MultiGBASE-T1 EEE Test Suite

TC16 – Energy Efficient Ethernet Test Specification (1.0)

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Foreword (Disclaimer)

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Introduction

These tests are intended to examine interoperability and stability of PHYs in EEE mode. Devices tested with this specification are expected to have already passed basic data mode testing, as specified in other OPEN Alliance documents (e.g., those produced under TC15).

Identification of patent holders, if any.

Abbreviation/Symbols

*	*AND*
!	*NOT*
+	*OR*

BS	*Burst Size*
COM	*Communication ready (status bit)*
DUT	*Device Under Test*
EEE	*Energy Efficient Ethernet*
GMII	*Gigabit Media Independent Interface*
HDMI	*High-Definition Multimedia Interface*
IBG	*Inter-burst gap*
IEC	*International Electrotechnical Commission*
IPG	*INter-Packet Gap*
ISO	*International Organization for Standardization*
JTAG	*Joint Test Action Group*
LP	*Link Partner*
LPI	*Low Power Idle*
MDIO	*Management Data Input/Output*
MII	*Media Independent Interface*
MMD	*MDIO Manageable Device*
PHY	*Physical Layer Device*
PL	*Payload Length*
PSD	*Power Spectral Density*
RX	*Receiver*
Tx	*Transmitter*
VGA	*Video Graphics Array*

ITEMS FOR FURTHER STUDY:

1. *Test setup (Appendix B) specify loss requirements (maximum insertion loss, return loss) for line tap.*

2. *Environmental tests (e.g., EMC) are expected to be done in other TCs, referencing these profiles. (possibly this is an ECU-level test)*

2 Scope (mandatory)

The scope of this document is the definition of test procedures to investigate interoperability and robustness of IEEE Std 802.3 2.5GBASE-T1, 5GBASE-T1, and 10GBASE-T1 PHYs when operating with Energy Efficient Ethernet enabled. These tests assume that interoperability and compliance with normal (i.e., non-EEE) operation has been sufficiently established. The test configurations in this document may be referenced by other test specifications (e.g., EMC or temperature testing) to exercise the EEE Low Power Idle quiet-refresh signalling under those conditions, but those performance tests are beyond the scope of this document. Additionally, testing auto negotiation, competitive analysis, power measurements, and latency measurements are out of scope of this test plan.

3 Normative references (mandatory)

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEEE Standard for Ethernet," in IEEE Std 802.3-2022 (Revision of IEEE Std 802.3-2018) , vol., no., pp.1-7025, 29 July 2022, doi: 10.1109/IEEESTD.2022.9844436 - see especially clauses 149 (for 2.5GBASE-T1, 5GBASE-T1, and 10GBASE-T1 PHYs), and relevant parts of clauses 45 (for MDIO registers), 46 (for XGMII codes), and 78 (for Energy Efficient Ethernet)

4 Terms and Definitions (mandatory)

For the purposes of this document, the following terms and definitions apply.

- 'Assert LPI' means that the PHY shall behave as if the 'Assert LPI' codeword is applied at the XGMII Tx. This may be achieved by directly applying signals at the XGMII Tx, or by other means.
- 'Deassert LPI' means that the PHY shall behave as if the 'Assert LPI' codeword is **not** applied at the XGMII Tx. This may be achieved by directly applying signals at the XGMII Tx, or by other means.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

Other terms, such as low power idle (LPI), and quiet-refresh are as defined in Clause 1.4 and used in Clause 149 of IEEE Std 802.3-2022.

5 Organization of Tests

The tests are primarily designed to indicate EEE LPI interoperability (or operability) of the device.

These tests are defined based on the assumption that normal operation without Energy Efficient Ethernet enabled has been previously established.

To Bring:

Equipment (each participant brings):

- EEE capable DUT and any converters necessary to interface to the traffic generators/analyzers (i.e., a native 2.5G/5G/10G capable Ethernet interface), including any necessary scripts or configuration files.
- Any special Programming cables (JTAG etc) needed for the DUT
- Power Supplies
- Clock Sources

Equipment needed at the Lab (common equipment):

- Computer Monitors (VGA interface, HDMI or DisplayPort may require adapters)
- Power Strips
- Keyboards and Mice
- A limited selection of Power Supplies
- High Speed Oscilloscopes / line probing equipment
- Traffic generators/monitor
- Cabling for connecting PHYs and connecting monitor computers to the DUT

(Note – While precision measurements are not made except in 8.3 timing, channels and line probes (if used) require measurement to understand the setup for repeatability. For these, calibration data is needed.)

- Test channels compliant with channels C1 and C2 specified in (TC15 and) Appendix B.
- Line tap specified in Appendix B (optional).

Test Outline:

- Mandatory tests: EEE LPI interoperability/operability tests
    - Assert/Deassert LPI on control (Group 1)

- LPI based on traffic (Group 2)
  - Traffic Profile A: Low-utilization = Master
  - Traffic Profile B: Low-utilization = Slave
- Optional tests:
  - "Autonomous" LPI mode (optional) (Group 3)
  - Fully loaded traffic/Stress Test (Group 4)

The first set of tests (Group 1) attempt a simple transition, asserting and deasserting LPI functionality on control. This test requires the ability to control the codeword asserted at the XGMII interface (or equivalent) in both the DUT and the LP, and to assess whether the RX LPI indication and RX LPI received bits are set in the MDIO registers. The assessment criteria is that the bits indicate the transition to and from LPI mode and that the link remains up.

The second set of tests (Group 2) assert the traffic pattern at the DUT and the link partner and monitor for dropped frames (i.e., that the frame count in = the frame count out). This is repeated in each direction, and repeated reversing which PHY is the master and which is the slave, for a total of 4 combinations.

With the traffic profiles listed, interoperability will be observed for the following testing matrix, testing vendor to vendor, where the column indicates the vendor device sourcing the timing (master), and the row indicates the vendor recovering timing (slave).

Each matrix will be repeated for each traffic profile and speed supported.

For each test configuration, read and record any negotiated link parameters (e.g., interleaver and precoder settings).

(2.5G, 5G, or 10G)BASE-T1 EEE (speed as appropriate)

	V1	V2	V3	V4	V5
V1					
V2					
V3					
V4					
V5					

6 DUT / LP Configuration Permutation Definitions

The test groups shall be executed in multiple DUT/LP configurations, unless the test groups states otherwise. The intention is to guarantee that a test is executed in all relevant permutations. The table below shows the basic configurations executed for each test group. Support of slow wake is optional in the standard. The test plan shall note the speeds supported by the DUT, and whether the DUT supports slow wake. Speeds not supported shall be omitted from the test. If slow wake is not supported, tests x-B and x-D shall be omitted for all speeds.

Example: For a device which supports three speeds (2.5G, 5G and 10G) there are a total of 6 mandatory configurations (2.5G-A & C to 10G-A & C).

Table 1: DUT/LP Configurations Baseline. X denotes the speed grade (2.5G, 5G or 10G)

Configuration	DUT	LP	Optional?
x-A	LinkSync, SLAVE, Normal EEE	LinkSync, MASTER, Normal EEE	No
x-B	LinkSync, SLAVE, Slow Wake EEE	LinkSync, MASTER, Slow Wake EEE	Yes (Slow Wake)
x-C	LinkSync, MASTER, Normal EEE	LinkSync, SLAVE, Normal EEE	No
x-D	LinkSync, MASTER, Slow Wake EEE	LinkSync, SLAVE, Slow Wake EEE	Yes (Slow Wake)

7 EEE Profile Definition

The following sections define the traffic profiles which are used throughout different test groups. A traffic profile is the traffic that is sentby a single traffic generator into either DUT or LP as described further in the test group procedures.

The following figure illustrates the parameters in the defined traffic profiles.

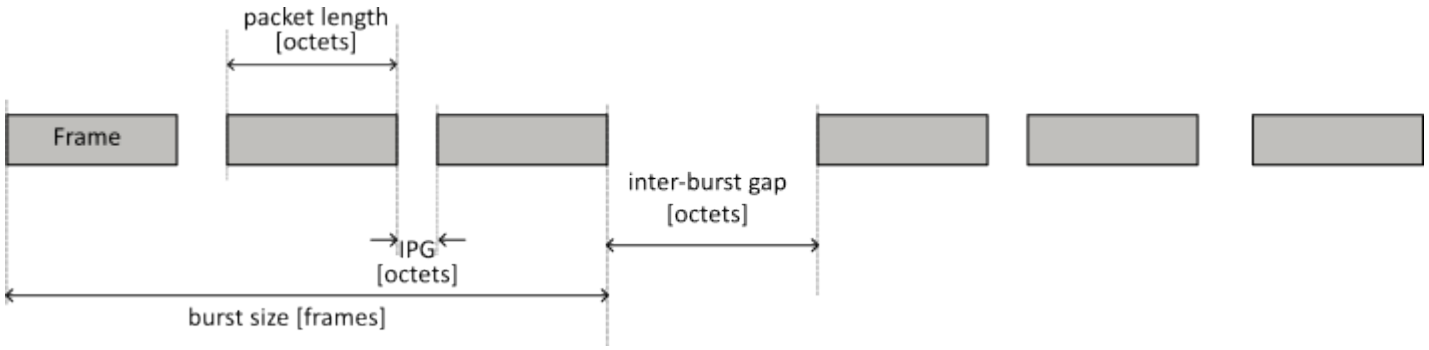

Figure 1 Traffic Profile Parametrization

7.1 General Definitions – EEE Timing at xMII

Depending on the test procedure, the traffic generator sends LPI code words during longer IDLE times (IBG or similar), or the DUT has the ability to generate LPI internally. The timing of the LPI code words shall obey the IEEE Std 802.3-2022 requirements. That specifically means, that while the link is in LPI and the traffic generator is about to generate traffic, the first frame after LPI must always be preceded by a wake-up period. The wake-up is a period of Idles after the LPI assertion period has completed and before the first frame of the burst is transmitted. The wake-up period is referred to as $T_{w\_sys\_tx}$ in IEEE Std 802.3-2022, Clause 78. The duration must exceed the minimum values in Table 78-4 for the speed (and wake mode) selected (case 3 for slow wake and case 1 for no slow wake). For definitions of the Case-1 and Case-3 in Table 2, see IEEE Std 802.3-2022 at subclause 78.5.

Table 2: Wake period (from IEEE Std 802.3-2022, Table 78-4)

PHY type	Case	Tw_sys_tx (min) (µs)
2.5GBASE-T1	Case-1	35.84
	Case-3	148.48
5GBASE-T1	Case-1	17.92
	Case-3	74.24
10GBASE-T1	Case-1	8.96
	Case-3	34.56

7.2 Profile A-1

Profile A-1 and A-2 mimic a camera scenario. Traffic comes in a high-utilization stream (A-1) from one direction and a low-utilization, but bursty, stream (A-2) in the other direction. High utilization may be either the master or slave, as specified in the test scenario. Average data rates are over a 1 second interval.

Throughout this document the utilization (U in equations) is defined as all non-control (or IDLE) octets that are transmitted by the MAC divided by all octets in a sufficiently large observation time window.

Table 3: Traffic Parameters Profile A-1

Description	Continuous 90% L1 utilization in downstream direction. Specifically, the "non-control (or IDLE)" octets do not include control codes such as LPI.
L1 data rate	9.0 Gbps (10GBASE-T1) 4.5 Gbps (5GBASE-T1) 2.25 Gbps (2.5GBASE-T1)
Inter-packet gap[1]	Value implicitly given by $\mathrm{IPG} = PL \cdot (\frac{1}{U} - 1)$, where PL is the payload length and U is the average L1 link utilization (i.e. 0.9).
Inter-burst gap	-
Burst-size	-
Packet length	1518 octets

7.3 Profile A-2

Profile A-2 is the low data rate, control flow for in a typical video scenario, see Profile A-1 for details.

Table 4: Traffic Parameters Profile A-2

Description	Bursty control traffic in upstream direction. Depending on the test, the packet generator sends LPI code words on the xMII interface with the intention to bring the link into LPI.
L1 data rate	Average 0.01 Gbps (same for 2.5/5/10GBASE-T1)
Inter-packet gap	12 octets
Inter-burst gap[2]	Value implicit given by: $\mathrm{IBG} = BS \cdot PL \left(\frac{1}{U} - 1\right) - BS \cdot IPG$, where IBG denotes the inter-burst gap in octets, U is the average L1 link utilization (here 0.1 % for 10G, 0.2 % for 5G, 0.4 % for 2.5G and 1 % for 1G) , BS denotes the burst-size in frames, PL denotes the packet length in octets and IPG denotes the inter-packet gap during a burst in octets.

[1] The equations for IPG and IBG yield non-integer values. In practice, the actual IPG/IBG shall be close to the integer octet value and only vary by +/-1 octet. For example, deficit idle count (DIC) or other methods can be used to meet this requirement.
[2] See comment for IPG.

Burst-size	100 frames (fixed)
Packet length	64 octets

7.4 Profile B

The traffic pattern in this profile is a simple stop-and-go scenario in which the generator sends a single frame followed by a long idle time. Depending on the test, the traffic generator sends LPI code words, resulting in a repetitive interleaved LPI/frame sequence.

Table 5: Traffic Parameters Profile B

Description	Single frame, followed by IDLE. Depending on the test, the traffic generator sends LPI code words, resulting in a repetitive interleaved LPI/frame sequence.
Inter-packet gap	12 octets
Inter-burst gap	1 ms
Burst-size	1 frames (fixed)
Packet length	1518 octets

7.5 Profile C

This is a high load scenario to stress a single direction with the maximum possible data rate.

Table 6: Traffic Parameters Profile C

Description	Continuous high utilization in one direction. Specifically, the "non-control (or IDLE)" octets do not include control codes such as LPI.
Inter-packet gap	12 octets
Packet length	1518 octets

8 Interoperability Test Cases

8.1 Group 1: Simple Interoperability

Overview: These tests are designed to identify problems that may exist between two EEE capable devices in establishing a complete link, exchanging packets with each other, while entering and leaving the LPI state, using slow wake or not, as specified for the configuration.

Out of Scope: Competitive performance evaluation of a vendor's product will not be performed. Extensive protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

Additional DUT capabilities needed: Devices will be required to be able to be forced into a LPI mode via management registers, physical switches, or equivalent. Devices should be capable of indicating if they and/or the link partner is in a LPI mode through management registers, LEDs, or equivalent.

MDIO access to management registers will be required to access the following:

- Link status MMD 1.1.2 or 1.2310.0
- Rx LPI indication, MMD 3.1.8, or 3.2323.8
- Rx LPI received, MMD 3.1.10, or 3.2323.10

NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.

Ability to manually configure MASTER/SLAVE without AutoNeg.

NOTE – tests are designed and configured to test devices as both MASTER and SLAVE. Timing mode of the test is noted, and will be separately reported (i.e., results of steps 1-5 below are reported separately from results of steps 6 & 7). Future tests may consider whether single-mode devices are permitted.

Test Setup: Connect link pair together with channel C1 as specified in Appendix B, and with a traffic generator/packet tester. Repeat test with channel C2.

If a traffic generator is unavailable, this test can be performed if the PHY can enter LPI quiet-refresh signalling by a forced configuration (e.g., register bit or pin).

Refer to test suite appendix A.

Configurations: Configurations specified in Table 1. If the DUT does not support slow wake, omit cases x-B and x.-D.

General Procedures:

1. Reset DUT and LP prior to test execution
2. Establish a link between the link pair (no autoneg)
3. Observe both Link Partners Entering and Exiting the LPI mode
4. Observe that traffic can be sent from the link partner while the local transmitter is in LPI mode

Specific Procedures:

1. Establish a link between the link pair, as per the selected configuration and confirm the configuration by reading the configuration back from the DUT/LP.
   Read negotiated interleaving and precoder settings from DUT and LP and document.

2. Assert LPI at DUT, and deassert LPI at LP.

   Expect Rx LPI indication = 1 at LP, and Rx LPI indication = 0 at DUT.
   Expect Rx LPI received = 1 at LP, and Rx LPI received = 0 at DUT.

   Observe for **1** minute.
   Continuously monitor link status on DUT and LP – fail if link does not remain stable.

   NOTE – use of a line tap is not required, but if available:
   Verify that DUT produces a quiet-refresh cycle with the line tap.
   Fail if quiet-refresh cycle is observed from the LP.

3. Assert LPI at LP, and deassert LPI at DUT.
   Expect Rx LPI indication = 1 at DUT, and Rx LPI indication = 0 at LP.
   Expect Rx LPI received = 1 at DUT, and Rx LPI received = 0 at LP.

   Observe for **1** minute.
   Continuously monitor link status on DUT and LP – fail if link does not remain stable.
   NOTE – use of a line tap is not required, but if available:
   Verify that LP produces a quiet-refresh cycle with the line tap.
   Fail if quiet-refresh cycle is observed from the DUT.

4. Assert LPI at DUT, and assert LPI at LP.
   Expect Rx LPI indication = 1 at DUT, and Rx LPI indication = 1 at LP.
   Expect Rx LPI received = 1 at DUT, and Rx LPI received = 1 at LP.

   Observe for **1** minute.
   Continuously monitor link status on DUT and LP – fail if link does not remain stable.

   NOTE – use of a line tap is not required, but if available:
   Verify that DUT produces a quiet-refresh cycle with the line tap.
   Verify that LP produces a quiet-refresh cycle with the line tap.

5. Send traffic Profile B from the traffic generator into DUT's xMII.
   Send traffic Profile B from the traffic generator into LP's xMII.
   Continuously monitor link status on DUT and LP and expect that link remains stable.

   Observe for 2 minutes (120 seconds).

Expect all frames transmitted by the DUT to be received by the LP, without any frame errors or missing frames.

Expect all frames transmitted by the LP to be received by the DUT, without any frame errors or missing frames.

Expect Rx LPI received = 1 at DUT, and Rx LPI received = 1 at LP.

Other expected results:

a) After the links have been established the link status of MMD 1.1.2 should always be reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem potentially caused by an EEE interoperability problem.
b) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0 indicates a problem in the LPI wake-up sequence.

Notes:
NOTE – If one wishes to perform tests specified by TC15 while exercising EEE functionality, the Group 1 test sequence can be used.

8.2 Group 2: Typical Application

Overview: This test is designed to monitor packet-handling for asymmetric traffic with a pair of EEE capable devices entering and exiting LPI operation. These tests can by used to identify whether problems exist causing packet loss or link drop during entry to or exit from LPI operation..

Out of Scope: Competitive performance evaluation of a vendor's product will not be performed. Extensive protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

Additional DUT capabilities needed: Devices will be required to accept packets for transmit and deliver packets on reception to a packet generator/monitor. Devices must be capable of indicating if they and/or the link partner is in a LPI mode through management registers or equivalent functionality.

MDIO access to management registers will be required to access the following:

- Link status MMD 1.1.2 or 1.2310.0
- Rx LPI indication, MMD 3.1.8 or 3.2323.8
- Rx LPI received, MMD 3.1.10 or 3.2323.10
- NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.

Ability to manually configure MASTER/SLAVE without AutoNeg.

NOTE – tests are designed and configured to test devices as both MASTER and SLAVE. Timing mode of the test is noted, and will be separately reported (i.e., results of steps 1-5 below are reported separately from results of steps 6 & 7). Future tests may consider whether single-mode devices are permitted.

Test Setup: Connect link pair together with test channel C1 from Appendix B. Connect each end of the link pair to the traffic generator in full duplex. Repeat test with channel C2.

General Procedures:

1. Reset DUT and LP prior to test execution
2. Establish a link between the link pair (no autoneg)
3. Monitor link status, transmit and received frame counts in both directions
4. Observe that link remains stable over at least 2 minutes (120 seconds) and transmit frame count = receive frame count in each direction. (A large finite number of frames should be transmitted in both directions, from DUT to LP and from LP to DUT.)

Specific Procedures:

1. Establish link between the link pair, as per the selected configuration and confirm the configuration by reading the configuration back from the DUT/LP.
   Read negotiated interleaving and precoder settings from DUT and LP and document.

2. Assert Profile A-1 at the DUT and Profile A-2 at the LP.
   Confirm that the link has entered LPI in LP-to-DUT direction by reading:
   Rx LPI indication, MMD 3.1.8, or 3.2323.8
   Rx LPI received, MMD 3.1.10, or 3.2323.10

   NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.

   Observe for 2 minutes (120 seconds)..

   Expect transmit frame count = received frame count in each direction after time elapsed.
   Continuously monitor link status on DUT and LP and expect that link remains stable.

Other expected results:

c) After the links have been established the link status of MMD 1.1.2 (link status) should always be reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem potentially caused by an EEE interoperability problem.
d) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0 indicates a problem in the LPI wake-up sequence.

8.3 Group 3: Typical Application – Autonomous LPI (Optional)

Scope: This test is designed to monitor packet-handling for asymmetric traffic with a pair of EEE capable devices entering and leaving a LPI state autonomously.

Overview: These tests are designed to identify problems that may exist between two EEE capable devices exercising entry and exit of LPI with asymmetric traffic. In this test, the DUT enters LPI autonomously based on traffic heuristics. This is a mode which is commonly implemented, but exceeds the IEEE Std 802.3-2022 specification and is optional.

Out of Scope: Competitive performance evaluation of a vendor's product will not be performed. Extensive protocol conformance testing will not be pursued unless warranted for troubleshooting purposes. The performance of the LPI heuristics in terms of power savings is not performed.

Additional DUT capabilities needed: Devices will be required to accept packets for transmit and deliver packets on reception to a packet generator/monitor. Devices should be capable of indicating if they and/or the link partner is in a LPI mode through management registers, LEDs, or equivalent. The device shall be able to autonomously enter LPI.

MDIO access to management registers will be required to access the following:

- Link status, MMD 1.1.2 or 1.2310.0
- Rx LPI indication, MMD 3.1.8 or 3.2323.8
- Rx LPI received, MMD 3.1.10 or 3.2323.10

NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.

Ability to manually configure MASTER/SLAVE without AutoNeg.

Test Setup: Connect link pair together with test channel C1 from Appendix B. Connect each end of the link pair to the traffic generator in full duplex. Repeat test with channel C2.

Configurations: No deviations from baseline definition.

General Procedures:

1. Reset DUT and LP prior to test execution
2. Disable LPI generation for traffic generator connected to DUT.
3. Establish a link between the link pair (no autoneg)
4. Monitor link status, transmit and received frame counts in both directions
   Observe that link remains stable over at least 2 Minutes (120 seconds) and transmit frame count = receive frame count in each direction. (A large finite number of frames should be transmitted in both directions, from DUT to LP and from LP to DUT.)

Specific Procedures:

1. Establish link between the link pair, as per the selected configuration and confirm the configuration by reading the configuration back from the DUT/LP.
   Read negotiated interleaving and precoder settings from DUT and LP and document.

3. Assert Profile A-1 at the DUT and Profile A-2 at the LP.

a. Traffic generator connected to LP shall send LPI at times of IDLE.
b. Traffic generator connected to DUT shall be configured to never send LPI.
c. Confirm that the link has entered LPI in LP-to-DUT direction by reading:
Rx LPI indication, MMD 3.1.8, or 3.2323.8
Rx LPI received, MMD 3.1.10, or 3.2323.10
NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.
Observe for 2 minutes (120 seconds).

Expect transmit frame count = received frame count in each direction after time elapsed.
Continuously monitor link status on DUT and LP and expect that link remains stable.

4. Assert Profile A-2 at the DUT and Profile A-1 at the LP.
a. Traffic generator connected to LP shall send LPI at times of IDLE.
b. Traffic generator connected to DUT shall be configured to never send LPI.
c. Confirm that the link has entered LPI in DUT-to-LPI direction by reading:
Rx LPI indication, MMD 3.1.8, or 3.2323.8
Rx LPI received, MMD 3.1.10, or 3.2323.10
NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.
Observe for 2 minutes (120 seconds).

Expect transmit frame count = received frame count in each direction after time elapsed.
Continuously monitor link status on DUT and LP and expect that link remains stable.

Other expected results:

e) After the links have been established the link status of MMD 1.1.2 (link status) should always be reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem potentially caused by an EEE interoperability problem.
f) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0 indicates a problem in the LPI wake-up sequence.

8.4 Group 4: Stress Pattern

Scope: This test is designed to stress the LPI quiet-refresh cycles

Overview: These tests are designed to identify problems that may exist between two EEE capable devices exercising entry and exit of LPI under synthetical traffic conditions. The link will be mostly LPI in one direction, sending frames sparsely. The other direction is utilized as per line rate, and should only have minimum IPG spacing, hence should not go into LPI.

Out of Scope: Competitive performance evaluation of a vendor's product will not be performed. Extensive protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

Additional DUT capabilities needed: Devices will be required to accept packets for transmit and deliver packets on reception to a packet generator/monitor. Devices should be capable of indicating if they and/or the link partner is in a LPI mode through management registers, LEDs, or equivalent.

MDIO access to management registers will be required to access the following:

- Link status MMD 1.1.2 or 1.2310.0
- Rx LPI indication, MMD 3.1.8 or 3.2323.8
- Rx LPI received, MMD 3.1.10 or 3.2323.10

NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.

Test Setup: Connect link pair together with test channel C1 from Appendix B. Connect each end of the link pair to the traffic generator in full duplex. Repeat test with channel C2.

Configurations: No deviations from baseline definition.

General Procedures:

1. Reset DUT and LP prior to test execution
2. Establish a link between the link pair (no autoneg)
3. Monitor link status, transmit and received frame counts in both directions

Observe that link remains stable over at least 2 Minutes (120 seconds) and transmit frame count = receive frame count in each direction. (A large finite number of frames should be transmitted in both directions, from DUT to LP and from LP to DUT.)

Specific Procedures:

2. Establish link between the link pair, as per the selected configuration and confirm the configuration by reading the configuration back from the DUT/LP.
   Read negotiated interleaving and precoder settings from DUT and LP and document.

   Assert Profile B at the DUT and Profile C at the LP.
   Confirm that the traffic generator is sending LPI code words for Profile B by reading:
   Rx LPI indication, MMD 3.1.8, or 3.2323.8
   Rx LPI received, MMD 3.1.10, or 3.2323.1
   NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.
   Observe for Observe for 2 minutes (120 seconds).
   Expect transmit frame count = received frame count in each direction after time elapsed.
   Continuously monitor link status on DUT and LP and expect that link remains stable.

5. Assert Profile C at the DUT and Profile A at the LP.
   Confirm that the traffic generator is sending LPI code words for Profile A-2 by reading:
   Rx LPI indication, MMD 3.1.8, or 3.2323.8
   Rx LPI received, MMD 3.1.10, or 3.2323.10
   NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid stable state result.
   Observe for Observe for 2 minutes (120 seconds).
   Expect transmit frame count = received frame count in each direction after time elapsed.

Continuously monitor link status on DUT and LP and expect that link remains stable.

Other expected results:

g) After the links have been established the link status of MMD 1.1.2 (link status) should always be reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem potentially caused by an EEE interoperability problem.
h) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0 indicates a problem in the LPI wake-up sequence.

Appendix A
(informative)

Test Setups

A.1 Interoperability Test Setup

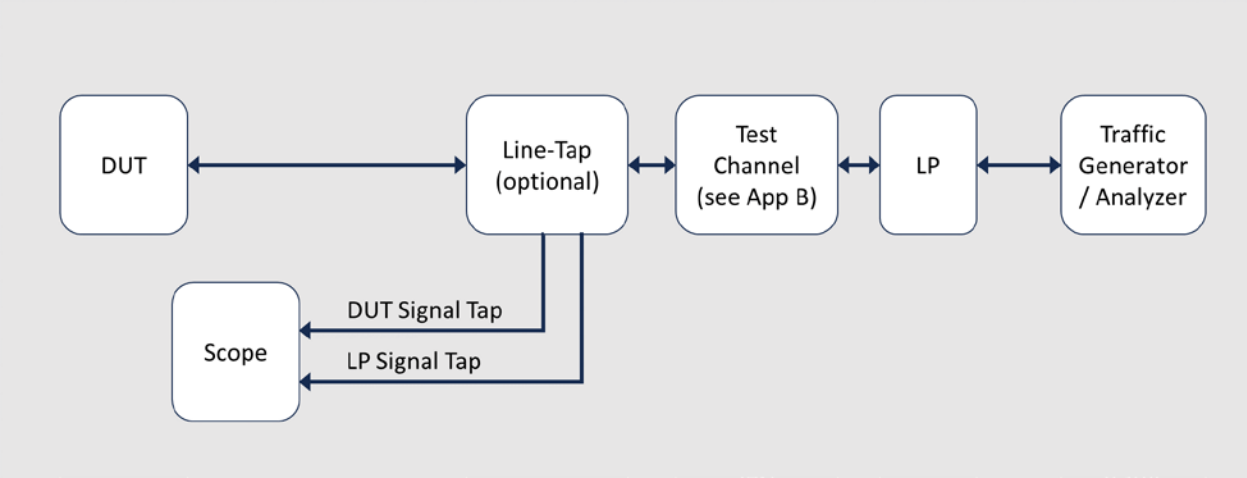

Figure 2: Example Test Setup

Proposed test setup involves the use of an optional line tap for monitoring LPI signalling of both the DUT and LP. This would also allow for some rough timer measurements. If a line tap is used, the channel (see Appendix B) must be verified for compliance with IEEE 802.3 insertion loss and return loss specifications, and, if necessary, the channel must be adjusted so that the resulting combination of cabling and line tap meets the IEEE 802.3 specifications for these parameters.

Note that connector interfaces may be needed between the various blocks depending on the connectors used on individual units (e.g., DUT to line-tap, line-tap to test channel, etc.)

The link partner will need to be able to interface with the traffic generator and convert the signalling to MGBASE-T1. If there is no desire to monitor the LPI signalling directly on the line, the line tap can be removed from the test setup.

The lab test environment (external to specific DUT or cabling used in temperature tests) shall be at room temperature, i.e., between 20C and 25C.

Appendix B
(normative)

Test Channels

The channel type C1 has a total length of 3.5 m, with cable connectors on each end as shown in Figure 2.

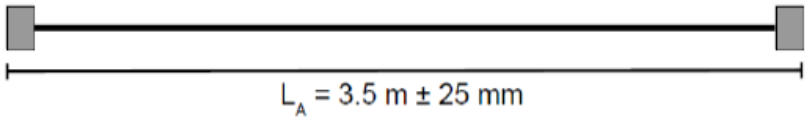

Figure 3: Channel type C1 (see TC15 specification)

The channel type C2 has a total length of 15 m, consisting of five cable segments and four inline connectors as shown in Figure 1.

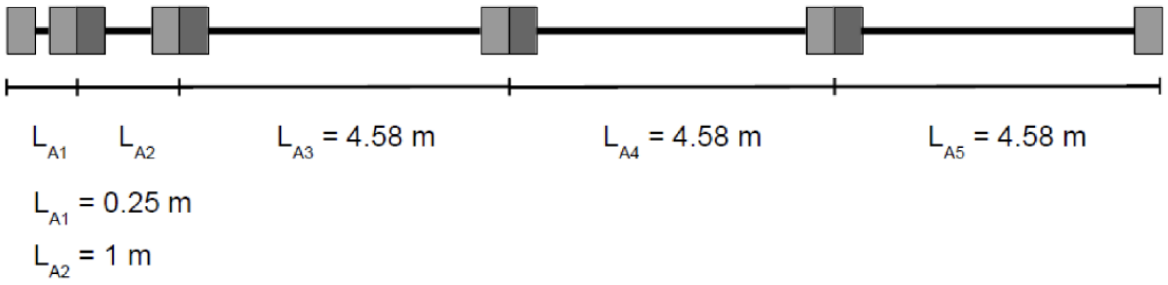

Figure 4: Channel type C2 (see TC15 specification)

NOTE - If a line tap is used, the channel must be adjusted so that the channel plus the line tap complies with the insertion loss and return loss specifications. Recommended adjustment is to replace a segment (i.e., A1 or A2) with the line tap, to take into account additional losses from the line tap. Channel insertion loss shall be less than or equal to Equation 149-18 of IEEE Std 802.3-2022 at all frequencies from 1 MHz to 4 GHz, repeated here for reference: *Insertion Loss (f) ≤ 0.002 f + 0.68 $f^{0.45}$*. **Use of the line tap is optional, and insertion loss specifications for the line tap are for further study.**

Channel return loss shall be greater than or equal to the return loss specified in 149.7.1.3 of IEEE Std 802.3-2022 for the given speed of the DUT and insertion loss of the actual channel used. See standard for details.

Addition of alien crosstalk is outside the scope of these tests. Noise may be added for tests under other TCs, as specified in those TCs, and those TCs may specify combining that with the Group 1 and Group 2 tests in this plan.

Proposed Additions for Next Edition

The following items are proposed for a future edition of this test specification.

Contributions proposing specific text changes and additions are requested on these topics:

- Support for 1000BASE-T1 EEE Testing,