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TECHNICAL NOTE

OC-192 Jitter Measurement

MP1570A SONET/SDH/PDH/ATM Analyzer

MP1580A Portable 2.5G/10G Analyzer

ANRITSU CORPORATION

Contents

1. Introduction

This technical note introduces the measuring method for verifying jitter generation and jitter transfer, and total jitter of the OC-192 network elements or its components.

2. Sources of Jitter

Depending on the jitter generation mechanisms or causes, various types of jitter occur in the OC-192 network elements. The typical types of jitters are classified in two, systematic and non-systematic jitters.

2.1 Pattern Dependent Jitter (Systematic Jitter)

Since systematic jitters are related to the data transmission patterns, they called as the pattern jitter. For example, applying a periodical signal like PRBS patterns to the network element, the jitters occur with their periodicity. The frequency spacing is given by the formula 1).

$$f_{pd} = \frac{Bitrate}{2^n - 1} \quad \text{(Hz)} \qquad \text{--------- 1)}$$

n: number of shift register

Inserting the parameters Bit-rate: 9953.28MHz, and n: 7(PRBS2^7-1), frequency of the pattern jitter is f_{pd}=78.372MHz (2f_{pd}=156.744MHz, 3f_{pd}=235.116MHz), and such periodical pattern jitter is likely occurred in the network element.

Moreover, the pattern jitter that caused by such as the SONET frame cycle account for a large part of the jitter generation in the network element. The frame cycle of 125u sec. cause the pattern jitter, which frequency is f_{pd}=8kHz, in the network element. The jitter components of the 8kHz pulse contain many higher harmonics, and they cannot be removed even though the 50kHz High Pass Filter used with the jitter measurement. These pattern jitters are usually generated in the optical transmitters, so the amplitude of the output jitter depends on them. Also, the each network elements have similar tendency of the jitter generation; hence, the total jitter in the network system is influenced by the accumulation effect of jitter output from the each network elements. Such the accumulation of jitter output significantly influences the transmission quality. Therefore, from the ITU-T recommendation, each network elements are required to evaluate for pattern dependent jitter so to avoid constructing the less quality network system. With the jitter measurement, the ITU-T recommendation defines data transmission pattern as follows.

STM-64, VC-4-64c-Bulk, Payload: PRBS2^23-1
(For SONET --- OC-192, STS-192c-Bulk, Payload: PRBS2^23-1)

2.2 Nonsystematic Jitter

Nonsystematic jitter is mainly caused by SSB-Noise of oscillators, and such the jitter generations differently and individually occur with the network elements; therefore, there are less effects of accumulation to influence the transmission quality. Especially in OC-192, the very narrow jitter transfer function (cut off frequency is 120kHz of filter) is specified, and the accumulation effect of nonsystematic jitter is extremely reduced.

3. Calibration Method for Jitter Analyzer

3.1 Calibration Method for Jitter Analyzer

Generally the calibration method of using the Bessel null point is used for a phase modulation. With a jitter analyzer, such the calibration method is used because the jitter modulation is equivalent with the phase modulation. So, the calibration method should be performed by the clock interface as shown in Fig. 1. At first, the jitter generator is calibrated by the Bessel null method, and then the clock signal with specified jitter amplitude X (UI_{p-p}) is applied into the jitter detector. At the detector, based on the calibrated amplitude of the jitter generator is used to adjust the jitter detector to the jitter amplitude X (UI_{p-p}). At this time, the sinusoidal wave with equivalent the jitter amplitude X (UI_{p-p}) is observed at the demodulation output of the jitter detector.

If the jitter analyzer is calibrated with an optical data interface as shown in Fig. 2, the calibration is made with pattern jitter components. Here, the pattern jitter is given as f_{pd}=8kHz, amp. = Y (UI_{p-p}) caused by SONET framing. At the jitter detector, X+Y (UI_{p-p}) is detected, and also the equivalent with the jitter amplitude X+Y (UI_{p-p}) is observed at the demodulation output of the jitter detector. However, under such circumstances, the jitter detector is calibrated and displays the inaccurate jitter amplitude as X (UI_{p-p}). From the calibration with the optical data interface, the jitter measurement result will display smaller than the actual amount of jitter, and the pattern jitters, which are important elements in the jitter generation, cannot be evaluated.

Hence, the jitter analyzers should be calibrated with clock interface, and ITU-T O.172 (Recommendation for the jitter analyzer) recommends the accuracy for clock interface. Anritsu jitter analyzers follow with this calibration method.

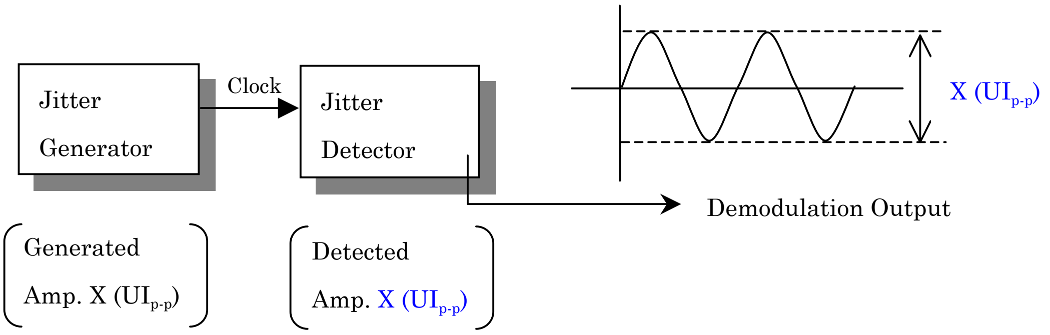


Fig.1 Calibration with Clock Interface

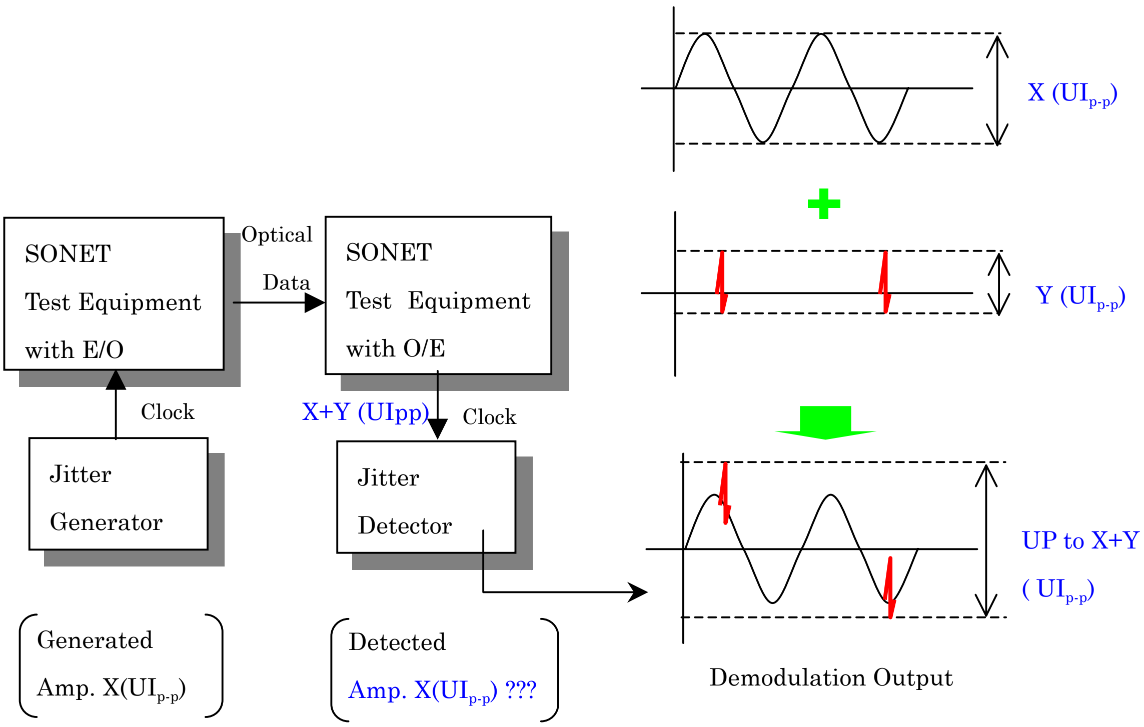


Fig.2 Calibration with Data Interface

3.2 Practical Measurement Result

The practical waveform of Demodulation Output on the jitter analyzer, which is calibrated with optical interface, is shown in Fig.3 and 4. Here, Sinusoidal jitter is applied as fm=4kHz, amp.=$0.1UI_{p-p}$ in the same configuration as shown in Fig.2. Total jitter component is shown as $0.1UI_{p-p}$ + $0.05UI_{p-p}$ =$0.15UI_{p-p}$ (there is some difference for the convolution amplitude, because of the frequency or phase between sinusoidal jitter and pattern jitter) at the Demodulation Output. In this case, read amplitude is $0.1UI_{p-p}$ on the jitter detector, which is calibrated with optical interface. However, actual read amplitude should be $0.15UI_{p-p}$. Moreover, residual jitter of measurement equipment may be reduced on the display, but it is incorrect since pattern jitter is deducted.

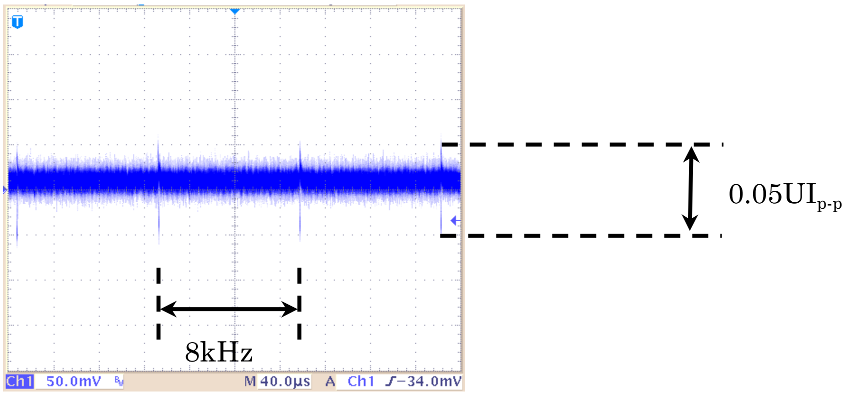


Fig.3 Demodulation Output (No jitter applied)

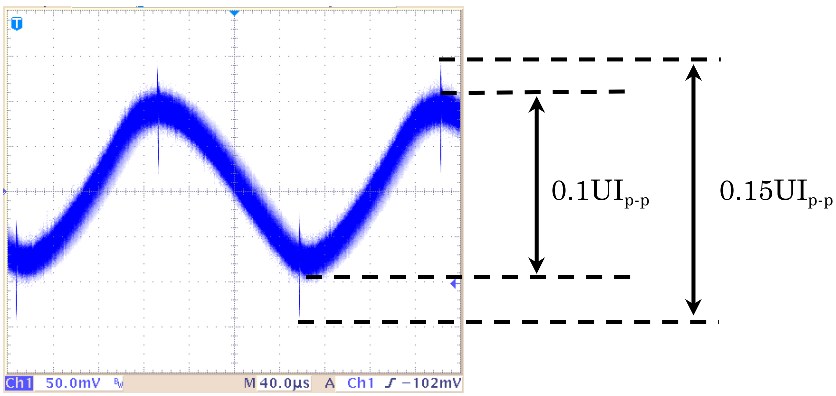


Fig.4 Demodulation Output (Sinusoidal jitter convoluted)

4. Methodologies for more Accurate Jitter Measurement

4.1 Jitter Generation Measurement (Telcordia $_{TM}$ GR-253-CORE Issue3)

Recently the output jitter performance of network elements or components is required very tight specification with higher date stream. Based on Telcordia GR-253-CORE, the jitter generation of OC-192 network element is specified as $0.1UI_{p\text{-}p}$ or less (with 50k-80MHz filter). Especially, the measurement error or the residual jitter influence of the analyzers in optical interface to the measurement result cannot be disregarded in the jitter generation measurement. This chapter shows the correction method for the residual jitter of Analyzers in the optical interface to obtain the measurement result more near the true value.

• Procedure

1) Loop back the optical interface with the analyzers as shown in Fig.7.
2) Set the test pattern for Non-frame pattern with “01” repetition.
3) Set the jitter generator with Mod.select = OFF (No jitter applied).
   Measure the residual jitter, and note the value as Y0 ($UI_{p\text{-}p}$).
4) Apply fm=300kHz, Amp.=$0.01UI_{p\text{-}p}$ with jitter generator, note as X1(UIpp), and note the measured Rx values as Y1($UI_{p\text{-}p}$).
5) Apply X2=$0.02UI_{p\text{-}p}$, X3=$0.03UI_{p\text{-}p}$…..and X20=$0.2UI_{p\text{-}p}$ to repeat the measurement.

The result obtained from the procedure is applied to the formula 2), and compensates for the optical interface. The example of compensated result is shown in Fig.5 and Fig.6.

$Xrn = Yn - Y0$ ($UI_{p\text{-}p}$) ----------2)

Using “01” repetition pattern, the residual jitter of the analyzer is measured without the influence of the pattern jitter. The residual jitter is deducted from the jitter detector’s measurement result to compensate the residual jitter of the optical data interface accurately.

The practical jitter generation measurement is explained in the page 9 and 10. At first, measure the residual jitter Y0 ($UI_{p\text{-}p}$) of the analyzer with using “01” repetition pattern. The specified test pattern for SONET is set. With the detected value of Y ($UI_{p\text{-}p}$), the residual jitter Y0 ($UI_{p\text{-}p}$) of the analyzer is deducted to compensate the result.

In this case, this theory is based on the assumption, when use repetition of “01” pattern that the cause of the residual jitter is in the receiver and that the effects from the transmitter are extremely small on the jitter analyzer. Moreover, this consideration is not applied to the evaluation of the clock interface.

n	Xn (UI_{p-p})	Yn (UI_{p-p})	Xrn (UI_{p-p})
0	0.000	0.023	0.000
1	0.010	0.031	0.008
2	0.020	0.040	0.017
3	0.030	0.052	0.029
4	0.040	0.061	0.038
5	0.050	0.072	0.049
6	0.060	0.082	0.059
7	0.070	0.092	0.069
8	0.080	0.105	0.082
9	0.090	0.113	0.090
10	0.100	0.124	0.101
11	0.110	0.133	0.110
12	0.120	0.142	0.119
13	0.130	0.152	0.129
14	0.140	0.164	0.141
15	0.150	0.175	0.152
16	0.160	0.187	0.164
17	0.170	0.194	0.171
18	0.180	0.206	0.183
19	0.190	0.215	0.192
20	0.200	0.234	0.211

Bit Rate: 9953.28Mbit/s

Pattern: “01” repetition

$Y0 = 0.023UI_{p-p}$

Fig.5 Jitter Generation Measurement Result (Example)

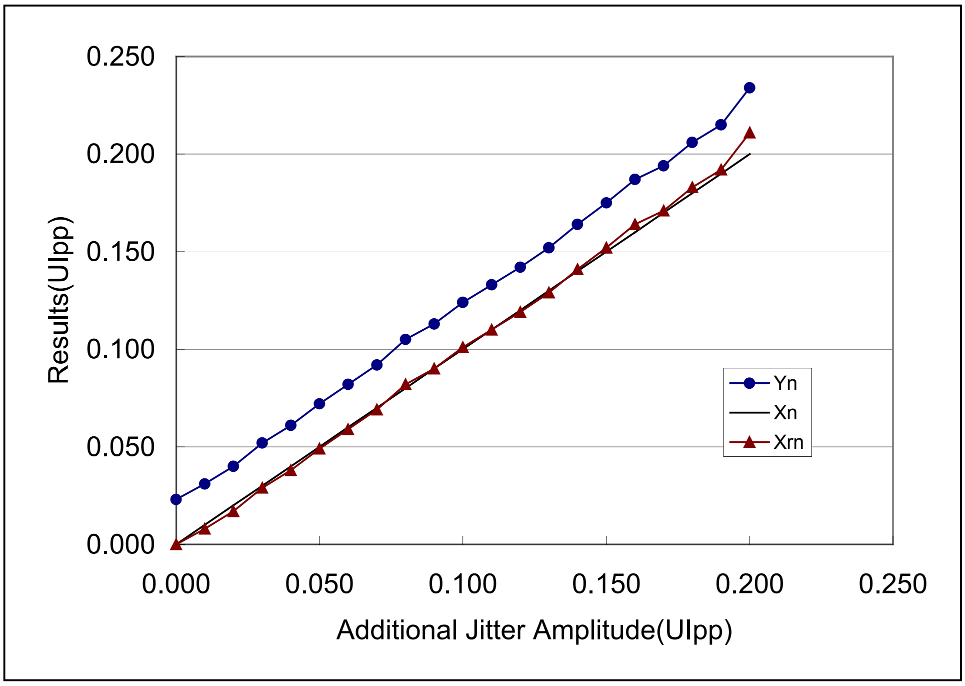


Fig.6 Compensated Result (Example)

Jitter Generation Measurement (Telcordia$_{TM}$ GR-253-CORE Issue 3)

○Connecting Measurement System

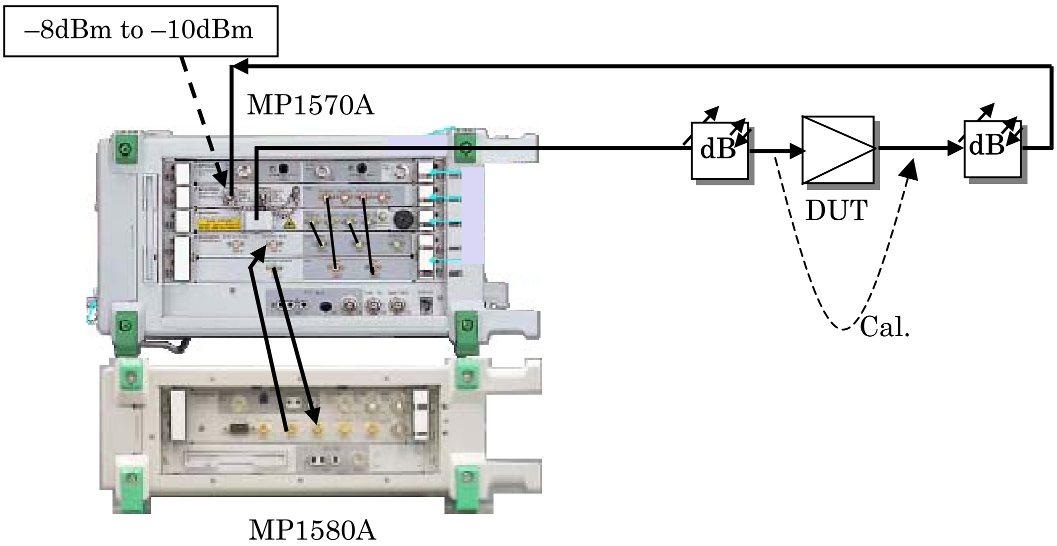


Fig.7 Jitter Generation

When calibration (measuring the residual jitter Y0 (UI$_{p\text{-}p}$)), the optical interface is looped back.
DUT is in place while applying the jitter generation.
At the time of the calibration and the jitter generation measurement, keep the optical power constant.

As the Fig.13, Power Divider can be used to measure.

Caution

Check the interface matches between transmitter and receiver and input/output optical power of DUT

Jitter Generation Measurement (Telcordia$_{TM}$ GR-253-CORE Issue 3)

○Setting Loop back the optical interface with the analyzers

1) Set the MP1570A's screen as below.

Setup: Mapping   Config: Non frame pattern

Test menu: Manual   Test patt: word16   [0101010101010101]

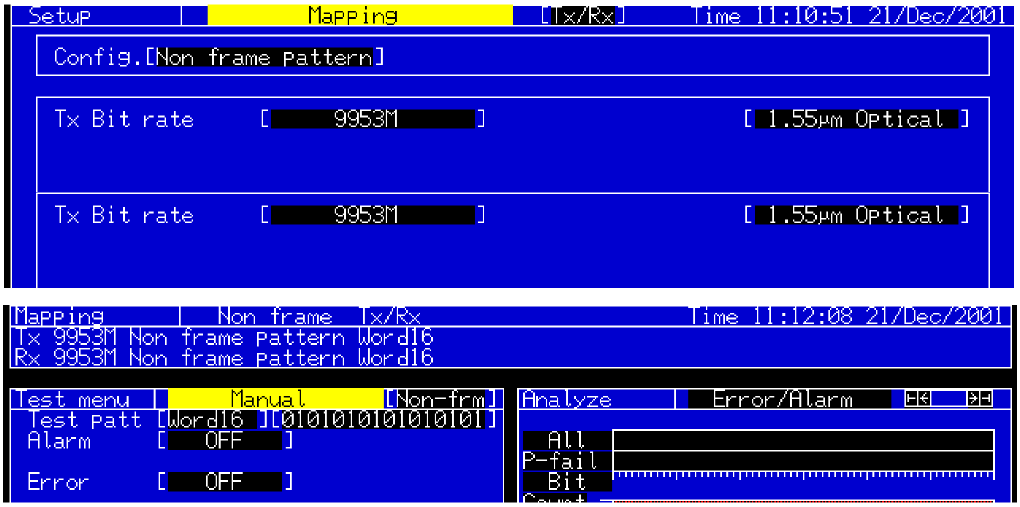


Fig.8 MP1570A Screen

2) Set the MP1580A's screen as below.

Test menu: Manual   Tx mod. select: OFF

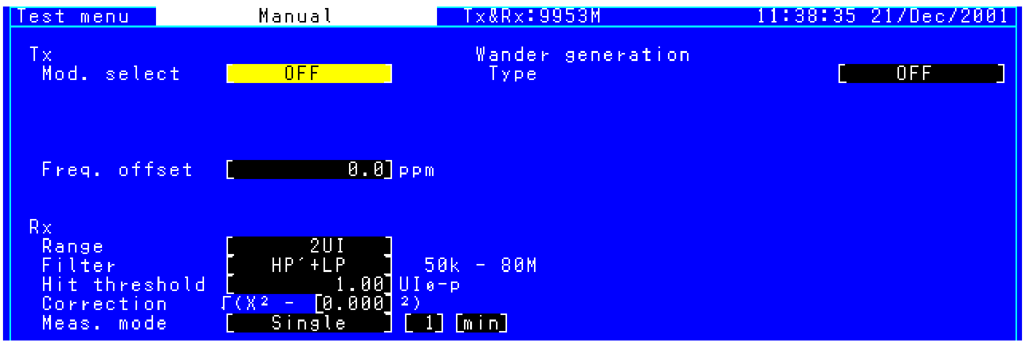


Fig.9 MP1580A Screen

3) Measure the residual jitter Y0 (UI$_{p\text{-}p}$).

4) Specify test pattern with MP1570A.

Ex) Setup: Mapping screen

Config: SONET,

Mapping: OC-192, STS-192c-Bulk

Test menu: Manual screen

Test patt: PRBS23

5) Insert the DUT, measure the jitter generation, and note the result as Y (UI$_{p\text{-}p}$).

6) Use the formula 2) to calculate the compensated result.

4.2 Jitter Transfer Measurement (Telcordia $_{TM}$ GR-253-CORE Issue 3)

In this section, the better way of measuring jitter transfer is introduced, and the method is explained in the following pages. From the procedure, such jitter transfer measurement raises the maximum ability of the analyzer.

In Telcordia GR-253-CORE Issue 3 (ex Bellcore 1377) of SONET recommendation, the jitter transfer mask is defined as follows.

The Cutoff frequency of the jitter transfer mask is increased in proportion to the bit rate below OC-48 level. In that case, the maximum attenuation of jitter transfer on the upper frequency limit is -19.9dB. However, in OC-192 case, it goes down to -56.4dB. Because this limit value is close to the dynamic range of test equipment, as a result of performance limitation of test equipment, it will appear less repeatability or out of specification. Jitter transfer value is defined by the formula 3).

Jitter transfer = $20*\log_{10}(A_{Rx}/A_{Tx})$ [dB] --------- 3)

A_{Tx}: Tx added jitter amplitude A_{Rx}: Rx measured jitter amplitude

So the Tx jitter amplitude will influence to dynamic range of test equipment. It says that increasing Tx jitter amplitude will magnify the dynamic range.

〈The trend of ITU-T G.783 standard and the Telcordia GR-253 standard〉

The ITU-T Rec.G.783 (Telcordia GR-253) specifies the cutoff frequency of Jitter transfer measurement and the gain characteristic of the pass band and the roll-off zone. However, the measurement frequency range was not indicated in detail. When applying the zone of Jitter generation or Jitter measurement filter, it will become difficult to accurately measure the gain at the upper limit frequency and it will become difficult to re-present the condition because the noise area gets closer. For example, the GR-253 standard mask in the OC-192 bit rate will be -56.4dB at 80MHz Jitter measurement upper limit frequency, when considering the inclination of -20 dB/Decade at cutoff frequency fc=120kHz. However, if we obtain a value of -56.4dB @ 80MHz by drawing a straight line from the cutoff frequency fc to the upper limit frequency, the specification will be over specified compared to the nature of the standard.

The ITU-T SG15 has also discussed this issue, and has determined to set the upper limit at fc x 100 in May this year, and has reflected this in the up to date standard.

The GR-253 standard similarly describes as follows. Although the input Jitter amplitude is limited with the Jitter tolerance mask, the standard now demands for large attenuation volume around high modulation frequency band. Therefore since it has become impossible to disregard the relation with the noise floor, they recommend the upper limit frequency by using an expression, <u>two decade of the break point</u> (Refer to appendix-1).

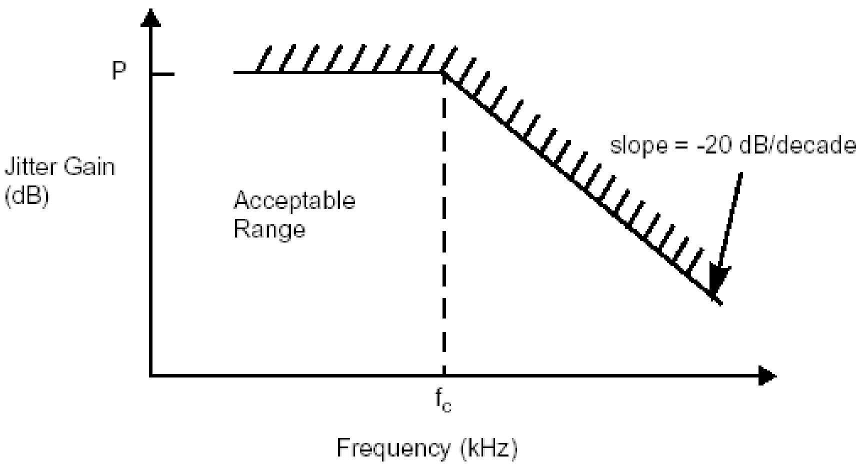
Consequently, it is an indispensable condition to clear -40dB gain at fc x 100 frequency.

⟨Anritsu's proposal⟩

We would like to forward the following proposal.

Measure up to fc x 100, and by maintaining -40dB at frequencies further up, we consider that the present standard interpreted is met. As for the standard mask of MP1580A, by editing a User table, it is possible to adapt the up to date standard. Consequently, it becomes possible to measure the performance satisfactorily with the existing measuring instrument MP1580A (with MP1570A). Please consider -40dB measurement conditions referring to the trend of the standards and Anritsu's proposal.

Reference standard: Telcordia GR-253-CORE Issue3



OC-N/STS-N Level	f_c (kHz)	P (dB)
1	40	0.1
3	130	0.1
12	500	0.1
48	2000	0.1
192	120	0.1

Figure 5-27. Category II Jitter Transfer Mask

⟨Reference standard: ITU-T G.783⟩

Replace left hand Figure by right one.

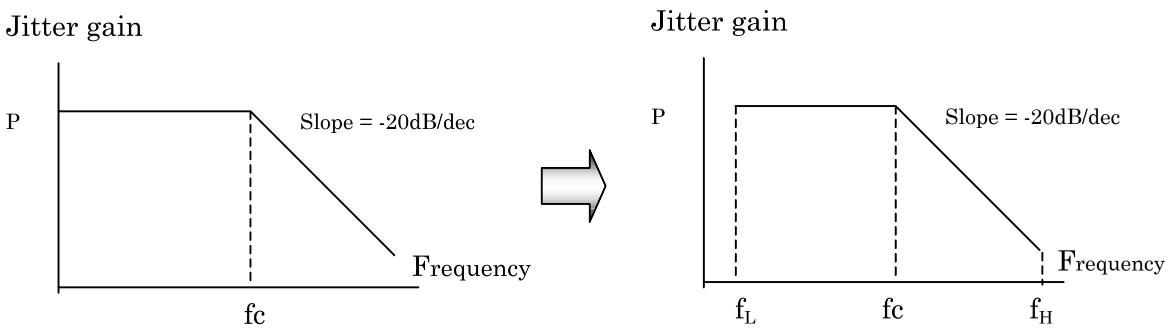


Figure 15-1/G.783– Jitter transfer

Table 15-2/G.783 - Jitter transfer parameters

STM-N level (Type)	f_L (kHz)	fc (kHz)	f_H (kHz)	P (dB)
STM-1 (A)	1.3	130	1300	0.1
STM-1 (B)	0.3	30	3000	0.1
STM-4 (A)	5	500	5000	0.1
STM-4 (B)	0.3	30	3000	0.1
STM-16 (A)	20	2000	20000	0.1
STM-16 (B)	0.3	30	3000	0.1
STM-64 (A)	10	1000	80000	0.1
STM-64 (B)	TBD	TBD	TBD	TBD
STM-256 (A)	TBD	TBD	TBD	TBD
STM-256 (B)	TBD	TBD	TBD	TBD

4.3 Improvement of Measurement Dynamic Range (Reference)

We have two ways to improve of measurement dynamic range, one of method is increased Tx jitter amplitude below tolerance mask, on the other hand not change the Tx jitter amplitude. This section will explain the method to improve dynamic range without increasing Tx jitter amplitude.

To improve a measurement result, better quality of clock (after optical and electrical conversion) is inserted into the jitter analyzer. Proceeding with MP1570A and MP1580A, branch off the clock of MP1570A by using power divider* to supply one of the divided clocks to MP1580A for the jitter measurement. By using this method, the signal quality of the measurement clock will be improved, and it will be expected better result of jitter transfer. Fig.10 shows the dynamic range with the cable connections before improvement (Fig.12). Fig.11 shows the dynamic range with the cable connections after improvement (Fig.13). By using this method, the dynamic range will be improved maximally 10dB at the high frequency band around over 20-MHz.

* By using the power divider, the frequency characteristics of measurement result will be improved at the high frequency band around over 20MHz.

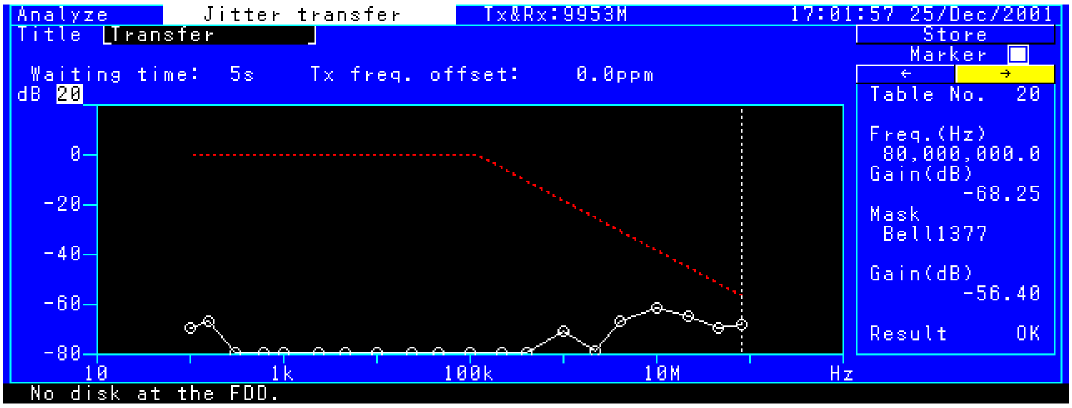


Fig.10 Measured Dynamic Range Result (Before improvement)

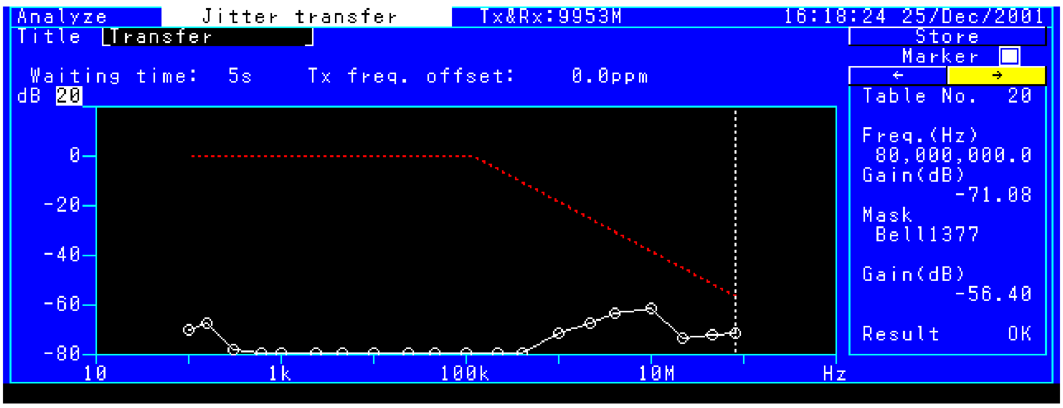


Fig.11 Measured Dynamic Range Result (After high-frequency band improvement)

Measurement system connections for Jitter transfer measurement are as follows.

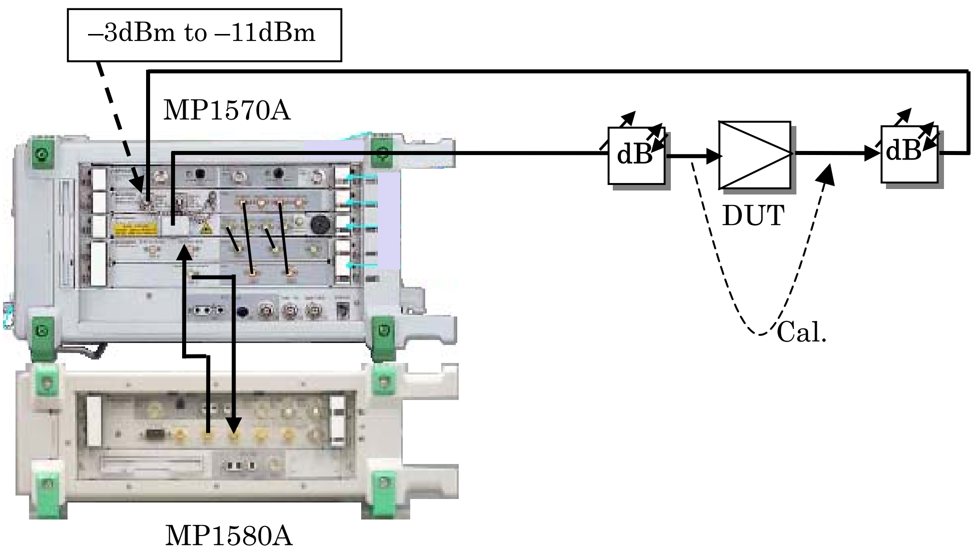


Fig.12 Ordinary Cable Connections

Jitter Transfer Measurement (Telcordia$_{TM}$ GR-253-CORE Issue 3)

○Connecting Measurement System

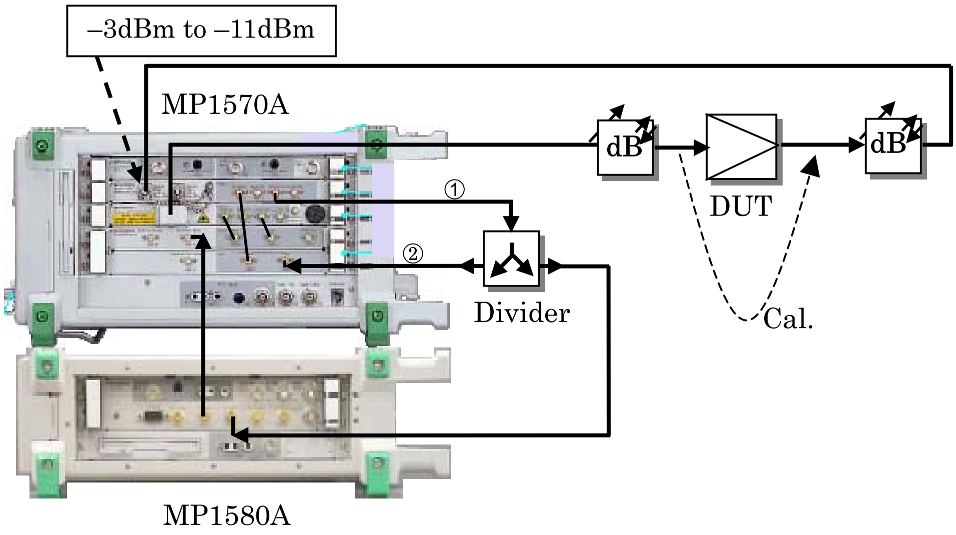


Fig.13 Cable Connections

Insert the power divider between Clock output (Cable ①) of MU150017A/B and Clock input (Cable ②) of MU150000A Unit. See Fig.13.

Connect the remaining output of power divider to Clock input of MU150018A (MP1580A).

To begin the calibration setup, the optical fiber connection is set in loop back.

To begin the measurement setup, insert the DUT between transmitter and receiver.

Caution

1. If the cable length change between data and clock, the phase difference will be caused, and then the error detection appears. In that case, adjust clock phase on the Setup menu (Fig.14) and then check error free performance. Note that this function can be performed in 9953.28Mbit/s configuration.
2. Check the correction of interface between transmitter and receiver and input/output optical power of DUT

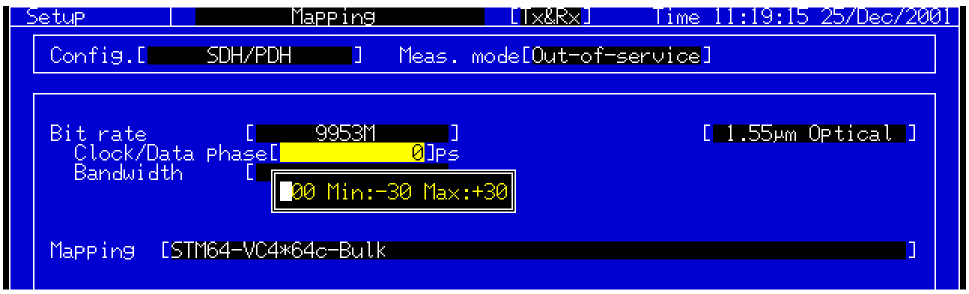


Fig.14 MP1570A Phase Adjustment Setting

Jitter Transfer Measurement (Telcordia$_{TM}$ GR-253-CORE Issue 3)

○Settings

1) At the Test menu screen, select Jitter transfer mode.
2) Set the waiting time to <u>5 s.</u>
3) Start the calibration with loop-back connection.

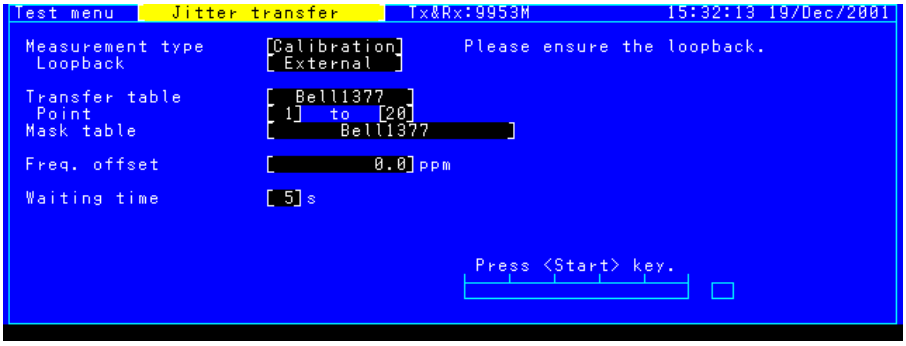


Fig. 15 Settings

4) After the calibration, insert DUT between transmitter and receiver of MP1570A
5) Start the Measurement.

○Measurement result

Examples of the measurement result are as follows.

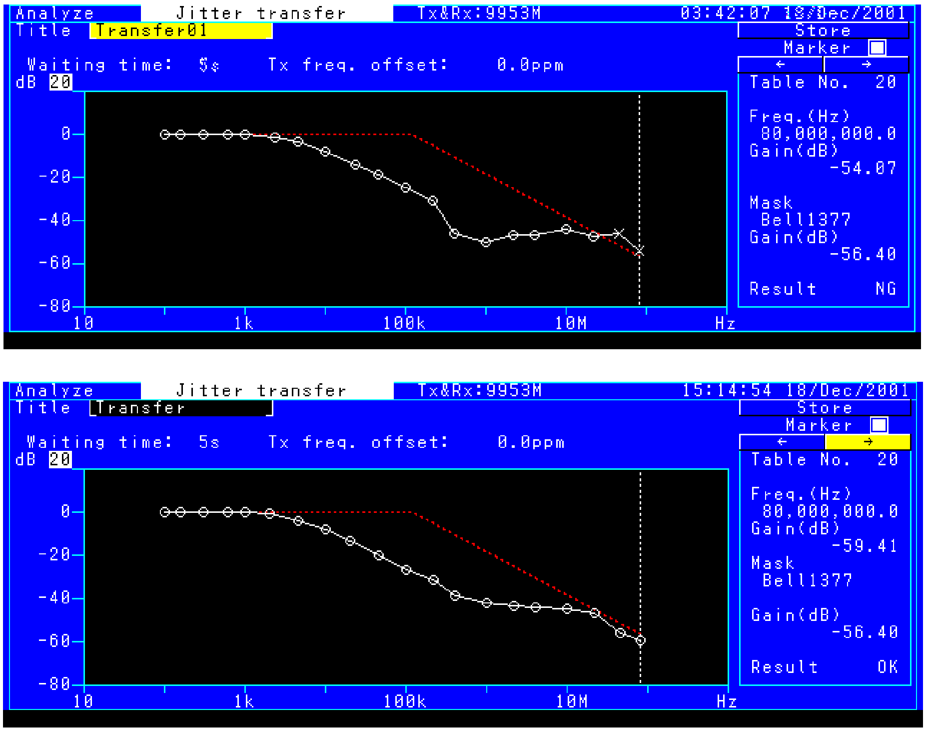
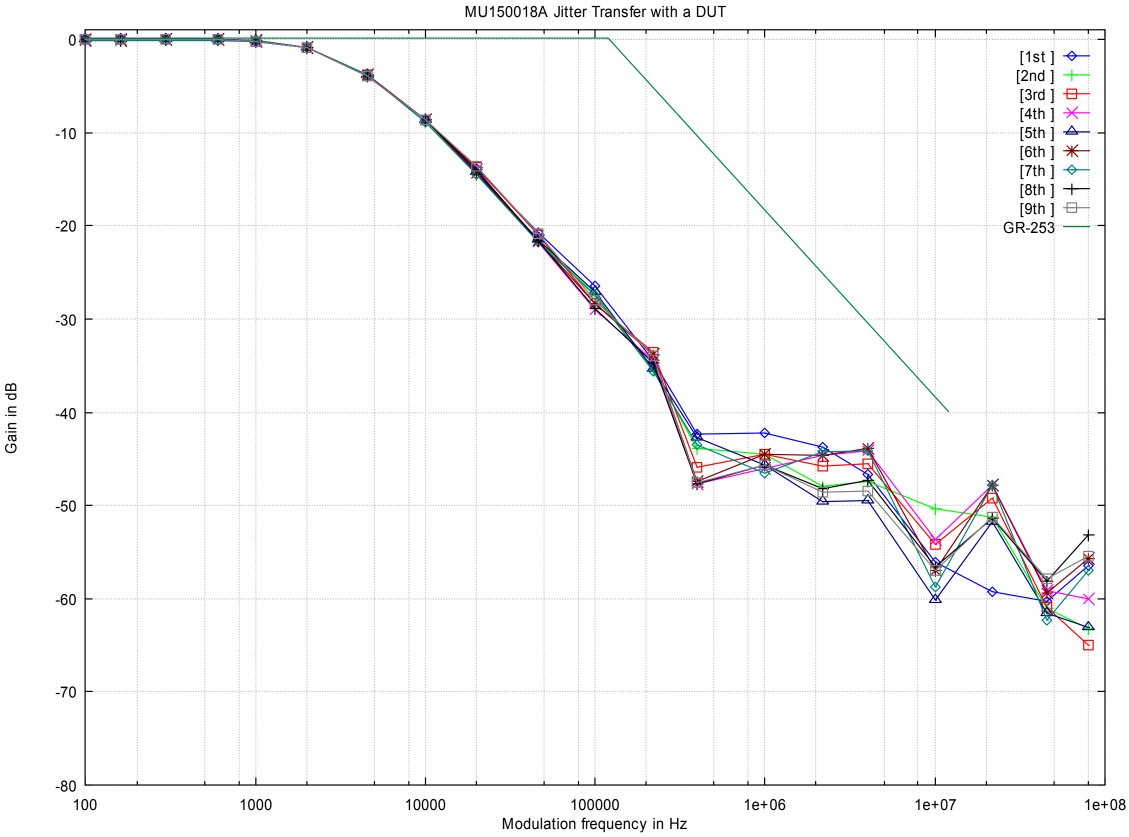


Fig. 16 Measurement Result Upper side: Before improvement
Lower side: After improvement

By using the power divider, the frequency characteristics of measurement result will be improved at the high frequency band around over 20MHz.

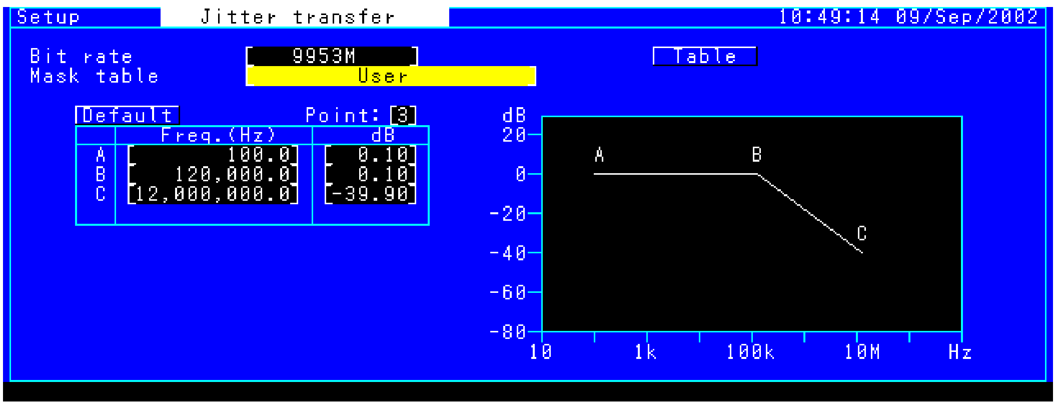
⟨Reference data⟩

(1). Repeatability of MP1570A/MP1580A with a Divider



Compared with edited Mask table

(2). Jitter transfer Mask : An example of edited user table of -40dB/2decade



Appendix-1

An extract of ITU-T Temporary Document 036
STUDY GROUP 15
Geneva, 29 April – 10 May 2002
TITLE: Draft Amendment 1 to Recommendation G.783 (for consent)

The lower frequency f_L is set to fc/100(where fc is corner frequency), and f_H is defined as the lower of either 100*fc or maximum frequency specified for the low pass filter function for measurement of jitter at each of the defined rates (Upper –3dB frequency in Measurement Band column of Table 9-6/G.783 – Jitter Generation for STM-N type A Regenerators in 2048kbit/s based networks, and Table 9-7/G.783 - Jitter Generation for STM-N Regenerators in 1544kbit/s based networks). Jitter above f_H is generally agreed to be insignificant relative to regenerator jitter accumulation, and low levels of in-spec jitter generation can easily be confused with an out-of-spec jitter transfer measurement when attempting to measure jitter transfer at high input/output attenuation levels (i.e., below –40 dB). The limits set for f_L at fc/100 will always include the frequency at which maximum gain peaking occurs, and limiting jitter transfer measurements to frequencies between f_L and f_H will help limit testing time.

Replace left hand Figure by right one.

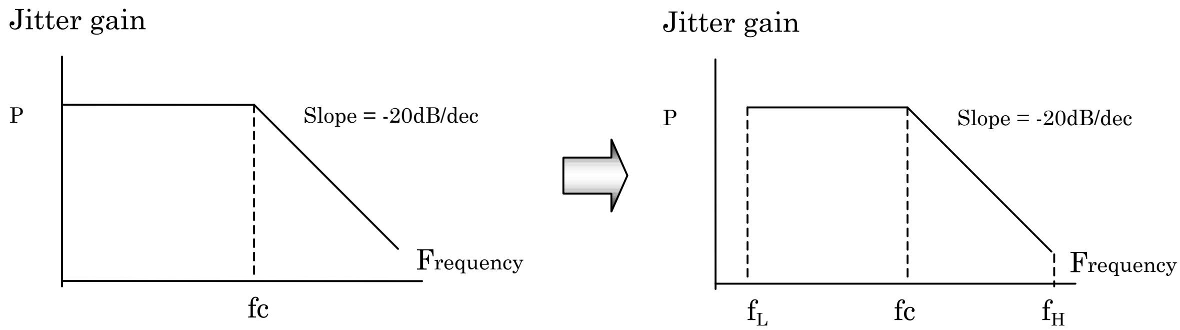


Figure 15-1/G.783 – Jitter transfer

Table 15-2/G.783 - Jitter transfer parameters

STM-N level (Type)	f_L (kHz)	fc (kHz)	f_H (kHz)	P (dB)
STM-1 (A)	1.3	130	1300	0.1
STM-1 (B)	0.3	30	3000	0.1
STM-4 (A)	5	500	5000	0.1
STM-4 (B)	0.3	30	3000	0.1
STM-16 (A)	20	2000	20000	0.1
STM-16 (B)	0.3	30	3000	0.1
STM-64 (A)	10	1000	80000	0.1
STM-64 (B)	TBD	TBD	TBD	TBD
STM-256 (A)	TBD	TBD	TBD	TBD
STM-256 (B)	TBD	TBD	TBD	TBD

Telcordia GR-253-CORE Issue 3

September 2000

5.6.2.1 Jitter transfer (An Extract)

Jitter transfer tests would normally be expected to concentrate on frequencies within approximately <u>two decades of the break point</u> in the jitter transfer mask.

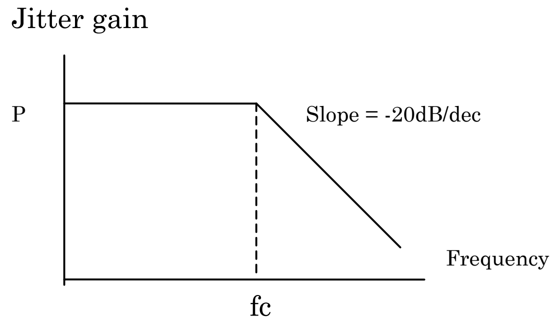


Figure 5-27. Category II Jitter Transfer Mask

OC-N/STS-N Level	fc (kHz)	P (dB)
1	40	0.1
3	130	0.1
12	500	0.1
48	2000	0.1
192	120	0.1

5. Total Jitter vs. Measurement Period

The data quality of today's higher-bit rate digital transmissions should be controlled. There are several ways to evaluate data quality and jitter measurement is one way. Jitter can be classified into two types: Random Jitter caused by noise generated in the signal source, and Deterministic Jitter caused by lower range cut-off characteristics of the data signal and distortion of the duty cycle or interference. Random Jitter has a Gaussian distribution and the jitter value is influenced by the measurement period. Deterministic Jitter does not have a Gaussian distribution and generally is not influenced by the measurement period. However, this paper focuses on one cause of the jitter value. Several types of Deterministic Jitter are actually superimposed on the transmission signal. Normally, Deterministic Jitter is influenced by measurement period. The jitter specification in the ITU-T and Telcordia recommendations includes all kinds of jitter as total jitter. Due to the jitter generation cause, these jitter elements will effect the performance of transmission equipment, so we examine the relationship between Total Jitter vs. Measurement period.

Deterministic Jitter

Figure 1 shows the jitter in an SDH/SONET frame signal measured using a sampling oscilloscope. The measurement actually shows the synchronized pattern condition using Pattern Sync as the trigger. For the measurement, the clock and data signals are shown on the same screen for reference. The entire pattern was checked and the earliest data rising edges were searched for and these waveforms were written to memory using the sampling oscilloscope memory function. Next the most delayed at data rising edges were searched for and these were superimposed on the same screen. The amount of jitter measured in this manner did not match the jitter value measured over a wide bandwidth using a jitter analyzer and it is clear that the jitter is widely centered on these rising edges. On the other hand, Figure 2 shows the same measurement under the same conditions using 64 averagings only for Deterministic Jitter (Pattern Jitter).

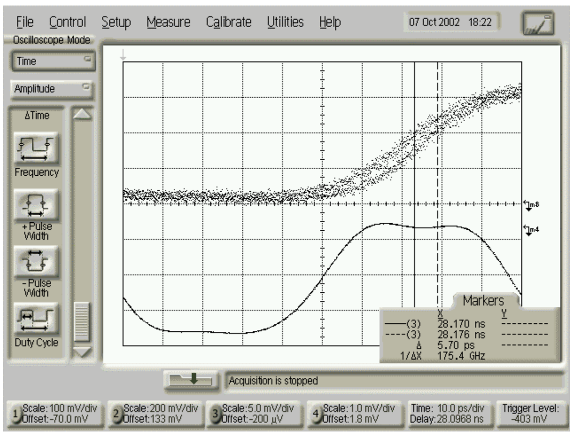


Figure 1 Deterministic Jitter (Pattern Jitter) Non- Average

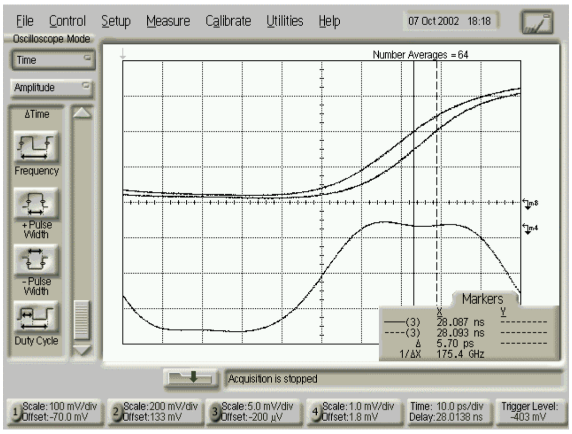


Figure 2 Deterministic Jitter (Pattern Jitter) Averaged

Random Jitter

Comparing Figure 1 and Figure 2, generation of the Random Jitter component is clearly centered on Deterministic Jitter. Figure 3 shows this as a histogram. As described previously, Random Jitter has a Gaussian distribution so the jitter value changes with measurement period. For 10 Gbit/s, the relationship between measurement period and the deviation is shown in Table 1. In other words, the jitter components in the actual transmitted signal are composed of Random Jitter and various types of Deterministic Jitter, so jitter measurement results are proportionally increased as shown in Table 1.

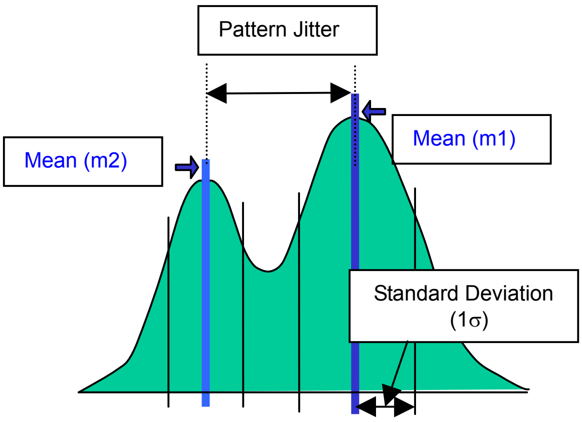


Table 1 Measurement period vs Jitter deviation

Meas. Time(s)	BER	Jitters Deviation
1	1.00E-10	12.72σ
10	1.00E-11	13.40σ
60	1.67E-12	13.92σ
120	8.37E-13	14.14σ
180	5.58E-13	14.24σ

Figure 3 Jitter Measurement Distribution (Random Jitter + Pattern Jitter)

Total Jitter

Figure 4 shows the measurement period and jitter value (dotted line) considering only the Random Jitter component as well as the jitter value (solid line) actually measured for a DUT. Since the actual measurement result includes Deterministic Jitter other than Pattern Jitter, it is different from the ideal value shown by the dotted line. Looking at the actual jitter, it is affect by measurement period as shown by the solid line. Since the causes differ with the DUT, it is necessary to investigate each cause individually.

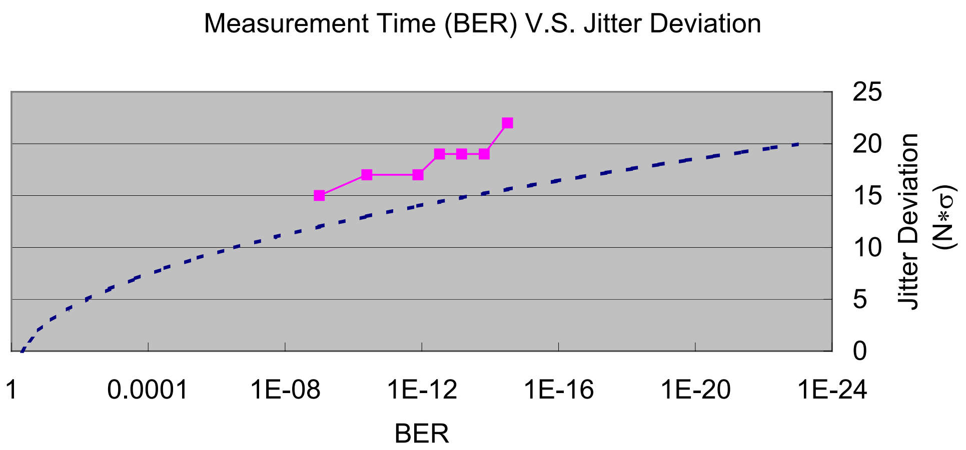


Figure 4 Absolute Jitter Value vs. Measurement Period

Summary

The actual jitter value includes Deterministic Jitter in addition to the jitter explained above. This is currently being examined and research but since this non-Gaussian distributed jitter has a long measurement period, the total jitter value increases. When the measurement period exceeds the 60 s recommended by ITU-T and Telcordia, it is necessary to pay sufficient attention to investigation of the above problems.

MP1570A/MP1580A TECHNICAL NOTE

Specifications are subject to change without notice.

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