Considerations for Clause 98.8.2.2 Impedance Balance

IEEE P802.3bq 40GBASE-T Task Force

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Objectives

- Review the 40GBASE-T MDI impedance balance requirement defined in P802.3bq D1.1.1, Clause 98.8.2.2
- Discuss the measurement approaches outlined in the text
- Propose alternate text for Clause 98.8.2.2 that is more aligned with (what are believed to be) current industry practices

P802.3bq Clause 98.8.2.2 D1.1.1 “core” text

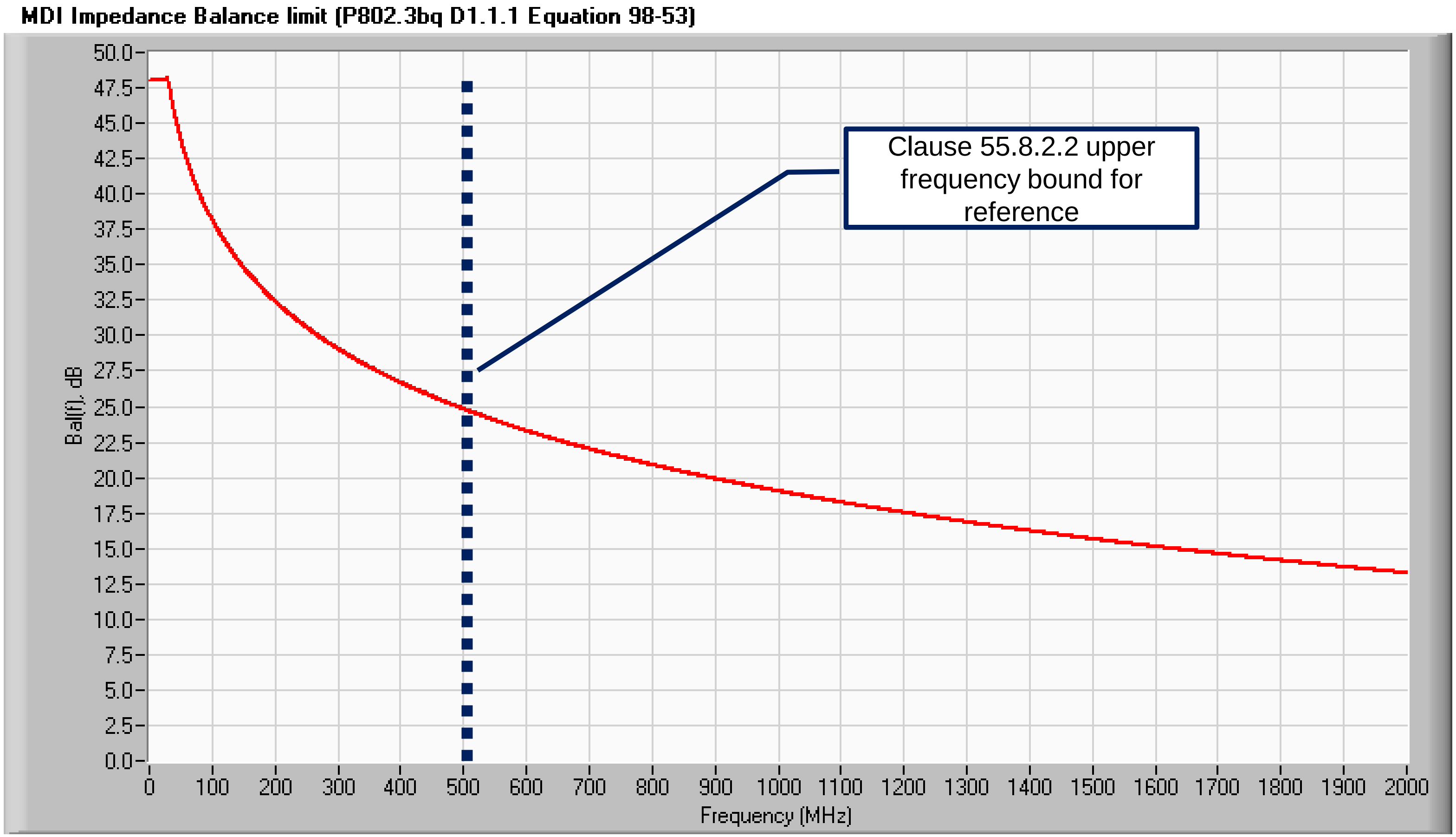
98.8.2.2 MDI impedance balance

Impedance balance is a measure of the impedance-to-ground difference between the two MDI contacts used by a duplex link channel and is referred to as common-mode-to-differential-mode impedance balance. The common-mode-to-differential-mode impedance balance, $Bal(f)$, of each channel of the MDI shall meet the relationship:

$$Bal(f) \geq \begin{cases} 48 & 1 \leq f < 30 \quad (\text{dB}) \\ 44 - 19.2\log_{10}\left(\frac{f}{50}\right) & 30 \leq f \leq 2000 \quad (\text{dB}) \end{cases} \qquad (98\text{–}53)$$

where f is the frequency in MHz when the transmitter is transmitting random or pseudo random data.

Equation 98-53 Bal(f)



Clause 98.8.2.2 Methodology (1/3)

Test-mode 4 may be used to generate an appropriate transmitter output. The impedance balance (in dB) is defined as:

$$Bal(f) = 20\log_{10}\left(\frac{E_{cm}(f)}{E_{dif}(f)}\right) - IL_{cal}(f) \quad \text{(dB)} \tag{98–54}$$

where E_{cm} is an externally applied common-mode sinusoidal voltage as shown in Figure 98–42, E_{dif} is the resulting differential waveform due only to the applied sine wave E_{cm} and not the transmitted data, and $IL_{cal}(f)$ is the coupling circuit common-mode insertion loss (in dB). The coupling circuit common-mode insertion loss is defined as:

$$IL_{\mathrm{cal}}(f) = 20\log_{10}\left(\frac{E_{Cin}(f)}{E_{cout}(f)}\right) \quad \text{(dB)} \tag{98–55}$$

where E_{cin} and E_{cout} are test signals used to measure the coupling circuit common-mode insertion loss as shown in Figure 98–43.

Clause 98.8.2.2 Methodology (2/3)

The impedance balance is measured with a common-mode coupling circuit presenting a differential termination of 100 Ω and a common-mode termination of 50 Ω to the MDI pair under test as shown in Figure 98–42. The return loss for both differential and common terminations in the common-mode coupling circuit should be greater than 20 dB from 10 MHz to 2000 MHz. The insertion loss IL_{cal} (in dB) of the common-mode coupling circuit can be measured with the test circuit shown in Figure 98–43.

NOTE 1—Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component.

NOTE 2—The imbalance of the test equipment should be insignificant relative to the balance requirements.

The impedance balance may also be measured with a mixed mode four port network analyzer capable of measuring the common-mode voltage and differential mode voltage of a balanced port. Impedance balance is the S parameter measurement of Scd11 in dB at the MDI where two ports of the four port network analyzer are connected between two MDI contacts used by a duplex link channel and these two ports are configured as a single balanced port. For this test the PHY ground is connected to the network analyzer ground. The other two ports of the network analyzer are unconnected. The network analyzer should be capable of measuring Scd11 to at least –60 dB and should use a differential input impedance of 100 Ω and a common-mode impedance of 75 Ω.

During the test the PHY is connected to the MDI as in normal operation, but with the transmitter output disabled.

Clause 98.8.2.2 Methodology (3/3)

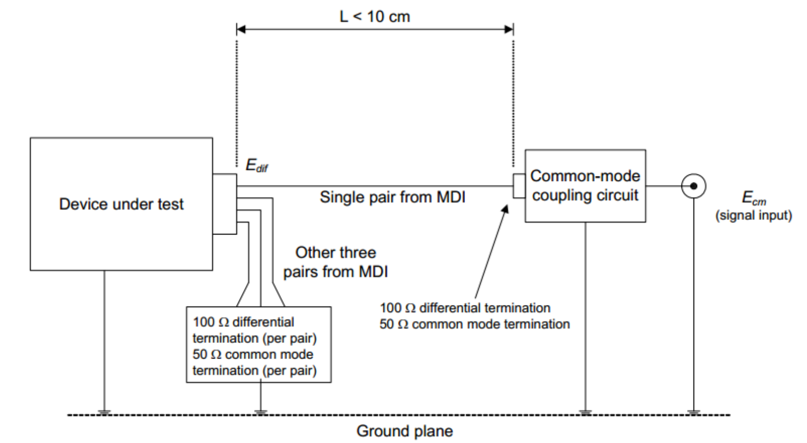


Figure 98–42—MDI impedance balance test circuit

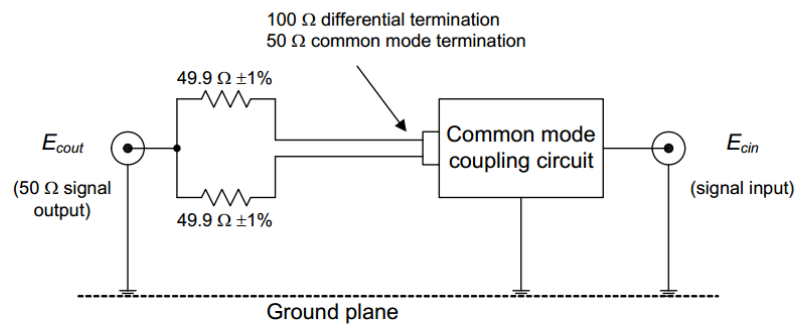


Figure 98–43— Impedance balance calibration circuit

Making the Impedance Balance Measurement

- Time domain methodology carries legacy techniques forward
  - Requires more complex test fixtures and additional steps to compensate for fixture loss
  - How many points are required to “fill in the gaps”?
    - 10BASE-T specifies 11 points from 1MHz to 21MHz (2MHz steps, 10% of b/w per step)
    - A comparable 40GBASE-T measurement would include 200 points per pair, or **1600 measurements!** (including calibration circuit measurements)
    - Time consuming, even with test automation
- Frequency domain methodology (several frequency sweeps at most) is more appropriate
  - Both 2-port or multi-port instruments can be used
    - Described in several equipment application notes, IEEE paper

Alternate Approaches

- scd11/sdc11 are used for 6G SAS and 8G FC
- Well-defined and accepted test procedures for scd11 exist
  - Example - UNH IOL SERIAL ATTACHED SCSI (SAS) CONSORTIUM, Clause 5, SAS 3.0 Transmitter Test Suite, Version 1.4, Test 5.4.3 - RX Differential Impedance Imbalance (SCD11)

The University of New Hampshire
InterOperability Laboratory

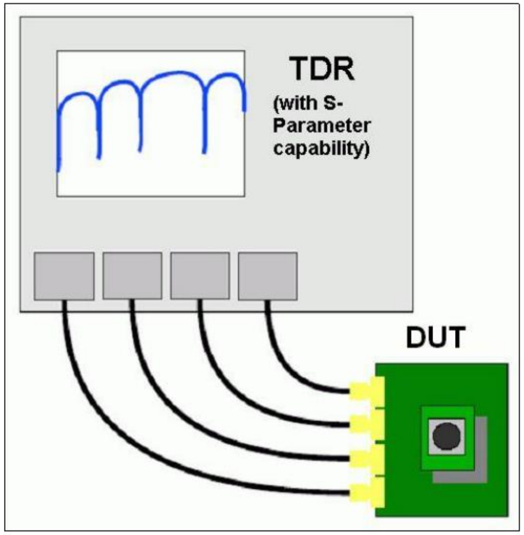


Figure 5.A.5-1: TDR Setup

For the S-parameter measurements, the DUT is configured such that it is transmitting a repeating 1100 NRZ data pattern at the line rate being tested. This ensures that the transmitter circuitry is measured in its typical operating state during SAS data transmission (which may be different than when transmitting OOB signaling.) Configuration of the DUT may be achieved either by vendor-specific means (e.g., register settings), or via the SAS interface (using the PHY TEST function via the Protocol-Specific diagnostic page[2]).

Summary of P802.3bq D1.1.1 Comments #154 and #155

- Use Test Mode 5 to place the transceiver in an appropriate state for the measurement

- Use a frequency-domain-based measurement methodology

Proposed Text for 98.8.2.2 (1/2)

"Impedance balance is a measure of the impedance-to-ground difference between the two MDI contacts used by a duplex link channel and is referred to as common-mode-to-differential-mode impedance balance.

The common-mode-to-differential-mode impedance balance, Bal(f), of each channel of the MDI shall meet the relationship:

$$Bal(f) \geq \begin{cases} 48 & 1 \leq f < 30 \quad \text{(dB)} \\ 44 - 19.2\log_{10}\left(\frac{f}{50}\right) & 30 \leq f \leq 2000 \quad \text{(dB)} \end{cases} \qquad (98\text{–}53)$$

where f is the frequency in MHz when the transmitter is transmitting random or pseudo random data.

Test-mode 5 may be used to generate an appropriate transmitter output."

Proposed Text for 98.8.2.2 (2/2)

"The impedance balance is defined as the S parameter measurement of Sdc11 in dB at the MDI.

The impedance balance may be measured with a mixed mode four port network analyzer capable of measuring the common-mode voltage and differential mode voltage of a balanced port.

Impedance balance is the S parameter measurement of Sdc11 in dB at the MDI where two ports of the four port network analyzer are connected between two MDI contacts used by a duplex link channel and these two ports are configured as a single balanced port.

For this test, the PHY ground is connected to the network analyzer ground.

The other two ports of the network analyzer are unconnected.

The network analyzer should be capable of measuring Sdc11 to at least –60 dB and should use a differential input impedance of 100Ω and a common-mode impedance of 75Ω.

During the test the PHY is connected to the MDI as in normal operation."

Potential Follow-up?

- What practices and methods are generally used for this measurement with 10GBASE-T ports?
  - Is the description of the text correct?
  - Any known issues with sdc11 fixtures or calibration?
  - Should we include a 2-port option? (e.g. sdc11 can be calculated from s11/s21/s12/s22 and is basically "free" if this approach is used to measure return loss/sdd11)
- Comments from 802.3aw?
- Other?

Thank You!

Existing Requirements – 10BASE-T

14.3.1.2.4 Transmitter impedance balance

The common-mode to differential-mode impedance balance of the TD circuit shall exceed $29-17\log_{10}(f/10)$ dB (where f is the frequency in MHz) over the frequency range 1.0 MHz to 20 MHz. This balance is defined as $20\log_{10}(E_{cm}/E_{dif})$, where E_{cm} is an externally applied sine wave voltage as shown in Figure 14–14.

NOTE—The balance of the test equipment (such as the matching of the 147 Ω resistors) must exceed that required of the transmitter.

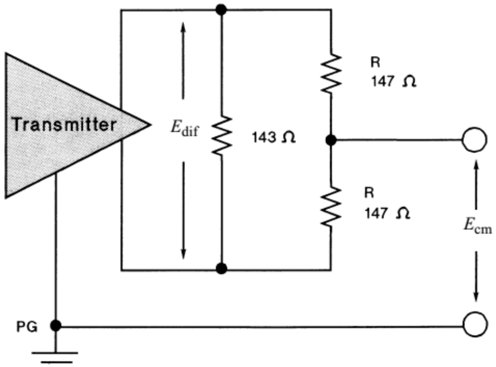


Figure 14–14—Transmitter impedance balance and common-mode rejection test circuit

Test Case ID	:	1411.10.08
Test Case Name	:	Common-mode to differential-mode conversion.
Status	:	MANDATORY
Standard Reference	:	14.3.1.2.4
PICS Reference	:	14.10.4.5.12/9
History	:	
Test Purpose	:	To verify the transmitter impedance balance over the frequency range of 1.0–21 MHz.
Note	:	The balance of the test equipment (such as the matching of the 147 Ω resistors) must exceed that required of the transmitter.
Test Setup	:	Test setup E.
Test Procedure	:	Apply power. Apply a 1 MHz sine wave with a 15 V peak amplitude to represent the E_{cm} signal and monitor the differential voltage at the TD circuit, E_{dif}, ignoring the Link Test Pulses. In steps of 2 MHz, increase the frequency up to a maximum of 21 MHz. For each step, calculate the common-mode to differential-mode impedance balance as $20\log_{10}(E_{cm} / E_{dif})$.
Conformance	:	The common-mode to differential-mode impedance balance of the transmitter shall exceed $29 - 17\log_{10}(f / 10)$ dB (where f is the frequency in MHz) over the frequency range 1.0 MHz to 20 MHz.

Existing Requirements – 1000BASE-T

40.8.3.2 MDI impedance balance

Impedance balance is a measurement of the impedance-to-ground difference between the two MDI contacts used by a duplex link channel and is referred to as common-mode-to-differential-mode impedance balance. Over the frequency range 1.0 MHz to 100.0 MHz, the common-mode-to-differential-mode impedance balance of each channel of the MDI shall exceed

$$34 - 19.2\log_{10}\left(\frac{f}{50}\right) \quad \text{dB}$$

where f is the frequency in MHz when the transmitter is transmitting random or pseudo random data. Test-mode 4 may be used to generate an appropriate transmitter output.

The balance is defined as

$$20\log_{10}\left(\frac{E_{cm}}{E_{dif}}\right)$$

where E_{cm} is an externally applied sine wave voltage as shown in Figure 40–32 and E_{dif} is the resulting waveform due only to the applied sine wave and not the transmitted data.

NOTE 1—Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component.

NOTE 2—The imbalance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

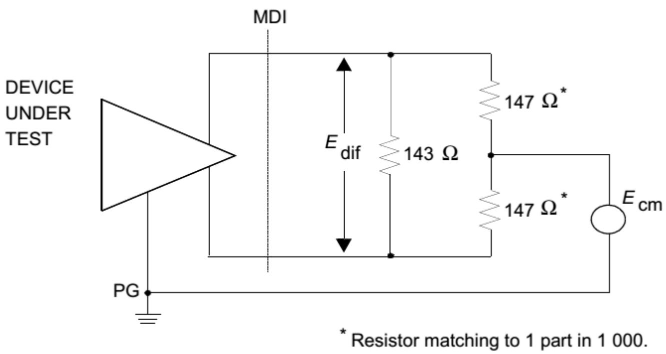
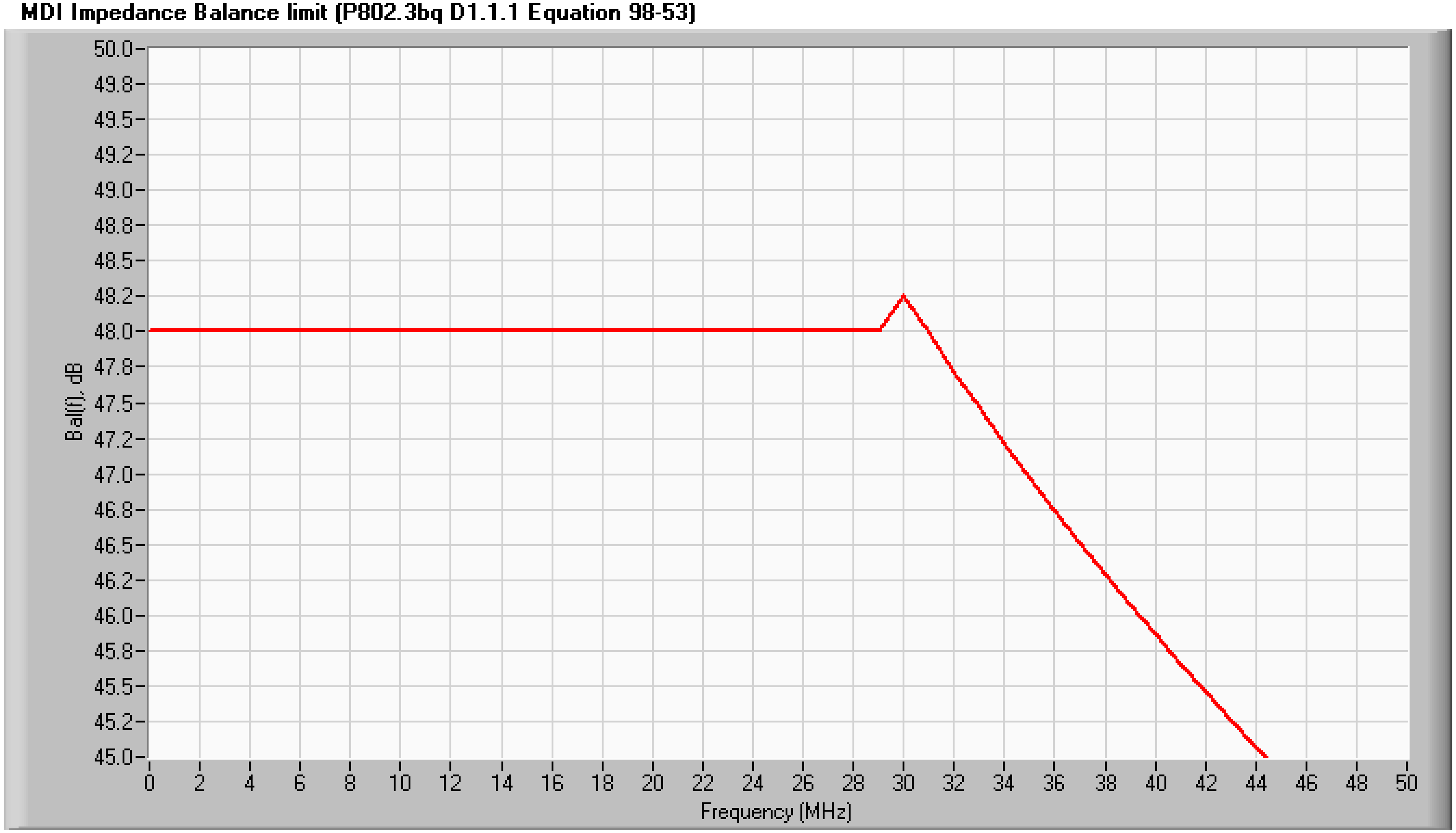


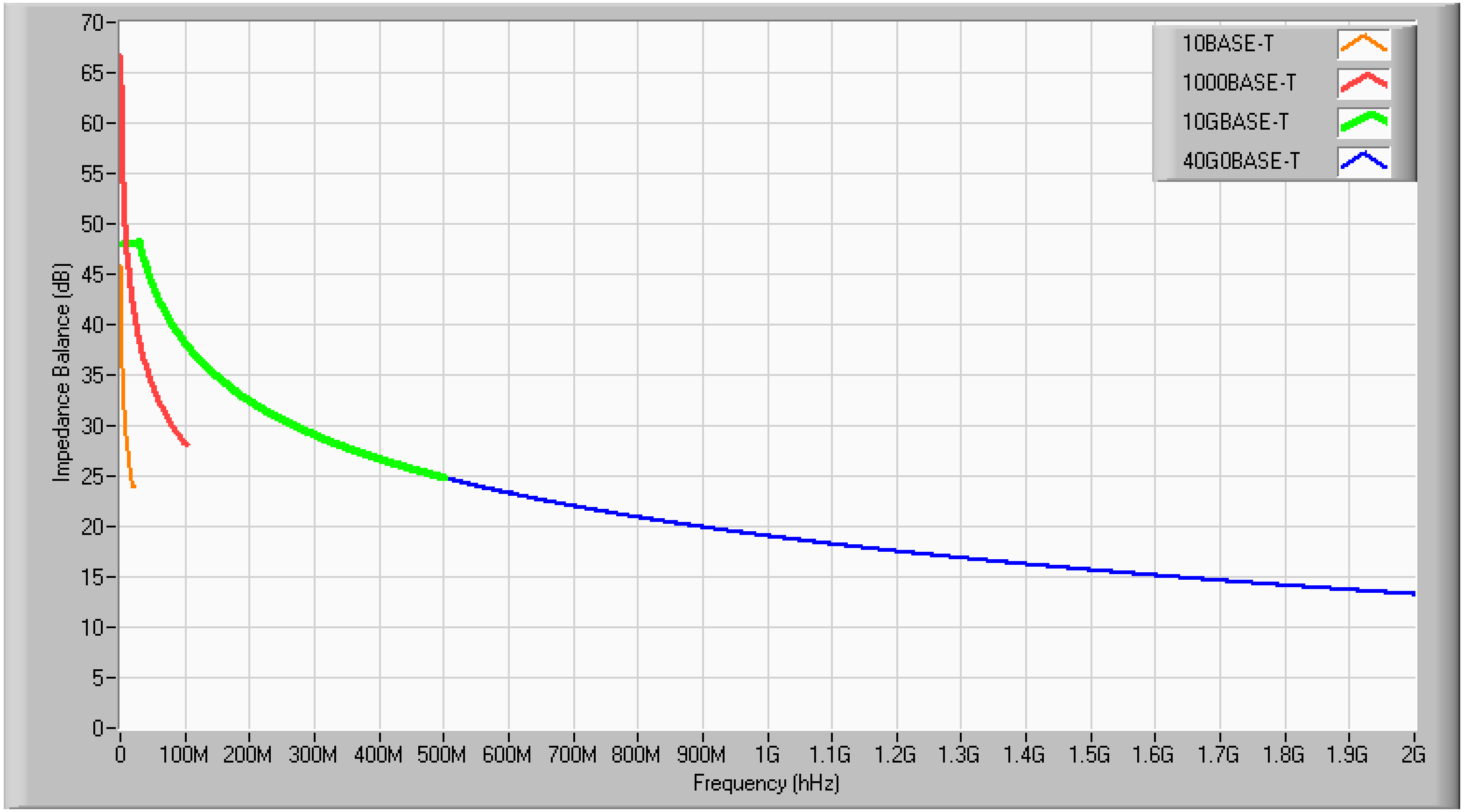
Figure 40–32—MDI impedance balance test circuit

Slight Discontinuity in Equation 98-53

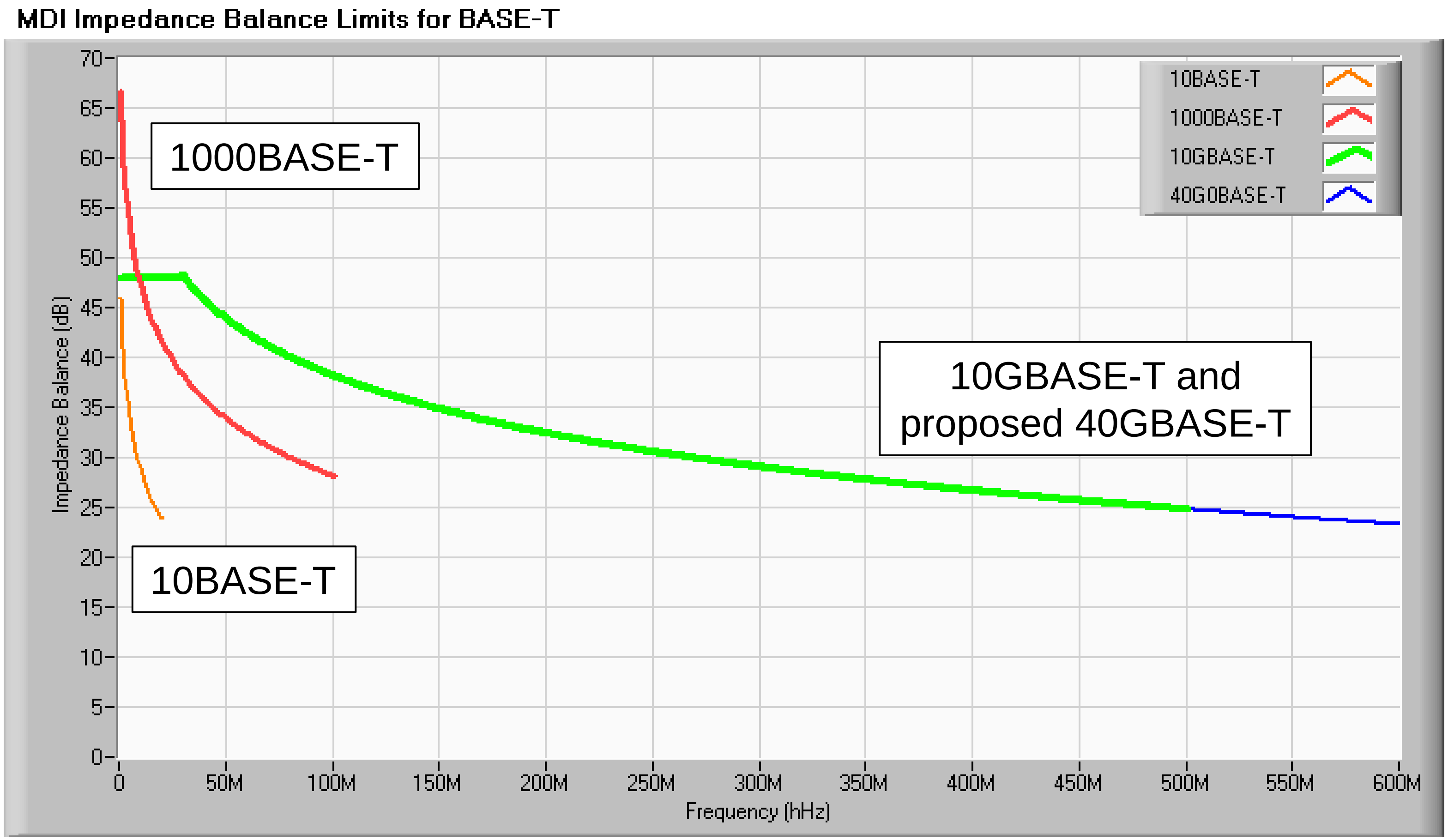


Impedance Balance Limits for BASE-T Standards

MDI Impedance Balance Limits for BASE-T



Impedance Balance Limits for BASE-T Standards



802.3aw Maintenance Comments Against Clause 55.8.2.2

Cl **55** *SC* **55.8.2.2** *P* **152** *L* # 8

Piers Dawe Avago Technologies

Comment Type **T** *Comment Status* **R**

Figure 55-35 shows 50 ohm common mode termination while the paragraph below shows 75 ohm common-mode impedance, also implied for 1000BASE-T in figs 40-31 and 40-32. It's not reasonable to expect the reader to spontaneously understand that "common mode termination" is not the same as "common-mode impedance", especially as the former term is not defined anywhere in 802.3. The common-mode coupling circuit does not present a common-mode termination to the MDI pair under test: what it presents is the common-mode impedance.

SuggestedRemedy

Now or later, change "a differential termination of 100 ohm and a common-mode termination of 50 ohm" to "a differential impedance of 100 ohm and a common-mode impedance of 75 ohm". Make similar changes (two instances) in Figure 55-35.

Response *Response Status* **C**

REJECT.

This is out of scope of this project. The commenter is requested to resubmit this comment against the IEEE 802.3 Revision project.

Cl **55** *SC* **55.8.2.2** *P* **153** *L* # 13

Piers Dawe Avago Technologies

Comment Type **T** *Comment Status* **R**

"when the transmitter is transmitting random or pseudo random data. Test-mode 4 may be used to generate an appropriate transmitter output." But test mode 4 contains several two-tone options for the transmit distortion test, so it's ambiguous.

SuggestedRemedy

Should this be test mode 7?

Response *Response Status* **C**

REJECT.

Test mode 4 is an appropriate test mode. Any of the two tone options can be used during the test.

802.3aw Maintenance Comments Against Clause 55.8.2.2

IEEE 802.3aw (IEEE P802.3-2005/Cor 2) D1.1 10GBASE-T Corrigendum comments

Cl **55** *SC* **55.8.2.2** *P* **153** *L* # 12

Piers Dawe Avago Technologies

Comment Type **T** *Comment Status* **R**

Text says that measurement of Scd11 is equivalent to measuring ~Ecm/Edif. Scd11 means the common-mode power out over the differential-mode power in, while the formula for Z_bal ~ Ecm/Edif is more-or-less the common-mode power in over the differential-mode power out. Apart from a possible sign change (see another comment), I believe this relies on reciprocity: Scd11 being known to be equal to Sdc11.

SuggestedRemedy

If this is so, (now or later), please add a sentence to state it.

Response *Response Status* **C**

REJECT.

This is out of scope of this project. The commenter is requested to resubmit this comment against the IEEE 802.3 Revision project.

Cl **55** *SC* **55.8.2.2** *P* **153** *L* # 11

Piers Dawe Avago Technologies

Comment Type **E** *Comment Status* **R**

Text says "During the test the PHY is connected to the MDI as in normal operation, but with the transmitter output disabled. It's not clear if this applies only to the network analyser method or to the Ecm/Edif method also. NOTE 1 above apparently says the opposite: "Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component." Are you sure that disabling the transmitter output gives a valid result, and are you sure it is necessary with a network analyser (which can do averaging also - but it may depend on whether it's a scalar or vector network analyser)?

SuggestedRemedy

Choose whether the transmitter should be on or off and (now or later) make changes to make the choice clear.

Response *Response Status* **C**

REJECT.

This is out of scope of this project. The commenter is requested to resubmit this comment against the IEEE 802.3 Revision project.

Cl **55** *SC* **55.8.2.2** *P* **153** *L* # 10

Piers Dawe Avago Technologies

Comment Type **E** *Comment Status* **R**

The small fonts (7, 6, even 4.5 point!) make Figure 55-35 unnecessarily hard to read.

SuggestedRemedy

If modifying this figure at all, make all the text in this figure bigger, e.g. 10 point for the "E"s, 8 point for everything else

Response *Response Status* **C**

REJECT.

Out of scope.

Cl **55** *SC* **55.8.2.2** *P* **153** *L* # 9

Piers Dawe Avago Technologies

Comment Type **E** *Comment Status* **R**

Scd11: it would be nicer to use the format S_CD11 (where _ denotes subscript).

SuggestedRemedy

If this sentence is altered, change the format per comment.

Response *Response Status* **C**

REJECT.

This sentence is not being changed.