# Tech Talks LIVE Schedule – Presentation will begin shortly

Silicon Labs LIVE:

Wireless Connectivity Tech Talks
Summer Series

Topic	Date
Come to your Senses with our Magnetic Sensor	Thursday, July 9
Exploring features of the BLE Security Manager	Thursday, July 23
New Bluetooth Mesh Light & Sensor Models	Thursday, July 30
Simplicity Studio v5 Introduction	Thursday, August 6
Long Range Connectivity using Proprietary RF Solution	Thursday, August 13
Wake Bluetooth from Deep Sleep using an RF Signal	**Thursday, August 20**
Implementing a Bluetooth Network Co-Processor	Thursday, August 27

5:00
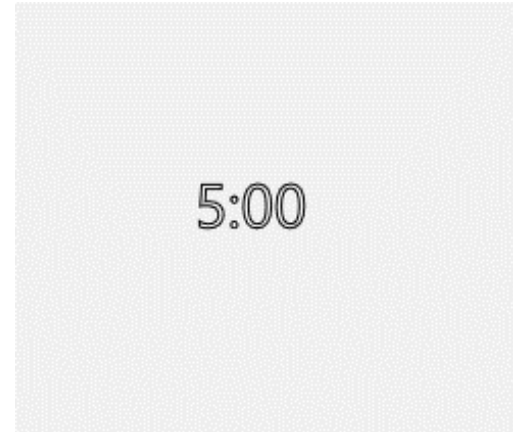
Fill out the survey for a chance to win a BG22 Thunderboard!

Find Past Recorded Sessions at:
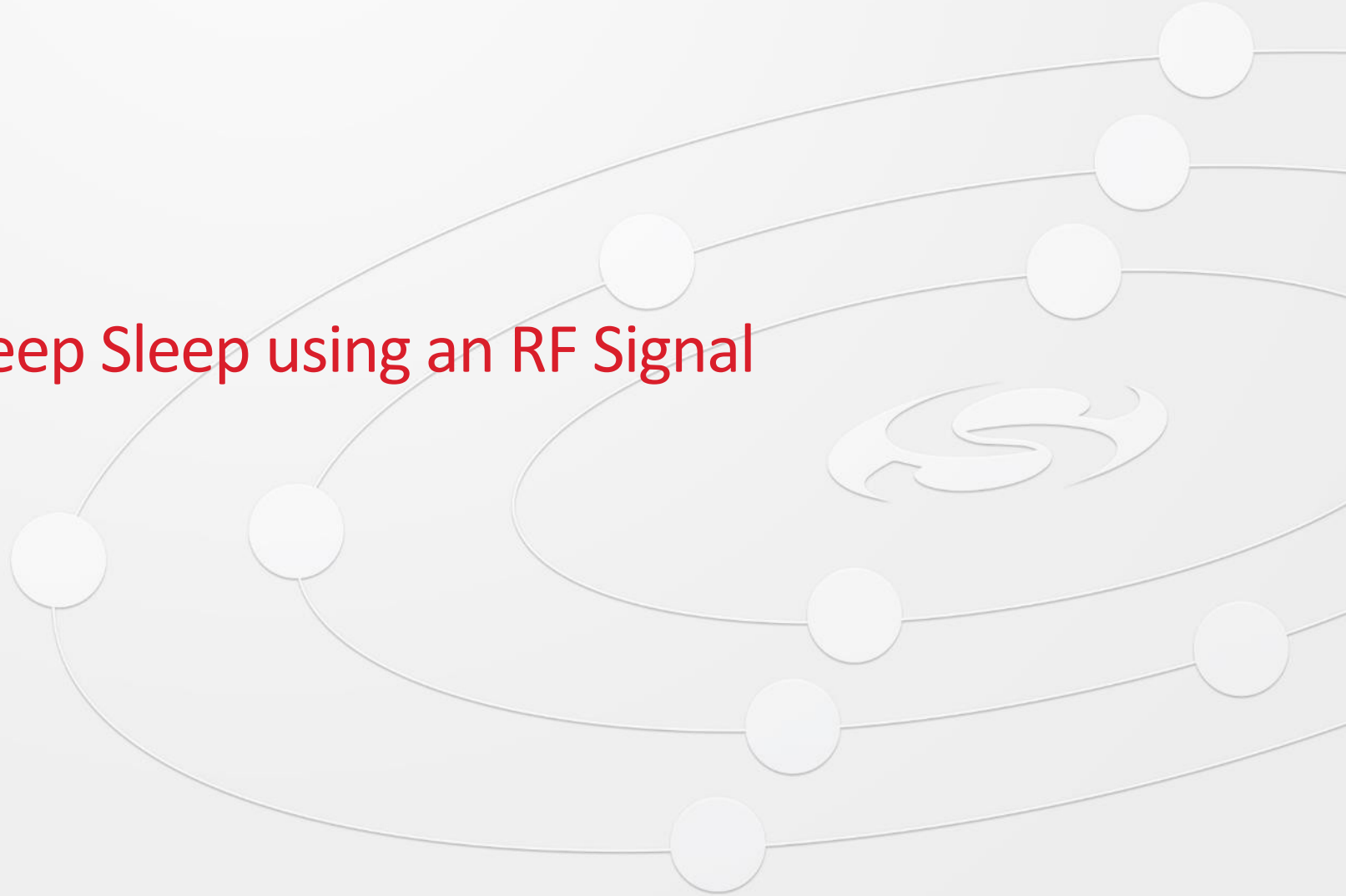https://www.silabs.com/support/training

1

WELCOME

Silicon Labs LIVE:

Wireless Connectivity Tech Talks
Summer Series

Wake Bluetooth from Deep Sleep using an RF Signal

August 20th, 2020
David Seymour

RF (Radio Frequency). What is it?

- Radio frequency is the oscillation rate of an alternating electric current or voltage or of a magnetic, electric or electromagnetic field or mechanical system in the frequency range from around 20 kHz to around 300 GHz. [Wikipedia](#)
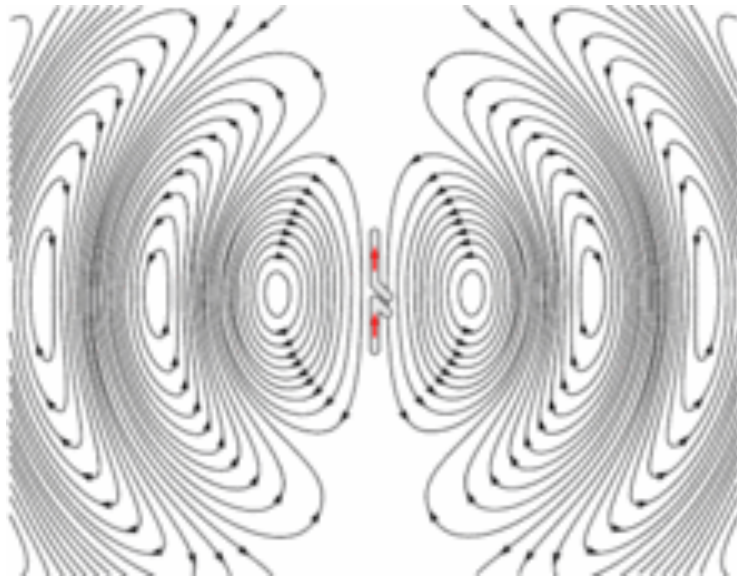
Frequency range	Wavelength range	ITU designation		IEEE bands[5]
		Full name	Abbreviation[6]	
Below 3 Hz	$>10^5$ km	Tremendously low frequency[7]	TLF	N/A
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF	N/A
30–300 Hz	10^4–10^3 km	Super low frequency	SLF	N/A
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF	N/A
3–30 kHz	100–10 km	Very low frequency	VLF	N/A
30–300 kHz	10–1 km	Low frequency	LF	N/A
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF	N/A
3–30 MHz	100–10 m	High frequency	HF	HF
30–300 MHz	10–1 m	Very high frequency	VHF	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF	UHF, L, S
3–30 GHz	10–1 cm	Super high frequency	SHF	S, C, X, Ku, K, Ka
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF	Ka, V, W, mm
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF	N/A

https://en.wikipedia.org/wiki/Radio_wave
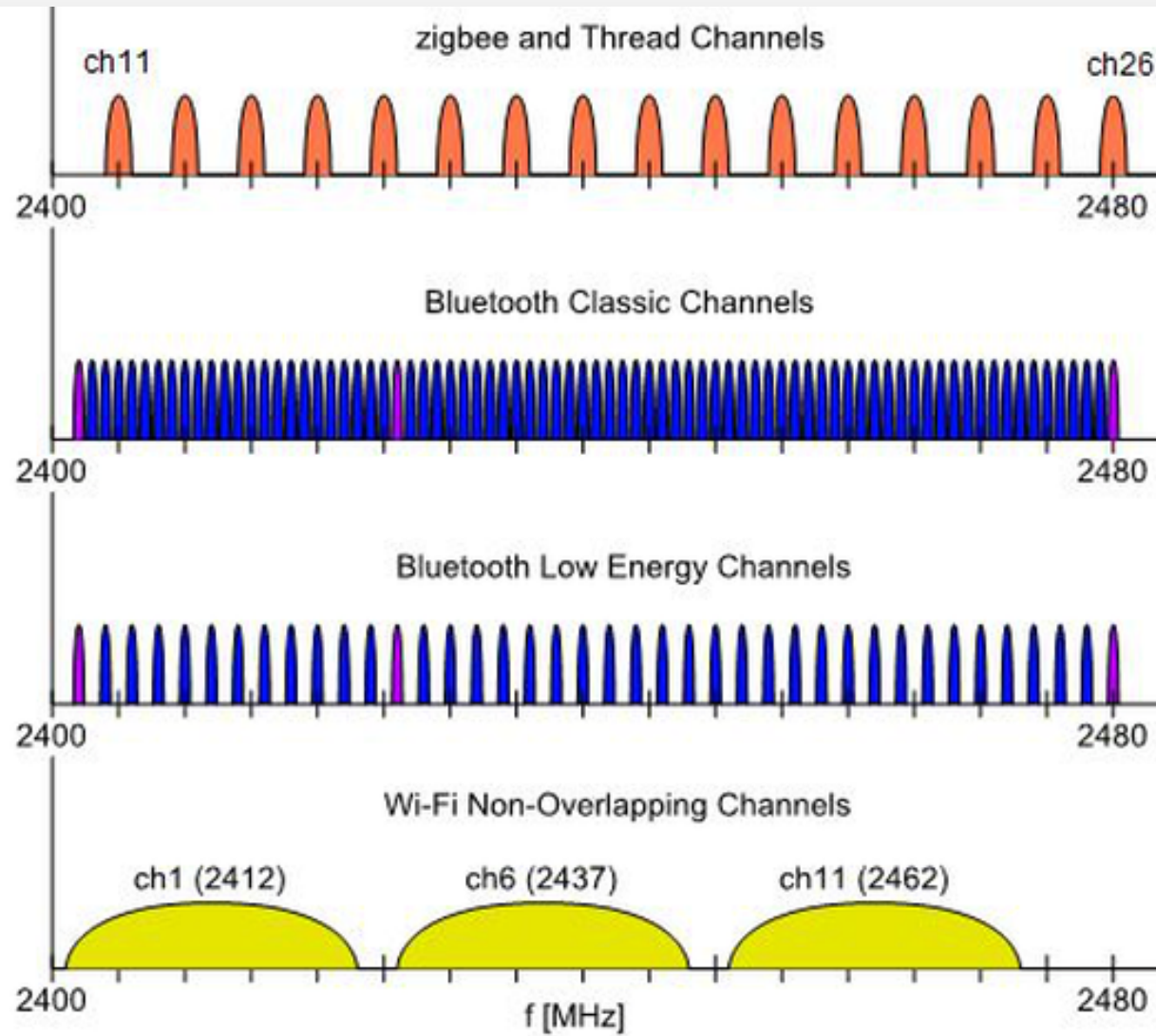
RF Transfer of Power

Signal Transmit Flow

Digital Data → DAC → Analog Signal → RF Transmitter Chain → RF Signal → Antenna

Signal Receive Flow

Digital Data ← ADC ← Analog Signal ← RF Receiver Chain ← RF Signal ← Antenna
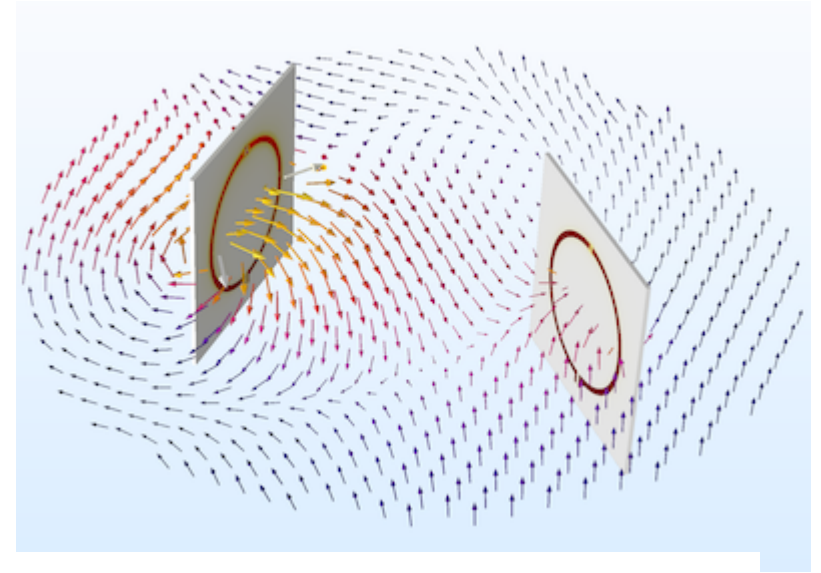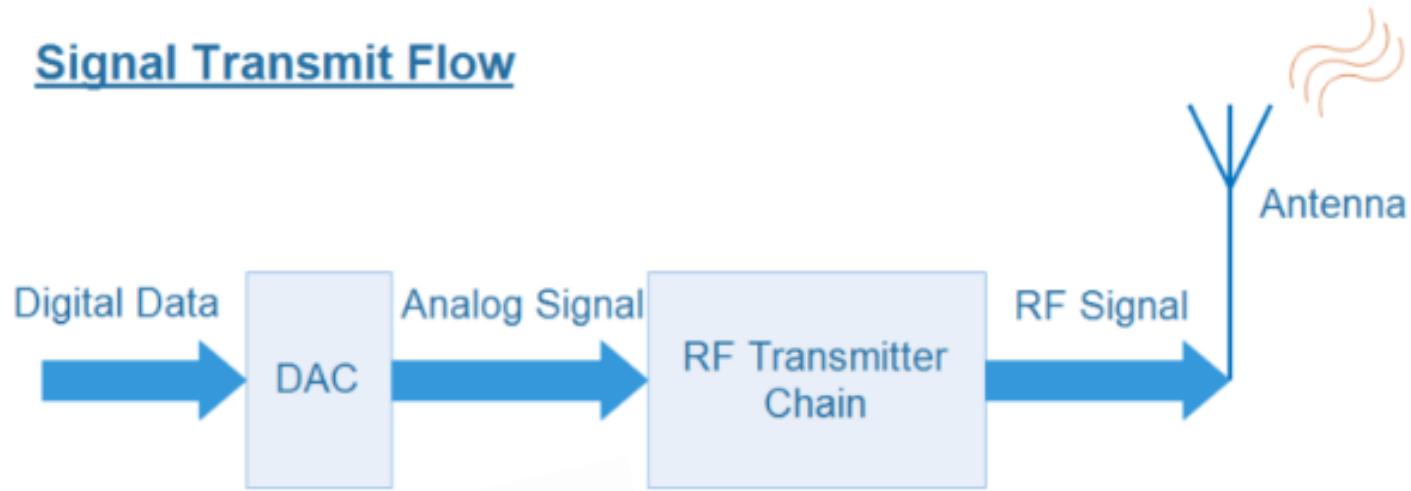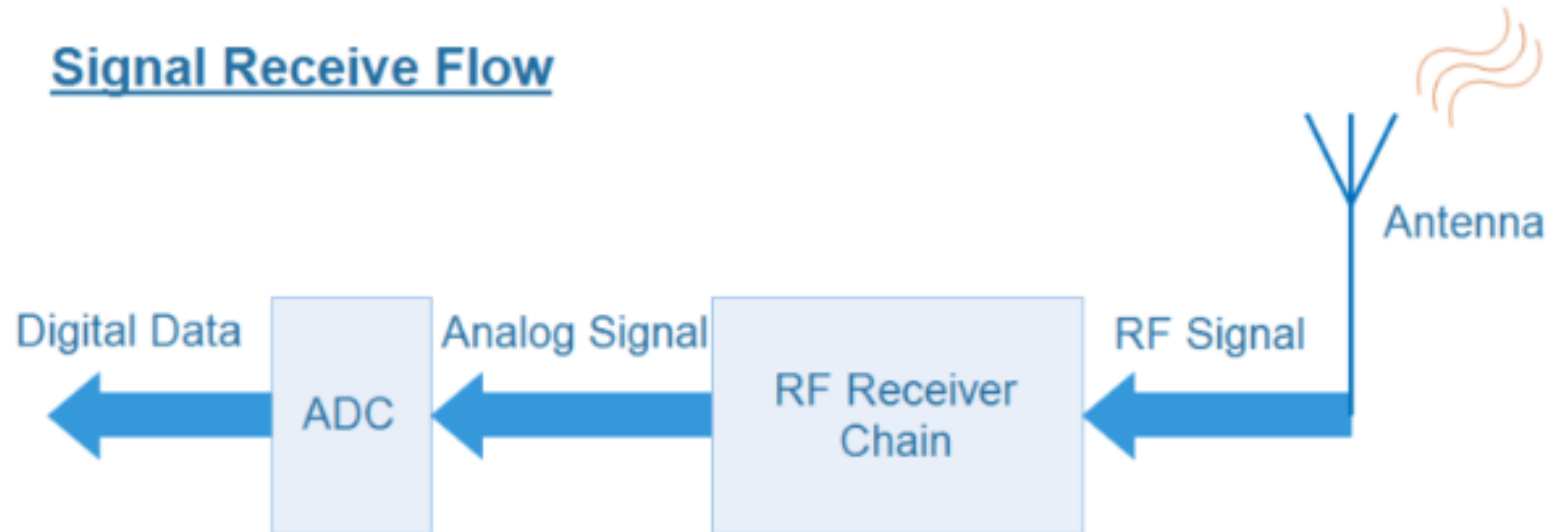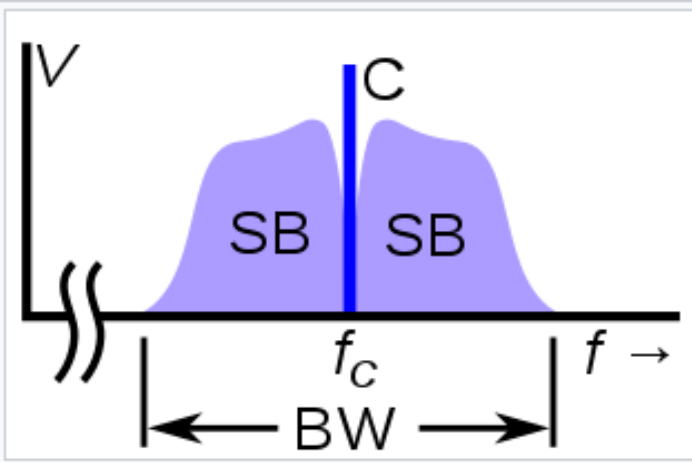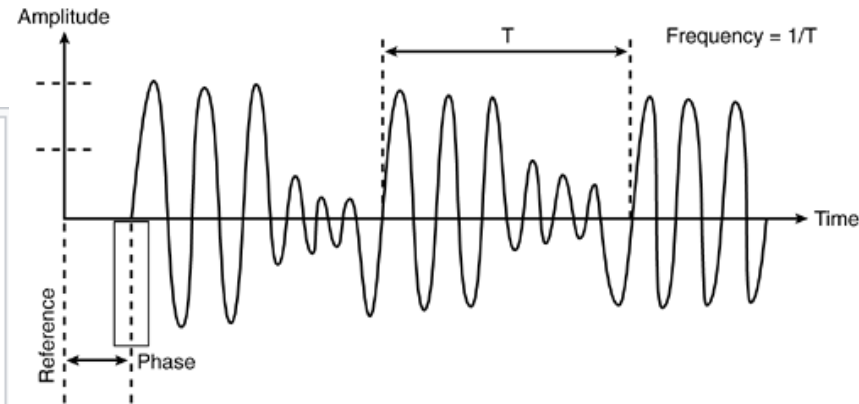
Amplitude modulation (AM) the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal being transmitted.

Frequency modulation (FM) is the encoding of information in a carrier-wave by varying the instantaneous frequency of the wave.

```
101  0111
110  1001
110  1011
110  1001
111  0000
110  0101
110  0100
110  1001
      1
```

Signal

AM

FM

Amplitude

Reference

Phase

T

Frequency = 1/T

Time

SB   SB

f_C

$f \rightarrow$

BW
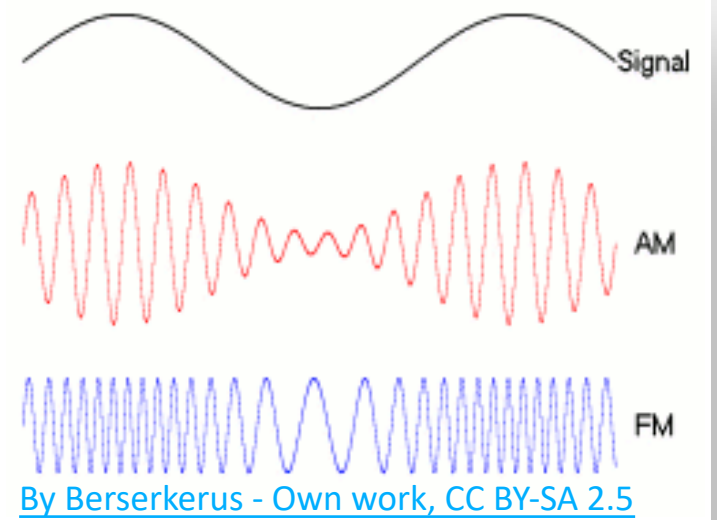
The frequency spectrum of a typical radio signal from an AM or FM radio transmitter. The horizontal axis is frequency; the vertical axis is signal amplitude or power. It consists of a signal (C) at the carrier wave frequency f_C, with the modulation contained in narrow frequency bands called sidebands (SB) just above and below the carrier.

Amplitude

Time

Data Signal

Amplitude

Time

Carrier Signal

X

FM Signal

Amplitude

xG22 Block Diagram

CPU and Memory

- ARM Cortex-M33 with DSP, FPU & TrustZone
- 512 kB Flash
- Debug Interface
- 32 kB RAM
- LDMA Controller

Clock Management

- High Freq Crystal Osc
- High Freq RC Osc
- Fast Startup RC Osc
- UL Freq RC Osc
- Low Freq Crystal Osc
- Precision LF RC Osc

Energy Management

- Voltage Regulator
- Brown-out Detector
- DC-DC Converter
- Power-on Reset
- Voltage Scaling

Security

- AES-128/256, SHA-1/2 ECC
- Secure Boot RTSL
- Secure Debug
- TRNG

32-bit Bus

Peripheral Reflex System

Serial Interfaces

- 2x USART
- 2x I2C
- 1x EUSART
- 2-ch 16-bit PDM

I/O Ports

- External Interrupt
- Up to 26 GPIO
- Pin Reset
- GPIO Wakeup

Timers and Triggers

- 5x Timer/Counter
- Low Energy Timer
- RTC
- Watchdog
- Backup RTC

Analog Modules

- 12-bit, 1Msps ADC
- Temp. Sensor

Radio

- Prop. 2.4 GHz
- Radio Cortex-M0+
- Integrated 0/6 dBm PA
- Radio Crypto
- RFSense

Current

mA

uA

nA

Feature available down to Energy Mode

- EM0 — Run
- EM1 — Sleep
- EM2 — Deep Sleep
- EM3 — Stop
- EM4 — Shutoff

RF Sense Analogy

Sleeping at very low power

+

Async Noise

=

Awake and using energy

Selective RF Sense Analogy

Sleeping at very low power

+

Async Noise
Or
OOK with Wrong Sync Word

=

Still sleeping like baby at very low power

Selective RF Sense Analogy

Sleeping at very low power

OOK with Correct Sync Word

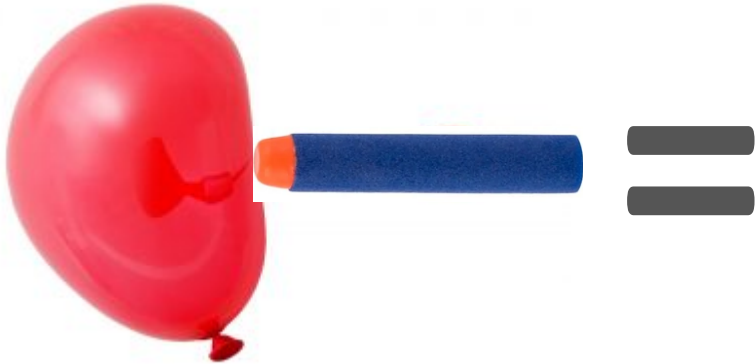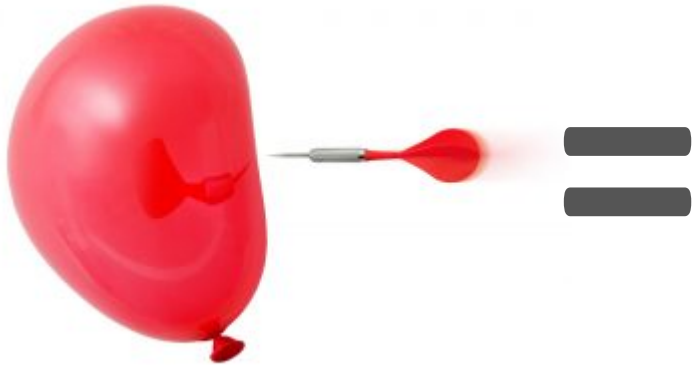Awake and using energy

Reference Manual Review

5.1.12 RFSENSE

The RFSENSE block on the EFR32xG22 is an ultra-low energy RF signal detector which provides wake-on-RF capabilities from any energy mode. The system can remain in low energy modes such as EM2 or EM4 for long durations while continuously monitoring for a valid wake condition. RFSENSE can operate as a selective On Off Keying (OOK) detector, or a simple RF energy detector.

- Selective OOK pattern detection:
  - 1 kHz OOK symbol rate, manchester encoded (0.5 kHz bit rate)
  - Configurable 4/8-bit preamble length with fixed 1010 pattern
  - Configurable 8/16/24/32-bit sync word length with fully programmable pattern
- Simple RF energy threshold detection:
  - Programmable RF energy trip point
  - Configurable energy averaging duration

OOK (On/Off Keying) Modulation

1kHz signal
Manchester-coded

| Preamble 10101010 | Data DE | Data CA | Data FB | Data AD |
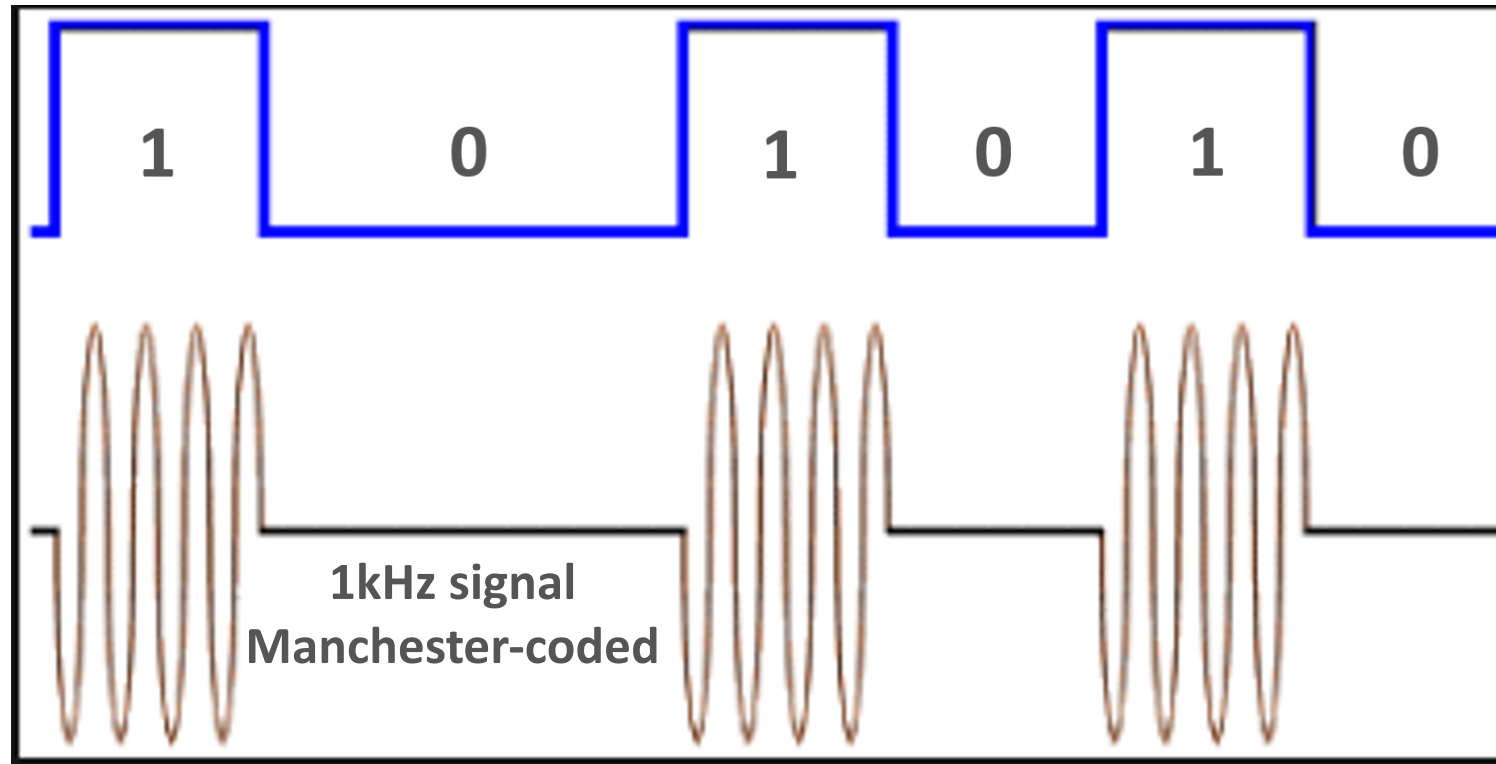
Preamble is 8-bits

Data is 1 byte with option for being 2/3 or 4 bytes
The "data" is your custom sync word (secret key)

Data Sheet Review

4.9 RFSENSE Low-energy Wake-on-RF

Table 4.11. RFSENSE Low-energy Wake-on-RF

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Average current	$I_{RFSENSE}$	RF energy below wake threshold	—	138	—	nA
		Selective mode, RF energy above threshold but no OOK sync detected	—	131	—	nA
RF level above which RFSENSE will detect signal[1]	$THRES_{TRIG}$	Threshold set to -34 dBm	-28	—	—	dBm
		Threshold set to -22 dBm	-19	—	—	dBm
RF level below which RFSENSE will not detect signal[1]	$THRES_{NOTRIG}$	Threshold set to -34 dBm	—	—	-40	dBm
		Threshold set to -22 dBm	—	—	-26	dBm
Sensitivity in selective OOK mode[1]	$SENS_{OOK}$	Sensitivity for > 90% probability of OOK detection[2], threshold set to -34 dBm	-28	—	—	dBm
		Sensitivity for > 90% probability of OOK detection[2], threshold set to -22 dBm	-19	—	—	dBm

Note:
1. Values collected with conducted measurements performed at the end of the matching network.
2. Selective wake signal is 1 kHz OOK Manchester-coded, 8 bits of preamble, 32-bit sync word.

Extending Battery Life in Bluetooth Applications

10+ years on a coin cell battery

SILICON LABS BG22

Location Services	Data Transfer
Connected to a phone at 2000ms interval	Advertising 10 bytes every 2000ms
Using 2M PHY and transmitting 10 Byte / packet	TX at 0dBm and 3 using channels
Average current: 4.2µA	Average current: 4.7µA

5+ years on CR2032
10+ years on a CR2354

Selective RF Sense will extend battery lifetime

RF Transfer of Power

Received Signal Power

The received signal power is calculated according to the formula:

$$RxPower(d, f) = TxPower + TxAntennaGain - Pathloss(d, f) + Rx\ AntennaGain$$

RF Sense (Classic) Mode

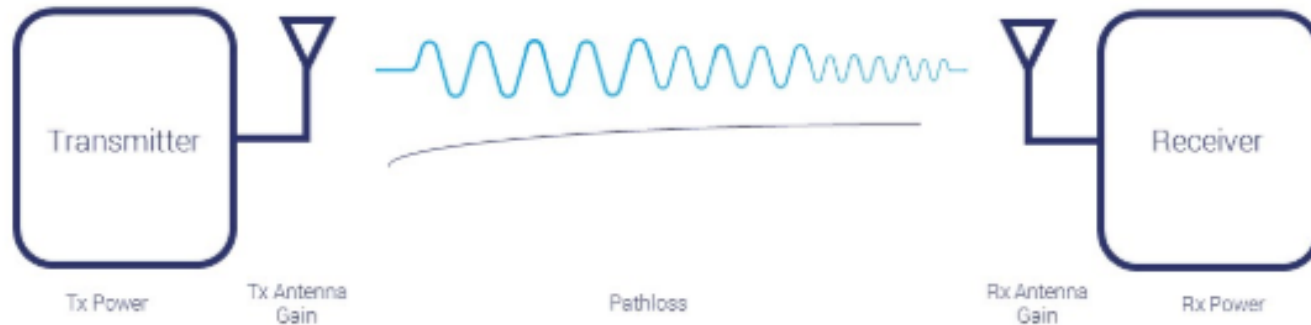§ The EFR series of energy-friendly radios have the ability to wake themselves upon detecting of RF signal.
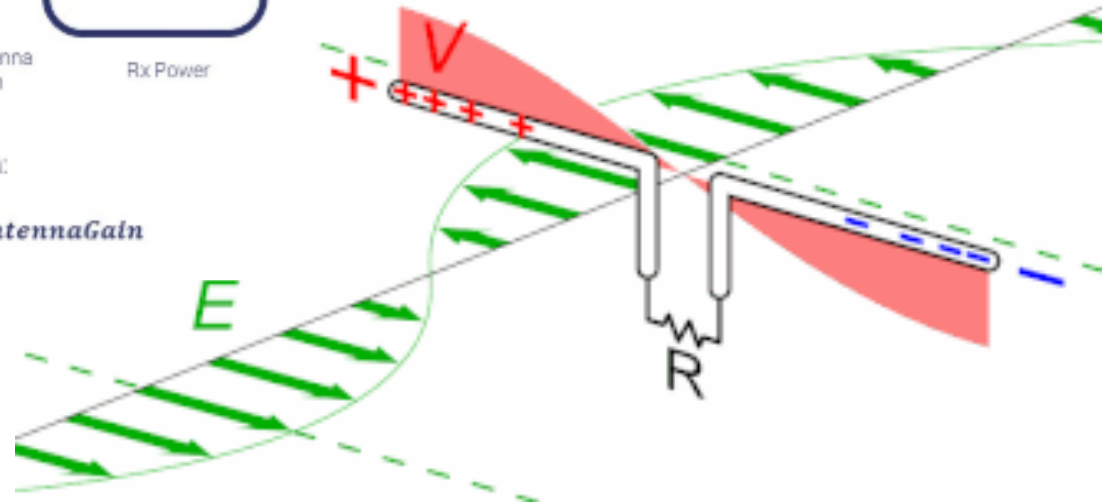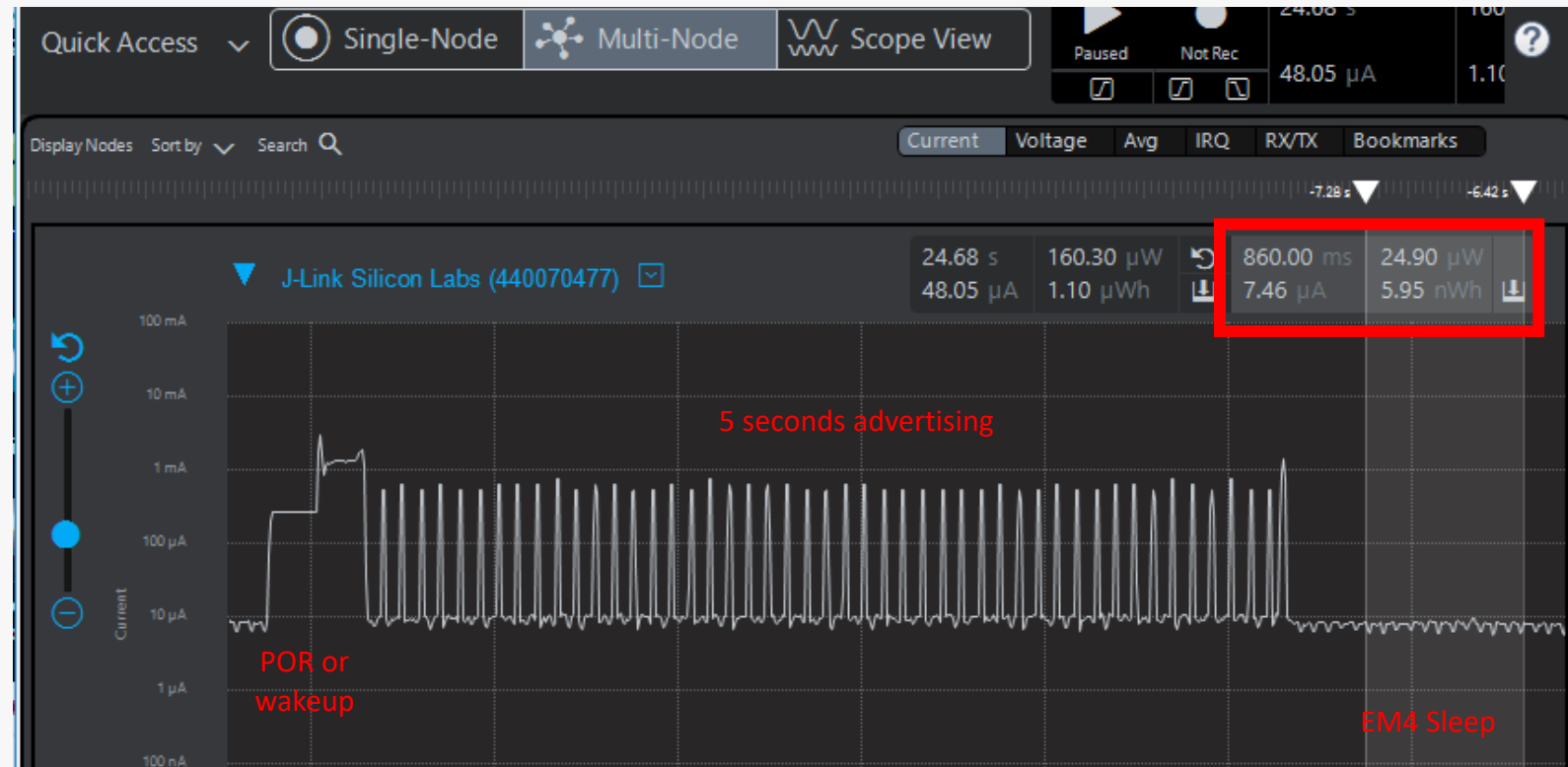
- In Legacy (Energy Detection) mode, EFR32xG22 RF Sense is fully compatible with the feature in Series 1 devices

- The EFR32 has the ability to sense the presence of RF Energy above -20 dBm within 2.4 GHz band

- This triggers an event if that energy is continuously present for certain durations of time

Selective RF Sense Mode – Series 2 EFR32xG22
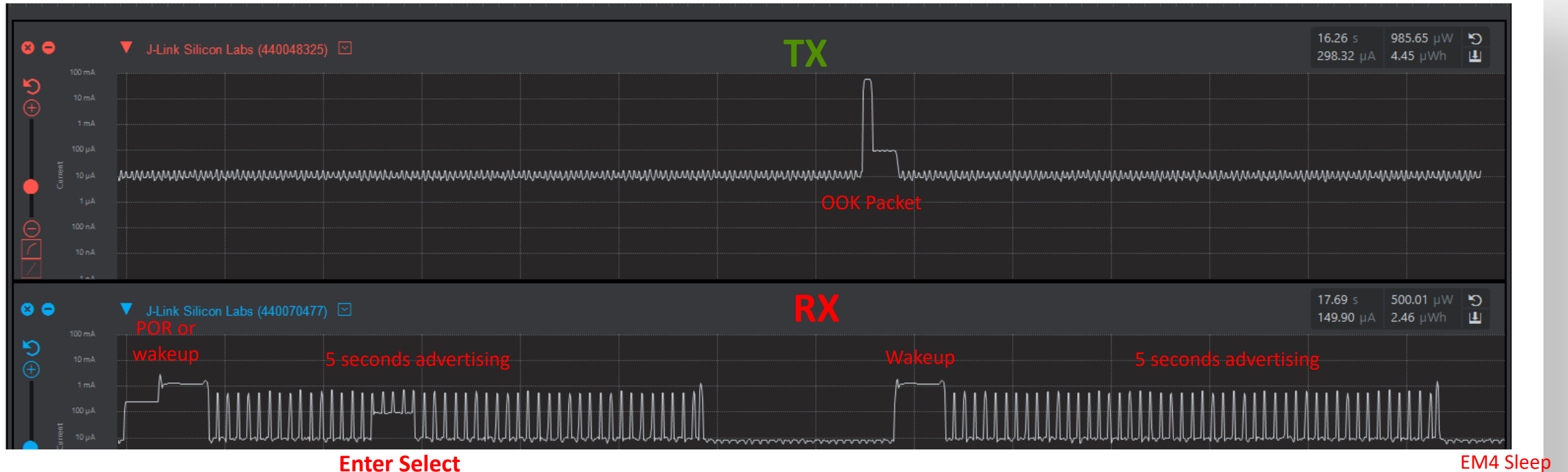
Receive Side: Selective RF Sense mode mitigates the unfiltered nature of RF Sense. Instead of simply detecting energy for a given time period, it detects "a pattern of energy" - which is essentially an On-Off Keying (OOK) packet.

The packet is Manchester-coded and uses a fixed 1 kbps bitrate, 1 Byte preamble, and 1-4 Byte sync word.

Transmit Side: This packet can be transmitted by any OOK-capable device, including all EFR32 wireless MCUs (Series 1 and Series 2). EFR32 radios transmit this packet on 2.4 GHz.

RF Sense Selective Mode Test Setup
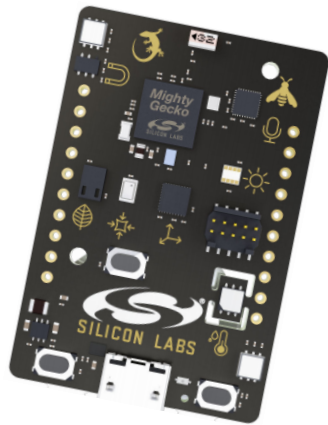
Thunderboard Sense 2
Or
Thunderboard BG22

TX

```
1    // Syncword Length in bytes. 1-4 bytes.
2    #define NUMSYNCWORDBYTES (2U)
3    // Syncword Value.
4    #define SYNCWORD           (0xB16FU)
5
6    // Configure the transmitting node for sending the wakeup packet.
7    RAIL_Idle(railHandle, RAIL_IDLE_ABORT, true);
8    RAIL_ConfigRfSenseSelectiveOokWakeupPhy(railHandle);
9    RAIL_SetRfSenseSelectiveOokWakeupPayload(railHandle, NUMSYNCWORDBYTES, SYNCWORD);
10   RAIL_StartTx(railHandle, channel, RAIL_TX_OPTIONS_DEFAULT, NULL);
11
12   // Configure the receiving node (EFR32XG22) for RF Sense.
13   RAIL_RfSenseSelectiveOokConfig_t config = {
14     .band = rfBand,
15     .syncWordNumBytes = NUMSYNCWORDBYTES,
16     .syncWord = SYNCWORD,
17     .cb = &RAILCb_SensedRf
18   };
19   RAIL_StartSelectiveOokRfSense(railHandle, &config);
```

RX

WSTK
+
BG22 Radio Board
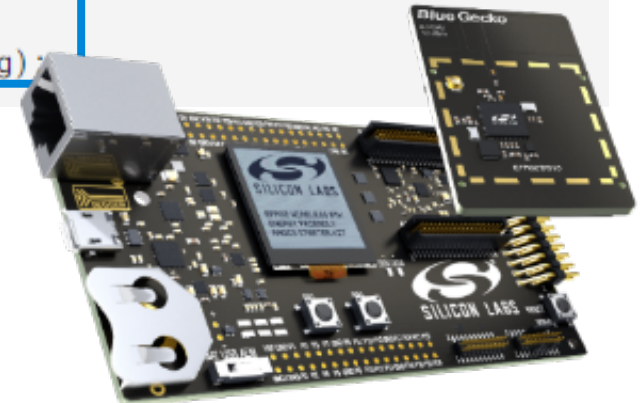
```
VT  COM6 - Tera Term VT
File  Edit  Setup  Control  Window  Help
boot event – starting advertising
        gecko_evt_hardware_soft_timer_id: start RAIL_StartRfSense()
stack version: 2.13.4
local BT device address: 08:6b:d7:c3:78:df
boot event – starting advertising
        gecko_evt_hardware_soft_timer_id: start RAIL_StartSelectiveOokRfSense()
stack version: 2.13.4
local BT device address: 08:6b:d7:c3:78:df
boot event – starting advertising
        gecko_evt_hardware_soft_timer_id: start RAIL_StartRfSense()
```

BG22: Optimized for Battery Powered Bluetooth LE

Secure Bluetooth 5.2 SoCs for High-Volume Products

Optimized

Radio
Bluetooth 5.2
+6 dBm TX*
-99 dBm RX
AoA & AoD

Ultra-Low Power
3.6mA Radio TX
2.6mA Radio RX
1.4uA EM2 with 32kB RAM
0.54uA in EM4
RTC in EM4

World Class Software
Bluetooth 5.2
Bluetooth mesh LPN
Direction Finding

Compact Size
5x5 QFN40 (26 GPIO)
4x4 QFN32 (18 GPIO)
4x4 TQFN32 (18 GPIO)

ARM Cortex-M33 with TrustZone
76.8 MHz
FPU and DSP
352/512kB of flash
32kB RAM

Peripherals Fit for Purpose
2x USART, 2x I2C, 2x PDM and GPIO
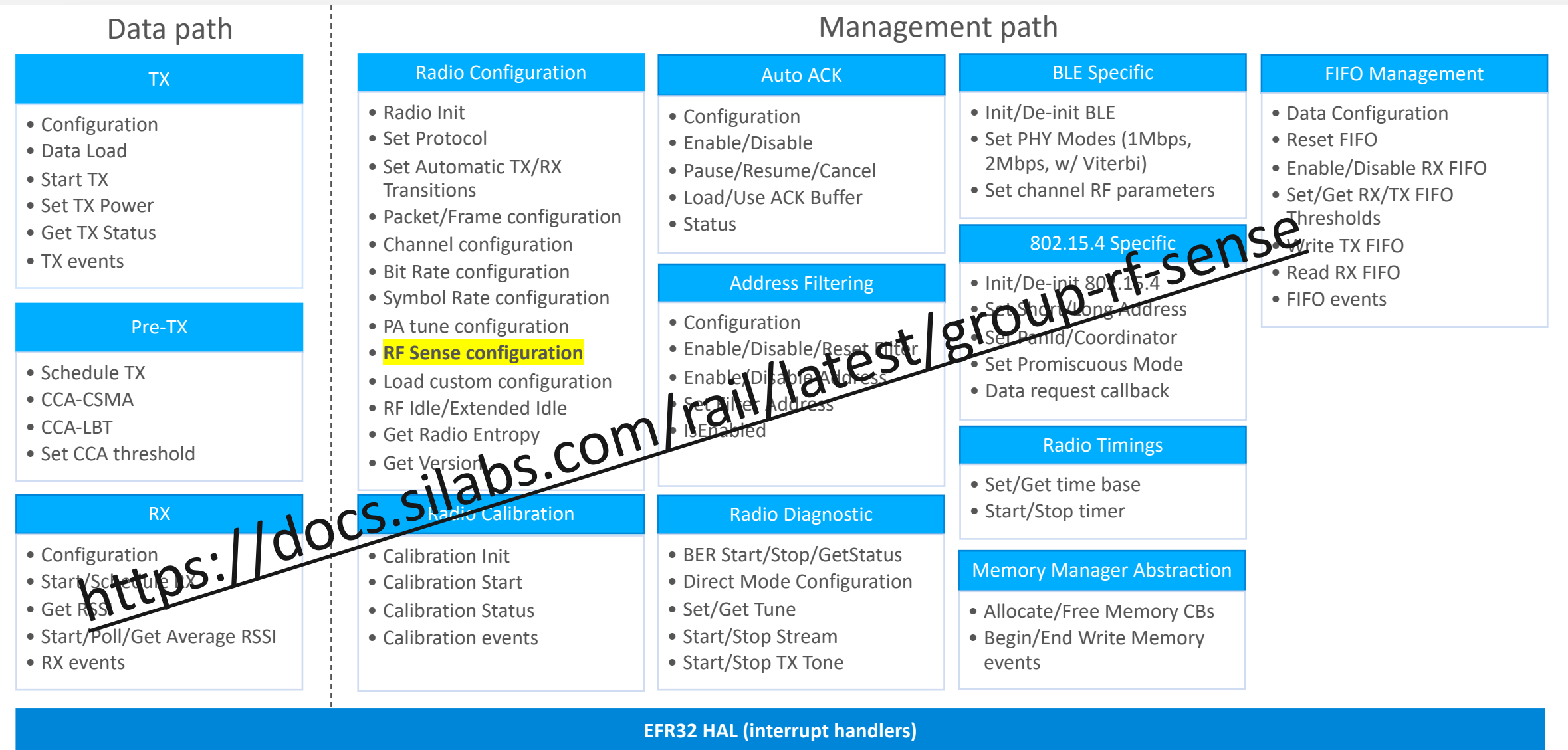12-bit ADC (16 channels)
RFSENSE wake-on radio
Built-in temperature sensor with +/- 1.5 ^{o}C
32kHz, 500ppm PLFRCO

Security
AES128/256,SHA-1, SHA-2 (256-bit)
ECC (up to 256-bit), ECDSA and ECDH
True Random Number Generator (TRNG)
Secure boot with RTSL
Secure debug with lock/unlock

*NOTE: Certain module options of the BGM220 can offer +8dBm

RAIL API Supported Features

Data path

TX

- Configuration
- Data Load
- Start TX
- Set TX Power
- Get TX Status
- TX events

Pre-TX

- Schedule TX
- CCA-CSMA
- CCA-LBT
- Set CCA threshold

RX

- Configuration
- Start/Schedule RX
- Get RSSI
- Start/Poll/Get Average RSSI
- RX events

Management path

Radio Configuration

- Radio Init
- Set Protocol
- Set Automatic TX/RX Transitions
- Packet/Frame configuration
- Channel configuration
- Bit Rate configuration
- Symbol Rate configuration
- PA tune configuration
- **RF Sense configuration**
- Load custom configuration
- RF Idle/Extended Idle
- Get Radio Entropy
- Get Version

Radio Calibration

- Calibration Init
- Calibration Start
- Calibration Status
- Calibration events

Auto ACK

- Configuration
- Enable/Disable
- Pause/Resume/Cancel
- Load/Use ACK Buffer
- Status

Address Filtering

- Configuration
- Enable/Disable/Reset Filter
- Enable/Disable Address
- Set/Get Address
- IsEnabled

Radio Diagnostic

- BER Start/Stop/GetStatus
- Direct Mode Configuration
- Set/Get Tune
- Start/Stop Stream
- Start/Stop TX Tone

BLE Specific

- Init/De-init BLE
- Set PHY Modes (1Mbps, 2Mbps, w/ Viterbi)
- Set channel RF parameters

802.15.4 Specific

- Init/De-init 802.15.4
- Set Short/Long Address
- Set PanId/Coordinator
- Set Promiscuous Mode
- Data request callback

Radio Timings

- Set/Get time base
- Start/Stop timer

Memory Manager Abstraction

- Allocate/Free Memory CBs
- Begin/End Write Memory events

FIFO Management

- Data Configuration
- Reset FIFO
- Enable/Disable RX FIFO
- Set/Get RX/TX FIFO Thresholds
- Write TX FIFO
- Read RX FIFO
- FIFO events

EFR32 HAL (interrupt handlers)

Functions

RAIL_Time_t	**RAIL_StartRfSense** (RAIL_Handle_t railHandle, RAIL_RfSenseBand_t band, RAIL_Time_t senseTime, RAIL_RfSense_CallbackPtr_t cb)

Start/stop the RF Sense functionality in Energy Detection Mode for use during low-energy sleep modes.

RAIL_Status_t	**RAIL_StartSelectiveOokRfSense** (RAIL_Handle_t railHandle, RAIL_RfSenseSelectiveOokConfig_t *config)

Start/stop the RF Sense functionality in Selective(OOK Based) Mode for use during low-energy sleep modes.

RAIL_Status_t	**RAIL_ConfigRfSenseSelectiveOokWakeupPhy** (RAIL_Handle_t railHandle)

Switch to RF Sense Selective(OOK) PHY.

RAIL_Status_t	**RAIL_SetRfSenseSelectiveOokWakeupPayload** (RAIL_Handle_t railHandle, uint8_t numSyncwordBytes, uint32_t syncword)

Set the transmit payload for waking up a node configured for RF Sense Selective(OOK).

bool	**RAIL_IsRfSensed** (RAIL_Handle_t railHandle)

Check whether the RF was sensed.

Use-case 1: Electronic Shelf Labels (ESL)...Real Product!

- **Brings the online experience into the store**
  - Accurate & dynamic pricing matching
  - Interactive product guides & promotions

- **Centralized pricing & inventory management**

- **Energy efficiency with FG22**
  - Extend battery life with 0.5µA in EM4 mode
  - RFSENSE with selective OOK preventing false wake-up events

- **Best-in-class embedded security**
  - Arm® TrustZone®
  - Secure boot
  - Secure debug with lock/unlock
  - Hardware Cryptographic Acceleration
  - True Random Number Generator compliant with NIST/AIS
 - Single chip implementation reduce attack vectors and simplifies design

RFSense Extends Battery life

- **Enables autonomous RF system wake-up**
  - Works in all energy modes down to EM4
  - Continuously monitors the spectrum for RF signals
  - Enables radio transceiver only when required

- **Operational modes**
  - Standard: Wakeup on detection of 2.4 GHz RF energy
  - Selective: Wakeup based on Synch-word
    - Customer-configurable On-Off Keying packet
    - Prevents false detections from interferers
    - Allows Selective wake-up of certain devices

- **Two configurable detection thresholds**
  - Wake-up triggered above -19 dBm or -28 dBm
  - Wake-up not triggered below -26 dBm or -40 dBm

Use-case 2: Asset Tracking On-Demand

10 feet
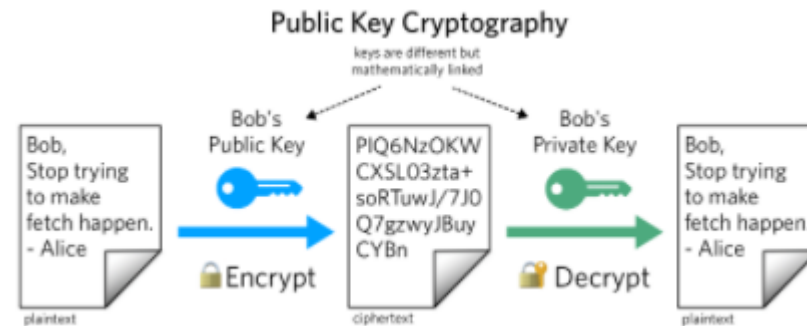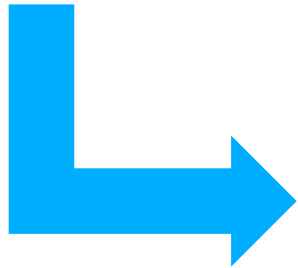
10 feet

1,000's of Tag's present
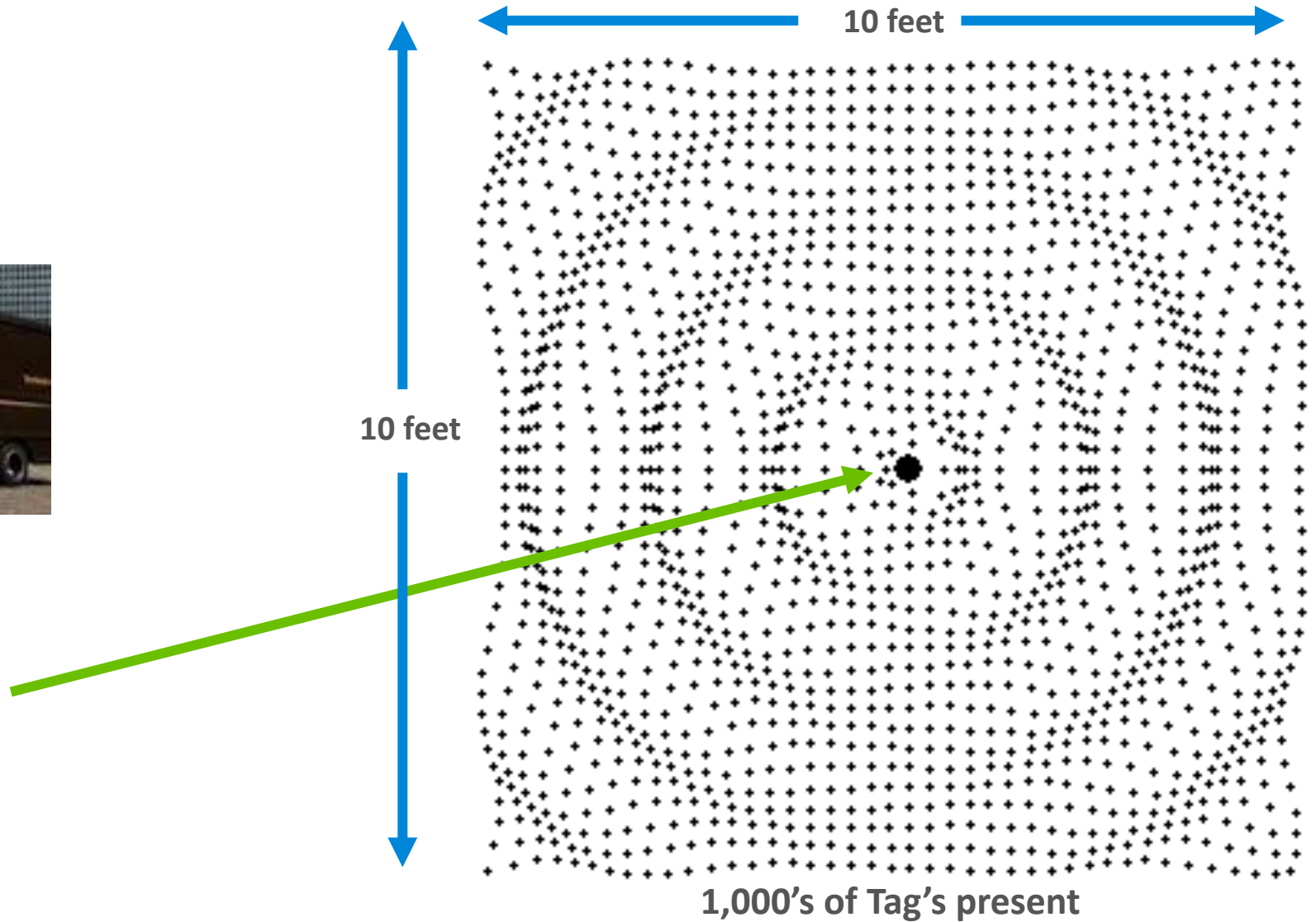
Use-case 3: Equipment Access

- Waking a product to access wirelessly using SmartDevice

- OOK Selective RF Sense with unique key word adds security to who can wake up the product

Public Key Cryptography

keys are different but mathematically linked

Bob,
Stop trying
to make
fetch happen.
- Alice

plaintext

Bob's
Public Key

PIQ6NzOKW
CXSL03zta+
soRTuwJ/7J0
Q7gzwyJBuy
CYBn

ciphertext

Encrypt

Bob's
Private Key

Bob,
Stop trying
to make
fetch happen.
- Alice

plaintext

Decrypt

- Adding application level Public/Private key as next level of security and authentication

- Use SmartDevice to control, monitor, update, configure, active, and more

References

- [KBA RFSense](#)

- [RFSense Selective on docs.silabs.com](#)

- [https://docs.silabs.com/bluetooth/latest/code-examples/stack-features/system-and-performance/waking-from-deep-sleep-using-rf-sense](#)

- [https://www.silabs.com/documents/public/application-notes/an1244-migration-efr32-families.pdf](#)
  - Describes an enhancement to RF Sense now available on the EFR32xG22

- [https://www.silabs.com/documents/public/user-guides/ug409-railtest-users-guide.pdf](#)

Demonstration Time – 4:13

- Silicon Labs Dane Taylor - Channel Product Marketing Manager
- Quick video to demo RF Sense (classic) and Selective RF Sense (new)

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BY SILICON LABS
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Thank you…..Questions?