High Performance Transceiver for Sub 1-Ghz Applications

SPIRIT1

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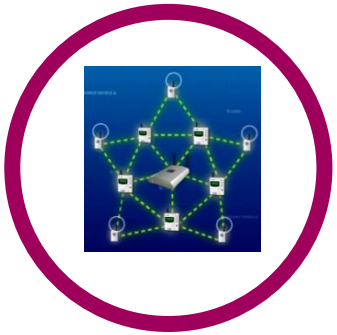
SPIRIT1 application focus

HOME/BUILDING AUTOMATION

SMART METERING



WIRELESS SENSOR NETWORKS

ALARM SYSTEMS

INDUSTRIAL MONITORING & CONTROL

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SPIRIT1: Best in class transceiver

Operation Lifetime Doubles in Smart Meters and Other Wireless Sensor Node Applications with New Wireless Transceiver from STMicroelectronics

ST's SPIRIT1 wireless transceiver cuts power budget by 50% over competing devices

Geneva, April 26, 2012 - STMicroelectronics (NYSE:STM), a global semiconductor leader serving customers across the spectrum of electronics applications and a world leader in smart metering and industrial applications, today introduced a high-performance, ultra-low-power wireless transceiver for Automatic Meter Infrastructure and other wireless sensor node applications, such as alarm and security systems, home and building automation, and industrial monitoring and control. ST's **SPIRIT1** transceiver combines excellent receiver sensitivity with unbeatable current consumption, delivering 50% power reduction over existing solutions in the market.

Replacing traditional electromechanical meters, 'smart' electronic meters bring many advantages for utility providers and consumers alike. Features like full remote control, power peak and consumption analysis, anti-tampering mechanisms, fault alert, and time-variable tariffs, help make both the supply and usage of electricity, gas or water more efficient and economical.

ENTERING THE MARKET WITH BEST IN CLASS SOLUTION

Cuts power budget up to 50% over competing devices

Design focused on Power Savings

- RX 9 mA
- TX 21 mA (+11 dBm)
- Shutdown 2.5 nA

Excellent Sensitivity -120 dBm

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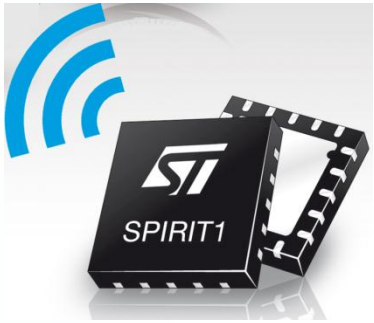
SPIRIT1: Description

- **Frequency bands: 169, 315, 433, 868, 915, 920 MHz**
- **Configurable data rate from 1 to 500 kbps**
- **SPI interface**
- **Supply voltage: 1.8 V to 3.6V**
- **Modulation schemes: 2-FSK, GFSK, MSK, GMSK, OOK, and ASK**
- **Suitable for Systems targeting compliance**
  - Wireless MBUS standard
  - ETSI EN 300 220, FCC CFR47 Part 15, ARIB STD-67



QFN20 4x4
(thickness 0.9mm)

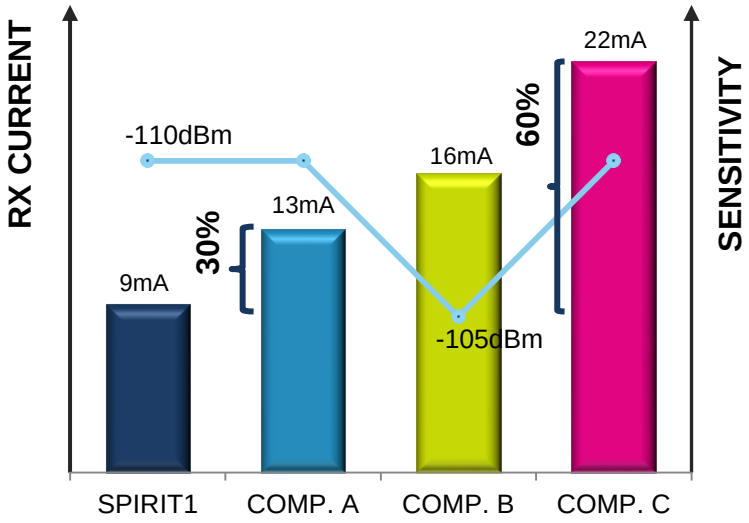
Available NOW

SPIRIT1: Key Features

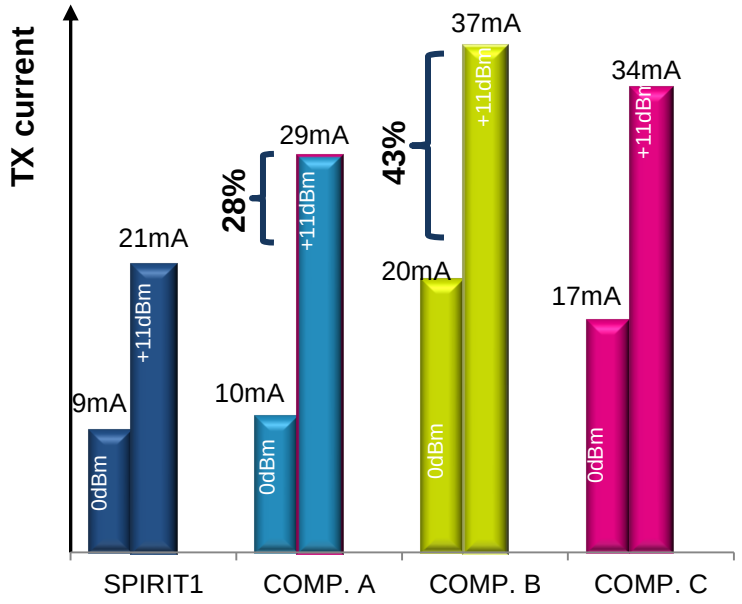
- **Output Power: -36 dBm to +11 dBm, in 0.5 dB steps**
- **Excellent receiver sensitivity: - 120 dBm** (1.2 kbps – 169MHz)
- **Adjacent channel selectivity : 55 dB at 12.5 kHz channel spacing**
  (1% PER – 20 bytes packet length)
- **Integrated SMPS allows very low power consumption**

Shutdown Mode	2.5 nA	Everything OFF
RX	9 mA	SPI on, XTAL on, Synth on
TX	21 mA	SPI on, XTAL on, Synth on
Standby Mode	650 nA	SPI on, register retention
Sleep	950 nA	SPI on, register retention, RC oscillator

SPIRIT1: Operation lifetime increases



- **RX Current consumption cut >30%**
- Sensitivity performances are not sacrificed



TX Current consumption cut >28% @ max o/p power

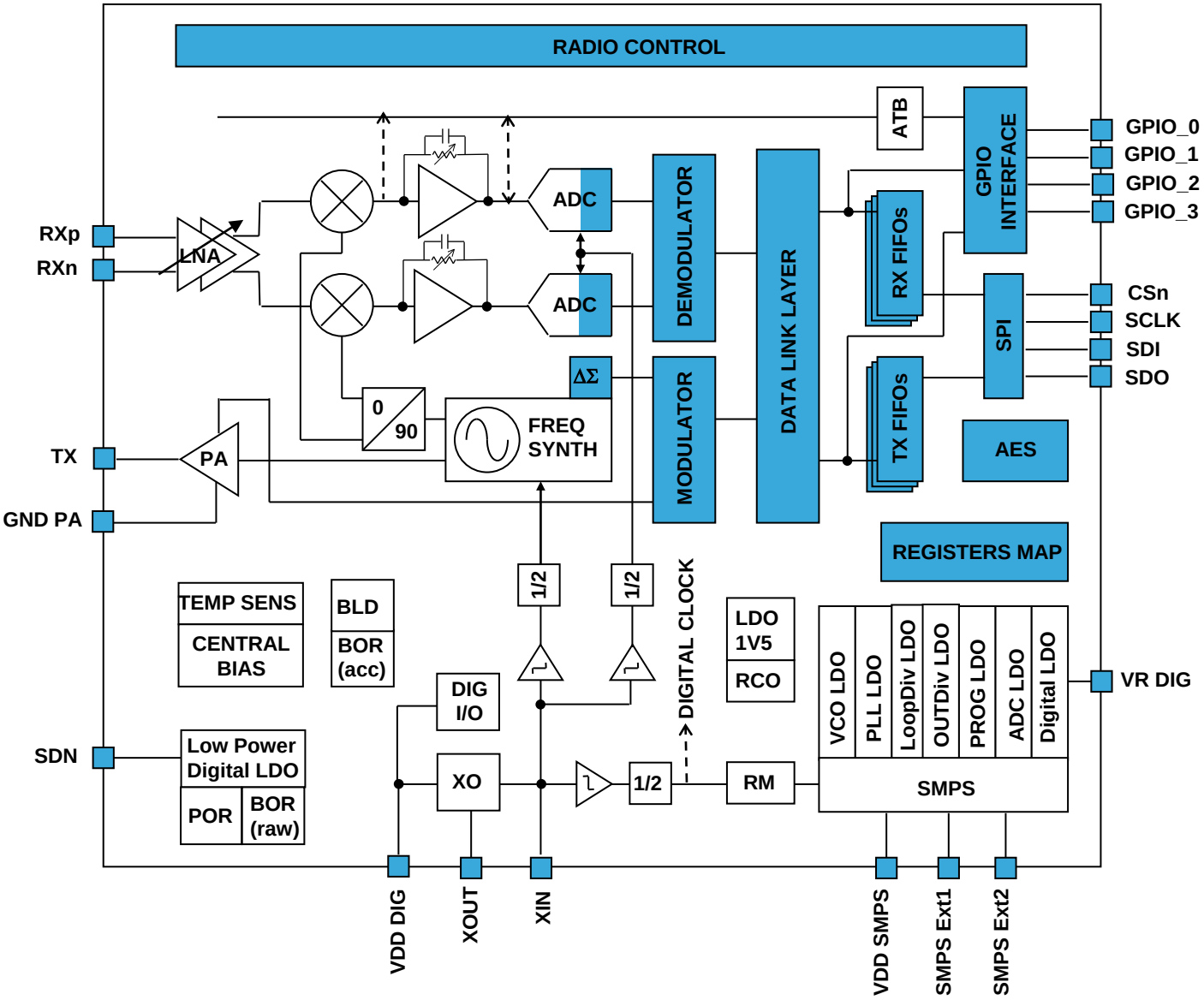
SPIRIT1: Key Features

- **Integrated packet handler**
  - **Support for automatic acknowledgment, retransmission, low duty cycle protocol and timeout protocol**
- **Automatic clear channel assessment (CCA) engine**
  - **Channel access mechanism, based on the rule ‘’Listen-before-talk’’ systems. Embedded CSMA/CA protocol**
- **Fully integrated ultra low power RC oscillator**
- **AES 128-bit encryption co-processor for secure data transfer**

SPIRIT1: Key Features

- **Frequency Hopping under MCU control**
  - **Calibration can be made each time the MCU decide to change frequency or MCU can save and restore calibration data to make the frequency hopping faster**
- **Separate 96-byte RX/TX FIFOs**
  - **accessible via the SPI interface for host processing**
- **Supports automatic antenna selection through an integrated antenna diversity switching mechanism**
- **Programmable RX digital filter from 6 kHz to 800 kHz**

SPIRIT1 Block Diagram



Main Block Description

- **Receiver**
  - Architecture based on LOW IF conversion
  - The received RF signal is amplified by a two-stage low noise amplifier (LNA) and down-converted in quadrature (I and Q) to the intermediate frequency (IF). At IF, the I/Q signals are digitized by high dynamic range ADCs.
  - The Demodulator data is then provided to an external MCU either through the 96-byte RX FIFO, readable via SPI, or via a GPIO pin.
- **Transmitter**
  - Architecture is based on direct synthesis of the RF frequency
  - The data to be transmitted are provided by an external MCU either through the 96-byte TX FIFO writable via SPI, or directly using a programmable GPIO pin
- **Power Management**
  - Integrates a high efficiency step-down converter (SMPS) cascaded with LDOs to supply both analog and digital parts.
  - Operates from a battery voltage ranging from 1.8 V to 3.6V, with high power efficiency

Main Block Description

- **Clock Signal : External crystal**
  - An external 24, 25, 26, 48, 50 or 52 MHz Crystal (between XIN and XOUT) or an external clock signal can be used
  - An integrated low-power RC oscillator, generating the 34.7 kHz signal is used as a clock for the slowest timeouts (i.e low duty cycle protocol or CSMA/CA protocol)

- **Digital Interface**
  - A 4-wire SPI serial interface is used to communicate with the external MCU.
  - 4 GPIOs that can be registered through the SPI registers to perform various functions, including
    - MCU clock output
    - FIFO status flags
    - Wake-up input
    - Battery level detector
    - TX-RX external switch control
    - Antenna diversity control
    - Temperature sensor output
    - Interrupts

Main Block Description

- **Data link layer**
  - Support for channel configuration, packet handling and data buffering
  - Support Packet Formats (Basic, STack and Wireless M-BUS)

  - The Host MCU can stay in power down until a valid RF packet has been received, and then burst read the data, greatly reducing the power consumption and computing power required from the host MCU

- **AES encryption co-processor**
  - Provides data security support as it embeds an advanced encryption standard (AES128) core which implements a cryptographic algorithm

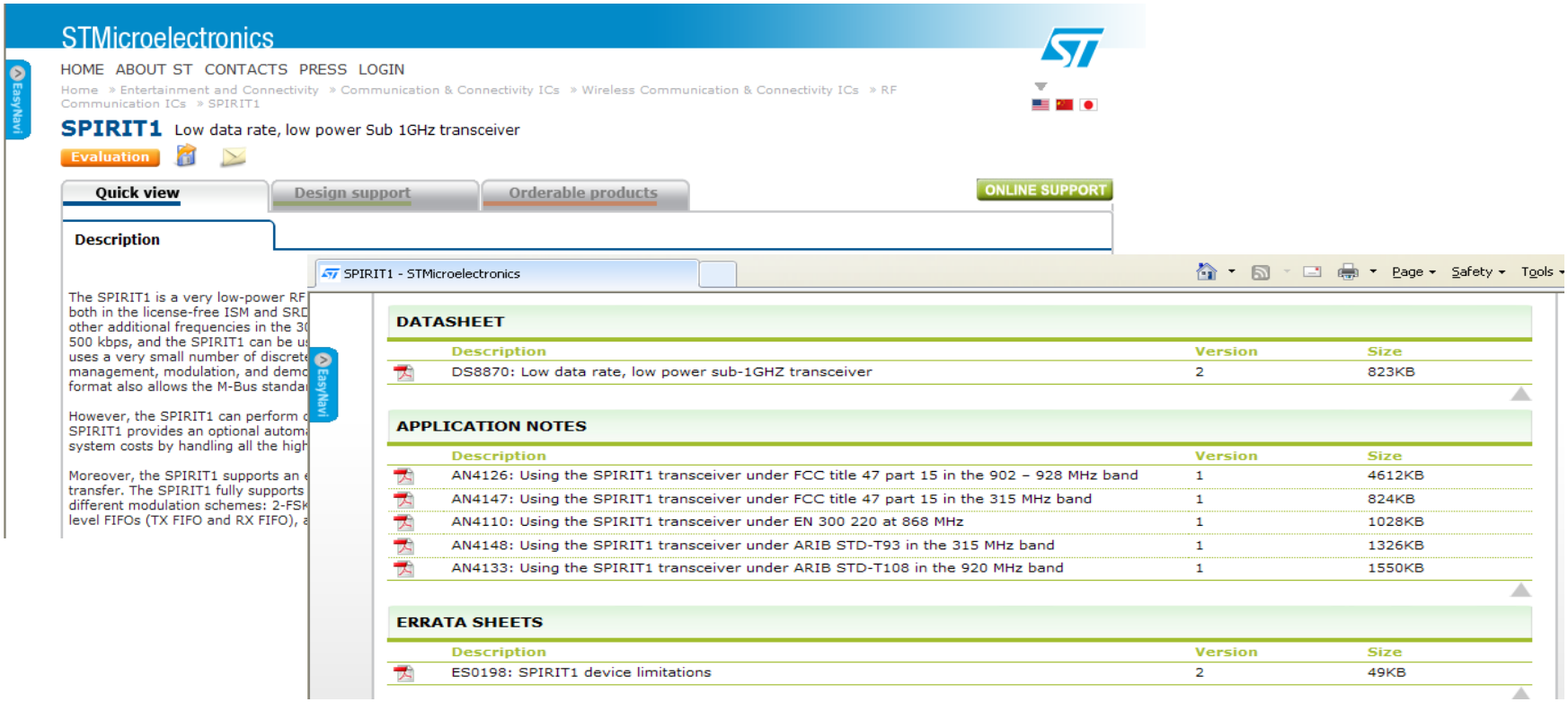
- **Analog temperature sensor**
  - The Host MCU can be used to read the chip temperature (e.g. it can be used to force radio recalibration)

- **Battery indicator and low battery detector**

Product Status & Material

- **Product RTM with All Documentation available on**

http://www.st.com/internet/imag_video/product/253167.jsp



- **Application Notes, Schematics, BOM, Gerber Files**
- **SW Development Kit (SDK) for STM32L, includes WM-Bus library, Set of examples**

Application Notes

AN4110
Application note

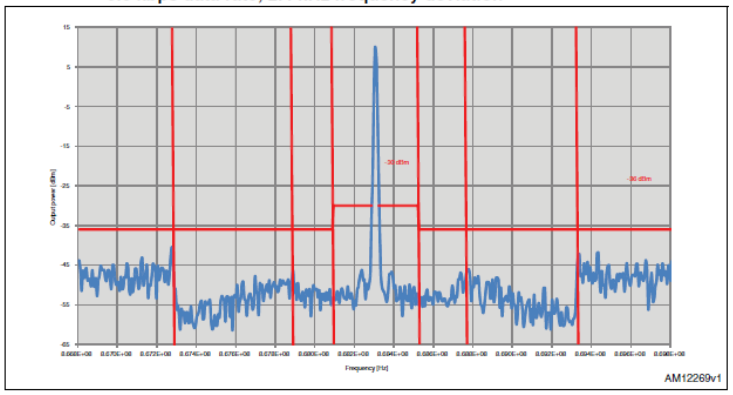
Using the SPIRIT1 transceiver under EN 300 220 at 868 MHz

Introduction

The SPIRIT1 is a very low power RF transceiver
sub-1 GHz band. It is designed to operate both
bands at 169, 315, 433, 868 and 915 MHz.

This application note outlines the expected perf
300 220-1 (v2.3.1, 2012-02) [2] in the 863 to 87
bands where the application, the maximum radi
mitigation requirement (duty cycle etc.) are diffe
+27 dBm (500 mW) in 869.4 to 869.65 MHz, an
Table 5 in ETSI EN 300 220-1 v2.3.1 [2]). This a
applications.

Figure 6. Spectral mask measurement, 25 kHz narrowband channel spacing, 9.6 kbps data rate, 2.4 kHz frequency deviation



AN4133
Application note

Using the SPIRIT1 transceiver under ARIB STD-T108 in the 920 MHz band

By Placido De Vita

Introduction

SPIRIT1 is a very low power RF transceiver, intended for RF wireless
sub-1 GHz band. It is designed to operate both in the license-free ISM
bands at 169, 315, 433, 868, 915 and 920 MHz.

The Japanese Association of Radio Industries and Businesses (ARIB)
response to several trends such as the growing internationalization of
unications and broadcasting and the nee
ARIB organism defines the basic technica
o equipment.

the expected performance when using th
n page 33) in the 920 MHz band. For det
cy band, please refer to the ARIB STD-T

m www.arib.or.jp/english/index.html.

AN4147
Application note

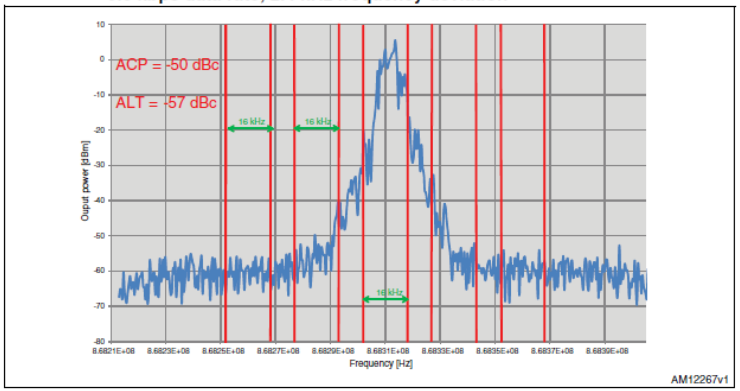
Using the SPIRIT1 transceiver under FCC title 47 part 15 in the 315 MHz band

By Placido De Vita

ow power RF transceiver, intended for RF wireless applications in the
esigned to operate in both the license-free ISM and SRD frequency
868, 915 and 920 MHz.

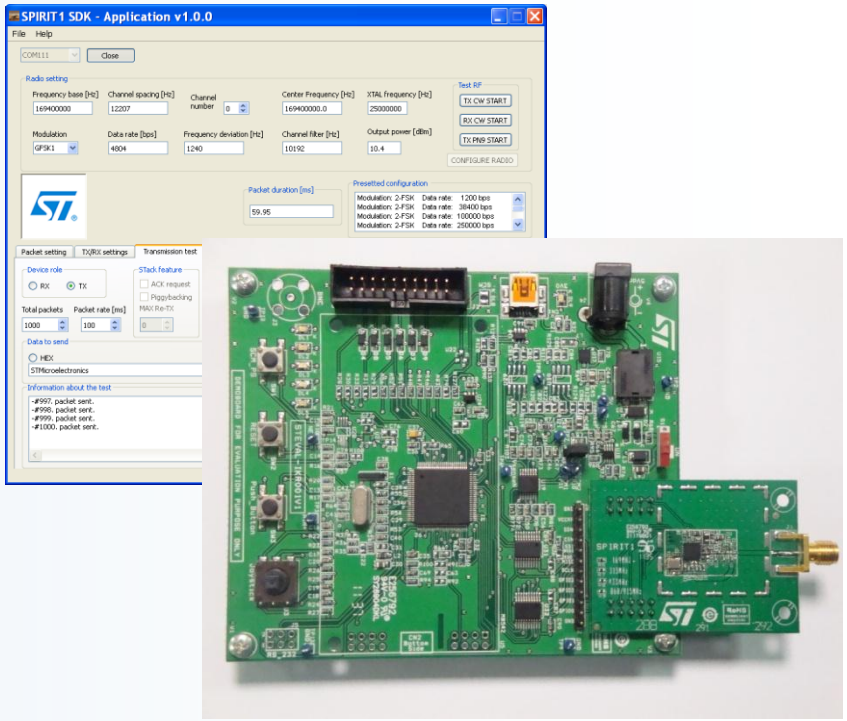
tlines the expected performance when using the SPIRIT1 under
in the 315 MHz band. There are no specific requirements in this
nd no channel spacing are defined.

Figure 4. Adjacent power measurement, 25 kHz narrowband channel spacing, 9.6 kbps data rate, 2.4 kHz frequency deviation



Development Kits

- **SPIRIT1 Development Kits**
  - STEVAL-IKR001V1 – 169 MHz
  - STEVAL-IKR001V2 – 315 MHz
  - STEVAL-IKR001V3 – 433 MHz
  - STEVAL-IKR001V4 – 868MHz
  - STEVAL-IKR001V5 – 915 MHz
  - STEVAL-IKR001V6 – 920 MHz



- **Development kit content**
  - 2 x STM32L based motherboard
  - 2 x SPIRIT1 RF modules
  - 2 x Antennas
  - 2 x USB cables
  - Software development kit (SDK) has to be downloaded from http://www.st.com
    - Includes ST Wireless MBUS stack, Examples, Documentation
  - Kit boards are preprogrammed with a firmware for GUI evaluation (DFU for firmware upgrade over USB)

SPIRIT1: Summary

- **Multi Band Transceiver, Targeting the Following Applications :**
  - Wireless Metering and Wireless Smart Grid
  - Home & Building Automation
  - Industrial Monitoring and Control
  - Wireless Fire and Security Alarms
- **Best in Class Solution in Power Saving : Cuts power budget by 30% over competing devices**
- **Excellent RF performances : High Sensitivity, High Selectivity, Antenna Diversity ensuring reliability & robustness performances**
- **Compliant Wireless MBus standard**
- **Demo Kit @ All frequency Band available NOW**
- **Product in Mass Production**

Technical Details

Transmission & Reception

RF Related Features – Packet Handler Engine -

MCU Interface & Others

Development Kit (HW, SW, SDK Suite)

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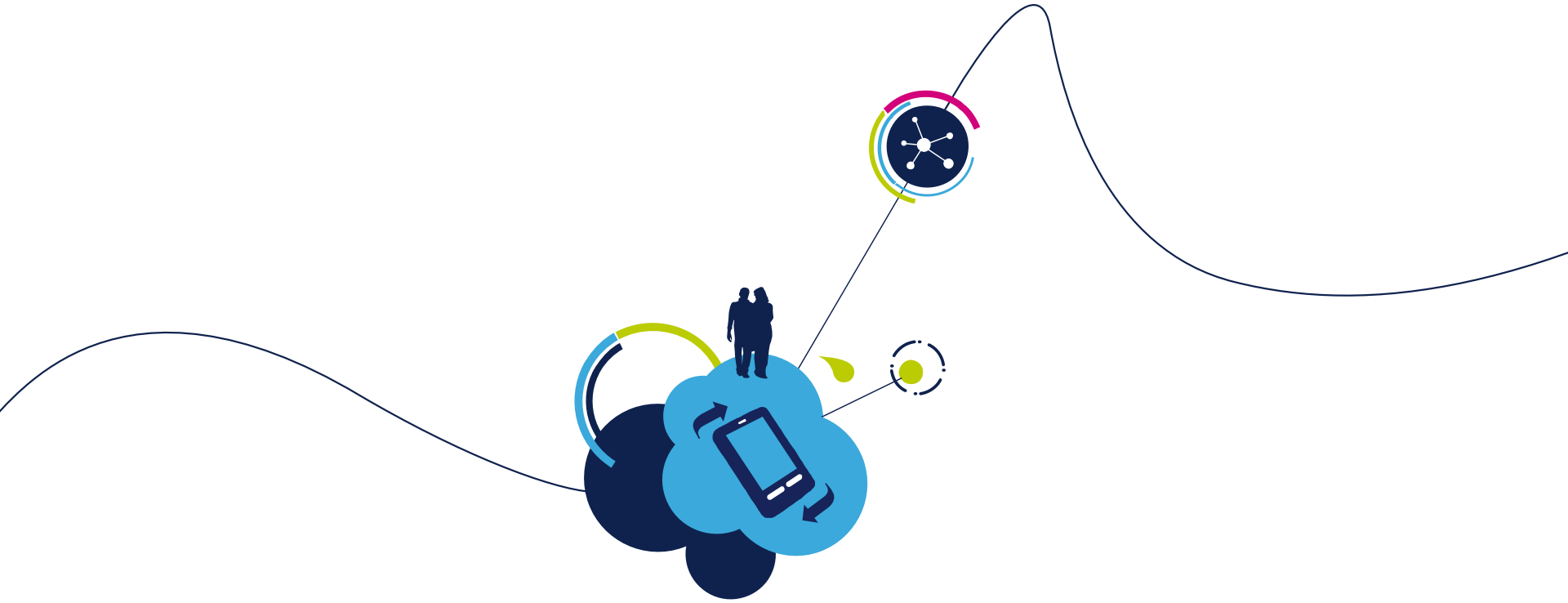

Transmission & Reception

RF Related Features

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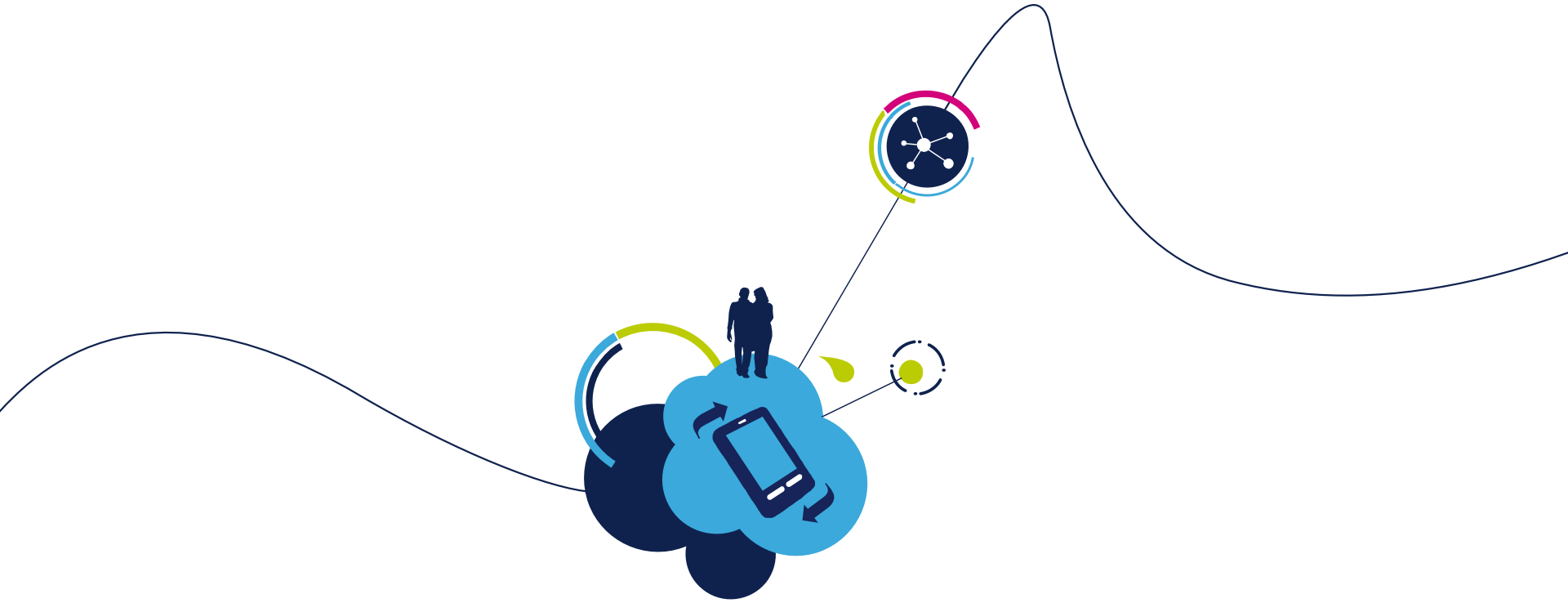
SPIRIT1 Oscillator and RF synthesizer

- An external XTAL (24, 25, 26, **48, 50, 52** MHz), provide a clock signal to the frequency synthesizer.
- The digital macro always requires clock in the range (24-26 MHz), so the clock must be divided when using 48-52 MHz XTAL.
- RF synth has fractional sigma delta architecture for fast settling and narrow channel spacing.
- It uses a multi-band VCO to cover the whole frequency range.
- The frequency is programmed using SYNT0-SYNT3 registers of SPIRIT1 (easiest way is to use SPIRIT1 SW library)
- Calibration can be automatic (80 us) or manual (20 us), in the latter case the micro should save/restore the calibration words and take into account for temperature/VBAT variation which could require recalibration.

Receiver Quality Indicators

- **Received signal strength indicator (RSSI)** - Measured received signal power. RSSI reading is available after the reception of a packet in a register
- **Carrier Sense (CS)** – based on RSSI (threshold, static/dynamic mode)
- **Link quality indicator (LQI)** – level of noise power on the demodulated signal
- **Preamble quality indicator (PQI)** - the reliability of the preamble detections
  - Preamble valid IRQ can be used
  - Packet demodulation can be stopped when PQI is below threshold
- **Synchronization quality indicator (SQI)** - measurement of the best correlation between the received synchronization word and the expected one
  - Sync word detected IRQ
  - Packet demodulation can be stopped when SQI is below threshold



Transmission & Reception

Packet handler Engine

SPIRIT1 Packet Handler Engine

Embedded packet format:

- **STack**

Preamble	Sync	Length	Destination Address	Source Address	Control	Seq. No.	No ACK	Payload	CRC

- **WM-Bus**

Preamble	Sync	Payload	Postamble

- **BASIC**

Preamble	Sync	Length	Destination Address	Control	Payload	CRC

SPIRIT1 Direct mode

The purpose of the direct modes are to by-pass completely the packet handler engine and to give the user more flexibility. The direct modes are available both for RX and TX.

- **Direct mode through FIFO (SPI)**
  - In the direct mode through FIFO the data are continuously read from the TX FIFO and transmitted without any processing of the packet handler for the transmitter and the data are continuously received in the RX FIFO without any processing.
- **Direct mode through GPIO**
  - In the direct mode through GPIO the data are sampled by the device on the rising edge of the clock signal and send on air without any processing of the packet handler for the transmitter and the data are continuously written to one GPIO together with the clock in another GPIO.
- **PN9 mode (for TX)**
  - A pseudo-random binary sequence is generated internally for test purpose only.

SPIRIT1 Automatic Packet Filtering

Embedded automatic packet filtering

- CRC (Packet discarded if CRC check do not pass)
- Destination address (My own address, Broadcast, Multicast)
- Source address (reference one in AND bitwise with the source mask)
- Control field (reference one in AND bitwise with the control mask)

- **The automatic packet filtering engine works only in STack and BASIC packet format.**
- **More than one automatic filtering feature can be enabled at the same time.**

SPIRIT1 Link Layer Protocol

Available only through the STack packet format, with following features

- **Automatic acknowledgment**
  - The receiver sends an ACK packet, if a packet is received with success and bit NO_ACK = 0. The transmitter goes in RX state to wait the ACK packet. If the transmitter does not receive any ACK packet when it should, the packet transmitted before is considered lost.
- **Automatic acknowledgment with piggybacking**
  - The receiver can fill the ACK packet with data (as payload field of the packet). The data to send is stored in the TX FIFO (up to 96 bytes without any additional interaction from the MCU !!!)
- **Automatic retransmission**
  - If the transmitter does not receive the ACK packet within the RX timeout programmed, it can be configured to do another transmission. Up to 15 retransmissions.

SPIRIT1 Data coding and integrity check

Error correction and detection methods

- **FEC/Viterbi and interleaving**
  - Convolutional coding in transmitter and on the receiver side - error correction is performed using soft Viterbi decoding.
  - Technique used for controlling errors in data transmission over unreliable or noisy communication channels. The number of transmitted bits is roughly doubled, hence the on-air packet duration in time is roughly doubled as well. Automatic data padding for FEC supported. (~1dB link budget increase)
- **Data whitening/ dewhitening**
  - To prevent short repeating sequences that create spectral lines, which may complicate symbol tracking at the receiver or interferer with other transmissions
- **CRC (Cyclic Redundancy Check)**
  - CRC polynomials can be selected (4 options). Programmable to 8, 16, or 24 bits

CRC and whitening is applied over all fields excl. preamble and synchronization word

RX timeout mechanisms

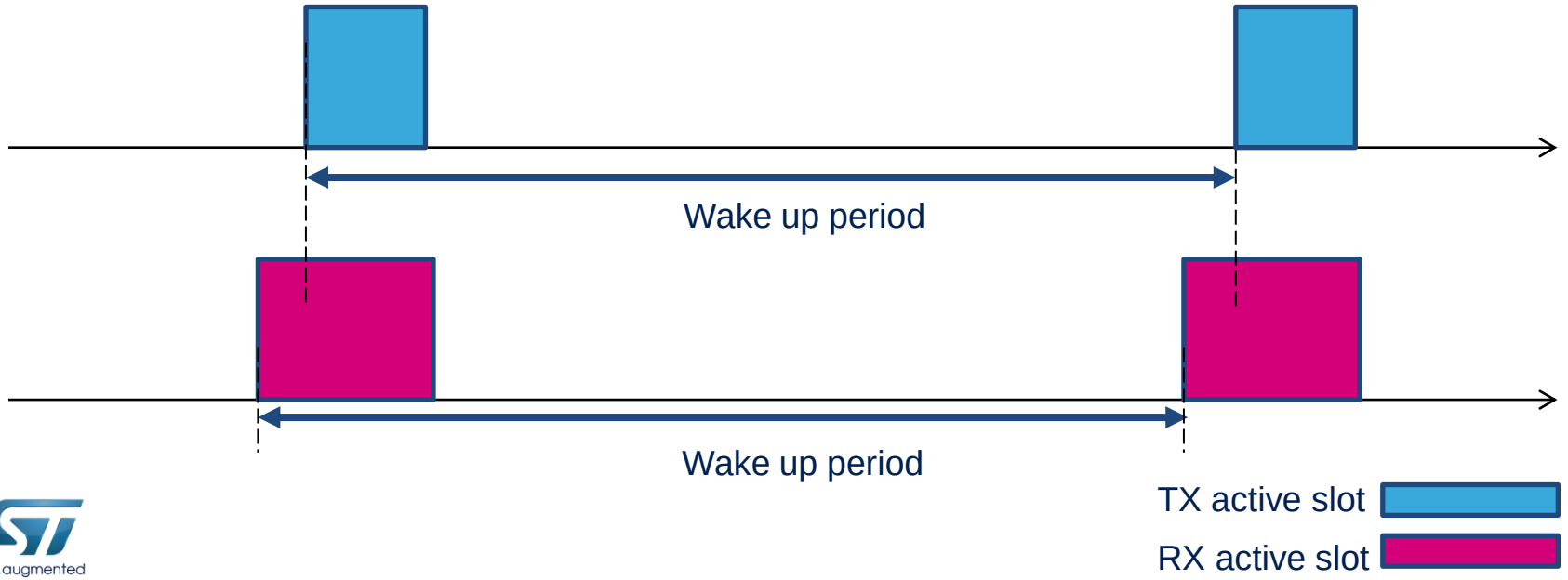
In order to reduce power consumption, a few automatic RX timeout modes are supported.

- **Infinite timeout** – RX stops when the packet ends or when the SABORT SPI command comes from the microcontroller
- **Carrier sense timeout** - RX is aborted if the RSSI never exceeds a programmed threshold within preset timeout (TIMER)
- **SQI timeout** - RX is aborted if the synchronization quality indicator (SQI) does not exceed a programmed threshold within preset timeout
- **PQI timeout** - RX is aborted if the preamble quality indicator (PQI) does not exceed the programmed threshold within preset timeout

The value of the Time out can be programmed up to ~3 seconds

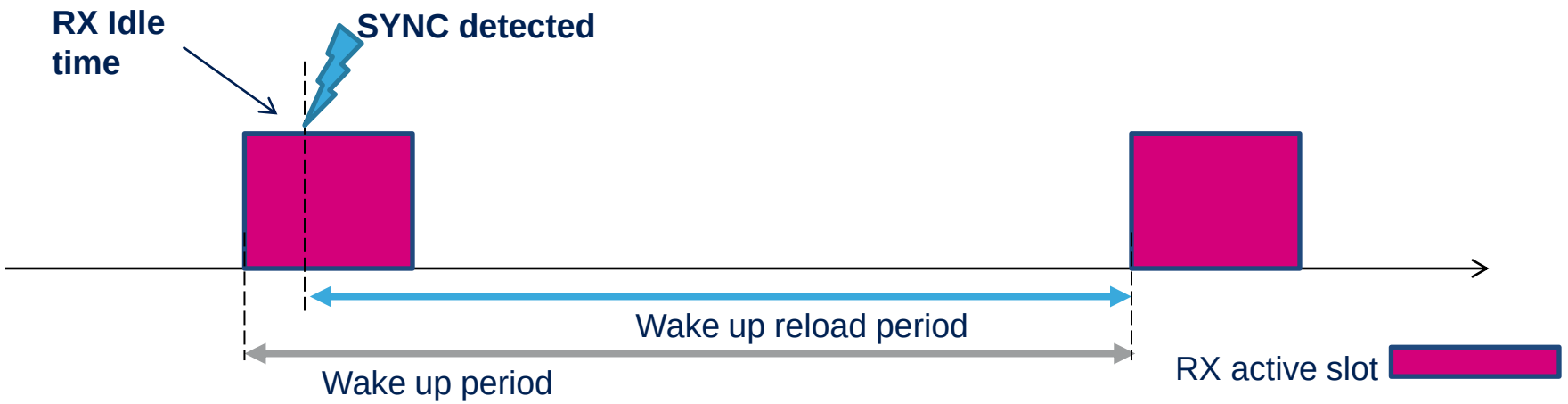
SPIRIT1 Low Duty Cycle mode

- The low duty cycle (LDC) mode allows operations with very low power consumption, while still keeping an efficient communication link
- WAKE_UP timer is used in LDC mode. It periodically wakes up the SPIRIT1 to perform a transmission or a reception
- When LDC is enabled the device runs on the 34.7 kHz RC oscillator keeping unused blocks off
- To maintain the correct synchronization between the receiver and a transmitter, the value of the wake-up timer can be automatically reloaded at the time the SYNC is detected



SPIRIT1 Low Duty Cycle mode

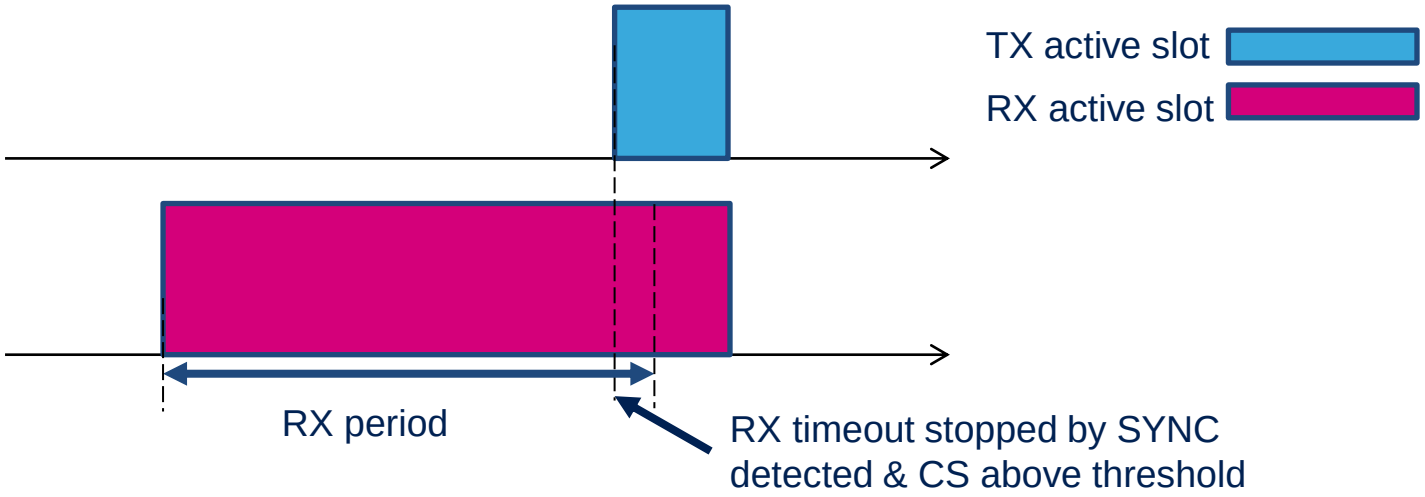
- LDC mode with wake-up timer reload on SYNC allows a better synchronization with the transmitter
- RX Idle time - Settling time of the analog RF circuits



The value of the Wake up period can be programmed up to ~2 sec (RC Oscillator)

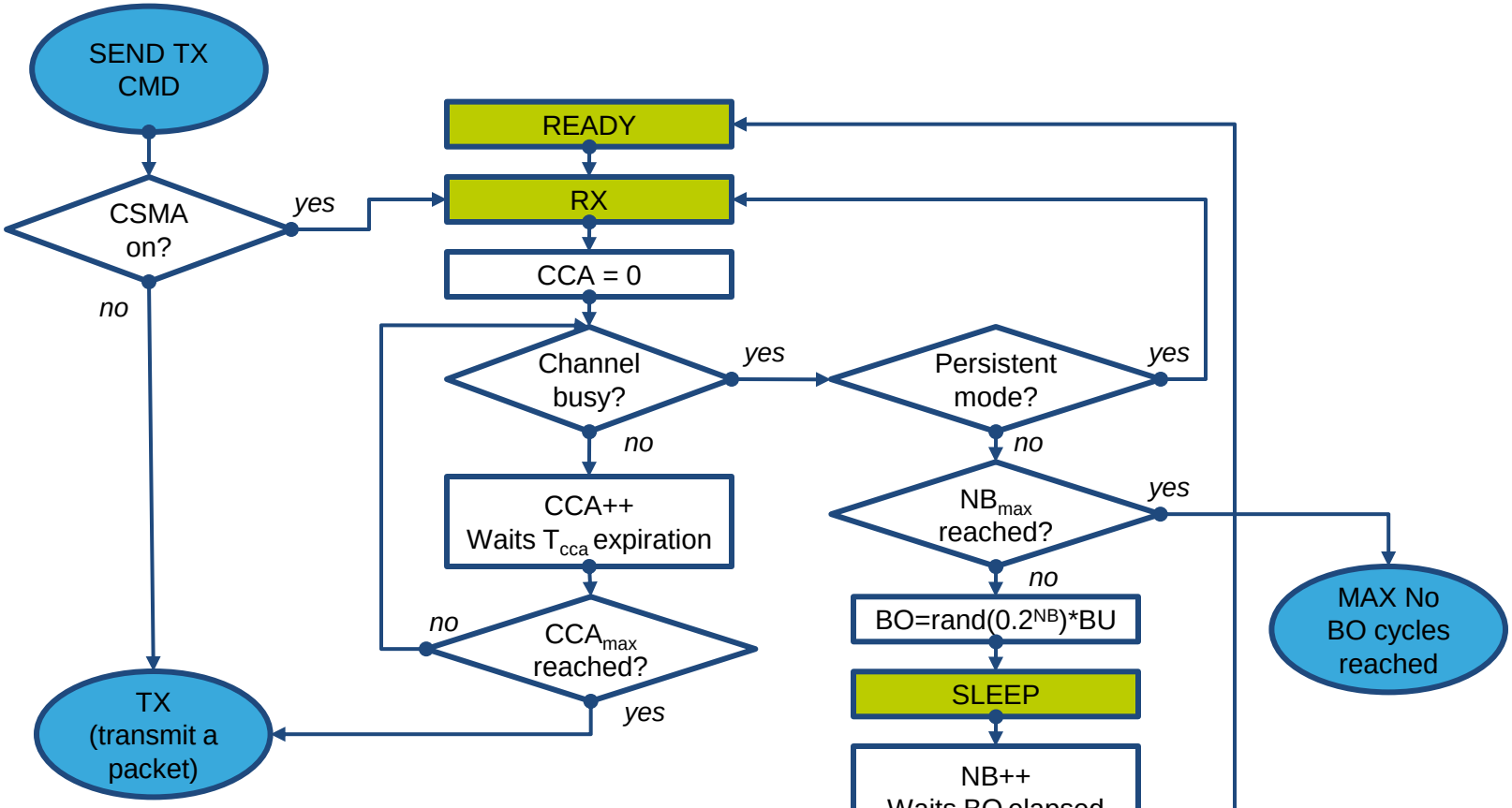
SPIRIT1 Quality Indicator use

- The expiration of the RX timer reduces the power consumption. However, to avoid a reception to be interrupted during a valid packet, some quality indicators can be configured together with their thresholds:
  - Carrier sense level
  - Sync quality indicator
  - Preamble quality indicator
- These parameters (also in AND/OR combination) can be used to recognize a valid packet to stop the RX timeout.

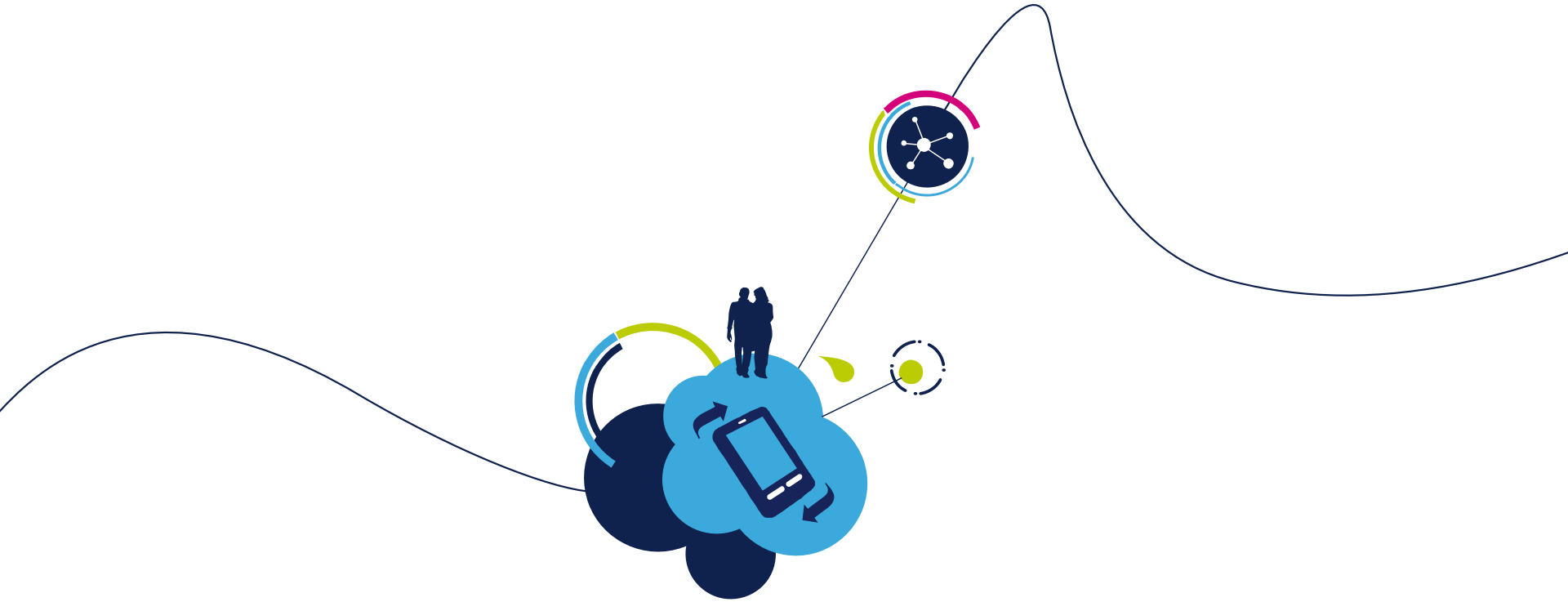


SPIRIT1 CSMA/CA Engine

The CSMA/CA engine is a channel access mechanism based on the rule “listen before talk”. This avoids the simultaneous use of the channel by different transmitters.

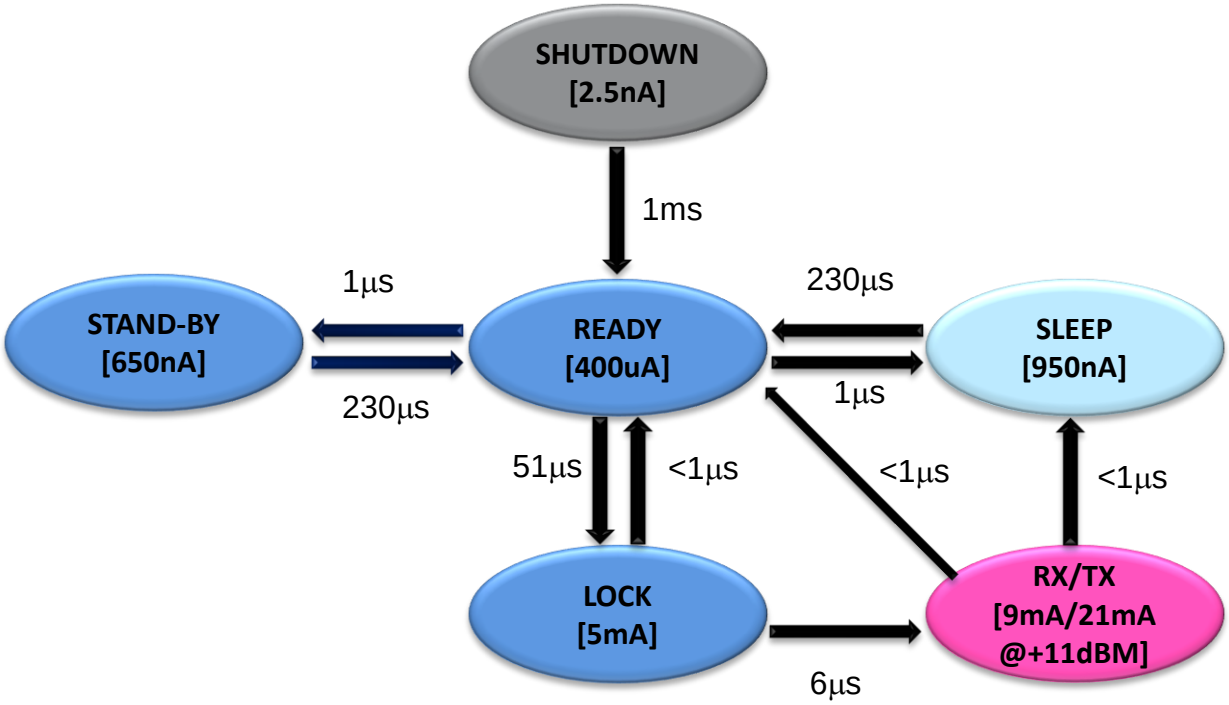


Clear Channel Assessment (CCA)



State Machine, MCU Control Interface & Others

Operating Modes/Consumption



Mode	Description
Shutdown	Off, no register retention
Standby	SPI On, register retention
Sleep	SPI on, register retention, Wakeup timer on
Ready	SPI on, XTAL on
RX	SPI on, XTAL on, RF Synth on
TX	SPI on, XTAL on, RF Synth on

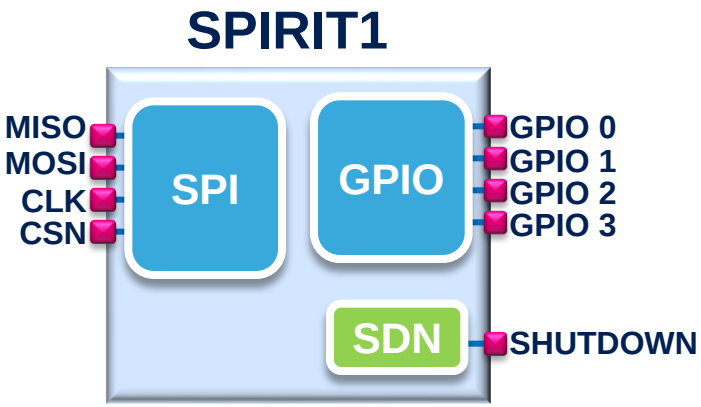
Built-in main controller handles operating mode transitions

Transition times using 26MHz Xtal

MCU interface

SPI communication

- Write registers or FIFOs
- Read registers or FIFOs
- 17 Commands (State diagram, AES, FIFO flush)



GPIO communication

- Interrupt signals
- Monitoring signals (Valid preamble detected, valid sync word detected, …)
- Commands (TX/RX mode, Wake-up from external input, …)
- Input/output data (direct mode)
- Input/output reference clock (MCU clock out, 34.7 kHz for LDC mode input)
- Analog output: temperature sensor (GPIO 0)

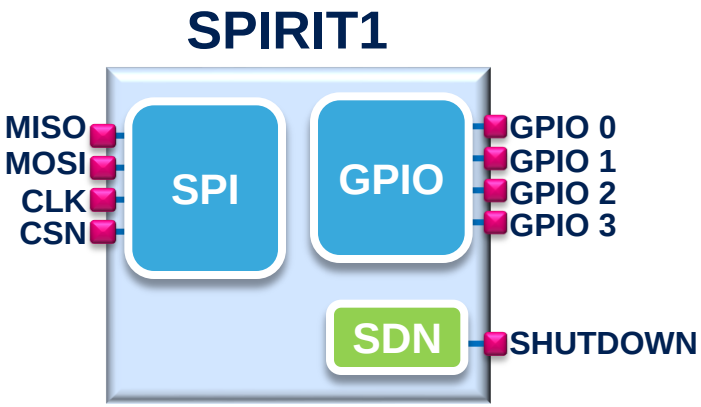
SDN pin

- Shutdown signal

Monitoring signals

GPIO communication

- **Monitoring signals**



Packet oriented
Valid preamble detected
Sync word detected
RSSI above threshold

FIFOs oriented
TX FIFO almost full
TX FIFO almost empty
RX FIFO almost full
RX FIFO almost empty

Status oriented
Device in READY state
Device in SLEEP or STANDBY states
TX state indication
RX state indication
TX or RX mode indicator
Device in LOCK state

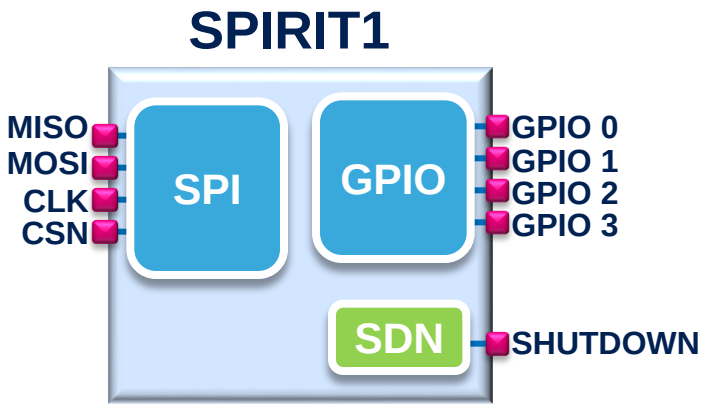
Status oriented
Low battery level
Power-On Reset
Antenna switch used for antenna diversity

Other
VDD/GND (to emulate an additional GPIO of the MCU)
Wake-Up timeout in LDC mode

Interrupts

GPIO communication

- **Interrupt signals**



Packet oriented
RX data ready
RX data discarded
TX data sent
CRC error
Valid preamble detected
Sync word detected
RSSI above threshold

FIFOs oriented
TX FIFO underflow/overflow error
RX FIFO underflow/overflow error
TX FIFO almost full
TX FIFO almost empty
RX FIFO almost full
RX FIFO almost empty

Protocol oriented
Max re-TX reached
Max number of back-off during CCA
Wake-up timeout in LDC mode
AES End–Of – Operation

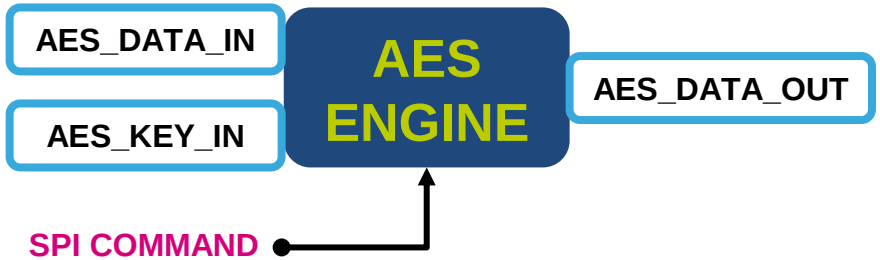
Status oriented
READY state in steady condition
STANDBY state switching in progress
Low battery level
Power-On Reset
RX operation timeout

SPIRIT1 AES-128 Engine

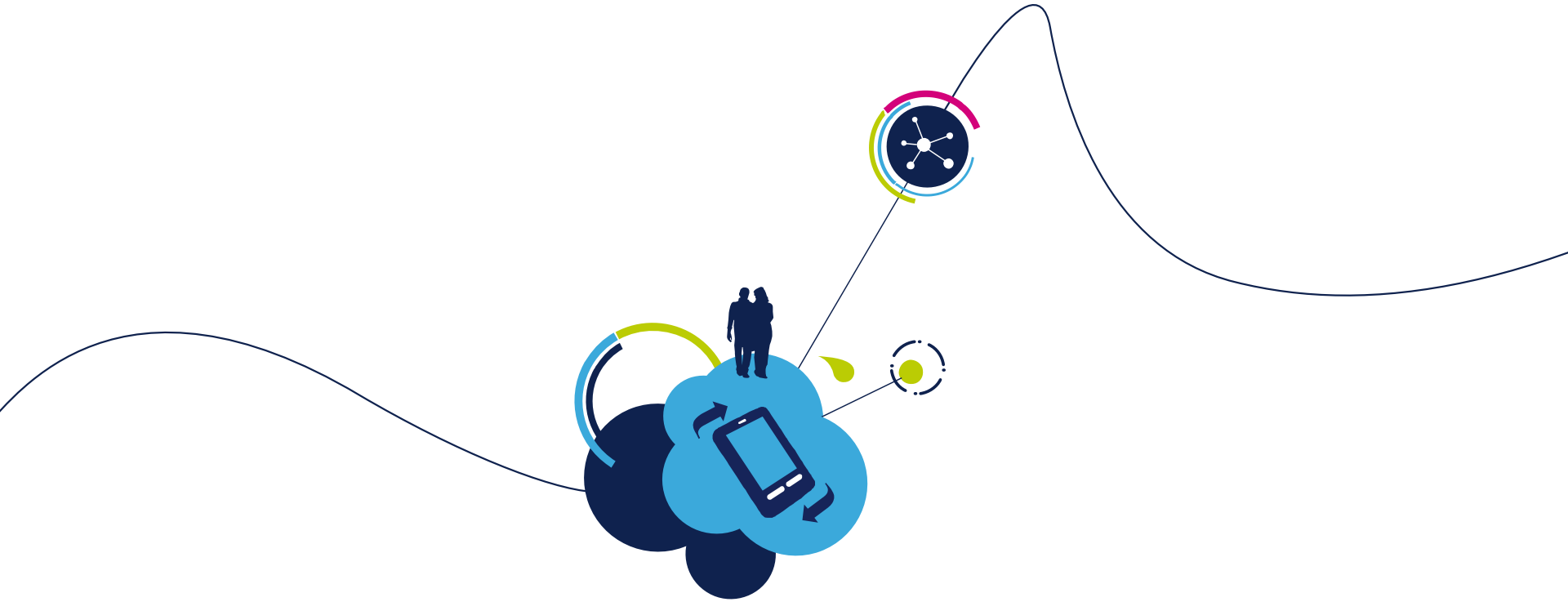
The SPIRIT1 provides data security support as it embeds the Advanced Encryption Standard (AES) 128-bit core.

The AES-128 engine can be used at anytime.

- The SPIRIT1 provides 3 banks of 128 bits registers:
  - Input register (*AES_DATA_IN*)
  - Output register (*AES_DATA_OUT*)
  - Key register (*AES_KEY_IN*).

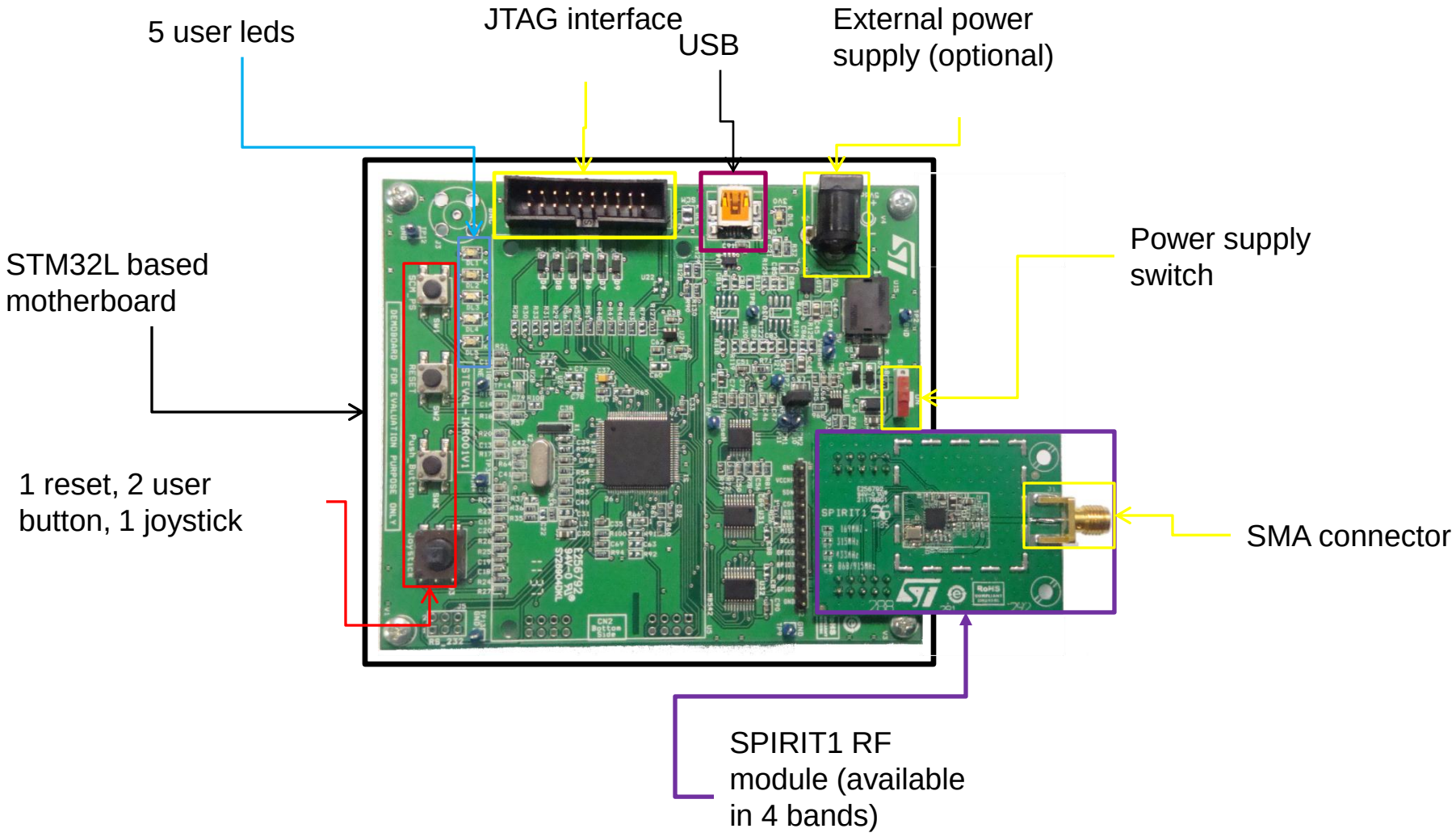


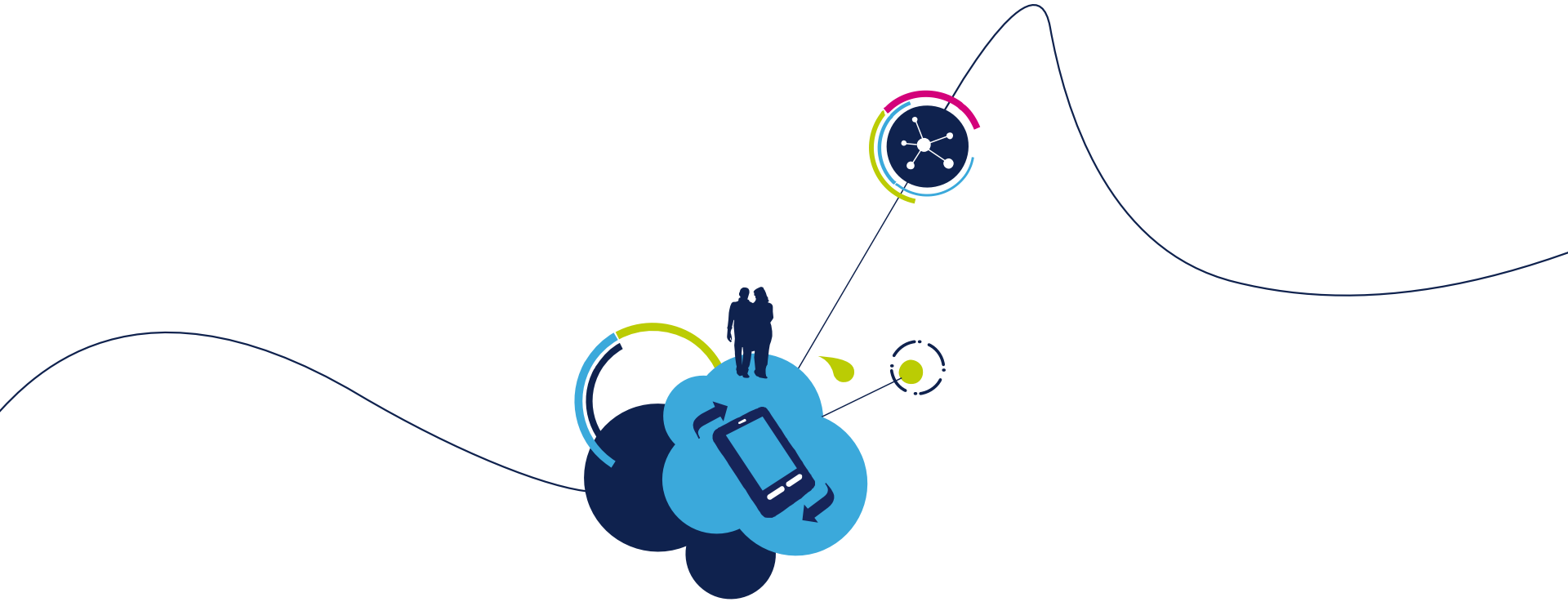
- Four operations are available:
  - Encryption using a given encryption key.
  - Decryption key derivation starting from an encryption key.
  - Data decryption using a decryption key.
  - Data decryption using a encryption key.



Development Kit HW

SPIRIT1 Development kit description





Development Kit SW package

Description of SW package (SDK)

- SPIRIT1_Library project: composed of three sub-modules (see the attached user manual to have more details):
  - Spirit1 Libraries: APIs to manage the features the device offers (platform independent)
    - **Radio, GPIO, IRQ, Calibration, CSMA etc**.
  - SDK_EVAL Libraries: some APIs to manage the motherboard main features
  - Examples
- WMBUS_Libraries: the library file with the PHYSICAL and LINK layer of the WMBUS STACK
  - WMBUS_Example: The example has four configuration to differentiate between these combination : 169 or 868 bands and meter or concentrator
- SpiritSDK_Virtual_Com: VirtualCom Libraries for the SDK motherboard.
- STM32L_StdPeriph_Lib: standard peripheral library for the STM32L microcontroller.
- STM32_USB-FS-Device_Lib: USB library for STM32L microcontroller.

Memory FootPrint

	Flash (KBytes)	Ram (Bytes)
SPIRIT1 Library (on STM32L)	20	28

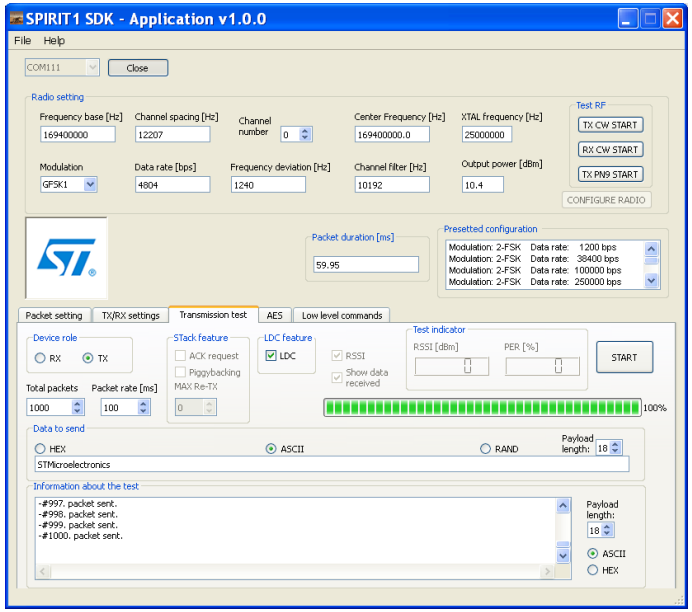
- Maximum usage using all the driver features (Typical application will use much lower flash, e.g 4K)
- Preliminary data

	Flash (KBytes)	Ram (Bytes)
WM-BUS protocol stack	9.1	2148

- Maximum usage of the Wireless M-Bus library
- Both data are reffered from libraries in SPIRIT1 Dev Kit version 1.0.4 compiled with IAR with high optimization on the code size

SPIRIT1 SDK Suite GUI
RF performance evaluation

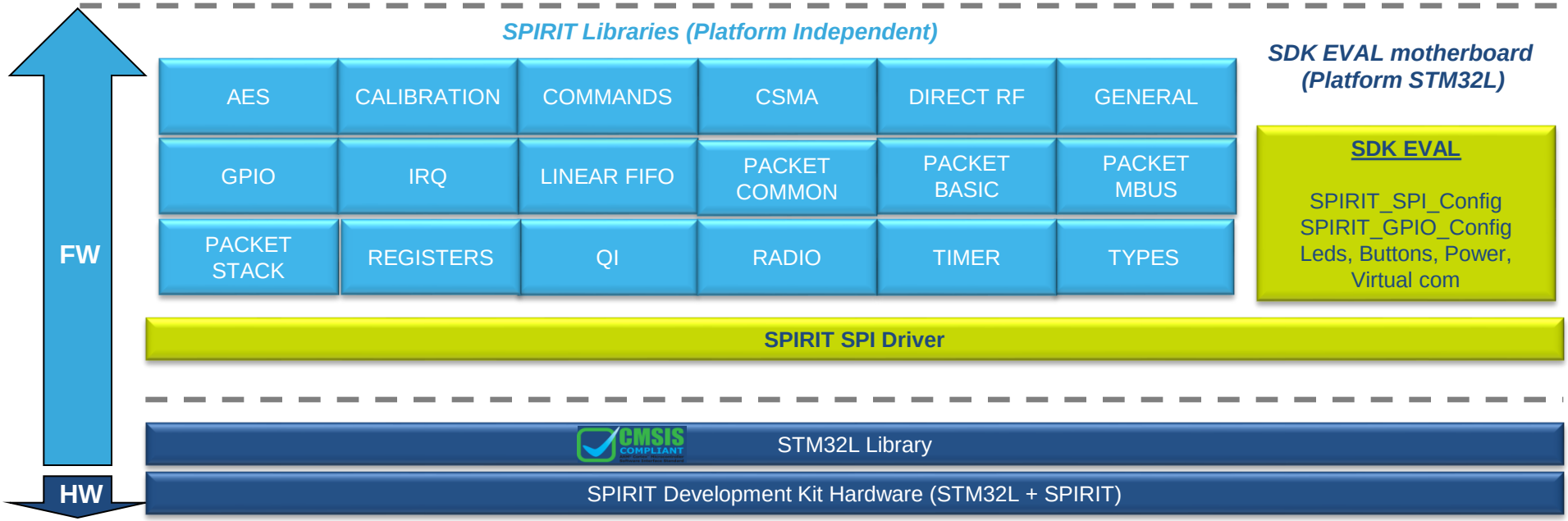
- SPIRIT1 contains a GUI allowing to perform
  - Radio configuration
  - RF tests (TX of unmodulated carrier, TX PN9 sequence, RX activation)
  - Packet transmission/reception test with PER evaluation
  - AES engine encryption/decryption tests
  - Register read/write and dump
  - Store/load radio and packet configuration
  - Automatic Firmware Upgrade



SPIRIT1 SDK Firmware Package Architecture

The firmware package of the Spirit Development Kit provides in addition to the SPIRIT1 Library:

- SDK Eval: a set of API functions to manage the motherboard of the SDK (STM32L microcontroller) including USB library and DFU project files for firmware upgrade
- STM32L library: the standard peripheral library for the STM32L microcontroller.
- SPIRIT1 Examples: BasicGeneric, LDCGeneric, StackGeneric etc.
- Developed under EWARM IAR v.6.30 IDE (ST-Link, J-Link required for debugging)



ST WM-BUS library support

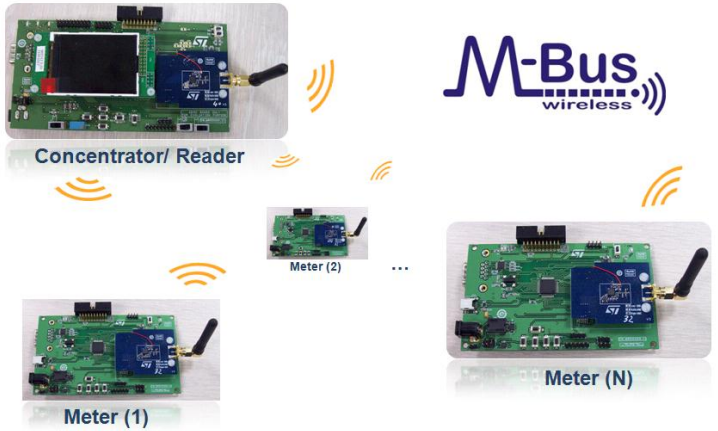
- Wireless M-Bus firmware stack is based on prEN 13757-4:2011
- Supported modes are: S, T, R, N (except N2g which requires 4-GFSK modulation)
- PHY and LINK layer implementation provided as binary library for ARM Cortex-M3 (STM32L).
- Example application layer provided in source code for user customization.

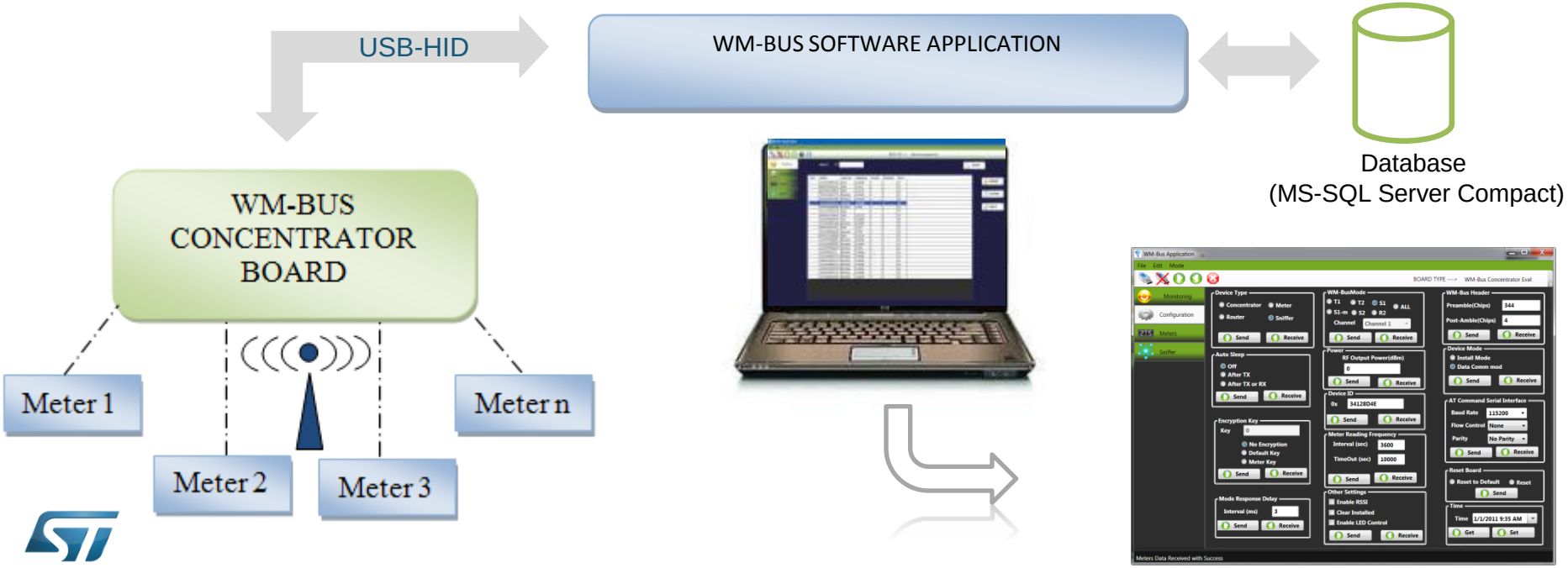
ST Wireless M-BUS Stack features

→ EN13757-4:2005 (S1, S1m, T1, T2, R2).
- Radio band: 868 MHz

→ EN13757-4:2011 (N mode)
- Radio band 169 Mhz

- GUI over USB Interface
- Device type: Meter/Concentrator/Sniffer





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ST RF IPD FOR SPIRIT1

IPD Integration of Filter+Balun

868 & 915 MHz

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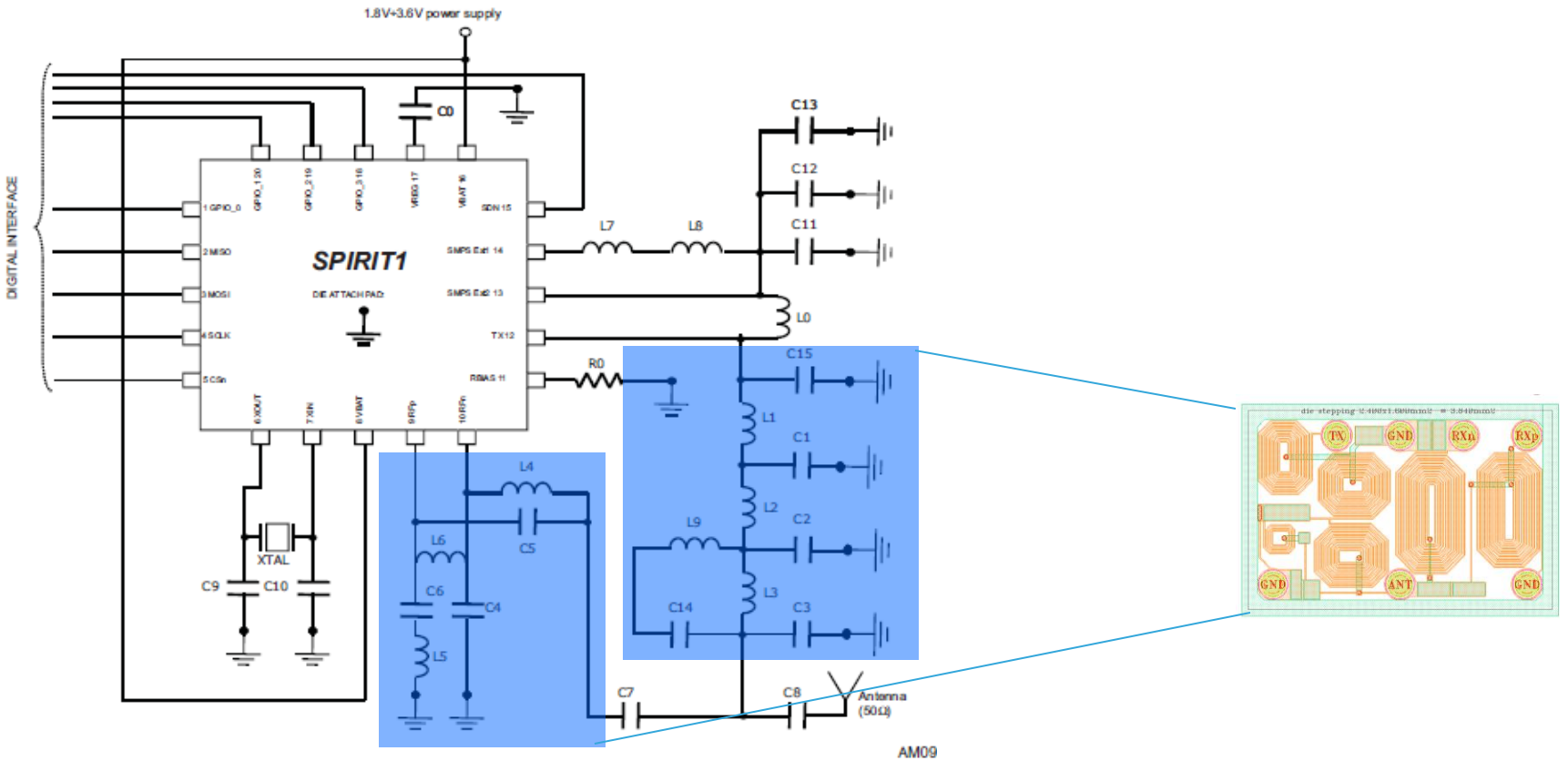
IPD – Integrated Passive Devices

IPD INTEGRATION FOR SPIRIT1



7.5mm²

2.34mm²

15 external components in 1 die

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Benefits

- **IPD integration benefits:**
  - Up to 69% IN PCB SPACE SAVING compared to equivalent discrete solution size (for 868/915MHz design)
  - IPD designed with direct tracks routing from the RF chip Spirit1
  - No RF validation at end-customer (ST selling a turnkey RF solution), hence allowing FASTER TIME TO MARKET for the end customer.
  - No RF performance drift thanks to monolithic glass substrate integration SMD dispersion causes drift in RF performances
  - No temperature drift thanks to glass substrate (depending on PCB design)
  - HIGHER RELIABILITY thanks to high reduction in solder joints

Thank you!