0. General:

a. These procedures describe FEE S11 measurements using the Copper Mountain Technologies M5045 VNA, FEE Test Fixture V2, and custom Calibration Fixtures.

b. The Calibration Fixtures are V2 with the MCL AMT-32+ 180° hybrid coupler. The Calibration Fixtures have been characterized by measurements and loaded into the VNA as Data-Base Standards. Refer to *Calibration Fixture Measurements & Associated Data-Based Standards*. The FEE Test Fixture V2 Coupler PCB 180° hybrid coupler (MCL AMT-32+) is de-embedded during calibration by using custom Calibration Fixtures.

c. Dual assembly FEEs are mounted using all four studs (feedpoints) in the FEE Test Fixture. For reference, FEE Side A = Side facing up and FEE Side B = Side facing down when mounted in the Test Fixture.

d.

e. The instrument calibration protocol is as follows: Calibrate at the beginning of each measurement day. Recalibrate if any of the following are changed after initial calibration: Frequency range; IF Bandwidth; or Resolution; Lab temperature. Notes: 1) These procedures do not require changing any of these settings and the lab temperature and humidity is stable; 2) Output power of the CMT VNA can be changed without affecting calibration.

f. The measurement frequency range is 5 to 200 MHz.

1.1. Preliminary:

a. The 30 dB attenuator on the FEE Test Fixture RF Input, if equipped, is to be removed and not reconnected until all measurements are completed. This attenuator is used only when a spectrum analyzer with tracking generator is used to measure FEE gain.

c. Test equipment:
   1) FEE Test Fixture V2 (equipped with MCL AMT-32+ on Coupler PCB and MCL 141-SMRSM+ internal Jumper Cable), custom
   2) Calibration Fixtures V2, Open, Short, and Load, custom
   3) Copper Mountain Technologies M5045 vector network analyzer
   4) Test cable, 1 m long, SMA-M : N-M, MCL ULC-1M-SMNM+ (Red)
   5) Jumper Cable, 6 in long, MCL 141-6SMRSM+ (proxy Jumper Cable)
   6) 50 ohm termination, SMA-M
   7) Torque wrench, 5/16 in (8 mm), Pre-set to 5 in-lbs (0.56 N-m)

d. Test set status as of 18 January 2023:

Mfr	Type	S/N	Cal due
CMT	Compact M5045 VNA, SW 22.4.3	22160017	15 Jul 2024

1.2. S-Parameter Measurements:

a. These procedures measure only the FEE feedpoint impedance as the S11 reflection coefficient in terms of dB and angle.

b. The VNA Port 1 is calibrated using Full 1-Port procedures with output power set to 0 dBm. The Port 1 output power is then reduced to −35 dBm for the S11 measurements to prevent compression in the FEE. This level provides a 16.5 dB margin below the 1 dB output compression level of the FEE.

c. To compensate for the reduced dynamic range when the output power is reduced, the IF bandwidth is reduced to 1 kHz. Moderate sweep averaging also is used if needed.

d. S11 is measured on both sides (A & B) of each FEE while in the FEE Test Fixture. This requires reconnecting and rotating the FEE in the FEE Test Fixture. The FEE serial number and side (SNxxx-A or SNxxx-B) is placed in the filename when saving the measurements.

1.3. Setup:

a. <u>FEE Test Fixture V2</u>:

☐ Set FEE Test Fixture switches for Internal Power and turn <u>OFF</u>
☐ Install a 50 ohm termination on the FEE Test Fixture RF Output

b. <u>Stimulus setup</u>:

☐ Start ⇢ 5.0 MHz, Stop ⇢ 200.0 MHz
☐ Points ⇢ 1001
☐ Sweep type ⇢ Lin Freq
☐ IF Bandwidth ⇢ 1 kHz
☐ Port Power ⇢ Port 1 ⇢ 0 dBm
☐ Trigger ⇢ Continuous

c. <u>Display setup</u>:

☐ Allocate Channels ⇢ x1
☐ Number of Traces ⇢ 1
☐ Allocate Traces ⇢ x1
☐ Trace 1 ⇢ S11 ⇢ Log Mag, 5 dB/div, −25.0 dB Ref

d. <u>Average setup</u>:

☐ Averaging ⇢ Off
☐ Average Factor ⇢ 10 (default)
☐ Smoothing ⇢ Off

e. <u>Connections for analyzer calibration</u>:

☐ Connect the VNA Port 1 to the Calibration Fixture Side A through the Test Cable and proxy Jumper Cable as shown in Diagram 1.3.1 below. With this setup, the 180° hybrid coupler on the Test Fixture Coupler PCB and associated Jumper Cable are de-embedded by proxy of the three Calibration Fixtures and identical external Jumper Cable

FEE S-Parameter Measurement Procedures for V1.8 FEE

    f.   <u>Calibration</u>:

- ☐ Select the Red Side A Data-Based Standards Cal Kit from the Cal Kit list: Calibration ⤳ Cal Kit ⤳ LWAF_Red-A ⤳ Select
- ☐ Calibrate ⤳ Full 1-Port Cal
- ☐ Select ⤳ Port ⤳ Port 1 (S11)
- ☐ Start Calibration, follow in sequence to Calibrate VNA Port 1
- ☐ Port 1 Open -F- ⤳ Port 1 Short -F- ⤳ Port 1 Load -F-
- ☐ Apply
- ☐ Save/Recall ⤳ Save Type ⤳ State & Cal
- ☐ Save State ⤳ File ⤳ Cal_5-200MHz_CalFixt_Date.Time
- ☐ Averaging ⤳ Off
- ☐ Remove the proxy Jumper Cable from the VNA Test Cable
- ☐ Connect the VNA Test Cable to the FEE Test Fixture RF Input

    g.   <u>Reduce Port 1 output power</u>:

- ☐ Stimulus ⤳ Power ⤳ Port Power ⤳ Port 1 ⤳ −35 dBm

    h.   <u>Markers</u>:

- ☐ Markers ⤳ Add Marker ⤳ 5M, 10M, 20M, 40M, 80M, 160M
- ☐ Marker Properties ⤳ Stimulus Digits ⤳ 5, Response Digits ⤳ 5, Discrete ⤳ OFF, Marker ⤳ Couple

    i.   <u>Connections for FEE measurements</u>:

- ☐ Check that FEE Test Fixture power is <u>OFF</u>
- ☐ Refer to Diagram 1.3.2 below and connect the FEE side A (B) to the internal RF output cable
- ☐ Install the FEE in the FEE Test Fixture using all four studs

    j.   <u>Measure FEE as DUT and save data</u>:

- ☐ Turn <u>ON</u> FEE Test Fixture power
- ☐ Averaging ⤳ On if needed to reduce trace noise; otherwise Off
- ☐ After Averaging completes, Save/Recall ⤳ Save Data to Touchstone File ⤳ 1 Port (s1p) ⤳ Format ⤳ dB-Angle
- ☐ Save File ⤳ Filename SNxxxx-A(B)_S11_ Date.Time.s1p
- ☐ System ⤳ Print ⤳ Print Color ⤳ Color ⤳ Invert Image ⤳ Print Date & Time ⤳ Print to File
- ☐ Save File ⤳ Filename SNxxxx-A(B)_ S11_Date.Time.png
- ☐ Averaging ⤳ Off
- ☐ Turn <u>OFF</u> FEE Test Fixture power and prepare to measure FEE side B or the next FEE
- ☐ Repeat measurements from beginning of step i

FEE S-Parameter Measurement Procedures for V1.8 FEE

Diagram 1.3.1 (Analyzer Calibration)

Vector Network Analyzer

VVS

Port 1   Port 2

N-M

Test Cable

Port 1 Reference Plane

MCL Hand-Flex
141-6SMRSM+

Proxy Jumper Cable

D

180°
Hybrid
Coupler

A

B

OPEN
SHORT
LOAD

Calibration Fixture

Diagram 1.3.2 (FEE S-Parameter Measurement)

Vector Network Analyzer

VVS

Port 1   Port 2

N-M

Test Cable

Port 1 Reference Plane

MCL Hand-Flex
141-6SMRSM+

RF Input

D

180°
Hybrid
Coupler

A

B

FEE

OUT

DUT

Bracke 92306.12
RG-188D

FEE Test Fixture
~ Upper Bay

Coupler PCB

RF Output
+ dc

MCL Hand-Flex
086-4SM+

50 ohm
Termination

RF Output

MCL Hand-Flex
086-12SBSM+

RF

MCL Bias-Tee
ZFBT-4R2GW

RF + dc

MCL Hand-Flex
086-12SBSM+

RF Input
+ dc

15 Vdc Power
Supply

Internal Power Supply Selected
and On during measurements

FEE Test Fixture
~ Lower Bay

Document Information

Author: Whitham D. Reeve

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0.1 (First pass thru procedures, 02 Jan 2023)

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