

# W

BT-202

## Bluetooth HADM: Perfecting Location-Centric Services.

Priyanka Sukumar | August 22<sup>nd</sup>, 2023



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# High Accuracy Distance Measurement

# HADM – Beyond RSSI



## Accuracy & Reliability

RSSI is sensitive to indoor multipath environment



## Simplicity

Enable design of low-cost devices  
Single antenna design  
Reduce system resources



## Security

Attacker manipulation of RSSI via RF signal amplification



## Interoperability

Standards Based Feature

# HADM – Target Applications



## PROXIMITY AWARENESS

- Door locks
- Keyless entry
- Building access systems
- Geofencing - security alerts



## LOCALIZATION

- Indoor asset management – hospitals, warehouses
- Pet tracking inside homes
- Item finding - wallet, keys, tools



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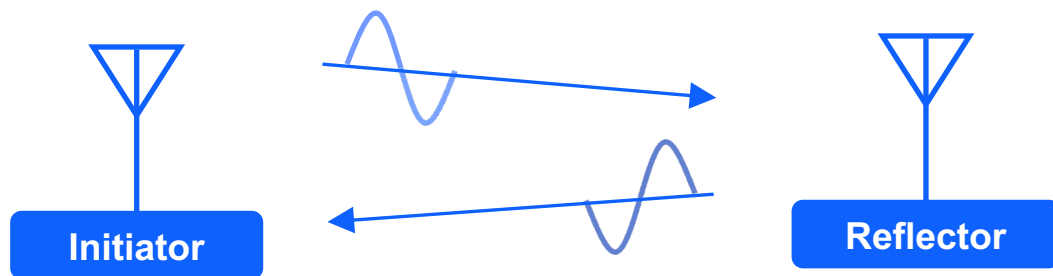
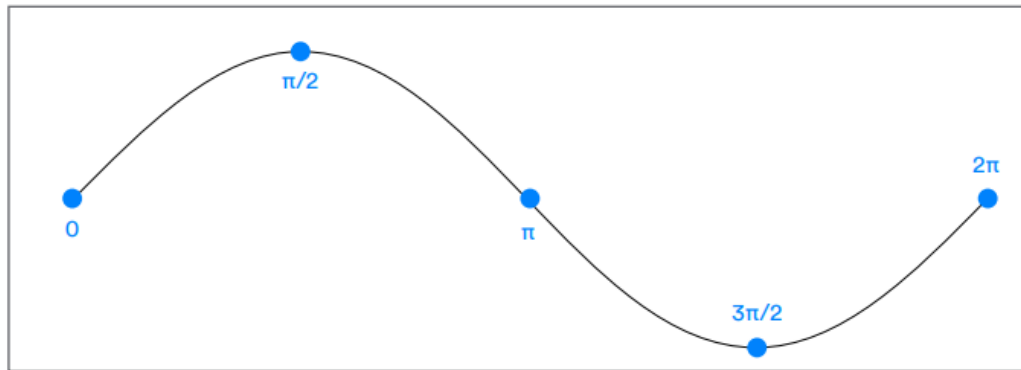
# Range Estimation Techniques

Draft Specifications publicly available at:  
[www.bluetooth.com/specifications/specs/channel-sounding/](http://www.bluetooth.com/specifications/specs/channel-sounding/)

# Phase-Based Ranging (PBR)

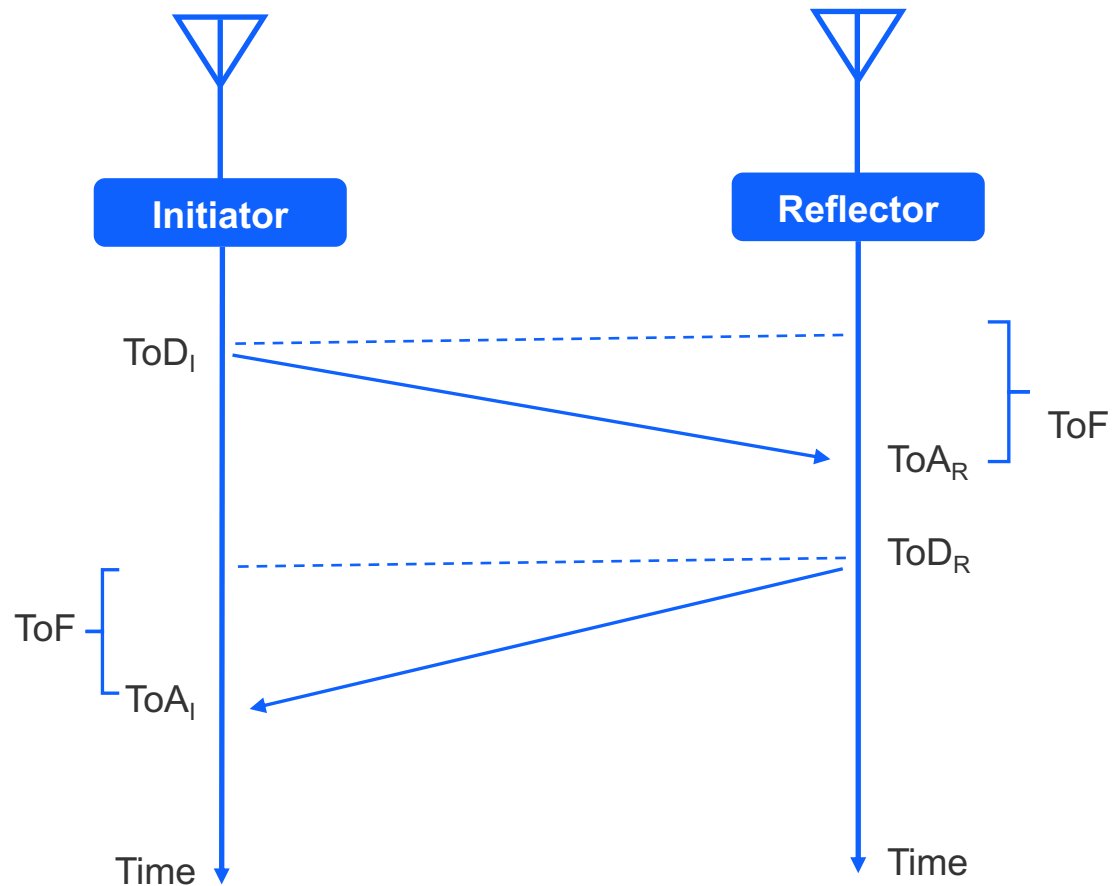
## Phase

A specific point in a wave cycle, perhaps measured as the wave passes over an antenna, is known as its *phase*. Phase is measured as an angle from 0 at the start of the wave cycle to 360 degrees or  $2\pi$  radians at the end of the wave cycle. Figure 8 illustrates the concept of phase.



- Tone exchange between two devices
- Phase of RF signals is a function of the frequency of the carrier and the distance traveled
  - Phase rotation due to spatial propagation determined
  - Measurements at multiple RF frequencies to resolve distance ambiguity
- Distance is calculated using the phase difference between the transmitted and received signal
- Security
  - Manipulation of phase is more complex than RSSI
- Higher accuracy than RSSI

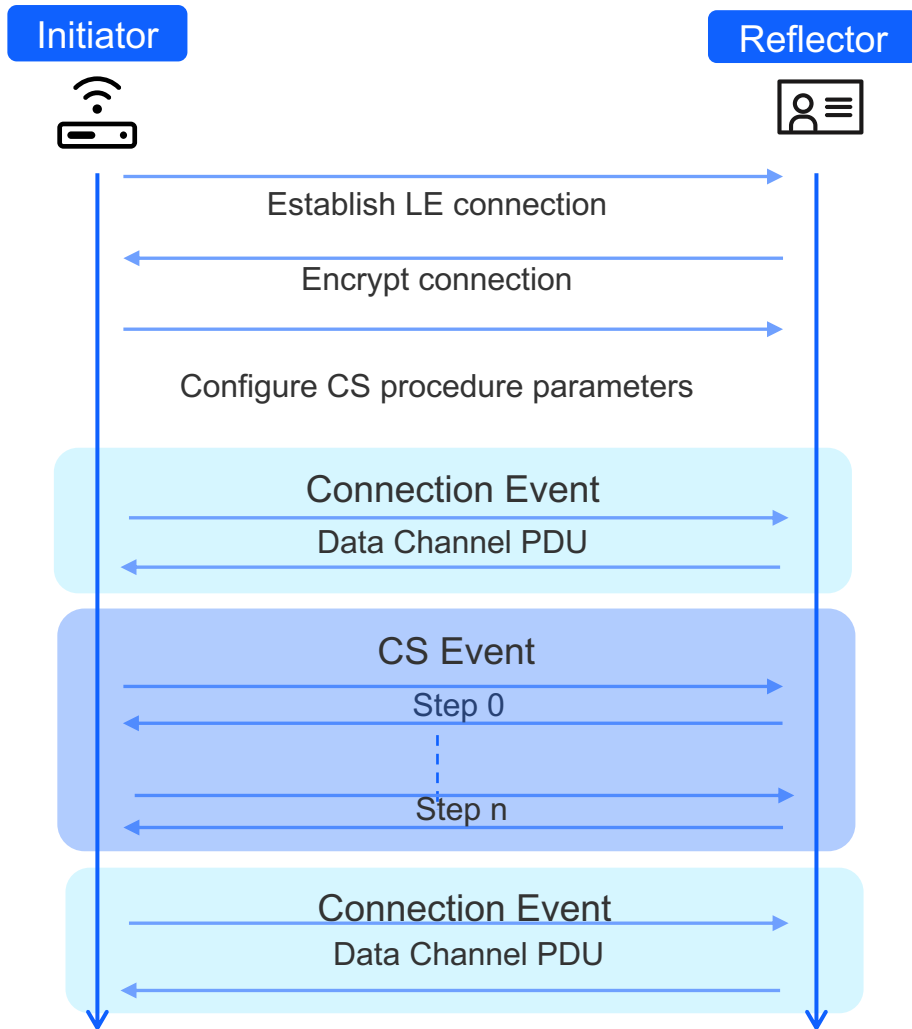
# Round Trip Timing (RTT)



$$RTT = 2 ToF = (ToA_I - ToD_I) - (ToD_R - ToA_R)$$

- Packet transmission time (ToF) is measured on both the initiator and reflector side using Time-of-Arrival (ToA) and Time-of-Departure (ToD)
  - Modulated packets exchanged over multiple channels to determine ToF and estimate distance
  - Fractional timing techniques used to resolve sampling uncertainty and improve resolution
- Time cannot be reversed -> RTT increases security
- PBR is more accurate than RTT

# Measurement Procedure Explained



- Connection-based 2-way ranging with encrypted Bluetooth LE connection events and secure CS events
  - Reflector exposes received signal info via GATT service.
- Interchangeable device roles (central, peripheral) and CS roles (initiator, reflector)
- Initiator configures CS procedure parameters
  - Number of channels, channel map(randomized), TX power
  - Allowed duration of connection interval, CS event
  - Measurement modes – PBR, RTT
  - Trade-offs between accuracy, duration, power, number of channels
- CS Event
  - Calibration – frequency offset
  - Modulated packets or tones exchanged over multiple channels
  - Channel mapping is randomized to prevent attackers
- Distance Estimation
  - Initiator parses the measured data - IQ samples, time
  - Signal processing – averaging, filtering outliers, detecting multipath, etc



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The word 'Results' is centered within a grey trapezoidal shape that overlaps the 'w' graphic. The text is in a black, sans-serif font.

Results

# Performance in Indoor Office Environment



- **Ceiling rail infrastructure**

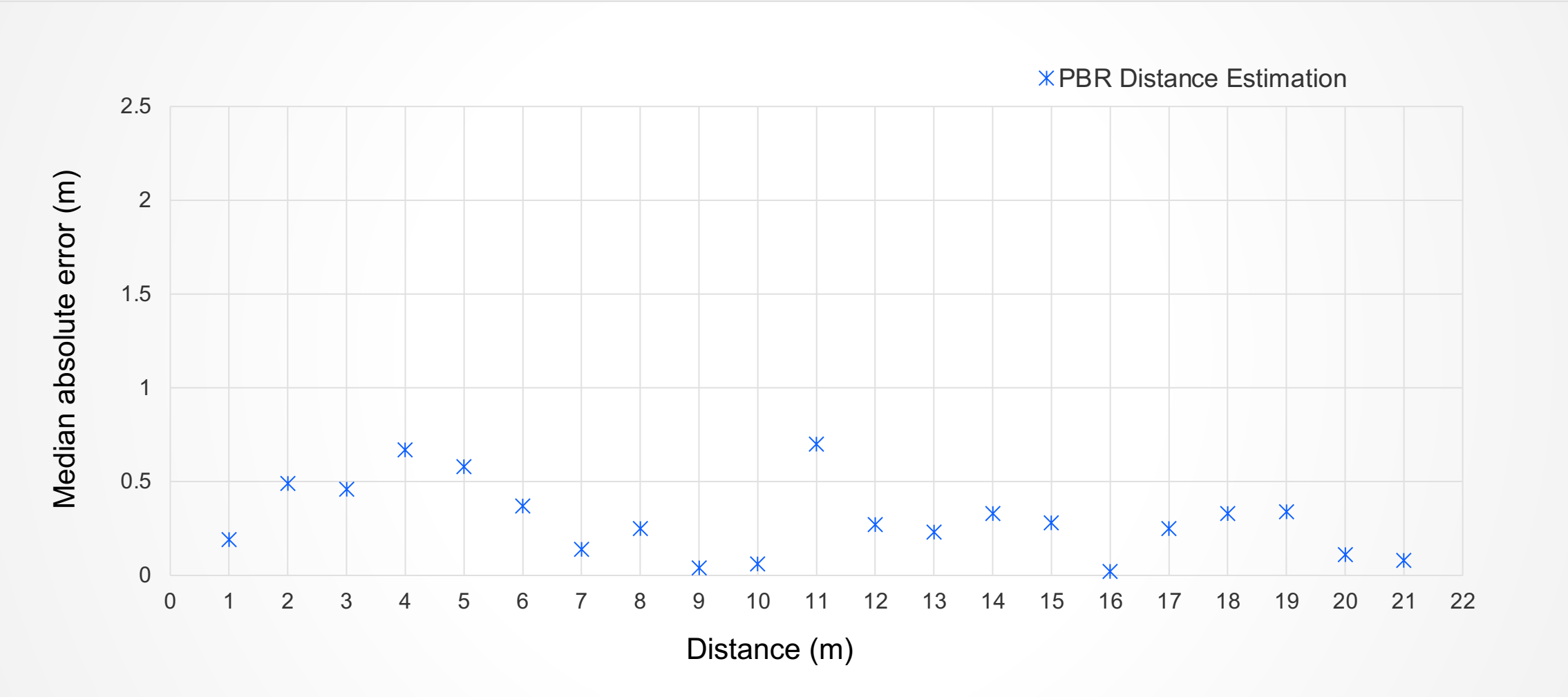
- Internal test environment
- Multiple stationary EFR32 devices placed at different locations
- Mobile EFR32 device for controlled measurements (repeatability)

- **Challenges - heavy multi-path in an indoor office setting**

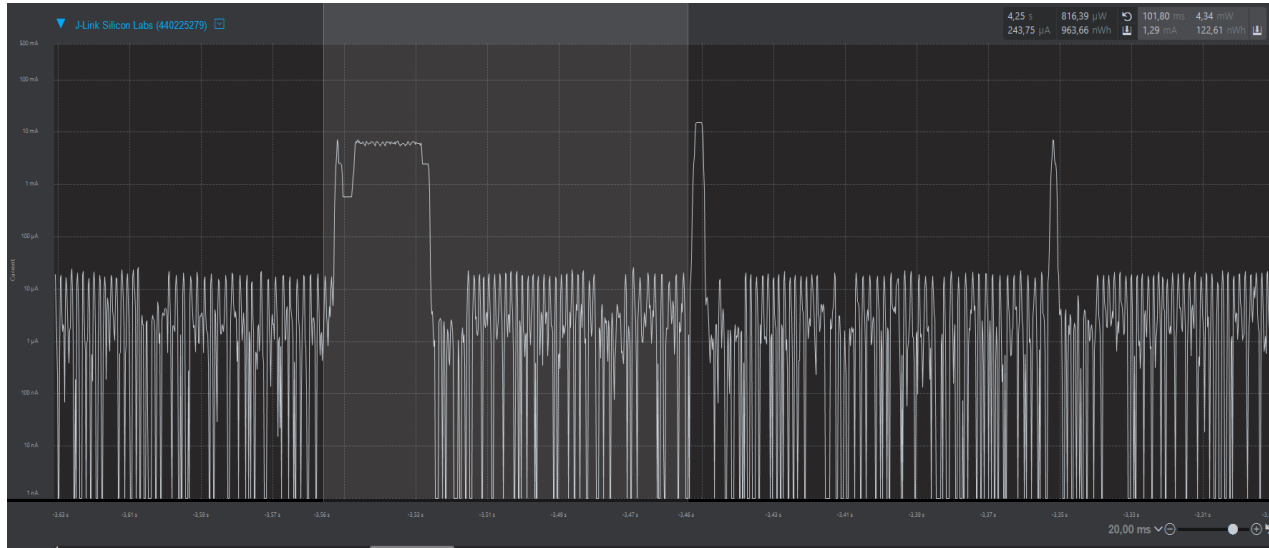
- **Statistical analysis**

- Static measurements at multiple distances up to 30 meters
- Hundreds of measurements per distance to determine min/max, mean, median, std, absolute error

# Indoor Performance Result – PBR

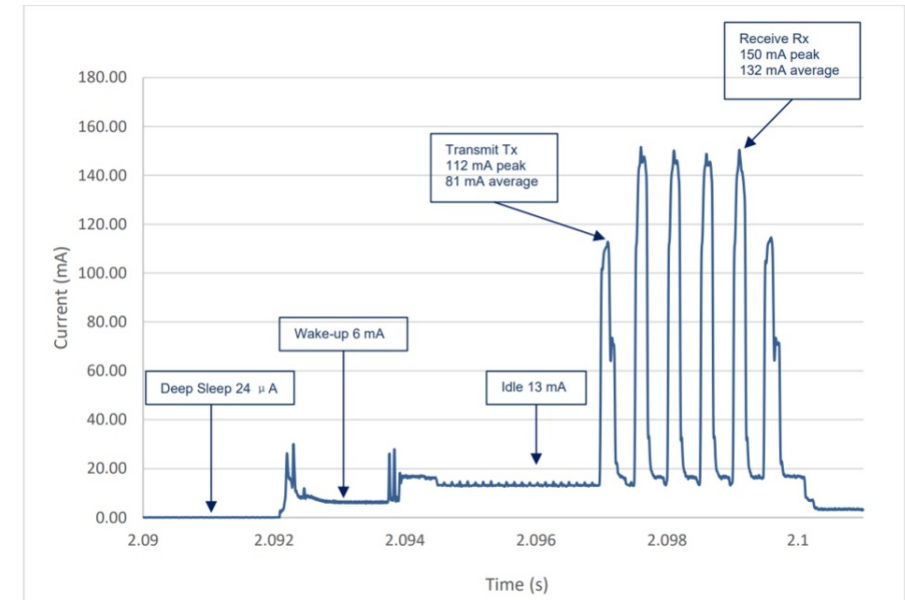


# Power Consumption – HADM vs UWB



PBR	Time (ms)	Current
Sleep	71.80	4.16 $\mu$ A
Measurement	27.60	4.74 mA

**Average power consumption over 100 ms = 1.31 mA**



UWB	Time (ms)	Current
Sleep	89.89	24 $\mu$ A
Measurement	10.11	26.03 mA

**Average power consumption over 100 ms = 2.68 mA**

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# Silicon Labs Offerings

# BG24 and BGM241S: 2.4 GHz SoC Ideal for Bluetooth Location Services

## SOCS AND MODULES



BG24 SoC



BGM241S SiP Module

## SOC DEVICE SPECIFICATIONS

### High-Performance Radio

- Up to +19.5 dBm TX
- -97.6 dBm RX @ BLE 1 Mbps

### Efficient ARM® Cortex®-M33

- 78 MHz
- 1536kB Flash, 256kB RAM

### Low Power

- 33.4  $\mu$ A/MHz
- 5.0 mA TX @ 0 dBm
- 5.1 mA RX (802.15.4)
- 4.4 mA RX (BLE 1 Mbps)
- 1.3  $\mu$ A EM2 sleep

### Multiple protocol support

- Bluetooth (1M/2M/LR)
- Bluetooth mesh
- Proprietary 2.4 GHz

### SoCs and Modules

- 5x5 QFN40
- 6x6 QFN48
- 7x7 SiP Module
- 12.9x15.0 PCB Module

## DIFFERENTIATED FEATURES

### +20 dBm output power

- Eliminates need for external power amplify

### High Accuracy Distance Measurement

- Measures distance between connected LE devices w/ sub-meter accuracy

### AI/ML accelerator

- Accelerates inferencing while reducing power consumption

### Secure Vault High

- Protects data and devices from local and remote attacks

### 20-bit ADC

- 16-bit ENOB for advanced sensing

### Antenna Diversity

- Provides 6-8 dBm better link budget

### Improved Coexistence

- Ideal for gateways and hubs

### PLFRCO

- Eliminates need for 32 KHz xtal

## SEGMENTS AND APPLICATIONS

### SMART HOME

- HVAC
- Locks
- LED Lighting
- Switches
- Sensors
- Gateways, Hubs and Panels

### CONNECTED HEALTH

- Portable Medical

### INDUSTRIAL AND SMART BUILDINGS

- Access Control
- HVAC
- Predictive Maintenance

- Asset Tracking

### SMART CITIES

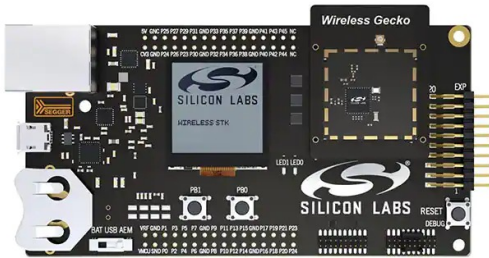
- EV Charging

### COMMERCIAL

- Lighting
- Access Points
- Clinical Medical
- Indoor Real Time Location Services

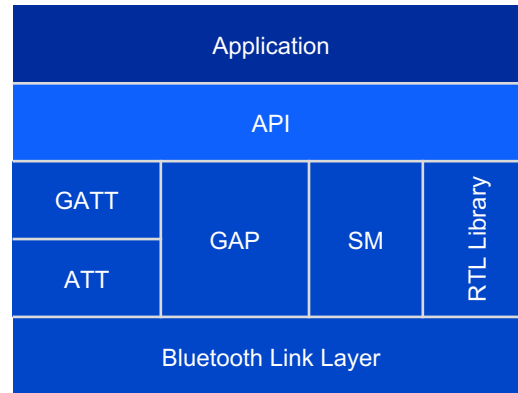
# Early Access and Application Development

Early Access already integrated into GSDK release in June 2023!



## SOC, DEV KITS

2x BRD4198A  
2x Dipole Antennas  
Wireless Pro Kit  
EFR32MG24 + 10dBm OPN



## STACK SOFTWARE

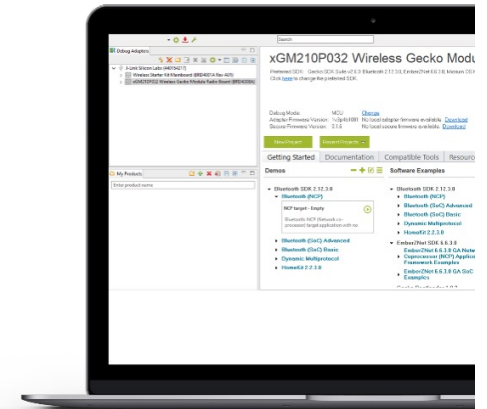
In-house developed stack  
Supports Bluetooth 5.4 features  
All security features supported  
New and improved Ranging features

```
exe --zsh -- 80x49
vevearati@mac0015025 bt_abr_host_initiator % cd exe
vevearati@mac0015025 exe % ./bt_abr_host_initiator -u /dev/tty.usbmodem0004402801
515
[E] Invalid operation mode selected. Please select either 1 (RTT) or 2 (PBR)
vevearati@mac0015025 exe % ./bt_abr_host_initiator -u /dev/tty.usbmodem0004402801
515 -# 2 -#
[I] Accepting any suitable reflector.
[I] NCP host initialised.
[I] Resisting NCP target...
[I] Press Ctrl+C to quit

[I] Initialising RTL...
[W] abr_report_PBR.json already exist!
[W] Renaming abr_report_PBR.json --> abr_report_PBR.json_bkp31-5-2023-17_13_43
[I] Renamed successfully.
[I] File logger initialized.
[I] Bluetooth stack booted: v6.0.0-b37
[I] Bluetooth public device address: 34:25:84:A8:D8:15
[I] Scanning...
[I] Opening connection to Reflector
[I] Connection opened to the Reflector
[I] Connection connection
[I] Connection encrypted
[I] Service found
[I] Service discovered
[I] Found remote value characteristic
[I] Characteristic discovered
[I] Creating ABR config...
[I] RTL process 48 channels
[I] Open file abr_report_PBR.json to write header...
[I] Config created
[I] Log measurement cycle 0000 ...
[I] Measurement result: 2051 mm | RSSI distance: 56 mm
[I] Log measurement cycle 0001 ...
[I] Measurement result: 1056 mm | RSSI distance: 40 mm
[I] Log measurement cycle 0002 ...
[I] Measurement result: 1068 mm | RSSI distance: 56 mm
[I] Log measurement cycle 0003 ...
[I] Measurement result: 1075 mm | RSSI distance: 107 mm
[I] Log measurement cycle 0004 ...
[I] Measurement result: 1082 mm | RSSI distance: 78 mm
[I] Log measurement cycle 0005 ...
[I] Measurement result: 1103 mm | RSSI distance: 107 mm
[I] Log measurement cycle 0006 ...
[I] Measurement result: 1115 mm | RSSI distance: 56 mm
[I] Log measurement cycle 0007 ...
[I] Measurement result: 1115 mm | RSSI distance: 56 mm
```

## HADM DEMO

Python based Visualization tool  
RTL Library  
(GATT, IQ reporting)  
EFR32xG24 NCP/SoC  
PBR, RTT modes



## DEVELOPMENT TOOLS

Simplicity Studio  
Initiator & Reflector Example  
Energy Profiler + Network Analyzer  
Quick Start Guide  
Salesforce Support

# Sample Applications – Out-of-Box Experience

The image displays a web application interface for the BG24 Ranging Radio Board (BRD4198A Rev A00). The interface includes a navigation menu with tabs for OVERVIEW, EXAMPLE PROJECTS & DEMOS, DOCUMENTATION, and COMPATIBILITY. A search bar is set to 'abr'. A sidebar on the left contains filters for Demos, Example Projects, Solution Examples, and various categories like Wireless Technology, Device Type, Ecosystem, MCU, Capability, Project Difficulty, and Quality. The main content area shows three resources found, including 'Bluetooth - ABR NCP', 'Bluetooth - SoC ABR initiator', and 'Bluetooth - SoC ABR reflector'. A terminal window in the foreground shows the execution of a program, displaying logs for initialization, connection, and measurement cycles. A graph on the right plots Distance (m) on the y-axis (0.0 to 3.0) against measurement cycles. The graph shows a blue line fluctuating around a mean value of 1.08 m, with a legend indicating 'HADM : 1.08 m'.

```
vevarati@mac0015025 exe % ./bt_abr_host_initiator -u
[!] Accepting any suitable reflector.
[!] NCP host initialised.
[!] Resetting NCP target...
[!] Press Ctrl+C to quit

[!] Initialising RTL...
[!] File logger initialized.
[!] Bluetooth stack booted: v6.0.0-b37
[!] Bluetooth public device address: 34:25:B4:A0:D0:1
[!] Scanning...
[!] Opening connection to Reflector
[!] Connection opened to the Reflector
[!] Encrypting connection
[!] Connection encrypted
[!] Service found
[!] Service discovered
[!] Found remote value characteristic
[!] Characteristic discovered
[!] Creating ABR config...
[!] RTL process 40 channels
[!] Open file abr_report_PBR.jsonl to write header...
[!] Config created
[!] Log measurement cycle 0000 ...
[!] Measurement result: 596 mm
[!] Log measurement cycle 0001 ...
[!] Measurement result: 530 mm
[!] Log measurement cycle 0002 ...
[!] Measurement result: 509 mm
[!] Log measurement cycle 0003 ...
[!] Measurement result: 516 mm
[!] Log measurement cycle 0004 ...
[!] Measurement result: 517 mm
[!] Log measurement cycle 0005 ...
[!] Measurement result: 515 mm
[!] Log measurement cycle 0006 ...
[!] Measurement result: 507 mm
[!] Log measurement cycle 0007 ...
[!] Measurement result: 509 mm
[!] Log measurement cycle 0008 ...
[!] Measurement result: 507 mm
[!] Log measurement cycle 0009 ...
[!] Measurement result: 508 mm
[!] Log measurement cycle 0010 ...
```



# BG24: Supported Features



Feature	Now	Dec 2023	2024 *
Phase based ranging	Yes	Yes	Yes
RTT based ranging	Yes	Yes	Yes
Simultaneous connections	1	4	4+
TX Power	0 dBm	0 dBm 10 dBm	0 dBm 10 dBm
Initiator	Yes	Yes	Yes
Reflector	Yes	Yes	Yes
Antenna switching	No	No	Yes
Bluetooth Qualified	No	No	Yes

\* Subject to change

# Get Started Right Away



**CONTACT SALES**

Work with Silicon Labs Sales and get access to hardware



**DOWNLOAD**

Download Simplicity Studio 5



**HADM IN ACTION**

See our accurate, reliable and simple distance estimating solution in action !

W/

THANK YOU

