

STM32WL5 – SubGHz

Sub-GHz radio controller

Revision 1.0

Hello, and welcome to this presentation of the STM32WL5 sub-GHz radio controller.

- The sub-GHz radio integrates the following features:
 - ISM band 150 – 960 MHz
 - Modulations and bit rate:
 - LoRa™, from 0.013 to 17.4 kbps
 - (G)FSK, from 0.6 to 300 kbps
 - (G)MSK, from 0.1 to 10 kbps
 - BPSK, from 100 bps to 600 bps
 - Compliant
 - ETSI EN 300 220, EN 300 113, EN 301 166
 - FCC CFR 47 part 15, 24, 90, 101
 - ARIB STD-T30, T67, T108
 - Standards:
 - LoRaWAN™, Sigfox,
 - Proprietary protocols

Application benefits

- Multiple sub-GHz standards support
- Ultra low power
- High output power up to +22 dBm
- Automatic calibration



life.augmented

The sub-GHz radio operates in the ISM 150 -960 MHz band, providing LoRa, Frequency Shift keying, Minimum Shift Keying, Gaussian Frequency Shift keying, Gaussian Minimum Shift Keying, and Binary Phase Shift Keying modulations. The radio complies with the European telecommunication Standards Institute, European Norm 300 220, 300 113, and 301 166, Federal Communication Commission Code of Federal Regulation 47 part 15, 24, 90, and 101, and Association of Radio Industries and Businesses Standard T30, T67, and T108.

It enables the building of systems for the following standards: LoRa Wireless Area Network, Sigfox, etcetera, and proprietary protocols.

Key features

- Securable command base control
 - Using SPI interface
- Differential receive input
- Single ended High and default transmit output power
- Radio operating mode independent from CPU



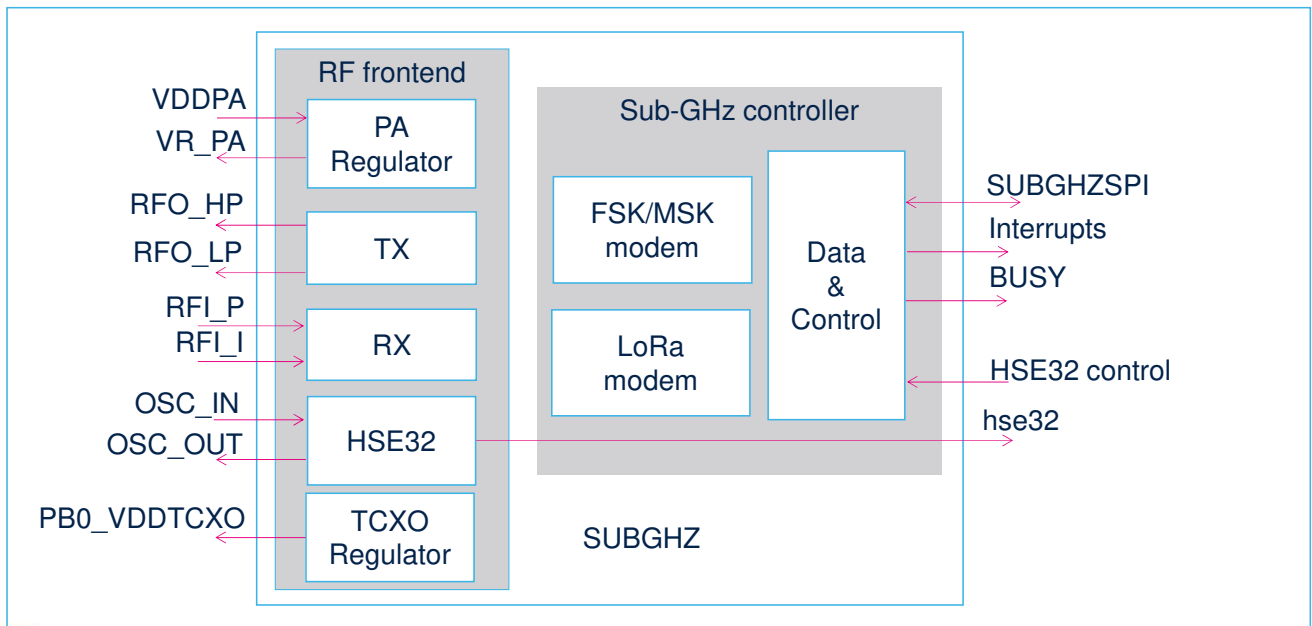
life.augmented

3

The sub-giga Hertz radio communication through the serial peripheral interface can be secured, preventing interaction from non-secure sources. It provides a differential receive input and a separate single ended transmit output for high power up to +22 dBm and default power up to max +14 dBm.

The sub-giga Hertz radio can operate independently from the CPU, this means the CPU system can be in one of its low power modes while the radio is receiving or transmitting data.

Block diagram



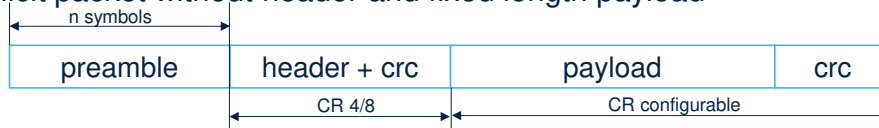
The sub-giga Hertz radio module is accessed through the sub-giga Hertz serial peripheral interface using SPI commands.

It consists of a controller part containing the data handling and control logic, a LoRa™ modem and a Frequency Shift Keying and Minimum Shift Keying modem, and the radio frontend containing the transmit chain with the power amplifier regulator, the receive chain, the high speed external 32 mega Hertz oscillator and the temperature-controlled crystal oscillator regulator.

Dedicated interrupt are provided to the CPU, as well as sub-giga Hertz radio busy information.

The high speed external 32 mega Hertz clock control enables the control of the high speed external 32 mega Hertz oscillator and its operation mode, including the temperature-controlled crystal oscillator regulator operation.

- Framing
 - Explicit packet with header and variable length payload
 - Implicit packet without header and fixed length payload



- Modem configuration:
 - Modulation bandwidth 7.81 kHz up to 500 kHz
 - Spreading factor from 32 Chips/symbol up to 4096 chips/symbols
 - Coding rate 4/4 up to 4/8
- Channel activity detection



The LoRa modem has two framing configurations: Explicit packet mode, using more overhead leading to increased airtime. This packet type allows transfers of packets with variable length payloads due to the inclusion of a header field.

Implicit packet mode, with minimum overhead leading to minimum airtime. This packet type requires the transfer of all packets with a predefined fixed length payload. It does not include a header field.

The preamble length can be configured.

The modem can be configured to trade off effective data rate versus range with the programmable modulation bandwidth and or spreading factor. A lower modulation bandwidth and/or spreading factor allows the increase of the range. The coding rate also improves the robustness against interferences at the expense of longer packet airtime. The higher the coding rate the more robust the communication

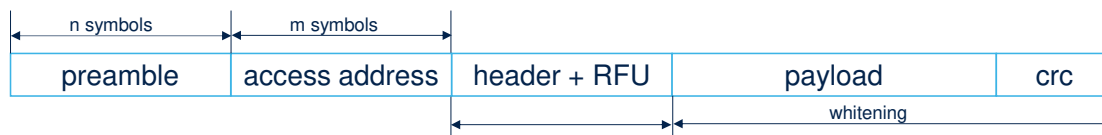
will be.

Channel activity detection can be used to detect the presence of a LoRa signal before initiating any communication.

Generic framing

- Framing

- Used with FSK and MSK modem
- NRZ coding
- Programmable preamble length
- Optional access address with programmable length
- Variable length packet with header and variable length payload
- Fixed length packet without header and fixed length payload
- Optional whitening (9-bits LFSR $x^9 + x^5 + x^1$, programmable initialization value)
- Payload CRC (programmable polynomial, initialization value, inversion and length)



The generic framing is used with frequency shift keying and minimum shift keying modulation and uses a Non Return to Zero coding.

- The preamble length can be configured.
- An optional access address field can be added for which the length can be configured.
- Variable length packet mode, using more overhead leading to increased airtime. This packet type allows the transfer of packets with variable length payloads due to the inclusion of a header field.
- Fixed length packet mode, with minimum overhead leading to minimum airtime. This packet type requires the transfer of all packets with a predefined fixed length payload. It does not include a header field.
- Optionally whitening can be added to the payload.
- The cyclic redundancy check is fully programmable for polynomial, initialization value, CRC inversion, and length.

- Modem configuration:
 - Bit rate 600 bps up to 300 kbps
 - Optional Gaussian filtering with BT 0.3 up to BT 1.0
 - Modulation bandwidth 4.8 kHz up to 467 kHz
 - Frequency deviation
- Above 1.2 kbps, can be used for MSK modulation by setting frequency deviation to a quarter of the bit rate.

The frequency shift keying modem can be configured for the following configurations:

- Bit rate,
- Gaussian filtering,
- Modulation bandwidth,
- and frequency deviation.

- MSK modulation is only available in transmit mode
- Modem configuration:
 - Bit rate 100 bps up to 10 kbps
 - Optional Gaussian filtering with BT 0.3 up to BT 1.0
 - Fixed modulation index 0.5

The minimum shift keying modem is only available in transmit mode and can be configured for the following configurations: Bit rate, and Gaussian filtering.

- BPSK modulation is only available in transmit mode
- Framing
 - Full flexible packet format under CPU control.
- Modem configuration:
 - Bit rate 100 bps and 600 bps
 - Fixed raise-cosine Gaussian filtering with BT 0.5
 - DBPSK modulation can be obtained by data pre-processing



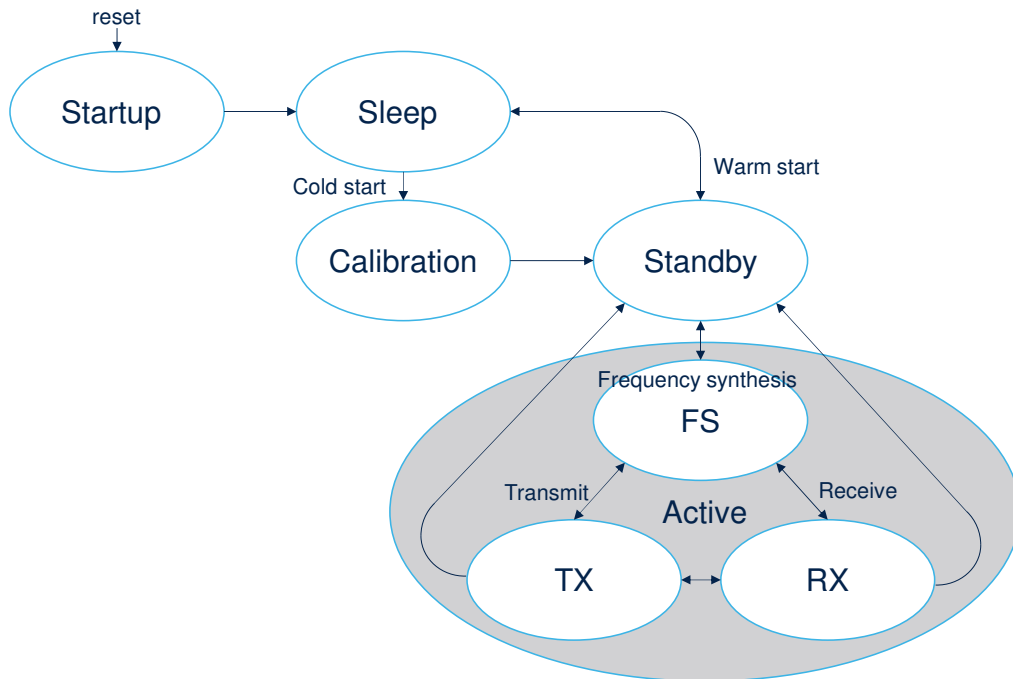
The Binary Phase Shift Keying modem is only available in transmit mode.

The Binary Phase Shift Keying framing is fully flexible and fully under firmware control.

Any preamble, access address, header field, payload, and CRC shall be provided by firmware.

The Binary Phase Shift Keying modem can only be configured for bit rate. With some data pre-processing Differential Binary Phase Shift Keying modulation can be obtained.

Sub-GHz radio operating modes



The sub-giga Hertz radio operating modes are depicted in this figure.

In the startup phase, some internal sub-giga Hertz radio supply and clock start up, after which the sleep state is entered.

The sleep state represents the lowest power mode, there is no radio activity, optionally the sub-giga Hertz RTC timer can be kept running for duty cycled operations. To exit the sleep state, firmware has to set the sub-giga Hertz serial peripheral interface NSS signal low.

On a cold start, the calibration phase is used to calibrate some sub-giga Hertz radio blocks, like the internal oscillators frequency, radio phase locked loop, radio analog to digital converter and image rejection.

Only once in Standby state, the firmware can communicate with the sub-giga Hertz radio through the sub-giga Hertz serial peripheral interface and program the configuration parameters before entering any active state.

In the Frequency Synthesis state, the radio PLL locks on the requested radio frequency. Then transmit and receive states can be entered.

In the transmit and receive states, actual data is transferred on the radio frequency with the selected modulation.

Sub-GHz radio communication

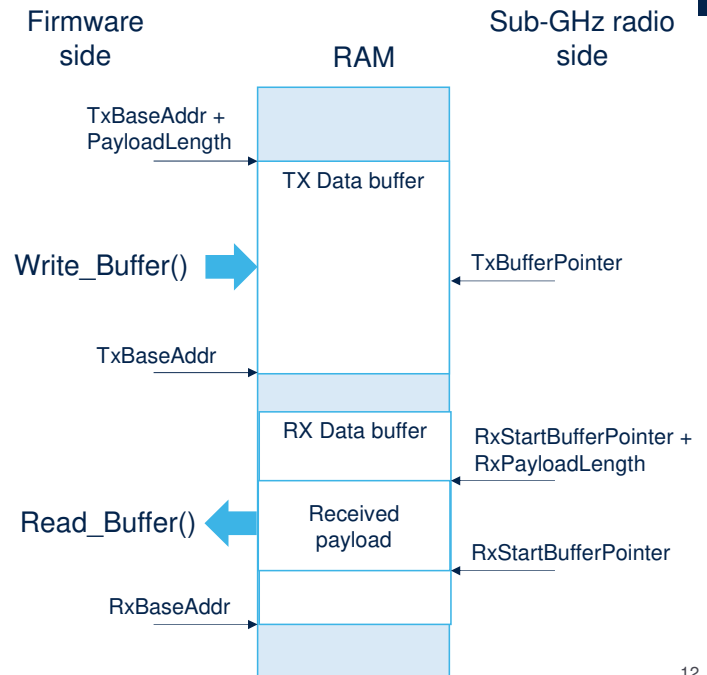
- The sub-GHz radio is controlled through a command-based SPI interface
- Command structure:
 - Opcode (one byte)
 - Parameters (0 to n, depending on command)
- The Opcode is used to identify the command such as Read_Buffer, Set_Tx, Set_ModulationParams, etc..
- Parameters are used to configuration and status information.
- Busy indication when no command can be received.



Communication with the sub-giga Hertz radio is done through the command-based Serial Peripheral Interface (SPI). The command structure uses a one-byte opcode to identify the command followed by the command parameters. The number of parameters depends on the command. A busy information is provided that indicates when the sub-giga Hertz radio can't receive commands, i.e. when the current requested command is being processed or when a low power mode is entered.

Data buffer

- A 256-byte RAM
- TX data buffer
 - Written by firmware, read by hardware
 - Parameters:
 - TxBaseAddr,
 - TxBufferPointer
 - PayloadLength
- RX data buffer
 - Written by hardware, read by firmware
 - Parameters:
 - RxBaseAddr,
 - RxStartBufferPointer
 - RxPayloadLength



Data for transmit and receive is in the sub-giga Hertz radio 256-byte data buffer RAM. The transmit and receive data buffers are accessed via the sub-giga Hertz radio serial peripheral interface command. The RAM has a circular nature, any address increment exceeding 0xFF wraps around to address 0x00.

The transmit buffer is written by firmware and read by hardware. The start of the transmit buffer is defined by the transmit base address, the length of the buffer is defined by the payload length. The hardware uses the transmit buffer pointer to read the data.

The receive buffer is written by hardware and read by firmware. The start of the receive buffer is defined by the receive base address. The hardware uses the receive start buffer pointer to start read the data. Data is read until the length of the buffer as defined by the receive payload length.

Note that if the amount of received data exceeds the receive buffer length, other data in the RAM are overwritten.

BaSiC LoRa™, (G)FSK, (G)MSK TX operation

- Define transmit data buffer `Set_BufferBaseAddress()`
- Write buffer data `Write_Buffer()`
- Select packet type `Set_PacketType()`
- Define frame format `Set_PacketParams()`
- Define synchronization word `Write_register()`
- Define radio frequency `Set_RfFrequency()`
- Define power amplifier configuration `Set_PaConfig()`
- Define transmit output power `Set_TxParams()`
- Define modulation `Set_ModulationParams()`
- Configure end of transmission interrupt `Cfg_DioIrq()`
- Start transmission `Set_Tx()`
sub-GHz radio transmit packet
- Wait for end of transmission interrupt and read status `Get_IrqStatus()`
- Clear interrupt `Clr_IrqStatus()`



This slide lists the subsequent steps to perform a basic LoRa transmission.

BaSiC LoRa™, (G)FSK RX operation

- Define receive data buffer `Set_BufferBaseAddress()`
- Select packet type `Set_PacketType()`
- Define frame format `Set_PacketParams()`
- Define synchronization word `Write_register()`
- Define radio frequency `Set_RfFrequency()`
- Define modulation `Set_ModulationParams()`
- Configure end of reception interrupt `Cfg_DioIrq()`
- Start reception `Set_Rx()`
sub-GHz radio reception
- Wait for end of reception interrupt and check received packet status `Get_IrqStatus()`
 - Read receive buffer information `Get_RxBufferStatus()`
 - Read received data `Read_Buffer()`
- Clear interrupt `Clr_IrqStatus()`



This slide lists the subsequent steps to perform a basic LoRa reception.

BaSiC BPSK TX operation

- Define transmit data buffer `Set_BufferBaseAddress()`
- Write buffer data for the whole packet definition `Write_Buffer()`
- Select packet type `Set_PacketType()`
- Define frame format `Set_PacketParams()`
- Define radio frequency `Set_RfFrequency()`
- Define power amplifier configuration `Set_PaConfig()`
- Define transmit output power `Set_TxParams()`
- Define modulation `Set_ModulationParams()`
- Configure end of transmission interrupt `Cfg_DioIrq()`
- Start transmission `Set_Tx()`
sub-GHz radio transmit packet
- Wait for end of transmission interrupt and read status `Get_IrqStatus()`
- Clear interrupt `Clr_IrqStatus()`



This slide lists the subsequent steps to perform a basic transmission using binary phase-shift keying (BPSK) modulation.