

Welcome ...

Wireless Connectivity

WITH TEXAS INSTRUMENTS



Accelerating Your Success™

Today's Agenda

9:00 – 9:10	10 mins	Welcome and Introductions
9:10 – 9:50	40 mins	Wireless Basics
9:50 – 10:00	10 mins	break
10:00 – 10:45	45 mins	Lab 1
10:45 – 11:30	45 mins	Wireless Connectivity Overview
11:30 – 12:00	30 mins	Lunch break
12:00 – 1:00	60 mins	Lab 2
1:00 – 1:30	30 mins	Designing with wireless modules
1:30 – 1:45	15 mins	Demo – RC Eval-bot with Chronos
1:45 – 2:00	15 mins	Closing comments / feedback

Expectations

- This training is ...
 - A scratch-the-surface introduction to basic wireless concepts
 - Terminology, protocols and applications
 - Some discussion of wireless design considerations
 - Centered around wireless solutions from Texas Instruments

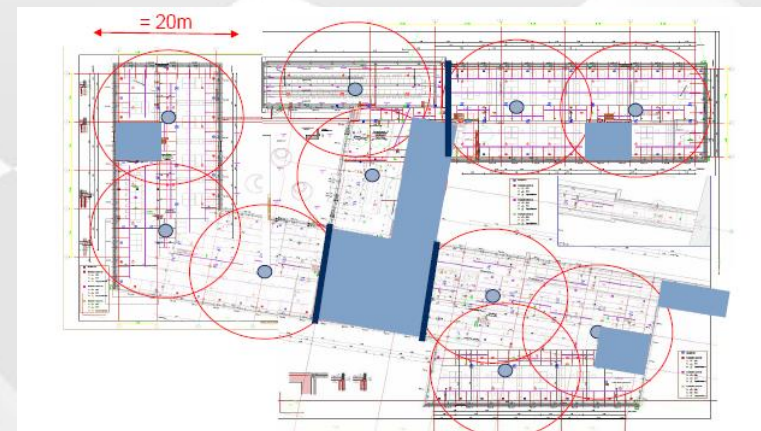


Why Wireless?

- Cable replacement
 - Costs of wiring
 - Labor for installation
- Expandability
 - New nodes easily added
- Reliability and maintenance
 - Self-healing
 - Dead node detection
- Where cabling isn't practical
 - Very long cable runs
 - Buried cabling
 - Moving equipment
 - Dangerous/harsh environments



Cambridge Consultants. Ltd.



EnOcean

Growing Markets / Applications



Process Automation



Access Control



Decawave. Ltd.

Remote Monitoring



Smart Energy



Home/Bldg Automation



Food/Water Quality



Asset Management



Lighting Controls



Remote Controls



Healthcare

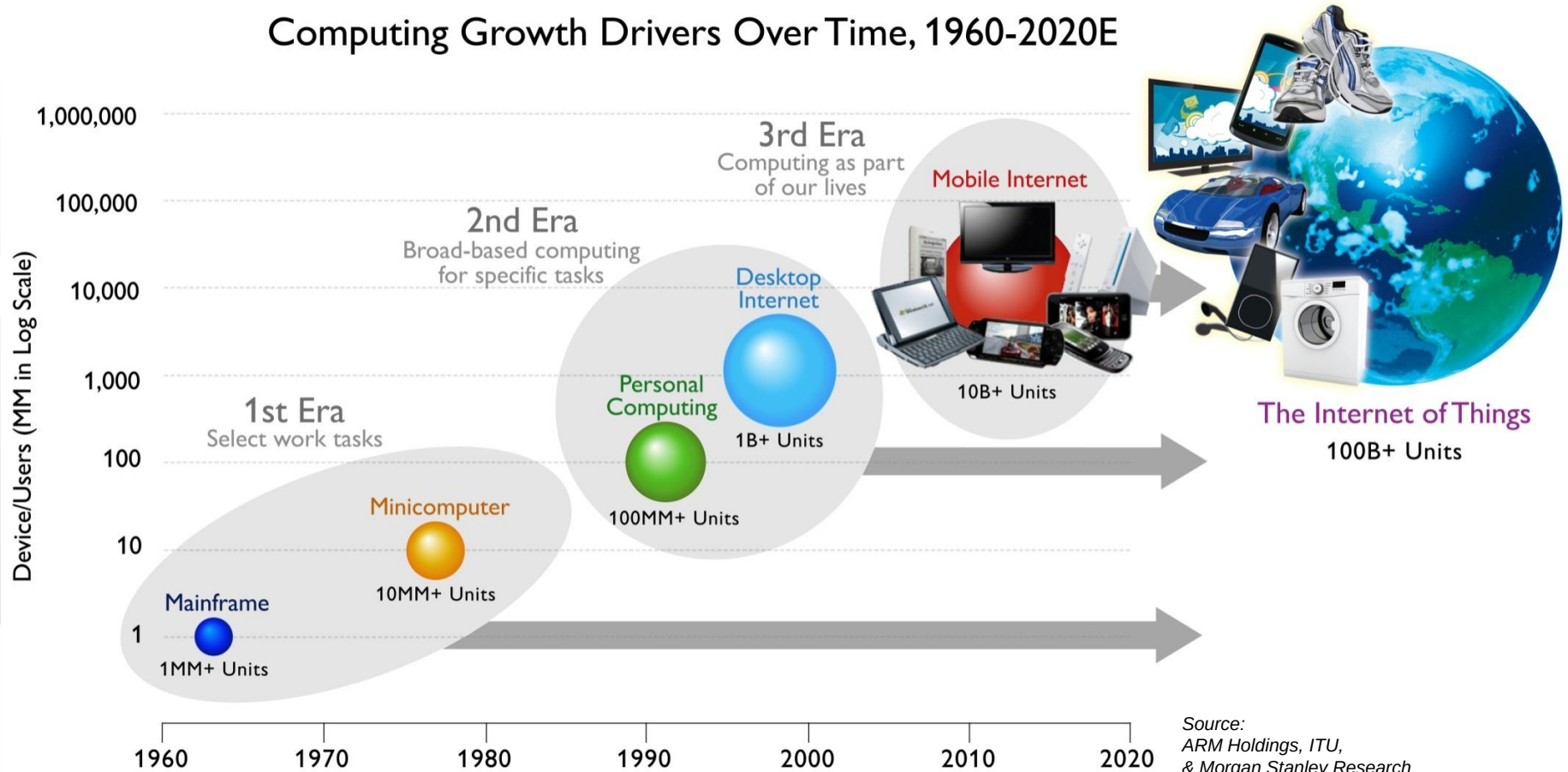


HVAC controls



Connectivity is Driving The Future

Computing Growth Drivers Over Time, 1960-2020E



The “Internet of Things”



WPAN : Wireless Personal Area Network

BAN : Body Area Network

HAN : Home Area Network

NAN : Neighborhood Area Network

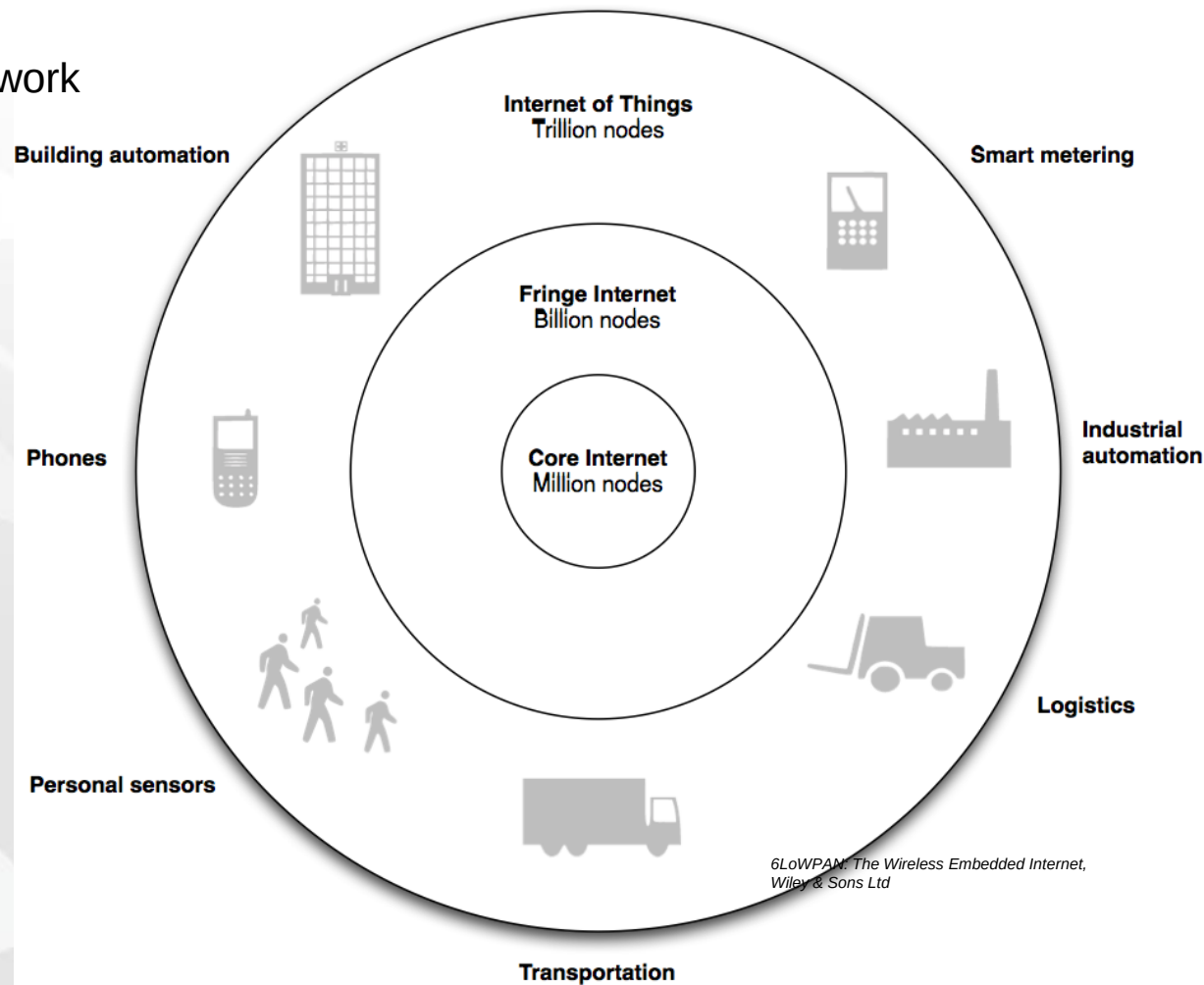
FAN: Field Area Network

WSN : Wireless Sensor
and Actuator Network

M2M : Machine to Machine

*“We are able to connect almost everybody now, Soon we will have the ability to **connect almost every thing of value.**”*

Paul Havinga, CTO, Ambient Systems

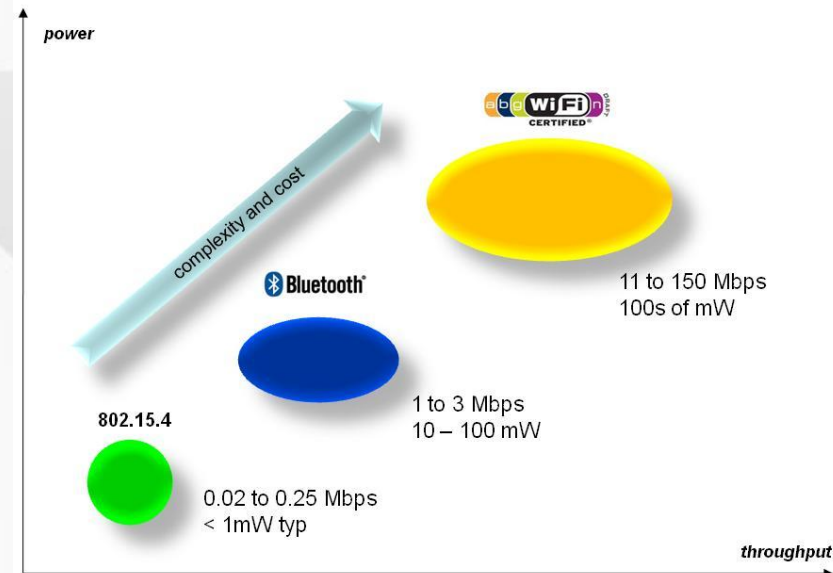


6LoWPAN: The Wireless Embedded Internet,
Wiley & Sons Ltd

Different Networks Have Different Needs

Wireless Technology	Version	Frequencies	Max Data Rate	Range*	Network Application	Max Power Permitted	Focus	Typical Applications
Wi-Fi	802.11a	5.0 GHz	54 Mbps	30m	WLAN	-	Data rates	Home Networking
	802.11b	2.4 GHz	11 Mbps	30m				
	802.11g	2.4 GHz	54 Mbps	30m				
	802.11n	2.4/5.0 GHz	200 Mbps	50m				
	Wi-Fi Direct	2.4/5.0 GHz	250 Mbps	-	WPAN	-	Peer-to-peer/ wire replacement	Consumer electronics (peer-to-peer)
ZigBee	802.15.4	868 MHz	20 Kbps	30m	WPAN	1W	Low cost Low power Low latency	Energy management Industrial control Consumer electronics
		915 MHz	40 Kbps					
		2.4 GHz	250 Kbps					
Bluetooth	Version 1.x	2.4GHz	1 Mbps	Class 1 - 100m	WPAN	Class 1 - 100 mW	Peer-to-peer/ wire replacement	Handsets PC Peripherals
	Version 2.x	2.4GHz	3 Mbps	Class 2 - 10m		Class 2 - 2.5 mW		
	Version 3.0	2.4GHz	24 Mbps	Class 3 - 1m		Class 3 - 1 mW		
	Bluetooth LE	2.4 GHz	1 Mbps	-		0.01-0.5 mW	Low power	Remote sensors

Source: In-Stat, 11/10



TI in the Embedded Connectivity Market

Proven Experience

- Nearly 10 years delivering connectivity solutions to market
- Multiple generations of proven solutions
 - Bluetooth® – 7th generation
 - WLAN – 7th generation
- Shipped more than 1B units
- Low-power devices optimized specifically for handheld applications
- Integrated & tested on TI processors
- Flexible engagement & support model

Proven Track Record



Mobile Phones & Portable Devices



Human Interface Devices & Peripherals



Industrial, Security & Automation



TI Wireless Connectivity Portfolio



134KHz /13.56MHz	Sub 1GHz	2.4GHz			5GHz	Satellite
RFID	SimpliciTi	SimpliciTi	ZigBee	Bluetooth	WiFi 802.11 a/b/g/n + Bluetooth	GPS
NFC ISO14443B ISO15693	6LoWPAN	PurePath™ Wireless Audio	6LoWPAN	Bluetooth Low Energy		
	W-MBus		RF4CE	ANT		

Applications

Point of sale	Metering Home automation Alarm & security	Headphone	Smart energy	Health & wellness	Consumer handheld devices	Asset tracking
Electronic shelf labeling		Speakers	Home automation	Sports & fitness	Portable data terminals	Navigation
Access & security		Gaming	Remote control	Mobile accessory	Medical	Precision timing
Smart energy		Human interface devices	Sensor networks	Gaming controllers	Home automation	Sports & fitness
Medical			Healthcare			

Products

TMS37157 TRF796x TRF7970	CC1101 CC1110 CC430 CC1120	CC2500 CC2510 CC8520	CC2530 CC2531 CC2533 CC2520	CC2560/7 CC2540 CC2570/1	WL1271/3	Coming soon
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Denotes TI Proprietary solution or customer defined protocol on these products

Wireless Design Considerations

- Operating frequency vs range and markets needs
- Data rate vs range and power consumption
- Regulatory requirements
 - Narrowband duty cycle limits
 - International variation of standards
- Standard (interoperable) or proprietary solution
- Radio + MCU or SoC solution
- Interface options
- Available protocol stacks
- Drivers for my OS
- Application scenarios: available power vs performance

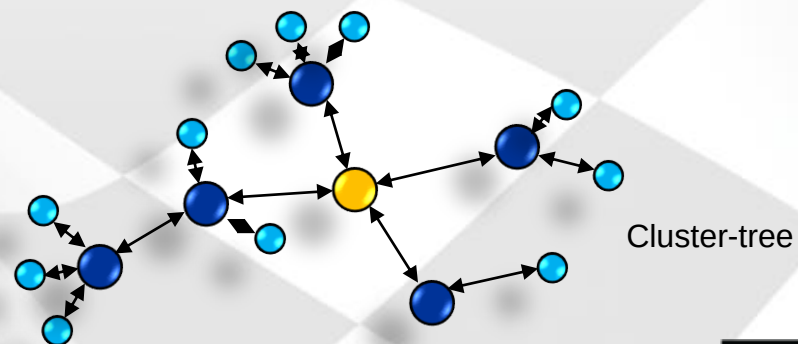
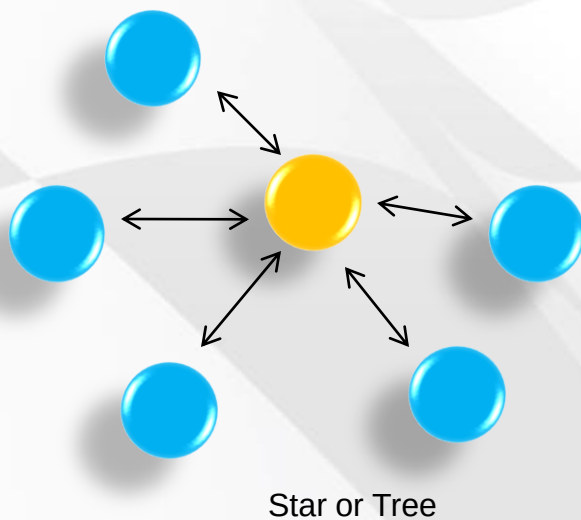
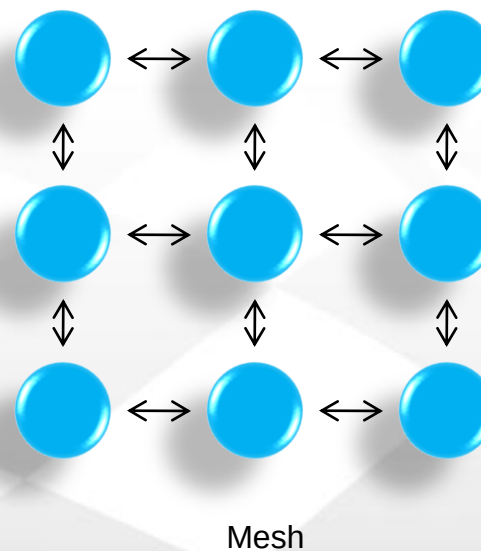
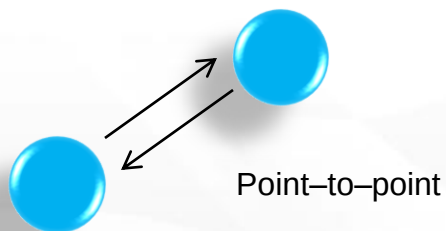


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Wireless Networking Topology 101



Which Frequency Band is Better?

	Advantages	Disadvantages
<1 GHz	Best range Less crowded	Lowest data rate Narrowband interference Restrictions on duty cycle at some frequencies
2.4 GHz	Works worldwide High data rate Full duty cycle allowed	Most crowded
5 GHz	Highest data rate Least crowded	Less range

Digital Carrier Modulation

$$s(t) = A(t) \cdot \cos(w(t) + \phi(t))$$



Phase Shift Keying

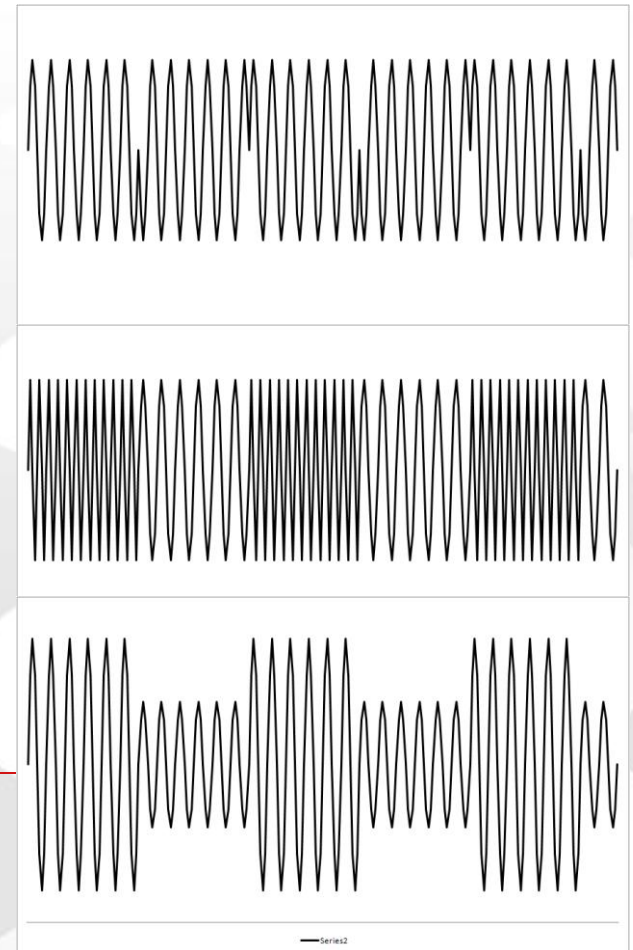
PSK
BPSK (2-PSK)
QPSK (4-PSK)
16PSK
DPSK

Frequency Shift Keying

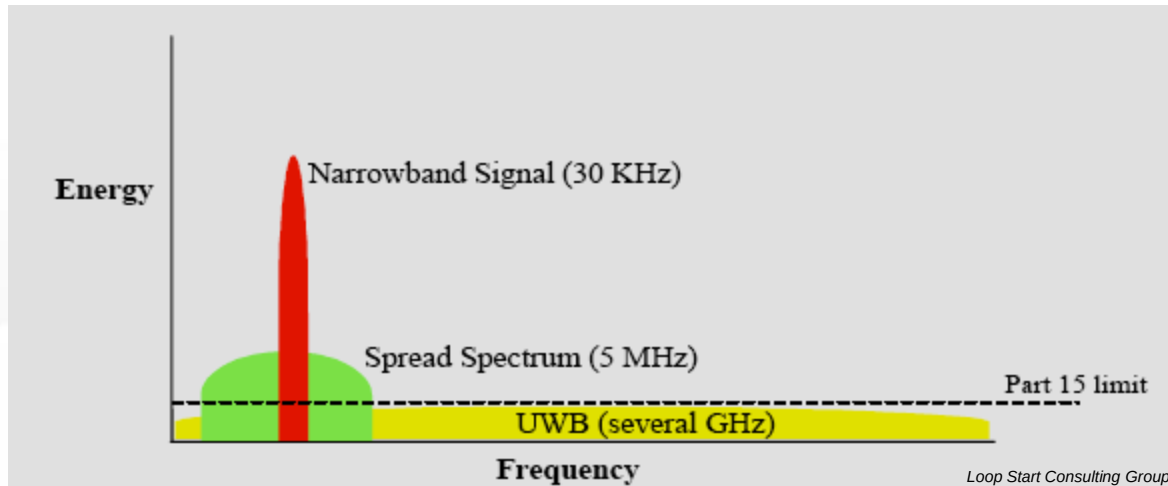
FSK
M-FSK
GFSK

Amplitude Shift Keying

ASK
OOK

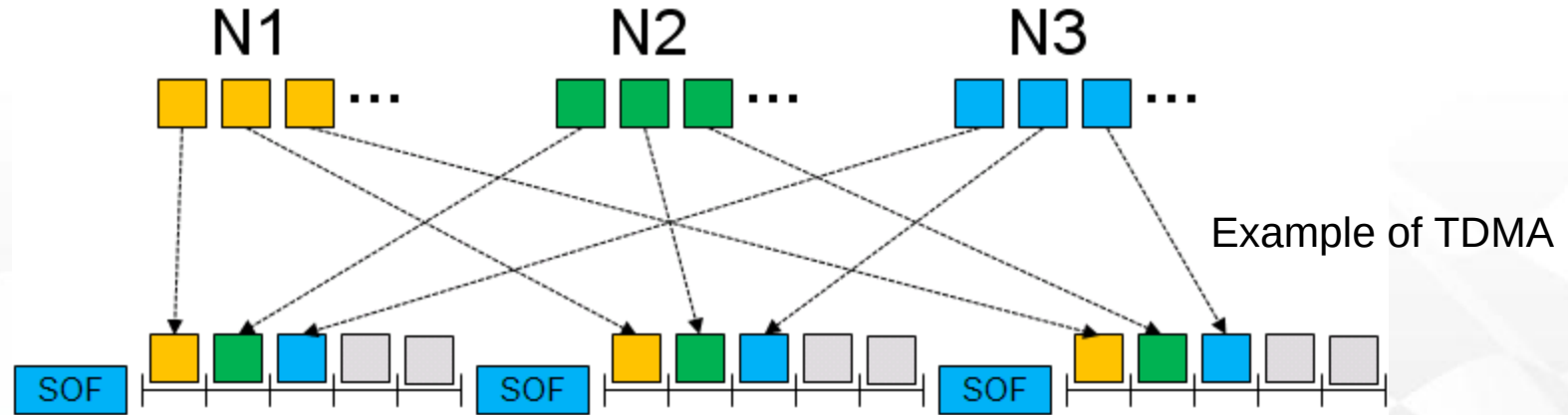


Spread Spectrum vs. Narrowband Modulation



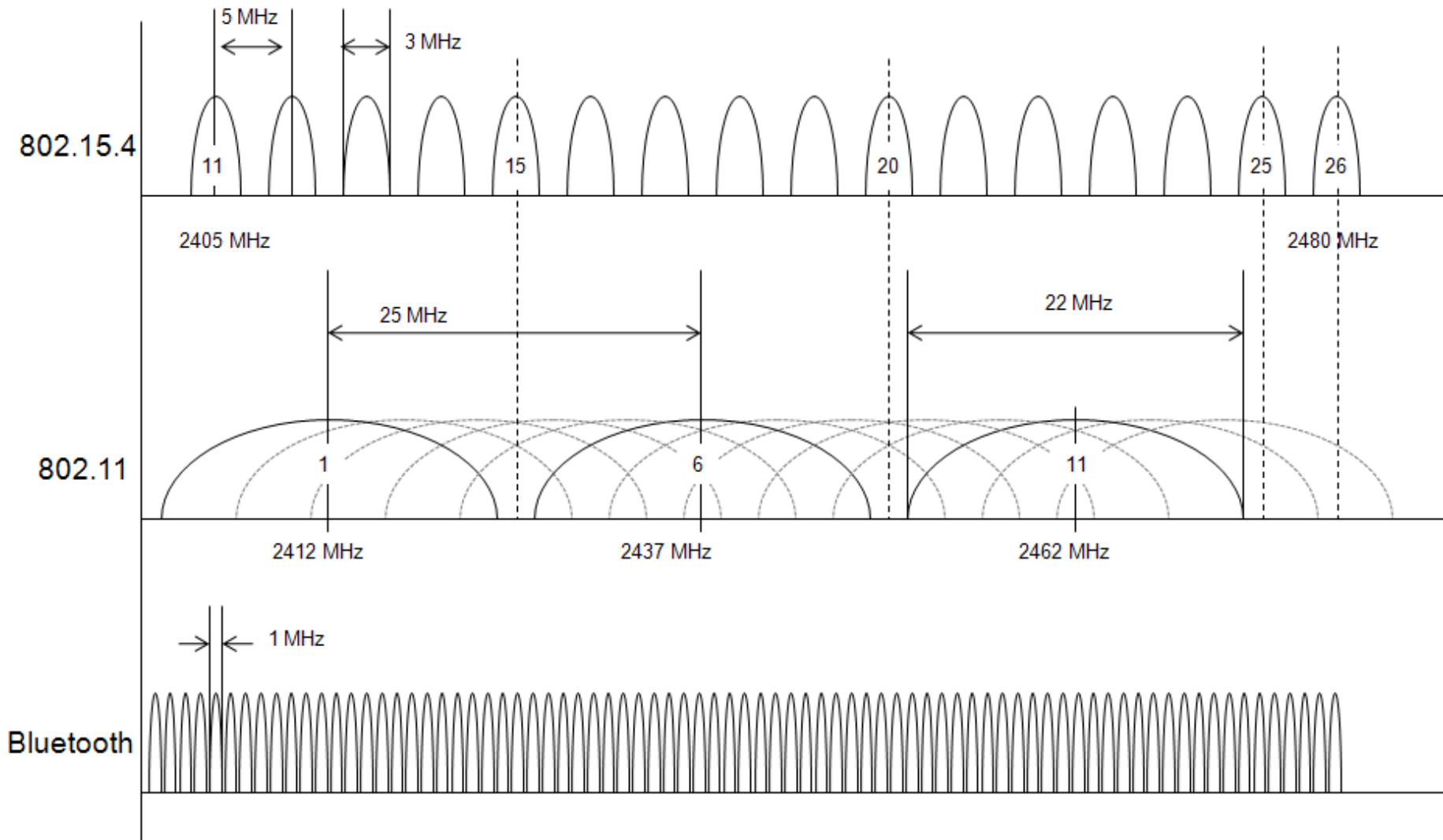
- Frequency Hopping Spread Spectrum (FHSS)
- Direct Sequence Spread Spectrum (DSSS)
- Chirp Spread Spectrum (CSS)
 - IEEE 802.15.4a UWB for precision locating

Channel Sharing Techniques



- TDMA - Time Division Multiple Access
- CSMA - Carrier Sense Multiple Access
- FDMA - Frequency Division Multiple Access
- CDMA - Code Division Multiple Access

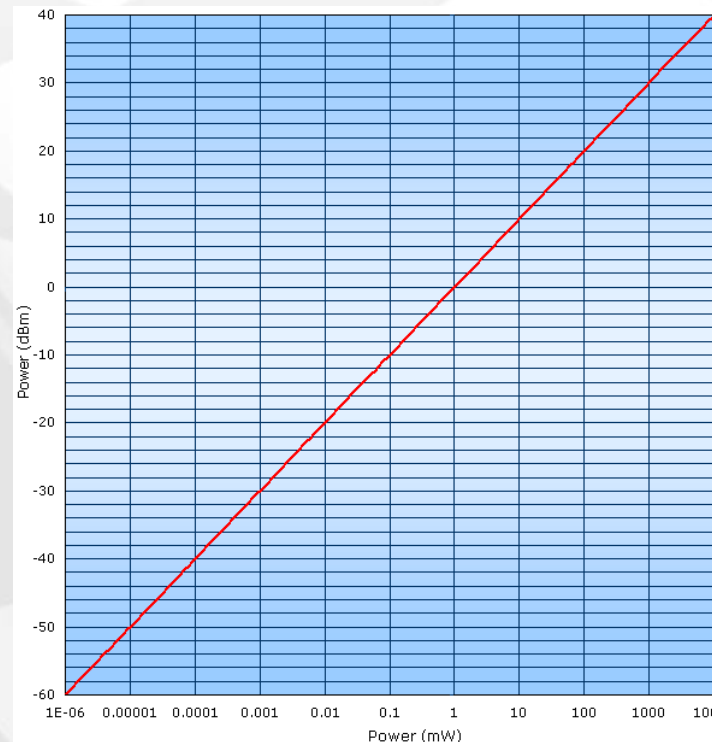
Co-existence at 2.4 GHz



About dB and Watts

- Voltage ratio:
 $\text{dB} = 20 \log (V_2/V_1)$
- Power ratio:
 $\text{dB} = 10 \log (P_2/P_1)$
- Voltage level:
 $\text{dB}\mu\text{V} = 20 \log (V/1\mu\text{V})$
- Power level:
 $\text{dBm} = 10 \log (P/1\text{mW})$
- RF datasheets show radio power in **dBm**
 - 0 dBm = 1mW
 - 10 dBm = 10mW
 - 20 dBm = 100mW
 - 30 dBm = 1000mW
 - 110 dBm = 10^{-11}mW

Typical transmit power in dBm	
Microwave oven	60 dBm (1kW)
Cell phone	27 dBm (500mW)
Bluetooth Class 1 (100m)	20 dBm (100mW)
WLAN card	18 dBm (70mW)
Bluetooth Class 2 (10m)	4 dBm (2.5mW)
Typical Rx signal in a sensor network	-70 dBm (100pW)
GPS Rx signal	-127 dBm (0.18fW)



Range Depends on Link Budget

Link budget = *transmitter power* – *receiver sensitivity* + *antenna gains*

Transmitter power



- How loud can you yell?
- Usually higher is better
- Often register selectable
- Measured in dBm (for example: +10dBm)

Receiver sensitivity



- How well can you hear?
- Lower is better
- Measured in dBm (for example: -93dBm)

Example: (+10 dBm) – (-93 dBm) + 0 = 103 dBm

Calculating RF range

Friis transmission formula (free space, line-of-sight)

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

P_t, P_r = transmit or receive power (W)

G_t, G_r = gain of transmitting or receiving antenna

λ = wavelength = $3 \times 10^8 / f$

R = range (meters)

$$R = \frac{23.9}{f \text{ (MHz)}} \sqrt{\frac{P_t G_t G_r}{P_r}}$$

Example:

$P_t = 0 \text{ dBm} = 1\text{mW}$

$P_r = -90 \text{ dBm} = 1 \times 10^{-12} \text{ W}$

$G_t = G_r = 0 \text{ dBi} = 1$

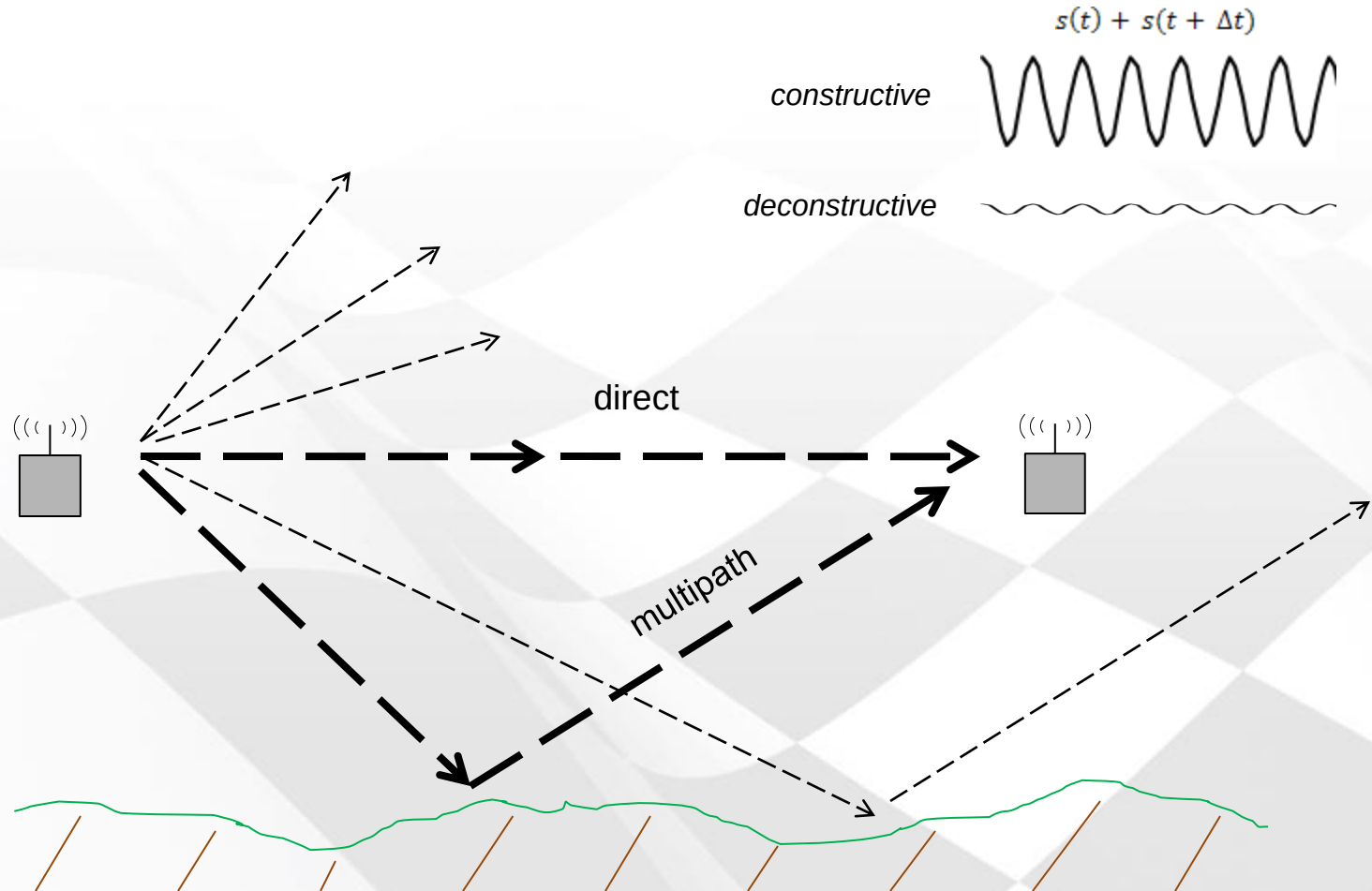
$f = 2450 \text{ MHz}$

$\therefore R = 308 \text{ meters}$

Online Friis calculator: <http://www.random-science-tools.com/electronics/friis.htm>



Propagation Effects – Multipath Fading



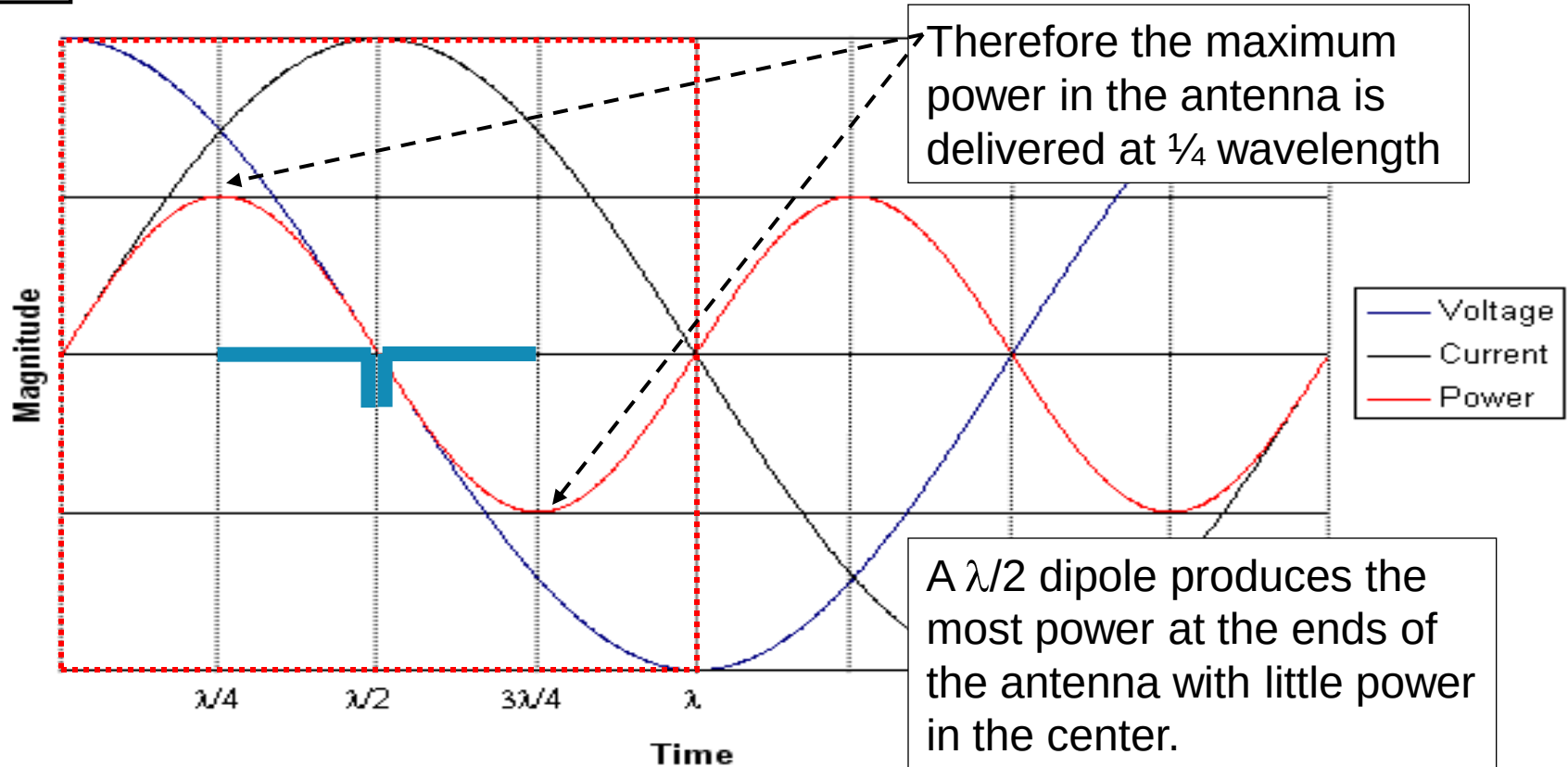
Antennas | Wavelength



An antenna is an air core inductor of a defined length λ

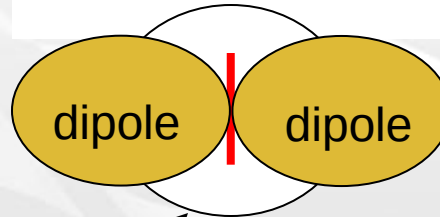
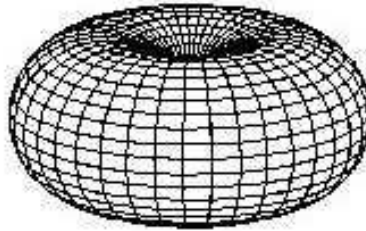
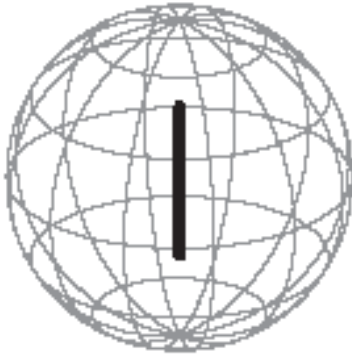
The AC current through an inductor lags the voltage by 90 degrees

Antenna Output Power



Antennas | Gain

Isotropic Antenna

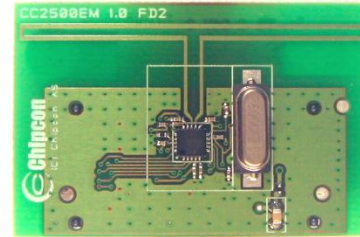


0 dBi

Antenna gain is referenced
to ideal isotropic antenna
 $0 \text{ dBd} = 2.14 \text{ dBi}$

Common Antenna Types

- PCB antennas
 - No added component cost
 - Size demanding at sub 433 MHz
 - Good performance at > 868 MHz
- Chip, puck antennas
 - Medium cost
 - Good performance at 2.4 GHz
 - OK performance at 868-955 MHz
- Whip, patch antennas
 - Expensive solutions for high volume
 - Good performance
 - Hard to fit in many applications
- Wire / helical antennas
 - Low cost
 - Ideal at sub-433 MHz
- Custom molded
 - High volume applications

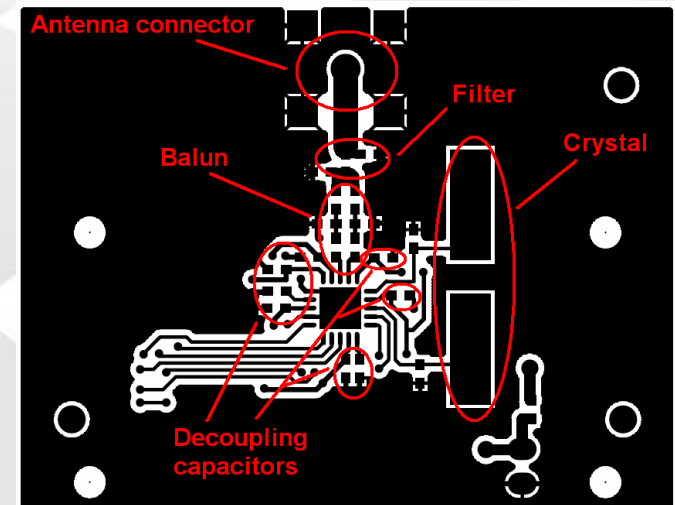
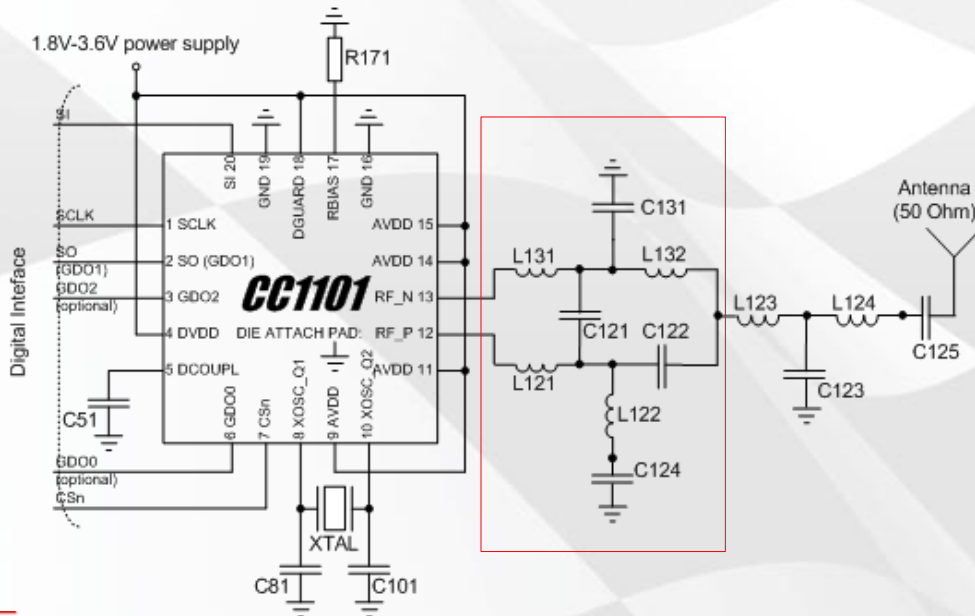


TEXAS
INSTRUMENTS



Balun

- In TX:
 - Converts signals from differential to single-ended
 - Provides optimum impedance matching for highest possible radiated power
- In RX:
 - Converts signals from single-ended to differential signal
 - Provides optimum matching for best possible sensitivity

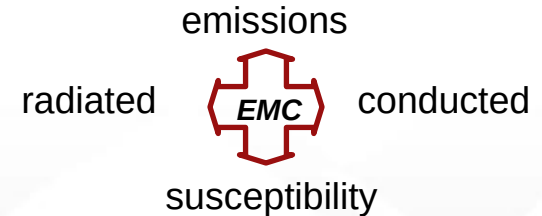


The Process:

- » FCC Registration Number
- » FCC Grantee Code
- » FCC ID Number
- » Emissions Designator Number
- » TCB Agreement
- » FCC Certification Letter

Typical Costs (from LS Research):

- FCC: ~\$8,000- 10,000
- IC: ~ \$2,000 - 3,000
- CE: ~ \$10,000- \$13,000



LS Research

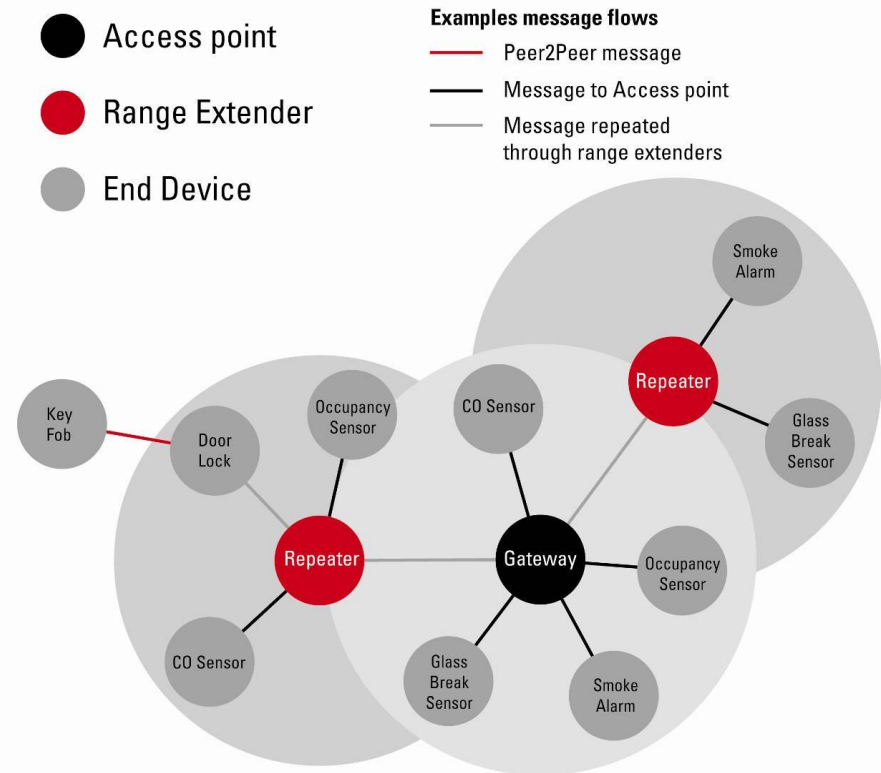
Modular Filing – FCC PART 15 UNLICENSED MODULAR TRANSMITTER APPROVAL

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SimpliciTI Networking Protocol

- TI proprietary **low-power RF** network protocol
- Low resource overhead:
 - < 8K FLASH
 - <1K RAM
- Flexible:
 - simple **star** w/extender
 - **p2p** communication
- Simple: utilizes a very **basic** core API
- Low power: supports **sleeping** devices



BlueRobin™ Data Transmission Protocol



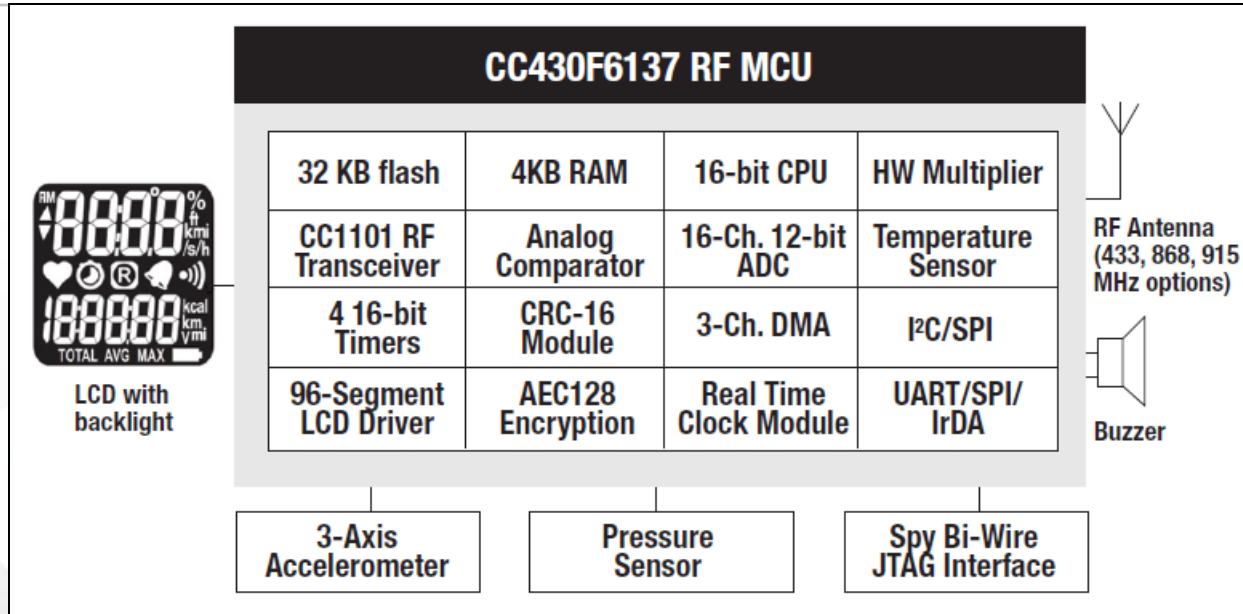
- Proprietary from BM Wireless
- Low data rate protocol for body area sensor networks and team monitoring systems
- Selectable from 8 bits to 256 bits per data packet
- Packet intervals of 500 ms up to 1 second
- Unidirectional transmission with on-demand acknowledge
- Built-in data packet collision avoidance
- Compact code size
- Versions available for 315/433/868/915MHz and 2.4GHz
- One receiver supports up to 200 nodes



Overview | eZ430-Chronos Eval Kit



Overview | eZ430-Chronos Eval Kit



www.ti.com/chronoswiki



Overview | eZ430-Chronos Eval Kit

- Free **development software**
 - Code Composer Studio
 - IAR Embedded Workbench
 - MSPGCC*
- Production-ready, **open-source projects**
- Multiple easy-to-use **RF stacks available**
 - SimpliciTI
 - BlueRobin
 - W-Mbus
 - 6LoWPAN
 - More coming...



- **User generated apps** and support located at www.ti.com/chronoswiki

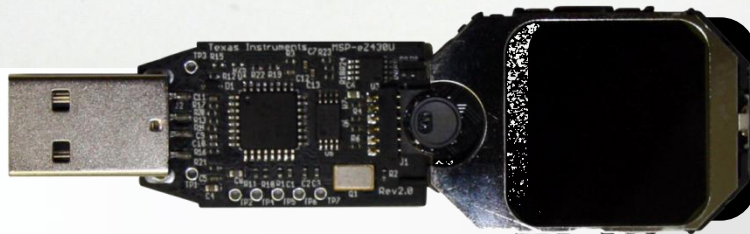
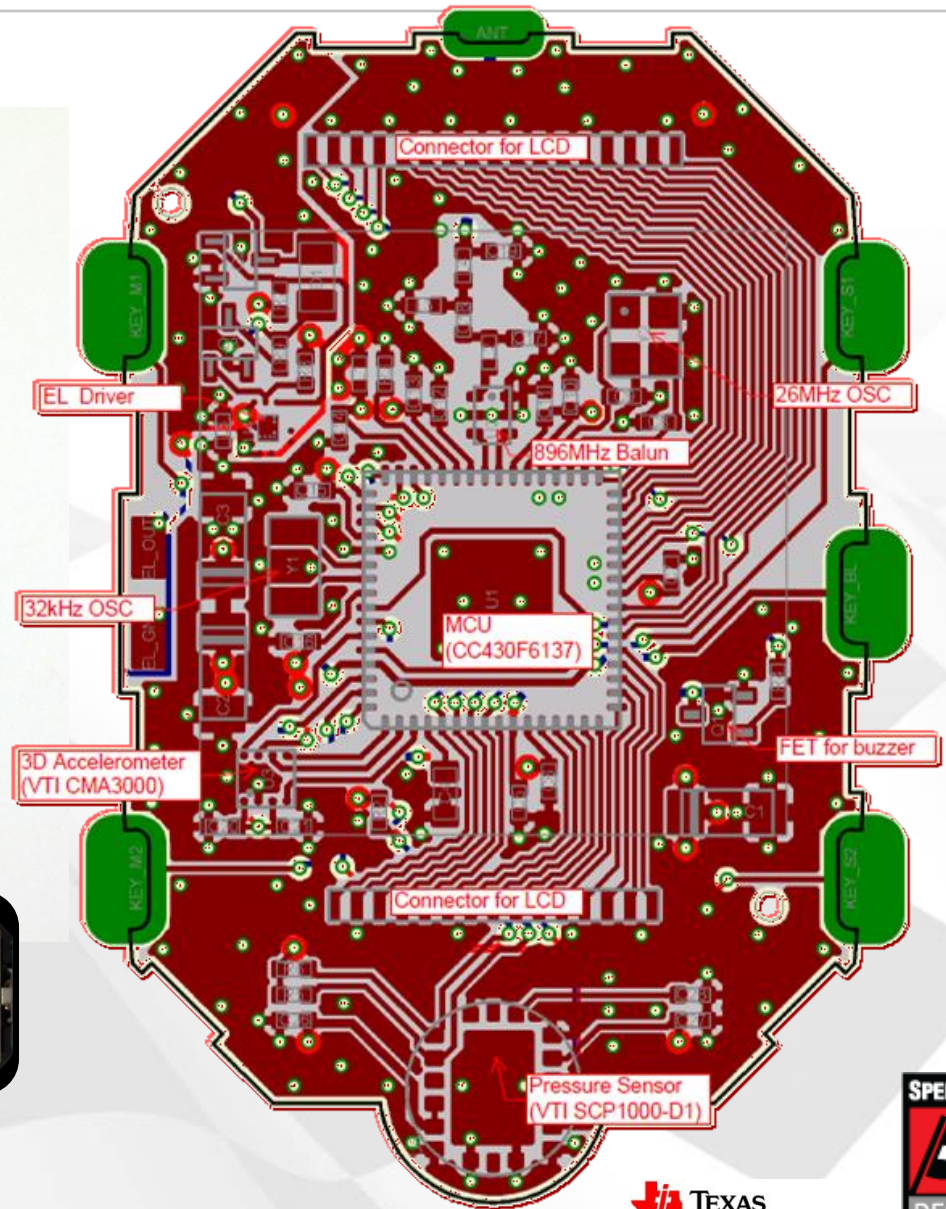
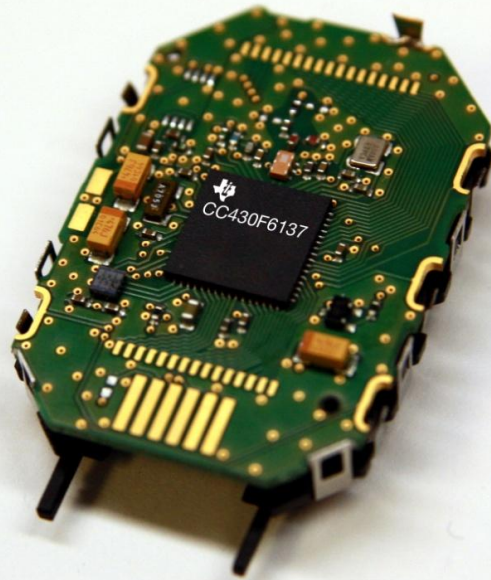
Chronos Projects include...

- Watch functions (time, date, alarm, stopwatch)
- Fitness programs: running speed, distance, heart rate, calories burned
- Sensor data logging w/ wireless PC download
- PowerPoint Control
- Media Remote
- Motion-based mouse/PC game control
- RF control of Beagle board game
- Robotics Control
- Elderly fall detection*
- Wireless App Updating*
- Car Horsepower/G-Force Estimator*
- Skier Speed & Altitude Logger*
- More apps to come...

*App in works



eZ430-Chronos Kit | Hardware Teardown

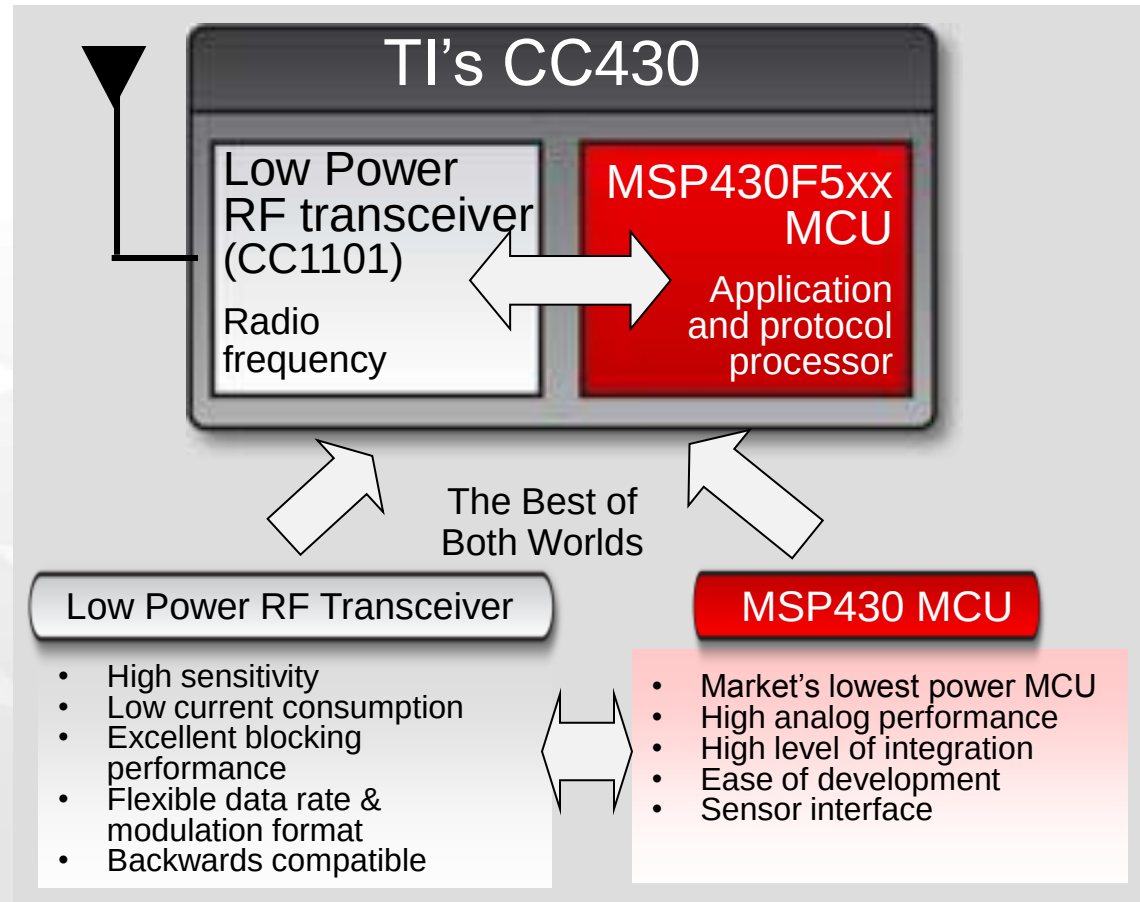


CC430 = MSP430 with <GHz RF connectivity

Wireless Made Easy

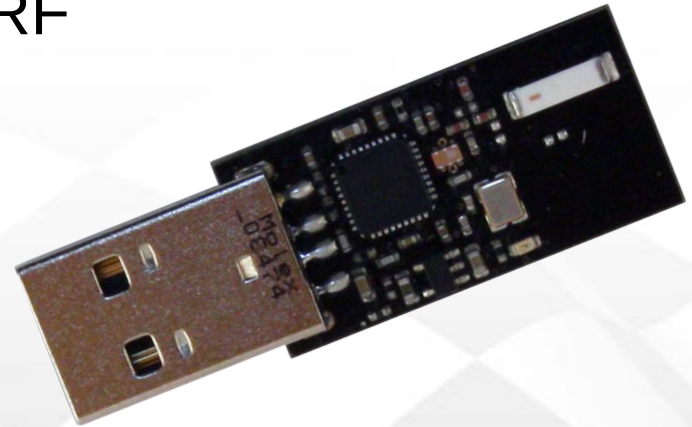
Free RF libraries and stacks

- SimpliCI™ (star network) - www.ti.com/simpliCI
- TIMAC – IEEE 802.15.4 Medium Access Control (MAC)
- Z-Stack – free ZigBee stack. Compliant with 2006 ZigBee™ spec (www.ti.com/zigbee)
- Third party partners with mesh network stacks – coming soon!
- SmartRF® Studio - automatically generates register values



Chronos Kit | RF Access Point

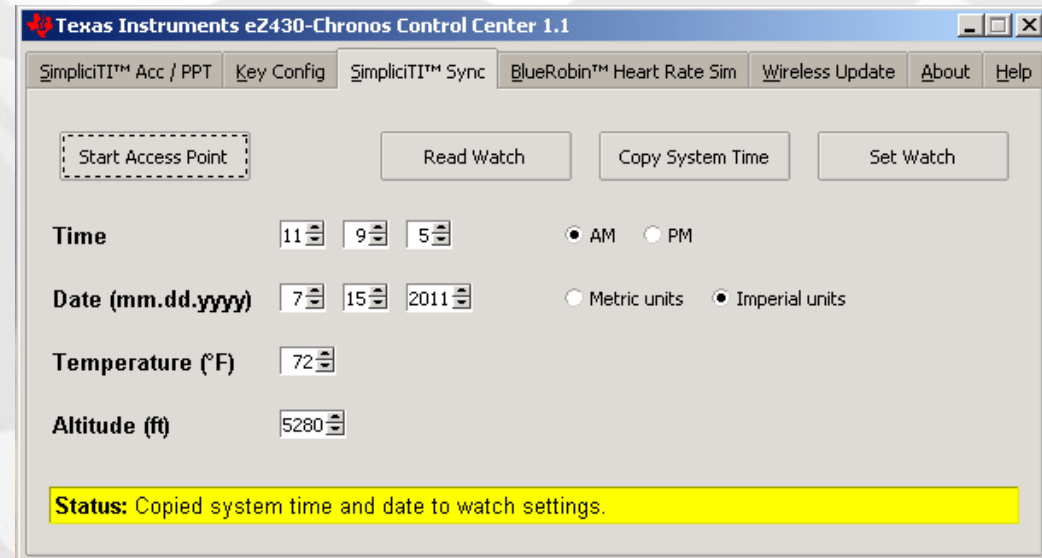
- Based on CC1111 w/ integrated USB and <1GHz RF
- “fixed function” to communicate with Chronos & PC
- Supports wireless update of Chronos firmware via rfBSL
- Can be manually reprogrammed with CC Debugger



header to JTAG signals
has to be manually added

PC-AP-Chronos Communication

- RF Access Point implements a Virtual COM Port over USB
 - bps 115200
 - Data bits 8
 - Parity None
 - Stop Bits 1
 - Flow Control None
- Control Center automatically
 - Opens COM port
 - Transfers data
 - Decodes packets
 - Displays info
- API available for manual data transfer
- Scripts available for:
 - Python
 - Processing
 - Ruby
 - .net
- All community developed, supported



eZ430-Chronos Software Install Package

Installation has copied all files to

C:\Program Files\Texas Instruments\eZ430-Chronos

What's included:

- Control Center
 - Control Center GUI binary
 - Data logger GUI binary
 - GUI source code
- Documentation
 - User guide
 - Schematics, layout (Gerbers) & BOM
 - RF Access Point
 - eZ430 Debug Interface
 - Watch
- RF Access Point driver
- Binary images (recovery)
 - Sports Watch app
 - Datalogger app
 - rfBSL
 - RF Access Point
- Software projects
 - Sports watch (CCS/IAR)
 - Datalogger (CCS/IAR)
 - RF Access Point (IAR)



LAB 1 – FOLLOW HANDOUT INSTRUCTIONS



Accelerating Your Success™

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Proprietary vs. Industry Standard

Advantages

Disadvantages

Examples

Proprietary

Tailored to the application
Specialized functions
Smaller software stack
Choice of frequency bands

Each OEM's topology can be different
Less options among suppliers
No interoperability

Sub-GHz
2.4GHz
PurePath

Industry Standard

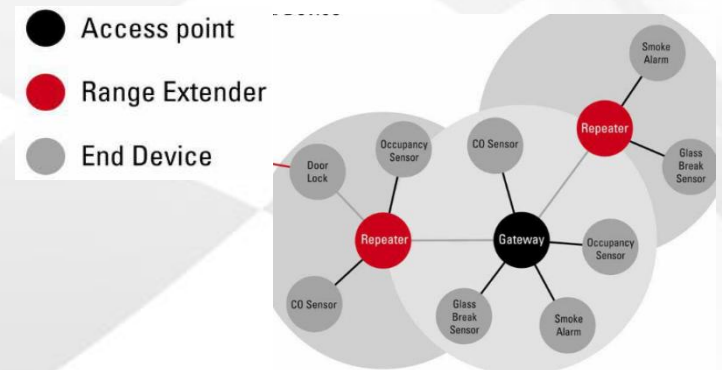
Interoperability among different suppliers
Standardization: customer choice of suppliers
Ease of network expansion

Larger software stack in most cases
Potentially higher power consumption

ZigBee
Bluetooth
BLE
ANT
6LoWPAN
Wi-Fi
RF4CE

SimpliciTI

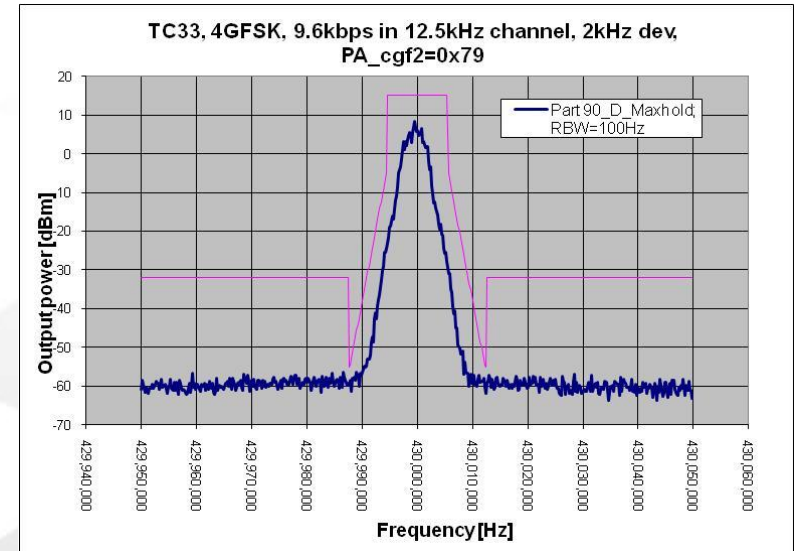
- Small footprint: uses ~12K FLASH and ~1.5K RAM depending on platform (MSP more code dense than 8051 core)
- Flexible: simple star w/ extender (4 hops) and/or p2p communication
- Low Power: supports sleeping devices for low power consumption
- Simple: utilizes a very basic core 6 instructions API by default. Can be extended to 10.
- Versatile – runs on any of these PHY's
 - MSP430+CC1101 / CC430 / CC2500,
 - CC1110 / CC1111 / CC2510 / CC2511
 - CC2520 / CC2530 / CC2531



SimpliciTI targets quick time-to-market wireless solutions for low power, low cost, and low data rate networks without the need to know the details of the network support.

Sub-GHz Proprietary

- Allows for the longest RF transmission range, up to several kilometers (“Wide Area Networks”)
- Strict RF regulations in sub1-GHz bands enable high reliability and strong RF links. Limits are typically imposed by regulatory body on:
 - RF spectrum output (“don’t emit in other RF channels that you aren’t supposed to”)
 - RF duty cycle in certain frequency bands (“you can’t occupy the RF channel too long”)
- Very popular for industrial applications

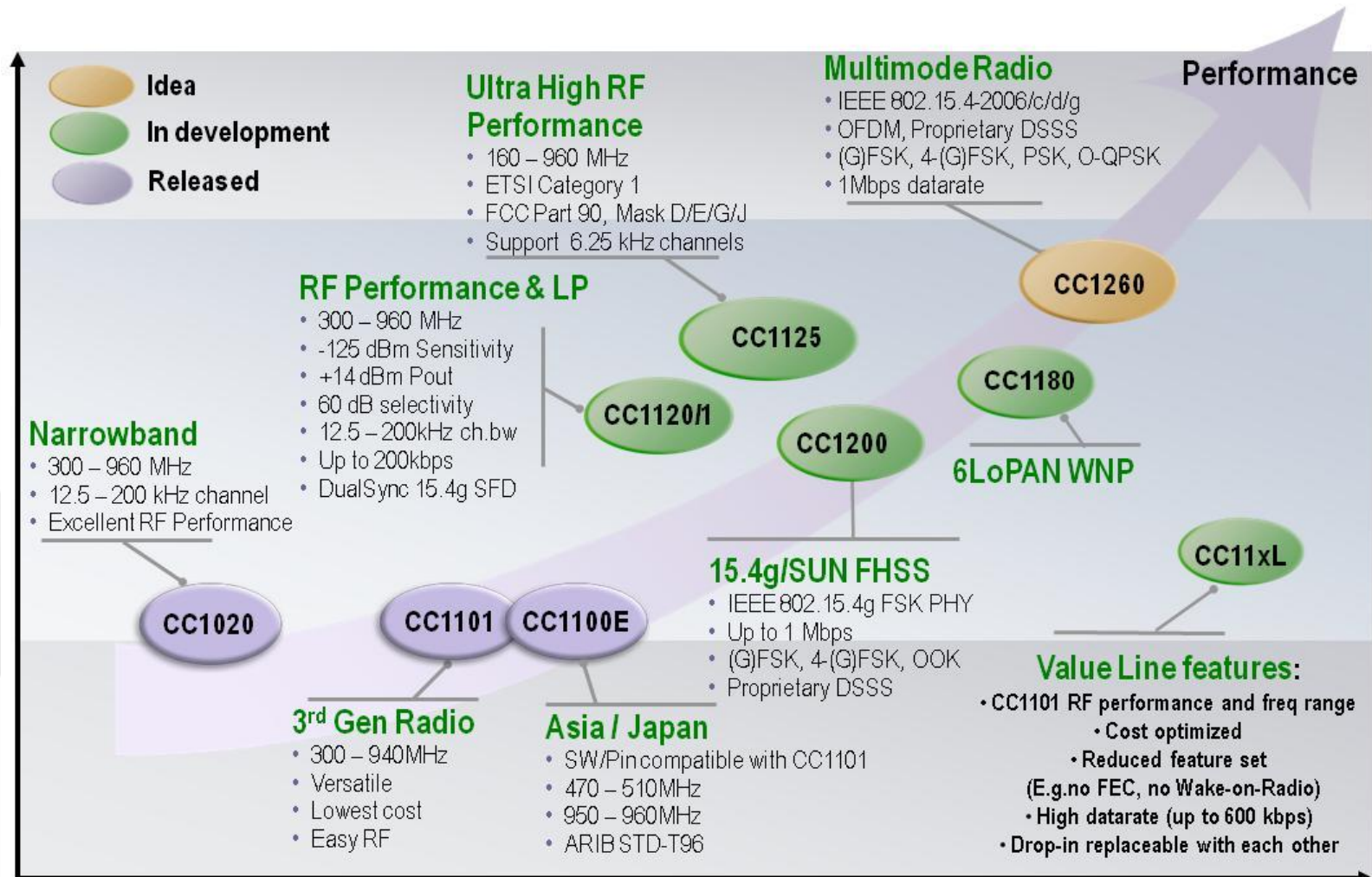


Why TI Sub-1GHz?

- Both best-in class RF performance and value line RF parts are available
- All TI parts have fast startup and lock times, enabling lower power consumption
- TI's parts meet the most stringent ETSI, FCC and ARIB RF regulations
- Extensive development kits, reference designs and application notes available

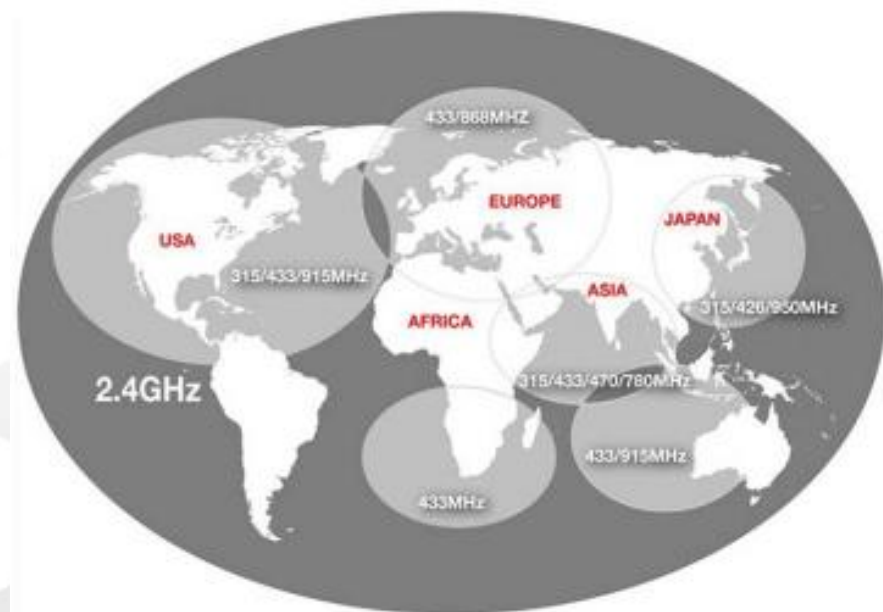


TI Sub-GHz Solutions Roadmap



2.4GHz Proprietary

- 2.4GHz band can be used world-wide
- RF protocol can be tailored to specific application needs
- Allows 100% duty cycle applications
- Very low-cost designs possible with “no-cost” PCB antennas
- Small form factor compared to sub-1GHz
- Very popular in the consumer segment

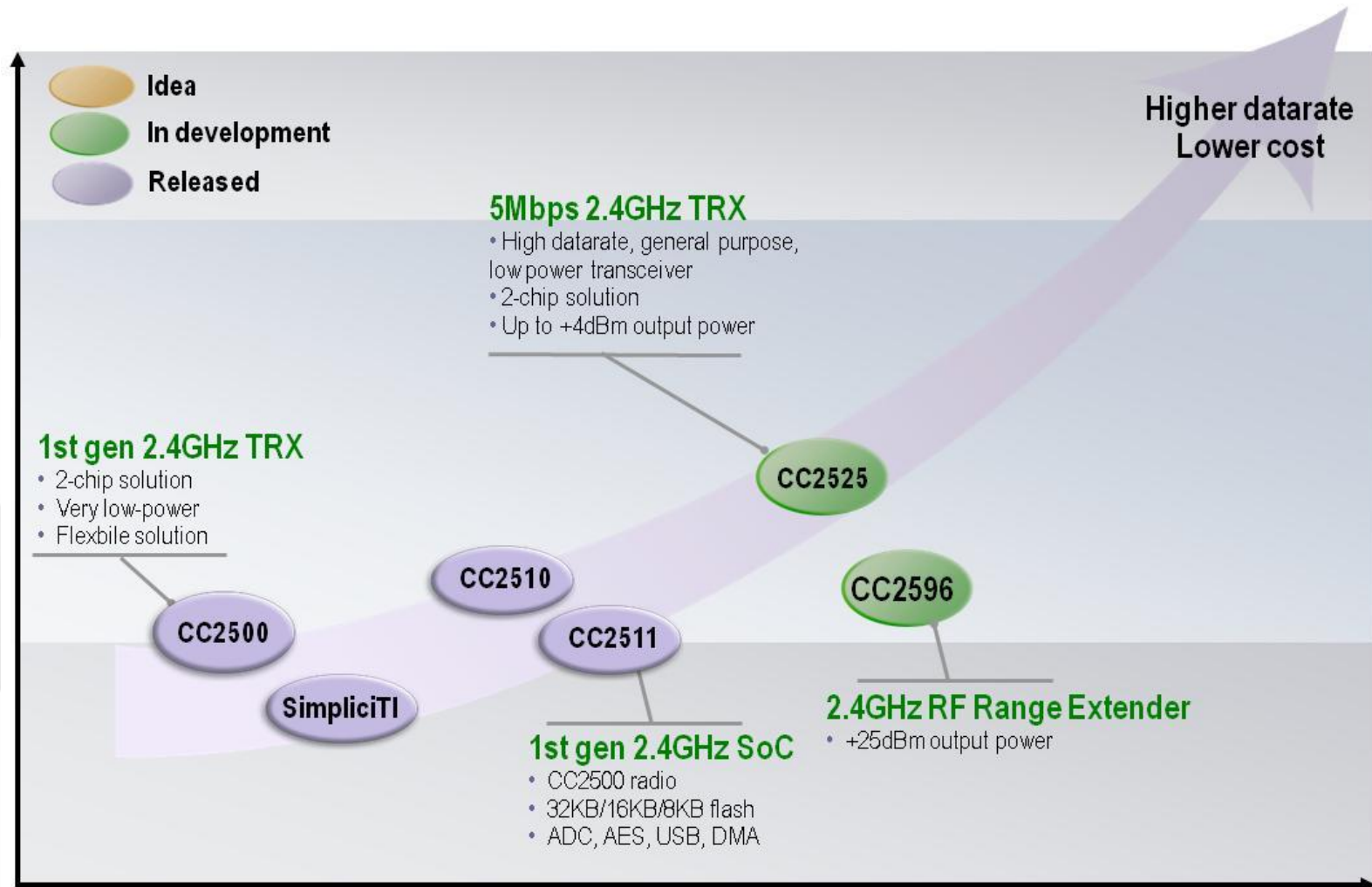


Why TI 2.4GHz?

- TI has transmitter, transceiver, and System-on-Chip RF parts with embedded microcontroller and USB
- Excellent co-existence performance in noisy environments
- Extensive development kits, reference designs and application notes available

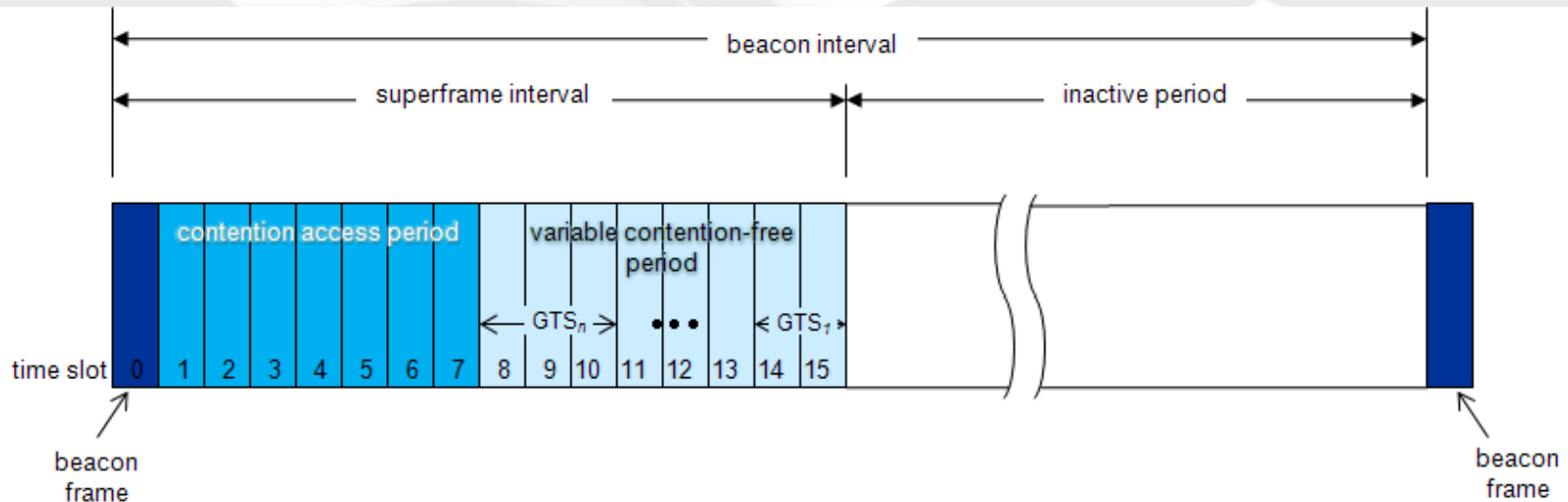
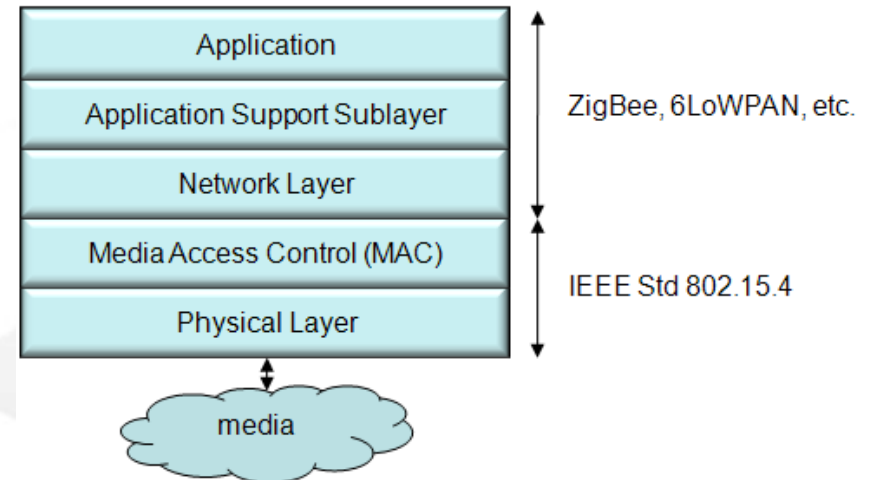


TI 2.4 GHz Proprietary Solutions Roadmap



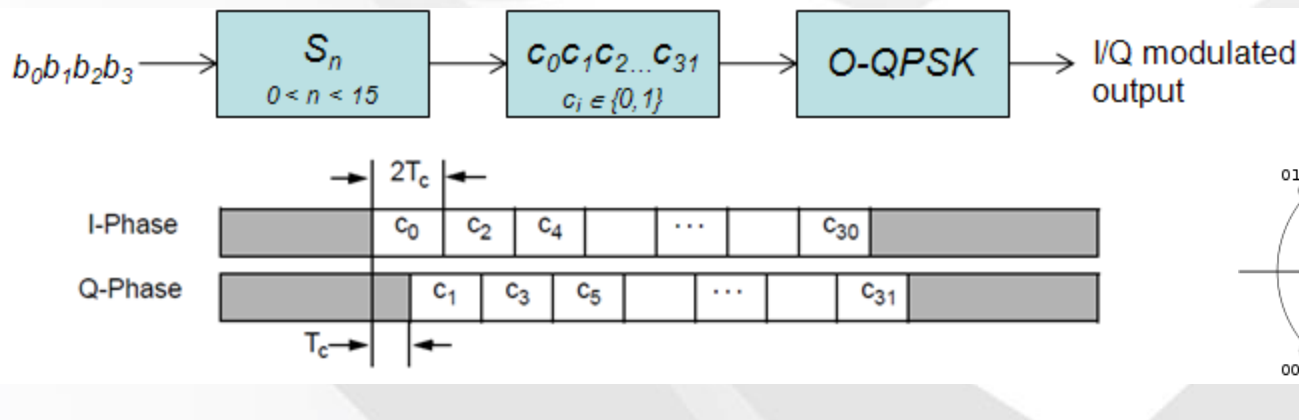
IEEE Std 802.15.4 MAC

- CSMA/CA: Carrier Sense Multiple Access with Collision Avoidance
- Fully acknowledged
- Up to 127 byte data packet with CRC
- 64 or 16-bit addressing
- Mesh, star or cluster tree topology
- Two devices types: FFD, RFD
- Three roles: end device, coordinator, and PAN coordinator
- 128-bit AES encryption link layer security
- Two modes:
 - Beaconless – pure CSMA
 - Beaconed – containing superframe with guaranteed time slots



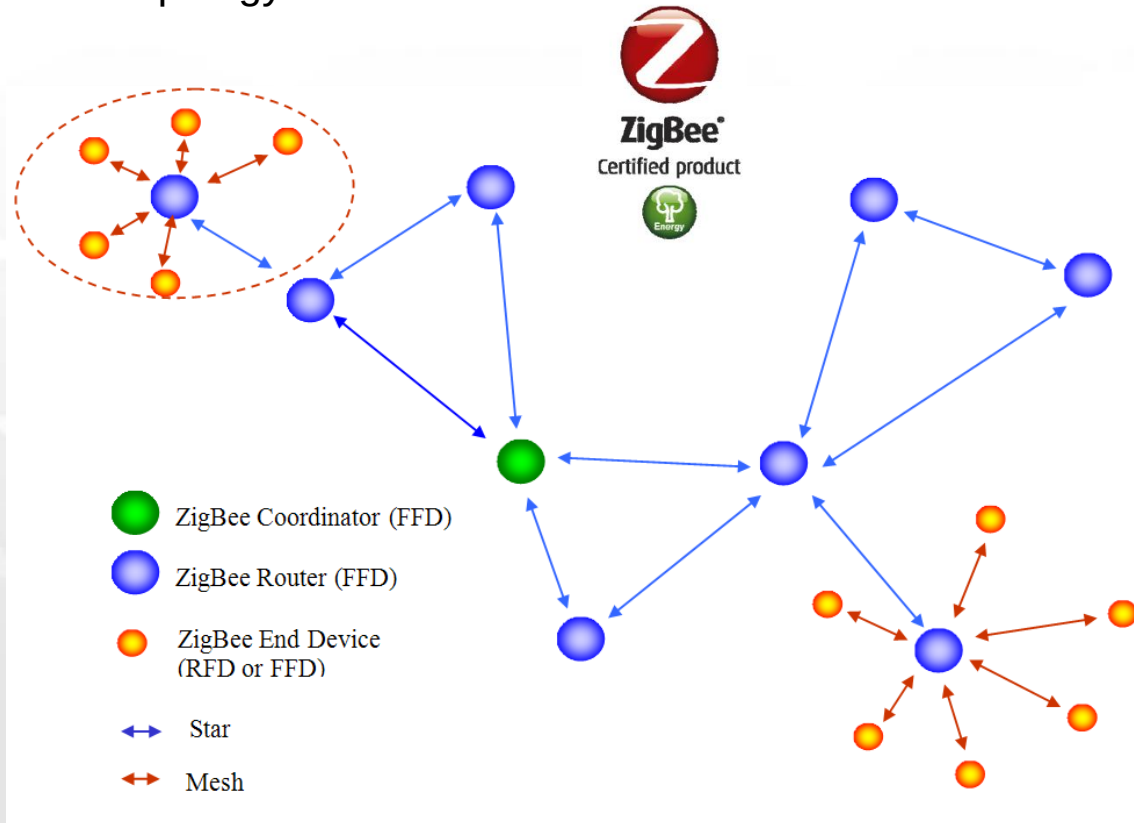
IEEE Std 802.15.4 PHY

PHY (MHz)	Frequency Band (MHz)	Modulation	Channels	Channel spacing	Bit rate (kbps)	Symbol rate (ksymbol/s)	Symbols
868	868-868.6	BPSK	1	-	20	20	binary
868	868-868.6	ASK	1	-	250	12.5	20-bit PSSS
868	868-868.6	O-QPSK	1	-	100	25	16-ary orthogonal
915	902-928	BPSK	10	2MHz	40	40	binary
915	902-928	ASK	10	2MHz	250	50	5-bit PSSS
915	902-928	O-QPSK	10	2MHz	250	62.5	16-ary orthogonal
2450	2400-2483.5	O-QPSK	16	5MHz	250	62.5	16-ary orthogonal



2.45GHz PHY Direct Sequence Spread Spectrum Conversion

- Original protocol stack for IEEE Std 802.15.4 radio
- Mesh, Star (tree, cluster tree) or P-P topology
- Self-forming, self-healing
- Two feature Sets:
 - ZigBee 2006
 - ZigBee PRO
- Three device types:
 - Coordinator
 - Router
 - End device
- Sense and control networks
 - Smart metering
 - Home/industrial automation
- ZigBee Alliance membership is required
 - Use of ZigBee trademark
 - \$3500 / yr



- Focus on ZigBee Application Profiles (ZAP)
 - Smart energy
 - Home automation
 - Building automation
 - Health care
 - Remote control
 - Telecommunication services
 - Retail services
 - 3D Sync



<http://www.zigbee.org/Standards/Overview.aspx>

- ZigBee RF4CE
 - RF for Consumer Electronics
 - Wireless Remote Controls
- ZigBee IP
 - ZigBee applications over 6LoWPAN network layer
 - Basis for Smart Energy 2.0 (draft)
- ZigBee Green Power
 - Lightweight ZigBee for energy harvesting nodes



6LoWPAN



- IPv6 over Low-Power wireless Area Networks
- Low power RF + IPv6 = The wireless embedded internet
- 6LoWPAN is an adaptation protocol
 - IPv6 and UDP header compression
 - IP Packet fragmentation/reassembly
 - 1280 byte IPv6 MTU
 - > 127 byte 802.15.4 frames

TCP/IP Protocol Stack

HTTP		RTP	
TCP	UDP	ICMP	
IP			
Ethernet MAC			
Ethernet PHY			

Application

Transport

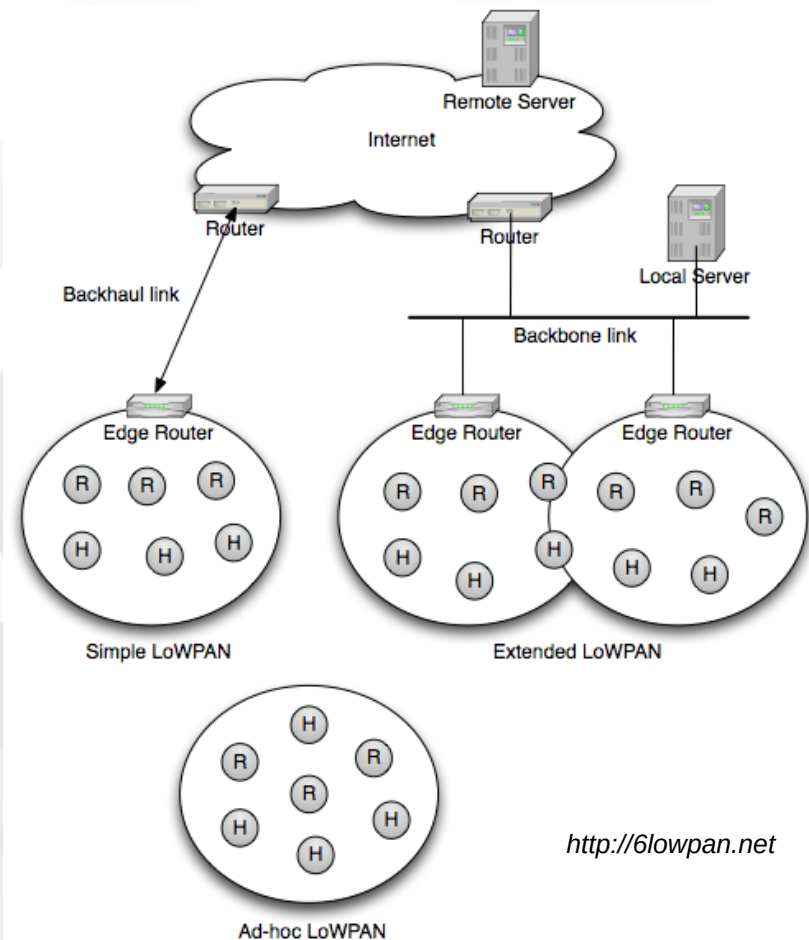
Network

Data Link

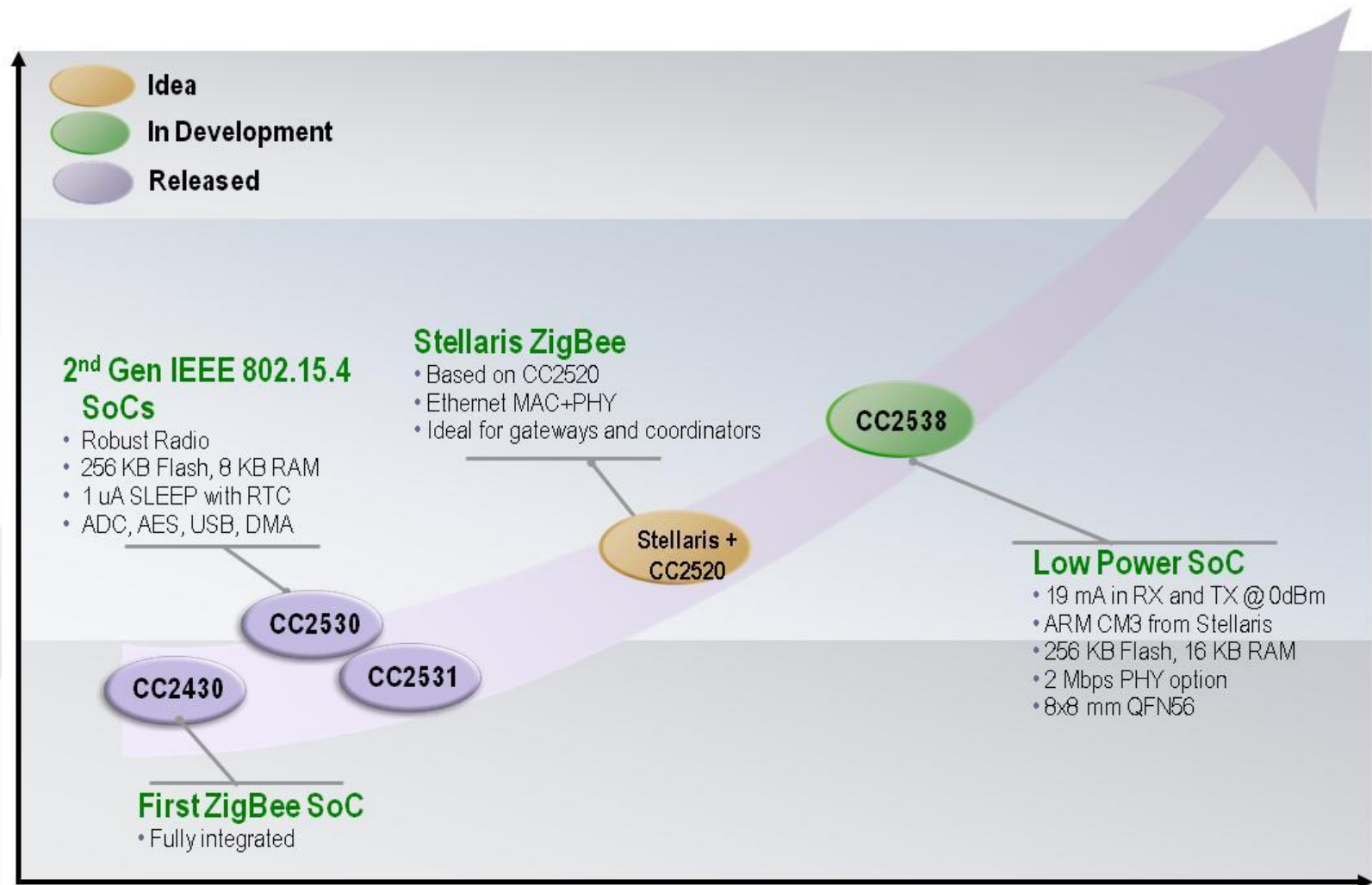
Physical

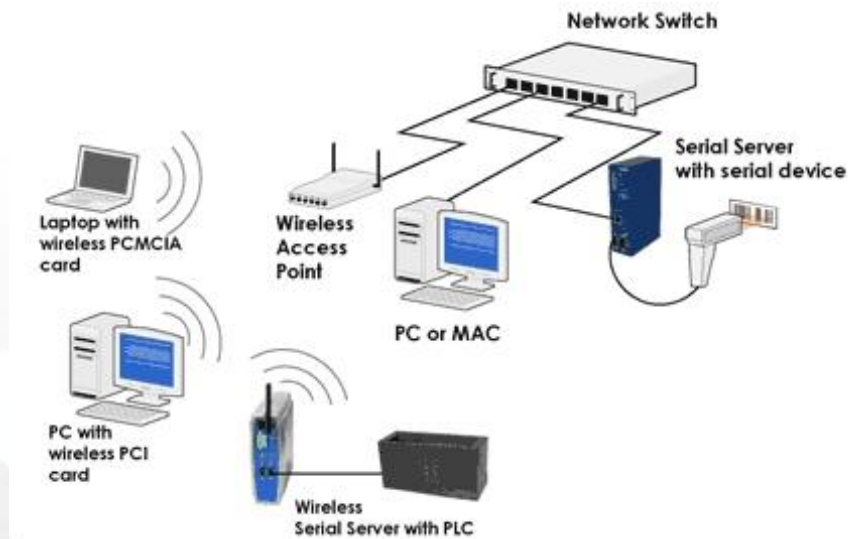
6LoWPAN Protocol Stack

Application	
UDP	ICMP
IPv6 with LoWPAN	
IEEE 802.15.4 MAC	
IEEE 802.15.4 PHY	



TI 802.15.4 / ZigBee Roadmap





- Based on IEEE 802.11 radio
- 2.4 GHz or 5 GHz ISM band
- Star topology with 255 clients
- Ad-hoc vs. managed/master mode
 - Ad-hoc allows client-to-client connections
 - Managed/master -- each managed device talks only to master (aka Access Point)



	802.11a	802.11b	802.11g	802.11n
Maximum Data Rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps
Modulation	OFDM	DSSS or CCK	DSSS or CCK or OFDM	DSSS or CCK or OFDM
RF Band	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz or 5 GHz
Number of Spatial Streams	1	1	1	1, 2, 3, or 4
Channel Width	20 MHz	20 MHz	20 MHz	20 MHz or 40 MHz

- Most prominent wireless connectivity technology for computers and internet
- Real-world throughput similar to wired networks
- Over 2.5B Wi-Fi units deployed in the market today:
 - ~1 billion units/year projected starting in 2011

Why TI Wi-Fi?

- 10 years of delivering connectivity solutions to market:
 - Wi-Fi – 7th generation
 - Bluetooth – 7th generation
- On-chip co-existence when using the integrated Bluetooth
- Highly integrated, fully certified modules available
- Platform solutions that integrate system hardware and software



WL1271/1273 WLAN and Bluetooth® v2.1 + EDR

Features

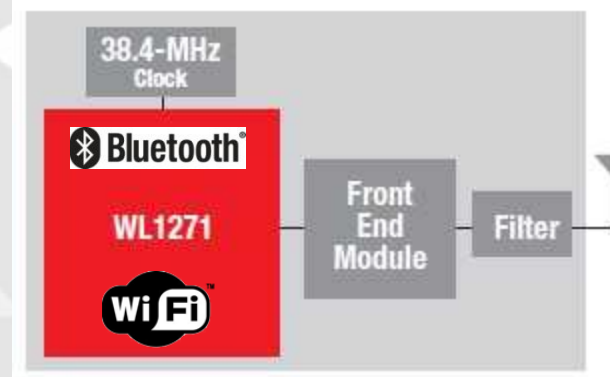
- WL1271 - IEEE 802.11 b/g/n compliant
- WL1273 – dual band IEEE 802.11 a/b/g/n compliant
- Typical WLAN Transmit power:
 - +20dBm , 11Mbps, CCK (b)
 - +14.5dBm , 54Mbps, OFDM (g)
 - +12.5dBm, 65Mbps, OFDM (n)
- Typical WLAN Receiver sensitivity:
 - -89dBm , 11Mbps
 - -76dBm , 54Mbps
 - -73dBm, 65Mbps
- Bluetooth v2.1 + EDR (Enhanced Data Rate)
 - Increased Bluetooth Transmit power: +9.5dBm
 - -92dBm Receiver sensitivity
- SW-upgradable for ANT & BLE
- Best-in-class coexistence technology on a single-chip (single shared antenna for Wi-Fi, Bluetooth, BLE, and ANT)
- 65nm Enhanced Low Power (ELP) technology for extended battery life

Benefits

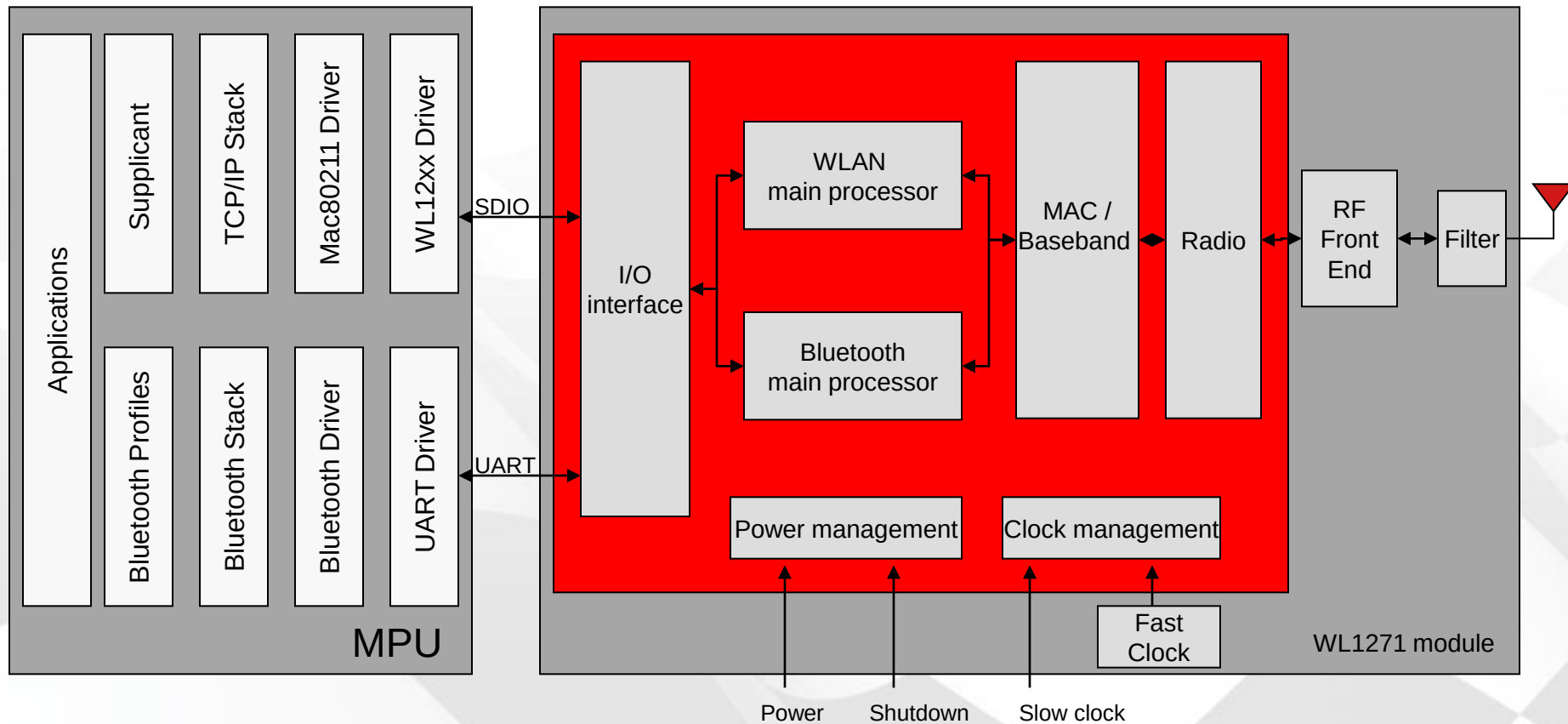
- Secure, fast and reliable Wi-Fi and Bluetooth connectivity
- High throughput, robust connection with extended range
- Extended battery life and power efficiency
- Reduced development time and costs

Applications

- Industrial and home automation
- Point of Sale and Point of Purchase
- Video conferencing, video camera and VoIP
- Consumer devices
- Medical devices
- Security and surveillance



WL1271 – MPU Platform Overview



- TI Platforms enable complete system integration of module and host MPU
- Primary WL1271 engagement model is through TI Platforms



WL1271 Supported Platforms: MPU-Based

Production

Sampling

Development

Future

Performance
Catalog

OMAP3530
WL1271

WiFi
Bluetooth®

AM3517
WL1271

WiFi
Bluetooth

AM3715/
DM3730
WL1271

WiFi
Bluetooth

Value
Catalog

AM1808/10/
OMAPL13x
WL1271

WiFi
Bluetooth

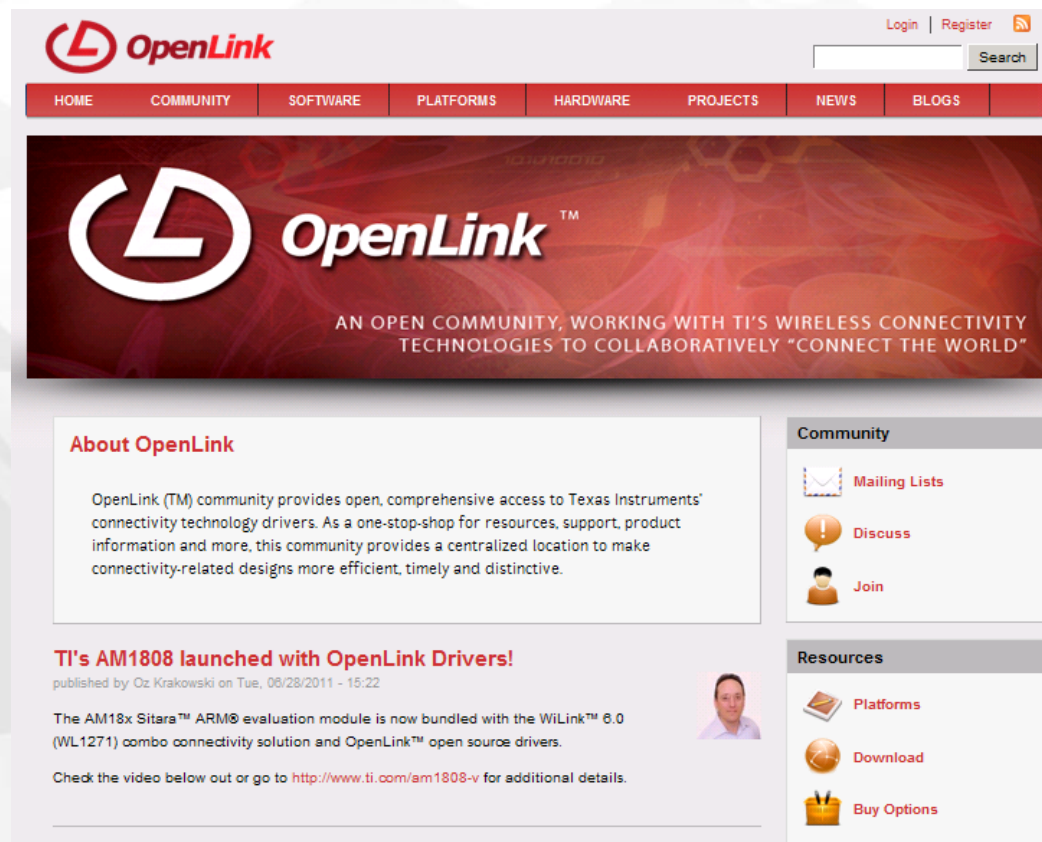
2010

2011



OpenLink™ Open Source Initiative

- TI Connectivity devices are available with open source Linux components
 - Linux Wi-Fi Driver - MAC802.11
 - Linux Bluetooth® Protocol Stack – BlueZ
 - Linux Bluetooth® Profiles – OpenOBEX
- Benefits
 - Minimizes customer integration and support effort
 - Using standard components widely accepted by the industry
- Openlink.org
 - Portal to Connectivity drivers in Linux Kernel, Support, News and Community Projects



TI Wi-Fi Development Platforms

WL1271 with AM37x



- WL1271 connectivity card plugs into AM37x EVM
- WLAN 802.11b/g/n and *Bluetooth*® connectivity
- OpenLink mac802.11 drivers

WL1271 with AM18x



- WL1271 connectivity card plugs into AM18x EVM
- WLAN 802.11b/g/n and *Bluetooth* connectivity
- OpenLink mac802.11 drivers

Wi-Fi Direct & Display

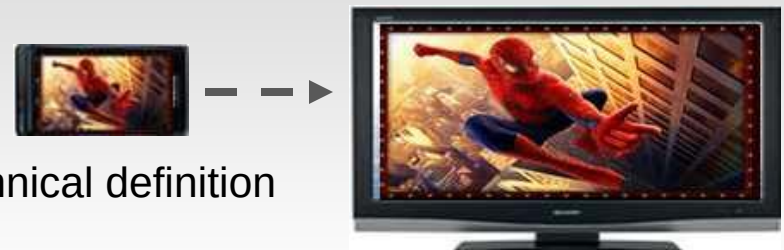
Wi-Fi Direct

- Allows wireless devices to directly connect with each other (peer to peer) without the need for an access point
 - On-the-Go Seamless Connectivity
 - Wireless Gateway
 - Peer-to-Peer
- *Available 3Q11*: SDK 5.0x for AM18x, AM37x & AM387x



Wi-Fi Display

- Replicate small screen content on to a larger screen
- Specifies compression and decompression of media content
- *Available 2012*: Certification program is in technical definition



Classic Bluetooth



- 79 channel (1 MHz) in 2.4GHz band
- FHSS with 1600/3200 hops/s
- Data rates up to 3Mbps (v 2.1)
- QoS for voice
- Ad-hoc star network with 7 slaves
- High latency
- Primarily cable replacement
- More than 3B devices deployed



2002- Version 1.x

- 1.0 Mbps data rate

2004- Version 2.x + EDR (Enhanced Data Rate)

- 3.0 Mbps data rate

2009- Version 3.0 + HS

- Up to 24 Mbps data rate with AMP
(802.11 Alternate MAC/PHY)

2010- Version 4.0

- Adds BLE

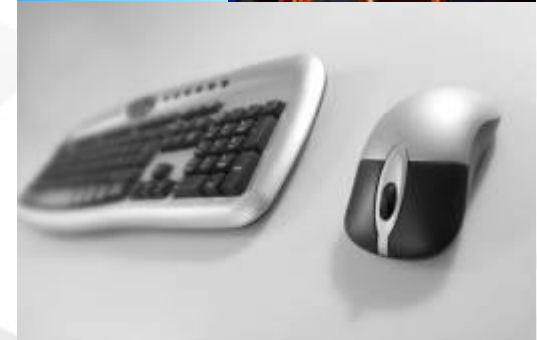
Power Class	Maximum Power Output	Distance
Class 1	100mW (20dBm)	100 meters
Class 2	2.5mW (4dBm)	10 meters
Class 3	1 mW (0dBm)	1 meter



Bluetooth Low Energy (BT v4.0)



- 40 (1MHz) channels in 2.4GHz band, FHSS
- “unlimited” nodes
- No voice
- Not radio compatible with BT Classic
 - Requires dual band radio
- Low power, <1/10th of Bluetooth classic
- Low latency, ~6ms to link vs. 2+ seconds
- Data rate up to 1Mbps
- Range to 200m
- Dual mode
 - Supports BT & BLE sharing radio and antenna
 - Typically in cell phones and laptops
- Single mode
 - Supports Bluetooth Low Energy only
 - Typically in peripherals



CC2560 Bluetooth v2.1 + EDR

Features

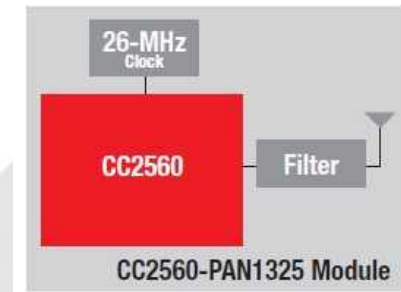
- Fully qualified Bluetooth v2.1 + EDR
- Data rate up to 2.1Mbps, UART throughput of 4Mbps
- Best-in-class Bluetooth RF performance (Tx power, Rx sensitivity, blocking)
 - +10 dBm Tx power with transmit power control
 - -93 dBm receiver sensitivity
- Best-in-class power consumption through low power scan (145uA)
- Support for Bluetooth power saving modes (sniff, hold)

Benefits

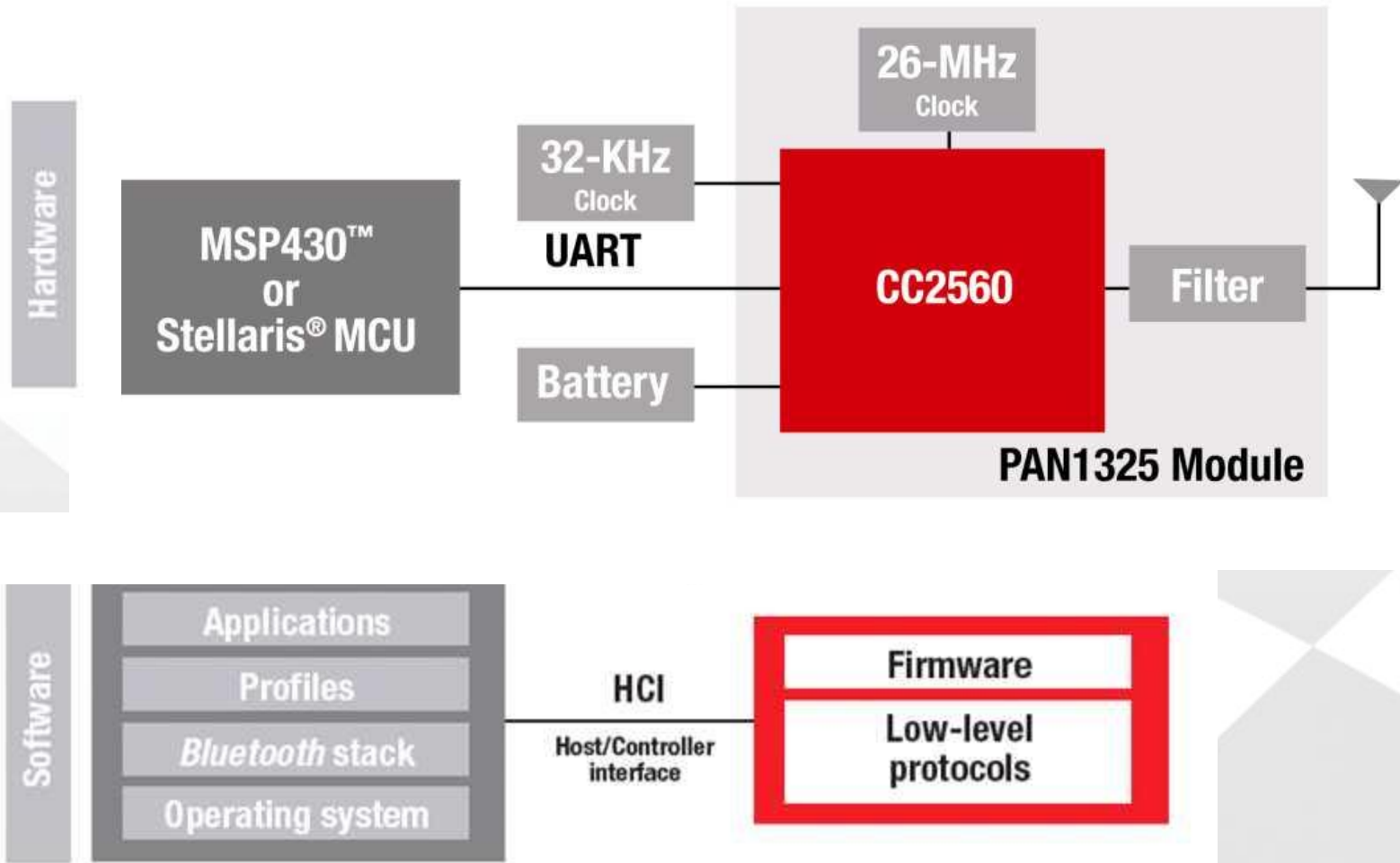
- Best-in-class link budget extends application range
- 1/3rd the power consumption of traditional reception window scan systems
- Simplified hardware and software development
- Supports replacement of serial cables for personal area networks
- Extended battery life and power efficiency

Applications

- Cable replacement
- Wireless sensors
- Medical devices
- Computer peripherals
- Industrial control
- Consumer devices



Bluetooth System Platform



CC256x Supported Platforms: MCU-Based

Production **Sampling** Development Future

Stellaris® (ARM® Cortex™-M3)

Stellaris
CC2560

Bluetooth®

Stellaris
CC2567

Bluetooth
ANT

MSP430™

MSP430
CC2560

Bluetooth

MSP430
CC2567

Bluetooth
ANT

MSP430
CC2564

Bluetooth
BLE



2010

2011



TI Bluetooth Development Kits

CC2560
with MSP430



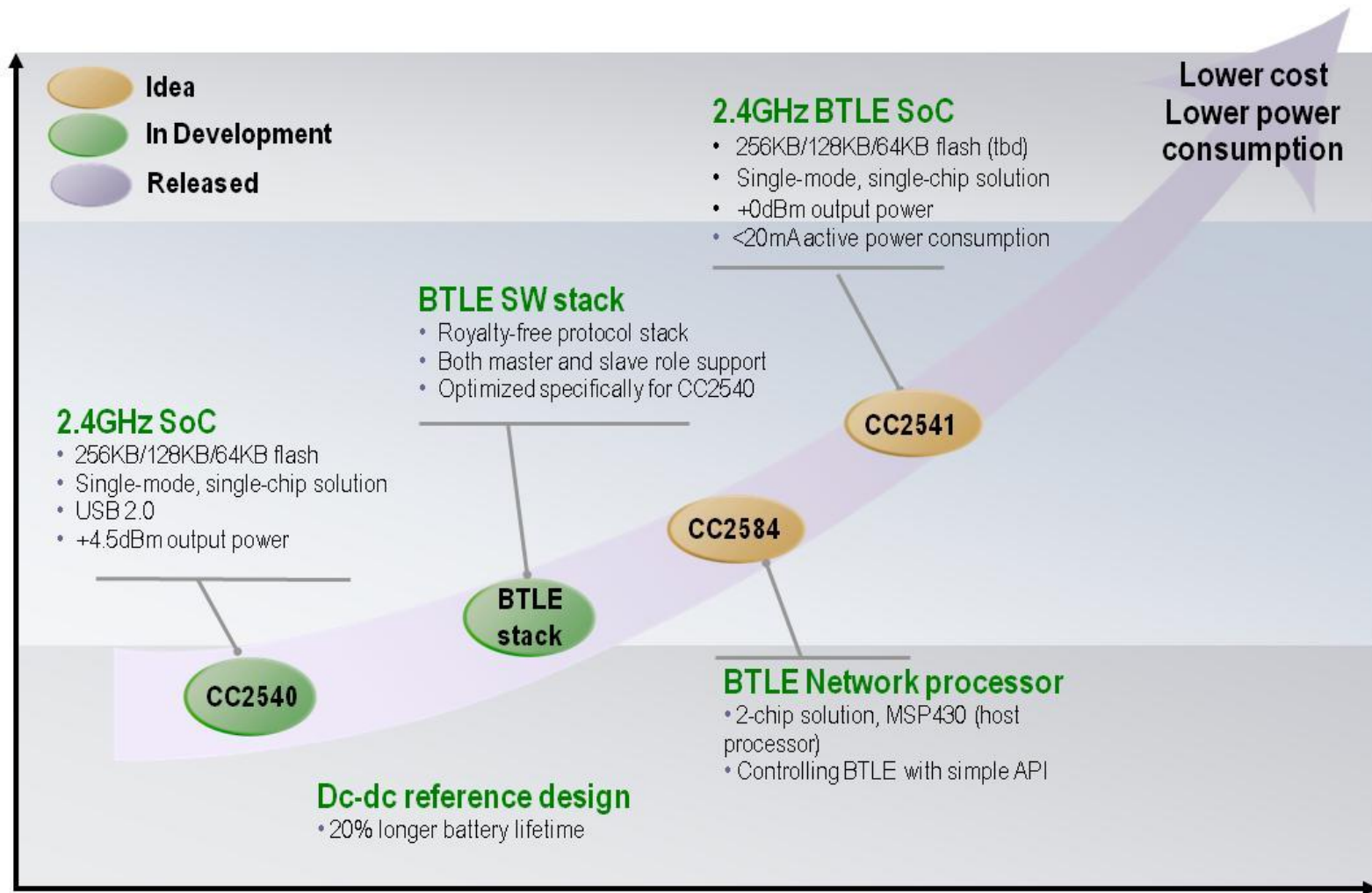
- PAN13xx (CC256x-based) module plugs into MSP430F5438 experimenter board
- *Bluetooth* connectivity

CC2560
with Stellaris®

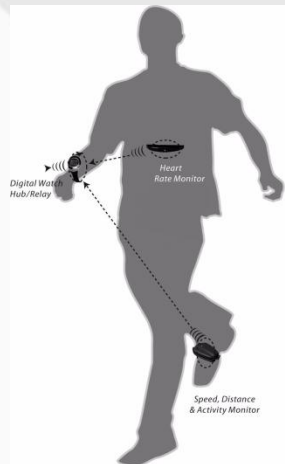


- PAN1315 (CC2560-based) module plugs into Stellaris LM3S9B96 development kit

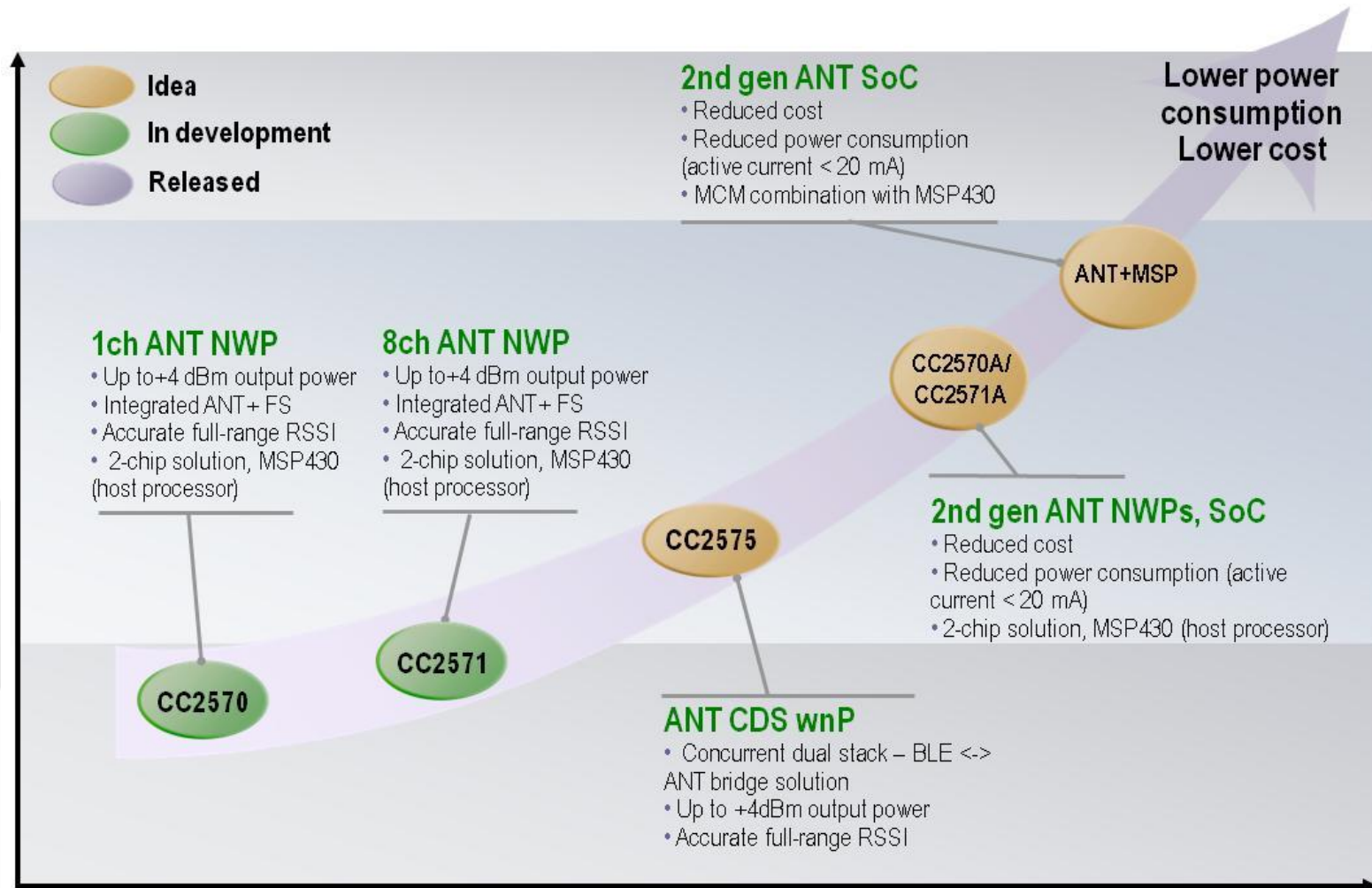
TI Bluetooth Low Energy Solutions Roadmap



- Narrowband 2.4GHz GFSK radio
- 78 non-overlapping channels, 1MHz wide
- Frequency *adaptive* TDMA
- 20 kbps burst data rate
- Peer-to-peer, star or tree
- Dynastream (Garmin) proprietary protocol
 - Very low overhead, low power
- ANT-FS session based file system
- Established ANT+ ecosystem of over 14 million devices



TI ANT+ Solutions Roadmap

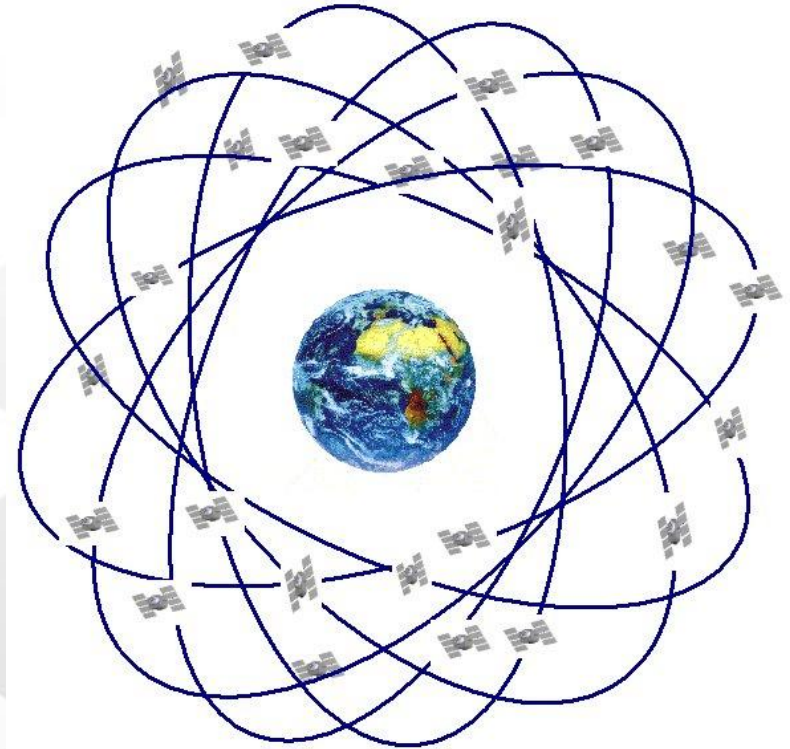


GPS

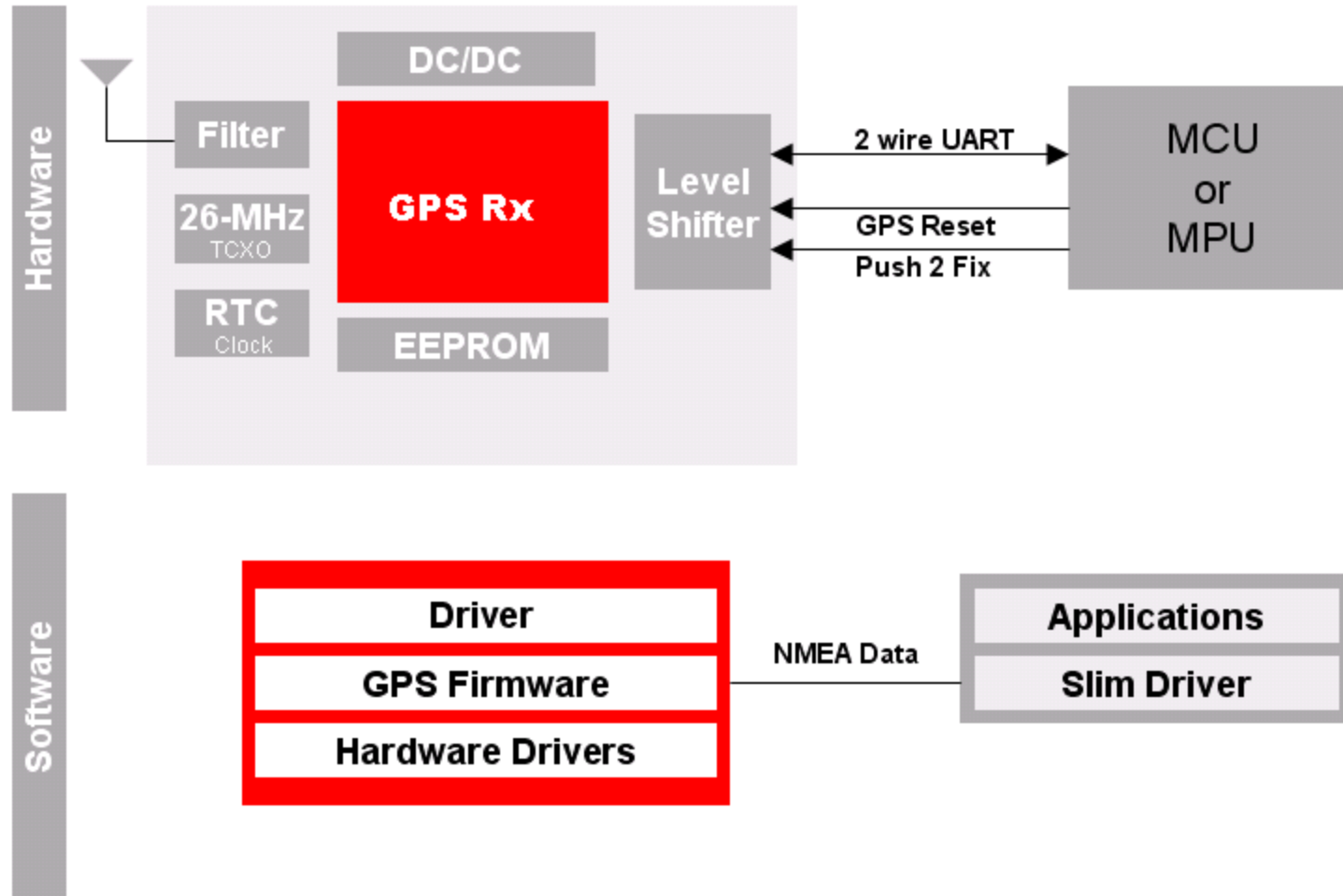
- Space-based global navigation satellite system utilizing a constellation of 27 Earth-orbiting satellites
- Provide reliable location, time, and velocity information to a receiver anywhere in the world
- Widely deployed and useful tool for asset tracking, industrial automation, surveillance, banking, power grids

Why TI GPS?

- Connect to host processor simply
- Utilizes industry standard NMEA protocol
- Quick startup performance – or Time To First Fix (TTFF)
- Highly integrated, fully certified modules available to reduce cost and time to market



GPS NMEA Module



RFID

- Passive RF solution – no batteries
- 13.56Mhz (HF) or 134Khz (LF)
- HF and LF systems use the Magnetic field to transfer power by induction
- Tags are mainly in label (flat) and inexpensive
- Applications include POS (point of sale), access control, authentication, medical



Why TI RFID?

- Best in class RF performance and easier RF and Antenna design
- Highest level of integrated protocol handling
- Lowest power consumption (7 selectable power modes)
- Single chip solution for multiple protocol layers (ISO14443A/B, ISO15693, Felica)



Near Field Communications (NFC)

- NFC can be considered as a “super-set” of RFID
- Operates at 13.56 MHz (HF) and provides data-rates up to 424 kbps
- Highly stable wireless connectivity technology that provides intuitive, safe & simple two-way interactions between electronic devices
- NFC-device can operate in 3 modes
 - Traditional RFid Reader/Writer
 - Peer-Peer Communication
 - Card Emulation (Tag Emulation)



Why TI NFC?

- Best in class RF performance and easier RF and Antenna design
- Integrated encoders, decoders and data framing for NFC initiator, active & passive target operation for all three bit rates (106, 212 & 424 kbps)
- Highest level of integrated protocol handling

Agenda

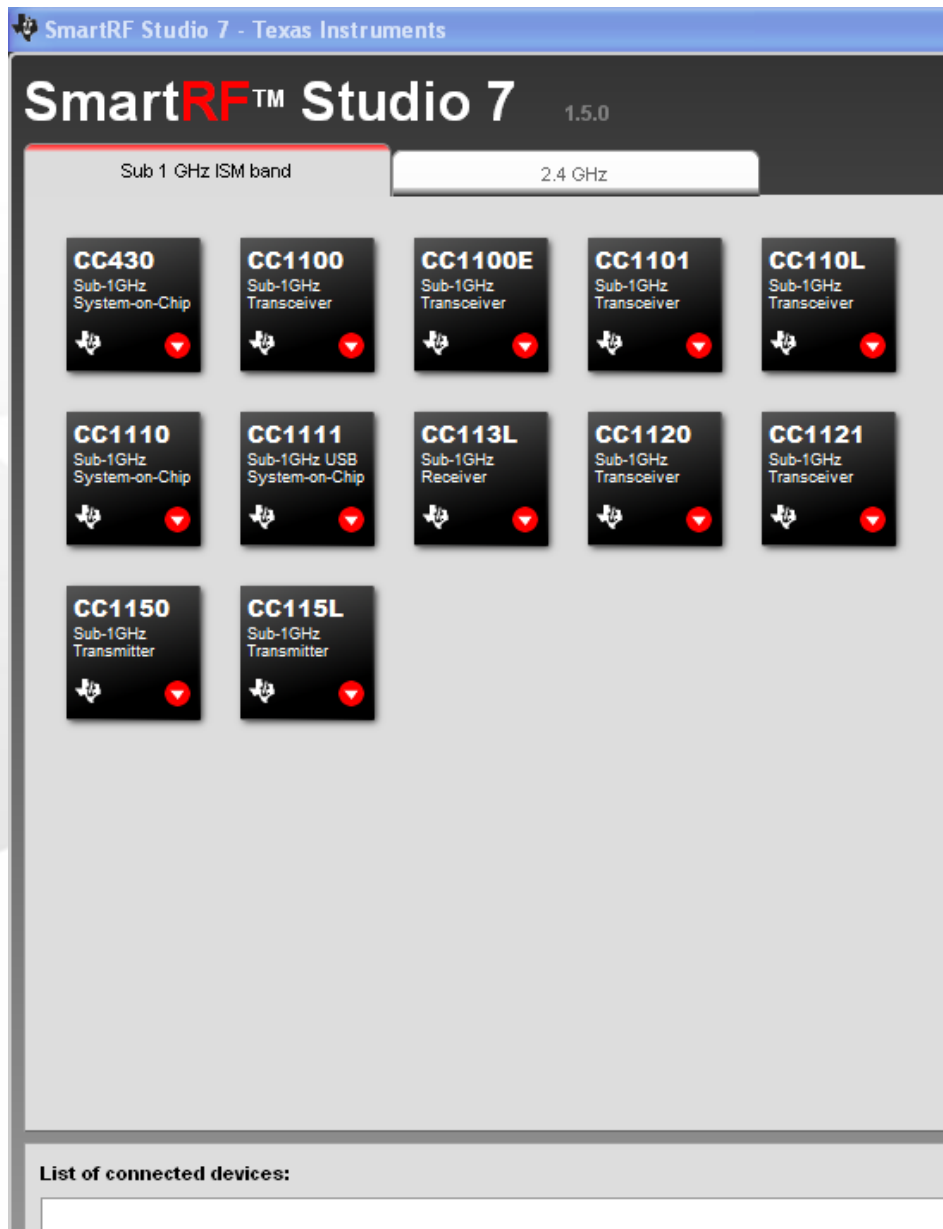
9:00 – 9:10	10 mins	Welcome and Introductions
9:10 – 9:50	40 mins	Wireless Basics
9:50 – 10:00	10 mins	break
10:00 – 10:45	45 mins	Lab 1
10:45 – 11:30	45 mins	Wireless Connectivity Overview
11:30 – 12:00	30 mins	Lunch break
12:00 – 1:00	60 mins	Lab 2
1:00 – 1:30	30 mins	Designing with wireless modules
1:30 – 1:45	15 mins	Demo – RC Eval-bot with Chronos
1:45 – 2:00	15 mins	Closing comments / feedback

Lab 2

- Lab 2A :
 - Disassemble watch and re-compile firmware for Chronos-to-Chronos pairing in peer to peer mode.
- Lab 2B:
 - Use SmartRF Studio to configure wireless parameters
- Lab 2C:
 - Setup Chronos watch to display RSSI value from instructor's broadcast channel



SmartRF Studio



- Generate and export register values from common RF parameters
 - Frequency, data rate, modulation, output power, etc.
- Quick and simple performance testing
 - Continuous TX for antenna testing and RF spectrum analysis
 - Continuous RX for radiation testing
 - Packet sending and receiving
- “Easy” mode – predefined data sets
- “Expert” mode – full control
- Supports all LPRF devices

SmartRF Studio

The screenshot displays the SmartRF Studio software interface, which is used for configuring Texas Instruments CC1101 radio modules. The interface is divided into several sections:

- File, Settings, View, Evaluation Board, Help:** The top menu bar.
- Easy Mode / Expert Mode:** A toggle switch at the top left, currently set to 'Expert Mode'.
- Register View / RF Parameters:** Checkboxes at the top right, both of which are checked.
- Typical settings:** A section on the left with a list of preset configurations under the 'Generic 868MHz' category. The selected preset is: 'Data rate: 1.2 kBaud, Dev.: 5.2 kHz, Mod.: GFSK, RX BW: 58 kHz, Optimized for sensitivity'.
- RF Parameters:** A central section for configuring the radio's physical layer parameters.
 - Base frequency:** 867.999939 MHz
 - Channel number:** 0
 - Channel spacing:** 199.951172 kHz
 - Carrier frequency:** 867.999939 MHz
 - Xtal frequency:** 26.000000 MHz
 - Data rate:** 1.19948 kBaud
 - RX filter BW:** 58.035714 kHz
 - Modulation format:** GFSK
 - Deviation:** 5.157471 kHz
 - TX power:** 0 dBm
 - Manchester enable:** ☐
 - PA ramping:** ☐
 - Range Extender:** None
 - High Gain Mode(RX):** ☒
- Continuous TX / Continuous RX / Packet TX / Packet RX / RF Device Commands / PER Test Configuration:** A row of tabs at the bottom left. 'Packet TX' is currently selected.
- Packet TX Configuration:**
 - Packet payload size:** 30
 - Add seq. number:** ☒
 - Packet count:** 100
 - Infinite:** ☐
 - Random:** ☒ (Hex: 47 de b3 12 4d c8 43 bb 8b a6 1f 03 5a 7d 09 38 25 1f 5d d4 cb fc 96 f5 45 3b 13 0d 89 0a)
 - Text:** ☐
 - Hex:** ☐
- TX / RX Indicators:** Two green indicator lights labeled 'TX' and 'RX' at the bottom center.
- CC1101 - Register View (offline):** A panel on the right showing the current register values.

Register	Value (Hex)
IOCFG2	29
IOCFG1	2E
IOCFG0	06
FIFOTHR	07
SYNC1	D3
SYNC0	91
PKTLEN	FF
PKTCTRL1	04
PKTCTRL0	05
ADDR	00
CHANNR	00
FSCTRL1	06
FSCTRL0	00
FREQ2	21
FREQ1	62
FREQ0	76
MDMCFG4	F5
MDMCFG3	83
MDMCFG2	13
MDMCFG1	22
MDMCFG0	F8
DEVIATN	15
MCSM2	07
MCSM1	30
MCSM0	18
FOCCFG	16
BSCFG	6C
AGCCTRL2	03
AGCCTRL1	40
AGCCTRL0	91
- Buttons:** At the bottom right of the register view are buttons for 'Register reset', 'Help', and 'Refresh'.

LAB 2 – FOLLOW HANDOUT INSTRUCTIONS

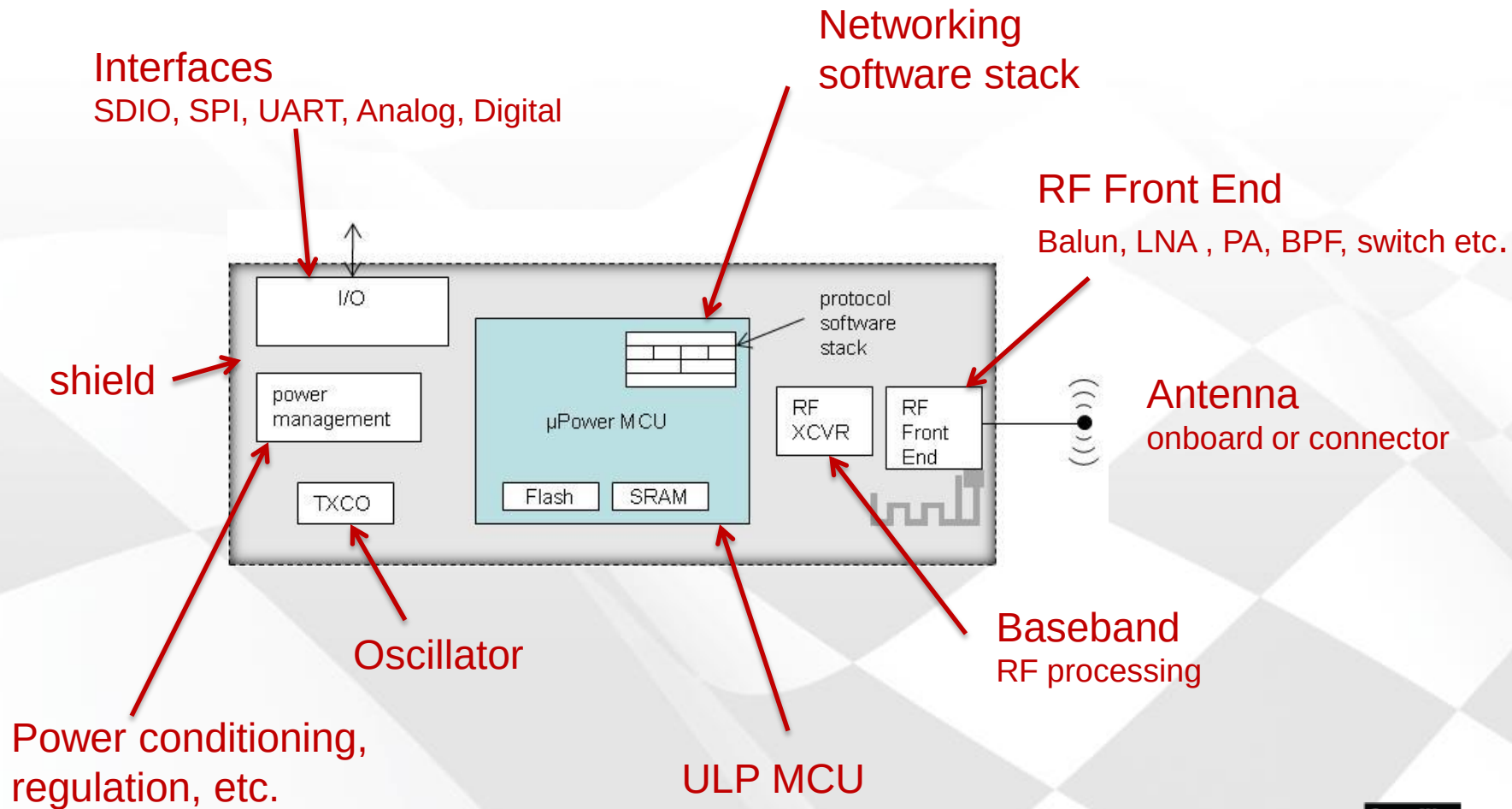


Accelerating Your Success™

Agenda

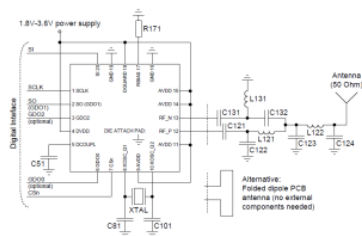
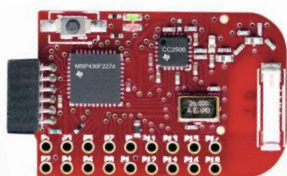
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Components of a Wireless Module

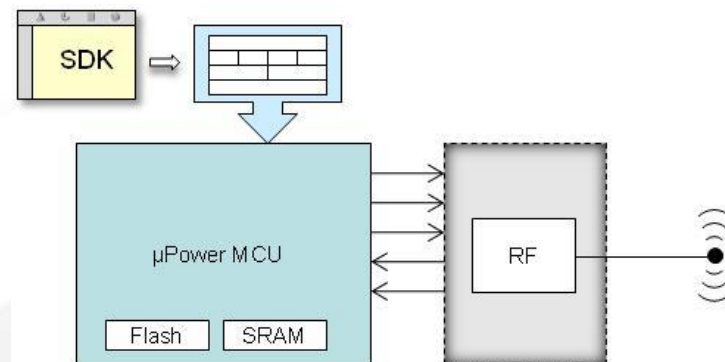


Design Strategies

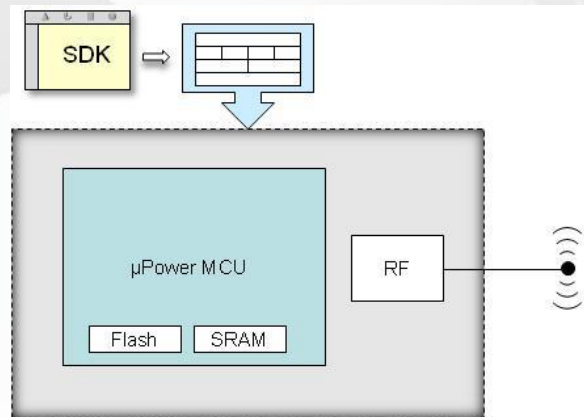
Discrete



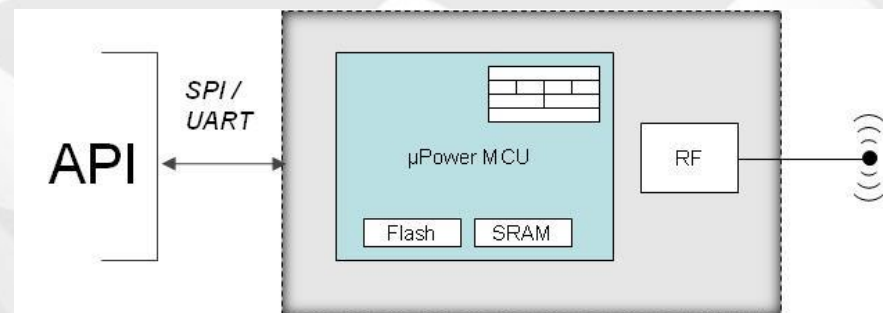
Radio-only module



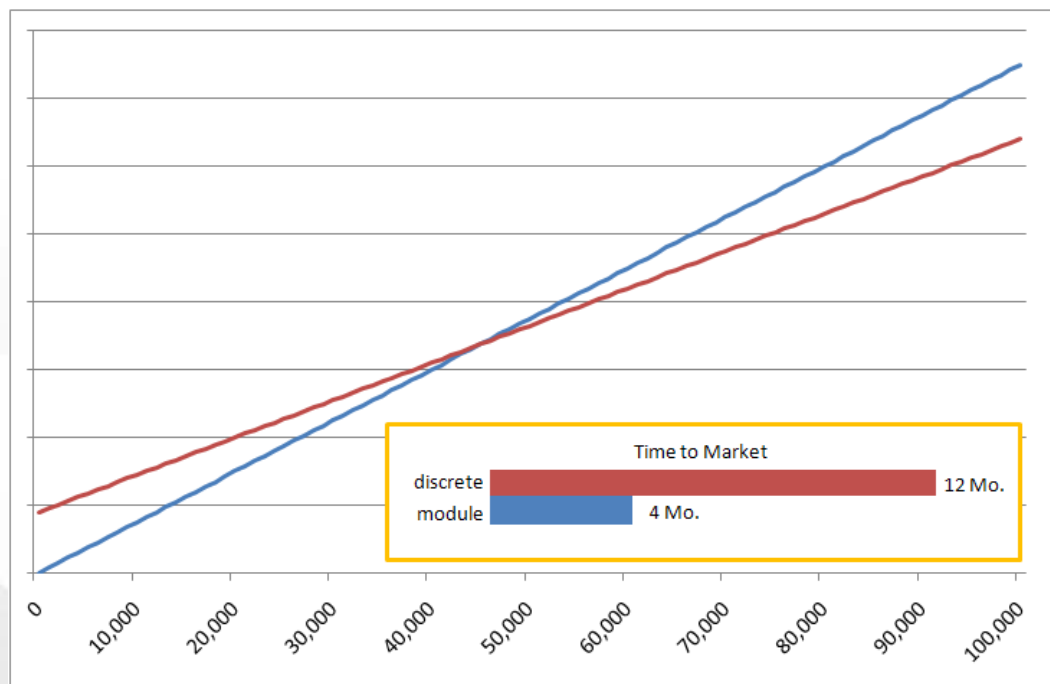
Integrated module



Hostless module



Modules: Make vs. Buy



Buy

- No design risk
- Pre-certified
- Assembled, tested, calibrated
- Smallest size
- One part number
- Shortest time-to-market

Make

- RF Circuit Design & Layout
- Firmware
- Test & debug
- *Re-spin?*
- Certification
- Multi-component BOM
- Fab & Test

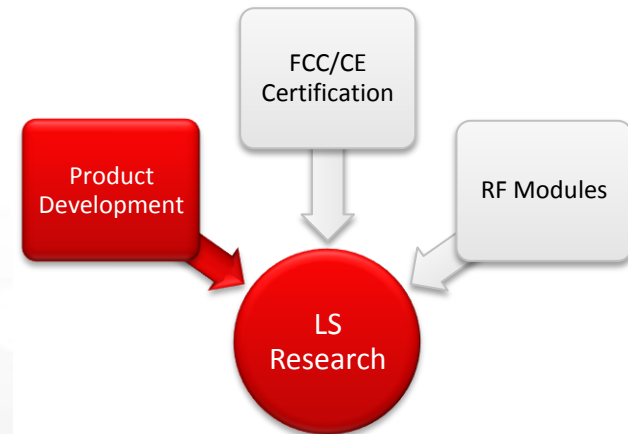


Product development services:

- Hardware and software design
- Antenna design, simulation, and testing
- On-site compliance testing

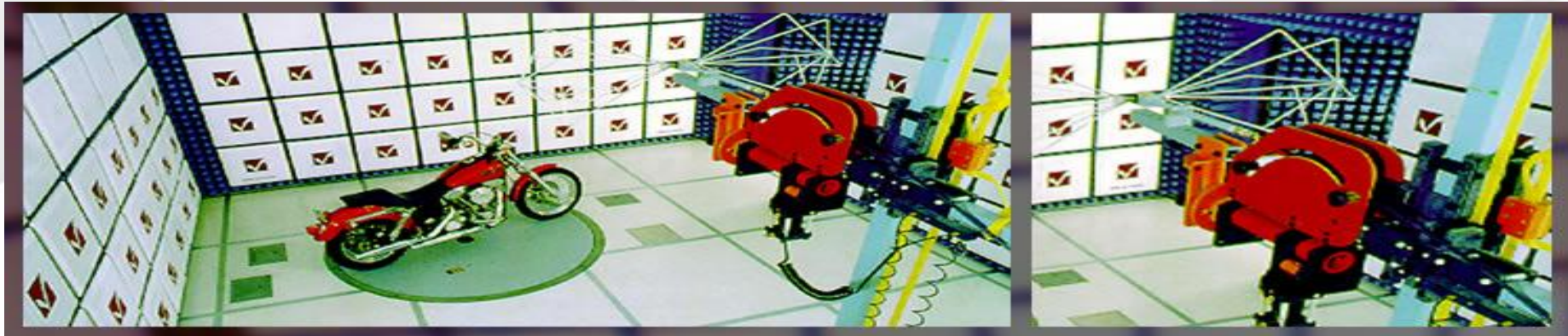
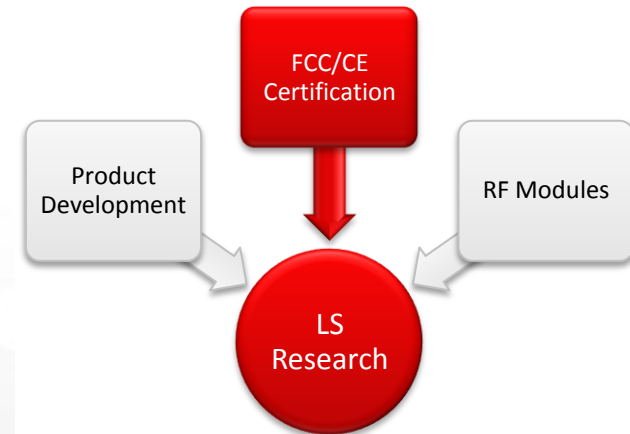
Wireless technologies, including:

- 802.11 a/b/g/n
- Bluetooth & BLE
- IEEE 802.15.4 / ZigBee / RF4CE
- 6LoWPAN
- ANT+
- Remote Keyless Entry 315/390/433
- MICS
- <1 GHz, 2.4 GHz, 5.8 GHz
- White Spaces
- Mesh Networks
- RFID

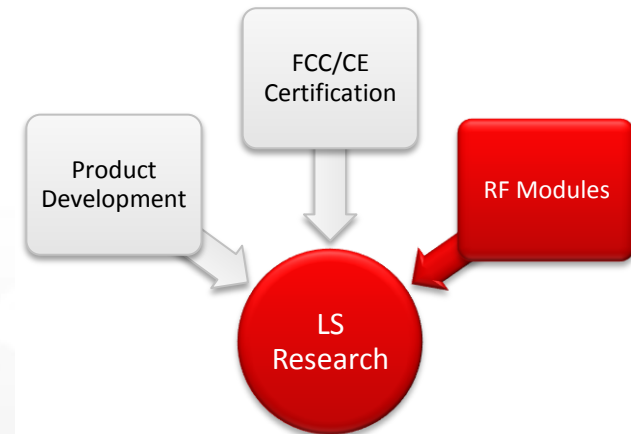


EMC & FCC Compliance Center

- LS Research provides EMC testing and radio certification services for companies worldwide
- On-site FCC / IC / CE certifications
- On-site antenna patterning and scans



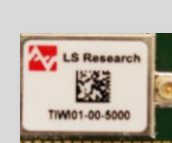
- 900Mhz, 2.4 and 5Ghz Modules
 - ZigBee™, Wi-Fi and Bluetooth®
 - FCC / IC certified
 - ETSI tested (where applicable)
 - Industrial temp rated (-40 to 85C)
- Antennas and connectors
- Custom modules



ProFLEX
(ZigBee Pro Modules)



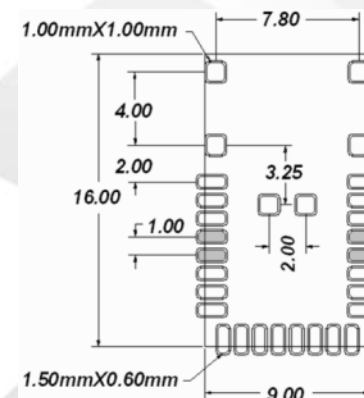
SiFLEX
(High Performance 900 MHz Modules)



TiWi - based on TI WL127x
802.11b/g/n + Bluetooth 2.1+EDR Module

Anaren Integrated Radio

- NRE-free product line
- Targeting: non-RF-enabled customers
- Common footprint for families of radios
- FCC, IC & ETSI certification or compliant
- Exclusively use TI silicon – CC1101, CC2500 & CC8520
- Anaren & TI applications support
- Interchangeable with TI development tools
- Available through Avnet

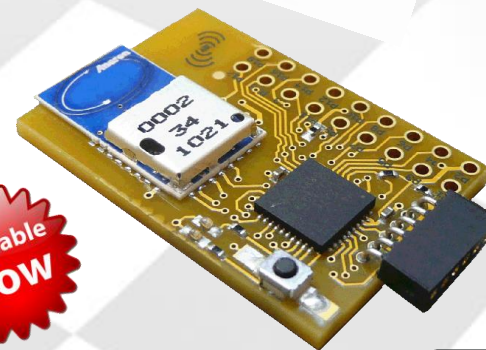


Anaren knows RF... so you don't have to!

- Reduces risk, engineering time, time-to-market & certification costs
- Reduces carrying-board complexity & BOM / sourcing workload
- Produced by high-volume manufacturer
- Based on Texas Instruments silicon
- Reasonably priced

When to use AIR...

- Low-power, battery operated
- Command / control applications
- High-quality audio applications (CC8520)
- Data rates < 250Kb/s
- Listen better, not talk louder (LNA's over PA's)
- Distances < 1,000 ft.
- Industrial environments



eZ430 Target Boards - \$24.99





AIR: Connectorized 433, 868, 915& 2400MHz

- 9mm x 12mm x 2.5mm (height without mated connector)
- Common footprints for all family members
- Impedance-controlled, multilayer RF assembly
- 100% RF-tested and FCC qualified
- Shielded package
- Supplied in tape & reel and matrix tray



AIR: Embedded Antenna 868, 915 & 2400MHz

- 9mm x 12mm x 2.5mm – 2400 MHz
- 9mm x 16mm x 2.5mm – 900 MHz
- Common footprints for all family members
- Impedance-controlled, multilayer RF assembly
- 100% RF-tested and FCC qualified
- Shielded package
- Supplied in tape & reel and matrix tray



AIR: Embedded Antenna 2400MHz Purepath Module (with range extender)

- Based on TI CC8520
- Includes CC2591 Range Extender
- 11mm x 19mm x 2mm Module
- Over 70 SMT components enclosed
- FCC, IC, ETSI* at full power
- Compatible with TI development tools
- Shielded package
- Supplied in tape & reel and matrix tray
- Under \$20 in 10K quantities



 TEXAS INSTRUMENTS	<u>Dual Mode</u>		<u>Single Mode</u>
<u>PAN1315</u>	<u>PAN1317/1327</u>	<u>PAN1316/1326</u>	<u>PAN1720</u>
<u>PAN1325</u>	<u>BT Classic + ANT</u>	<u>BT Classic + LE</u>	<u>Low Energy</u>
<u>Bluetooth Classic</u>			

Panasonic | PAN1315 Evaluation Kit



Features

- Serial link *Bluetooth* applications on MSP430BT5190
- Bluetooth* 2.1+EDR
- Bluetooth* Low Energy (BLE) upgradeable
- Pre-integration into the MSP430 platform



Bluetooth® PAN1315ETU card

- PAN1315 (CC2560-based) module
- Chip antenna
- Plugs into MSP430F5438 Experimenter Board



Benefits

- Best-in-class RF performance & low power consumption
- Fast and easy application development on MSP430 with *Bluetooth*
- Robust and proven *Bluetooth* technology
- No NRE, royalty-free (SPP solution only)



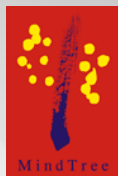
Out of the box

- Bluetooth* sample applications (source code format)
 - Accelerometer-based game
 - RF link parameters
 - Thermometer readings

Platform partners



PAN1315 (CC2560-based)
Module supplier



System Integrator & *Bluetooth* /
BLE Stack Supplier



Software

- Available from TI
 - Data over SPP (serial port profile)
- Available from MindTree
 - Medical over HDP (health device profile)
 - Bluetooth* Low Energy (2H 2010)



Murata Type TN Wi-Fi / BT Module

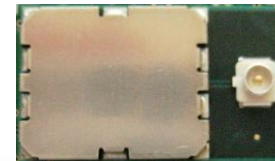
Description

Type TN is targeted to the broad market initiative providing IEEE802.11 b/g/n WiFi, BT v3, and BT low energy wireless connectivity.

Key Attributes

- Chipset: TI / WL1271
- Major components: reference oscillator, power management, RF front end, band pass filter
- RF interface: U.FL coaxial connector, PCB pad
- FCC tested, certified
- RoHS compliant
- Dimensions: 17.0 x 10.0 x 1.9 mm
- Temperature (operating): -20 to +70° C
- VBAT: 2.7 TO 4.3 Vdc
- VIO: 1.8 Vdc, 3.3Vdc
- Module Part Number: LBEE5ZSTNC
- Daughter Card Part Number: LBEE5ZSTNC-D
- Schedule: daughter card & module: September 2011
- Broad Market Platform: TI Centaurus AM387x / DM814x
- Linux 2.6.x

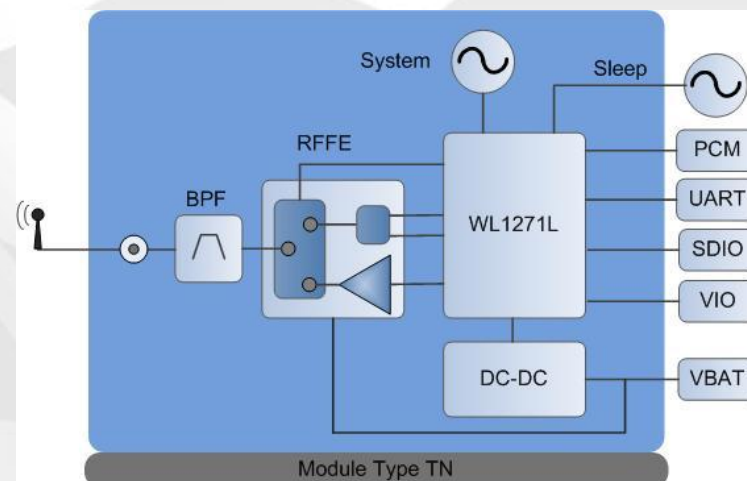
<http://www.murata-ws.com/802.11-bgn-bt3.htm>



Module



Daughter Card



Module Block Diagram

Murata Type SL Wi-Fi Module

1. W-LAN Module

- Chipset : TI / WL1270
- Module Size : **9.2 x 8.4 x 1.35(max.) mm**
- W-LAN : IEEE802.11b/g/n compliant
- Interface : SDIO, SPI

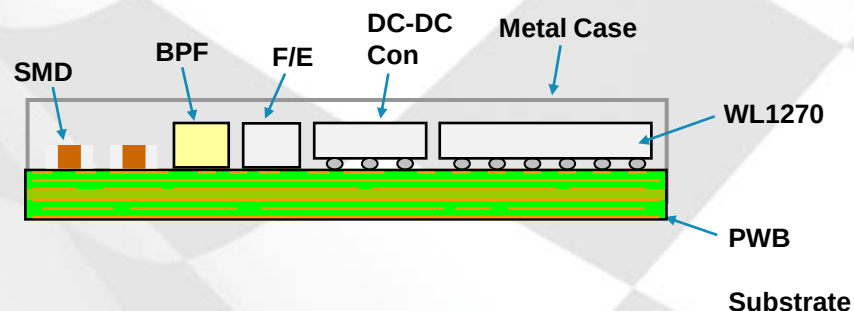
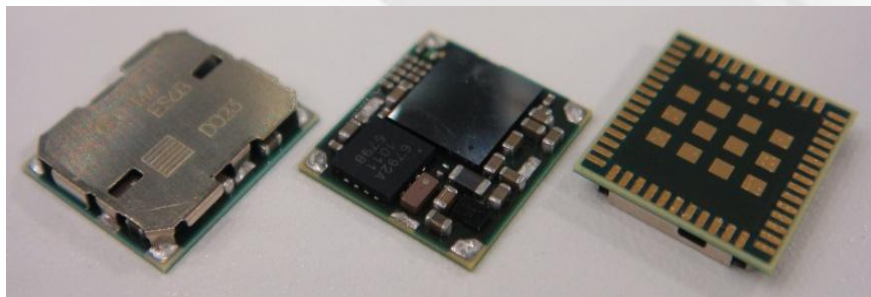
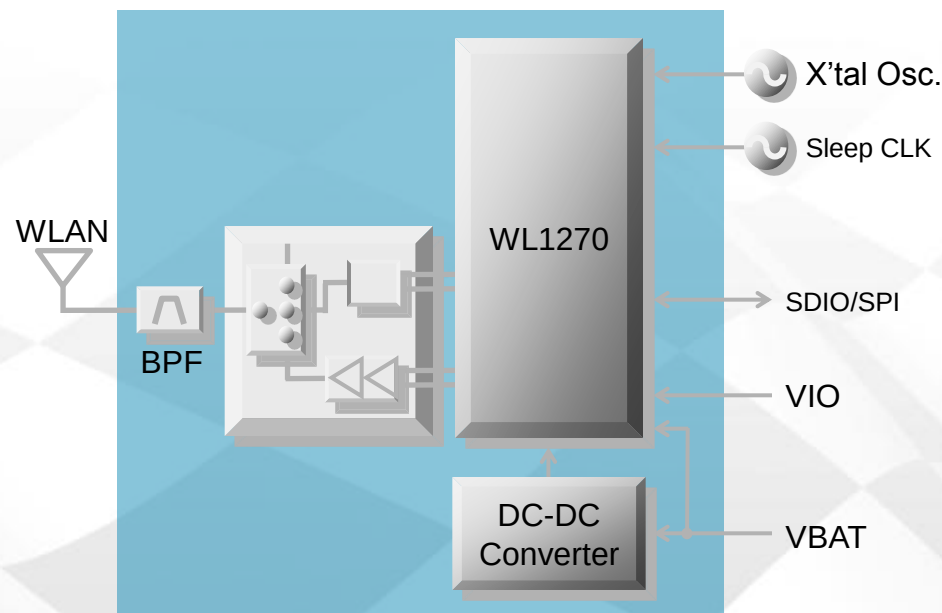
2. Characteristics

- Operating Temp. : -20 to +70 deg. C
- Supply Voltage : 2.7 to 4.3V for VBAT
- Host I/F Voltage : 1.8V for VIO

3. Sample Part Number

- Module Sample : **LBWA19XSLZ-TEMP**
- EVK : LBWA19XSLZ-TEMP-D

100K+ EAU min



Murata Type UW Dual Mode WIFI / BT / BLE Module

1. W-LAN + Bluetooth + FM Tx/Rx Module

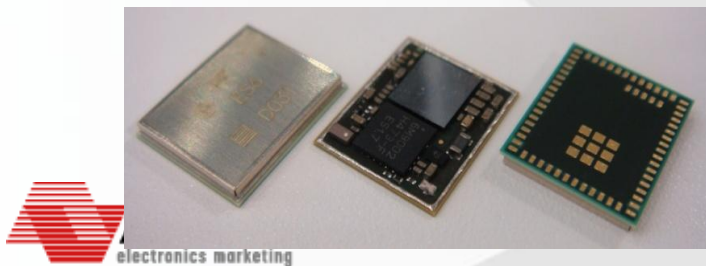
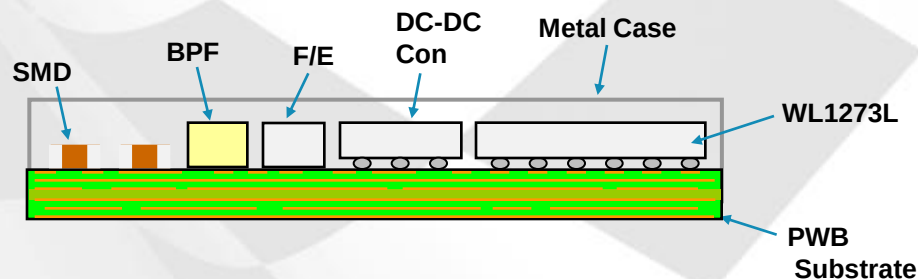
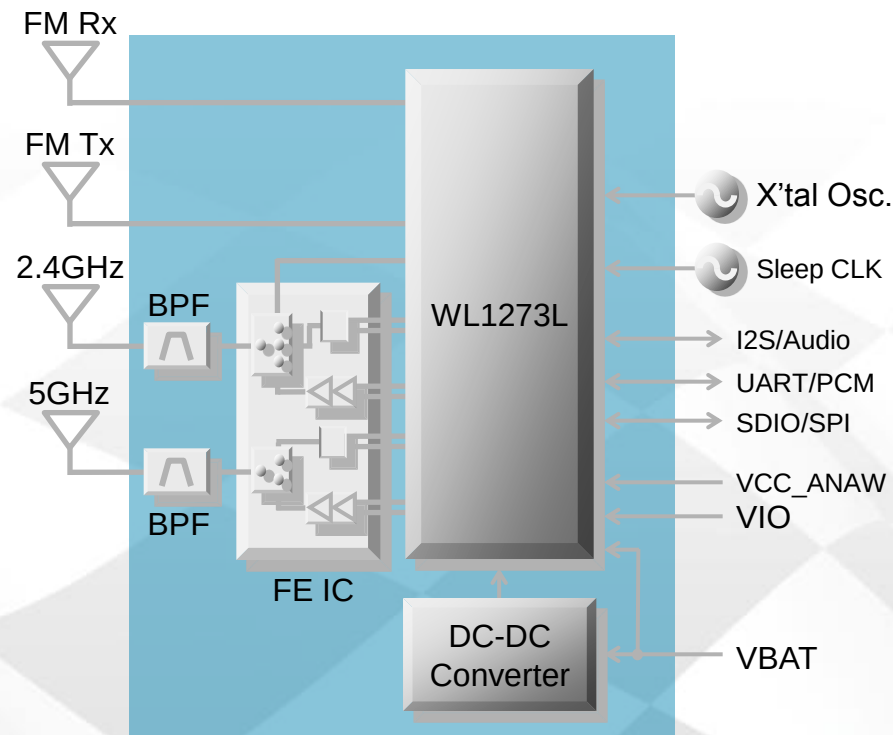
- Chipset : TI / WL1273
- Module Size : **11.4 x 9.4 x 1.4(max.) mm**
- W-LAN : IEEE802.11a/b/g/n compliant
- Bluetooth : ver.4.0
- FM : Tx/Rx
- Interface
 - > W-LAN : SDIO, SPI
 - > Bluetooth : H4(UART), PCM
 - > FM : UART, I2C, I2S, Audio

2. Characteristics

- Operating Temp. : -20 to +70 deg.C
- Supply Voltage : 3.0 to 4.2V for VBAT
- Host I/F Voltage : 1.8V for VIO

3. Sample Part Number

- Module Sample : **LBEH1Z9PFC-TEMP**
- EVK : LBEH1Z9PFC-TEMP-D
- 100k+ EAU min



TE Connectivity (TE) designs and manufactures antennas that comply with the most stringent operating requirements.

TE offers a standard family of embedded antennas as well as customized solutions.

Broad Range of Applications

- Routers
- M2M
- Vehicle trackers
- Gaming
- Remote control
- Femtocells
- Scanners
- Printers
- POS terminals



- Low-profile and high-performance
- Single through penta-band applications
- Two manufacturing processes
 - Stamped metal antennas
 - Flexible Printed Circuit (FPC) and Printed Circuit Board (PCB) Antennas
- Broad range of antennas
 - Surface mount
 - Tab mount
 - Surface mount over ground plane
 - Chassis mount cabled
- Frequency Range from 800MHz - 6GHz
- Advantages of standard antennas:
 - Small and lightweight
 - Minimum or no matching components required
 - Eliminated tooling lead-time and cost
 - Low cost

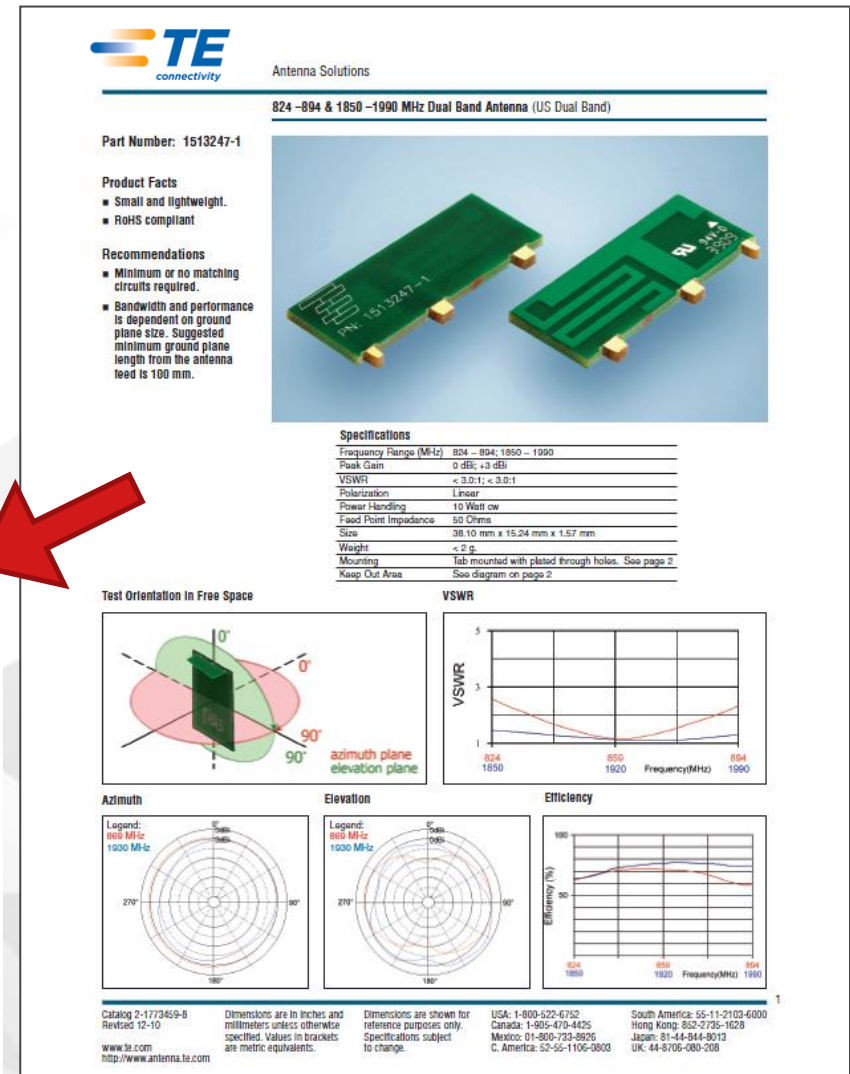


Vital details:

- Frequency range(s)
- Radiation pattern
- Gain
- Polarization
- VSWR or return loss
- Power handling
- Feedpoint

Specifications

Frequency Range (MHz)	824 – 894; 1850 – 1990
Peak Gain	0 dBi; +3 dBi
VSWR	< 3.0:1; < 3.0:1
Polarization	Linear
Power Handling	10 Watt cw
Feed Point Impedance	50 Ohms
Size	38.10 mm x 15.24 mm x 1.57 mm
Weight	< 2 g.
Mounting	Tab mounted with plated through holes. See page 2
Keep Out Area	See diagram on page 2



TE's Customized Solutions – Molded Interconnect Devices (MID)



Two Shot MID Technology

- Two-step basic process
 - Injection molding of two distinct thermoplastic polymers
 - Electroless plating process using copper, nickel and gold
- Advantages of Two Shot MID technology
 - Design flexibility for complex 3-D geometries
 - Ability to integrate multiple functions into one component
 - Tightest tolerance for pattern registration to carrier
 - Fewest manufacturing steps and processes



Laser Direct Structuring (LDS) MID Technology

- Three-step basic process
 - Antenna is injection molded using one of the LDS resins.
 - The desired pattern is directly structured onto using 3-D laser system.
 - Plating occurs using the industry-standard methods where the plating adheres only where the plastic that has been activated by the laser
- Advantages of LDS MID technology (in addition to Two Shot advantages listed above)
 - Ability to produce thin (0.15 mm) traces
 - Flexibility for pattern changes during production
 - Simple/fastest/lowest cost tooling



www.em.avnet.com/teantennas



Agenda

9:00 – 9:10	10 mins	Welcome and Introductions
9:10 – 9:50	40 mins	Wireless Basics
9:50 – 10:00	10 mins	break
10:00 – 10:45	45 mins	Lab 1
10:45 – 11:30	45 mins	Wireless Connectivity Overview
11:30 – 12:00	30 mins	Lunch break
12:00 – 1:00	60 mins	Lab 2
1:00 – 1:30	30 mins	Designing with wireless modules
1:30 – 1:45	15 mins	Demo – RC Eval-bot with Chronos
1:45 – 2:00	15 mins	Closing comments / feedback

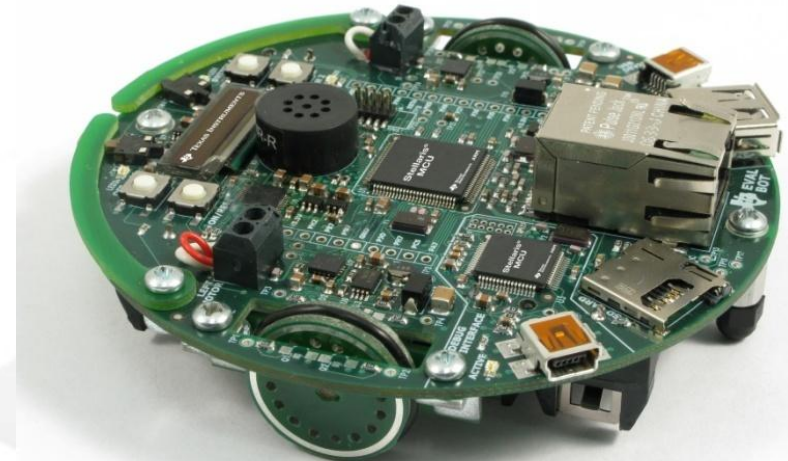
Lab3 Demo: Chronos Control of Stellaris EvalBot

www.ti.com/evalbot



Hardware & Software

- Updated for more flexibility & fun with 32-bit ARM® Cortex™-M3 microcontrollers & robotics
- Offers more tool & software options for more experimentation/dev
 - Keil MDK-ARM, IAR EWARM, TI Code Composer Studio, Code Red Technologies Red Suite & CodeSourcery G++
- Preloaded with a StellarisWare® application & includes more example projects in source code w/ more coming!



Highlights

- **LM3S9B92 EVALBOT features**
 - Integrated 10/100 Enet MAC/PHY, USB OTG, motion control
 - Bright 96x16 OLED display, SD card I/F, I²S audio codec, CAN I/F
 - TI wireless module I/F (*promotes 3rd party extensions*)
- Includes Chronos-SimpliciTI demo code that enables wireless control of EVALBOT using Chronos watch

Lab3 Demo: Android / BT messaging to Fossil MetaWatch

Based on TI's **MSP430F5438A** MCU and **CC2560** Bluetooth host controller!



- AU-1000 Analog Digital
 - Dual 16x80 OLED Displays
- AU-2000 Digital
 - 96x96 Reflective Display
- Features
 - Bluetooth® wireless technology
 - 3 ATM Water Resistance
 - Accelerometer
 - Ambient Light Sensor
 - Vibrating Motor
 - Rechargeable battery
 - Includes programming /charging clip & micro USB cable
 - Stainless steel case; mineral crystal lens; leather strap
 - Open source remote protocol, embedded firmware & SDK


METAWATCH™



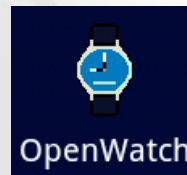
MetaWatch: Programming, Apps development, etc

How is MetaWatch Programmed?

- Via an external programmer clip/cable for MSP430™ development
- Code Composer Studio is free & unrestricted for watch development
- The watches comes with a call & message handling Smartphone application that works with Android & RIM
- Watch communication protocol for sophisticated remote control

What About Source Code?

- Open source; community supported
- Source code provided for watch & smartphone apps
- Bluetooth stack is provided as a binary for watch development



More details at www.metawatch.org and
<http://processors.wiki.ti.com/index.php/MetaWatch>



LAB 3 DEMOS – FOLLOW HANDOUT INSTRUCTIONS



Accelerating Your Success™

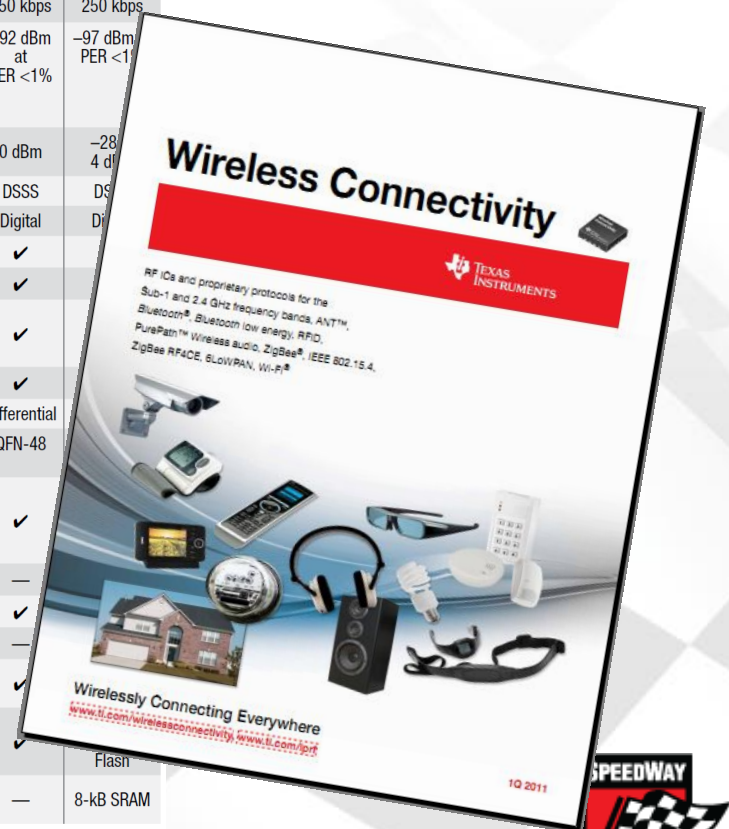
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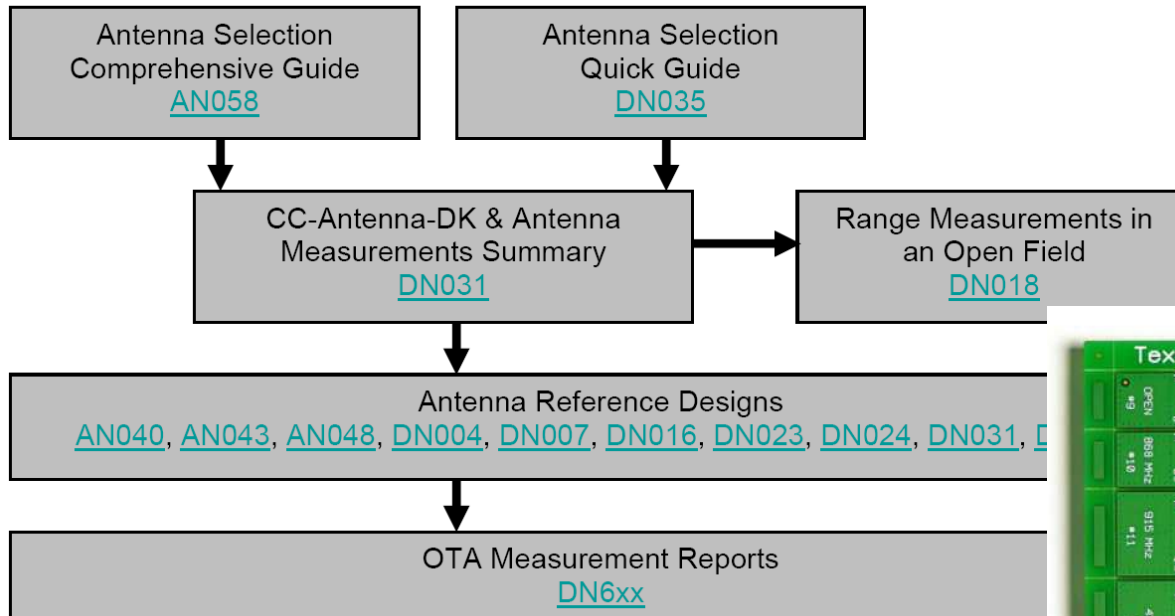
Selection Guide

www.ti.com/wirelessconnectivityguide

Features/Product	CC2400	CC2520	CC2430	CC2431	CC2550	CC2500	CC2510	CC2511	CC2590 CC2591	CC2480	CC2530 (Preliminary)
Product type	Transceiver	Transceiver	SoC	SoC	Transmitter	Transceiver	SoC	SoC	RF front end	ZigBee® processor	SoC
Programmable frequency, MHz	2400 to 2483	2394 to 2507	2400 to 2483	2400 to 483	2400 to 2483	2400 to 2483	2400 to 2483	2400 to 2483	2400 to 2483.5	2400 to 2483.5	2400 to 2483
Frequency resolution	1 MHz	1 MHz	1 MHz	1 MHz	427 Hz	427 Hz	427 Hz	427 Hz	—	5 MHz	1 MHz
Operating supply voltage	1.6 to 2.0 V	1.8 to 3.8 V	2.0 to 3.6 V	2.0 to 3.6 V	1.8 to 3.6 V	1.8 to 3.6 V	2.0 to 3.6 V	3.0 to 3.6 V	2.0 to 3.6 V	2.0 to 3.6 V	2.0 to 3.6
Current consumption (RX) 0 dBm (TX)	24.0 mA 19 mA	18.5 mA 25.8 mA	27 mA 27 mA	27 mA 24.7 mA	N/A 22.8 mA	12.8 mA 21.6 mA	19.8 mA 23 mA	22 mA 23 mA	1.8 mA 3.4 mA	27 mA 27 mA	25 mA 29 mA
Data rate (max)	1.0 Mbps	250 kbps	250 kbps	250 kbps	500 kbps	500 kbps	500 kbps	500 kbps	—	250 kbps	250 kbps
Receiver sensitivity	-101 dBm at 10 kbps BER = 10-3 85 dBm at 1 Mbps	-98 dBm	-92 dBm at PER < 1%	-94 dBm at PER < 1%	N/A	-89 dBm at 250 kbps 1% PER -99 dBm at 10 kbps	-88 dBm at 250 kbps 1% PER -99 dBm at 10 kbps	-88 dBm at 250 kbps 1% PER -99 dBm at 10 kbps	—	-92 dBm at PER < 1%	-97 dBm PER < 1%
Programmable output power ranging from	-25 to 0 Mbps	-20 to 5 dBm	-25 to 0 dBm	-24 to 0 dBm	-20 to 1 dBm	-20 to 1 dBm	-30 to 1 dBm	-30 to 1 dBm	—	0 dBm	-28 4 dBm
Multi-channel systems	FHSS	DSSS	DSSS	DSSS	FHSS	FHSS	FHSS	FHSS	—	DSSS	DSSS
RSSI output	Digital	Digital	Digital	Digital	—	Digital	Digital	Digital	—	Digital	Digital
Integrated bit synchronizer	✓	✓	✓	✓	—	✓	✓	✓	—	✓	—
Integrated packet handling	✓	✓	✓	✓	✓	✓	✓	✓	—	✓	—
Data buffering	32 bytes FIFO	128 bytes TX 128 bytes RX	128 bytes TX 128 bytes RX DMA	128 bytes TX 128 bytes RX DMA	64 bytes	64 bytes TX 64 bytes RX	128 bytes TX 128 bytes RX DMA	128 bytes TX 128 bytes RX DMA	—	✓	—
Internal RF switch/IF Filter	✓	✓	✓	✓	—	✓	✓	✓	—	✓	—
RF chip interface	Differential	Differential	Differential	Differential	Differential	Differential	Differential	Differential	—	Differential	—
Package type	QFN-48 7x7 mm	QLP-48 7x7 mm	QLP-48 7x7 mm	QLP-48 7x7 mm	QLP-16 4x4 mm	QLP-20 4x4 mm	QLP-36 6x6 mm	QLP-36 6x6 mm	QFN-16 QFN-48	QFN-48	—
Complies with EN 300 220, FCC CFR 47, part 15 and ARIB STD-T66	✓	✓	✓	✓	✓	✓	✓	✓	—	✓	—
Integrated MCU	—	—	✓	✓	—	—	✓	✓	—	—	—
IEEE 802.15.4 compliant	—	✓	✓	✓	—	—	—	—	—	✓	—
USB	—	—	—	—	—	—	—	✓	—	—	—
AES encryption/ authentication	—	✓	✓	✓	—	—	✓	✓	—	✓	—
Program memory	—	—	32/64/128 -kB Flash	128-kB Flash	—	—	32-kB Flash	32-kB Flash	—	—	Flash
Data memory	—	768 bytes	4 kB + 4 kB SRAM	4 kB + 4 kB SRAM	—	—	4-kB SRAM	4-kB SRAM	—	—	8-kB SRAM



Design Guides



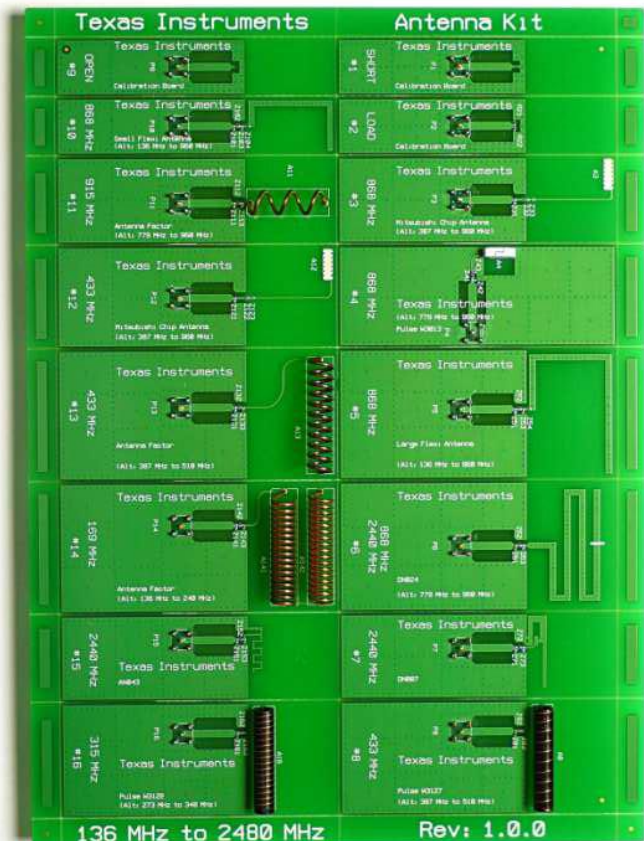
CC-Antenna-DK Full Characterization data in DN031

Design Note DN031

CC-Antenna-DK and Antenna Measurements Summary
By Richard Wallace

Keywords

- 169 MHz (136 – 240 MHz) Antenna
- 315 MHz (273 – 348 MHz) Antenna
- 433 MHz (387 – 510 MHz) Antenna
- 868 MHz (779 – 960 MHz) Antenna
- 915 MHz (779 – 960 MHz) Antenna
- 2440 MHz Antenna
- PCB Antenna
- Wire Antenna
- Ceramic Chip Antenna
- CC-Antenna-DK
- Dual Band Antenna (868 & 2440 MHz)
- Mitsubishi Chip Antenna
- Pulse Chip Antenna
- Helical Wire Antenna
- Pulse Helical Wire Antenna



TI Customer Support Resources on the Web

To learn more about the industry's broadest wireless portfolio, please see:

- E2E Forum:

www.ti.com/wiconforum

- Ask questions about devices, platforms, or applications



- TI Connectivity Wiki:

www.ti.com/connectivitywiki

- Getting Started Guides, demos, software downloads, hardware specs, orderables



Avnet Resources

- Wireless solutions guide
- RF line card
- Antenna selector guide
- On the web:
 - www.em.avnet.com/rf
 - www.em.avnet.com/SmartNetworks
- Development kits:
 - www.AvnetExpress.com
- Training & events
- Online technical support
- Local FAEs

[illegible]

Thank You

PLEASE RETURN FEEDBACK FORMS



Accelerating Your Success™