SKYWORKS®

Enhancing Wi-SUN® Alliance Product Range with Skyworks RF Front End Modules

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The Skyworks portfolio of front-end modules (FEM) offers many choices for engineers and developers working on a broad range of wireless products and systems such as mobile and Internet of Things (IoT). Under the IoT umbrella, Skyworks supplies high-performance, small footprint FEMs operating in the industrial scientific and medical (ISM) and licensed bands covering 169 to 2700 MHz for multiple protocols and regions of the world.

Wireless Smart Utility Network (Wi-SUN®), a protocol devised for smart utilities, has expanded into applications beyond utilities such as smart cities, smart home, smart agriculture, and asset management. This has led to an alternate abbreviation as Wireless Smart Ubiquitous Network [1, 2]. Wi-SUN networks are currently deployed in 46-plus countries and 100-plus million endpoint devices.

Wi-SUN supports two operational profiles - Field Area Network (FAN) and Home Area Network (HAN). Wi-SUN FAN devices are predominantly used in the end applications with each node providing typical range coverage of 200 meters, and clear line of sight (LoS) range of more than 800 meters with FSK at 50 kbps. To extend the coverage beyond 500 to 800 meters, Wi-SUN supports mesh topology, and star topology or hybrid combinations thereof [1]. This allows addition of new devices in an easy manner. These topologies support self-healing by providing redundant paths from endpoint devices to router node. If an endpoint fails due to battery life or otherwise the network will automatically re-configure to an alternate path for other endpoints to the router node.

The Wi-SUN nodes (sometimes called "motes") are referred to as leaf, router, and border-router nodes. As illustrated in Figure-1, multiple personal area networks (PAN) form a Wi-SUN FAN.

- The border-router node is the concentrator for wide area network (WAN) connectivity through internet backhauls.
- The router nodes are flexible to operate in any mode.
- The leaf nodes are the Reduced Function Devices (RFD) or end nodes and participate in star topology with router and border-router nodes.

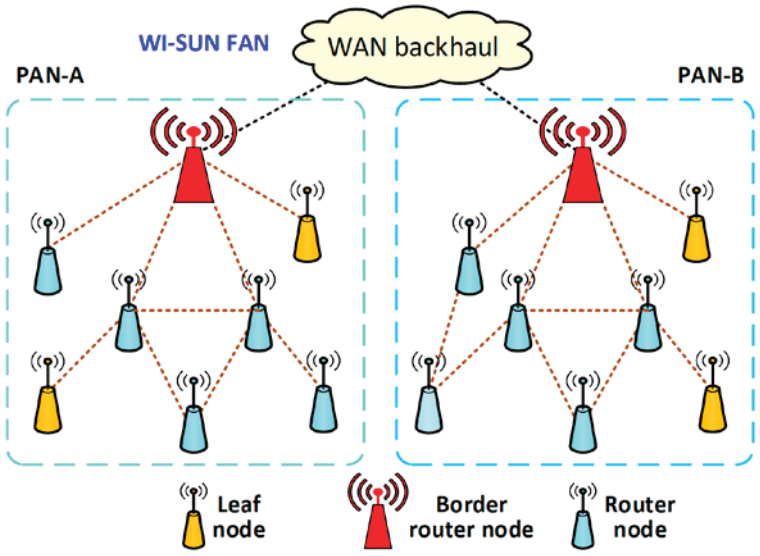

Figure-1 Wi-SUN network topology.

Wi-SUN specifications are built on open global standards from organizations such as IEEE, IETF, TIA, TTC and ETSI. The physical layer is adopted from IEEE 802.15.4g [3]. Some geographical locations (such as India) have adopted IEEE 802.15.4u as the physical layer to support extended 5 kms range [4]. The media access control (MAC) layer has been adopted from IEEE 802.15.4e. The higher layers are based on various Internet engineering task force (IETF) standards such as IPV6, 6LoWPAN, ICMPv6 etc.

The Wi-SUN FAN 1.1 physical layer supports three different modulations - multi-rate frequency shift keying (MR-FSK) and multi-rate orthogonal frequency division multiplexing (MR-OFDM) which are used at sub-GHz bands, and offset quadrature phase shift keying (O-QPSK) for the ISM 2.4 GHz band. MR-FSK was introduced in the early standard definition and allows devices to operate efficiently using 2-level or 4-level FSK modulation schemes. Newer versions of the standard introduced MR-OFDM that allows devices to scale to higher data rates with BPSK, QPSK, and 16QAM modulation schemes. BPSK ½ rate code with 4x repetition achieving 50-kbps rate is the most popular option and used in long-range coverage applications. Refer to Table-1 for other modes of operation and corresponding data rates for the MR-OFDM scheme.

Wi-SUN supports different frequency bands based on geography

- 470 to 510 MHz and 779 to 787 MHz for China.
- 863 to 928 MHz is a popular band supported in majority of the region across the world (except China).
- 2400 to 2483.5 MHz (ISM band) also has world-wide support but will have limited range due to propagation losses.

IEEE 802.15.4g parameters		Option-1	Option-2	Option-3	Option-4	Units
Sampling rate in kHz		1333.33	666.67	333.33	166.67	kHz
FFT SIZE		128	64	32	16	#
Tone spacing		10416.67	10416.67	10416.67	10416.67	Hz
FFT duration in µs		96	96	96	96	microSec
Guard period (GP)		24	24	24	24	microSec
Total symbol period with GP		120	120	120	120	microSec
Symbol rate		8.33	8.33	8.33	8.33	kSymb/sec
# Active (data+pilot) tones		104	52	26	14	#
# Data tones		96	48	24	12	#
# Pilot tones		8	4	2	2	#
# DC null tone		1	1	1	1	#
Approximate signal BW		1094	552	281	156	kHz
		Data rate for each MCS[0-6] and Options-[1-4]				
Modulation types in IEEE 802.15.4g	**MCS#**	**Option-1**	**Option-2**	**Option-3**	**Option-4**	**Units**
BPSK 1/2 rate coded and 4x repetition	**MCS0**	100	*50	25	13	kbps
BPSK 1/2 rate coded and 2x repetition	**MCS1**	200	100	50	25	kbps
QPSK 1/2 rate coded and 2x repetition	**MCS2**	400	200	100	50	kbps
QPSK 1/2 rate coded	**MCS3**	800	400	200	100	kbps
QPSK 3/4 rate coded	**MCS4**	1200	600	300	150	kbps
16-QAM 1/2 rate coded	**MCS5**	1600	800	400	200	kbps
16-QAM 3/4 rate coded	**MCS6**	2400	1200	**600	300	kbps

Table 1. OFDM based Wi-SUN PHY for various options and data rates.

*MCS0, Option-2: (8333 Symb/sec) * (48 tones) * (1bit BPSK) * (1/2 rate) * (4x repetition, use 1/4) = 50 kbps.
**MCS6, Option-3: (8333 Symb/sec) * (24 tones) * (4bits 16QAM) * (3/4 rate) = 600 kbps.

Long Range Coverage

Wi-SUN supporting wireless SoCs typically provide 0 to +14 dBm RF output power in stand-alone mode. Certain geographies (such as USA) allow for up to +30 dBm output power at the antenna to enable long-range coverage for IoT devices.

Designed to enable greater range extension, the SKY66122-11 RF front end module (FEM) provides more than five times the range of a standalone SoC. SKY66122-11 incorporates an efficient power amplifier delivering +30 dBm to the antenna which enhances coverage by multi-fold up to 5 kms line-of-sight [4]. This FEM supports the popular 863 to 928 MHz frequency range. The SKY66122-11 is designed into products supporting Wi-SUN and other proprietary technologies operating in unlicensed bands. Features such as a high efficiency power amplifier, fast switching, and low sleep current makes this Skyworks FEM attractive for battery operated nodes. Integration of RF matching network and harmonic filters inside the FEM enables easier RF qualification through Protocol Implementation Conformance Statement (PICS).

Key features supported by the SKY66122-11:

- Frequency range: 863 to 928 MHz
- Receive gain 16 dB with NF: 2.5 dB
- Wi-SUN OFDM output power:
  - Option-1 MCS0: +30 dBm
  - Option-1 MCS3: +30 dBm
  - Option-3 MCS6: +25 dBm
- Integrated power detector
- RF input and output: 50 Ω
- Integrated output matching and harmonic filter
- Flexible transceiver RF interfaces
- Supply: 3 to 5 volts
- Sleep current < 1 µA
- Package: 6 x 6 x 0.9 mm

Functional Block Diagram

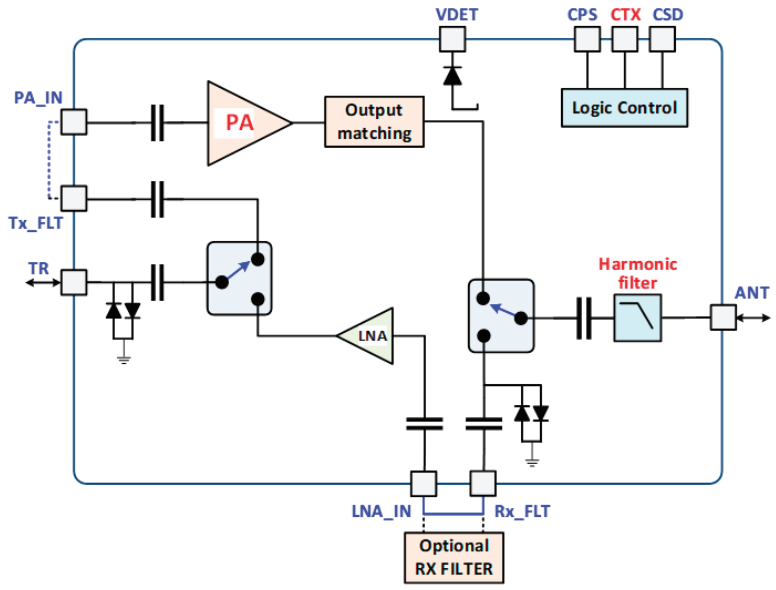

Figure 2. Features of SKY66122-11.

Skyworks carries many more RF FEMs that operate in the 900 MHz ISM band are applicable for Wi-SUN depending on regional output power limits and frequency ranges. Some of these RF FEMs are also suitable for other IoT protocols such as LoRa, Zigbee, etc., and applications such as Amazon Sidewalk that operate in the 900 MHz ISM band. Table-2 provides a list of the part numbers and key specifications for the ISM-900 family FEMs. Refer to the individual data sheets parametric information such as linearity characteristics, leakage currents, and switching time, etc. .

#	Data-sheet	Skyworks Part number	PA	LNA	Ant1, Ant2	Package (mm x mm)	Frequency (MHz)	Tx Pout (dBm)	Gain (dB), Icc (mA) @Pout (dBm)	Tx bypass loss (dB)	LNA gain/NF(dB), Icc (mA)	Rx bypass loss (dB)	Sleep Icc (µA)	ON/OFF switching (µs)	VDD/VCC (volts)
1		SE2435L	✓	✓	Ant1 Ant2	4 x 4	860-930	30	26, 550@30 26, 275@24	NA	16/2, 6	2	< 1	< 1	2.0-4.8
2		SKY65313-21	✓	✓	Ant1	6 x 6	860-960	30.5	24, 600@30	NA	16.6/1.9, 20	0.5/3	0.05	0.5	3.0-4.4
3		SKY65362-11	✓	✓	Ant1 Ant2	6 x 6	900-930	30.5	33, 515@30.5	NA	16/2.5, 6	3	0.05	< 11	3.0-5.25
4		SKY65364-21	✓	✓	Ant1	6 x 6	890-960	30	16, 680@30	NA	15/1.5, 12	0.5/3	0.50	0.5	Tx: 3.4-3.8 Rx: 3.0-3.45
5		SKY66101-11	✓	✓	Ant1 Ant2	6 x 6	902-928	30	33, 670@30	NA	16/2.5, 6	3	< 1	< 1	2.0-4.8
6		SKY66105-11	✓	NA	Ant1 Ant2	6 x 8	902-931	30	29, 450@29	NA	NA	0.7	< 10	1-2	2.0-4.8
7		SKY66122-11	✓	✓	Ant1	6 x 6	863-928	30	30, 640@30	NA	16/2.5, 6.5	NA	< 1	3/1	3.0-5.0
8		SKY66420-11	✓	✓	Ant1	3 x 3	860-930	27	16, 280@27	< 1.5	18/1.5, 5	NA	< 1	Tx: < 2 Rx: < 4	2.0-4.8
9		SKY66421-11	✓	NA	Ant1	3 x 3	860-930	27	16, 280@27	NA	NA	0.6	< 1	< 1	2.0-4.8
10		SKY66422-11	✓	✓	Ant1	3 x 3	860-930	22	20, 80@20	2.2	17/1.7, 4	NA	0.40	Tx: 20/0.2 Rx: 10/4	2.5-3.6
11		SKY66423-11	✓	✓	Ant1	3 x 3	860-930	27	29, 280@27	< 1.5	18/1.5, 5	NA	< 1	Tx: 2 Rx: 4	2.0-4.8

Table 2. ISM-900 family FEMs for Wi-SUN (NA indicates not applicable)

References

1. What is the Wi-SUN Alliance? https://wi-sun.org/
2. Comparing IoT Networks at a Glance - How Wi-SUN FAN stacks up against LoRaWAN and NB-IoT. https://wi-sun.org/wp-content/uploads/Wi-SUN-Alliance-Comparing-IoT-Networks-2019-Nov-A4.pdf
3. Implementation of IEEE 802.15.4g wireless communication platform for smart utility service. https://ieeexplore.ieee.org/document/6698045
4. 802.15.4u-2016 - IEEE Standard for Low-Rate Wireless Networks--Amendment 3: Use of the 865 MHz to 867 MHz Band in India. https://ieeexplore.ieee.org/document/7852415

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