Foreign object detection tuning guide for wireless power transmitters

Applicable to WLC ICs

About this document

Scope and purpose

The wireless charger (WLC) power transmitter solution reference board is a highly integrated wireless solution with Type-C power delivery (PD).

This application note is a guide to configure the foreign object detection (FOD) parameters required for custom designs based on the WLC power transmitter reference design.

Intended audience

Experts who customize designs based on REF_WLC_TX15W_C1-based wireless power transmitters.

Table of contents

Acronyms/Abbreviations

Table 1 Acronyms/Abbreviations

Acronym/Abbreviation	Definition
USB PD	Universal serial bus power delivery
DUT/EUT	Device under test/Equipment under test
TX	Transmitter
RX	Receiver
BPP	Baseline power profile
EPP	Extended power profile
TPR	Test power receiver
ASK	Amplitude shift keying
FSK	Frequency shift keying
WPT	Wireless power transfer
CE	Control error
CEP	Control error packet
FO	Foreign object
OVP	Overvoltage protection
OCP	Overcurrent protection
UVP	Undervoltage protection
FOD	Foreign object detection
PCB	Printed circuit board
EMI	Electromagnetic interference
NTC	Negative temperature coefficient
UART	Universal asynchronous receiver-transmitter
LED	Light-emitting diode
RPP	Reported power packet
RP	Reported power
NAK	Not acknowledge packet (FSK response)
ACK	Acknowledge packet (ASK response)
RF	Resonance frequency

1 Introduction

This application note serves as a guide to tune the FOD parameters for optimal power transmitter performance. The Wireless Charging Configuration Utility enables the user to configure FOD parameters. Refer to **[8]** and **[9]** for more details on the product reference design, referred to as "reference design" in this document. Please contact the Infineon sales team for any additional support.

1.1 Document structure

- **Section 2** [**Getting started**] describes the FOD mechanism recommended by the Qi Standard and the WLC power transmitter approach for the FOD mechanism. Advanced users may skip this section.
- **Section 3** [**FOD parameter tuning**] describes the data collection, configuration parameter calculation, and updating the WLC power transmitter using the Wireless Charging Configuration Utility. This section gives the following details:
    - **Q factor scaling factor and threshold tuning:** This section defines the process for configuring the scaling factor and thresholds for a Q factor-based FOD approach.
    - **Resonance frequency scaling factor and threshold tuning:** This section defines the process for configuring the scaling factor and thresholds for a RF-based FOD approach.
    - **System power loss curve coefficient tuning:** This section defines the tuning process to estimate and configure the power loss parameters. These parameters shall be programmed to the WLC power transmitter for aiding FOD using power loss measurements.
- **Section 4** [**FOD functionality verification**] refers to the post-tuning process to validate the configurations and confirm the performance of the new settings the user makes.
- **Section 5** [**Checklist for tuning operation**] is a checklist of items to be ensured during the tuning operation.
- The appendices contain normative information for users.

2 Getting started

The WLC power transmitter provides Qi-compliant FOD features. Refer to the FOD chapter in the Qi Standard for further details (see [1] and [4]). The following sections discuss the WLC power transmitter implementation of the FOD functionality.

2.1 FOD mechanism

The Qi Standard defines two mechanisms for FOD:

1. FOD before power transfer or pre-power transfer method
2. FOD during power transfer or in-power transfer method

2.1.1 FOD before power transfer

The pre-power transfer FOD method has the following mechanisms to detect a FO before power transfer between Rx and Tx starts:

1. Q factor FOD (FOD/qf)
2. Resonance frequency FOD (FOD/rf)

The receiver sends FOD/rf and/or FOD/qf packets during the negotiation phase. The Tx responds to these packets with an ACK packet if no FO is found and with a NAK packet if a FO is found. The Rx measures the Q factor and resonance frequency values with a standard MP-A1 coil. The transmitter may measure Q factor and resonance frequency values different from the receiver-reported values, as it may have a different coil. A scaling factor is used to convert the receiver-reported Q factor and resonance frequency values to those equivalent to the transmitter coil.

The scaling factor is a function of the shielding material and friendly materials present in the Rx. This is derived by looking at the relation between the Q factor and resonance frequency devised by the MP-A1 coil and the experimentally measured Q factor and resonance frequency values. The scaling factors for Q factor and resonance frequency measurements can be unique. The FOD/qf packets are sent by all extended power profile (EPP) receivers compliant with Qi 1.2 or above. The FOD/rf packets are sent by all EPP receivers compliant with Qi 1.3 or above.

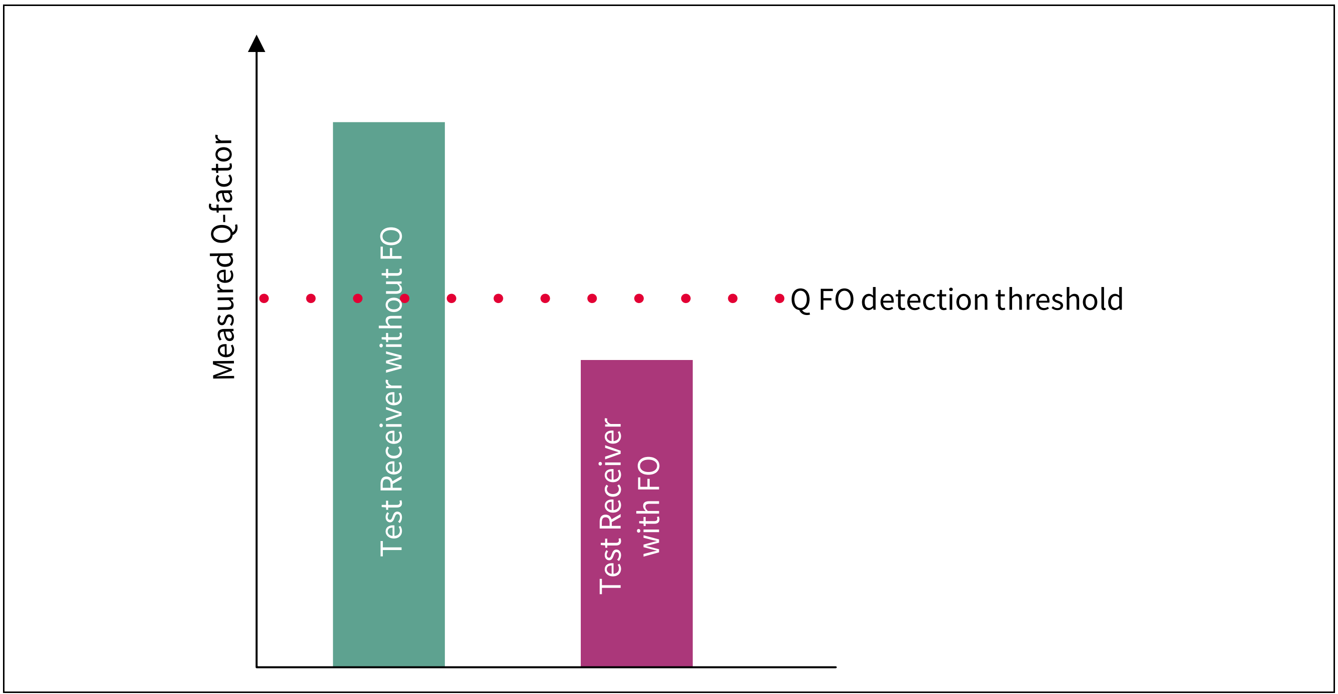


Figure 1 **FOD mechanism based on Q factor**

Q factor: This involves measurement of the Q factor when an EPP TPR is placed on the interface surface of the transmitter. All the EPP TPRs report the reference Q factor measured with a MP-A1 transmitter coil. The transmitter controller needs to apply a scaling factor to derive the reference Q factor value with its transmitter coil (i.e., the coil considered for transmitter design). The measured Q factor by the WLC power transmitter needs to be compared with the Q FO detection threshold, which is calculated from the scaled reference Q factor. The comparison of the measured Q factor with Q FOD threshold determines the FO presence on the interface surface before power transfer starts. The FO is detected if the difference between measured and receiver-reported reference Q factor (FOD/qf packet) is less than the threshold. The measured Q factor includes a scaling factor [7].

If Q_{rep} is the receiver-reported Q factor and Q_{scl} is the scaled Q factor, then,

$$Q_{rep} = S_{factor} * Q_{scl} \qquad \text{Equation 1}$$

Where S_{factor} is the scaling factor for the custom transmitter. FO detection occurs when:

$$Q_{meas} < Q_{threshold} \qquad \text{Equation 2}$$

Where $Q_{threshold}$ is the threshold Q factor and Q_{meas} is measured Q factor. The measurement of $Q_{threshold}$ and its relation with Q_{scl} is explained in [11].

Resonance frequency: This involves measurement of the resonance frequency (RF) when an EPP TPR is placed on the interface surface of the Tx. The reported RF is scaled to the Tx coil type by using a scaling factor. The measured RF is compared with the scaled RF and if the shift (difference) in RF is greater than the threshold, FO presence is confirmed.

The resonance frequency (in Hz) is derived from the supporting data as follows:

$$F_{res} = (2 * \text{FOD/rf supporting data}) + 72 \qquad \text{Equation 3}$$

$$F_{scaled} = \text{ScalingFactor} * F_{res} \qquad \text{Equation 4}$$

$$F_{threshold} = F_{scaled} * \text{Threshold\_percent} \qquad \text{Equation 5}$$

Where F_{res} is the reported RF, F_{scaled} is the scaled RF, $F_{threshold}$ is the threshold RF. Threshold_percent and ScalingFactor are configurable from the Wireless Charging Configuration Utility.

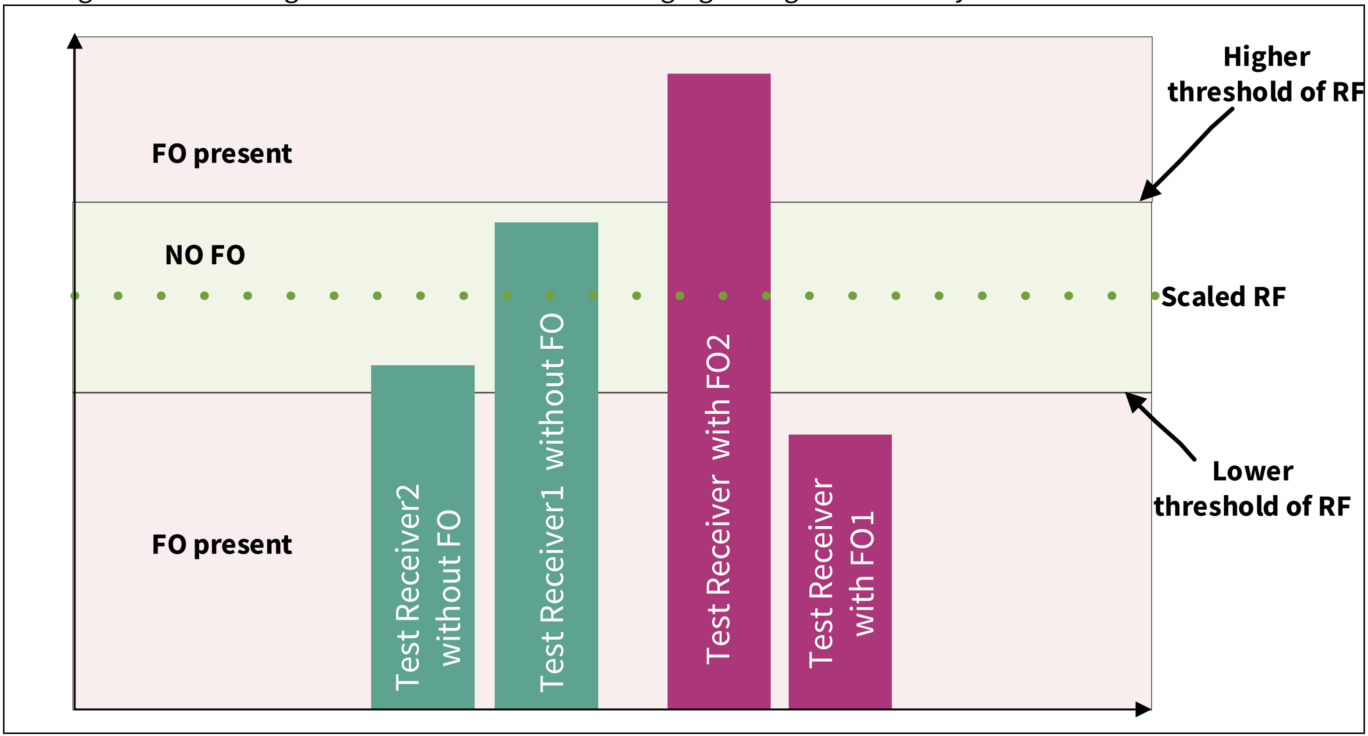


Figure 2 Resonance frequency-based FOD

The FO is detected if the difference between measured and scaled reference resonance frequency is greater than the threshold. “ScalingFactor” and “Threshold_percent” are configurable from the wireless charging configuration utility.

In case of a FOD, the Tx responds to the FOD/rf or FOD/qf packets with a NAK packet leading to immediate power disconnect. The communication is re-established only after the object is removed. Refer to the user manual for LED user interface for FO detection.

2.1.2 FOD during power transfer

The power loss FOD mechanism involves measuring the transmitter power periodically during power transfer and comparing the measured power with the loss curve estimates given by the receiver. To improve the reliability and accuracy of FOD, additional methods are introduced by the WLC power transmitter.

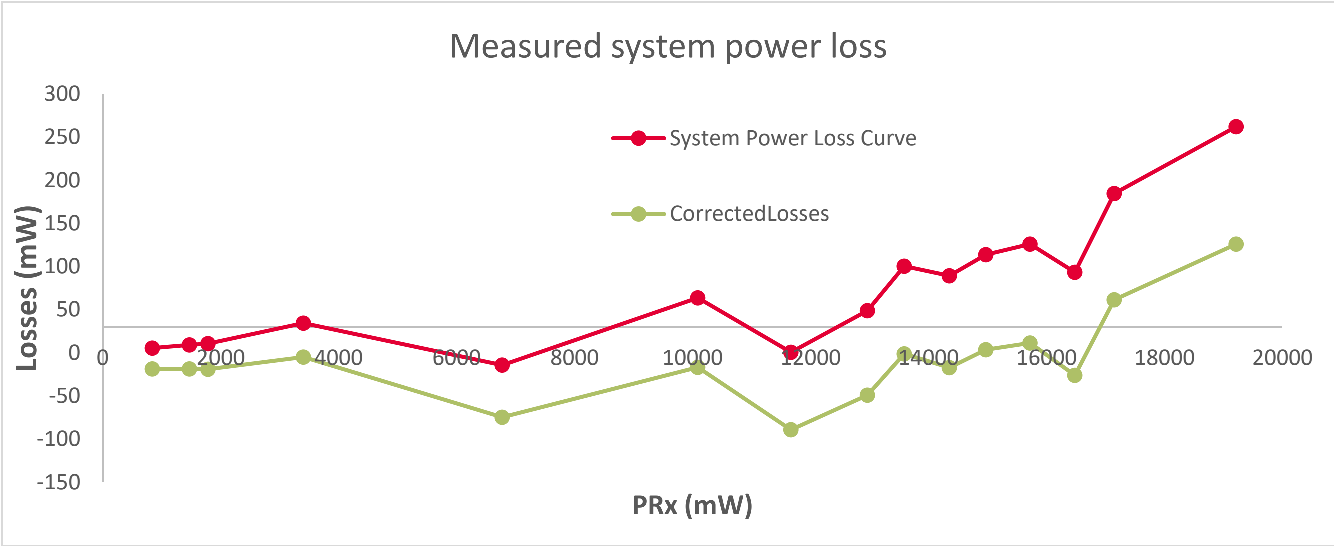


Figure 3 **Typical power loss measurement with power delivery range**

System power loss: The FO is detected if the measured system power loss exceeds the system power loss threshold value. Refer to [2] for more details on the FOD techniques recommended by the Qi Standard.

Accurate FOD requires reference to the power loss calibrated parameter data for a given hardware design and interface surface height (Z-axis). This reference calibration data is required to compensate for the power loss balance deviations induced by the system. The WLC power transmitter system power loss varies with transmitter power delivery range, receiver device coupling factor, temperature, etc. Section 3.5 shows a typical power loss measurement over the power delivery range and the respective loss correction curve. This is a typical behavior of loss correction along with the system power losses.

Power loss calculations are initiated on receipt of a RPP. The calibrated transmitter power is derived from RP value as follows:

$$P_{Tx\_calib} = \mathbf{a} * P_{Rx}^2 + \mathbf{b} * P_{Rx} + \mathbf{c} \qquad \text{Equation 6}$$

Where **a**, **b** and **c** are the system power loss curve coefficients. These coefficients are unique for each power transfer mode as follows:

- EPP 15 watt (EPP15W): Representative test power receiver (TPR) is TPR#MP3. The load power typically ranges from 300 mW to 15 W.
- EPP 5 watt (EPP5W): Representative TPR is TPR#7. The load power typically ranges from 300 mW to 5 W.
- Baseline power profile (BPP): Representative TPR is TPR#5. The load power typically ranges from 300 mW to 5 W.

A **system power loss curve** is used to account for the losses from the transmitter. The power loss equation relates the transmitter power and the reported power as follows:

$$P_{loss} = P_{Tx} - P_{Tx\_calib} \qquad \text{Equation 7}$$

Where P_{Tx_calib} is derived from Equation 6. The criteria for FO presence are:

$$P_{loss} >= P_{Threshold} \qquad \text{Case 1}$$

$$P_{loss} >= P_{Threshold\_max} \qquad \text{Case 2}$$

Where $P_{Threshold}$ and $P_{Threshold\_max}$ are configuration parameters, and:

$$P_{Threshold\_max} > P_{Threshold}$$

Case 1 represents the region ① and Case 2 represents the region ② in **Figure 4**.

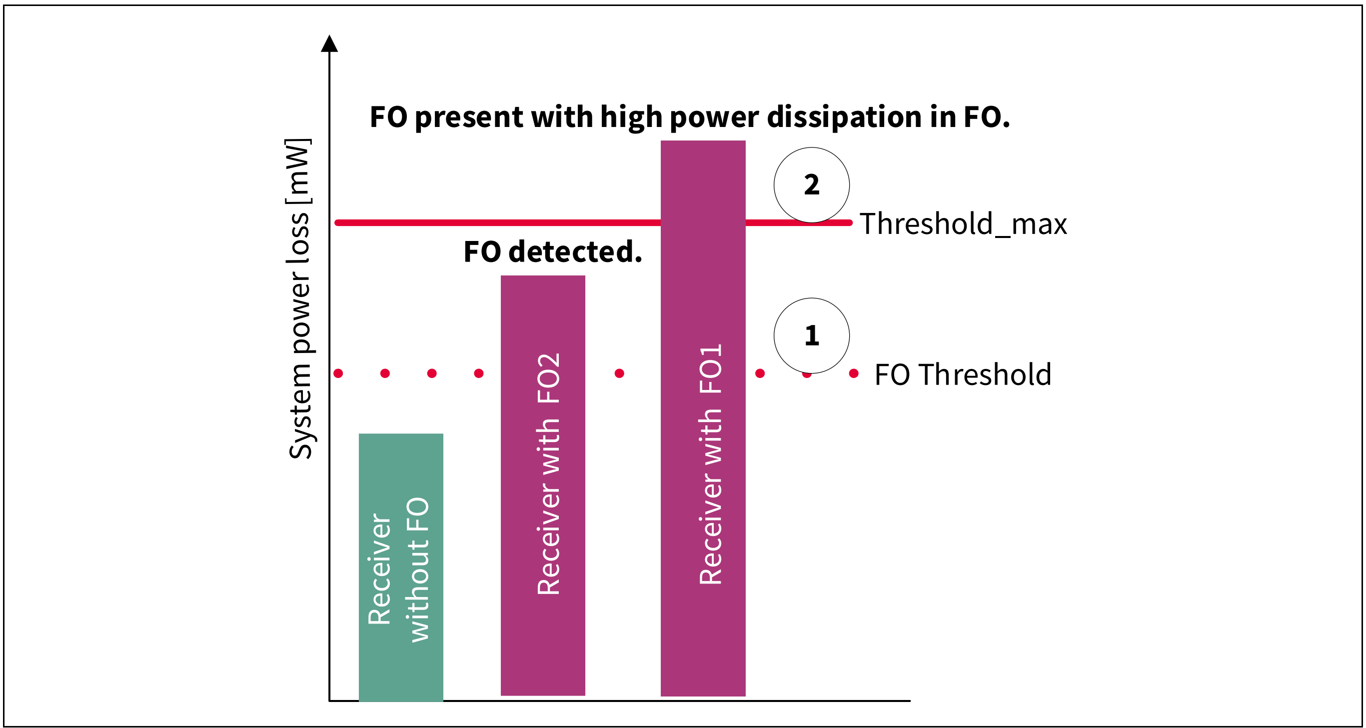


Figure 4 **FOD mechanism based on system power loss**

The thresholds for FOD can be configured. Refer to **Section 3.6** for tuning thresholds for power loss-based FOD.

2.1.3 FOD using pre- and in-power transfer methods

Figure 5 illustrates the free-air Q factor FOD mechanism. The object detection mechanism identifies the placement of an object and initiates the Qi communication stack, which involves pre- and in-power transfer FOD mechanisms. Pre-power transfer data is measured by Tx during the analog pings. Upon object detection, the free-air FOD method finds FOs. If the device is a valid receiver, it proceeds to the identification and configuration phases. The FOD/qf packet is exchanged for an EPP device optimizing the FOD for EPP devices. The WLC's patented Q factor-based FOD mechanism identifies the FOs already present or while entering the interface field before power transfer starts

A power loss-based FOD mechanism identifies FOs, which may enter the interface surface after power transfer. The WLC power transmitter uses a combination of both Q factor and power loss-based mechanisms for optimal and efficient FOD in BPP and EPP devices. Refer to the user manual for UI indication for FOD.

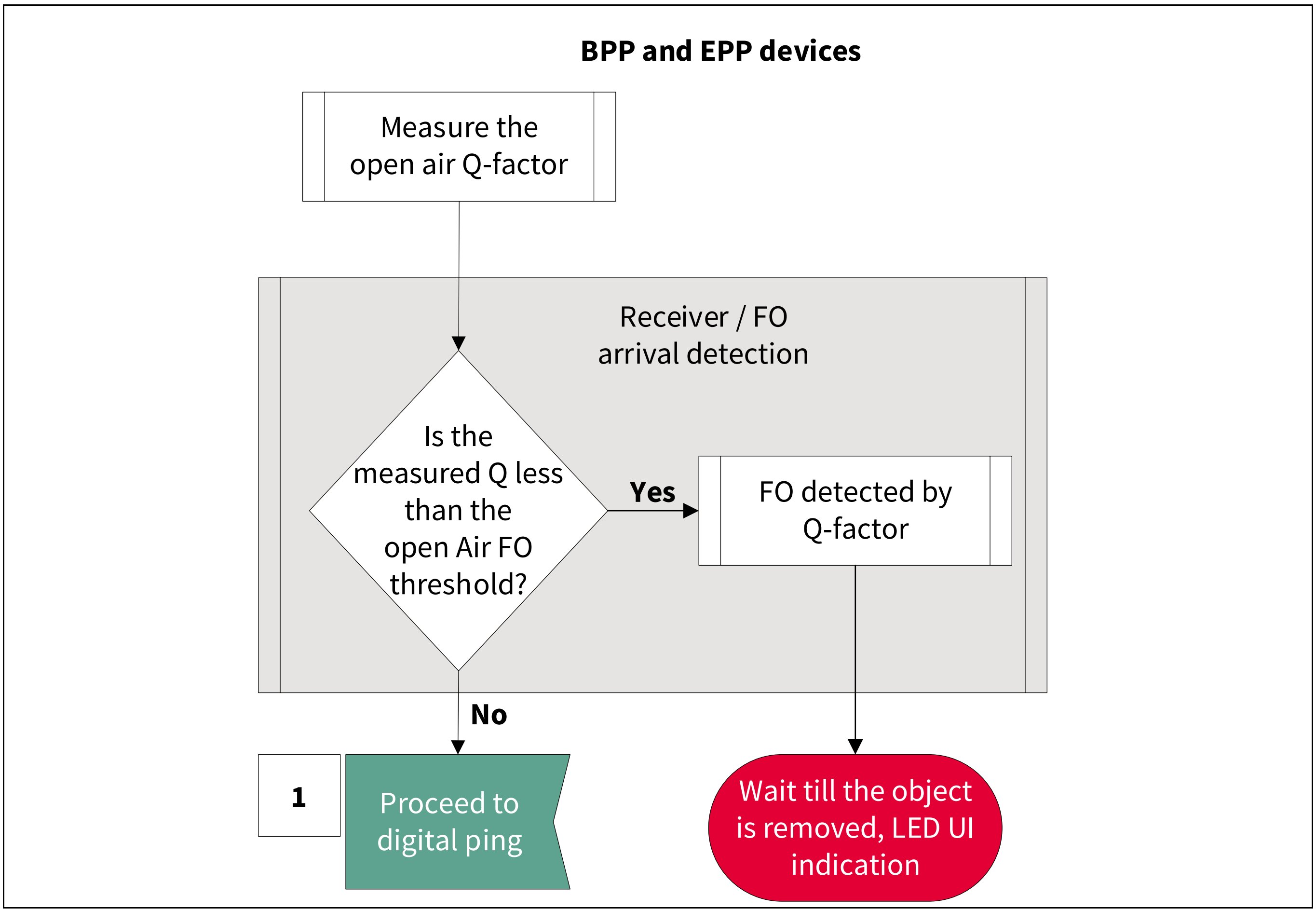


Figure 5 **Procedure for free-air Q factor FOD in BPP and EPP devices**

Figure 6 illustrates the FOD using Q factor mechanism:

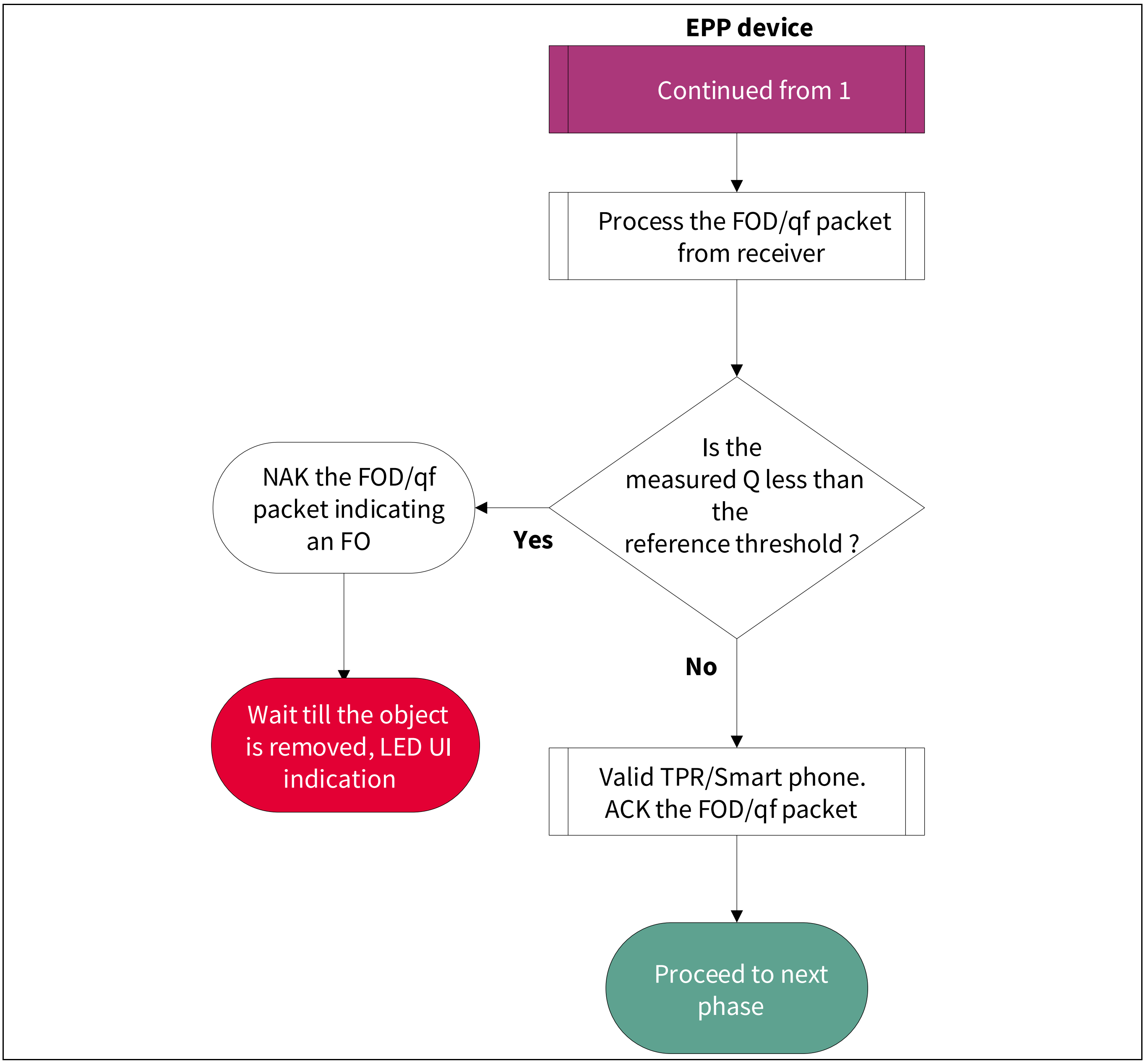


Figure 6 Procedure for Q factor FOD in EPP devices

Figure 7 illustrates FOD using the resonance frequency mechanism:

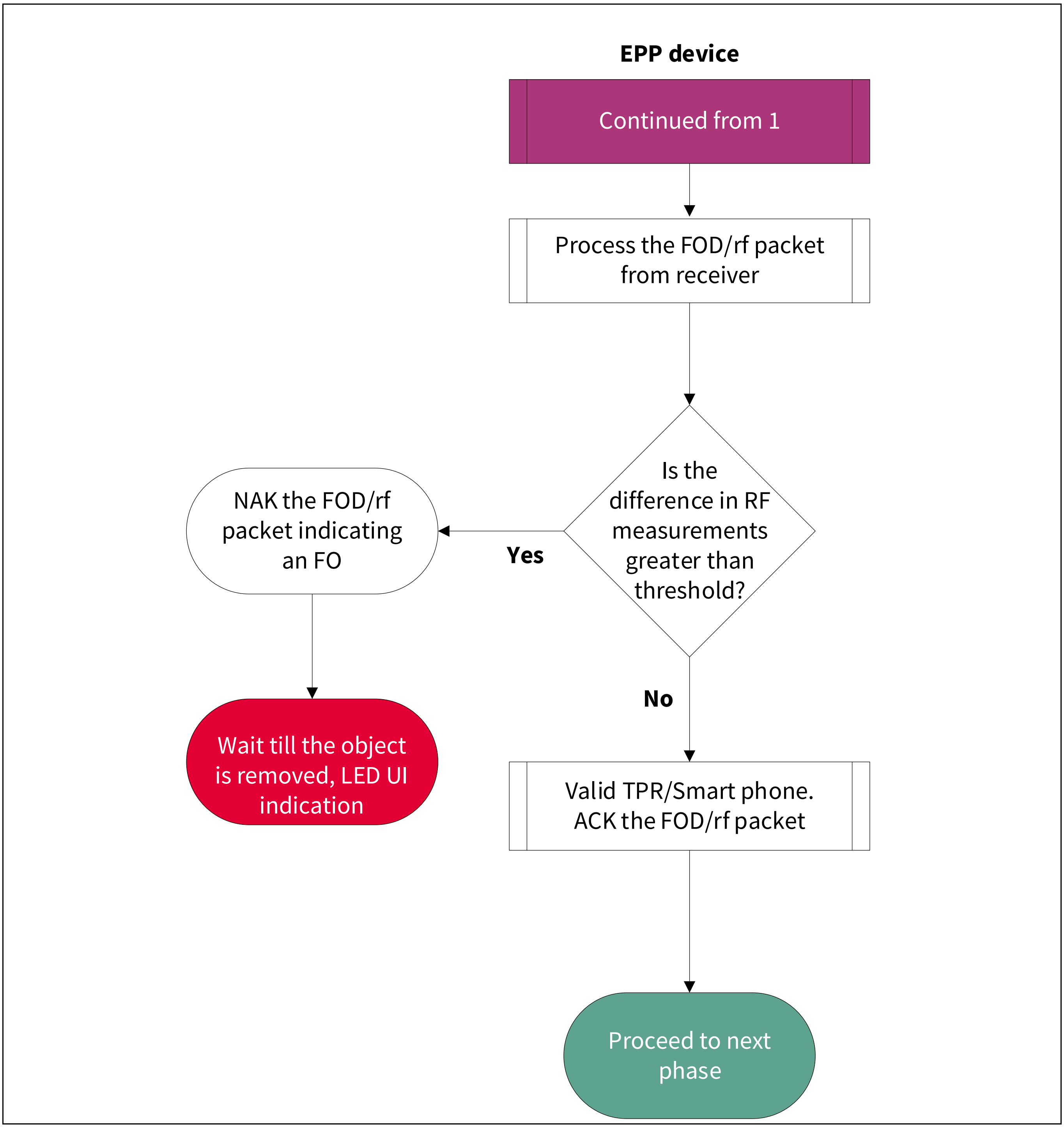


Figure 7 **Procedure for resonance frequency FOD on EPP devices**

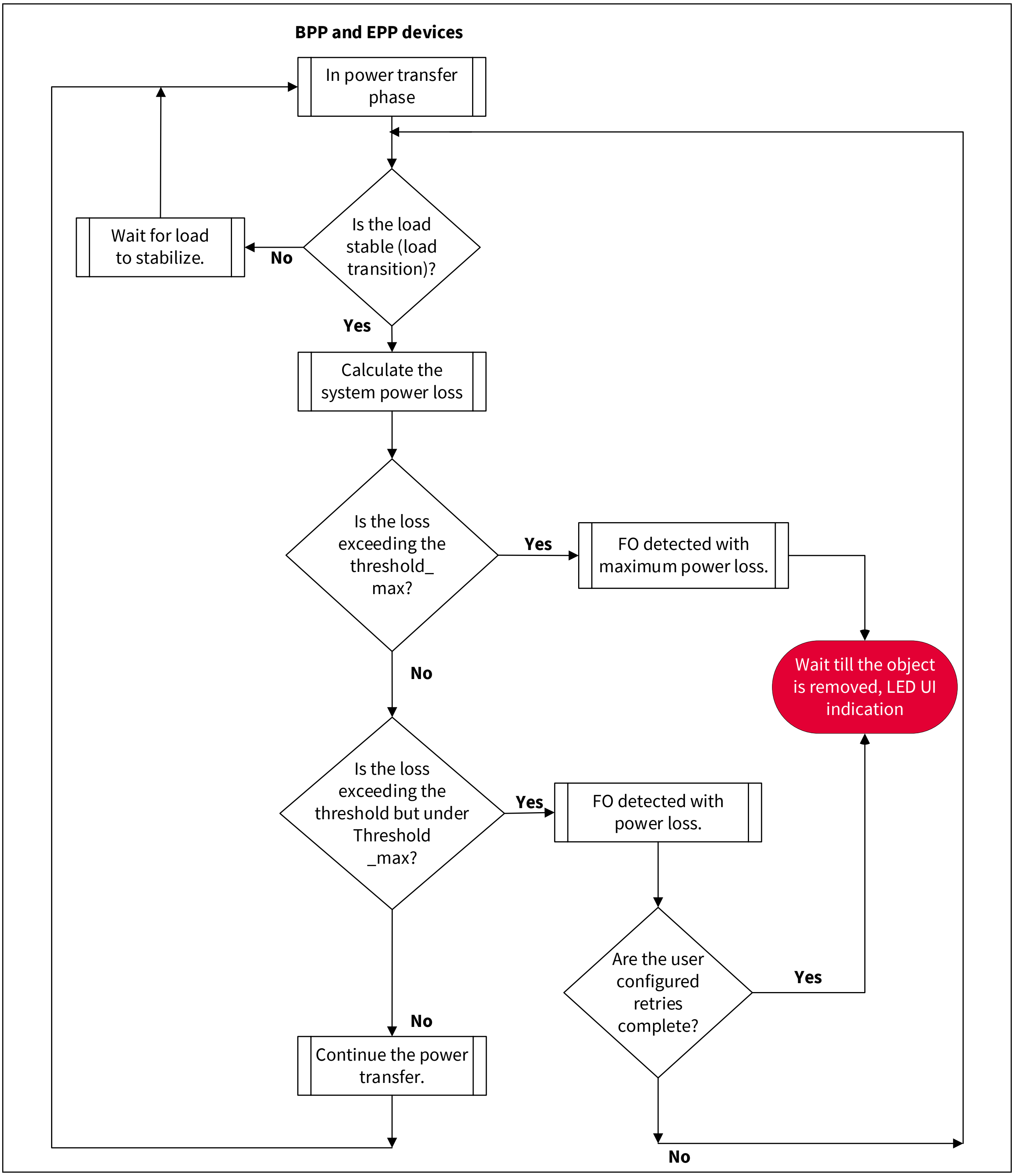


Figure 8 **Procedure for FOD using power loss mechanism on EPP and BPP devices**

As shown in **Figure 8**, the system power loss measurements start only after a stable load condition. This is ensured by checking the control error packet (CEP) value.

3 FOD parameter tuning

FOD parameter tuning is required when the reference design of the WLC power transmitter is changed. The following changes from the WLC power transmitter reference design will result in a need to retune the FOD:

1. Transmitter coil used in the design
2. Change in any shielding or packaging of the transmitter coil
3. Spacing between coil and interface surface (Z-height)

These lead to changes in the Q factor and/or resonance frequency and/or system power loss measurements. Tuning FOD by updating the configuration parameters optimizes the FOD functionality for custom designs.

FOD parameter tuning includes the process of data collection, calculating the appropriate parameters, and updating these parameters in the Wireless Charging Configuration Utility.

Data collection and calculation of parameter values use the *FOD_TuningGuide_Calculator.xlsx* as a supporting document. This tuning calculator provides the following worksheets that require user input:

- SystemPowerLoss_data: Input data for power loss FOD parameter calculations is collected here. The coefficients calculated here are used for configuring the WLC power transmitter.
- QF Scaling Factor Calc: Q factor tuning data is collected in the “User Inputs” section in this page. The calculations section gives the parameter values for Q factor tuning based on user inputs.
- RF Scaling_Threshold Calc: The RF-based data is collected in the “User Inputs” section. The scaling factor and threshold frequency are auto-generated based on the user data.

Wireless Charging Configuration Utility will save the configurations to the WLC power transmitter. These calculations are taken from *FOD_TuningGuide_Calculator.xlsx*.

The tuning process requires a WPC-approved compliance tester tool setup. The following sections discuss the tools required and the steps to prepare the setup. Use *FOD_TuningGuide_Calculator.xlsx* to enter the data from the setup to auto-generate the tuning parameters.

3.1 Tuning objectives

The following are the desired objectives for optimal FOD system performance:

- Scaling factor and threshold tuning for FOD using Q factor
- Scaling factor and threshold tuning for FOD using resonance frequency
- System power loss curve coefficient tuning

As discussed in section **2.1.2**, the system power loss curve coefficients relate the reported receiver power to the calibrated transmitter power and hence improve the reliability of the FOD mechanism. The reported Q factor and resonance frequency is measured using a MP-A1 transmitter coil. However, the transmitter may have any other coil in its design and so the reference values of Q factor have to be scaled (or converted) to the corresponding coil type. The scaling factor is a conversion constant factor to calculate Q factor values for the transmitter designed without a MP-A1 coil. Refer to **[2]** for more details on the Qi Standard FOD mechanisms.

3.2 Required tools

The following tools are required for the tuning process:

1. Custom design power transmitter board.

Figure 9 WPC-approved reference compliance tester

2. WPC-approved compliance tester. The user may approach the WPC's authorized test labs (ATLs) **[5]** in case of unavailability of the compliance tester tools. The user should refer to the WPC member login page for details of the list of WPC-approved compliance testers. The following accessories are available along with the software tool.
   - Test power receivers (TPRs): For the tuning process the following TPRs are needed:
     i. TPR#MP1A
     ii. TPR#MP1B
     iii. TPR#MP1C
     iv. TPR#MP4
     v. TPR#MP3
     vi. TPR#1A
     vii. TPR#7
     viii. TPR#5
   - FO frame.
   - Glass weight: For making the TPR stable.

3. USB-UART device for capturing UART logs from WLC power transmitter board.

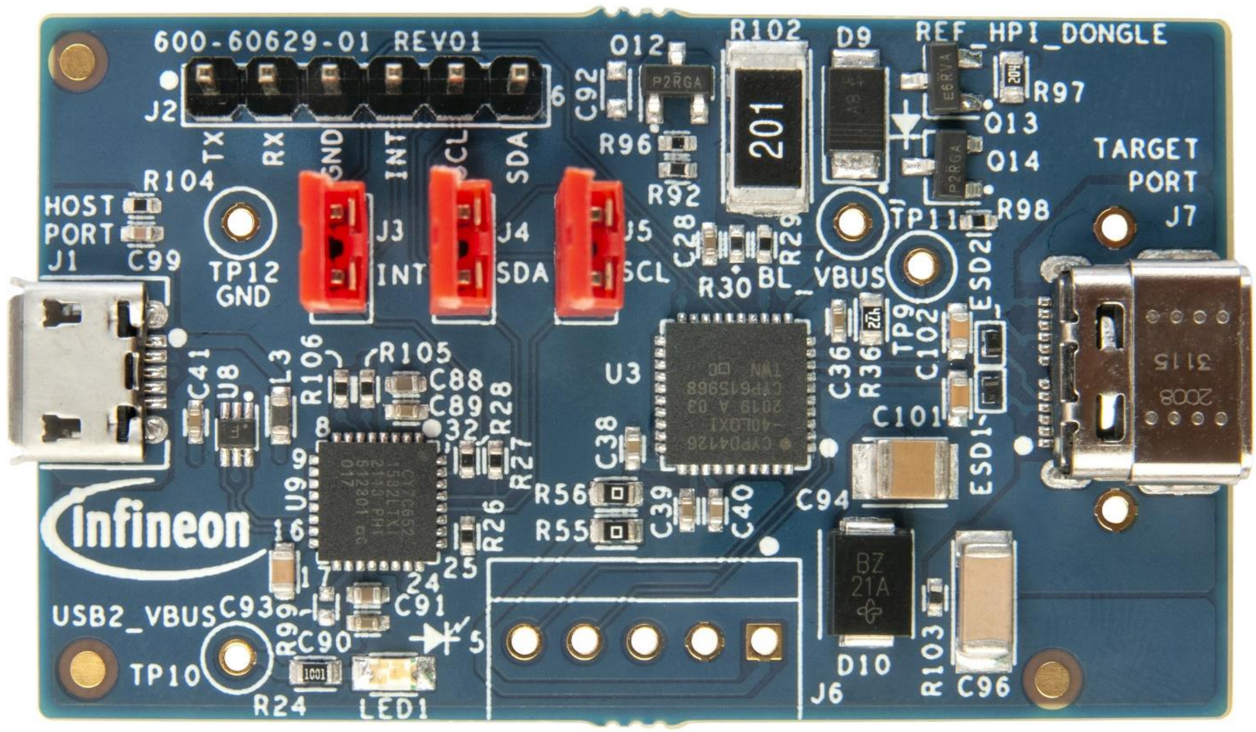


Figure 10 **Infineon USB to UART device**

4. Tera term or Putty or any serial communication-based PC tool for capturing UART logs from the WLC power transmitter board (ensure that the PC tool used for data logging is capable of processing UART data at 1,000,000 baud with minimal losses).

3.3 Hardware setup

1. Enable the UART debugs from the Wireless Charging Configuration Utility. See **Appendix III** for details.
2. Connect the UART Tx line from the power transmitter board to the UART Rx line of the USB-UART device.
3. Connect the ground of the transmitter board to the USB–UART device.

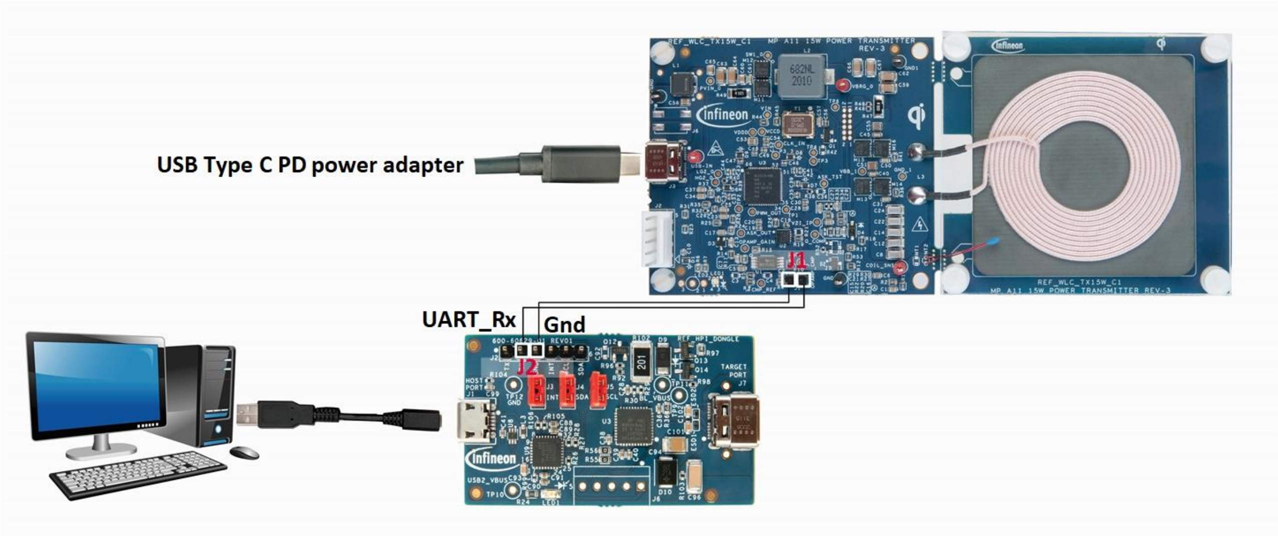
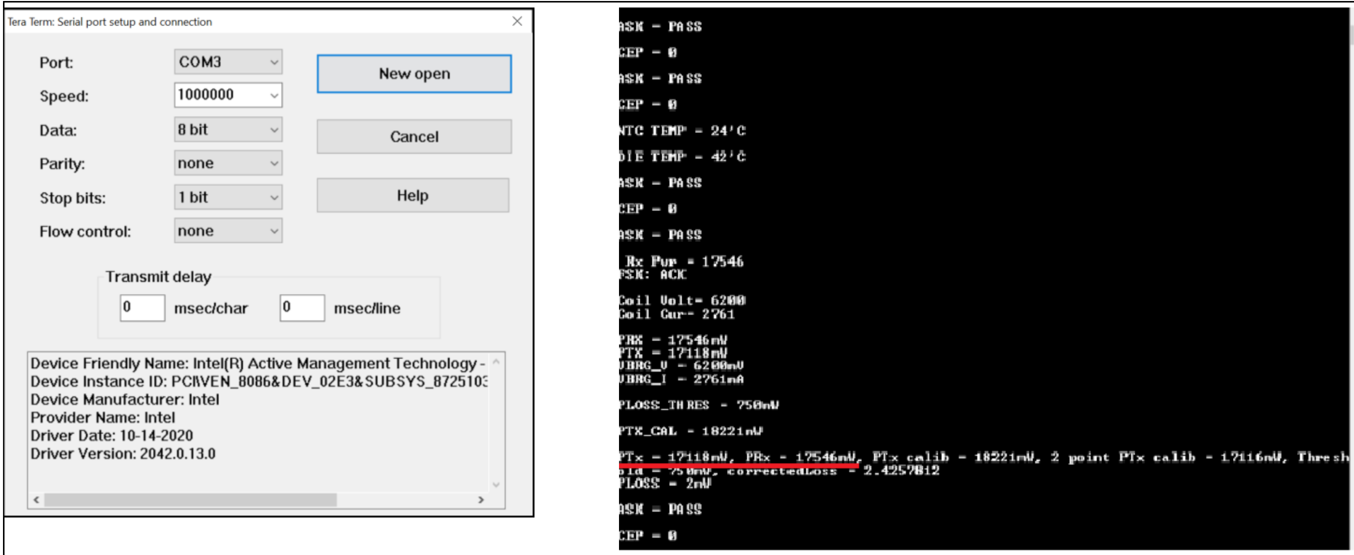


Figure 11 **UART connections with PC**

4. Open the serial communication terminal (such as Minicom/Tera Term/Putty) and set the baud rate to 1000000.
5. Leave the rest of the UART settings as default.
6. Power on the transmitter board to see UART logs (human-readable ASCII characters) on the serial communication tool (UART interface).



Default Tera Term screen

UART log on Tera Term

Figure 12 **Tera Term debug screen and log UI for reference**

3.4 Q factor scaling factor tuning process

Use the "*QF Scaling Factor Calc*" page in *FOD_TuningGuide_Calculator.xlsx* as the supporting document for this section. Update the "User Inputs" section with the measured and reported Q-Factor values. The measured and reported Q-Factor values can be taken from the UART logs of WLC power transmitter. The "Calculations" section in the "*QF Scaling Factor Calc*" page, generates the scaled Q–factor values. Q Factor method is based on TPRs with least friendly metals, for instance, standard Qi compliance TPRs like TPR#MP3, TPR#7 and TPR with high friendly metals like TPR#MP4.

3.4.1 Q factor scaling and threshold tuning process

The Q factor scaling derives the reference Q factor for the WLC power transmitter from the receiver-reported reference Q factor. The WLC power transmitter uses two scaling factors.

- Q-high scale factor: Used for scaling the reference Q factor by the TPRs without friendly metals. The EPP TPRs, without friendly metal, will report the reference Q factor greater than 100.
- Q-low scale factor: Used for scaling the reference Q factor by the TPRs with friendly metals. The EPP TPRs, with friendly metal, will report the reference Q factor less than 100.

The following steps should be followed to tune the Q scaling factor:

1. Capture the receiver-reported reference Q factor for all the EPP TPRs on the "QF Scaling Factor Calc" page of the supporting document under the "Q factor Scaling with TPRs without Friendly Metals" table for the following TPRs:
    a. TRP#MP3
    b. TPR#MP4
    c. TPR#7

    See **Figure 13** for the UART logs for receiver-reported reference Q factor.
2. Capture the measured Q value by the WLC power transmitter with all the EPP TPRs listed below. Ensure no foreign object is present on the interface surface during these measurements. See **Figure 13** for UART logs for the WLC-measured Q factor.

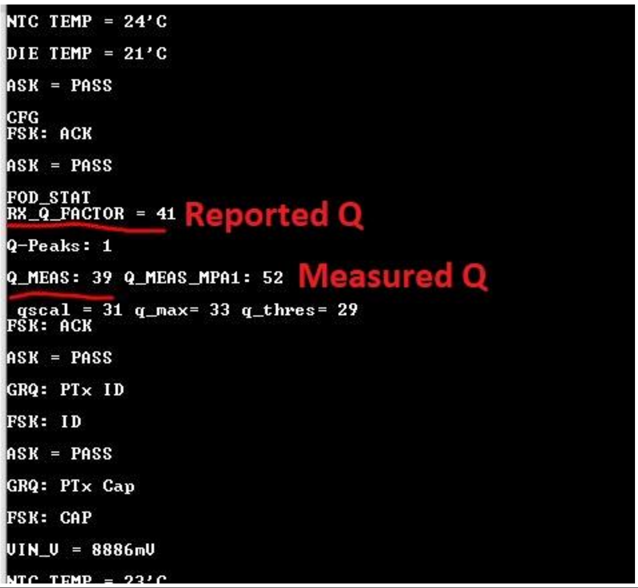


Figure 13 UART logs for receiver-reported and WLC power transmitter measured Q factor

3. Record high scaling factor from "QF Scaling Factor Calc" and update the Wireless Charging Configuration Utility parameters. Refer to section **3.4** for more details.
4. Repeat Steps 1 through 3 with Q factor scaling with TPRs without friendly metals.

5. Enter the measured and reported Q factor values in the respective cells in the “QF Scaling Factor Calc” page. The scaling factor is calculated in this page.

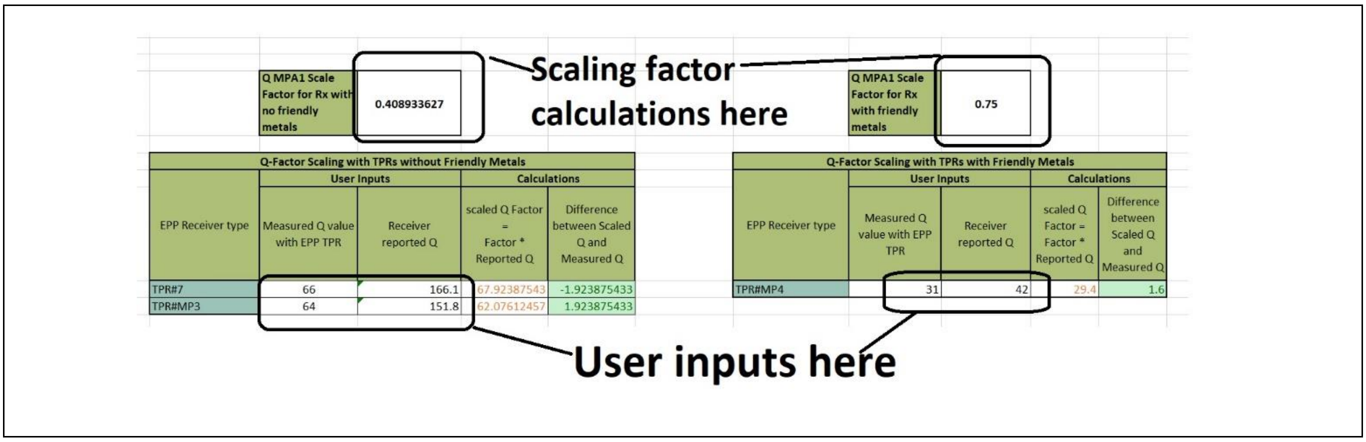


Figure 14 **User input section in “QF Scaling Factor Calc” page**

The next section explains the usage of the parameters generated in the supporting document.

3.4.2 Q factor-based FOD tuning

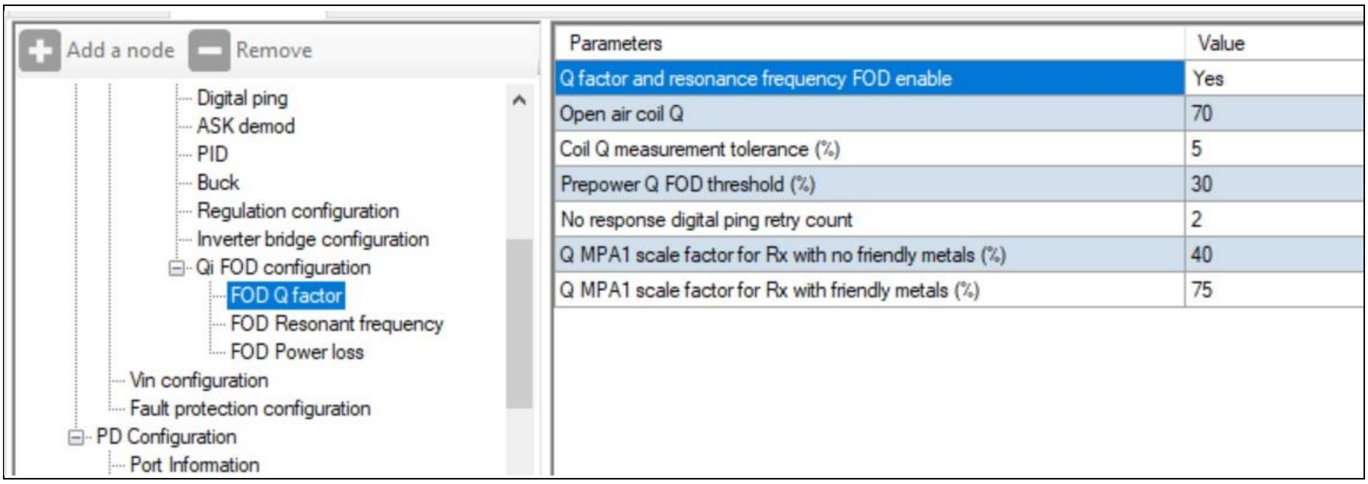


Figure 15 **View of Q factor settings configuration tool**

Table 2 **Q factor configuration setting parameters**

S. no.	Parameter	Description
1	Q factor and resonance frequency FOD enable	Enables Q factor measurement for FOD. Enabled by default.
2	Open air coil Q	Open air Q factor value. Measured by LCR meter without anything on the Tx Default value is 70
3	Coil Q measurement tolerance (%)	Coil Q measurement tolerance percentage of coil open air Q value. Default value is 5

S. no.	Parameter	Description
4	Prepower Q FOD threshold (%)	Q factor threshold for FO detection when there is no communication. Default value is 30.
5	No response digital ping retry count	Object detected with no communication/response to digital ping will retry for initiating communication. Retry count expiry will enter into idle state. Default value is 2.
6	Q MPA1 scale factor for Rx with no friendly metals (%)	Scaling factor for TPRs with higher Q measurements. Default value is 40%.
7	Q MPA1 scale factor for Rx with friendly metals (%)	Scaling factor for TPRs with lower Q measurements. Default value is 75%.

3.5 Resonance frequency scaling factor and threshold tuning process

The resonance frequency method is an improvement of the pre-power transfer of the FOD mechanism using Q factor. The experiments show that the resonance frequency-based FO is more efficient on Rx with friendly metals, like smartphones, tablets and so on. A reference TPR for such devices is TPR#MP4. Hence the scaling factor and threshold tuning process is based on the TPR#MP4.

Refer to section **3.2** for required tools and section **3.3** for setting up the hardware. Further steps for RF tuning are applicable for TPR#MP4.

3.5.1 Resonance frequency scaling and threshold tuning process

The process involves capturing the measured resonance frequency values from the UART logs (as shown in **Figure 16)** or alternatively use the digital signal oscilloscope or LCR Meter **[7]**.This section elaborates on using system measurements available from the UART logs as shown below:

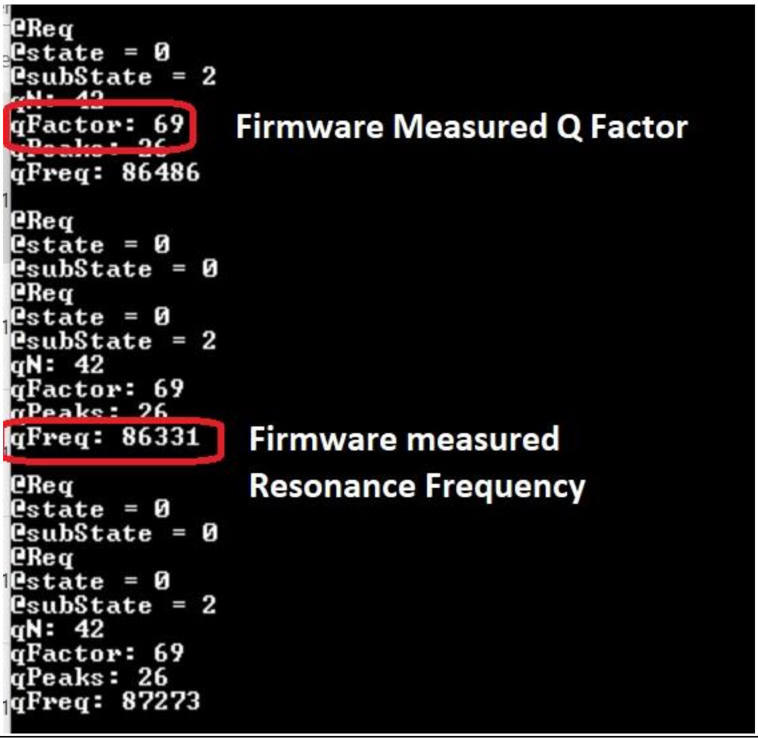


Figure 16 UART logs for receiver reported and WLC power transmitter measured resonance frequency

Follow these steps to tune the resonance frequency scaling factor and threshold values:

1. Place the TPR#MP4 on the interface surface along with FOD frame to ensure maximum signal strength. Note that no FO is placed in the FO frame:

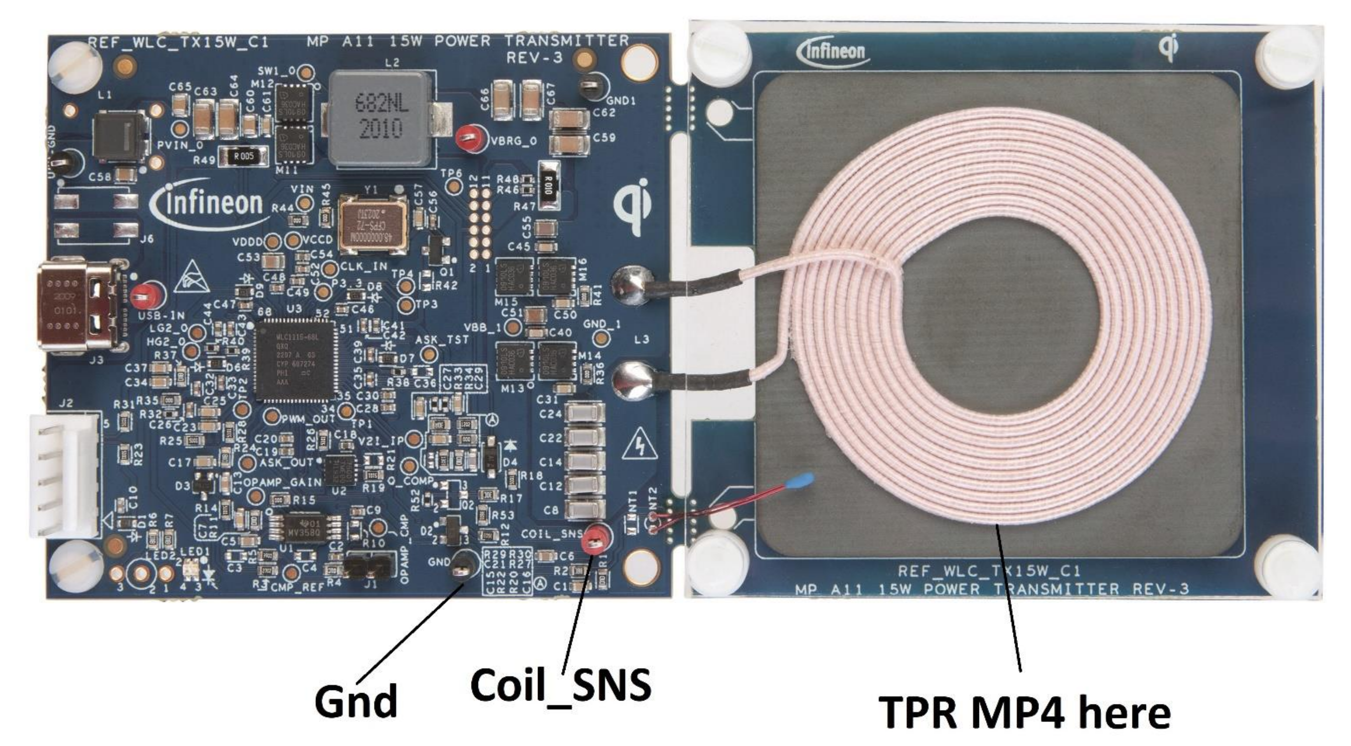


Figure 17 Lab setup for recording measured and reported resonance frequency values

2. Capture the receiver reported reference resonance frequency for all the EPP TPRs in the "RF Scaling_Threshold Calc" page in *FOD_TuningGuide_Calculator.xlsx*. Enter the data in the row named "FOD/rf".
3. Update the "FOD/rf" section with the Rx reported resonant values.
4. Update the row marked "Without FO" with the firmware-measured resonant values.
5. Insert FO1 to the FO frame such that FO is aligned with the center of the coils of Tx and Rx.
6. Enter the measured resonance frequency from the UART logs in the row marked as "FO_1_At_0mm".
7. Move FO1 to 15 mm marked on the FO frame. Enter the measured resonance frequency in the row marked under "FO_1_At_15mm".
8. Repeat steps 4, 5 and 6 for FO2, FO3 and FO4. Record the data in the respective FO rows (see **Figure 18**).

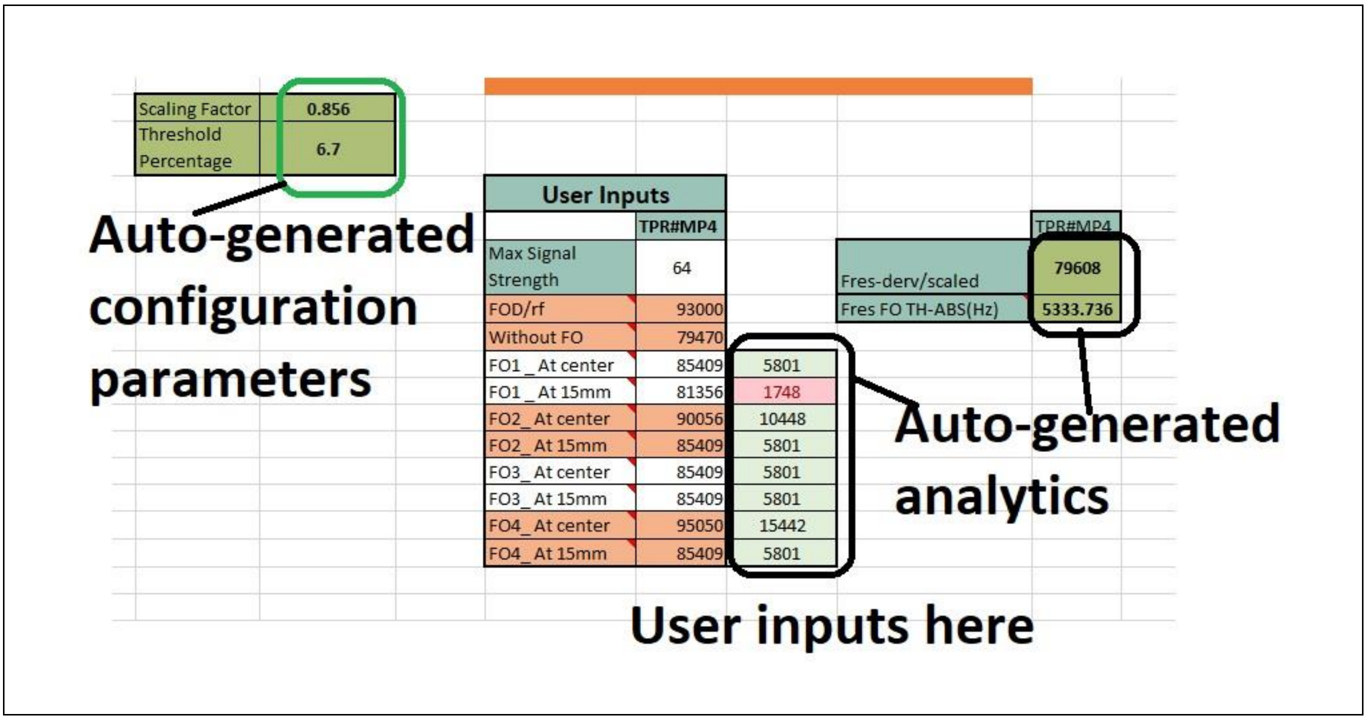


Figure 18 **Reference view for resonance frequency measurements data**

9. The analytics in this figure can be used for reference while tuning the scaling factor and threshold tuning parameters.

3.5.2 Resonance frequency-based FOD tuning

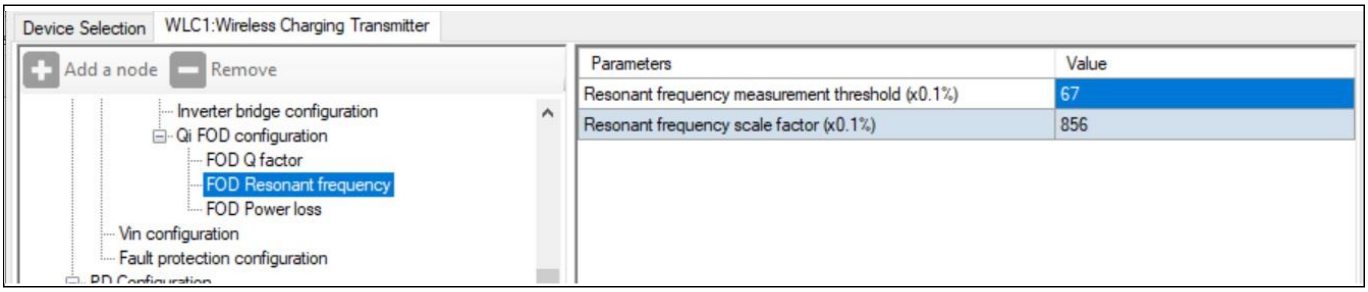


Figure 19 View of Q factor settings configuration tool

Table 3 Resonance frquency Q factor configuration setting parameters

S. no.	Parameter	Description
1	Resonance frequency measurement threshold (x0.1%)	Resonance frequency measurement threshold in percentage. x0.1% scale. Default value is 67.
2	Resonance frequency scale factor (x0.1%)	Resonance frequency measurement threshold in percentage. x0.1% scale. Default value is 856.

3.6 System power loss curve coefficient tuning

A Qi-compliant power transmitter has three modes of operation:

- EPP15: Illustrated with TPR#MP3
- EPP5W: Illustrated with TPR#7
- BPP: Illustrated with TPR#5

This section covers tuning FOD functionality parameters for all three modes of operation.

System power loss curve coefficient tuning requires a tuning setup based on the user. Refer to the WPC member login page for details of the list of WPC-approved compliance testers. Refer to section **3.2** for the required tools and section **3.3** for details on setting up the hardware. Refer to the WPC member login page for details of the list of WPC-approved compliance tester-based experimental setups required for this tuning process.

3.6.1 Data collection and system loss curve coefficient calculation

1. Enter the Advanced mode on the compliance tester tool user interface.
2. Connect TPR#MP3 to the compliance tester. Refer to the WPC member login page for details of the list of compliance tester tools and place it on the interface surface of the transmitter.
3. Select **Current load** in the **Power load** tab. (Default is Resistive load).
4. Ensure the best alignment between the transmitter and receiver coils. Refer to **Appendix I**.

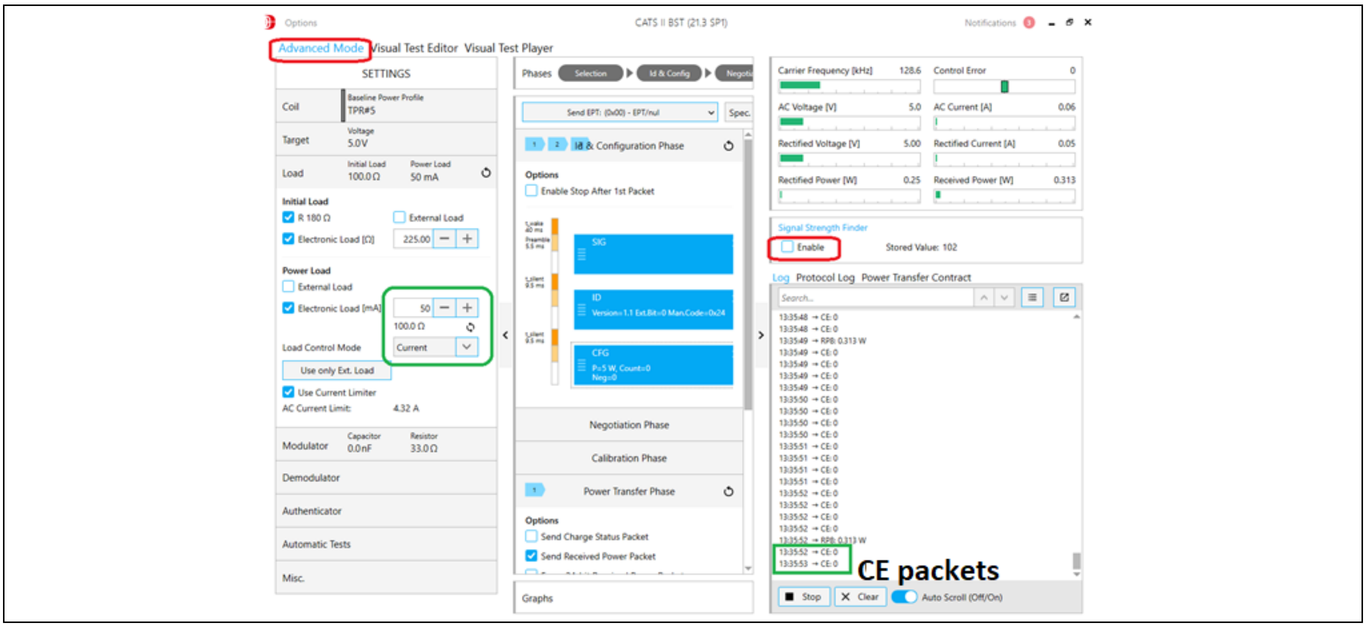


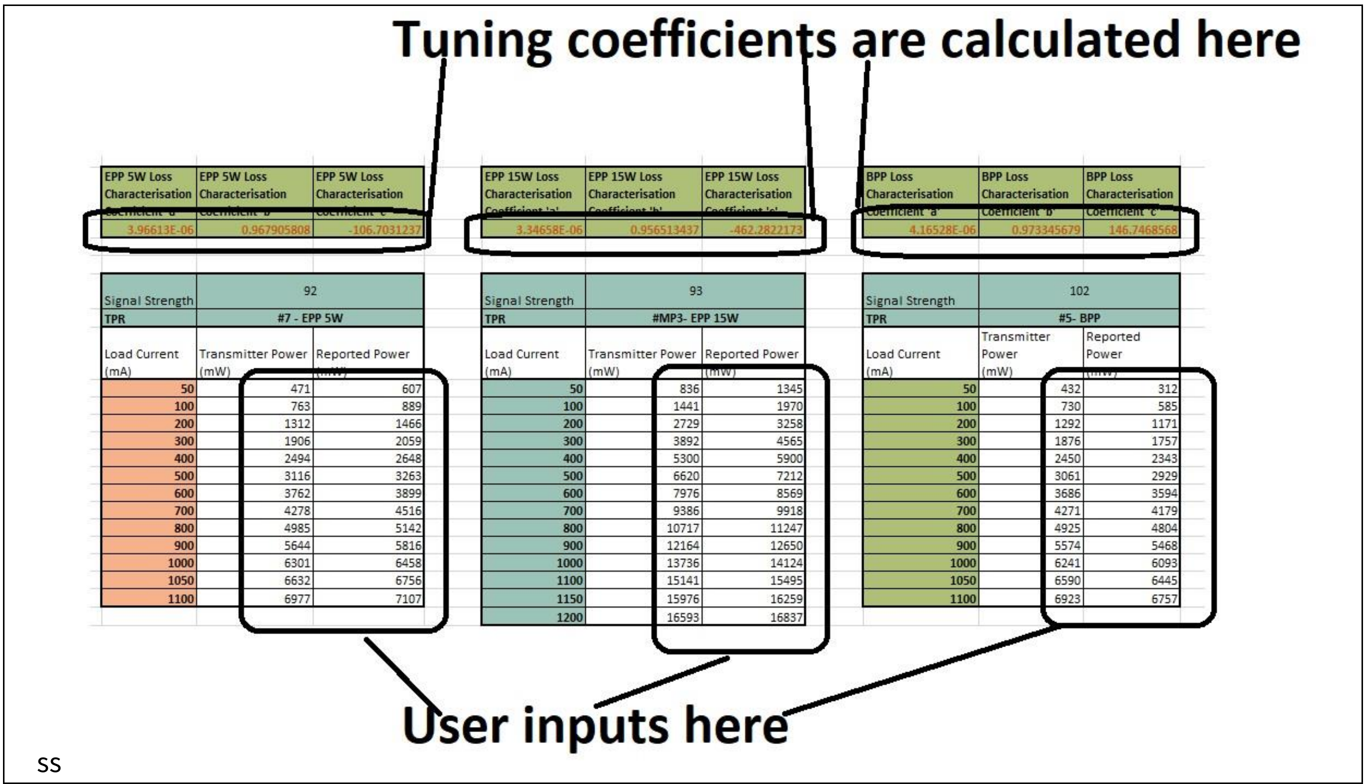
Figure 20 **UI for signal strength, CE packets, Advanced mode, Electronic load selection on reference compliance tester**

5. Set the load to the minimum load value. Refer to the "SystemPowerLoss_data" page in *FOD_TuningGuide_Calculator.xlsx* for load values.
6. Wait for two consecutive CE packets with 0 value (see **Figure 16**). Record the PTx (transmitter power) and PRx (reported receiver power) values from the UART debug log to the supporting document.
7. Increase the load to the next step. Refer to the "SystemPowerLoss_data" page in *FOD_TuningGuide_Calculator.xlsx* for the next load value.
8. Repeat steps 6, 7 and 8 until PRx and PTx values are captured for the maximum load value. The system power loss curve data for TPR#MP3 is ready.

```
PLOSS_THRES = 750mW

PTX_CAL = 4783mW

PTx = 4324mW, PRx = 4481mW, PTx calib = 4783mW, 2 point PTx calib = 3873mW, Threshold = 750mW, correctedLoss = -459.
PLOSS = -459mW

ASK = PASS

CEP = 0
```

Figure 21 **PTx and PRx values from UART logs**

9. Repeat steps 2 through 9 with TPR#7 and TPR#5 to get system power loss curve data for TPR#7 and TPR#5.
10. The "SystemPowerLoss_data" page in *FOD_TuningGuide_Calculator.xlsx* automatically calculates the system power loss curve coefficients for EPP15W, EPP5W and BPP devices upon entry of data in the respective cells.



EPP 5W Loss Characterisation Coefficient 'a'	EPP 5W Loss Characterisation Coefficient 'b'	EPP 5W Loss Characterisation Coefficient 'c'
3.96613E-06	0.967905808	-106.7031237

EPP 15W Loss Characterisation Coefficient 'a'	EPP 15W Loss Characterisation Coefficient 'b'	EPP 15W Loss Characterisation Coefficient 'c'
3.34658E-06	0.956513437	-462.2822173

BPP Loss Characterisation Coefficient 'a'	BPP Loss Characterisation Coefficient 'b'	BPP Loss Characterisation Coefficient 'c'
4.16528E-06	0.973345679	146.7468568

Signal Strength	92	
TPR	#7 - EPP 5W	
Load Current (mA)	Transmitter Power (mW)	Reported Power (mW)
50	471	607
100	763	889
200	1312	1466
300	1906	2059
400	2494	2648
500	3116	3263
600	3762	3899
700	4278	4516
800	4985	5142
900	5644	5816
1000	6301	6458
1050	6632	6756
1100	6977	7107

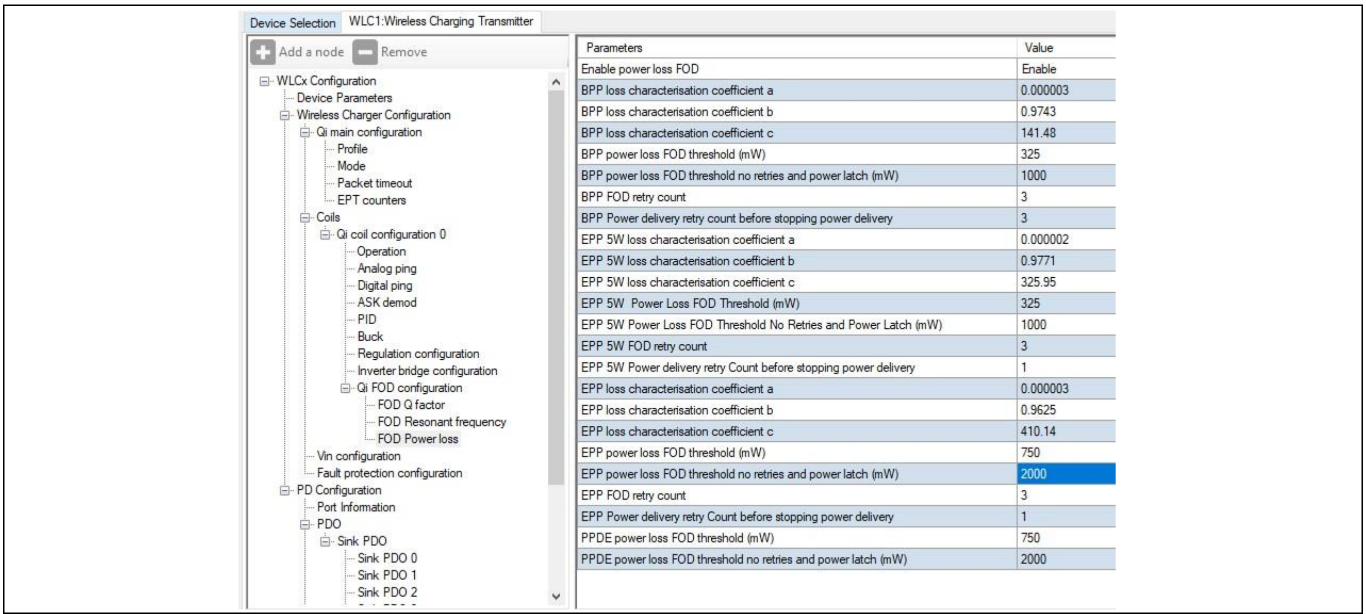
Signal Strength	93	
TPR	#MP3- EPP 15W	
Load Current (mA)	Transmitter Power (mW)	Reported Power (mW)
50	836	1345
100	1441	1970
200	2729	3258
300	3892	4565
400	5300	5900
500	6620	7212
600	7976	8569
700	9386	9918
800	10717	11247
900	12164	12650
1000	13736	14124
1100	15141	15495
1150	15976	16259
1200	16593	16837

Signal Strength	102	
TPR	#5- BPP	
Load Current (mA)	Transmitter Power (mW)	Reported Power (mW)
50	432	312
100	730	585
200	1292	1171
300	1876	1757
400	2450	2343
500	3061	2929
600	3686	3594
700	4271	4179
800	4925	4804
900	5574	5468
1000	6241	6093
1050	6590	6445
1100	6923	6757

Figure 22 User input section in "SystemPowerLoss_data" page

11. This data is used in the next section for configuring the WLC power transmitter.

3.6.2 Power loss-based FOD tuning



Parameters	Value
Enable power loss FOD	Enable
BPP loss characterisation coefficient a	0.000003
BPP loss characterisation coefficient b	0.9743
BPP loss characterisation coefficient c	141.48
BPP power loss FOD threshold (mW)	325
BPP power loss FOD threshold no retries and power latch (mW)	1000
BPP FOD retry count	3
BPP Power delivery retry count before stopping power delivery	3
EPP 5W loss characterisation coefficient a	0.000002
EPP 5W loss characterisation coefficient b	0.9771
EPP 5W loss characterisation coefficient c	325.95
EPP 5W Power Loss FOD Threshold (mW)	325
EPP 5W Power Loss FOD Threshold No Retries and Power Latch (mW)	1000
EPP 5W FOD retry count	3
EPP 5W Power delivery retry Count before stopping power delivery	1
EPP loss characterisation coefficient a	0.000003
EPP loss characterisation coefficient b	0.9625
EPP loss characterisation coefficient c	410.14
EPP power loss FOD threshold (mW)	750
EPP power loss FOD threshold no retries and power latch (mW)	2000
EPP FOD retry count	3
EPP Power delivery retry Count before stopping power delivery	1
PPDE power loss FOD threshold (mW)	750
PPDE power loss FOD threshold no retries and power latch (mW)	2000

Figure 23 Power loss settings in the configuration tool

FOD parameter tuning

The following table describes the parameters used for tuning the FOD using the power loss method.

Table 4 Power loss configuration setting parameters

S. no.	Parameter	Description
1	Enable power loss FOD	Enable the FOD functionality in firmware using the power loss method. Enabled by default.
2	BPP Loss characterisation co-efficient '**a**'	Coefficient "a" in Equation 6 for BPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 0.000003.
3	BPP Loss characterisation co-efficient '**b**'	Coefficient b in Equation 6 for BPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 0.9743.
4	BPP Loss characterisation co-efficient '**c**'	Coefficient c in Equation 6 for BPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 141.48.
5	BPP power loss FOD threshold(mW)	Power loss threshold (in mW) for BPP mode of operation. See Case 1. Default value is 325mW.
6	BPP power loss FOD threshold no retries and power latch (mW)	Maximum power loss threshold for BPP mode of operation. See Case 2. Default value is 1000mW.
7	BPP FOD retry count	Count for power recycle after FOD for BPP device. Default value is 3 counts.
8	BPP Power delivery retry count before stopping power delivery	Count for power cycle after FOD for BPP device. Default value is 3 counts.
9	EPP 5W loss characterisation coefficient '**a**'	Coefficient a in Equation 6 for 5W EPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 0.000002.

S. no.	Parameter	Description
10	EPP 5W loss characterisation coefficient ‘**b**’	Coefficient b in Equation 6 for 5W EPP mode of power transfer. This value is auto-generated under the cell with the same name in *SystemPowerLoss_data* page. Default value is 0.9771.
11	EPP 5W loss characterisation coefficient ‘**c**’	Coefficient c in Equation 6 for 5W EPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 325.95.
12	EPP 5W power loss FOD threshold (mW)	Power loss threshold for 5W EPP mode of operation. See Case 1. Default value is 325mW.
13	EPP 5W power loss FOD threshold no retries and power latch (mW)	Maximum power loss threshold for 5W EPP mode of operation. See Case 2. Default value is 1000mW.
14	EPP 5W FOD retry count	Count for power recycle after FOD for EPP 5W device. Default value is 3.
15	EPP5W Power delivery retry count before stopping power delivery	Count for power cycle after FOD for EPP 5W device. Default value is 3.
16	EPP loss characterisation coefficient ‘**a**’	Coefficient a in Equation 6 for 15W EPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 0.000003.
17	EPP loss characterisation coefficient ‘**b**’	Coefficient b in Equation 6 for 15W EPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 0.9625.
18	EPP loss characterisation coefficient ‘**c**’	Coefficient c in Equation 6 for 15W EPP mode of power transfer. This value is auto-generated under the cell with same name in *SystemPowerLoss_data* page. Default value is 410.14.
19	EPP power loss FOD threshold (mW)	Power loss threshold for 15W EPP mode of operation. See Case 1. The default value is 750mW.

S. no.	Parameter	Description
20	EPP power loss FOD threshold no retries and power latch (mW)	Maximum power loss threshold for 15W EPP mode of operation. See Case 2. Default value is 2000mW.
21	EPP FOD retry count	Count for Power Recycle after FOD for EPP 15W device. Default value is 1 count.
22	EPP Power delivery retry count before stopping power delivery	Count for power cycle after FOD for EPP 15W device. Default value is 1.
23	PPDE power loss FOD threshold (mW)	Threshold for a likely FO presence for PPDE Default value is 750mW.
24	PPDE power loss FOD threshold no retries and power latch (mW)	Threshold for a certain FO presence for PPDE Default value is 2000mW.

4 FOD functionality verification

The following tests from the Qi compliance test suite can ensure an appropriate tuning of the FOD parameters for BPP devices:

1. Test#25 (a)
2. Test#25 (b)
3. Test#25 (c)
4. Test#25 (d)

The following tests from the Qi compliance test suite can ensure an appropriate tuning of the FOD parameters for EPP devices:

1. MP.TX.FOD.OPERATE.FOD.REACT.TC1
2. MP.TX.FOD.OPERATE.FOD.REACT.TC1a
3. MP.TX.FOD.OPERATE.FO.CRIT.TC1
4. MP.TX.FOD.OPERATE.FO.CRIT.TC1a
5. MP.TX.FOD.BEFOREPOWER.FO.CRITIC.TC1
6. MP.TX.FOD.BEFOREPOWER.FO.CRITIC.TC1a

Tests 1 and 2 validate the Threshold_max setting in EPP devices. The critical section tests (3 through 6) validate the Q factor and threshold settings. Refer to [8] for details of the tools required for the Qi-recommended validation test setup, test procedure and pass criteria.

Free-air FO can be tested by placing a US nickel or an Indian 2 ₹ coin on the interface at the center of the coil. This should be indicated by the FO UI (user manual for FO indication).

5 Checklist for tuning operation

1. Use caution while moving the TPR toward the interface surface of the transmitter. Ensure that the movement is subtle and does not lead to any mechanical or electrical damage to the transmitter or receiver.
2. Ensure proper EMI discharge for the test equipment.
3. Ensure the power levels of the TPR are within the range of the expected current loads during load ramp tests.
4. Ensure best possible signal strength alignment between TPR and transmitter. Refer to **Appendix I** for finding the best signal strength.
5. Ensure proper offset values are considered while tuning the power loss FOD parameters. Refer to **Appendix II** for more details.
6. Ensure that no FO is present on the interface surface, or in the vicinity (field of influence) of the transmitter coil.
7. Ensure the FOD functionality is appropriately enabled before verifying the design using section **4**.
8. Ensure the FO temperature is monitored and appropriate actions are taken to avoid damage to Rx and Tx.
9. Ensure that the Debug prints are set to default after the tuning operation is complete.
10. Section **4** validates FOD functionality. To ensure complete Qi compliance, it is recommended to execute the compliance test in **WPC-recommended ATLs**.

Appendix I – Finding signal strength

Note: This process is unique for every compliance tester.

1. Enable the Signal Strength Finder in the compliance tester tool. See **Figure 24**.
2. Ensure the TPR is placed at maximum signal strength (best alignment with transmitter coil).
3. Disable the Signal Strength Finder once the alignment procedure is complete.

Appendix II – Received power offset

Note: This section is compliance tester-specific and may be subject to change. Please contact sales support for more details.

Received power offset is a modifiable parameter in the Power Transfer Phase setting in Advanced mode of the Qi compliance tester (see **Figure 24**).

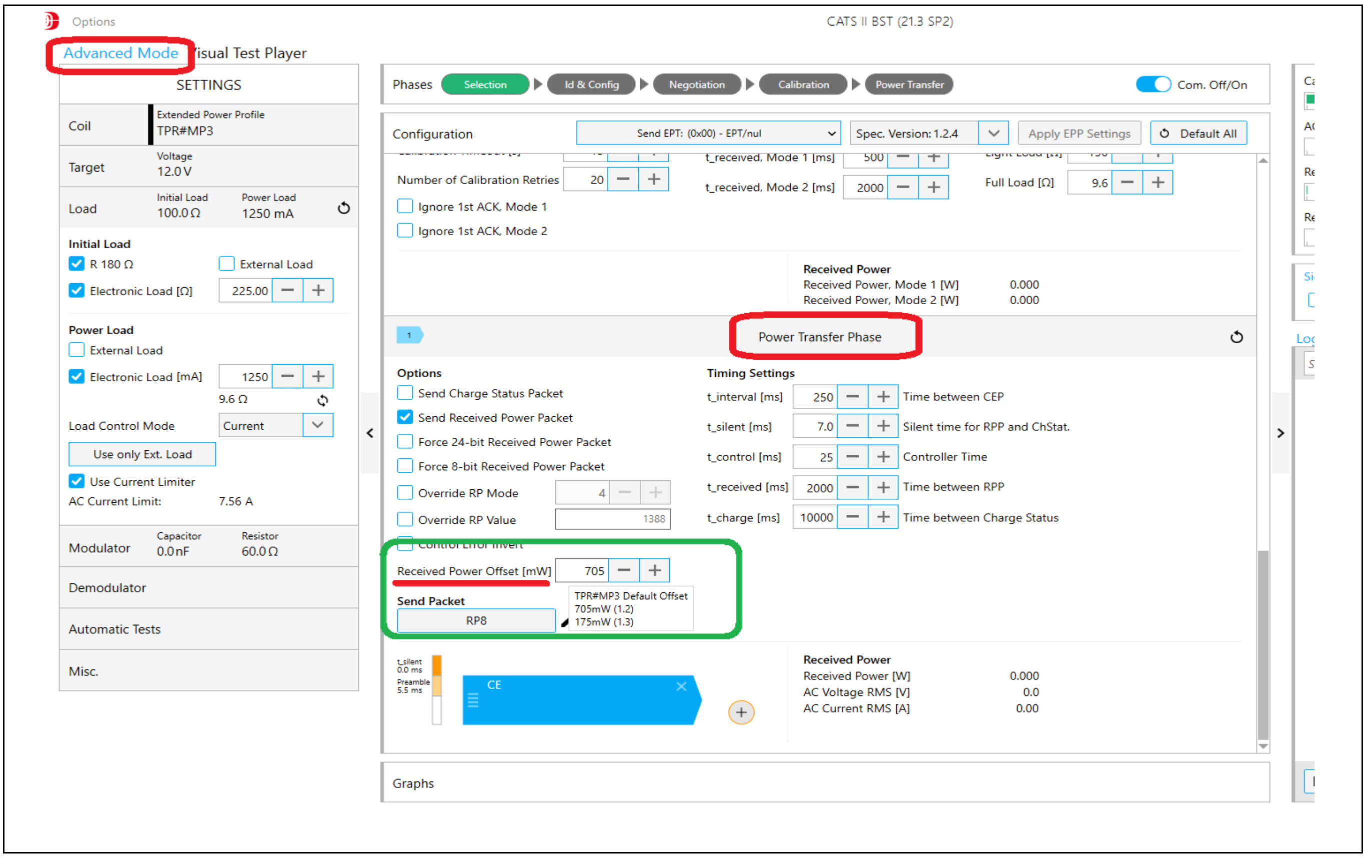


Figure 24 Received Power Offset in Advanced mode

The value of Received Power Offset in the Advanced mode operation determines the accuracy of the system power loss coefficients used to calculate the system power loss. The default values of received power offset are different for Qi 1.2 and Qi 1.3 and may vary for Qi compliance tests as well as guaranteed power (GP) tests. The following table provides the default values for Received Power Offset (mW) for various Qi versions and GP tests:

Table 5 Receiver power offset observed in compliance tool

TPR	Qi 1.2	Qi 1.3	GP test
TPR#MP3	705	175	705
TPR#7	335	335	335
TPR#5	35	35	35

Please use the GP values as offset for calibration operation.

Appendix III – Enabling UART logs using Wireless Charging Configuration Utility

Note: The UART logs are not enabled in the system. The user must disable the UART logs when not needed. The standard system behavior is tested with UART logs disabled.

The UART logs can be enabled by enabling the following parameters in the transmitter "Profile" page in the Wireless Charging Configuration Utility (see **Figure 25**).

- UART enable
- Critical enable
- Message enable
- Set Debug enable to Level 1

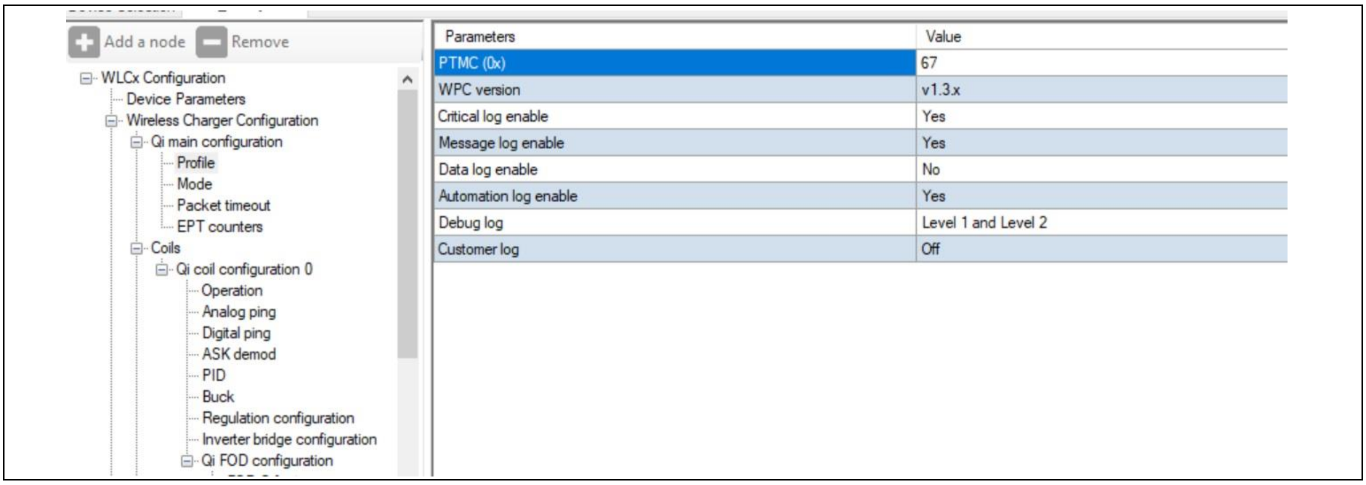


Figure 25 **Profile page settings for enabling UART logs**

Revert these changes to default on completion of the process. UART logs consume processor resource, and it is recommended to disable UART logs for optimal performance of the WLC power transmitter.

References

[1] Qi Standard Version 1.3.x

[2] Qi Standard (Version 1.3.1), Chapter "Foreign Object Detection"

[3] Two-point calibration – Section 11.4.3.1 of Part 12, Qi Standard Version 1.2.4

[4] FOD based on calibrated power loss accounting – Section 11.4 of Part 12, Qi Standard Version 1.2.4

[5] (External link) **WPC's list of ATLs**

[6] Section 5.4.3.3, Part 3, "Compliance Testing", Qi Standard Version 1.2.4

[7] Section 11.3.3, Part 12, "Definition of the Reference Quality Factor", Qi Standard Version 1.2.4

[8] Section 5.4.3, Part 3, "Foreign Object Detection", Qi Standard Version 1.2.4

[9] Reference board: REF_WLC_TX15W_C1 wireless power transmitter reference board

[10] **Product datasheet**: WLC1115, 15 W wireless power transmitter with integrated USB Type-C PD sink controller

[11] **Q factor – Analysis and insights**

[12] Annex A: Determining the reference FOD values, FOD Chapter of Qi-V1.3.2 Spec

Revision history

Document version	Date of release	Description of changes
**	2022-05-02	New application note

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