

推动蓝牙6.0 Channel Sounding走向实际应用

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2025
tech talk
WEBINAR SERIES



BLUETOOTH

Agenda

Technology Overview

Channel Sounding Applications

Silicon Labs Offerings

Algorithm Performance Data

Developer Tools

Q&A

蓝牙Channel Sounding带来物联网新机遇

THE CHALLENGE:

IOT applications need 'spatial' awareness to be more secure, reliable, and responsive



Earlier Bluetooth LE versions lack native support for precise ranging



RSSI-based ranging is noisy and unreliable in real-world use



Direction Finding needs complex antennas, adding cost & complexity



UWB is accurate but often too costly, and bulky for IoT

THE OPPORTUNITY:

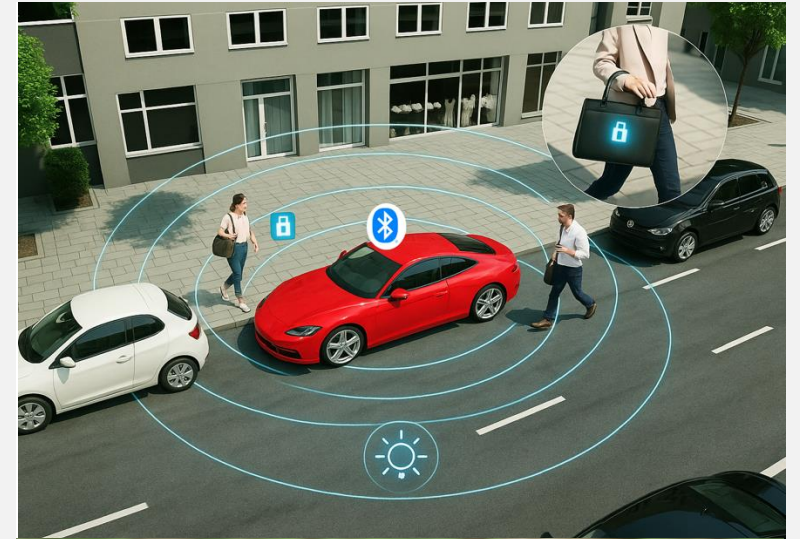
Channel Sounding for Bluetooth

Standardized approach for accurate, secure ranging in Bluetooth 6.0

Enables sub-meter accuracy with robust performance, even in NLOS

Works with single or dual antenna setups - flexible for different form factors

More cost efficient than UWB; requires minimal external components



Built on existing Bluetooth infrastructure, simplifying adoption and ecosystem integration

Bluetooth® Channel Sounding 概览

- **Measure distance between two devices using**
 - Phase-based Ranging (PBR)
 - Round Trip Time (RTT)
- **RTT and PBR operates across 2.4 GHz band**
 - Standard specifies up to 72 channels
 - Random channel hopping pattern
- **Connection-Oriented 2-way ranging with two roles**
 - Initiator: device that wishes to calculate distance from itself to another device
 - Reflector: device responding to initiator
- **Supports up to 4 antenna paths between devices**
 - 8 possible antenna combinations
- **Multiple security features included in the standard**
- **Can be combined with Angle of Arrival / Departure (AoA/AoD)**
 - Enables position estimation with single locator/tag pair

Additional Resources

- [Webpage](#) – Learn more about Silicon Labs offerings and demos
- [Tech Talk](#) – Explore Bluetooth Channel Sounding
- [Workswith 2024](#) - Enable Accurate Distance Estimation Using Channel Sounding
- [Blog](#): Learn more about Antenna Switching with Silicon Labs Channel Sounding
- [API Spec](#): Getting Started with Silicon Labs Bluetooth Channel Sounding

测距定位技术对比

	RSSI	UWB	Angle of Arrival	Channel Sounding
Localization metric	Resolve distance estimation from transmitter signal strength	Resolve distance between two points using high-resolution time-of-flight (ToF)	Resolve direction vector between two points	Resolve distance between two points using time of flight and phase-based ranging
Antenna requirements	Single antenna	Often complex hardware	Multi-antenna required by spec	Single or dual antenna
Connectivity	Connection-oriented and connectionless	Connectionless	Connection-oriented and connectionless	Connection-oriented
Performance metrics	+/- 5 m, high susceptibility to multipath interference	High accuracy (~10–30 cm)	+/- 3 degrees accuracy – azimuth +/- 5 degrees accuracy – elevation	+/- .3 m < 5m with PBR +/- 0.5 m > 5m with PBR
Solution advantages	Ubiquitous support for RSSI measurements in existing Bluetooth LE products	<ul style="list-style-type: none"> • High Precision • Low Latency 	<ul style="list-style-type: none"> • Scalable solution for real time position tracking • Supports 5-10 year battery life 	<ul style="list-style-type: none"> • Small form factor with flexible antenna design • Feature-add for security by proximity
Solution disadvantages	Highly susceptible to RF noise and multipath	Expensive and complex integration	<ul style="list-style-type: none"> • Needs complex antenna setup and calibration 	Scalability

Bluetooth® Channel Sounding – 目标市场与应用



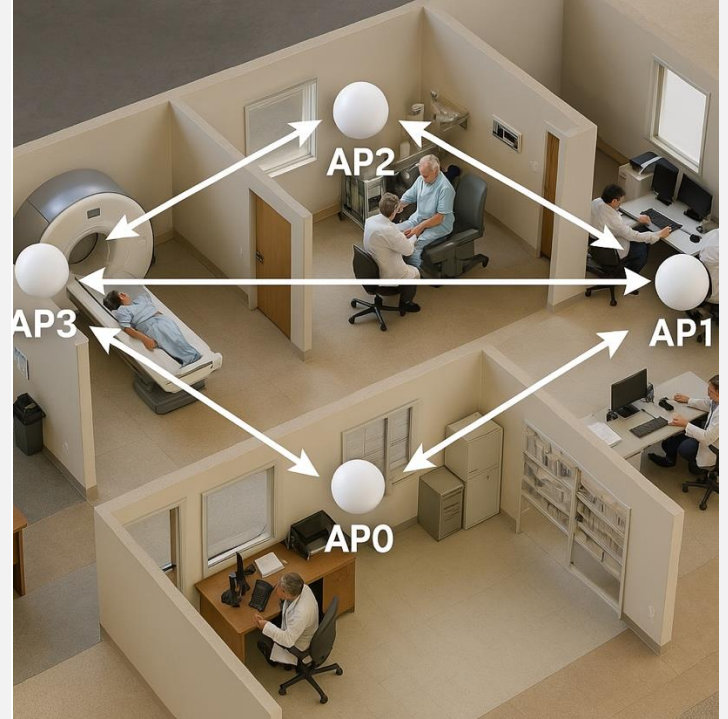
PROXIMITY AWARENESS

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



LOCALIZATION

- Indoor asset management - hospitals, warehouses
- Pet tracking
- Item finding - wallet, keys



AUTOMAPPING

- Solar Trackers
- Luminaires, Access Points
- Accurate Mapping for Battery Storage

BG24: Optimized for Battery Powered, Channel Sounding-enabled IoT Devices



- 5x5 QFN40 (26 GPIO), AEC-Q100
- 6x6 QFN48 (32 GPIO), AEC-Q100
- 3.1x3.0 WLCSP42

DIFFERENTIATED FEATURES

- **Ultra small form-factor**
 - 3.1 x 3.0 WLCSP package
- **+20 dBm output power**
 - Eliminates need for external power amplify
- **AI/ML accelerator**
 - Accelerates inferencing while reducing power consumption
- **Secure Vault High**
 - Protects data and device from local and remote attacks
- **20-bit ADC**
 - 16-bit ENOB for advance sensing
- **Improved Coexistence**
 - Ideal for gateways and hubs
- **PLFRCO**
 - Eliminates need for 32 KHz xtal

DEVICE SPECIFICATIONS

- **High Performance Radio**
 - Up to +19.5 dBm TX
 - -97.6 dBm RX @ BLE 1 Mbps
- **Efficient ARM® Cortex®-M33**
 - Up to 78 MHz
 - 1536kB Flash, 256kB RAM
- **Low Power**
 - 49.1 μ A/MHz (CoreMark)
 - 5.0 mA TX @ 0 dBm
 - 5.1 mA RX (802.15.4)
 - 4.4 mA RX (BLE 1 Mbps)
 - 1.3 μ A EM2 sleep
- **Multiple protocol support**
 - Bluetooth 6.0 (1M/2M/LR), Bluetooth mesh, Proprietary 2.4 GHz

BG24L: Channel Sounding Optimized, High-Performance & Low-Cost AI/ML Wireless SoC



- 5x5 QFN40 (26 GPIO)

DIFFERENTIATED FEATURES

- **Supports Bluetooth 6.0**
 - Channel Sounding optimized BLE SoC
 - Single-connection two-way ranging
 - Ideal Solution for Channel Sounding tags
- **Lowest Power RF**
 - Increases battery life
- **PLFRCO**
 - Eliminates need for 32 KHz XTAL and lowers overall system cost
- **16-bit ADC**
 - Up to 14-bit ENOB for better analog sensing
- **AI/ML accelerator**
 - Accelerates inferencing while reducing power consumption
- **Secure Vault Mid**
 - Protects data and device from local and remote attacks
- **Improved Coexistence**
 - Ideal for gateways and hubs

DEVICE SPECIFICATIONS

- **High Performance Radio**
 - Up to +10 dBm TX
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 - Up to 78 MHz
 - 768kB Flash, 96kB RAM
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 - 49.1 µA/MHz (CoreMark)
 - 5.0 mA TX @ 0 dBm
 - 5.1 mA RX (802.15.4)
 - 4.4 mA RX (BLE 1 Mbps)
 - 1.3 µA EM2 (16kB RAM retention)
- **Wide Operating Range**
 - 1.71 to 3.8 volts
 - +125°C operating temperature
- **Multiple protocol support**
 - Bluetooth 6.0 (1M/2M/LR), Bluetooth mesh, Proprietary 2.4 GHz

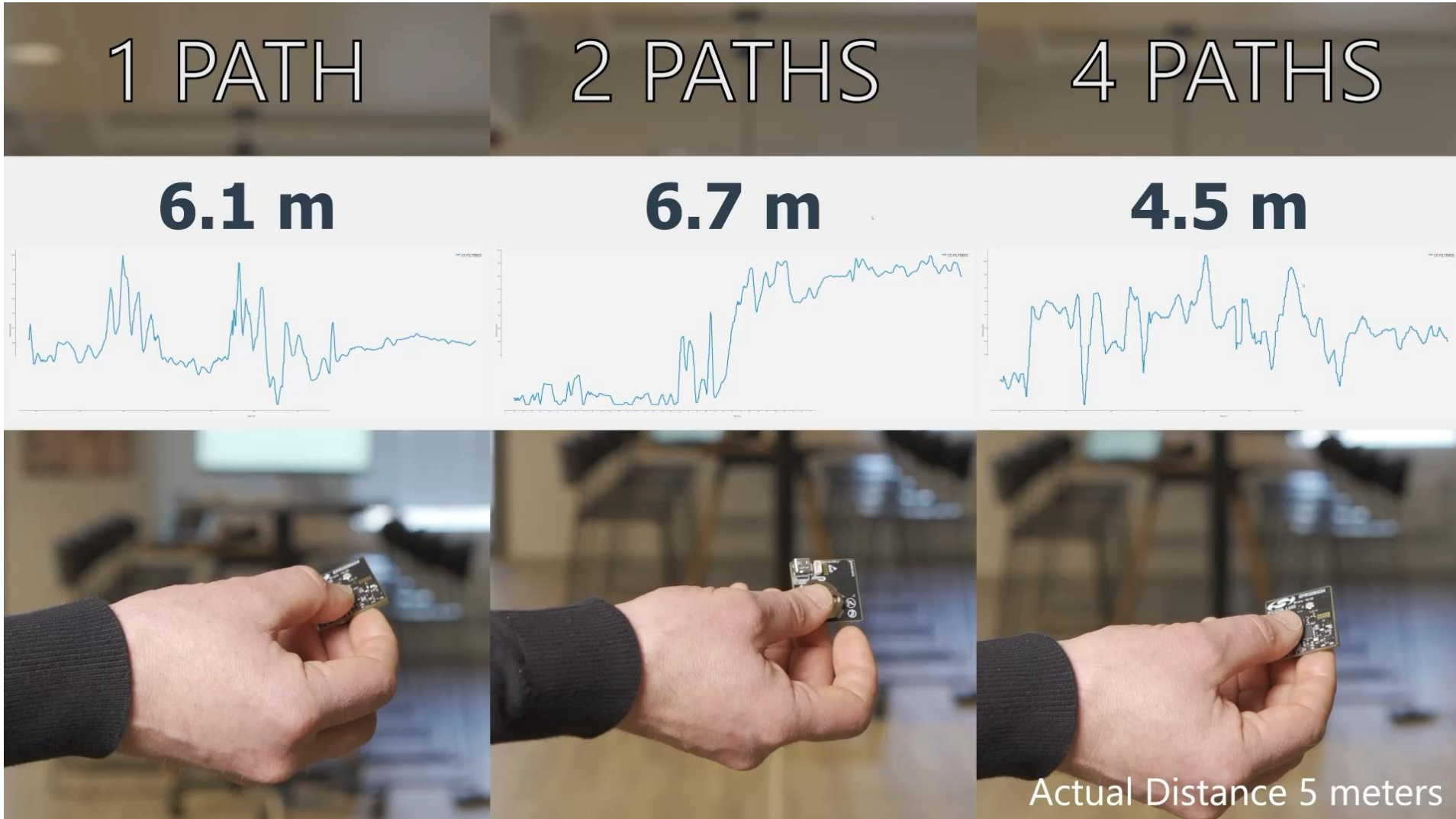
Bluetooth® Channel Sounding 双天线开发板



■ xG24 Channel Sounding Development Kit

- Available since March 2025
- Development Kit with two PCB antennas
 - Antenna diversity offers increased robustness and accuracy
- Intra-event antenna switching for optimal non-line of sight performance
- Includes IMU sensor to detect movement & wake-up the tag
- Small form factor
 - Ideal for size-constrained applications like key fobs
- AEC-Q100 Compliant
- SoC/NCP Sample Apps
 - Initiator and Reflector examples supported
- Ranging Library
 - Process IQ samples, post-filtering, and compute distance using configurable algorithm

天线分集 – What does it bring?



Silicon Labs Channel Sounding 算法

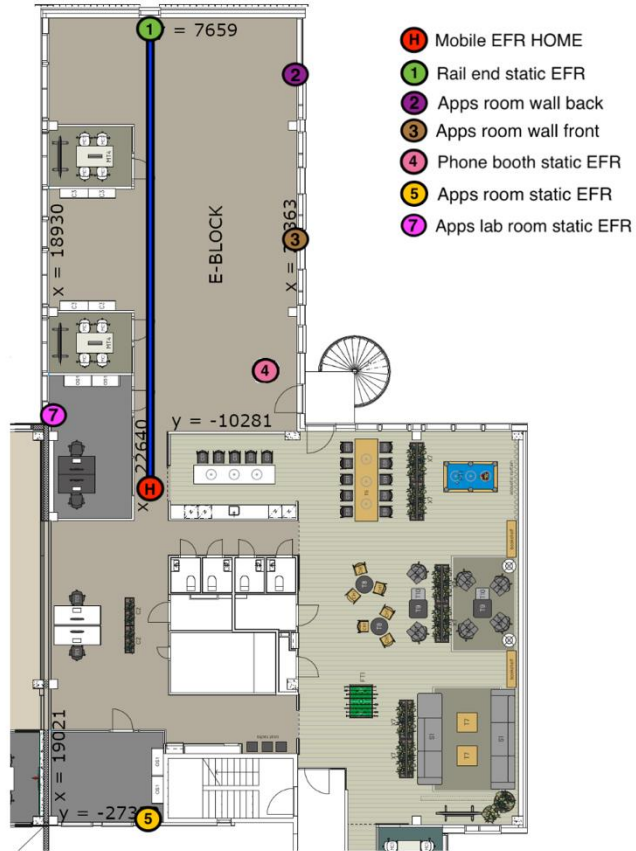
▪ Algorithm Features

- Supports Multiple Channel Sounding Ranging Modes
 - PBR, RTT, PBR with RTT as sub mode
- Antenna Switching
 - Built-in support for antenna diversity
 - Supports 1, 2 and 4 antenna paths
- Supported Algorithm modes
 - Static mode – Delivers the highest accuracy with high measurement latency; optimized for ranging between stationary devices
 - Real Time Basic – Provides high accuracy with increased computational and measurement latency; supports tracking at speeds up to 1 m/s
 - Real Time Fast – Balances moderate accuracy and range with low latency; supports tracking at speeds up to 2.1 m/s, additionally produces velocity metric
- Configurable Channel Selection (72, 37, or 20 Channels)
 - Selectable based on accuracy needs and power constraints

▪ Key Benefits

- Licensing cost free
 - Eliminates third-party royalties, simplifying BOM cost structure
- Optimized HW-SW Co-Design
 - Tight coupling between silicon & firmware ensures seamless performance & efficiency
- Single-Vendor Lifecycle Support
 - Unified hardware & software ownership streamlines debugging, validation, and updates

算法性能测试环境



Node Pairs	Distance (in m)	Obstacles
H & 1	20	Line-of-Sight
H & 4	7.9	Walls, Kitchen
1 & 4	14.84	Cubicles, Luminaires
1 & 5	33.9	Walls, Glass door



Algorithm Performance Data¹

Algorithm Mode	LOS 90 th Pct. Absolute Error (in m)	LOS 95 th Pct. Absolute Error (in m)	NLOS 90 th Pct. Absolute Error (in m)	NLOS 95 th Pct. Absolute Error (in m)	Computation time (in ms)
STATIC_HIGH_ACCURACY	0.5	0.6	1.7	2.7	20000 ²
REAL_TIME_BASIC	0.5	0.6	1.9	4.2	188
REAL_TIME_FAST	0.4	0.5	4.0	5.3	20

1. CS mode – PBR, CS channels – 72, number of antenna paths – 4
2. ~100 CS Procedures used to produce single distance estimate

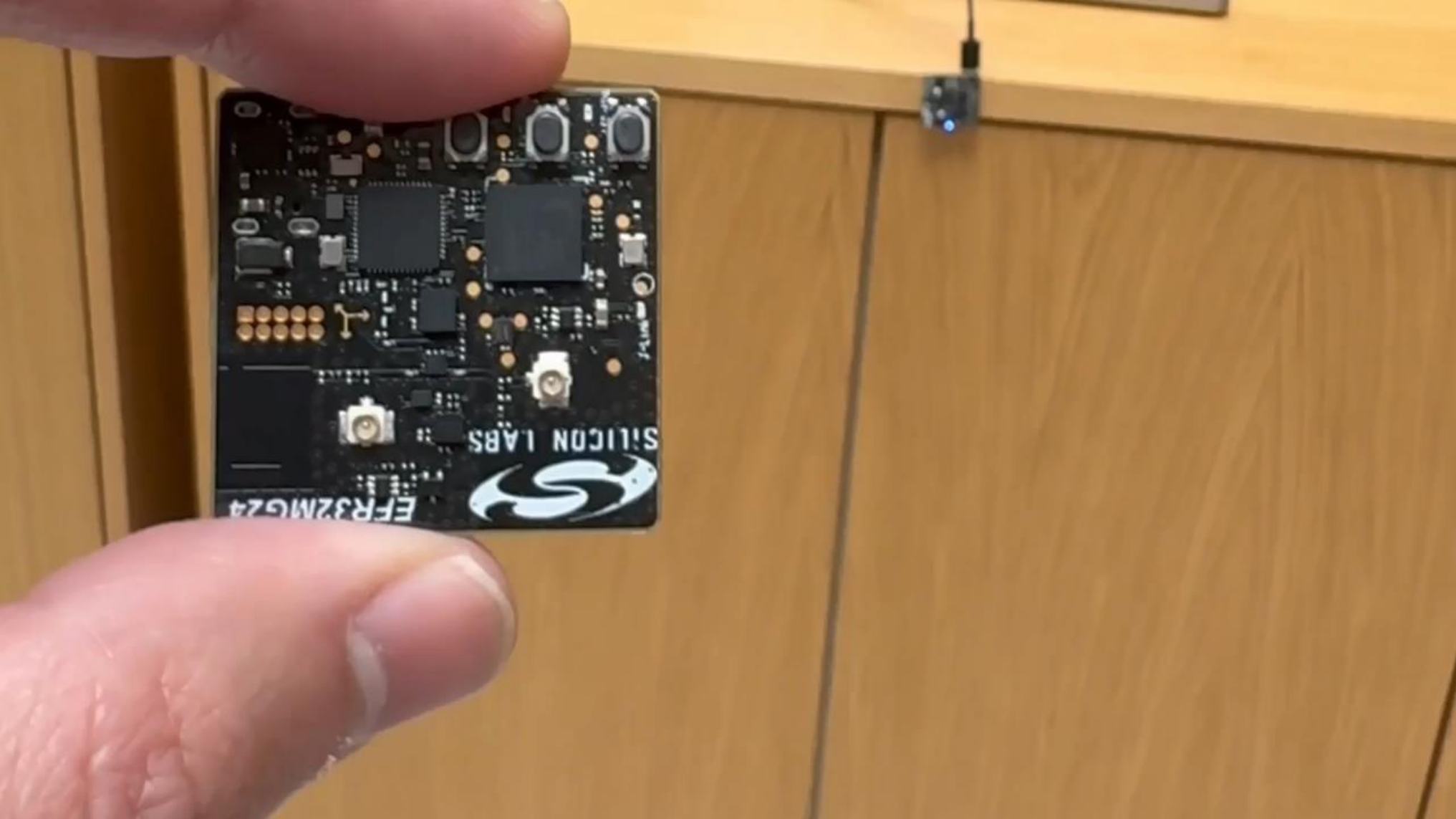
Fit For Purpose Algorithm Modes

Energy Consumption Profile – Reflector

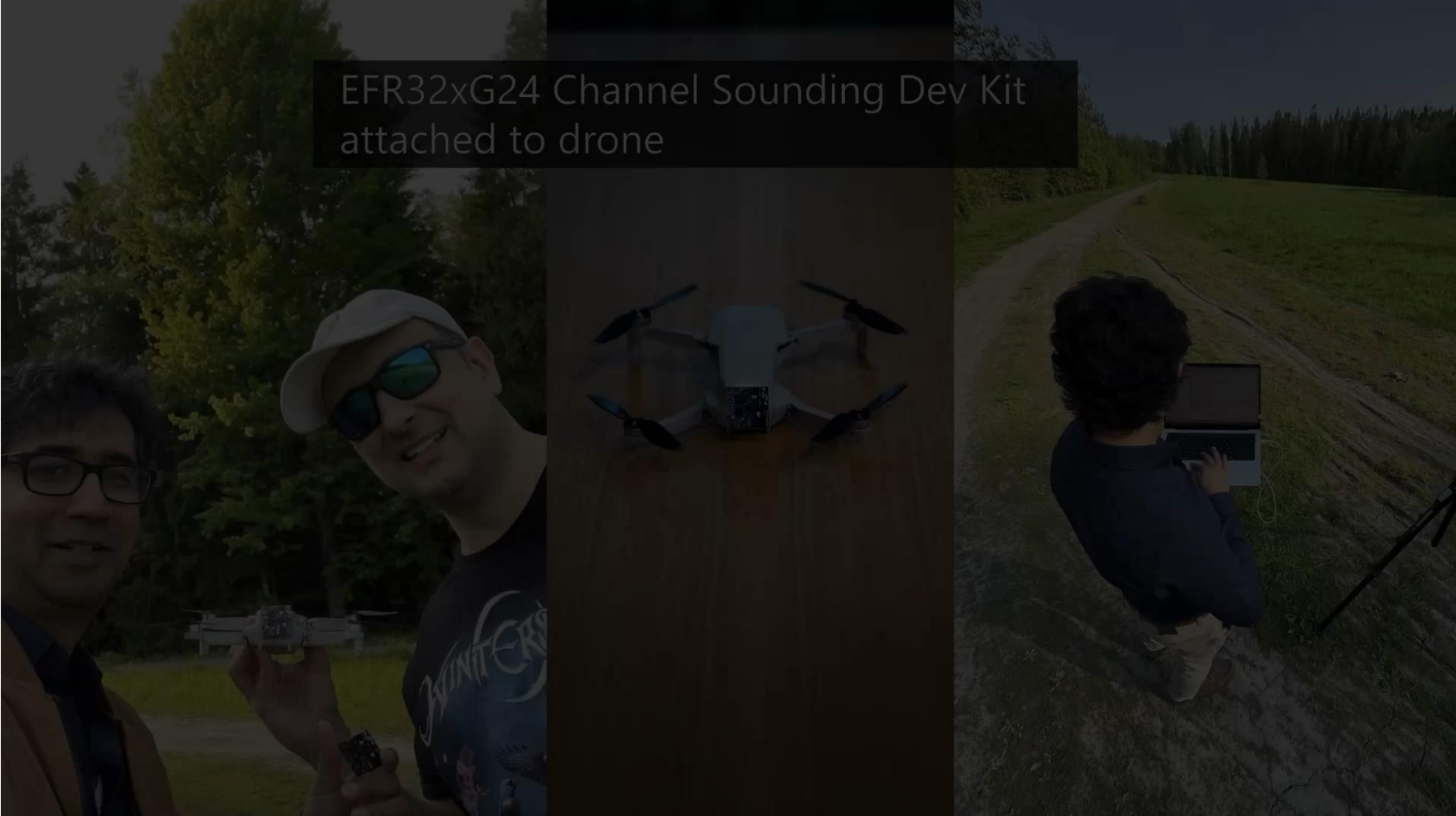
Reference Board	Number of Antenna Paths (NAP)	Number of Channels	Mean Current Consumption (mA)	Mean Energy Consumption (nAh)
BRD2606A	4	72	~2.2	~191.0
		37	~1.2	~111.0
		20	~0.9	~75.4
	2	72	~1.7	~146.0
		37	~1.0	~91.0
		20	~0.8	~65.0
	1	72	~1.5	~122.8
		37	~1.0	~79.0
		20	~0.7	~58.0

Antenna Diversity Increases Total Energy Per Measurement

室内性能测试



室外性能测试



Silicon Labs Bluetooth® Channel Sounding Offering



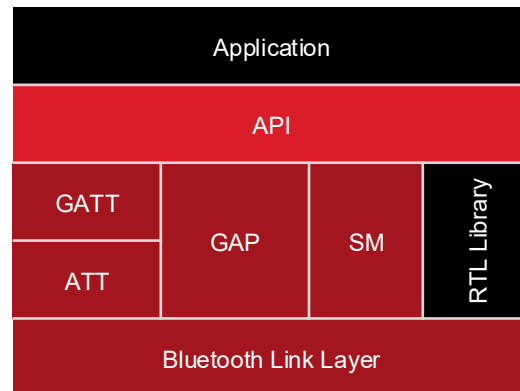
ICS & DEVELOPMENT KITS

Channel Sounding Supported by **B/MG24**

Kits:

xG24-RB4198A single antenna kit

xG24-DK2606A dual antenna kit

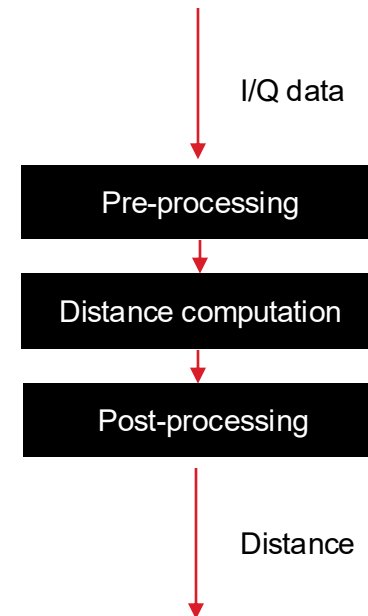


BLUETOOTH 6.0 STACK

In-house developed stack, supported and maintained stack

Bluetooth 6.0 qualified

PBR & RTT Modes



RTL LIBRARY

Computes distance from raw I/Q data

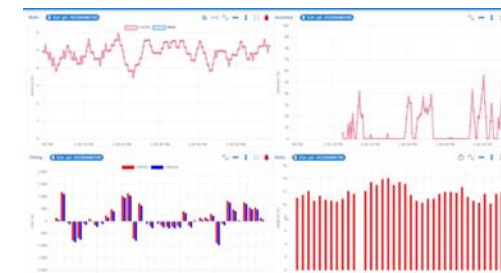
Developed and supported by Silicon Labs

New features added based on market needs

No 3rd party license fees



SIMPLICITY STUDIO



SDK & TOOLS

Initiator & Reflector examples

Real-time visualization tool for Bluetooth Channel Sounding

Energy Profiler etc.

可视化工具



Visualizer Tool displays real-time CS data

- CS configuration
 - ▶ Channel map selection
 - ▶ Antenna path configuration
 - ▶ Algorithm mode selection
- CS data visualization
 - ▶ RSSI based distance for comparison
 - ▶ Raw distance estimate and likelihood
 - ▶ Filtered distance estimate
 - ▶ IQ data visualization
- Interfaces with CS enabled EVKs

Q&A



2025年Works With开发者大会 – 深圳站



深圳 Works With 大会

10月23日 | 深圳湾万丽酒店

即刻注册



谢谢

芯科科技亚太区Tech Talks技术讲座 – 中文系列

日期 (星期四)	时间 (北京/台北时间)	主题
9月25日	14:00 - 15:00	将蓝牙6.0信道探测推向市场：实现安全且智能的精确测距应用
随选回放		
6月19日		Matter标准的最新动态
7月3日		借助芯科科技的xG22E为智能物联网收集能量
7月17日		面向未来应用需求、具备专门优化特性的蓝牙SoC
7月31日		MG26、PG26和BG26简介：高度灵活的SoC平台，满足您的所有物联网需求
8月14日		超越计量：通过Wi-SUN解锁新潜能
8月28日		探索多协议无线技术的最新进展
9月11日		探索基于超低功耗SiWx917 Wi-Fi 6解决方案的AI/ML应用

