# BHW TECHNOLOGIES

**Advanced RF IC, Front-End Module, RF Active integrated Antenna (RFAiA™) and Wireless Sub-System Solutions**

*RF Chips & Beyond*

## BHW AppNote #013

# Improving RF Range and Battery Life of 2.4GHz Wireless Systems with BHWM257 Compact FEM

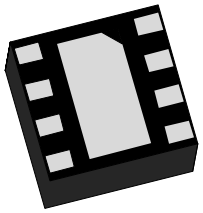
**Rev. 2.1**

www.bhw-tech.com

# Challenges for 2.4GHz Wireless Range Extension

- 2.4GHz radios are among the most popular wireless connectivity solutions today for a great variety of applications from consumer electronics, smart homes to industrial IoT
- Solid improvement in both RF performance and power consumption has been achieved with each new generation of wireless SoCs. However, there are still many use cases which need longer wireless range, better coverage, fewer/no packet drops (critical for gaming, audio, etc), and enhanced overall user experience
- The inherent physical limitations of the CMOS process, tradeoffs in digital mod/demod and error-correction algorithms, and constraints of RF circuit implementation (e.g., need of cellular co-existence or FCC filters) prevent most wireless SoCs from reaching their full potentials in standalone operation, without the assistance of external RF front-ends

**BHWM257, a tiny 2.4GHz FEM complete with PA, LNA, TRX Switch & Antenna Switch in a simple 2x2mm 8L-DFN package, provides a path to maximize the RF performance of any 2.4GHz SoCs. Using advanced GaAs E/D pHEMT process, BHWM257 provides record-breaking noise figure and power efficiency, to help improve the range of 2.4GHz RF products from wireless microphones to industrial IoT with minimal increase in power consumption. This AppNote provides an overview of the DC/RF performance of this easy-to-use chip, as well as some examples of practical implementation.**

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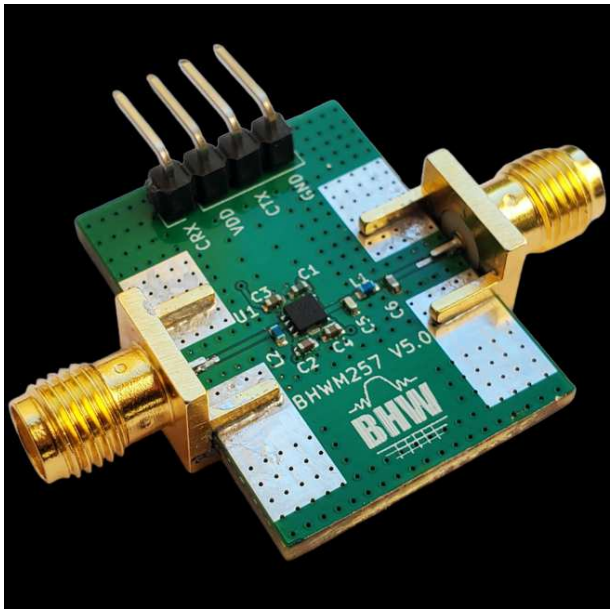
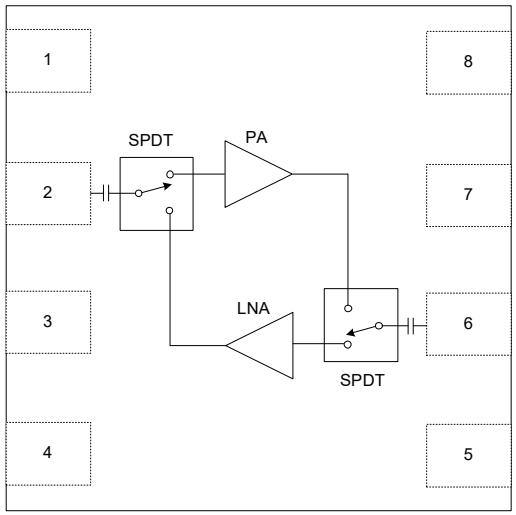


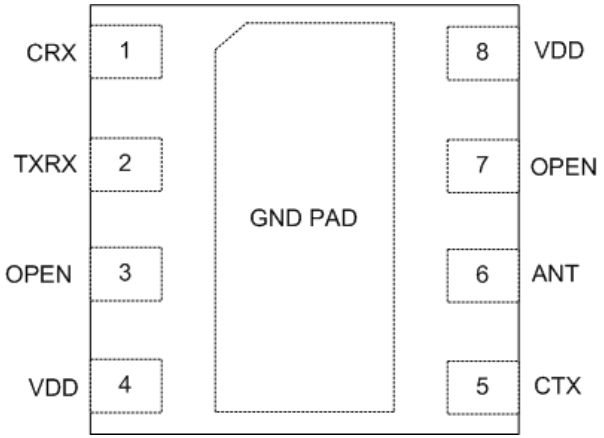
# BHWM257 2.4GHz RF FEM with PA, LNA & Switch

## Functional Block Diagram




## Package Pin-Out

(Top "See-Through" View)




DFN-8L 2x2x0.75mm

## Product Overview:

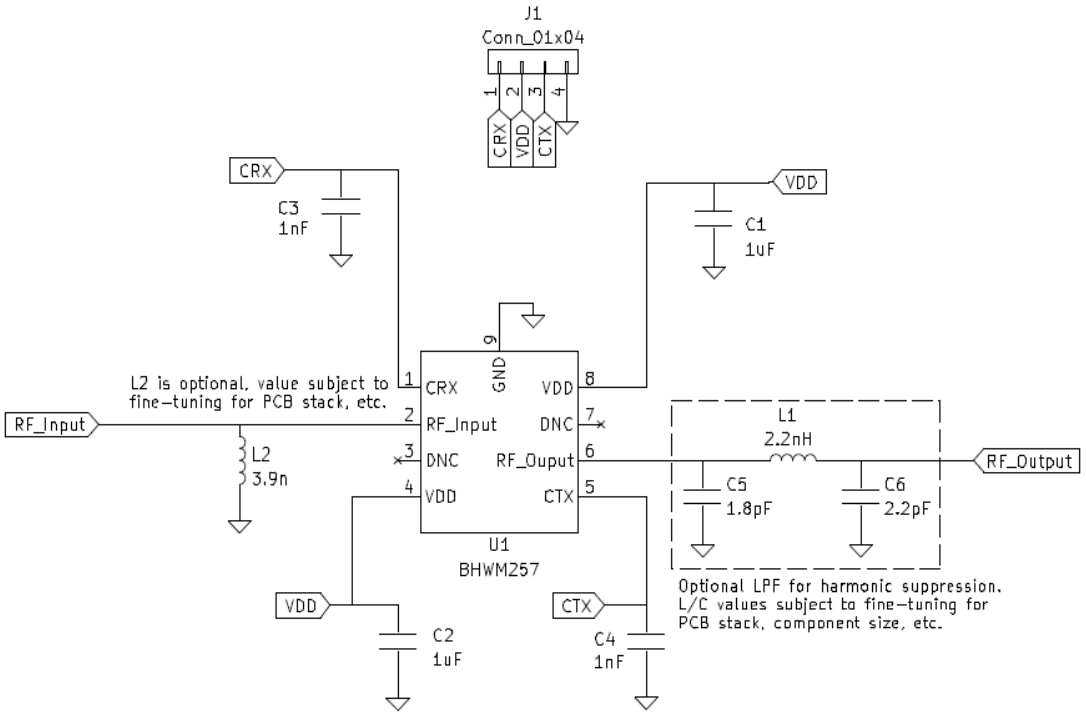
- Advanced GaAs E/D PHEMT Process
- 2.4-2.5GHz Operation Frequency Range
- Tx Power: 13dBm/3.3V, 15dBm/4.2V
- Tx Gain: 13dB w/ FCC-Compliant Harmonic Filter
- Total Current: ~22mA/13dBm, ~30mA/15dBm
- Rx Gain/Noise Figure: 14dB/1.7dB
- LNA Current: 4~15mA Adjustable
- High-Linearity LNA: Input P1dB~-2dBm at 3.3V
- System NF ~2.2dB including Harmonic Filter
- Integrated DC Block Capacitors on all RF Ports
- Robust ESD for All I/O Pins: ±700V HBM; ±2kV CDM
- Compact 2x2mm 8L-DFN Package

## Applications:

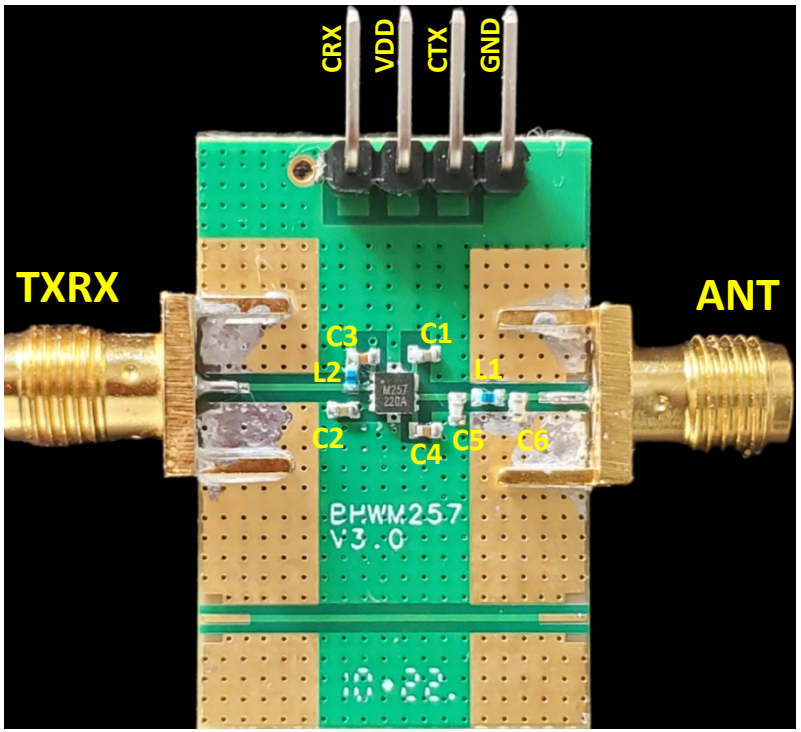
- Bluetooth/BLE System
- ZigBee/Thread/Matter
- Remote Control
- Asset Tracking
- Smart Home, Smart Meters
- Wireless Audio/Video/Microphone
- Generic 2.4GHz TDD Radio Designs

# BHWM257 Schematic and EVB with BOM

## Application Schematic




## Evaluation Board with Pi-Filter

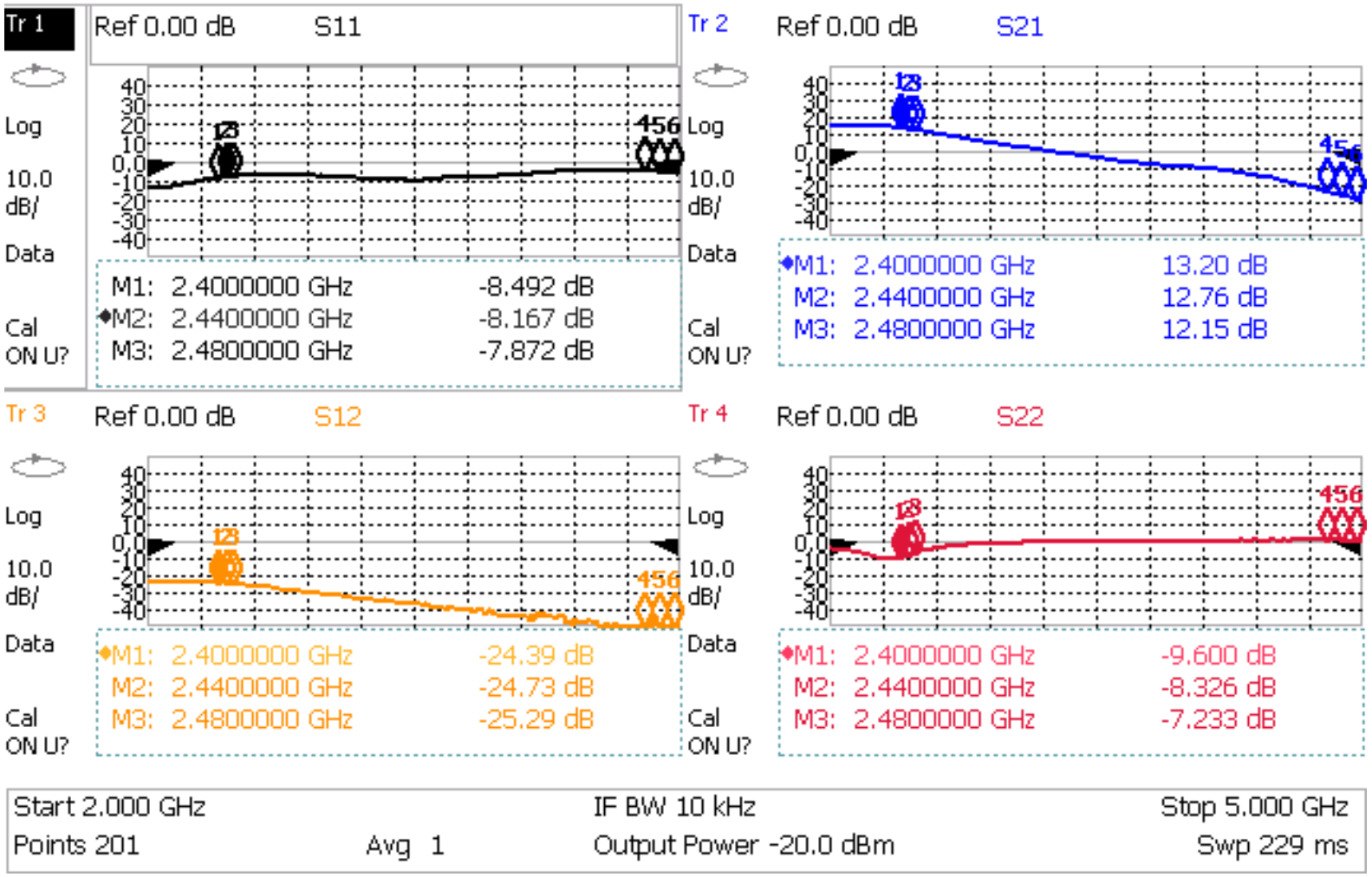



**Notes:**

**-VDD decoupling capacitors C1=C2=1uF must be placed close to device Pin8 and Pin4.**
**-CTX/CRX decoupling capacitors C3=C4=1nF locations are not critical in PCB layout.**
**-An optional serial resistor can be added to CTX line to reduce Tx current; similarly add a serial resistor on CRX to lower Rx current.**
**-Harmonic filter: C5=1.8pF,C6=2.2pF, L1=2.2nH (Murata LQW15AN2N2J00D), subject to fine tuning for different PCB stack/layout.**
**-L2=3.9nH helps improve S22 in Rx mode and my be omitted with only minor degradation in VSWR.**
**-Refer to the end of this AppNote for PCB layout recommendations.**

# BHWM257 EVB with Harmonic Filter: Tx S-Parameters

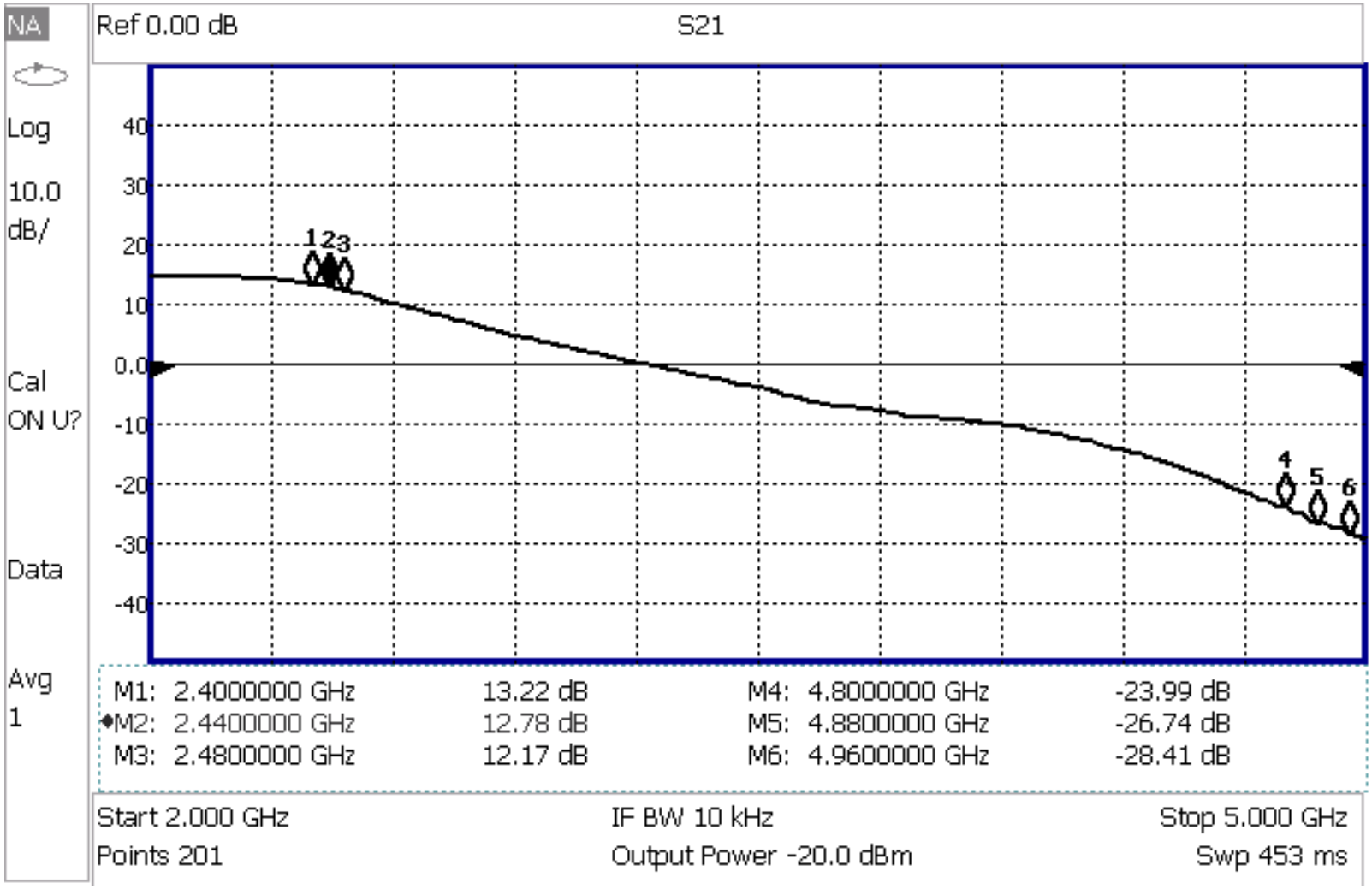
## Measured S-Parameters for Tx Mode, VDD=CTX=3.3V, CRX=0V




**Notes:**
**-Measured data include losses of harmonic filter, PCB traces and SMA connectors.**
**-Expect ~0.5dB higher gain if harmonic filter is not needed.**

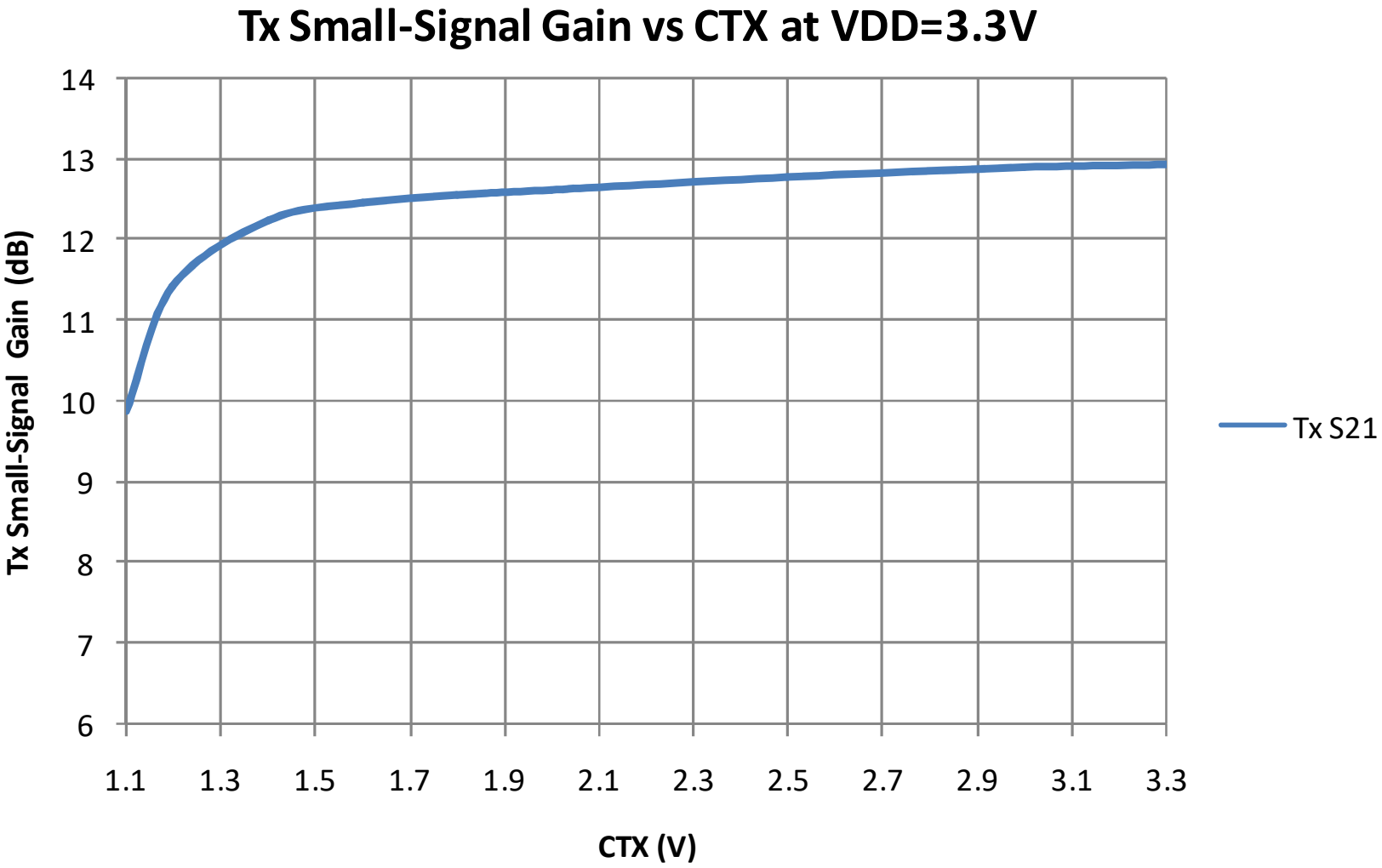
# BHWM257 EVB with Harmonic Filter: Tx S-Parameters

## Broadband (2~5GHz) S21 for Tx Mode, VDD=CTX=3.3V, CRX=0V



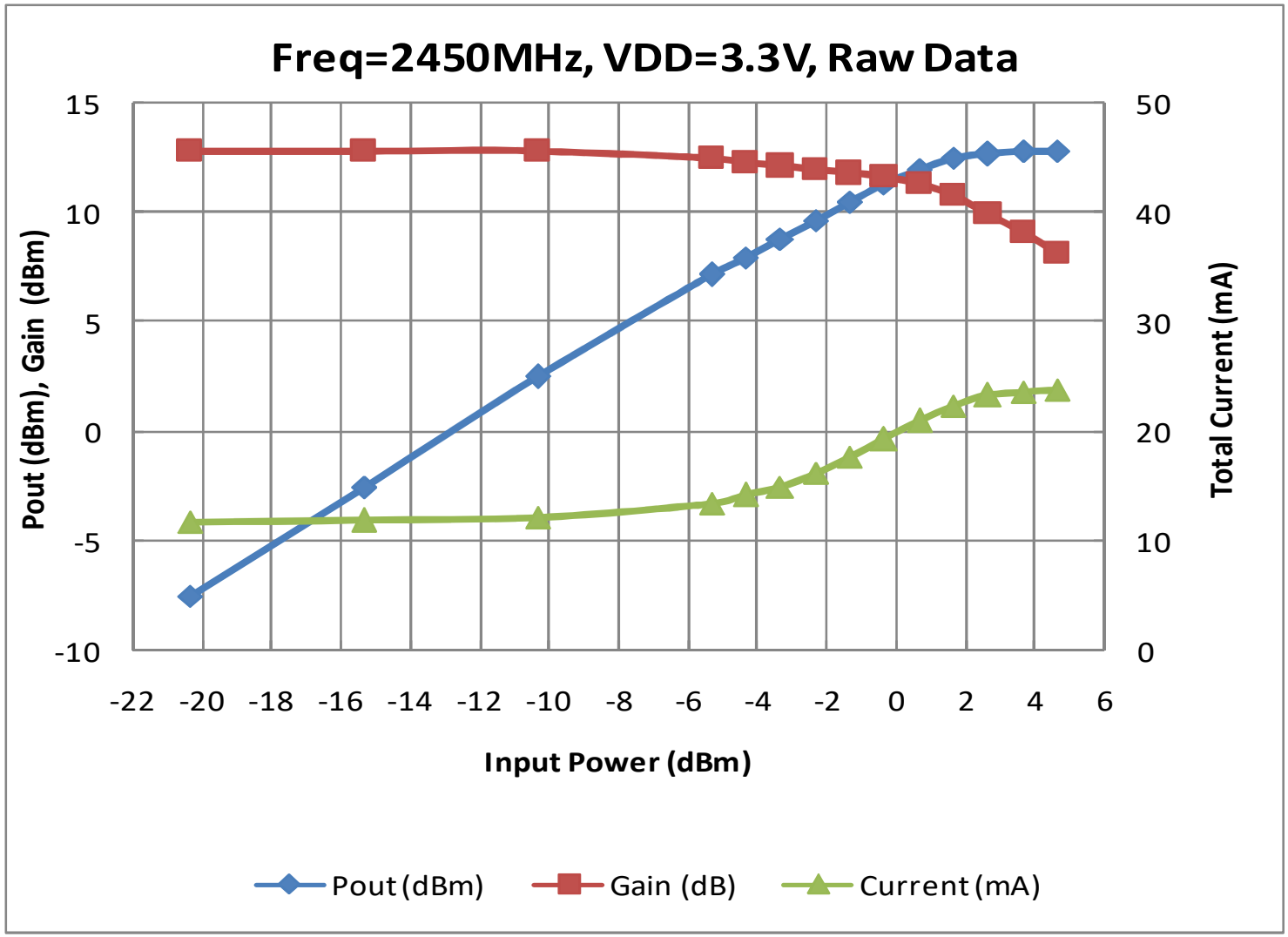

**Notes:**
**- Measured data include losses of harmonic filter, PCB traces and SMA connectors.**
**-Expect ~0.5dB higher gain if harmonic filter is not needed.**

# BHWM257 Tx Gain vs Control Voltage CTX




**Note:**
**-DC bias: VDD=3.3V, CRX=0V, CTX=Various**
**-EVB and SMA connector losses de-embedded with THRU calibration**

# BHWM257 Tx CW Power Sweep at VDD=3.3V




**Notes:**

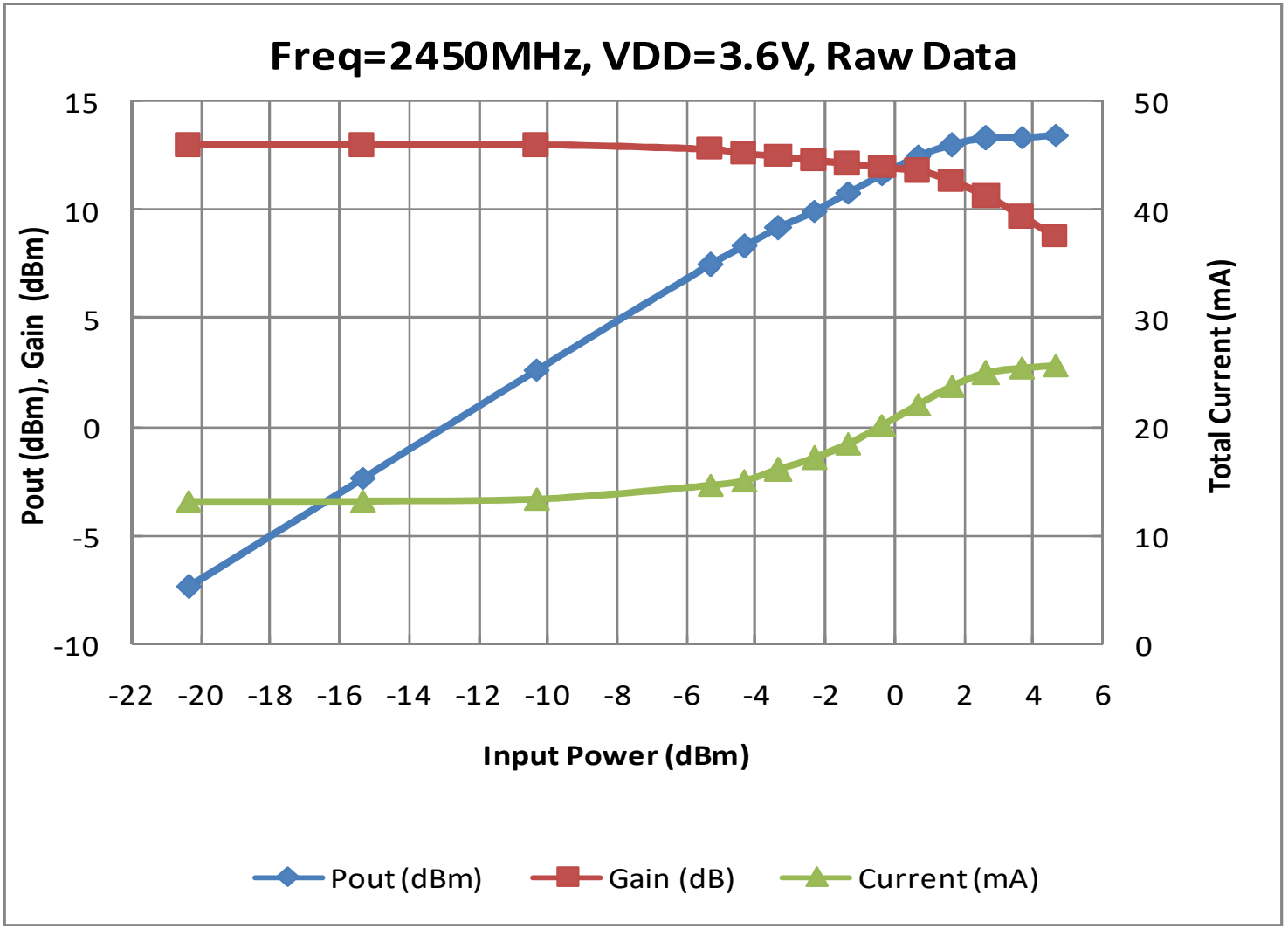
**-DC Bias: VDD=CTX=3.3V, CRX=0V**

**-Measured data include harmonic filter Loss (~0.5dB), PCB and SMA connector/cable losses (~0.15dB).**

**-If harmonic filter is not needed, expect about 0.5dB higher in gain and output power for the same total current.**

**-An optional serial resistor can be added to CTX line to reduce Tx current.**

# BHWM257 Tx CW Power Sweep at VDD=3.6V




**Notes:**

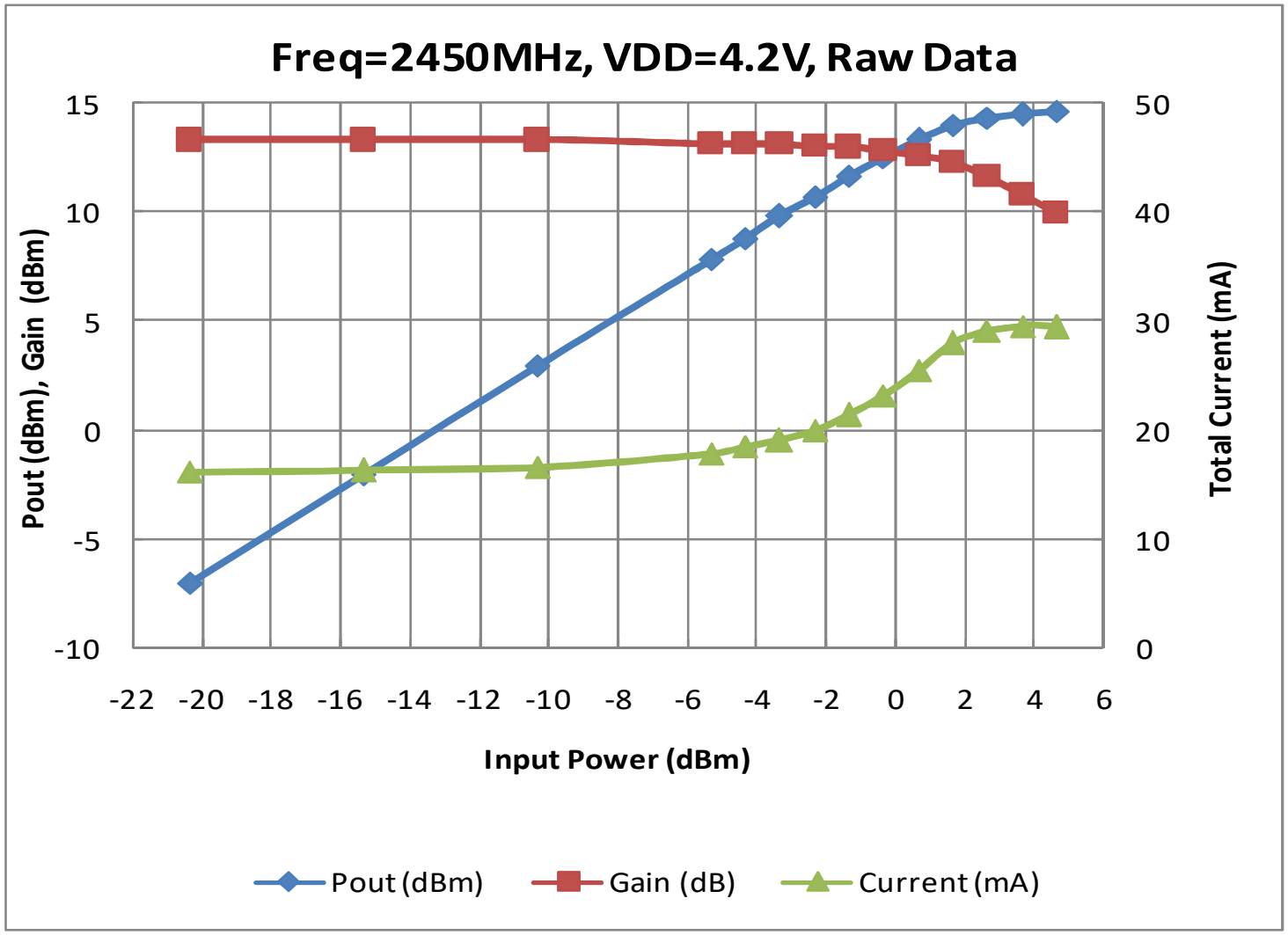
**-DC Bias: VDD=CTX=3.6V, CRX=0V**

**-Measured data include harmonic filter Loss (~0.5dB), PCB and SMA connector/cable losses (~0.15dB).**

**-If harmonic filter is not needed, expect about 0.5dB higher in gain and output power for the same total current.**

**-An optional serial resistor can be added to CTX line to reduce Tx current.**

# BHWM257 Tx CW Power Sweep at VDD=4.2V




**Notes:**

**-DC Bias: VDD=CTX=4.2V, CRX=0V**

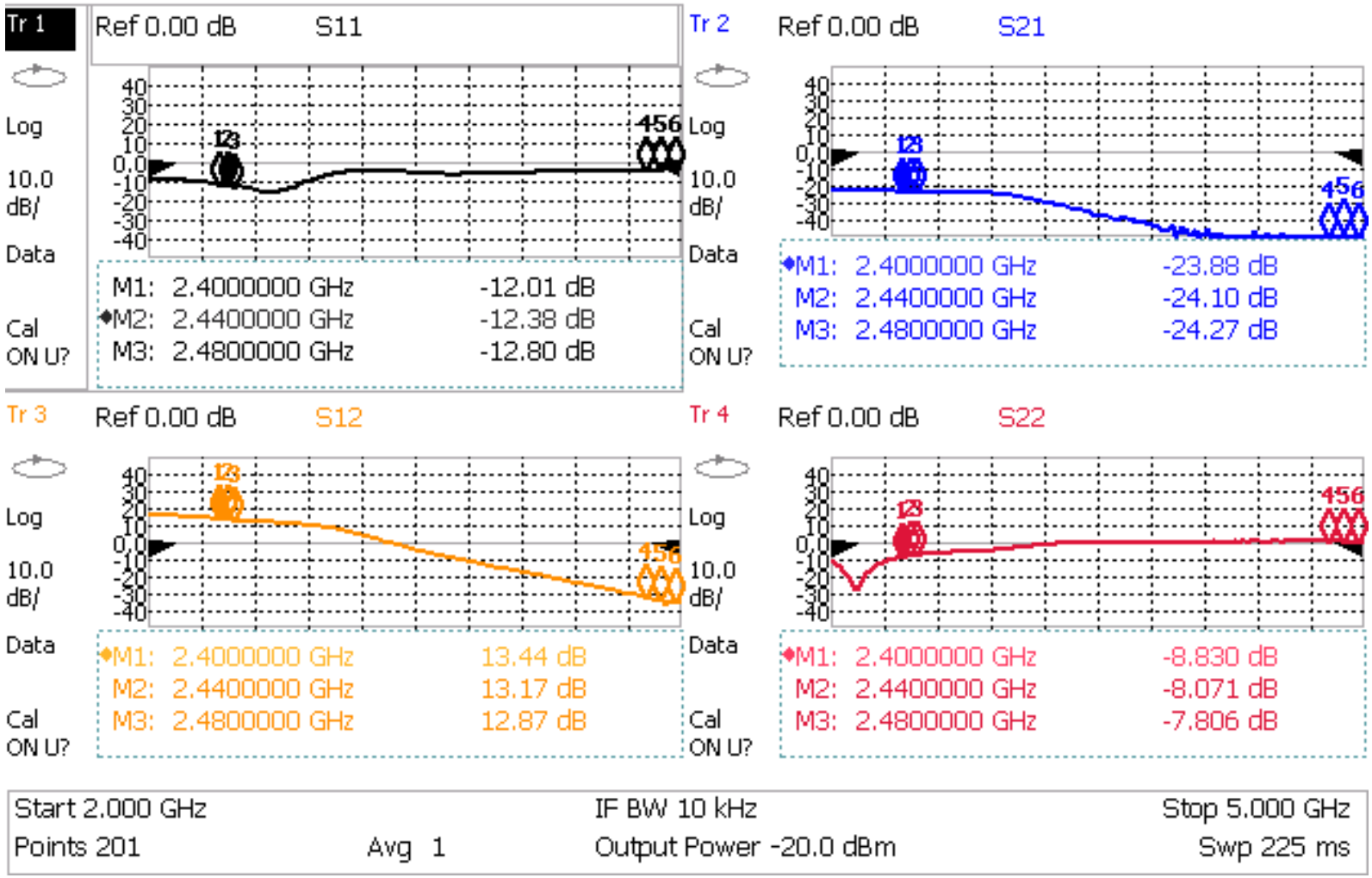
**-Measured data include harmonic filter Loss (~0.5dB), PCB and SMA connector/cable losses (~0.15dB).**

**-If harmonic filter is not needed, expect about 0.5dB higher in gain and output power for the same total current.**

**-An optional serial resistor can be added to CTX line to reduce Tx current.**

# BHWM257 Receive Mode: Rx S-Parameters

## Measured S-Parameters for Rx Mode, VDD=CRX=3.3V, CTX=0V

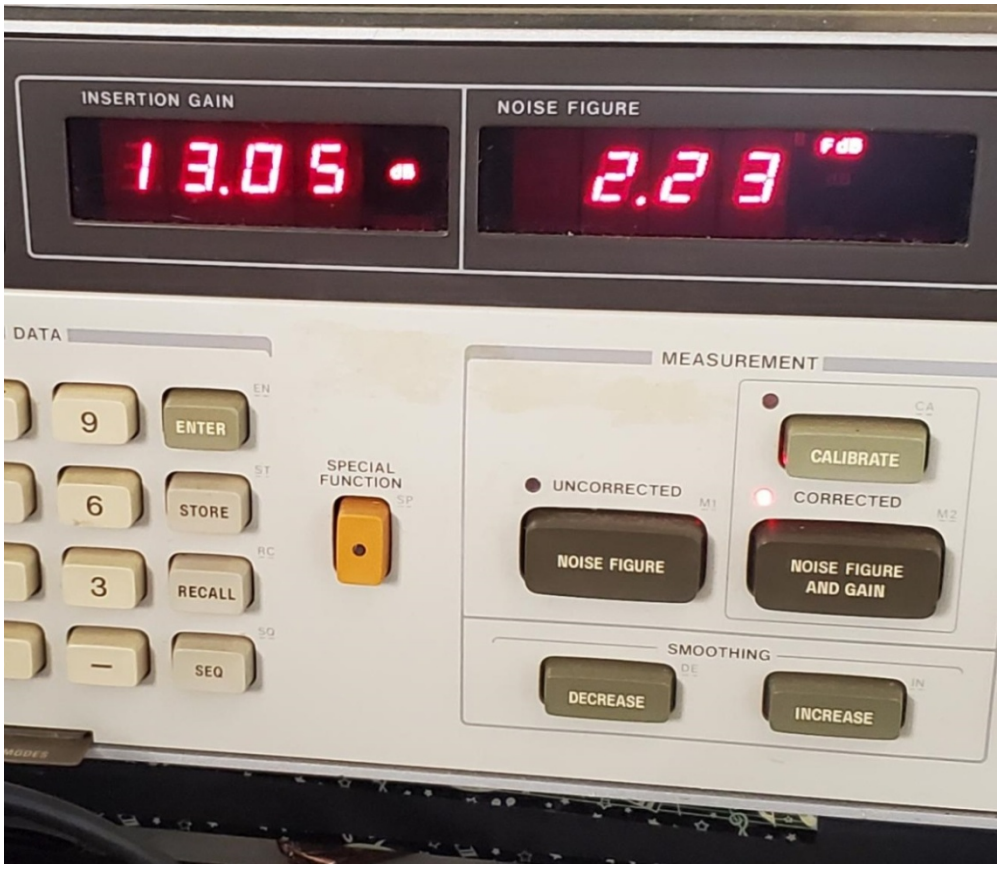



**Notes:**
**- Measured data include losses of harmonic filter, PCB traces and SMA connectors.**
**-Expect ~0.5dB higher gain if harmonic filter is not needed.**

# BHWM257 Receive Mode: Rx Noise Figure


## Measured Noise Figure at 2485MHz

### Raw Data Including Harmonic Filter and EVB/SMA Losses




**Notes:**

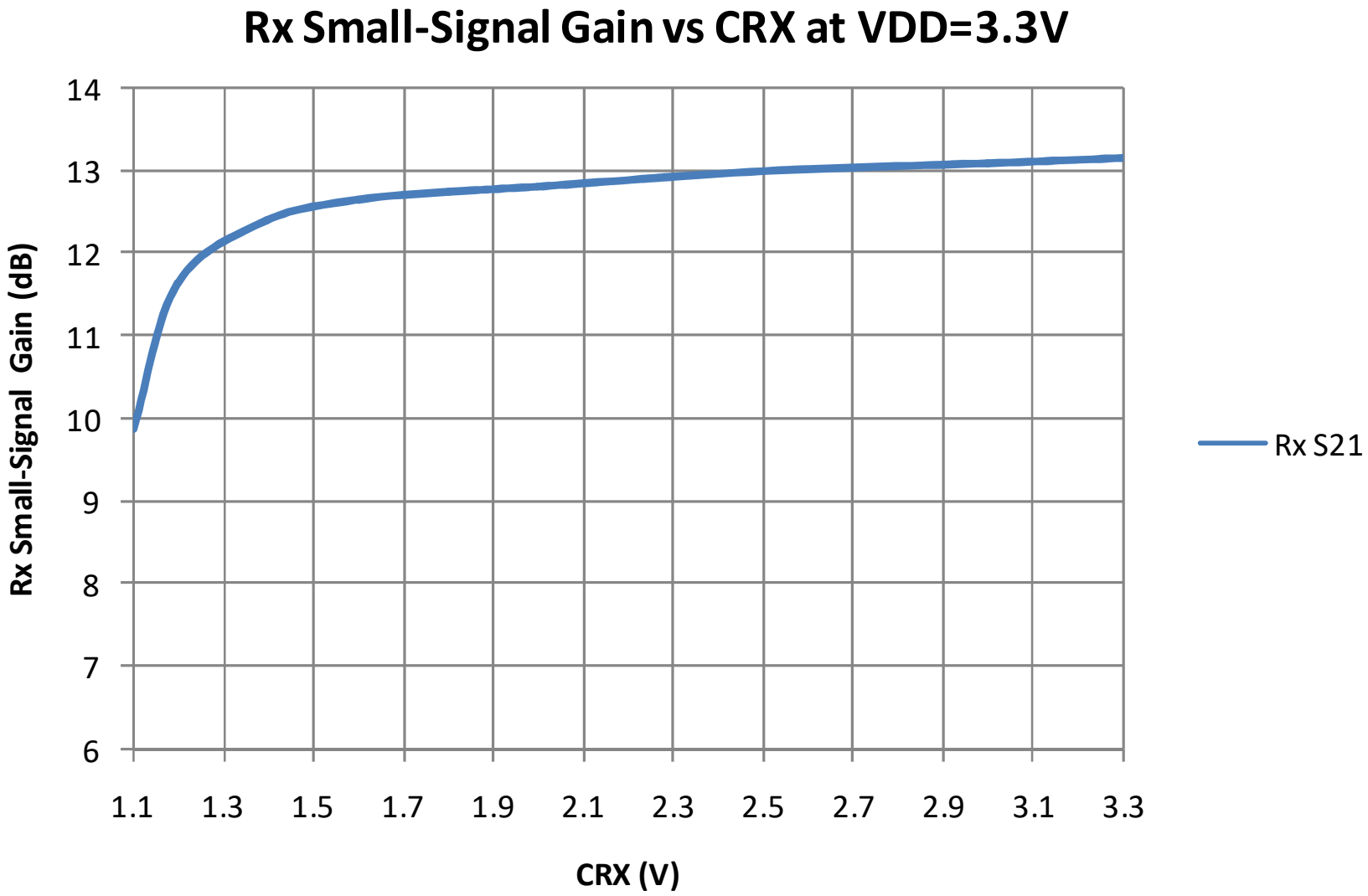
**-DC Bias: VDD=CRX=3.3V, CTX=0V.**

**-Measured NF~2.2dB includes antenna switch and harmonic filter for FCC compliance.**

**-Expect about 0.5dB lower NF (~1.7dB) if harmonic filter is not needed.**

**-For system implementations requiring the insertion of a co-existence filter between the SoC and antenna, RF FEMs like BHWM257 will greatly offset the degradation in system NF due to the LNA gain, enabling state-of-the-art receive sensitivity such as -101dBm for 1Mbps PHY.**

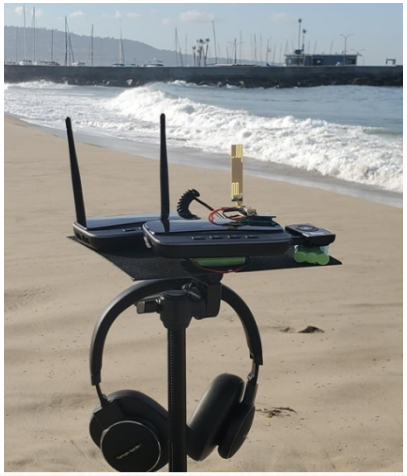
# BHWM257 Rx Gain vs Control Voltage CRX




**Note:**
**-DC bias: VDD=3.3V, CTX=0V, CRX=Various**
**-EVB and SMA connector losses de-embedded with THRU calibration**

# Case Study #1: 2.4GHz Audio Range Extender (Tx Only)

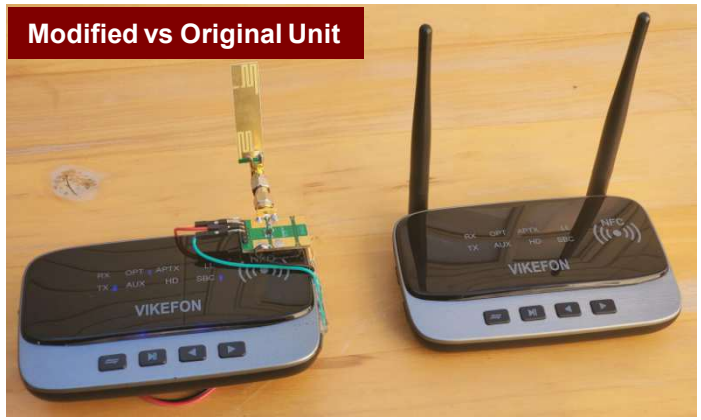
- Test Platform: Qualcomm CSR8675 BLE SoC for Audio
- Mode of Operation for Test: Tx Mode
- Original RF Front-End: 3x3mm FEM + Dual-Antenna
- Modification: Replace FEM with BHWM257 (2x2mm); Replace Dual Antennas with Single BHWR250 (57mm)
- Test Setup: Tx on Tripod at ~1.5m Height. Over-the-Ear Headphone Used for Rx, Open Space, LOS.



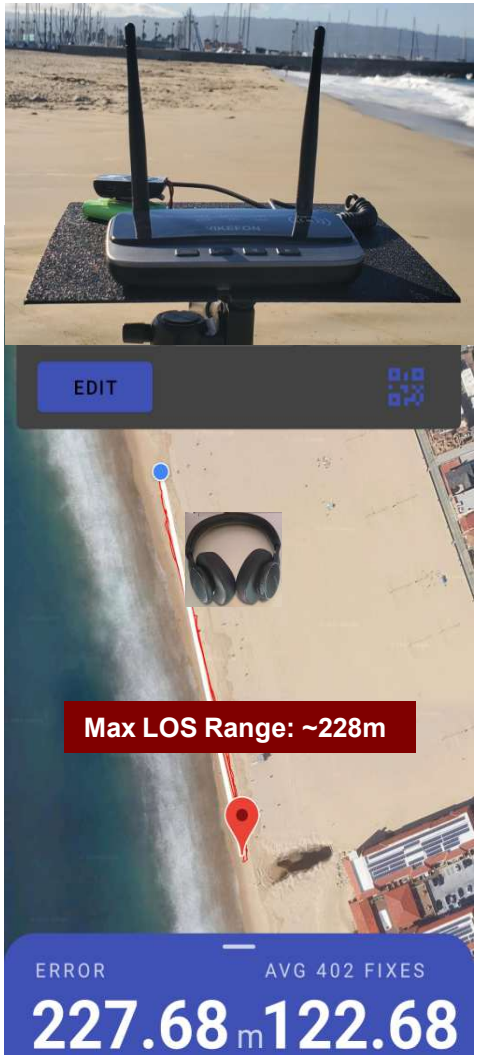
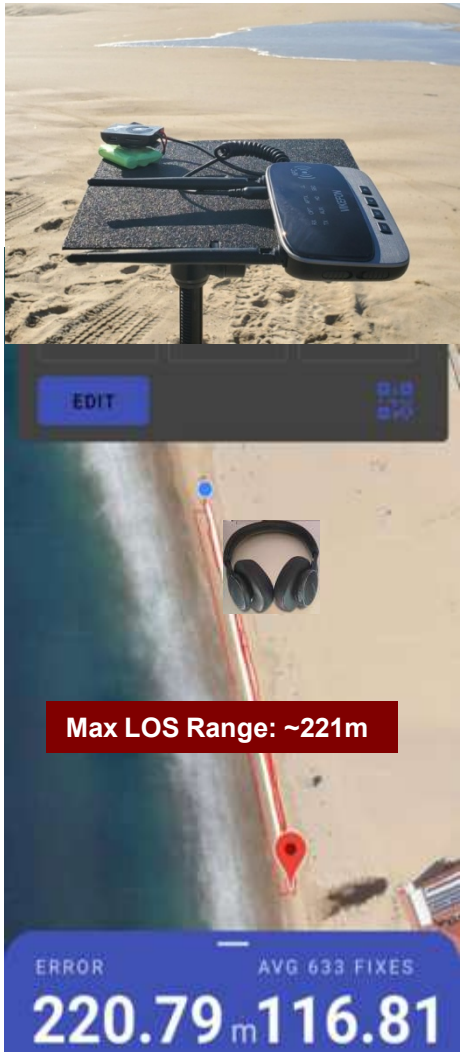
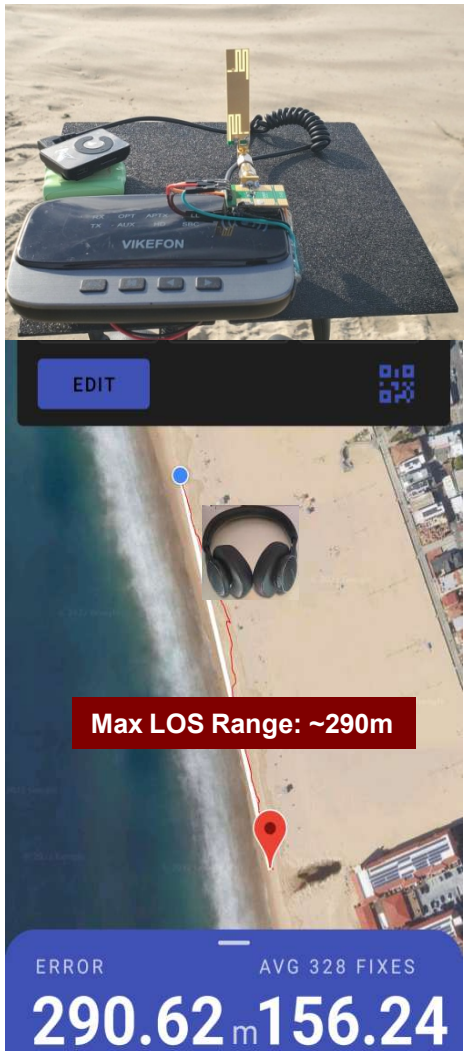
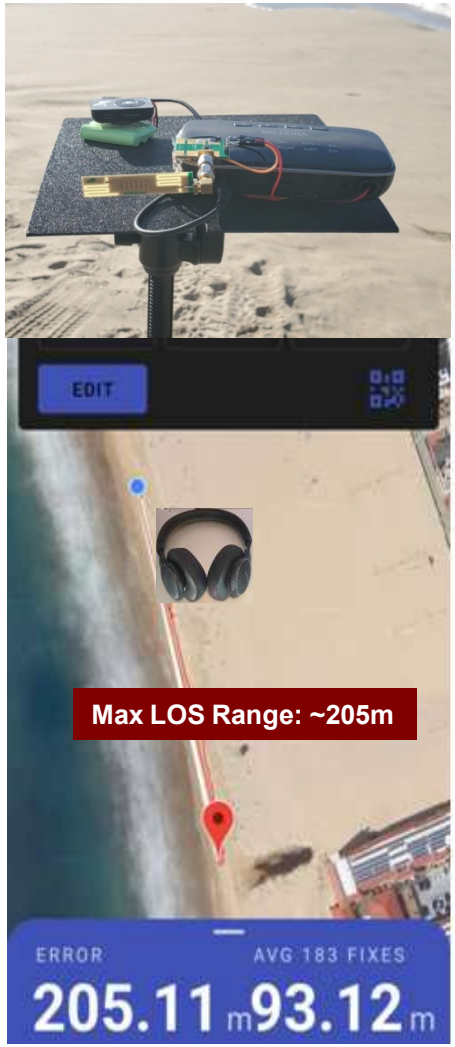
**Modified Unit**
**BHWM257 & BHWR250 Single Antenna**


**Original Unit: 3x3mm FEM & Diversity Antenna**


**Modified vs Original Unit**



# Case Study #1: 2.4GHz Audio Range Extender (Tx Only)

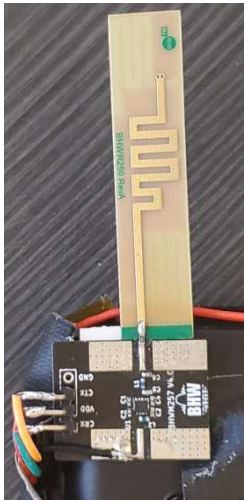
| Original Unit without Modification: Antenna in Vertical Orientation | Original Unit without Modification: Antenna in Horizontal Orientation | Modified Unit with BHWM257 & BHWR250 in Vertical Orientation | Modified Unit with BHWM257 & BHWR250 in Horizontal Orientation |
|---|---|---|---|
|  |  |  |  |
| Max LOS Range: ~228m | Max LOS Range: ~221m | Max LOS Range: ~290m | Max LOS Range: ~205m |
| ERROR 227.68 m AVG 402 FIXES 122.68 | ERROR 220.79 m AVG 633 FIXES 116.81 | ERROR 290.62 m AVG 328 FIXES 156.24 | ERROR 205.11 m AVG 183 FIXES 93.12 m |

**Comments: For much lower current consumption and smaller FEM size, and with only one compact PCB antenna instead of two longer dipoles, the BHWM257 & BHWR250 solution provides comparable range to that of the original design.**

# Case Study #2: 2.4GHz Range Extension (Both Tx & Rx)

**Transmitter: Qualcomm CSR8675 BLE SoC + BHWM257 FEM + BHWR250 Antenna**

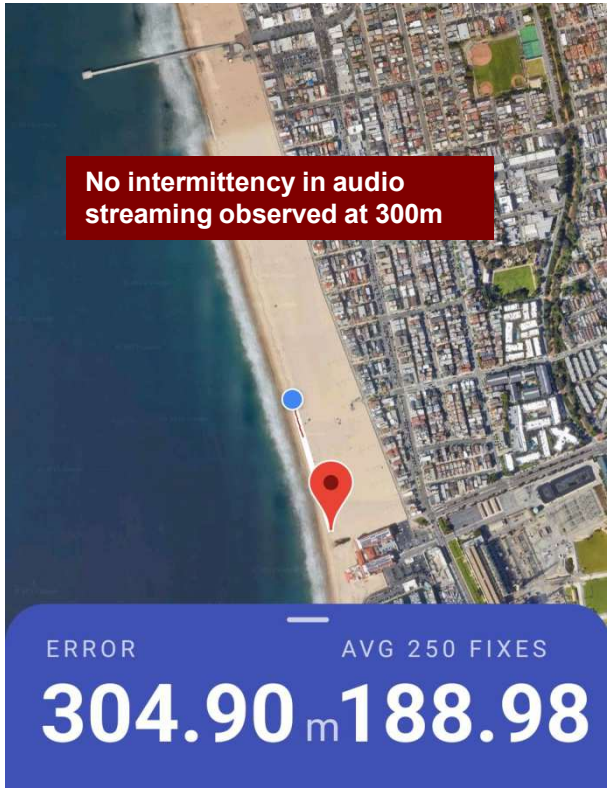

**Receiver: Qualcomm CSR8675 BLE SoC + BHWM257 FEM + BHWR250 Antenna**

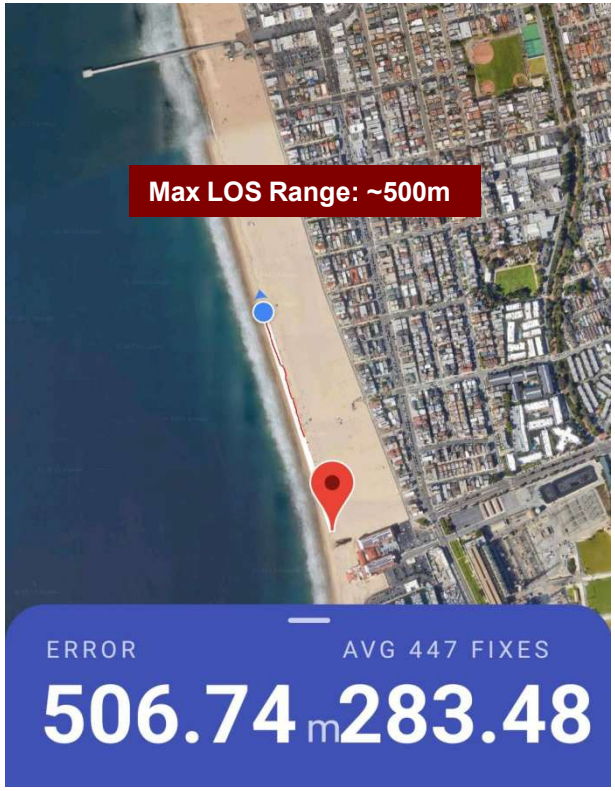
**Tx: ~1.5m above ground on tripod**

**Rx: Held above head in walk test**


**No intermittency in audio streaming observed at 300m**

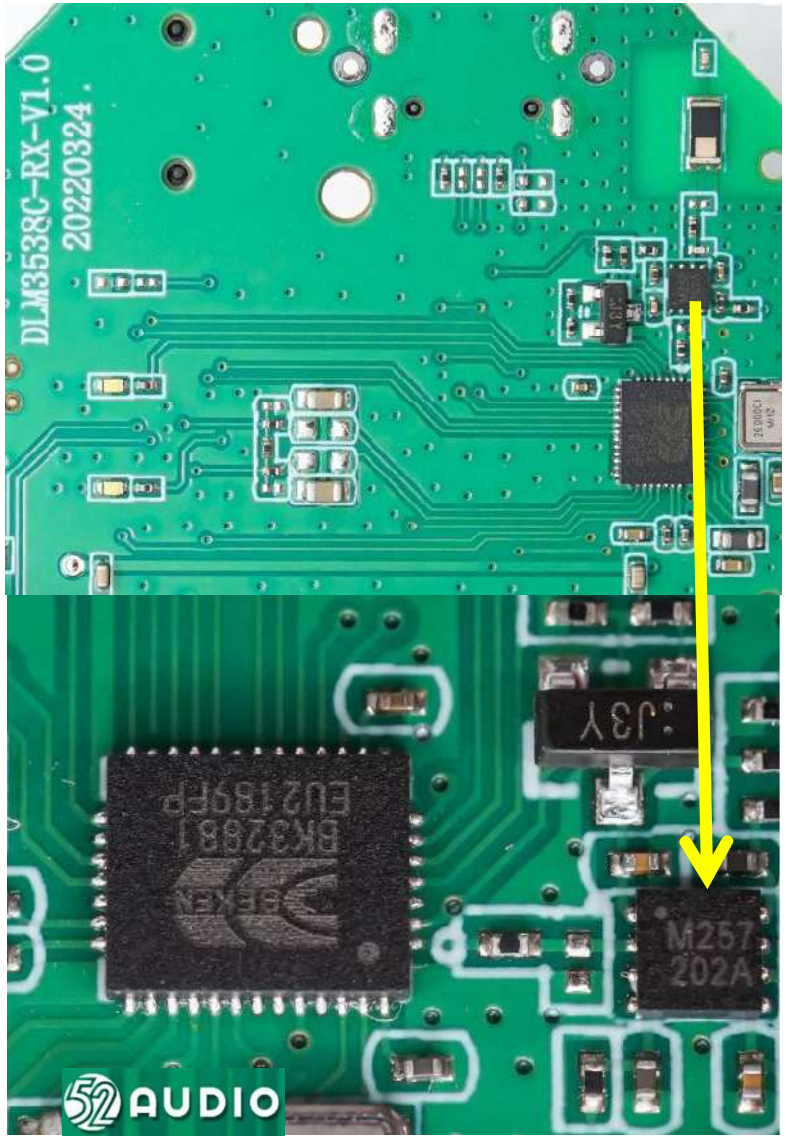



**Max LOS Range: ~500m**



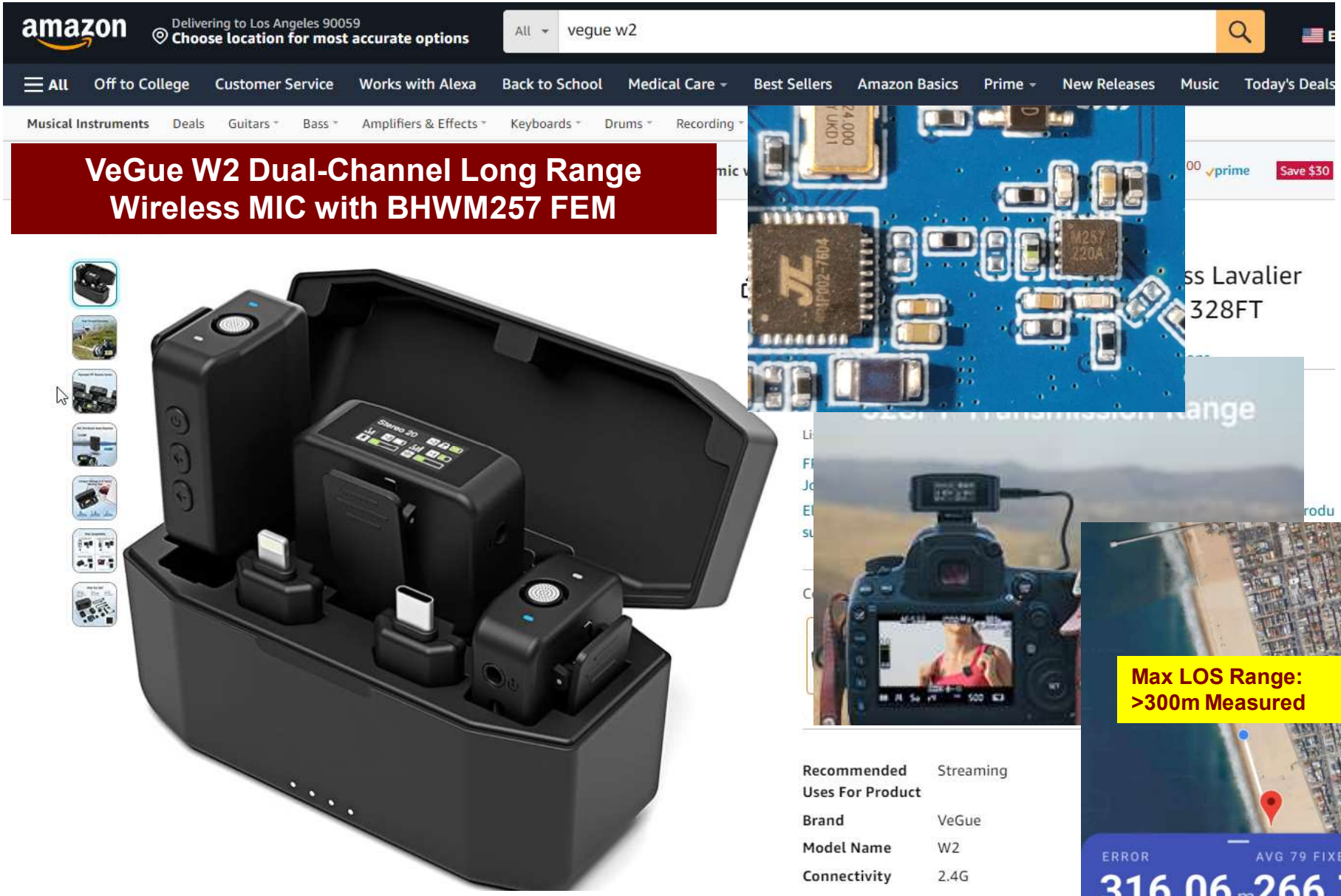
# Case Study #3: Philips 2.4GHz Wireless Microphone

## BHWM257 Enables DLM3538C with >100m Range & 8-Hour Battery Life

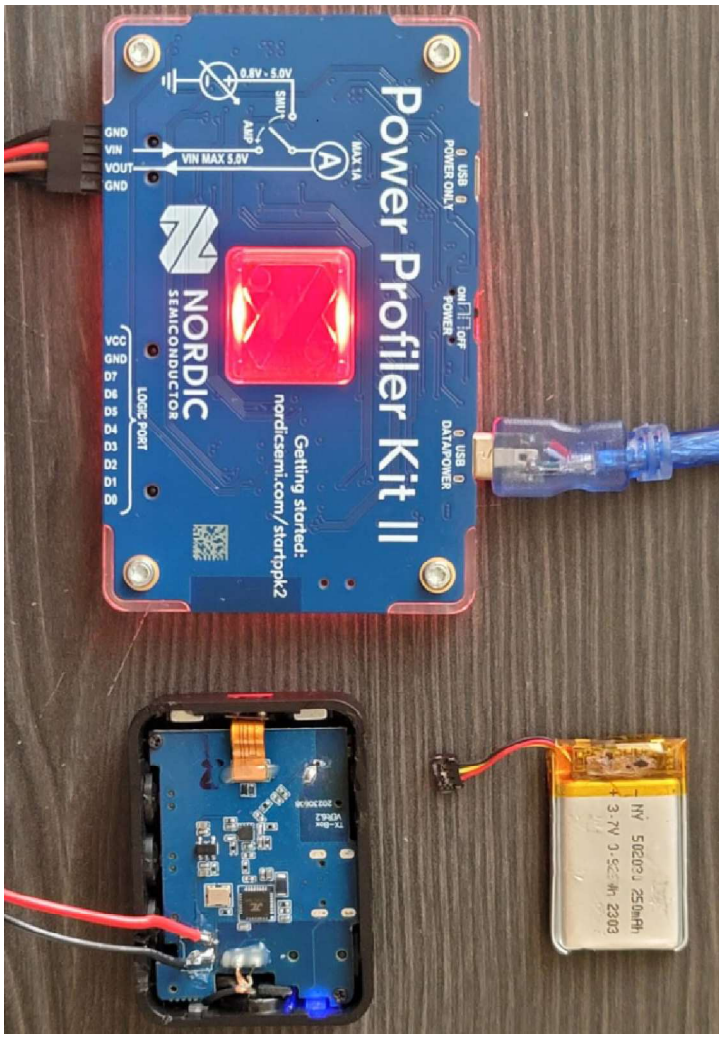

Source: www.52audio.com

# Case Study #4: VeGue W2 Dual-Channel 2.4GHz MIC

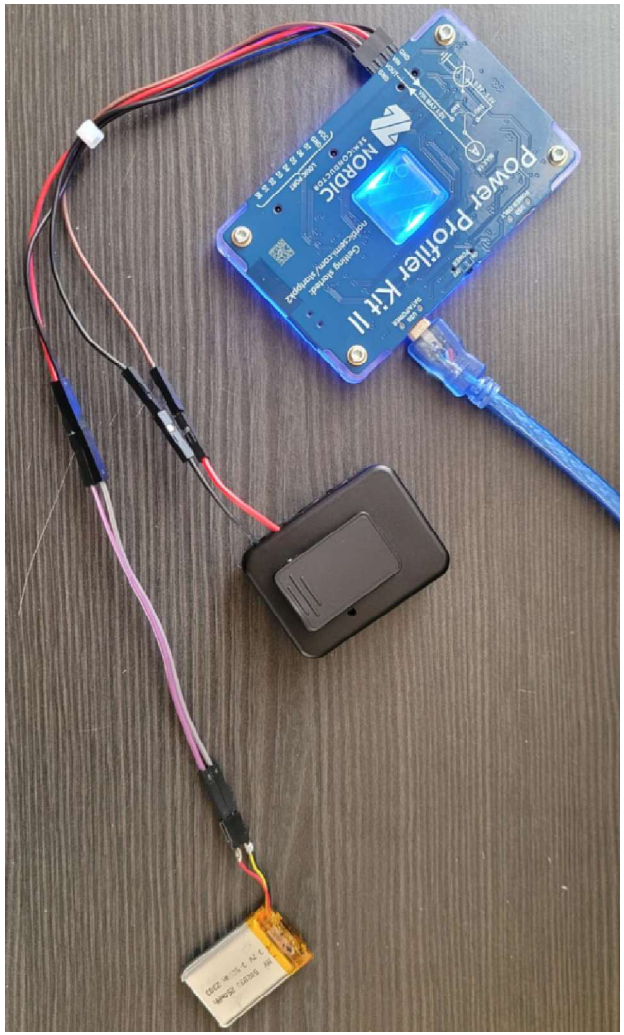


# Energy Profile of VeGue W2 TX with BHWM257

## Nordic PPK2 Test Mode A
## Source Meter Mode
## Apply 3.7V VDD to W2 TX Unit




## Nordic PPK2 Test Mode B
## Ampere Meter Mode
## Use PPK2 as Ampere Meter Only



# Energy Profile of VeGue W2 TX with BHWM257

## Measured Current Waveform over 10ms Time Window

### Test Mode A
### Source Meter Mode
**Apply 3.7V VDD from PPK2 to W2 TX Unit**


**Test Mode A Results:**
**-Peak Current: 77.64mA**
**-Average Current: 24.45mA**
**-Charge: 244.55uC**

### Test Mode B
### Ampere Meter Mode
**Use PPK2 as Ampere Meter Only**

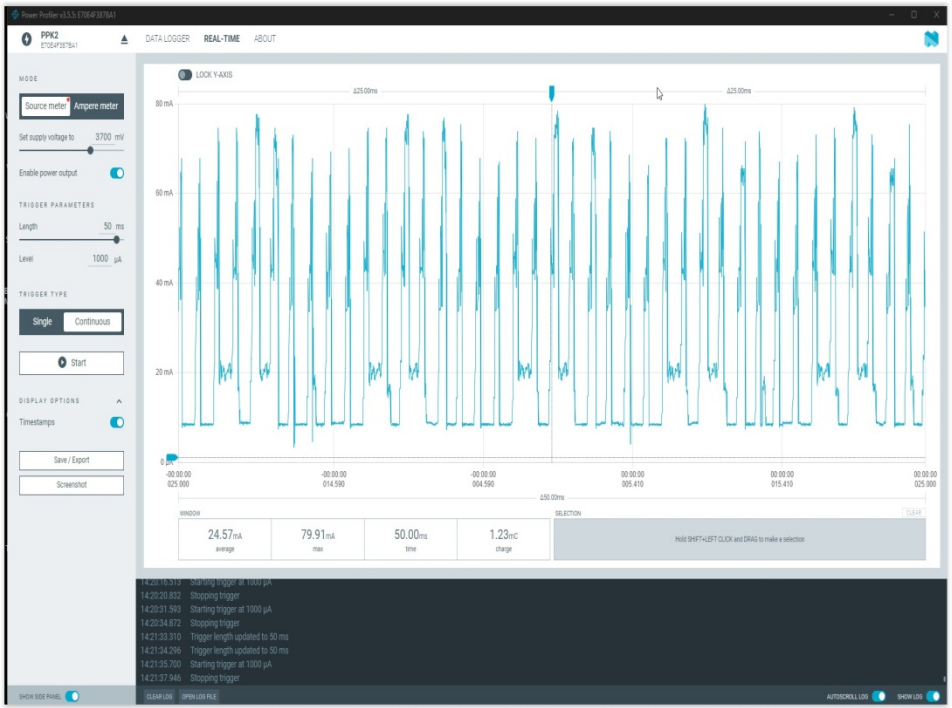

**Test Mode B Results:**
**-Peak Current: 78.40mA**
**-Average Current: 24.34mA**
**-Charge: 243.39uC**

**Note: TX in default mode of transmit operation, with ENC OFF.**

# Energy Profile of VeGue W2 TX with BHWM257

## Measured Current Waveform over 50ms Time Window

### Test Mode A
### Source Meter Mode
**Apply 3.7V VDD from PPK2 to W2 TX Unit**




### Test Mode B
### Ampere Meter Mode
**Use PPK2 as Ampere Meter Only**


**Test Mode A Results:**
**-Peak Current: 79.91mA**
**-Average Current: 24.57mA**
**-Charge: 1.23mC**

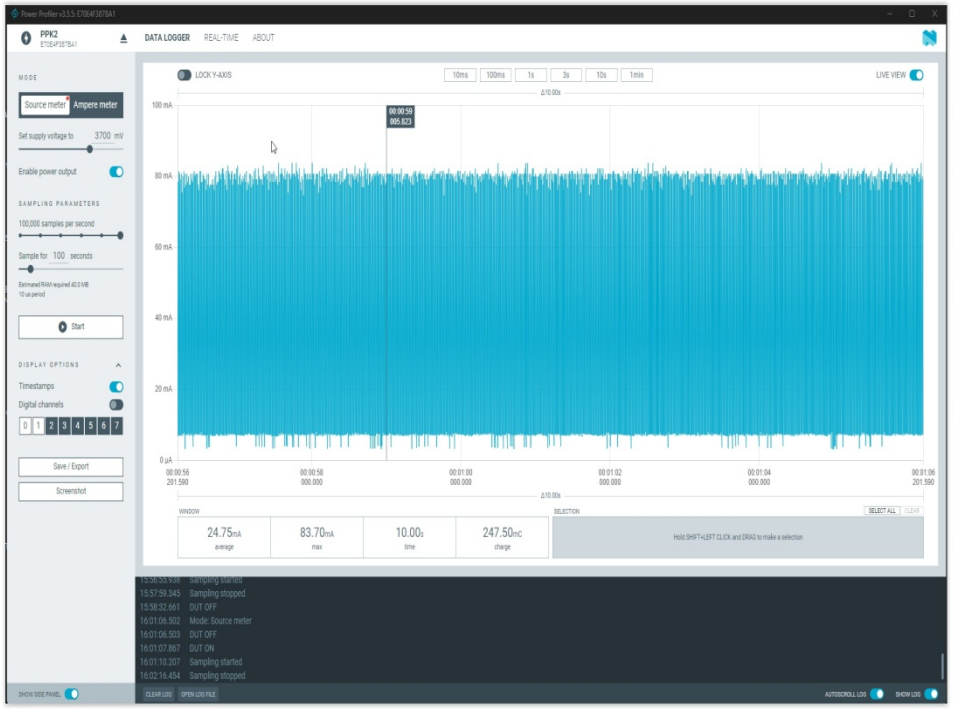
**Test Mode B Results:**
**-Peak Current: 79.16mA**
**-Average Current: 24.24mA**
**-Charge: 1.21mC**

**Note: TX in default mode of transmit operation, with ENC OFF.**

# Energy Profile of VeGue W2 TX with BHWM257

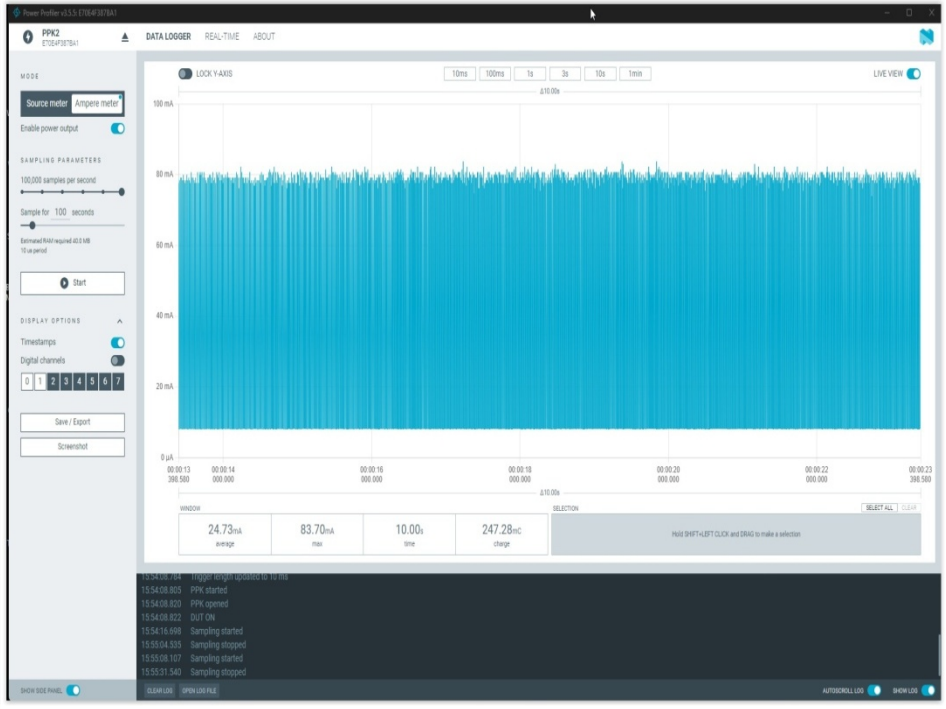
## Measured Current Waveform over 10sec Time Window

### Test Mode A
### Source Meter Mode
**Apply 3.7V VDD from PPK2 to W2 TX Unit**




**Test Mode A Results:**
**-Peak Current: 83.70mA**
**-Average Current: 24.75mA**
**-Charge: 247.50mC**

### Test Mode B
### Ampere Meter Mode
**Use PPK2 as Ampere Meter Only**

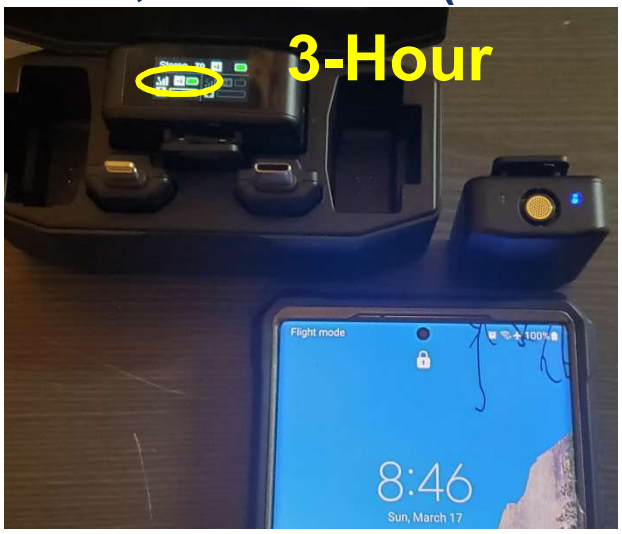


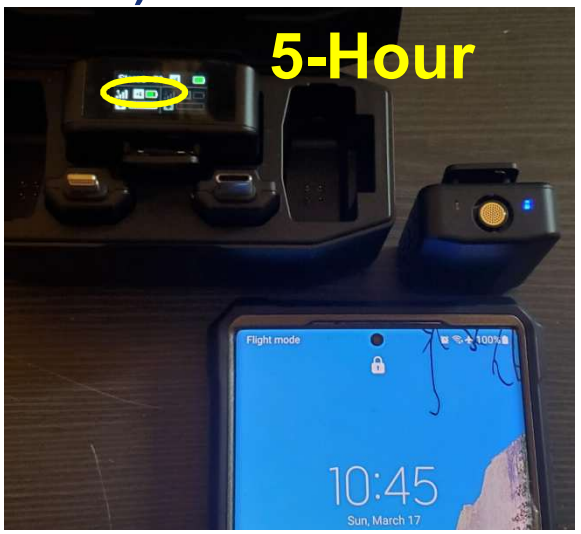

**Test Mode B Results:**
**-Peak Current: 83.70mA**
**-Average Current: 24.73mA**
**-Charge: 247.28mC**

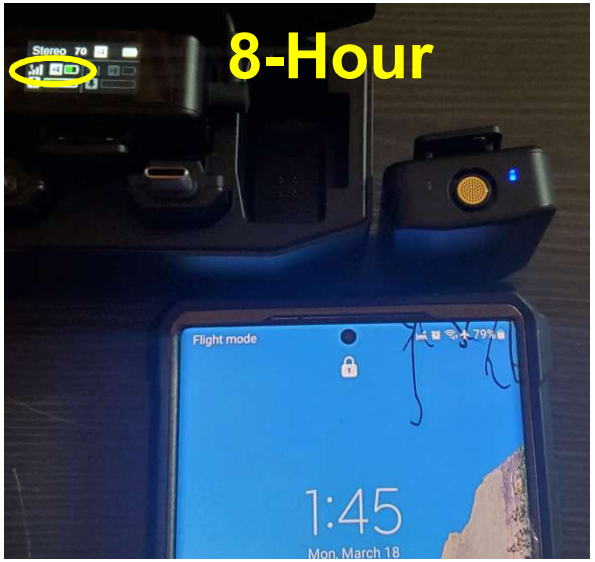
**Notes:**
**-TX in default mode of transmit operation, with ENC OFF.**
**-Based on the measured average current of ~25mA, it is expected that the TX unit with 250mAh Li-Battery will last 10 hours.**

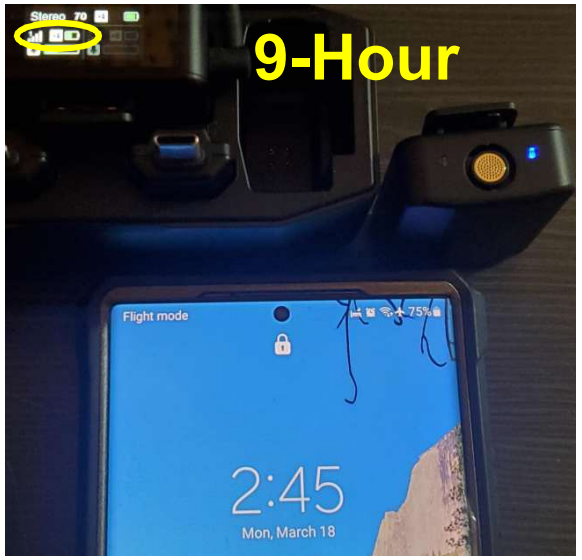
# Battery Life Test of VeGue W2 TX with BHWM257

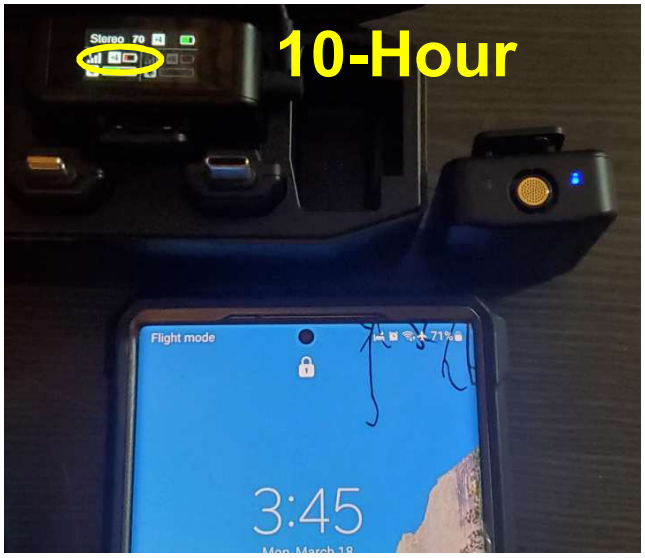
## Battery Life Test, TX Unit #1 (Un-Modified)

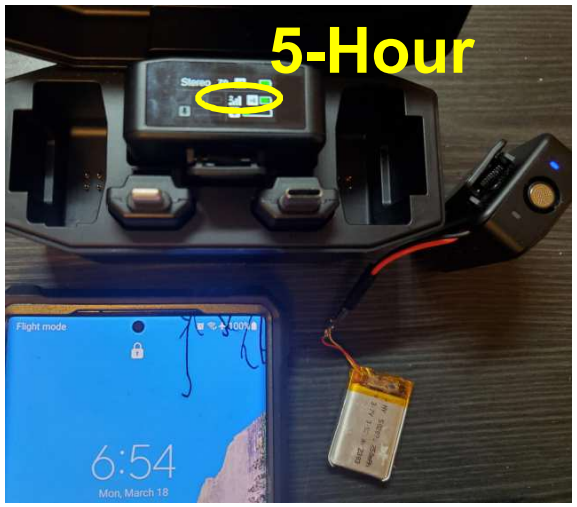




**Note: TX Unit #1 was set in default mode of transmit operation, with ENC OFF. RX remained inside the charger to support display ON. TX Unit #1 was operational for 10 hours without interruption, and automatically shut down slightly after that.**

# Battery Life Test of VeGue W2 TX with BHWM257

## Battery Life Test, TX Unit #2 (Battery Moved Outside)









**Note: TX Unit #2 was set in default mode of transmit operation, with ENC OFF. RX remained inside the charger to support display ON. TX Unit #2 was operational for 10 hours, and did not shut down even after 11 hours, although very close to battery depletion.**

# Battery Life & Capacity Comparison of 2.4GHz MICs

| Philips DL3538C (BHWM257) | VeGue W2 (BHWM257) | RODE Wireless GO II | Hollyland Lark150 | DJI MIC | SmallRig W60 |
|---|---|---|---|---|---|
|  |  |  | | | |
| RX TX | RX TX | RX TX | RX TX | RX TX | RX TX |
| 8Hrs 8Hrs | 8Hrs 8Hrs* | 7Hrs 7Hrs | 7Hrs 4Hrs | 5Hrs 5Hrs | 8Hrs 8Hrs |

*10Hrs Measured, ENC OFF

Note: Typical Data from Public Domain, May Vary Depending on Actual Use Cases.



**Battery Capacity:**

| RX: 250mAh<br>TX: 250mAh | RX: 300mAh<br>TX: 250mAh | RX: 350mAh<br>TX: 350mAh | RX: 530mAh<br>TX: 200mAh | RX: 320mAh<br>TX: 320mAh | RX: 630mAh<br>TX: 450mAh |
|---|---|---|---|---|---|

***BHWM257 PA-Lite FEM Enables Best-Class Operation Life with Smallest Batteries***

# BHW RF Front-End Solutions AppNote Library

**In addition to standard datasheets and EVB/BOM info, BHW publishes an AppNote series that address various topics on RF front-end design and performance over a wide frequency range from 300MHz to 6GHz, as an effort to assist customers in developing cutting-edge, cost-competitive products:**

- BHW AppNote #001 - Cross-Over Cascade of BHWM253 to Boost Tx Power and Rx Sensitivity of 2.4GHz Systems
- BHW AppNote #002 - Accurate Benchmark of GNSS CN0 Using the Power-Splitter Method
- BHW AppNote #003 - Boosting Wi-Fi Tx Power and Rx Sensitivity with BHWA251 and BHWM252
- BHW AppNote #004 - UHF 900MHz RF Front-End Solution Using BHWA251 Half-Watt PA and BHWL160 Sub-1dB-NF LNA
- BHW AppNote #005 - Sub-1GHz Applications of BHWA350 2-in-1 Wideband Fully Matched Amplifier
- BHW AppNote #006 - Low-Noise High-IIP3 LNB Architecture for Dual-Band High-Precision GNSS Using Cascade of BHWL160
- BHW AppNote #007 - UWB RF Front-End Solution Using BHWA350 and BHWM552
- BHW AppNote #008 - High-Power 5.8GHz RF Front-End Solution Using BHWA555 and BHWM552 for ETC, V2X and Wireless Video
- BHW AppNote #009 - 5.8GHz RF Front-End Using BHWA350 and BHWM552 for Wireless Audio
- BHW AppNote #010 - Multi-Constellation GNSS Active Antenna Using BHWL161 Cascade and Single-Fed Dual-Band Antenna
- BHW AppNote #011 - BHWL161 Super-Compact Low-Power Low Noise Amplifier for Range Extension of 2.4GHz RC and IoT
- BHW AppNote #012 - Enabling Cost-Effective High-Precision GNSS Using BHWL161 and Linear-Polarization PCB Antenna
- BHW AppNote #013 - Improving RF Range and Battery Life of 2.4GHz Wireless Systems with BHWM257 Compact FEM
- BHW AppNote #014 - Designing Ultra Low-Power High-Performance GNSS Products Using BHWL160 GaAs PHEMT LNA
- BHW AppNote #015 - BHWL161 GNSS Full-Band High-Performance LNA in Super-Compact 1x1mm DFN with Relaxed Pin Pitch
- BHW AppNote #016 - Improving GNSS NF Measurement Accuracy Using Broadband LNA BHWL161 as Pre-Amp
- BHW AppNote #017 - High-Efficiency, Low-NF 2.4GHz Front-End Solution for IoT Using BHWA251 and BHWM252
- BHW AppNote #018 - Optimizing BHWA555 Wideband One-Watt PA for Long-Range 5.8GHz Transmitter Applications
- BHW AppNote #019 - Miniature 2.4GHz RF Front-End with Integrated Chip Antenna and BHWM253 for TWS and IoT
- BHW AppNote #020 - Multiplying the Range for 2.4GHz Music Streaming with BHWR250L Active Integrated Antenna (AiA)
- BHW AppNote #021 - Range Extension for 2.4GHz Wireless Systems with BHWR250M Active Integrated Antenna (AiA)
- BHW AppNote #022 - Enabling Long-Range Angle-of-Arrival for High-Precision Indoor Positioning with BHWR250N RF AiA
- BHW AppNote #023 - Extend the Range for 5.8GHz Audio/Video Streaming with BHWR580M Active Integrated Antenna (AiA)
- BHW AppNote #024 - Improving 5.8GHz Radio Link Budget with BHWR580L Active Integrated Antenna (AiA)
- BHW AppNote #025 - Improving Range and Throughput of 2.4GHz Wi-Fi with BHWR250 Array Antenna
- BHW AppNote #026 - Improving Range and Throughput of 5GHz Wi-Fi with BHWR550 Array Antenna
- BHW AppNote #027 – Coin-Cell and Batteryless 1km Long Range NanoBeacon with BHWR250A AiA and Energy Harvesting
- BHW AppNote #028 - Use BHWM252 Cascade to Extend Range of 2.4GHz Wireless Systems with Single-Port SoCs
- BHW AppNote #029 - Improving Range of 2.4GHz Wireless Microphones and Audio Systems with BHWR250A Active Integrated Antenna (AiA)
- BHW AppNote #030 - Simultaneous Improvement in Range and Battery Life of 2.4GHz Wireless Systems with BHWR250M AiA

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