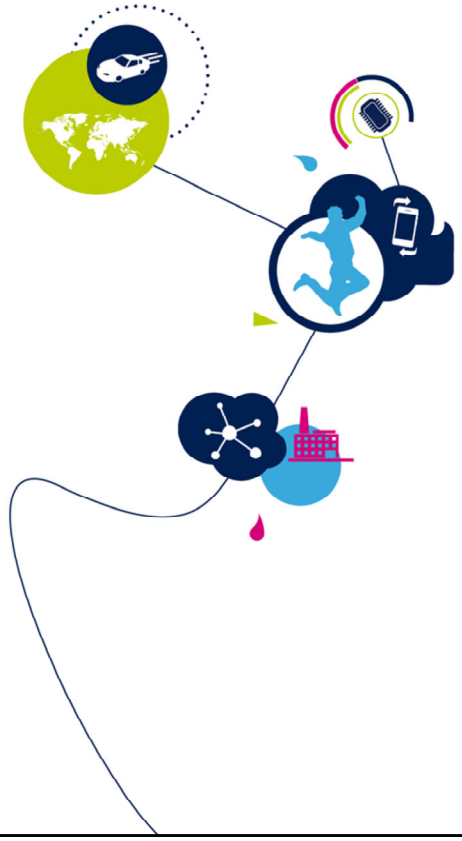
# STM32WB RF Overview

RF Overview

Revision 1.0



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Hello, and welcome to this overview of the radio frequency characteristics of the STM32WB microcontroller.
The STM32WB is a new family which combines on the same die an STM32 microcontroller and an RF part for connectivity.

# What's RF? Mandatory definition



**A radio communication is a wireless transmission of a signal through the air using electromagnetic radiation at a certain frequency**

- To do so, it requires the use of a complete radio system made of:
  - A transmitter (TX) that emits the signal over the air,
  - A receiver (RX) that gets the signal from the air,
  - An antenna (ANT), on both sides, which converts the electrical signal into electromagnetic waves, and reciprocally.
- Note: a component that embeds both a TRANSmitter and a reCEIVER is called a TRANSCEIVER.

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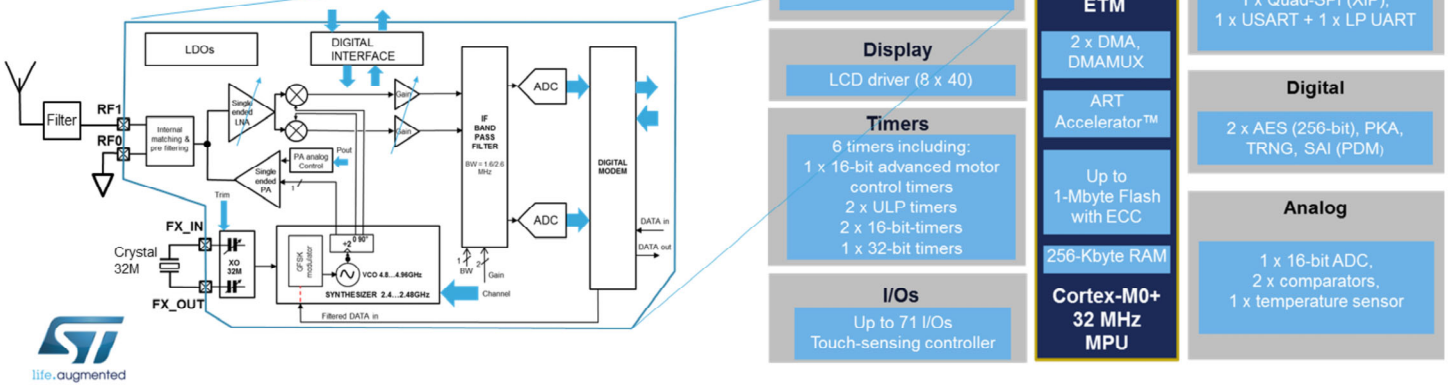
A radio frequency chain consists of a transmitter to send the signal over the air and, on the other hand, a receiver to acquire this signal.
At each side (transmitter and receiver), an antenna is needed to convert the electrical signal to electromagnetic waves on the transmitter side and conversely to transform the electromagnetic waves into an electrical signal on the receiver side.

# The STM32WB transceiver



**Some details about the RF transceiver inside the STM32WB**

- RF transceiver inside STM32WB:
  - Transmitter+ Receiver (single ended)
  - Crystal oscillator
  - Internal matching network and pre-filter
  - Digital interface
  - Dedicated power management circuit

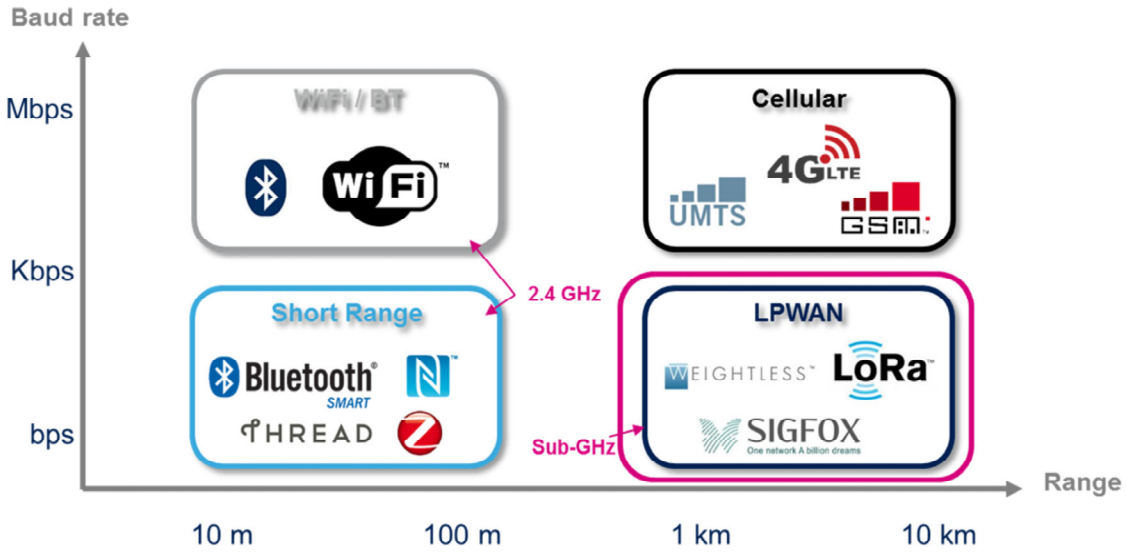



The RF transceiver embedded inside the STM32WB microcontroller comprises a digital interface, a 32 MHz external crystal oscillator for the internal synthesizer used for the modulation, an output-input stage and a dedicated power management circuit.
The output stage consists of a Power Amplifier (PA).
The input stage consists of a Low Noise Amplifier (LNA).

# Communication technology



**Several technologies are available depending on the baud rate and range**




STM32WB microcontrollers support short-range communication technologies such as Bluetooth Low Energy (Bluetooth LE, formerly marketed as Bluetooth Smart) and IEEE 802.15.4 (BLE, Thread, and Zigbee).

# SIG organism

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**In the particular case of Bluetooth, the features are under the control of the SIG organism**

- SIG, or Special Interest Group:
  - Initially created for Bluetooth products in 1998, this group provides standards and certifies that “on-market products” are compliant and ensure interoperability
- SIG 4.0:
  - First release of the specification that defines the Bluetooth “Smart”, or Bluetooth Low Energy (BLE)
  - Mainly focused to reduce the power consumed by Bluetooth devices (compared to historical “standard” ones)
- SIG 4.2:
  - Added advanced features to improve communication efficiency and security, but still limits the datarate to 1 Mbps
  - STM32WB is compliant with SIG 4.2
- SIG5.0:
  - This is the latest standard (Dec. 2016) with many new features, like a 2 Mbps data rate
  - STM32WB is compliant with SIG 5.0 and its 2 Mbps mode is supported

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The Bluetooth Special Interest Group (SIG) is the standards organization that oversees the development of the Bluetooth standards and the licensing of the Bluetooth technologies and trademarks to manufacturers. The SIG is a not-for-profit, non-stock corporation founded in September 1998.
STM32WB is certified Bluetooth 5 with the 2 Mbps RF physical layer (PHY).

# STM32WB RF in details (1/3)

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**The STM32WB RF part offers good performance without a lot of external components**

- STM32WB RF interface is single ended, “unique pin”
  - This eliminates the need for a balun or complicated external networks that usually try to mix the Tx pin with the Rx pin.
  - The unique Rx/Tx pin is internally pre-matched to directly interface with a 50 Ω environment.
- Internal pre-filtering
  - Internal band-pass pre-filtering helps to reduce the need for external RF components.
  - In practice, a simple T network and a low-cost off-the-shelf ceramic low-pass or band-pass filter is OK.
- Comfortable link budget
  - With +5 dBm output power and -95 dBm sensitivity, a 100 dB loss is possible between the antennas.
  - These 100 dB will be ideal to maximize the range.
- 2 Mbps
  - The STW32WB radio is designed to offer SIG 5.0 2 Mbps compatibility.
  - Programmable bandwidth in both analog and digital part of the circuit ensures a maximum of performances in the 2 Mbps operating mode.

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Thanks to an internal transformer connected to the RF pins, the circuit provides a direct interface for the antenna (single-ended connection, impedance close to 50 Ω).
The natural band-pass behavior of the internal transformer, simplifies the external circuitry used for harmonic filtering and out-of-band interference rejection.
To achieve the best RF performance for both transmission and reception, the use of an external matching network and an integrated low-pass filter (LPF) is recommended.

# STM32WB RF in details (2/3)

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**The STM32WB RF part aims to offer good performance without compromise**

- STM32WB RF uses state-of-the-art on-chip passive components
  - These integrated passive are used for both matching/filtering, but also to enhance the RF performance of critical blocks while saving current consumption.
  - In the same way, huge efforts have been made in the frequency synthesizer design to save as much current as possible without compromising the channel selectivity.
- Maximizing the dynamic
  - Architecture study focused on offering the maximum signal dynamic by using clever filtering all along the RF chain.
  - Very reactive, smoothed automatic gain control and high resolution Rx ADCs help to withstand huge interference signals at the antenna level.
- Compatibility with 802.15.4 Thread
  - The fast, direct modulation internal frequency synthesizer, supports 2 Mbps of GFSK modulation (Bluetooth LE) and also the 250 kbps + 8 time spreading factor of the 802.15.4 Thread Offset QPSK modulation.
  - Programmable bandwidth Rx filtering is well adapted to receive a Thread communication in excellent conditions.

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In Receiver mode, a linearized, smoothed analog control offers a clean power ramp-up. In Receive mode, the circuit can be used in standard high performance or in reduced power consumption (user programmable) mode. The Automatic Gain Control (AGC) is able to reduce the chain gain at both RF and IF locations, for optimized interference rejection. Thanks to the use of complex filtering and highly accurate I/Q architecture, high sensitivity and excellent linearity can be achieved.

# STM32WB RF in details (3/3)

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**The STM32WB RF part aims to maximize overall circuit performance**

- STM32WB RF contains its own dedicated microcontroller
  - In order to maximize the overall computation power, the STM32WB radio contains its own Cortex M0+ core with its associated memory
  - It is dedicated to the management of the Bluetooth and Thread low level stack, while offering the flexibility of programmable devices
- Maximizing the throughput
  - When the radio function is activated, the M4 core can be 100% used to run the customer application
- Transparent exchanges between cores
  - The customer doesn't need to manage the communication between M0+ and M4 cores
  - An internal "mail box" system is used, to manage the exchanges between the cores

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The STM32WB is a dual core device: the microcontroller has a Cortex-M4 core for the application and a Cortex-M0+ core dedicated to the radio.
A section of the Flash memory is secured for the RF subsystem CPU (i.e. Cortex-M0+ core), and cannot be accessed by the Cortex-M4 core.
Both cores can read/write or erase the embedded Flash memory thanks to a dedicated hardware mechanism.
The arbitration is based on time sharing.
The STM32WB microcontroller has the same read-out protection as the other STM32 microcontrollers with 3 levels of protection: Level 0 gives full access, while Level 2 ensures full protection by fuse, meaning it cannot be undone.

# STM32WB increases RF performance



**The STM32 WB RF offers flexibility**

- Increasing output power
  - The Tx maximum power is set at +5 dBm over the whole temperature range (-40 to +125°C junction) under a 50 ohm load.
  - At restricting temperature range (-40 to +85°C), the output power should be increased up to +6 dBm under a 50 ohm load.
- Decreasing output power
  - The maximum output power can be reduced by some dBs, and the current consumed during the transmission is also decreased.

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Depending on the application, the output power can reach its maximum value of +6 dBm with the maximum LDO voltage or can be reduced to minimize the current consumption.

# STM32WB Low component count (1/2)

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**The STM32WB RF does not require a lot of external components**

- Mandatory external components
  - The 32 MHz crystal oscillator is one of the mandatory external components.
  - However, thanks to internal tuning bank of capacitor inside the on-chip crystal oscillator, a room temperature relaxed tolerance crystal can be used.
  - Even if pre-filtering of Tx harmonics exists on chip, some external lowpass/bandpass filtering should be added to readily filter out the harmonics below the maximum authorized level (country dependent)
  - In some cases, the antenna can act as a filter (very dependent on antenna type/configuration)
  - Even if the STM32WB microcontroller is internally pre-matched to directly interface with a 50 ohm load, it is good practice to add 2 or 3 low-cost external components to compensate for possible on board sources of mismatch:
    - Antenna matching is usually poor
    - LP/BP filter can be mismatched
    - PCB trace width/length can add some impedance transformation
  - These components can be used to improve the harmonic filtering (high Tx power/poor antenna)

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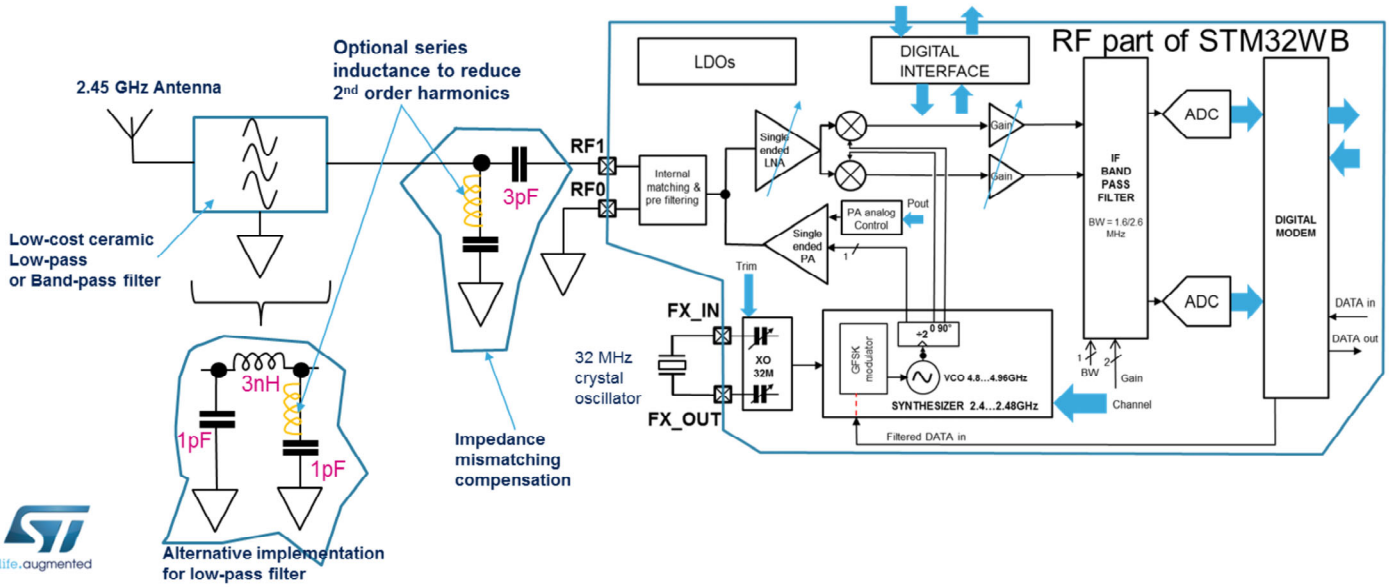
The 32 MHz crystal oscillator does not need an external trimming capacitor network thanks to a dual network of programmable integrated capacitors.
To achieve the best RF performance for both transmission and reception, the use of an external matching network and an integrated low-pass filter (LPF) is recommended.

# STM32WB Low component count (2/2)



**The STM32WB RF typical BOM is very reduced**

- Typical set of external components




This slide shows an example of a complete application circuit.