FEC Efficiency New Test Method
- Required by ITU-T New Rec. O.182 -

By Takashi Furuya
Kazuhiko Ishibe

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K. Ishibe and T. Furuya
Anritsu Corporation 5-1-1 Onna, Atsugi-shi, Kanagawa 243-8555, Japan
Kazuhiko.Ishibe@anritsu.com, Takashi.Furuya@anritsu.com

Abstract: This paper describes the analog and digital methods for evaluating Forward Error Correction (FEC) efficiency of OTN transmission equipment based on the new recommendation of ITU-T Rec. O.182. This method requires a random error generator with an error generation interval closely approximating a Poisson distribution. We give a simple explanation of the FEC efficiency test methods and present results using some random error generators. Applying the χ^2 test of goodness of fit to the results of the digital method for testing random error generators clarifies that this method evaluates FEC efficiency accurately and quickly.

1. Introduction

ITU-T G.709 Optical Transport Network (OTN) uses Reed Solomon codes RS 255 and 239 as the Forward Error Correction (FEC) technology. Generally, correction of random errors (errors occurring in an actual circuit) uses error-correcting code classified as block code. Since the Reed Solomon codes are block codes, generation of pseudo-random errors makes it impossible to evaluate FEC decoder performance by comparing the error correction efficiency with the theoretical curve. The theoretical error correction efficiency curve shown in Fig. 1 is calculated on the assumption of random error occurrence. There are two main methods for generating random errors. One is an analog method which uses an optical attenuator inserted between the EUT (Entity Under Test) and the ME (Measurement Equipment) to vary the S/N (Signal/Noise) ratio. The other method adds errors digitally. In this digital method, when errors are added, the FEC performance cannot be evaluated accurately because the errors are generated at the same interval. Consequently, it is necessary to generate errors randomly to create a condition under which errors can be corrected or not corrected. In addition, to evaluate FEC performance under conditions emulating an actual circuit, the long-term random error rate must be satisfied although the short-term error rate varies with respect to the set value.

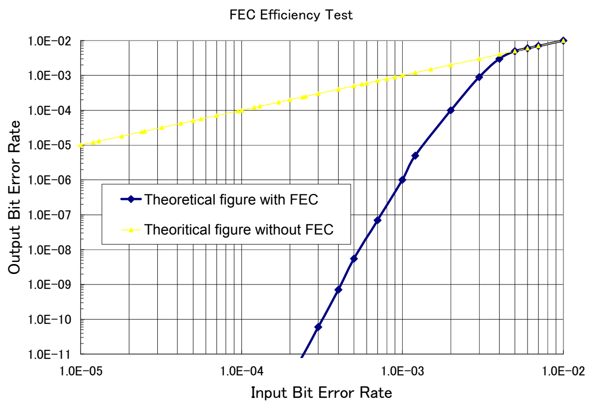

Fig. 1 Error Correction Efficiency

2. Analog Method

The analog evaluation method creates a random error generation condition by varying the signal S/N using an optical attenuator (Fig. 2). It is extremely difficult to obtain results matching the theoretical characteristics using this method because the required fine adjustment of the optical attenuation causes poor reproducibility. In this method, the equipment is setup as shown in Fig. 2 and the FEC of the EUT is set to OFF first. Then the attenuation of the optical attenuator is increased and fine-adjusted so that the error rate becomes the specified value (e.g. 2 x 10^{-2}). Next, the EUT FEC is set to ON and the error rate of the EUT output is measured. The measured error rate is the error correction efficiency of the EUT. The EUT FEC is set to

OFF again, the attenuation of the optical attenuator is increased and fine-adjusted again to the error rate for the next evaluation point (e.g. 1×10^{-3}). The EUT FEC is set to ON again and the EUT error efficiency is evaluated in the same way as described previously. Figure 3 shows the result of this type of evaluation.

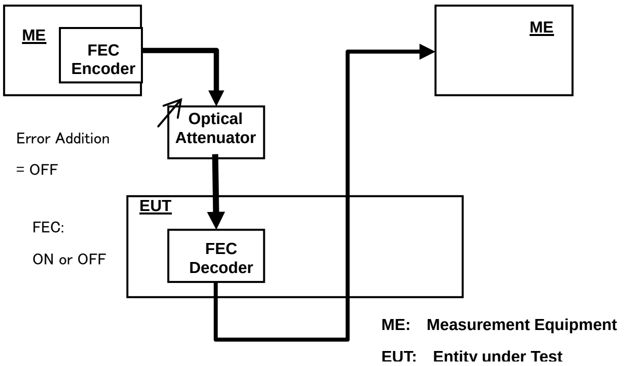

Fig. 2 Setup for Analog Method

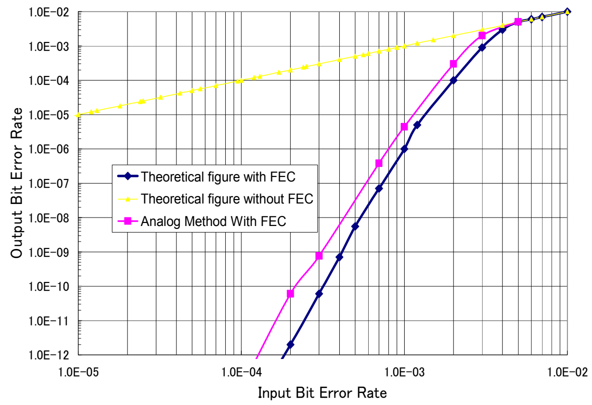

Fig. 3 FEC Efficiency Evaluation using Analog Method

3. Digital Method (New)

The digital evaluation method inserts errors so that the interval of errors inserted by the ME becomes a Poisson distribution. The difference between this digital method and the analog method is that the EUT FEC can be evaluated with FEC always ON (Fig. 4). However, it is important to evaluate whether or not the random error generator generates errors with a Poisson distribution. The χ^2 test is used to specify the random error generator error distribution numerically. The χ^2 test is a comparative index of the random error generator random error distribution and the theoretical Poisson distribution characteristics.

Figure 5 shows the overall random error occurrence and we can see that there is not a good match with the Poisson distribution function curve. Applying a χ^2 test to this example gives a χ^2 value of 1,648.96, which is much larger than the standard χ^2 value of 28.86 indicating a fit at the 95% probability level, confirming that the random errors generated by the random error generator do not fit the Poisson distribution curve. When a random error generator with this type of poor randomness is used as the error generator for the digital method, there is no match with the theoretical curve at the part where the insertion error rate is low and saturation also occurs at a fixed error rate (Fig. 7). This phenomenon occurs because the error insertion does not remain random.

On the other hand, the data for the random error generator in Fig. 6 show quite a good fit with the Poisson distribution curve. In this case, applying a χ^2 test gives a χ^2 value of 18, which is smaller than the standard value, confirming that the data fits the Poisson distribution. When this type of error generator is used for the digital method, we obtain a good fit with the theoretical curve.

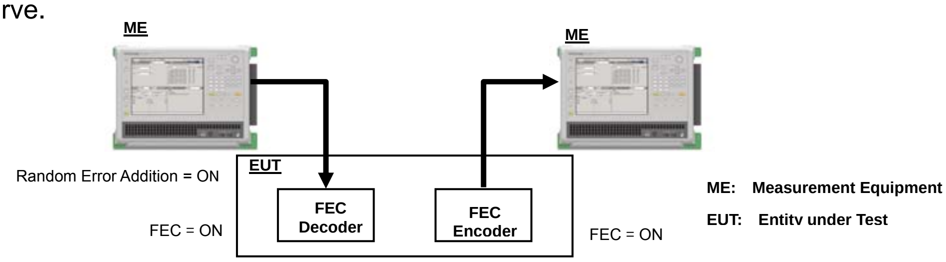

Fig. 4 Digital Method Setup

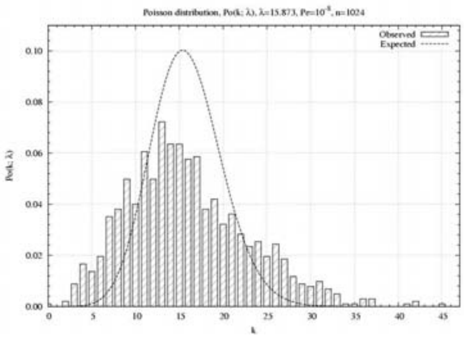

Fig. 5 Random Error Generator Distribution Characteristics (Bad Example)

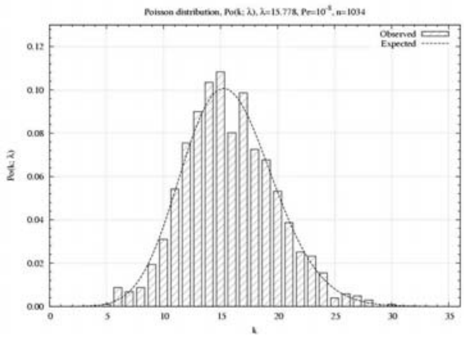

Fig. 6 Random Error Generator Distribution Characteristics (Good Example)

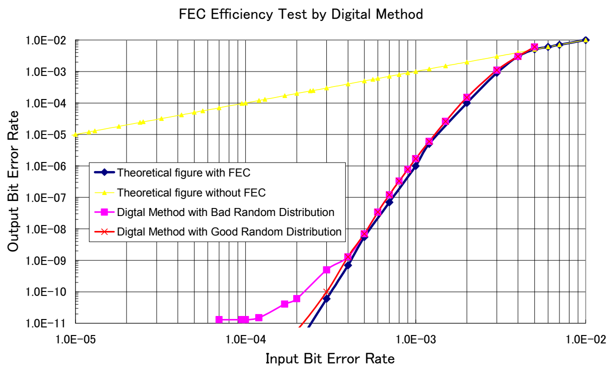

Fig. 7 FEC Efficiency Test Results using Digital Method

4. Summary

When evaluating FEC efficiency using the analog method by varying the S/N ratio, the poor measurement reproducibility caused by adjustment differences results in an offset from the theoretical curve. In addition, the EUT FEC must be set ON/OFF repeatedly and the optical attenuation must be fine adjusted every time.

Using a random error generator with the digital method supports quick and accurate evaluation of FEC efficiency. Using the χ^2 test to confirm that the random error generator generates random errors fitting the Poisson distribution (see ITU-T Rec. O.182 Annex I) supports accurate evaluation of FEC efficiency with no effect of randomness between measuring instruments.

Anritsu MP1595A 40G Analyzer have the random error insertion function for evaluating FEC performance which conforms to ITU-T New Rec. O.182.

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Anritsu Corporation
5-1-1 Onna, Atsugi-shi, Kanagawa, 243-8555 Japan
Phone: +81-46-223-1111
Fax: +81-46-296-1264

● U.S.A.
Anritsu Company
1155 East Collins Blvd., Suite 100, Richardson,
TX 75081, U.S.A.
Toll Free: 1-800-267-4878
Phone: +1-972-644-1777
Fax: +1-972-671-1877

● Canada
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

● Brazil
Anritsu Eletrônica Ltda.
Praca Amadeu Amaral, 27 - 1 Andar
01327-010-Paraiso-São Paulo-Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

● U.K.
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

● France
Anritsu S.A.
9 Avenue du Québec, Z.A. de Courtabœuf
91951 Les Ulis Cedex, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

● Germany
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

● Italy
Anritsu S.p.A.
Via Elio Vittorini 129, 00144 Roma, Italy
Phone: +39-6-509-9711
Fax: +39-6-502-2425

● Sweden
Anritsu AB
Borgafjordsgatan 13, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00
Fax: +46-8-534-707-30

● Finland
Anritsu AB
Teknobulevardi 3-5, FI-01530 VANTAA, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

● Denmark
Anritsu A/S
Kirkebjerg Allé 90, DK-2605 Brøndby, Denmark
Phone: +45-72112200
Fax: +45-72112210

● Spain
Anritsu EMEA Ltd.
Oficina de Representación en España
Edificio Veganova
Avda de la Vega, n° 1 (edf 8, pl 1, of 8)
28108 ALCOBENDAS - Madrid, Spain
Phone: +34-914905761
Fax: +34-914905762

● United Arab Emirates
Anritsu EMEA Ltd.
Dubai Liaison Office
P O Box 500413 - Dubai Internet City
Al Thuraya Building, Tower 1, Suit 701, 7th Floor
Dubai, United Arab Emirates
Phone: +971-4-3670352
Fax: +971-4-3688460

● Singapore
Anritsu Pte. Ltd.
10, Hoe Chiang Road, #07-01/02, Keppel Towers,
Singapore 089315
Phone: +65-6282-2400
Fax: +65-6282-2533

● India
Anritsu Pte. Ltd.
India Branch Office
Unit No. S-3, Second Floor, Esteem Red Cross Bhavan,
No. 26, Race Course Road, Bangalore 560 001, India
Phone: +91-80-32944707
Fax: +91-80-22356648

● P.R. China (Hong Kong)
Anritsu Company Ltd.
Units 4 & 5, 28th Floor, Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong
Phone: +852-2301-4980
Fax: +852-2301-3545

● P.R. China (Beijing)
Anritsu Company Ltd.
Beijing Representative Office
Room 1515, Beijing Fortune Building,
No. 5, Dong-San-Huan Bei Road,
Chao-Yang District, Beijing 10004, P.R. China
Phone: +86-10-6590-9230
Fax: +86-10-6590-9235

● Korea
Anritsu Corporation, Ltd.
8F Hyunjuk Building, 832-41, Yeoksam Dong,
Kangnam-ku, Seoul, 135-080, Korea
Phone: +82-2-553-6603
Fax: +82-2-553-6604

● Australia
Anritsu Pty. Ltd.
Unit 21/270 Ferntree Gully Road, Notting Hill,
Victoria 3168, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

● Taiwan
Anritsu Company Inc.
7F, No. 316, Sec. 1, Neihu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

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