5-4/J.142 – Test set-up for BER measurement versus  $E_b/N_0$  and noise margin measurement**

Calculate  $E_b/N_0$  from the following formula:

$$(E_b/N_0)_{dB} = (C/N)_{dB} - 10 \lg m$$

$$(E_b/N_0)_{dB} = (C/N)_{dB} + 10 \lg(BW_n) - 10 \lg(f_s) - 10 \lg m$$

where:

$f_s$  is the symbol rate

$BW_n$  is the noise bandwidth as used in RF noise power measurement

$m$  is the number of bits per symbol modulating the carrier (PSK or QAM). For example ( $m = 1$  for BPSK,  $m = 2$  for QPSK and TC8PSK,  $m = 4$  for 16-QAM,  $m = 6$  for 64-QAM and  $m = 8$  for 256-QAM)

The measurement procedure is as follows:

- Switch on the modulation and the noise generator
- Change the attenuator setting and measure the BER at the receiver output and the  $E_b/N_0$  at the input of the receiver.
- Repeat the above step to obtain a plot of BER versus  $E_b/N_0$ .

When measuring a QAM modulated signal as described in ITU-T J.83 in a CATV system, the  $E_b/N_0$  value referred to the net bit rate can be calculated using the FEC code rate including any other rate loss from added synchronization or framing headers,  $R_{FEC}$ .

Using the following conversion factor for the Annex A/J.83 and Annex C/J.83 RS(204, 184) code (See I.7 for details):

$$10 \lg_{10} (204/184) = +0.448 \text{ dB}$$

Using the following conversion factor for the Annex B/J.83 code (See I.7 for details):

$$10 \lg_{10} (1/R_{\text{FEC}}) = +0.512 \text{ dB (64-QAM)}$$

$$10 \lg_{10} (1/R_{\text{FEC}}) = +0.434 \text{ dB (256-QAM)}$$

When measuring a PSK, BPSK or QAM signal from satellite with additional convolutional FEC code or an OFDM modulated signal, the  $E_b/N_0$  value referred to the net bit rate value can be calculated taking into account both the inner code rate and the RS rate. If the inner code rate is 3/4, for example, the conversion factor can be calculated as follows:

$$10 \lg_{10} (4/3)(204/184) = +1.604 \text{ dB}$$

The measured BER is plotted versus  $E_b/N_0$  (dB). The point where the measurement of BER has been performed shall be indicated with the results.

### 5.1.8 Noise margin

The purpose of this measurement method is to provide an indication of the reliability of the transmission channel. The noise margin measurement is a more useful measure of system operating margin than a direct BER (Bit Error Rate) measurement due to the steepness of the curve of BER versus  $E_b/N_0$  ratio.

The measurement is performed at the system outlet of a cabled distribution network, while the modulated signal with the appropriate format is applied at the input of the headend or at the input of the distribution network, depending which part of the system is to be measured.

The headend can include modulation converters (from PSK to QAM format).

This measurement method must be performed under out of service conditions.

The measurement set-up for noise margin measurement is the same as that for the measurement of BER versus  $E_b/N_0$  and is shown in Figure 5-4.

The measurement procedure is as follows:

- Set the input signal to obtain the desired modulation format, channel frequency, and signal level;
- Select the proper operating conditions for the measuring equipment;
- Measure and note as  $N_1$  the C/N measured as described in 5.1.5;
- Add noise, to the modulated signal at the cable network output, until the BER is 1 in  $10^{-4}$ ;
- Measure and note as  $N_2$  the C/N measured as described in 5.1.5;
- Calculate the Noise Margin NM by the following formula:

$$NM_{\text{dB}} = N_1 - N_2 \text{ (dB)}$$

The measured noise margin is expressed in dB. The interface point where the measurement of BER has been performed shall be indicated with the results.

In the case of 64-QAM signal transmission, it is reported that BER versus C/N curve approaches to the theoretical curve in relatively low C/N domain, however the C/N curve leaves off from the theoretical one in relatively high C/N domain under the circumstance where one or more monotonies, second and third distortions exist within the transmission band. Appendix II describes test results.

### 5.1.9 Modulation Error Ratio (MER)

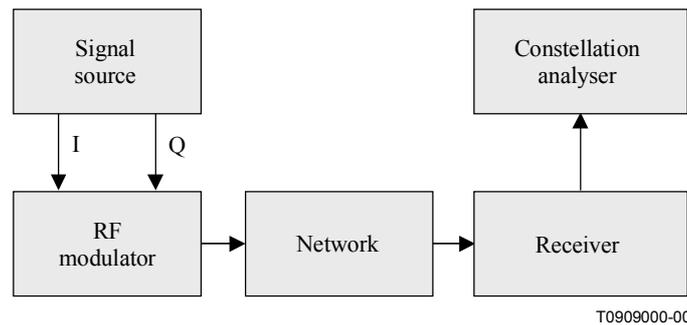
This measurement method provides a single "figure of merit" analysis of the received signal.

This figure is computed to include the total signal degradation likely to be present at the input of a commercial receiver's decision circuits and so give an indication of the ability of that receiver to correctly decode the signal.

The measurement is performed at the system outlet of a cabled distribution network, while the modulated signal with the appropriate format is applied at the input of the headend or at the input of the distribution network, depending which part of the system is to be measured.

The headend can include modulation converters (from PSK to QAM format)

The measuring set-up for the Modulation Error Ratio (MER) measurement is shown in Figure 5-5.



**Figure 5-5/J.142 – Test set-up for Modulation Error Ratio (MER) and phase jitter measurement**

The measurement procedure is as follows:

- Set the input signal to obtain the desired modulation format, channel frequency, and signal level;
- Select the proper operating conditions for the measuring equipment.

The carrier frequency and symbol timing are recovered, which removes frequency error and phase rotation. Origin offset (e.g. caused by residual carrier or DC offset), quadrature error and amplitude imbalance are not corrected.

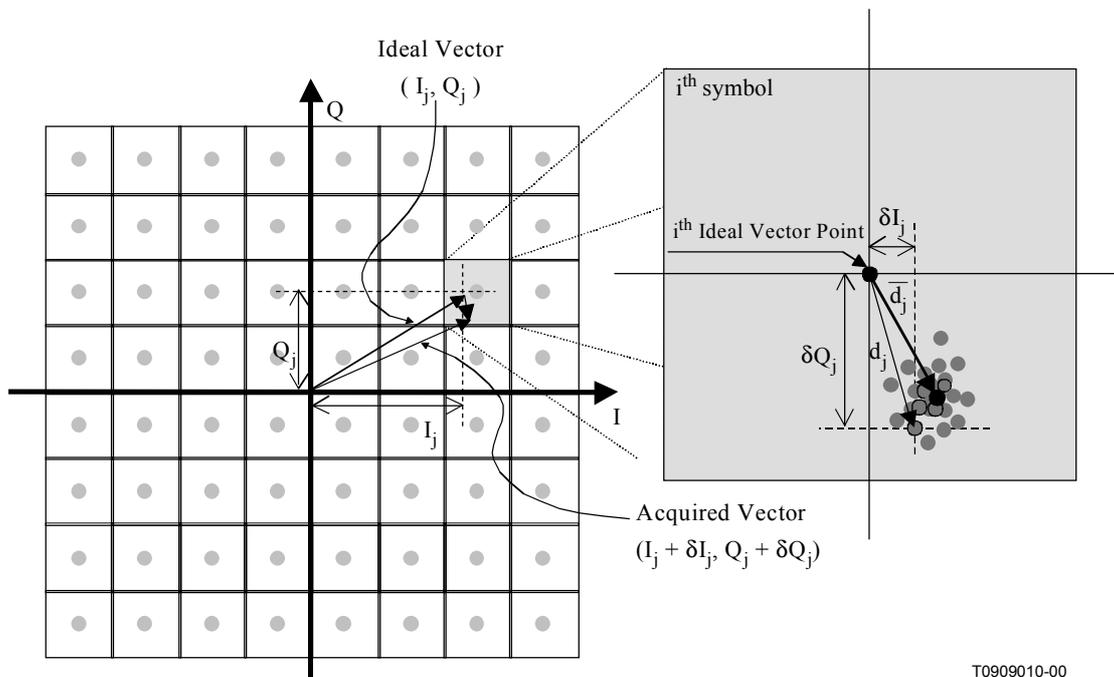
A time record of  $N$  received symbol co-ordinate pairs  $(I_j + \delta I_j, Q_j + \delta Q_j)$  is captured by the constellation analyser.  $N$  shall be significantly larger than the  $M$  symbol points.

The ideal symbol pair is regarded as  $(I_j, Q_j)$ .

For each received symbol a decision is made as to which symbol was transmitted. The error vector is defined as the distance from the ideal position of the chosen symbol (the centre of the decision box) to the actual position of the received symbol.

The difference can be expressed as a vector  $d_j = (\delta I_j, \delta Q_j)$ .

An example representation of the constellation diagram for a 64-QAM modulation format and the distance  $(\delta I_j, \delta Q_j)$  for each of the  $N$  received symbols in the  $i^{\text{th}}$  point from the ideal position  $(I_j, Q_j)$  is shown in Figure 5-6.



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**Figure 5-6/J.142 – Example of constellation diagram for a 64-QAM modulation format where  $i^{\text{th}}$  point has been enlarged to show the co-ordinates of the symbol error vector**

For each symbol  $M$  a cloud of error vectors appears.

The sum of the squares of the magnitude of the ideal symbol vectors is divided by the sum of the squares of the magnitudes of the symbol error vectors. The result, expressed as a power ratio in dB, is defined as the Modulation Error Ratio (MER):

$$MER = 10 \lg_{10} \left\{ \frac{\sum_{j=1}^N (I_j^2 + Q_j^2)}{\sum_{j=1}^N (\delta I_j^2 + \delta Q_j^2)} \right\} \quad (\text{dB})$$

Before starting the measurement, check the modulator performance, connecting the receiver with the constellation analyser at the output of the signal generator modulated by the digital source. The displayed constellation diagram shall be noted and assumed as the reference position for the measurement.

The measured Modulation Error Ratio (MER) is expressed in dB. The interface of the receiver where the measurement has been performed shall be stated with the results.

### 5.1.10 Signal to noise ratio (S/N)

This term refers to the demodulated signal seen after the demodulation process.

The total noise is that picked up from the transmission network plus the noise embedded in the modulated signal in the form of amplitude noise, phase noise and inter-symbol interference and other modulation impairments.

The S/N measurement is done from the constellation data after demodulation.

From each cloud, corresponding to a symbol in the constellation, it is possible to extract the statistical distribution. After removing the effects of quadrature distortion, amplitude imbalance, origin offset, residual carrier, non-linear distortions, phase jitter and continuous wave (CW) interferer, the remaining cloud is assumed to be due to Gaussian noise and is the basis for computing the signal to noise ratio.

When all the above errors have been suppressed, it is assumed that MER and S/N ratio will have the same value.

The S/N is then defined as:

$$S/N = MER = 10 \lg_{10} \left\{ \frac{\sum_{j=1}^N (I_j^2 + Q_j^2)}{\sum_{j=1}^N (\delta I_j^2 + \delta Q_j^2)} \right\} \quad (\text{dB})$$

### 5.1.11 Target Error Vector (TEV)

As an aid for reducing the errors mentioned above, the Target Error Vector can be defined as follows:

For each symbol  $i$  of the  $M$  symbol points in a constellation diagram compute the distance  $d_{ij}$  between the theoretical symbol point and the point corresponding to the mean of the cloud of this particular symbol point. This quantity  $\bar{d}_i$  is called the Target Error Vector (TEV) and is shown in Figure 5-7.

$$d_{ij} = (\delta I_{ij}, \delta Q_{ij})$$

Given that  $N_i$  samples, out of the  $N$  acquired samples, are associated to each symbol of index " $i$ ".

The TEV is described by:

$$\bar{d}_i = \frac{1}{N_i} \times \sum_{k=1}^{k=N_i} d_{ij}$$

where  $k$  represents each of those " $j$ " samples associated to the symbol " $i$ ".

The differences, from each sampled vector " $j$ " in the symbol " $i$ " to the centre of the cloud of vectors, is represented as:

$$(\Delta I_{ij}, \Delta Q_{ij}) = d - \bar{d}$$

for each symbol " $i$ " of the  $M$  symbols in the constellation. These differences can be used to calculate the RMS value of the noise for each symbol.

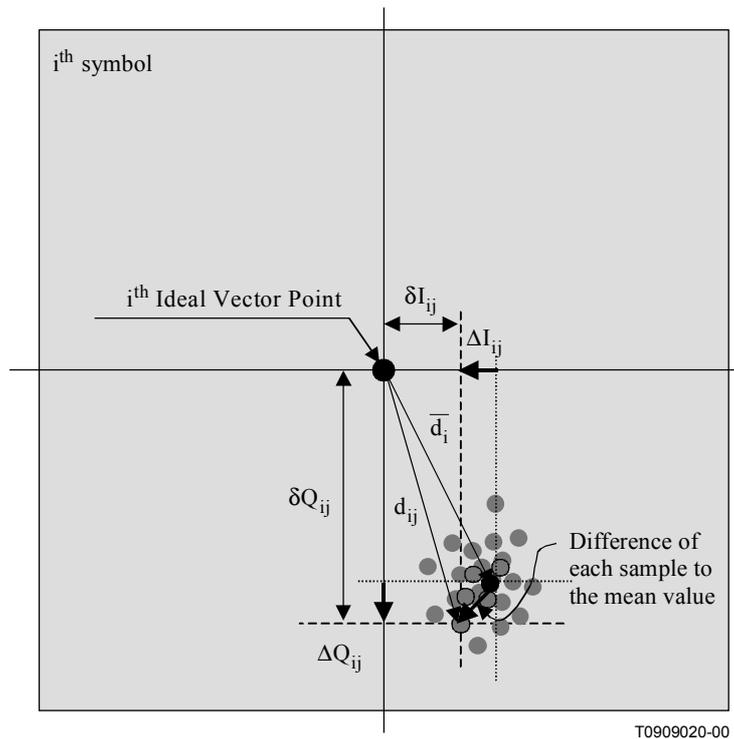
TEV indicates the level of distortions such as Residual Carrier, Amplitude Imbalance, Quadrature Error, Non-Linear distortions, etc.

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<sup>2</sup> Note that in the formula given for MER (5.1.9) the index " $j$ " ranges from 1 through  $N$ . In this formula " $j$ " does not represent the index of the symbol, but the index of the sample. As all the symbols are included in the calculation, it is not necessary to distinguish from symbol to symbol.

For the TEV it is convenient to specify an index to distinguish between symbols, so the index " $i$ " ranges from 1 through  $M$ . Associated to each symbol " $i$ " there are  $N_i$  samples.  $N_i$  is typically different for each symbol, but will eventually tend to be equal for each symbol as  $N$  becomes much greater than  $M$ .

Figure 5-7 shows the TEV as the mean of all  $d_{ij}$  vectors for each symbol in the constellation.



**Figure 5-7/J.142 – S/N measurement using the constellation**

### 5.1.12 RF phase jitter

This measurement method provides an indication of the phase or frequency fluctuations of an oscillator used in equipment within the cabled distribution system (i.e. in a frequency converter). Using such an oscillator with digitally modulated signals may result in sampling uncertainties in the receiver, because the carrier regeneration cannot follow the phase fluctuations.

The measurement is performed at the system outlet of a cabled distribution network, while the modulated signal with the appropriate format is applied at the input of the headend or at the input of the distribution network, depending which part of the system is to be measured. The headend can include modulation converters. These measurement methods can be performed under out of service conditions.

The measuring set-up for the phase jitter measurement is shown in Figure 5-5.

The measurement procedure is as follows:

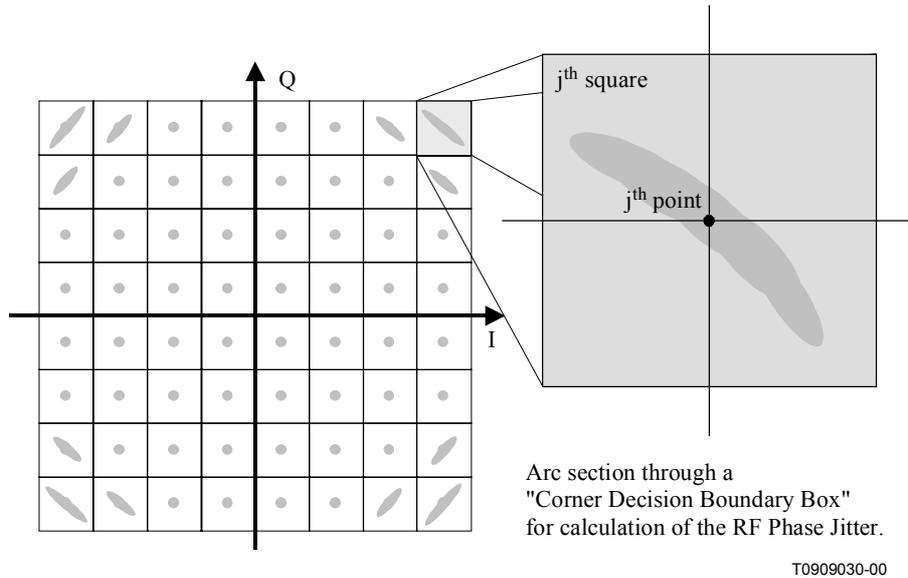
- set the input signal to obtain the desired modulation format, channel frequency, and signal level;
- select the proper operating conditions of the measuring equipment.

The carrier frequency and symbol timing are recovered, removing frequency error and phase rotation but not phase jitter. Origin offset (e.g. caused by residual carrier or DC offset), quadrature error and amplitude imbalance are not corrected.

A time record of  $N$  received symbol co-ordinate pairs  $(I_j + \delta I_j, Q_j + \delta Q_j)$  is captured by the constellation analyser.  $N$  shall be significantly larger than the  $M$  symbol points.

The ideal symbol pair is regarded as  $(I_j, Q_j)$ .

The signal points affected by phase jitter are arranged along a curved line crossing the centre of each decision boundary box as shown in Figure 5-8 for the four "Corner Decision Boundary Boxes".



**Figure 5-8/J.142 – Example of constellation diagram for a 64-QAM modulation format where the "Corner Decision Boundary Boxes" or the RF Phase Jitter measurement are shown**

The Phase Jitter can be calculated using the following procedure. For each received symbol:

- Calculate the angle between the I-axis of the constellation and the vector to the received symbol ( $I_{rcvd}$ ,  $Q_{rcvd}$ ):

$$\phi_1 = \arctan (Q_{rcvd}/I_{rcv})$$

- Calculate the angle between the I-axis of the constellation vector to the corresponding ideal symbol ( $I_{ideal}$ ,  $Q_{ideal}$ ):

$$\phi_2 = \arctan (Q_{ideal}/I_{ideal})$$

- Calculate the error angle:

$$\phi_E = \phi_1 - \phi_2^3$$

From these N error angles calculate the RMS phase jitter (PJ):

$$PJ = \sqrt{\frac{1}{N} \sum_{i=1}^N \phi_{E_i}^2 - \frac{1}{N^2} \left( \sum_{i=1}^N \phi_{E_i} \right)^2}$$

Before starting the measurement, check the modulator performance, connecting the receiver with the constellation analyser at the output of the signal generator modulated by the digital source. The displayed constellation diagram shall be noted and assumed as the reference position for the measurement.

The measured phase jitter is expressed in degrees.

<sup>3</sup> For the purpose of this measurement, care should be taken to ensure that the phase difference is calculated to be  $[-\pi/2, \pi/2)$  by subtracting or adding  $\pi$  if necessary.

### 5.1.13 Echoes (mask for a measurement equalizer)

This procedure is for in-service measurements and uses the capabilities of the adaptive equalizer filter built in the measurement receiver.

High order modulations such as 64-QAM are very sensitive to distortions. The eye aperture is so small that any perturbation can seriously disturb the reception of the signal. This problem is increased where the roll-off factor is low. In a real network, if no special processing is carried out in the receiver, the eyes appear completely closed, and no synchronization is possible. To overcome this, all cable receivers, professional or not, are equipped with equalizers.

Some of the most common impairments met on cable networks are echoes due to equipment impedance mismatching, or filtering effects. These impairments appear as perturbations of the frequency response (or impulse response) of the channel, and are corrected by the equalizer which is a form of adaptive filter. Equalizers are very efficient for linear distortions, but cannot combat those of a non-linear nature. They combat fixed frequency interference, which is equivalent to intermodulation products of analogue television signals. Equalizers have a large influence on the clock or carrier recovery systems, since these can use the equalized signals. Thus the overall behaviour of the receiver depends on the performance of the equalizer.

Most of the measurements specified in this Recommendation are carried out after equalization. The first reason is that the signal is too impaired before equalization to obtain meaningful measurement results. Moreover, as most of the distortion at that point would be removed in any practical receiver, such measurements may not be relevant. The consequence of this is that measurement results are dependant on the equalizer response. This also means that equipment with different equalizer architectures will have different performance characteristics. This situation is not acceptable from a measurement point of view, and has led to the specification of the equalizer.

Figure 5-9 represents an example of a practical mask for digital CATV systems.



Figure 5-9/J.142 – Example mask for a measurement equalizer

The specification of an equalizer is a difficult task, because there are a large number of types of equalizer, due to the range of algorithms for the updating of coefficients, and the different filter architectures (time based, frequency based, recursive or non-recursive). In addition, the performance of future equipment should not be limited by any current specifications. A convenient solution is to specify the overall performance of the receiver as regards a perturbation typically corrected by the equalizer, specifically – echoes.

The specification has to be defined so that the reference perturbation does not affect the measurements. We then define the minimum level of perturbation that the equalizer will have to correct. A solution is to set the minimum level of an echo that will not degrade the equivalent noise degradation of the incoming signal by more than 1 dB. This measurement is carried out for the worst case phase shift of the echo.

In some cases, when a consumer receiver is studied for its response to network signals, it is appropriate to have an equalizer in the measurement equipment whose performance is close to that of the consumer receiver.

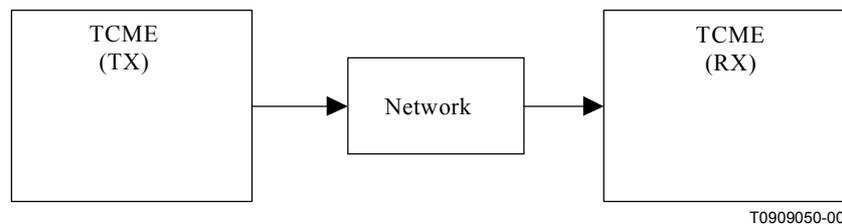
Echo is defined D/U (Desired/Undesired signal level ratio) versus delay time between forward and return signals. The test set up is shown in Figure 5-10. The result shall be plotted on a graph having D/U ratio in vertical axis and delay time in horizontal axis.

The measurement procedure is as follows:

NOTE – This procedure is for out of service measurements and uses a Network Analyser.

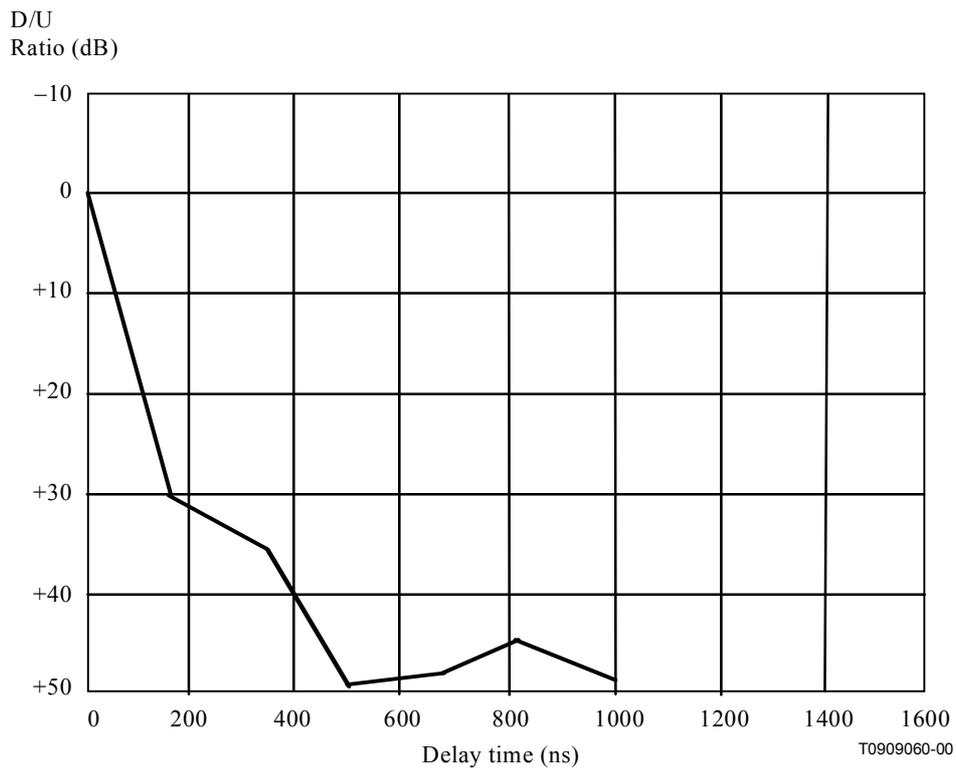
- Set up measurement equipment in accordance with Figure 5-10.
- Set the channel and output level of transmission characteristic measuring equipment (TCME).
- Set the input signal level of TCME.
- Confirm all the input and output signal levels are appropriate.

Measure Group Delay Time and D/U ratio to plot Echo characteristics.



**Figure 5-10/J.142 – Test set-up for echo measurement**

Figure 5-11 shows an example of echo measurement.



**Figure 5-11/J.142 – Example of Echo Measurement**

## ANNEX A

### End-to-End measurement of OFDM modulated television signals

There may be instances when it is desired to distribute programme signals received at a cable system head-end, without remodulating them. This may be the case of MATV systems, and also of some cable television systems, in which the expenditure required to install a remodulator at the head-end does not appear to be justified. In those cases, and in those regions where digital terrestrial television uses OFDM modulation, OFDM signals may need to be carried on a CATV distribution network. This annex provides measurement methods for OFDM television signals that may be carried on such systems.

#### A.1 End to End measurement of OFDM television signals

In this clause measurement of parameters of OFDM television signals is specified. All measurement items shall be set to "R-S OFF" condition.

##### A.1.1 Mutual isolation between system outlets

Isolation will usually be measured between:

- system outlets connected to adjacent subscribers' taps;
- system outlets connected to the same multiple subscribers' taps,
- adjacent looped system outlets.

The method of measurement is based on the use of a sweep generator as for analogue modulated signals.

### A.1.2 Signal level

OFDM is a multi-carrier system in which each carrier is modulated independently. Received signal waveform is similar to white noise. Therefore in the measurement of signal level with spectrum analyser, its resolution bandwidth shall be carefully selected. Test set up is shown in Figure A.1.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.1.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator
- Set the signal level and frequency of UP CONV.
- Confirm all the input and output signal levels are appropriate.
- Measure OFDM signal level with spectrum analyser and power meter.

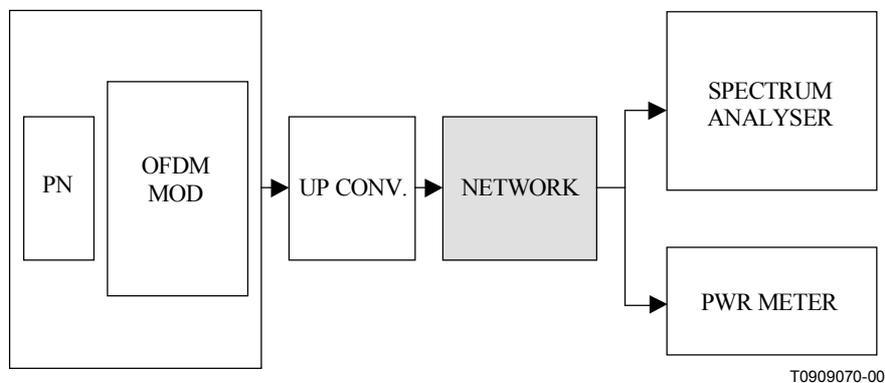


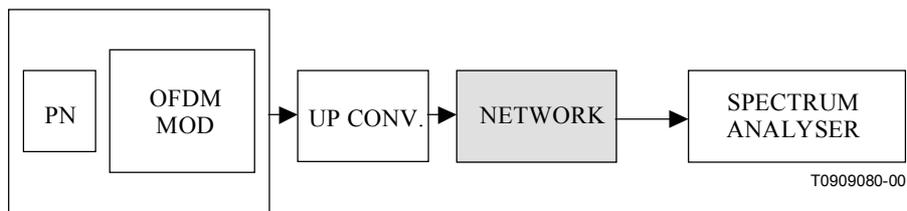
Figure A.1/J.142 – Measurement of signal level

### A.1.3 Carrier Bandwidth

OFDM system requires multi-carriers, narrow inter-carrier space and long effective symbol length in order to enhance its capability. In this measurement resolution bandwidth and video signal bandwidth shall be carefully selected. Test set up is shown in Figure A.2.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.2.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV.
- Confirm all the input and output signal levels are appropriate.
- Measure OFDM carrier bandwidth with spectrum analyser.



**Figure A.2/J.142 – Measurement of carrier bandwidth**

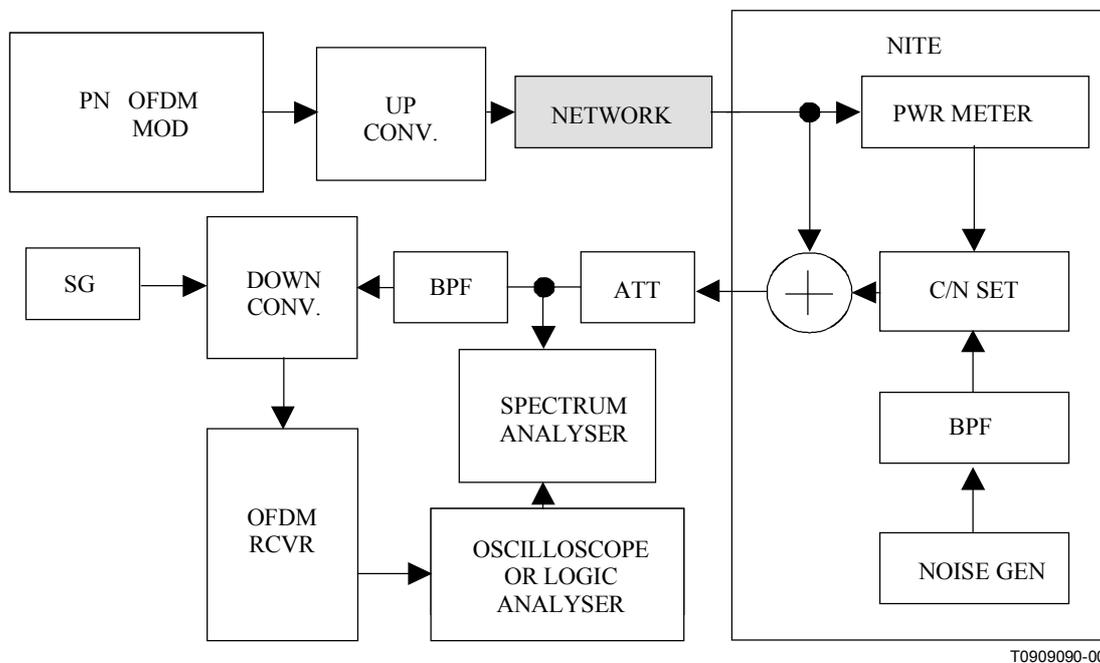
**A.1.4 C/N synchronization limit**

Two symbols (I and Q) of the same information shall be orthogonal to each other in the transmission of OFDM signals. Synchronization between data and clock must be securely maintained in the receiving process.

In this clause measurement of synchronization limit versus C/N when the Gaussian noise is loaded to OFDM signals is described. Test set up is shown in Figure A.3.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.3.
- Set the PN Pattern ( $2^{23} - 1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Connect Oscilloscope with synchronization circuit of OFDM receiver.
- Set input signal level and noise bandwidth of Noise Interference Test Equipment (NITE).
- Confirm all the input and output signal levels are appropriate.
- Measure out of synchronization point as synchronization limit by changing C/N ratio.



**Figure A.3/J.142 – Measurement of C/N synchronization limit**

### A.1.5 C/N versus BER

In this clause measurement of bit error ratio versus C/N when the Gaussian noise is loaded to OFDM signals is described. Test set up is shown in Figure A.4.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.4.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Set input signal level and noise bandwidth of Noise Interference Test Equipment.
- Confirm all the input and output signal levels are appropriate.
- Measure BER by changing C/N ratio. Measurement range of BER shall be between  $10^{-1}$  and  $10^{-8}$ .

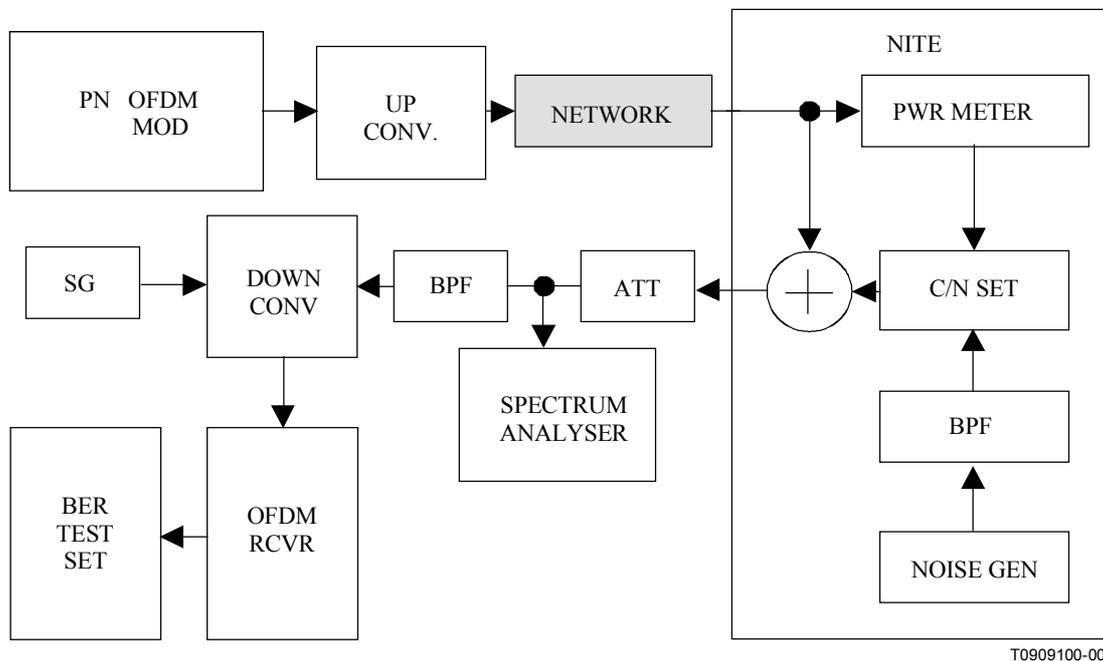


Figure A.4/J.142 – Measurement of C/N versus BER

## A.2 BER measurement of OFDM television signals

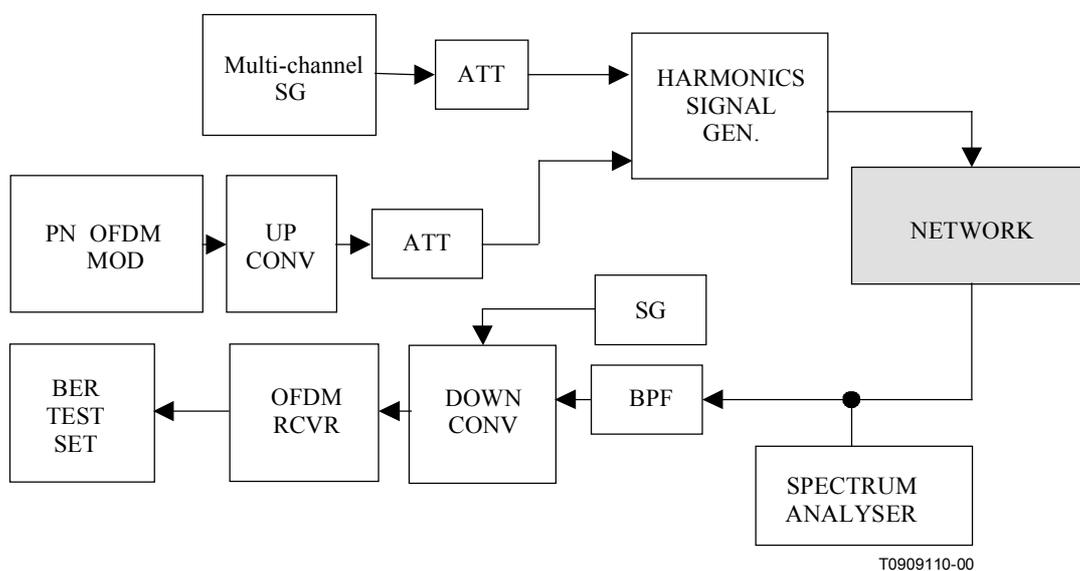
In OFDM transmission BER performance degradation due to inter-modulation may occur if the transmission system has non-linear characteristics. Therefore related parameters to non-linearity of transmission system shall be carefully measured. All the measurement items shall be set to "R-S OFF" condition.

### A.2.1 BER versus inter-modulation

Several distortions, mainly harmonics of transmission line may degrade OFDM performance. In this clause measurement of BER versus CTB (Composite Triple Beat), CSO (Composite Second Order) and XM (Cross Modulation) is described. Test set up is shown in Figure A.5.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.5.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Set input and output noise levels, measurement pattern and period of BER measuring equipment.
- Set frequency and level of Multi-channel signal generator.
- Confirm all the input and output signal levels are appropriate.
- Measure harmonics distortions at output of harmonics signal generator.
- Measure BER by changing harmonics levels. Measurement range of BER shall be between  $10^{-1}$  and  $10^{-8}$ .



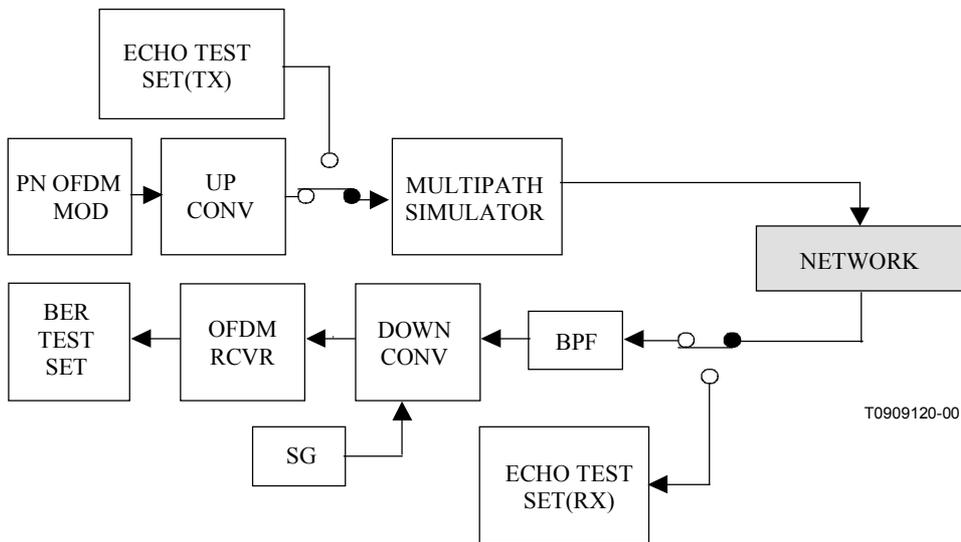
**Figure A.5/J.142 – BER versus inter-modulation**

### A.2.2 BER versus echoes

In this clause measurement of BER versus Echoes is described. Test set up is shown in Figure A.6.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.6.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Set input and output signal levels, measurement pattern and period of BER measuring equipment.
- Set input, output signal levels and echo parameters of multi-path simulator.
- Confirm all the input and output signal levels are appropriate.
- Measure BER by changing echo parameters. Measurement range of BER shall be between  $10^{-1}$  and  $10^{-8}$ . Calculate D/U ratio when BER becomes  $2 \times 10^{-4}$ .



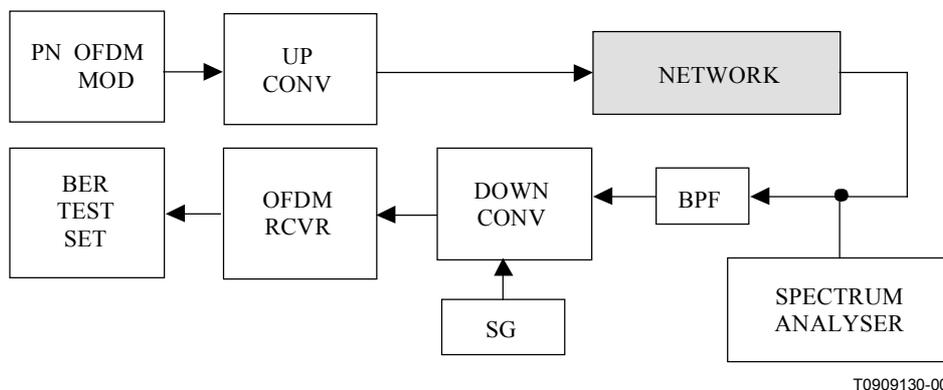
**Figure A.6/J.142 – Measurement of BER versus echoes**

### A.2.3 BER versus hum modulation

In this clause measurement of BER versus Hum Modulation is described. Test set up is shown in Figure A.7.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.7.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Set input and output signal levels, measurement pattern and period of BER measuring equipment.
- Confirm all the input and output signal levels are appropriate.
- Measure BER by changing hum modulation level of amplifier. Measurement range of BER shall be between  $10^{-1}$  and  $10^{-8}$ .



**Figure A.7/J.142 – Measurement of BER versus hum modulation**

#### A.2.4 BER versus phase jitter

In this clause measurement of BER versus Phase Jitter is described. Test set up is shown in Figure A.8.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure A.8.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator inside OFDM modulator.
- Set the signal level and frequency of UP CONV and DOWN CONV.
- Set input and output signal levels, measurement pattern and period of BER measuring equipment.
- Confirm all the input and output signal levels are appropriate.
- Measure BER by changing phase noise applied from signal generator connected with DOWN CONV. Measurement range of BER shall be between  $10^{-1}$  and  $10^{-8}$ .

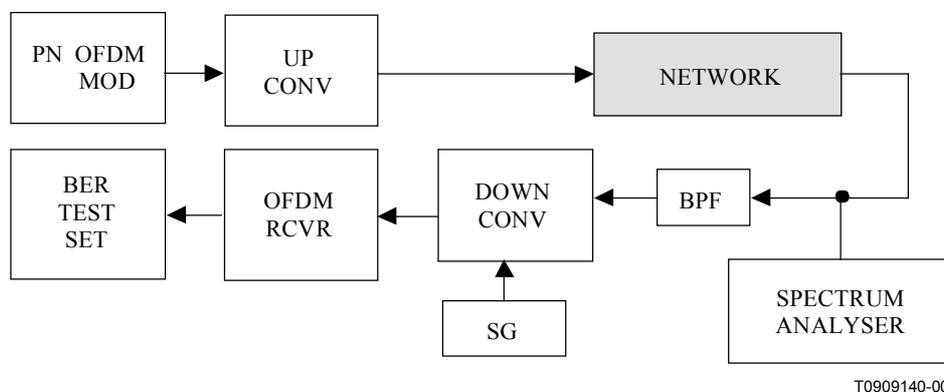


Figure A.8/J.142 – Measurement of BER versus phase jitter

## APPENDIX I

### Notes for measurement

#### I.1 RF measurement units

Carrier level measurements used by the CATV community for analogue carriers (a  $75\Omega$  environment) are usually expressed in dBmV or dB $\mu$ V.

To facilitate comparison to the analogue carriers it is possible to convert the average power measured on the digital carriers from dBm to dBmV by adding 48.75 dB to the measured value, or from dBm to dB $\mu$ V by adding 108.75 dB.

NOTE – The measurement in dBmV or dB $\mu$ V would represent the level of an equivalent unmodulated sinusoidal carrier having the same power as the measured dBm value in a  $75\Omega$  system.

#### I.2 Precautions for measurement of RF signal power

The operator or technician making power measurements should take into account several facts related to CATV systems and the measurement instruments being used.

### **I.2.1 Measurements using a power meter**

A power meter is an instrument with high absolute accuracy and resolution, however, it measures the total power present at its input. In order to measure the RF carrier power of a digitally modulated signal it is necessary to select measurement of the power within the nominal bandwidth of the channel. Any power existing out of this channel should not be measured, or it should be very low with respect to the power within the channel.

When measuring the output of a single channel, at a point in the network where only this channel is present (e.g. before the combiner in a headend) the most important factors to avoid are:

- harmonics of the signal itself which can be filtered out by a convenient filter;
- leakage into the adjacent channel. This is difficult to filter, however, errors in the measurement due to this can be estimated. If the leakage power is more than 20 dB lower than the total power the measurement error can be estimated not to exceed 0.044 dB. If the difference is of 10 dB the error is about 0.46 dB (differences lower than 10 dB cause correspondingly higher errors);
- other spurious signals from oscillators, etc. The criteria indicated in the above two cases (i.e. dependency on frequency offset from the channel and power level referred to the wanted power of the channel) can be applied;
- noise of the channel itself. This cannot be avoided but is typically very low with respect to the wanted power.

Measurement in the presence of adjacent channels (e.g. after the combiner of the headend) is almost impossible due to the numbers of filters required, one per channel, and also the complexity of each filter which must be flat within the channel under measurement, and have high attenuation for all other channels that may be present.

### **I.2.2 Measurements using a spectrum analyser.**

The spectrum analyser is an instrument with high selectivity, so that it can make measurements in very narrow frequency bandwidths. Its absolute accuracy is typically specified across the entire operational frequency range from a few kHz to a few GHz and across a wide temperature range of about 50°C. Typical amplitude accuracy specification range from  $\pm 1$  dB to  $\pm 2$  dB.

The spectrum analyser can be calibrated under controlled conditions for a restricted bandwidth and temperature, enabling an absolute accuracy in the order of 0.3 to 0.1 dB. The repeatability and resolution is also found to be in the same narrow range.

When measuring the output of a single channel, at a point in the network where only this channel is present (e.g. before the combiner in a headend), the spectrum analyser does not have the problems that are indicated above for measurement with the power meter. It should be noted however that spurious signals within the channel itself cannot be avoided with either a spectrum analyser or a power meter.

Measurement in the presence of adjacent channels (e.g. after the combiner of the headend or at any point in the distribution network up to the user tap) is straightforward for a spectrum analyser. This is due to the high selectivity provided by narrow filters with good shape factors (in practice as low as 5:1). This narrow measurement bandwidth also means that the sensitivity is usually very high compared to wideband instruments. Again, as indicated for single channel measurements, noise, interference or intermodulation products inside the nominal bandwidth of the channel itself cannot be avoided and will be reported as being part of the wanted power of the channel. However, if all these spurious sources of power are more than 15 dB below the RF signal power of the channel, they will pose no great inaccuracy to the total result.

### **I.3 Precautions for measurement of RF noise power**

Noise is generally a difficult measurement to make, especially when it is low and comparable to the internal noise of the measuring instrument.

#### **I.3.1 With a Power Meter**

When measuring the noise at the output of a single channel, at a point in the network where only this channel is present (e.g. before the combiner in a headend), the most important factors to consider are:

- the modulation and the carrier have to be switched off, but the RF stage of the channel has to be left on;
- the signal has to be filtered by a filter of the same central frequency and the same equivalent noise bandwidth as the nominal bandwidth of the channel under test.

NOTE – The shape of this filter need not be as flat and as selective as is required for the case for measurement after the combiner of the headend;

- if the measured noise is close in value to the noise floor of the power meter then correction factors should be applied. (See below under Noise proximity corrections);
- measurement in the presence of adjacent channels (e.g. after the combiner of the headend) is almost impossible due to the numbers of filters required, one per channel, and also the complexity of each filter which must be flat within the channel under measurement, and have high attenuation for all other channels that may be present.

#### **I.3.2 With a Spectrum Analyser**

The spectrum analyser, due to its high selectivity, can readily make measurements in both single channel and multiple channel applications.

When measuring the noise of a channel it is necessary to consider the following:

- the modulation and the carrier have to be switched off, but the RF stage of the channel has to be left on;
- alternatively, if the noise of the distribution system is to be measured, the RF stage of the channel has to be switched off also;
- if the measured noise is close in value to the noise floor of the power meter then correction factors should be applied. (See below under Noise proximity corrections).

### **I.4 Noise proximity corrections**

The noise floor of the measurement instrument can be measured by connecting at its input a resistive load of the same value as its input impedance (in CATV applications this value is typically 75Ω).

When an external noise signal with the same power as the internal noise floor is applied to the input of the instrument, the trace of the spectrum analyser, or the reading of whatever instrument it is, increases by 3 dB. Thus the value of the applied noise is equal to the reading minus a correction term, which depends on how much the reading is increased. In the above example the correction term is 3 dB.

If the difference between the reading at the noise floor and the actual measurement value is called "D" expressed in dB, the correction term may be calculated by the formula:

$$\text{Correction}_{\text{dB}} = -D + 10 \lg [10^{(D/10)} - 1]$$

Table I.1 provides correction terms for some values of D:

**Table I.1/J.142 – Correction terms for some values of D**

<b>D<sub>dB</sub></b>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
<b>Correction Term</b>	-16.43	-13.47	-11.76	-10.56	-9.64	-8.89	-8.27	-7.74	-7.28	-6.87
<b>D<sub>dB</sub></b>	1.5	2	3	4	5	6	7	8	9	10
<b>Correction Term</b>	-5.35	-4.33	-3.01	-2.20	-1.65	-1.26	-0.97	-0.75	-0.58	-0.46
<b>D<sub>dB</sub></b>	11	12	13	14	15	16	17	18	19	20
<b>Correction Term</b>	-0.359	-0.283	-0.223	-0.176	-0.140	-0.110	-0.080	-0.069	-0.055	-0.044

Several spectrum analysers that are currently available introduce this correction term automatically dependent on the value of the noise measurement with respect to the proper noise floor. To ensure measurement reliability, some instruments introduce corrections down to a value of D equal to 2 dB, but not when it is lower, due to the uncertainty caused by too large a correction factor.

As an example, if the measurement result of the noise floor is -160 dB/Hz and the noise measured in a network is -156 dB/Hz, the increase is 4 dB and the resulting correction is -2.2 dB. This results in a corrected value for the external noise of -158.2 dB/Hz.

### **I.5 Approximation of measurements for average power and carrier to noise**

The spectrum of a digitally modulated signal is similar to that of noise so the power measurement may be calculated using the power density applied to the total bandwidth of the channel.

Typically the spectrum is flat for the major part of the channel.

When the spectrum analyser does not have the capability of integrating all the power over the bandwidth of the channel, an approximate measurement of total power may be done.

The method explained below is valid both for carrier power and for noise power within the channel.

Noise proximity corrections should be added when necessary.

Due to the assumptions made, the values obtained with the method below are approximate and should never be used for system acceptance unless both parties agree on the methodology.

#### **I.5.1 Measurement with a spectrum analyser that does not include density spectrum measurement capability**

The measurement is made at a point near the centre of the spectrum using a resolution bandwidth at least 10 times narrower than the bandwidth of the channel. This method assumes that the level inside the channel is like flat noise with the same level as the one at the measured point.

Attention should be paid to the amplitude response of the noise spectrum inside the channel. If it is not a flat spectrum, care should be taken not to measure at the maximum or minimum points.

Calculate the carrier power by the following formula:

$$C = C_N + 10 \lg_{10} (BW/RBW) - k + 2.5 \text{ dB}$$

where:

- C is the carrier mean power in the same units as  $C_N$ .
- $C_N$  is the carrier level in dB $\mu$ V, dBmV or dBm, as measured at the selected measurement point. (Measured as if it were noise).
- BW is the bandwidth of the channel.

RBW is the resolution bandwidth of the spectrum analyser. (In the same units as BW).

k is a correction factor for the filter shape of the spectrum analyser.

The term 2.5 dB accounts for the 1.05 dB correction for narrowband-envelope detection plus 1.45 dB correction for the logarithmic amplification of the spectrum analyser.

The correction factor (k) depends on the measurement equipment used and should be provided by the manufacturer or obtained by calibration. The value of the k correction factor for a typical spectrum analyser is about 1.2 dB when the resolution bandwidth is defined at the –6 dB level. No correction k factor is used when the resolution factor is defined at –3 dB.

### **I.5.2 Measurement with a spectrum analyser that does include density spectrum measurement capability**

Correction factors are not necessary if the measuring equipment can be set to display the noise level in dBm/Hz units. In this case C can be obtained from the following formula:

$$C = C_N + 10 \lg_{10} (BW)$$

where:

C is the carrier mean power in the same units as CN.

CN is the normalized carrier level in dBμV/Hz, dBmV/Hz or in dBm/Hz.

BW is the bandwidth of the channel in Hz.

### **I.5.3 Measurement with a spectrum analyser that includes density spectrum measurement capability with normalization to any bandwidth**

Some existing spectrum analysers allow direct normalisation of the measurement to any value of bandwidth. The normalization value is set to the nominal bandwidth of the channel. The measurement is done directly by placing the measurement marker at the point of interest in the spectrum of the channel.

Note that in all these cases, the measurement point is selected at a point near the centre of the noise-like spectrum. The result is only an approximation due to the assumption made of flat spectrum through the channel band.

### **I.5.4 In service carrier to noise measurements**

When in-service measurements are needed, an approximation can be made to obtain an assessment of carrier to noise.

Assuming that the power may be represented by the level measured at the centre of the channel with a spectrum analyser using a marker, it is possible to assume a second approximation accepting that the noise in the gap between channels is representative of the noise inside the channel (this implies the assumption that the noise floor is flat along the channel and its surroundings).

With the above assumptions, it is possible to place one of the markers at the top-centre of the channel under measurement and a second marker at the minimum value in the notch between the measured channel and the adjacent upper or lower channel. The difference between markers represents the approximate C/N value.

Due to the assumptions made, the values obtained in this way, are approximate and should never be used for system acceptance.

## **I.6 Other procedures for average power measurements**

Other measurement instruments that measure the average power within the bandwidth of the channel under test are valid as long as the result is independent of the shape of the power spectrum of the measured signal and its calibration may be traced to a power meter.

Such instruments use a band-pass filter with the nominal bandwidth of the channel and calculate the rms value of the voltage in order to calculate the average power of the channel.

### **I.7 BER measurements before FEC decoder (gross rate and net rate)**

Should the errors be random, they may be expected to be equally distributed over the net 188 bytes per packet of information as well as over the 16 bytes of R-S FEC information. With this in mind the gross rate and the net rate will be equal.

However, if the PRBS is contained only in the payload of the TS packets, and if this payload (184 bytes, after discounting the header) is the only one taken into account for counting the erroneous bits received and they are related to the total 204 bytes per packet received to calculate the gross BER, then the net BER for a digital CATV system may be calculated by multiplying the gross BER by the ratio of total received bytes to payload bytes, that is 204/184 or 1.108. If expressed in dB this value represents 0.448 dB.

(BER for errors counted in 184 payload bytes contained within 204 received bytes has to be multiplied by a correction factor of 204/184 to equate with the BER for errors counted in 184 payload bytes that are contained within 184 received bytes.)

For satellite reception, including additional convolutional FEC, the net bit rate may be calculated by multiplying by the FEC code ratio used in the transmission. The FEC code ratio can be 1/2, 2/3, 3/4, 5/6 or 7/8.

For concatenated coding such as Annex B/J.83, the net bit rate may be calculated by multiplying by the total FEC concatenated code rate including synchronization framing headers. The forward error correction (FEC) definition is composed of a concatenated outer block code and an inner trellis code. A Reed-Solomon (R-S) block code with framing, interleaving, and randomization followed by trellis coded modulation (TCM) with differential pre-coding and punctured binary convolutional coding is used. This concatenated FEC coding definition produces an overall coding rate determined by the individual coding steps that expand the contents of the QAM channel symbols beyond the input user information. The overall coding rate that relates channel QAM symbol rate to the input information bit rate is derived in the following.

The outer block code consists of an R-S block code. In general, an R-S code is defined over a  $GF(2^m)$  finite field which carries K information symbols in an N symbol code word, where N is greater than K and each symbol consists of m bits. The input information rate to output coded rate ratio is defined as the code rate, which is less than or equal to one. Hence, the additional redundancy of the N-K syndrome symbols incurs a rate loss through the R-S code, defined as the R-S code rate  $R_{RS}$  given by:

$$R_{RS} = \frac{K}{N}$$

The R-S code words are subsequently interleaved and randomized, which are non-expanding operations (rate equal to one). The interleaved and randomized R-S code words are grouped into blocks of L code words to form an FEC frame. A frame synchronization sequence of s bits is appended to each L code word frame. This additional s bit sync word produces a framing rate loss  $R_{Frame}$  given by:

$$R_{Frame} = \frac{[L \cdot N \cdot m]}{[L \cdot N \cdot m + s]}$$

The resultant frames are supplied as the input to the inner trellis code. Trellis groups are formed by serializing the input frames to form groups of five QAM symbols of q bits per symbol, where each of two bits in the five QAM symbols are encoded by a rate 1/2 binary convolutional coder and

subsequently punctured to rate 4/5. Thus two of each of the q bits in the five QAM symbol trellis group are rate 4/5 coded for a total of 10 coded bits, and the remaining q-2 bits in each of the 5-QAM symbols trellis group are uncoded. The trellis code rate  $R_{Trellis}$  is therefore determined as:

$$R_{Trellis} = \frac{5(q-2) + 5(2)(4/5)}{5q} = \frac{[5q-2]}{5q}$$

The overall concatenated FEC code rate  $R_{FEC}$  is given by the product of the code rate of the individual coding procedures just described as:

$$R_{FEC} = R_{RS} R_{Frame} R_{Trellis}$$

Substituting the above derived code rates yields:

$$R_{FEC} = \frac{K}{N} \cdot \frac{[L \cdot N \cdot m]}{[L \cdot N \cdot m + s]} \cdot \frac{[5q-2]}{5q}$$

The information bit rate  $R_I$  is determined from the channel bit rate  $R_C$  by the concatenated FEC code rate as:

$$R_I = R_C R_{FEC}$$

where the channel bit rate is q times the channel symbol rate with q bits per QAM symbol.

The above derived relationships are tabulated for both 64-QAM and 256-QAM in Table I.2.

**Table I.2/J.142**

Parameter	Symbol	64-QAM Format	256-QAM Format
RS code symbols	N	128	128
RS information symbols	K	122	122
RS bits/symbol	m	7	7
FEC Frame code words	L	60	88
FEC Frame sync bits	s	42	40
QAM bits/symbol	q	6	8
RS code rate	$R_{RS}$	0.9531250	0.9531250
Framing rate	$R_{frame}$	0.9992194	0.9994930
Trellis code rate	$R_{trellis}$	0.9333333	0.9500000
FEC concatenated code rate	$R_{FEC}$	0.8888889	0.9050097
Channel symbol rate	$R_S$	5.056941 Msymb/s	5.360537 Msymb/s
Channel bit rate	$R_C$	30.34165 Mbit/s	42.88430 Mbit/s
Information bit rate	$R_I$	26.97035 Mbit/s	38.81070 Mbit/s

## APPENDIX II

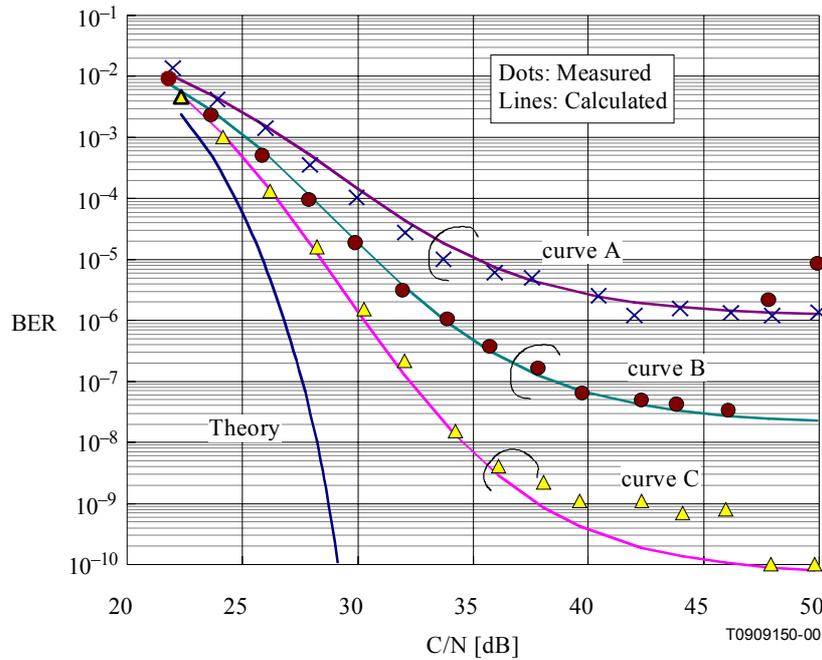
### Harmonics disturbance to noise margin measurement

In 64-QAM transmission over cable television network, under the condition that one (1) or more monotonics, 2nd and/or 3rd harmonic distortions exist in the transmission band, it is observed that BER vs. C/N characteristics approach the theoretical curve in the relatively low C/N domain,

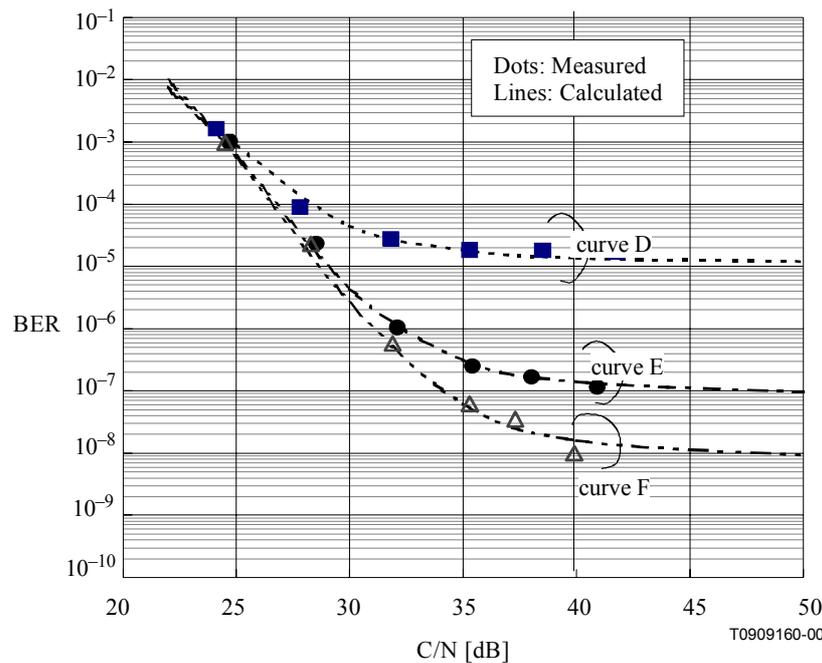
however the measured values depart from the theoretical one in the high C/N domain; such phenomenon is so called "floor effect".

Figures II.1 and II.2 are examples of BER vs. C/N characteristics that could be observed usually in a 64-QAM trans-modulated system where one or more monotone disturbances exist. It should be noted that each disturbance is intentionally given to the transmission line in order to accentuate the "floor effect" with relatively higher C/N ratio.

Table II.1 shows monotone disturbances added to the transmission line. Figure II.3 shows the measurement test set-up.



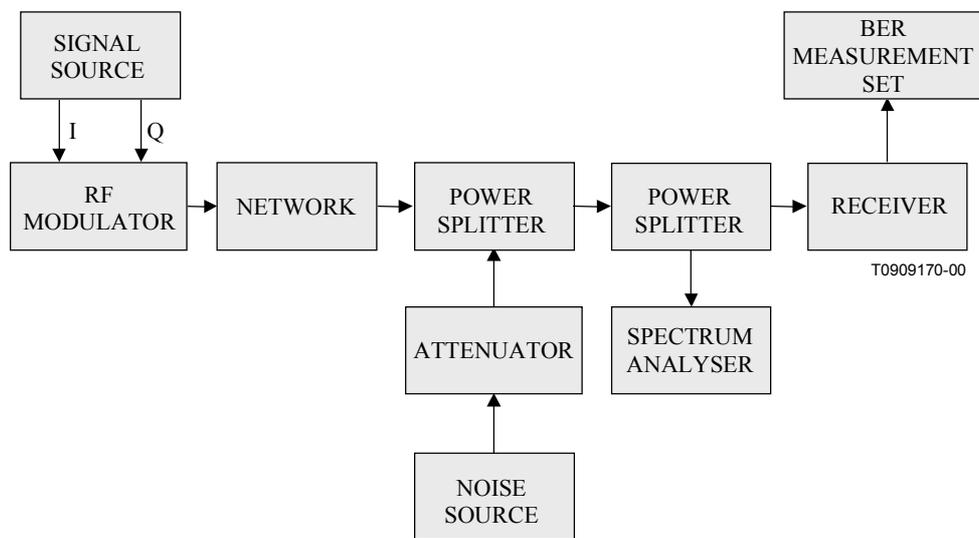
**Figure II.1/J.142 – Measured BER vs C/N where only single tone exists**



**Figure II.2/J.142 – Measured BER vs C/N where only single tone exists**

**Table II.1/J.142 – Monotones added to 64-QAM transmission line**

		<b>Tone disturbance conditions (C: average power of QAM, I: p-p level)</b>
Fig. II.1	Curve A	Monotone disturbance with C/I = -26.3 dB and white noise with variable C/N
	Curve B	Monotone disturbance with C/I = -31.3 dB and white noise with variable C/N
	Curve C	white noise only with variable C/N
Fig II.2	Curve D	5 monotones with C/I = -50.2, -62.2, -56.6, -60.4 and -56.5 dB and white noise with variable C/N
	Curve E	5 monotones with C/I = -55, -64.5, -60.8, -64.8 and -61 dB and white noise with variable C/N
	Curve F	5 monotones with C/I = -57.3, -66.3, -63.1, -66.2 and -63.5 dB and white noise with variable C/N



**Figure II.3/J.142 – Measurement test set-up**

Considering such disturbances, N1 is measured and noted where BER is kept fixed to the same value, in this case  $BER = 1 \times 10^{-5}$ , and then N2 is measured and noted with the same condition. The results are shown in Tables II.2 and II.3. In these measurements, N1 means the C/N ratio when only white noise exists, while N2, the C/N ratio when tone disturbances are given with white noise.

**Table II.2/J.142 – Noise margin of curves A, B and C**

	<b>N1 = C/N</b>	<b>BER</b>	<b>Measured N2</b>	<b>Noise margin</b>
Curve A	35 dB	$1 \times 10^{-5}$	31 dB	4 dB
Curve B	31 dB	$1 \times 10^{-5}$	27.5 dB	3.5 dB
Curve C	28 dB	$1 \times 10^{-5}$	23 dB	5 dB

**Table II.3/J.142 – Noise Margin of Curves D, E and F**

	<b>N1 = C/N</b>	<b>BER</b>	<b>Measured N2</b>	<b>Noise margin</b>
Curve D	better than 50 dB	$1 \times 10^{-5}$	28 dB	greater than 22 dB
Curve E	28.5 dB	$1 \times 10^{-5}$	27 dB	1.5 dB
Curve F	28 dB	$1 \times 10^{-5}$	27 dB	1 dB

Comparing curve C of Table II.2 (single tone disturbance) and curve F of Table II.3 (five tones disturbance), the measured values of N2 are 23 dB and 27 dB, and the calculated noise margin (NM) are 5 dB and 1 dB respectively, in spite of the same test conditions ( $N1 = 28$  dB and  $BER = 1 \times 10^{-5}$ ). This difference means that the noise margin test method by white noise only cannot always represent the accurate system margin.

From a different point of view: Suppose C/N is fixed to 40 dB ( $E_b/N_o$ ) in this case, Tables II.4 and II.5 are obtained from curves A through F.

**Table II.4/J.142 – Measured BER, N2 and NM in single tone method**

	<b>N1 = C/N (<math>E_b/N_o</math>)</b>	<b>BER</b>	<b>Measured N2</b>	<b>Noise margin</b>
Curve A	40 dB	$7 \times 10^{-5}$	31 dB	9 dB
Curve B	40 dB	$3 \times 10^{-7}$	27.5 dB	12.5 dB
Curve C	40 dB	$5 \times 10^{-10}$	23 dB	17 dB

**Table II.5/J.142 – Measured BER, N2 and NM in 5 tone method**

	<b>N1 = C/N (<math>E_b/N_o</math>)</b>	<b>BER</b>	<b>Measured N2</b>	<b>Noise margin</b>
Curve D	40 dB	$9 \times 10^{-4}$	28 dB	12 dB
Curve E	40 dB	$3 \times 10^{-7}$	27 dB	13 dB
Curve F	40 dB	$5 \times 10^{-10}$	27 dB	13 dB

These tables show the fact that the test method by white noise only can take different values in the presence of monotone disturbances. The difference means that the noise margin test method by white noise is highly affected by the presence of monotones or combined products which the transmission line usually contains.

Also it is not always appropriate to apply  $E_b/N_o$  ratio to a cable television system where one or more monotone disturbances exist with white noise. In stead of using  $E_b/N_o$ , it seems to be appropriate to use the total noise power test method although the suitable test method should be further studied.

NOTE – The noise margin test method by white noise may be applicable to a full-digital cable television system where no analogue carriers and only dispersed carriers do exist. This appendix can be useful for the noise margin test in the mixed condition of analogue and digital systems in which tone disturbances inevitably exist with QAM signals.

## Mutual interference between analogue and digital signals

### III.1 Mutual interference between analogue and digital signals

In this appendix measurement of parameters for mutual interference between Analogue NTSC and Digital (64-QAM modulated) television signals is described. Co-existence of analogue and digital signals is expected for some period prior to commencement of full-digital services. Mutual interference between analogue signals and digital signals except for 64-QAM should be further studied.

#### III.1.1 Interference to NTSC analogue signals from 64-QAM digital signals

In this clause measurement of interference to NTSC Analogue Signals from 64-QAM Digital Signals is described. Test set up is shown in Figure III.1.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure III.1.
- Set NTSC Analogue video and audio signals for evaluation.
- Set modulation ratio of video and audio signals of NTSC-VSB-AM modulator.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator and connect with 64-QAM modulator.
- Set signal level and frequencies (upper or lower adjacent channel to Digital channel) of UP CONV.
- Confirm all the input and output signal levels are appropriate.

Measure S/N of video and audio signals by changing D/U ratio. Confirm interference to video and audio signals by A/V Analyser and Television Monitor

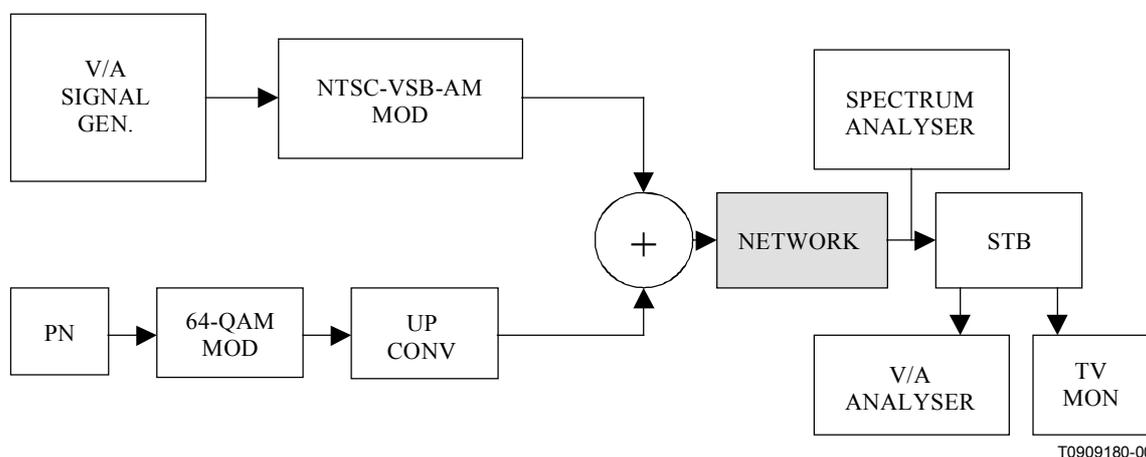


Figure III.1/J.142 – Measurement of interference to analogue signals from digital signals

#### III.1.2 Interference to 64-QAM digital signals from NTSC analogue signals

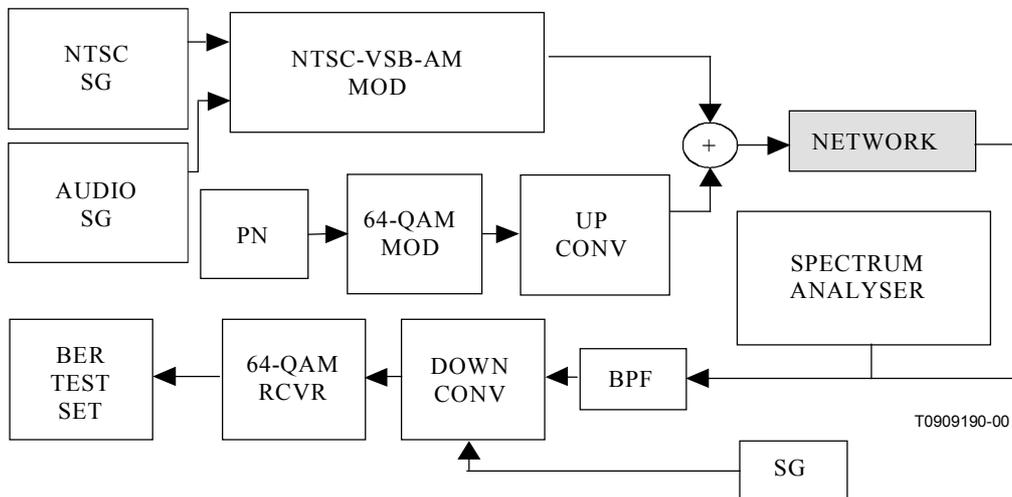
In this clause measurement of interference to 64-QAM Digital Signals from NTSC Analogue Signals is described. Test set up is shown in Figure III.2.

The measurement procedure is as follows:

- Set up measurement equipment in accordance with Figure III.2.
- Set the PN Pattern ( $2^{23}-1$ ) of Pseudo Noise generator and connect with 64-QAM modulator.

- Set signal level and frequencies (upper or lower adjacent channel to Analogue channel) of UP CONV. and DOWN CONV.
- Set video and audio signal levels of signal generators.
- Confirm all the input and output signal levels are appropriate.

Measure BER of Digital channel by changing D/U ratio.



**Figure III.2/J.142 – Measurement of interference to 64-QAM digital signals from NTSC analogue signals**

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