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ANSI/SCTE 272 2021

Standardized Loading for Reverse-Path Bit Error Ratio Testing

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1. Introduction

1.1. Executive Summary

This document defines the channel plans to be used when testing reverse path upstream bit error ratio.

1.2. Scope

This document provides details on channel loading bandwidth and modulation specifics for pre/post bit error ratio (BER) measurements. This document is intended to be used in conjunction with ANSI/SCTE 132, “Test Method for Reverse Path (Upstream) Bit Error Ratio.” This document does not detail the procedure to measure BER nor the test methodology. This document is intended for measurement of 75-ohm devices having type "F" or 5/8-24 KS connectors. See the Cable Telecommunications Testing Guidelines document, ANSI/SCTE 96, for a discussion of proper testing techniques.

For bit error ratio measurements in the forward path see ANSI/SCTE 121.

1.3. Benefits

By creating a standardized channel loading plan along with modulation specifications, this document provides a standard means of testing, along with ANSI/SCTE 132, to measure upstream bit error ratio between various types of RF products.

1.4. Intended Audience

The intended audience is any engineer or technician who is responsible for testing reverse path (upstream) bit error ratio.

1.5. Areas for Further Investigation or to be Added in Future Versions

Additional DOCSIS 3.1 OFDMA channel plans may be added along with a possible mixture of DOCSIS 3.0 and 3.1 channel loading.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- ANSI/SCTE 96 2020: Cable Telecommunications Testing Guidelines
- ANSI/SCTE 121 2018: Test Method for Downstream Bit Error Rate
- ANSI/SCTE 132 2019: Test Method for Reverse Path (Upstream) Bit Error Ratio
- DOCSIS 3.1 PHY: SCTE 220-1 2016 DOCSIS 3.1 Part 1: Physical Layer Specification

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
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5. Abbreviations and Definitions

5.1. Abbreviations

BER	bit error ratio
CIN	carrier to intermodulation noise ratio
FEC	forward error correction
OFDMA	orthogonal frequency division multiple access
CMTS	cable modem termination system
CM	cable modem
kHz	kilohertz
MHz	megahertz
MSO	multiple system operator
QAM	quadrature amplitude modulation
SC-QAM	single carrier quadrature amplitude modulation
SCTE	Society of Cable Telecommunications Engineers
RFoG	RF over Glass

5.2. Definitions

bit error ratio (BER)	The ratio of error bits to the total number of bits transmitted. BER is normally expressed as the negative exponent of a number (e.g. $1x10^{-7}$ means that 1 out 10,000,000 bits is in error).
forward error correction (FEC)	A system of error control for data transmission wherein the receiving device has the capability to detect and correct any character or code block that contains fewer than a predetermined number of symbols in error.
symbol rate	The number of symbols transmitted over a given time.
carrier to intermodulation noise ratio (CIN)	The ratio of the CW carrier to the noise-like signals generated by the non-linearity of a broadband transmission system carrying a combination of analog signals and digitally modulated signals. These distortion products are analogous to the CSO and CTB products generated by analog carriers, but due to the pseudo random nature of the digital modulation signals, appear as a noise-like interference. When CIN products fall within the analog portion of the spectrum, their effect on the analog signal is similar to increasing thermal (random) noise. Since CIN is a distortion product, its contribution is dependent on the output signal level.

6. Channel Loading Bandwidths

ANSI/SCTE 132 specifies that digital loading can consist of individual QAM channels or broadband simulated digital noise loading. This document details the use of individual QAM channel loading and does discuss simulated digital loading.

Four return path bandwidths are specified:

- 5-42 MHz – Common in North America
- 5-65 MHz – Common in Europe

- 5-85 MHz – Being used by MSOs to increase upstream capacity
- 5-204 MHz – Enabled by DOCSIS 3.1; being evaluated by MSOs to increase upstream capacity

When testing each of these bandwidths, the RF spectrum is comprised of individual QAM channels, with three channels being used for test (low, mid and high band).

QAM channels will intermodulate with each other creating composite intermodulation noise (CIN) underneath each QAM channel. Third order products will accumulate in the mid-band region and second order products will peak at the upper and lower frequencies. Testing at three frequencies will ensure measurements are made where intermodulation interference is maximized.

Four types of modulation are typically used for data transmission: 16, 64, 256 QAM and OFDMA will be defined herein.

6.1. 5-42 MHz

6.1.1. Case 1: 1024 QAM OFDMA

When testing the bandwidth 5-42 MHz with OFDMA, the channel loading and configurations listed in Table 1 ***shall*** be used.

Table 1 - Test Channels for 5-42 MHz 1024 QAM OFDMA Loading Configuration

5-42 MHz 1024 QAM				
Channel Center Frequency (MHz)	Subcarrier Spacing (kHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
23.4	50	36.8	5	41.8

6.1.2. Case 2: SC-QAM

When testing the bandwidth 5-42 MHz, the channel loading and configurations listed in Table 2 ***shall*** be used. The test channels for each frequency plan are highlighted.

Table 2 - Test Channels for 5-42 MHz Loading Configuration

5-42 MHz 16 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
6.6	3.2	5	8.2
9.8	3.2	8.2	11.4
13	3.2	11.4	14.6
16.2	3.2	14.6	17.8
19.4	3.2	17.8	21
22.6	3.2	21	24.2
25.8	3.2	24.2	27.4
29	3.2	27.4	30.6
32.2	3.2	30.6	33.8
35.4	3.2	33.8	37
38.6	3.2	37	40.2

5-42 MHz 64 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
8.2	6.4	5	11.4
14.6	6.4	11.4	17.8
21.9	6.4	18.7	25.1
27.6	3.2	26	29.2
32.4	6.4	29.2	35.6
38.8	6.4	35.6	42

5-42 MHz 256 QAM			
Channel Center Frequenc y (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
8.2	6.4	5	11.4
14.6	6.4	11.4	17.8
21.9	6.4	18.7	25.1
27.6	3.2	26	29.2
32.4	6.4	29.2	35.6
38.8	6.4	35.6	42

6.2. 5-65 MHz

6.2.1. Case 1: 1024 QAM OFDMA

When testing the bandwidth 5-65 MHz with OFDMA, the channel loading and configurations listed in Table 3 ***shall*** be used.

Table 3 - Test Channels for 5-65 MHz 1024 QAM OFDMA Loading Configuration

5-65 MHz 1024 QAM				
Channel Center Frequency (MHz)	Subcarrier Spacing (kHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
35	50	60	5	65

6.2.2. Case 2: SC-QAM

When testing the bandwidth 5-65 MHz, the following channel loading and configurations in Table 4 ***shall*** be used. The test channels for each frequency plan are highlighted.

Table 4 - Test Channels for 5-65 MHz Loading Configuration

5-65 MHz 16 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
7.8	3.2	6.2	9.4
11	3.2	9.4	12.6
14.2	3.2	12.6	15.8
17.4	3.2	15.8	19
20.6	3.2	19	22.2
23.8	3.2	22.2	25.4
27	3.2	25.4	28.6
30.2	3.2	28.6	31.8
33.4	3.2	31.8	35
36.6	3.2	35	38.2
39.8	3.2	38.2	41.4
43	3.2	41.4	44.6
46.2	3.2	44.6	47.8
49.4	3.2	47.8	51
52.6	3.2	51	54.2
55.8	3.2	54.2	57.4
59	3.2	57.4	60.6
62.2	3.2	60.6	63.8

5-65 MHz 64 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
9.4	6.4	6.2	12.6
15.8	6.4	12.6	19
22.2	6.4	19	25.4
28.6	6.4	25.4	31.8
35	6.4	31.8	38.2
41.4	6.4	38.2	44.6
47.8	6.4	44.6	51
54.2	6.4	51	57.4
60.6	6.4	57.4	63.8

5-65 MHz 256 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
9.4	6.4	6.2	12.6
15.8	6.4	12.6	19
22.2	6.4	19	25.4
28.6	6.4	25.4	31.8
35	6.4	31.8	38.2
41.4	6.4	38.2	44.6
47.8	6.4	44.6	51
54.2	6.4	51	57.4
60.6	6.4	57.4	63.8

6.3. 5-85 MHz

6.3.1. Case 1: 1024 QAM OFDMA

When testing the bandwidth 5-85 MHz with OFDMA, the channel loading and configurations listed in Table 5 ***shall*** be used.

Table 5 - Test Channels for 5-85 MHz 1024 QAM OFDMA Loading Configuration

5-85 MHz 1024 QAM				
Channel Center Frequency (MHz)	Subcarrier Spacing (kHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
45	50	80	5	85

6.3.2. Case 2: SC-QAM

When testing the bandwidth 5-85 MHz, the channel loading and configurations in Table 6 ***shall*** be used. The test channels for each frequency plan are highlighted.

Table 6 - Test Channels for 5-85 MHz Loading Configuration

5-85 MHz 16 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
6.6	3.2	5	8.2
9.8	3.2	8.2	11.4
13	3.2	11.4	14.6
16.2	3.2	14.6	17.8
19.4	3.2	17.8	21
22.6	3.2	21	24.2
25.8	3.2	24.2	27.4
29	3.2	27.4	30.6
32.2	3.2	30.6	33.8
35.4	3.2	33.8	37
38.6	3.2	37	40.2
41.8	3.2	40.2	43.4
45	3.2	43.4	46.6
48.2	3.2	46.6	49.8
51.4	3.2	49.8	53
54.6	3.2	53	56.2
57.8	3.2	56.2	59.4
61	3.2	59.4	62.6
64.2	3.2	62.6	65.8
67.4	3.2	65.8	69
70.6	3.2	69	72.2
73.8	3.2	72.2	75.4
77	3.2	75.4	78.6
80.2	3.2	78.6	81.8
83.4	3.2	81.8	85

5-85 MHz 64 QAM			
Channel Center Frequency (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
8.2	6.4	5	11.4
14.6	6.4	11.4	17.8
21	6.4	17.8	24.2
27.4	6.4	24.2	30.6
33.8	6.4	30.6	37
40.2	6.4	37	43.4
45	3.2	43.4	46.6
49.8	6.4	46.6	53
56.2	6.4	53	59.4
62.6	6.4	59.4	65.8
69	6.4	65.8	72.2
75.4	6.4	72.2	78.6
81.8	6.4	78.6	85

5-85 MHz 256 QAM			
Channel Center Frequenc y (MHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
8.2	6.4	5	11.4
14.6	6.4	11.4	17.8
21	6.4	17.8	24.2
27.4	6.4	24.2	30.6
33.8	6.4	30.6	37
40.2	6.4	37	43.4
45	3.2	43.4	46.6
49.8	6.4	46.6	53
56.2	6.4	53	59.4
62.6	6.4	59.4	65.8
69	6.4	65.8	72.2
75.4	6.4	72.2	78.6
81.8	6.4	78.6	85

6.4. 5-204 MHz

6.4.1. Case 1: 1024 QAM OFDMA

When testing the bandwidth 5-204 MHz with OFDMA, the channel loading and configurations listed in Table 7 ***shall*** be used.

Table 7 - Test Channels for 5-204 MHz 1024 QAM OFDMA Loading Configuration

5-204 MHz 1024 QAM				
Channel Center Frequency (MHz)	Subcarrier Spacing (kHz)	Channel Width (MHz)	Channel Start Frequency (MHz)	Channel Stop Frequency (MHz)
53	50	96	5	101
156	50	96	108	204

6.4.2. *Case 2: SC-QAM*

When testing the bandwidth 5-204 MHz with SC-QAM, the channel loading and configurations listed in Table 8 ***shall*** be used. The test channels for each frequency plan are highlighted.

Table 8 - Test Channels for 5-204 MHz with Standard 64 QAM Loading Configuration

5-204 MHz 64 QAM				
Channel Center Frequency (MHz)	Modulation Rate (kHz)	Channel Width (MHz)	Channel Start Fequency (MHz)	Channel Stop Fequency (MHz)
8.2	5120	6.4	5	11.4
14.6	5120	6.4	11.4	17.8
21	5120	6.4	17.8	24.2
27.4	5120	6.4	24.2	30.6
33.8	5120	6.4	30.6	37
40.2	5120	6.4	37	43.4
46.6	5120	6.4	43.4	49.8
53	5120	6.4	49.8	56.2
59.4	5120	6.4	56.2	62.6
65.8	5120	6.4	62.6	69
72.2	5120	6.4	69	75.4
78.6	5120	6.4	75.4	81.8
85	5056.941	6	82	88
91	5056.941	6	88	94
97	5056.941	6	94	100
103	5056.941	6	100	106
109	5056.941	6	106	112
115	5056.941	6	112	118
121	5056.941	6	118	124
127	5056.941	6	124	130
133	5056.941	6	130	136
139	5056.941	6	136	142
145	5056.941	6	142	148
151	5056.941	6	148	154
157	5056.941	6	154	160
163	5056.941	6	160	166
169	5056.941	6	166	172
175	5056.941	6	172	178
181	5056.941	6	178	184
187	5056.941	6	184	190
193	5056.941	6	190	196
199	5056.941	6	196	202

7. Modes of Operation

The channel configurations listed in section 6 may be tested with both continuous and burst mode test sources.

7.1. Continuous Mode

Test equipment is commercially available which supports both 16 and 64 QAM upstream testing. This test equipment is continuous mode only.

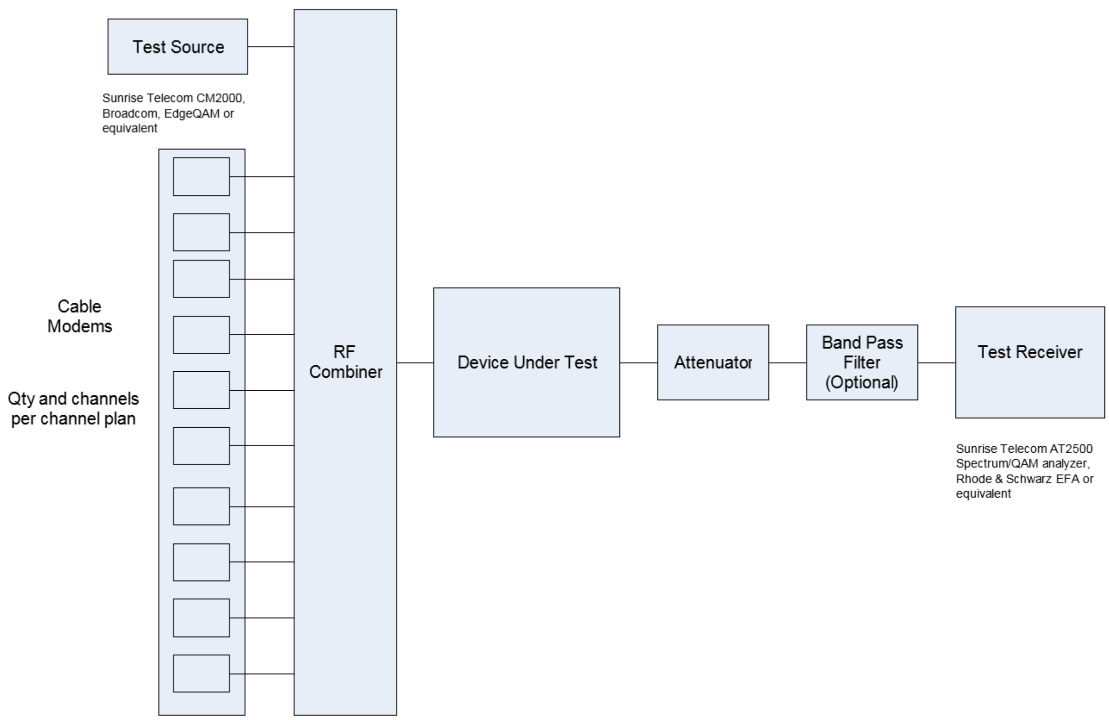

Figure 1 - Continuous Mode Test Diagram

7.2. Burst Mode

Burst mode better simulates real world conditions and can ‘stress” the test system during turn on/turn off. This is especially critical when testing systems such as RFoG, which trigger off the burst/data of the CM sources. Burst mode testing requires a system with a CMTS and configured cable modems. Modulation settings are detailed in section 9.0.

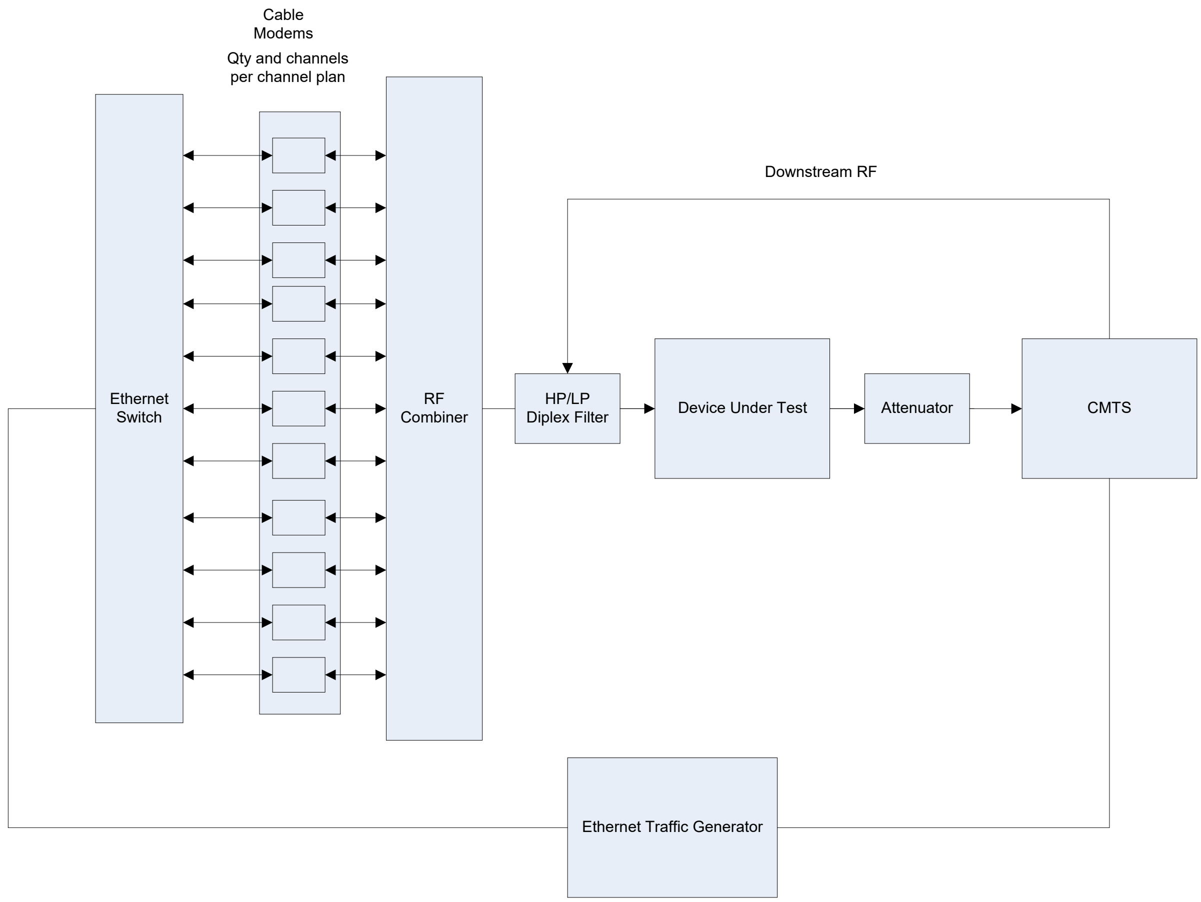

Figure 2 - Burst Mode Test Diagram

8. Error Correction

Both commercially available test equipment and CMTSs can provide pre and post error correction error ratio data. Both are meaningful as they provide a measurement of the quality of the signal and the ability of the CMTS to correct for errors. Ideally post-EQ BER should be 0, although DOCSIS specifications allow for some post errors.

8.1. BER

Commercially available test equipment can provide both pre and post FEC BER. Examples of this test equipment are the Sunrise Telecom CM2000 Upstream Signal Generator and AT2500RQv Spectrum/QAM analyzer.

8.2. Codeword Error Ratio

The Codeword Error Ratio is the ratio of the number of uncorrectable or unreliable code words to the total number of code words sent without errors, with corrected errors and with uncorrectable or unreliable errors. When using cable modems and a CMTS to make upstream measurements, the CMTS measures and counts the code words received with correctable and uncorrectable or unreliable errors. The codeword error ratio is related to the bit error ratio, but the bit error ratio can only be estimated from the codeword error ratio as a codeword error can contain one or more bit errors. The codeword error ratio is calculated as follows:

Computation of Codeword Error Rate, R_C:

$$R_C = \frac{(E_U - E_{U0})}{(E_U - E_{U0}) + (E_C - E_{C0}) + (C - C_0)}$$

Where:

E_U is the value of the count of code words with uncorrectable errors;

E_C is the value of the count of code words with correctable errors and;

C is the value of the count of code words without errors.

'0' subscript denotes initial starting counts.

9. Modulation Settings

Table 9 lists the modulation settings for 16 and 64 QAM configurations when testing with cable modems in burst mode.

Table 9 – 16 and 64 QAM Modulation Settings

MODULATION	16 QAM	64 QAM
Diff Encoding	OFF	OFF
Preamble Length	96	64
FEC CW Length	130	75
Guard Time	8	8
Interleaver Depth	1	1
Interleaver Block Size	1536	1536
Preamble Type	QPSK1	QPSK1
Interleaver Step Size	0	0
TCM Encoding	OFF	OFF

Max Burst	6	4
Channel Type	TDMA	ATDMA

Note: Use an edgeQAM for the 256-QAM testing (continuous mode)

9.1. 1024 QAM OFDMA Modulation Settings

Modulator settings for 1024 QAM OFDMA ***shall*** be as shown in Table 10.

Table 10 - 1024 QAM Modulation Settings

Sub Carrier Spacing	Sample Rate	# Sub Carriers
25 kHz	102.4 MHz	3840
50 kHz	102.4 MHz	1920

10. Report Template

Table 11 - BER Tabular Dynamic Range

Device Under Test							
Date							
Modulation Rate							
Modulation Order							
	RF Level	Pre FEC BER	Post FEC BER	Codeword Error Ratio	Uncorrectable or unreliable Code Words	Correctable Code Words	Code Words Without Errors
Test Frequency (MHz)							