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Author	Pascal DARAGON
Stream	TRAX-Net
Security	Level 1 – Restricted
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Status	Final

Revision History

Version/Revision	Details	Date	Editor
1.0	Initial version	28/04/2016	P. DARAGON
1.1	Minor corrections & add typical design	06/05/2016	P. DARAGON
1.2	Change VDD range & add conformity information	22/06/2016	P. DARAGON
1.3	Conformity declarations upgrades & add LBT + AFA	05/07/2016	P. DARAGON
1.4	Add integration guidelines & product testing	20/07/2016	P. DARAGON

INDEX

1 INTRODUCTION

This manual is intended solely to TRAXENS internal use, as part of the integration of Wing4TRAX module into its asset tracking devices TRAX-Box® and their derivatives, or to system integrators duly certified by TRAXENS

1.1 REFERENCES

ID	Name	Author	Date	Version
R1	UART COMMUNICATION PROTOCOL WING4TRAX-HOST	N. GUZZO	16/06/2016	1.59
R2	DSE - W4T - HOSTCOM Test commands	P. DARAGON	05/07/2016	1.5

1.2 TERMS AND ABBREVIATIONS

AES Advanced Encryption Standard
AFA Adaptive Frequency Agility
AGFS Automatic Geographic-based Frequency Selection
CTS Clear To Send
FHSS Frequency Hopping Spread Spectrum
GMSK Gaussian Minimum Frequency Shift Keying
GPS Global Positioning System
GSM Global System for Mobile communications
ISM Industrial – Scientific – Medical
LBT Listen Before Talk
MAC Media Access Control (radio layer)
MCC Mobile Country Code
NET NETwork (radio layer)
NPM Network Phy Mode (message)
P2P Peer To Peer
PHY PHYsical (radio layer)
PIFA Planar Inverted-F Antenna
RTS Request To Send
UART Universal Asynchronous Receiver Transmitter
VSWR Voltage Standing Wave Ratio
WAN Wide Area Network
WOR Wake On Radio
WSN Wireless Sensor Network

1.3 GENERAL PRESENTATION

Wing4TRAX is a universal sub-GHz radio module with the native capability to support the 3 unlicensed ISM bands available worldwide: 433 MHz, 868 MHz and 915 MHz

It has been designed to be connected to a host controller thru an UART interface, like a standard radio modem. It embeds the robust and efficient TRAX-Net® protocol stack, with P2P communication and/or mesh routing capabilities, between single or several nodes registered into a TRAX-Net® cluster

Selection of the working band depends on the country where the Wing4TRAX module is operated and is performed thanks to a specific command issued by the host controller, using proprietary AGFS algorithm. TRAXENS provides a fully portable ANSI-C library to be executed on the host controller, to select the proper band as a function of geolocation information, gathered from multiple sources: GPS position, GSM MCC or NPM messages broadcasted by other TRAX-Net® nodes.

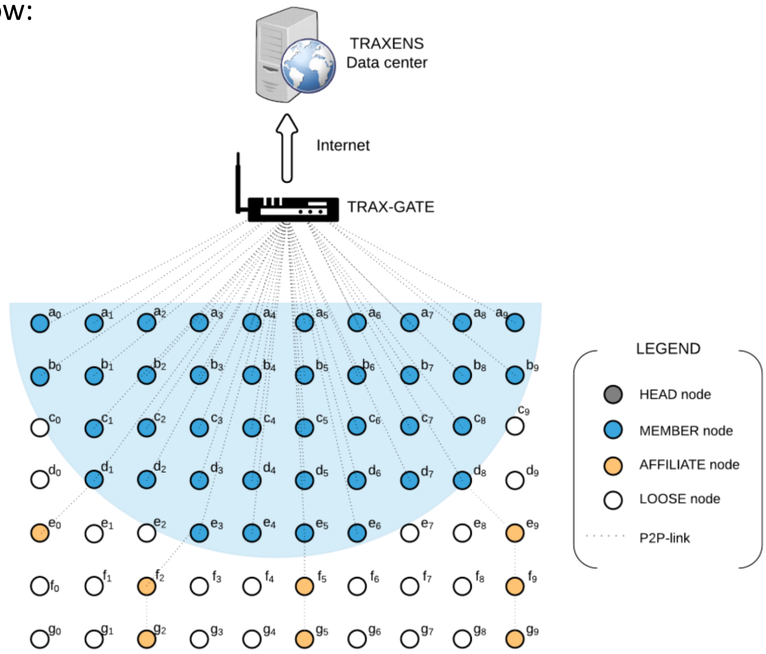
In any case, frequency hopping channels and RF output power are settled to be in conformity with local regulations; if geolocation information is not available, Wing4TRAX module remains silent and enters by default in sniffer mode, listening for a NPM message.

Note: AGFS algorithm controls the Wing4TRAX firmware execution and guarantees the non-infringement of local radio regulations in force where the module is operated by a host controller; therefore, integrity and conformity of AGFS algorithm implementation into the host controller is verified during the TRAXENS certification process of its own products, as for those developed by integrators

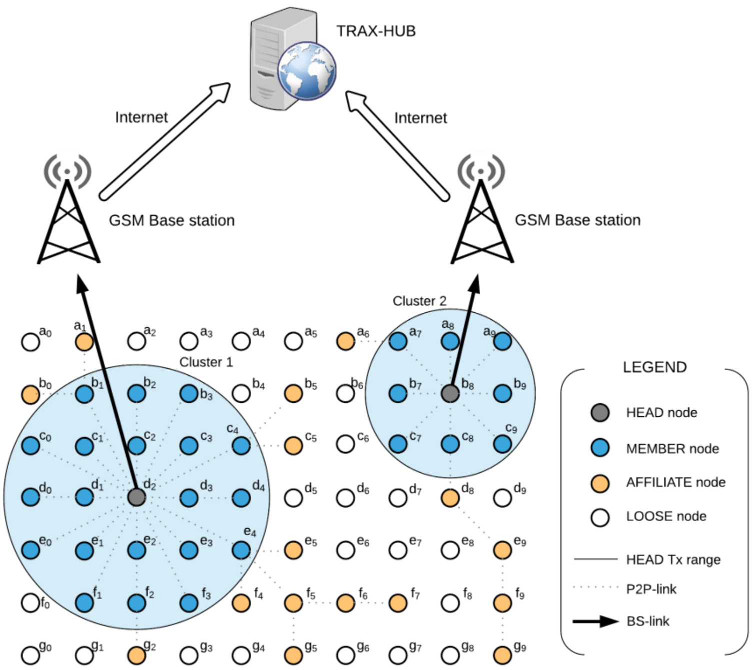
1.4 TRAX-NET AT A GLANCE

TRAX-Net® is a cluster-based WSN protocol in which some nodes are in charge to aggregate the data collected from other nodes and deliver it to the sink. The sink is either a TRAX-Gate gateway connected to a WAN thru Ethernet, WiFi or GSM, or another TRAX-Net® node with GSM connection capabilities

When a TRAX-Gate is present, it forms a super cluster and all TRAX-Net® nodes in its communication range join it, as illustrated below:



When no Gateway is present in the nearby, an **election scheme** selects some TRAX-Net® nodes to be in charge of collecting the data generated by the neighbors and transmit it to the TRAXENS data center passing through the GSM connection, as illustrated below:



TRAX-Net® protocol stack is divided into 3 main layers:

1. PHY, responsible for controlling the output power, channel frequency, modulation/demodulation, symbol encoding/decoding and bit framing
2. MAC, responsible for controlling frame preamble, synchronization, packet format, node addressing thanks to unique TRAX-Net ID, integrity checking and communication retries
3. NET, responsible for controlling cluster election policy, node status (HEAD, MEMBER, AFFILIATE, LOOSE) and message routing thru the cluster

Each layer can be individually started by host controller, respecting a strict order: PHY layer first, followed by MAC layer, then NET layer. Activation of PHY and MAC layers is direct thru specific commands; activation of NET layer is conditioned to a prior mutual authentication between the host and Wing4TRAX module, based on a shared secret AES key. This security has been put in place to avoid malicious generation of fake TRAX-Net® clusters, with intention to dump data of registered nodes and thus create a denial of service

Main features of TRAX-Net® are listed in table below:

Parameter	Value
Max number of members in a cluster	250
Max number of members in a super-cluster	Undefined
Max number of affiliates per member	16
Max hop-distance	8+1 hops
Max data in a packet	2500 Bytes

1.5 MAIN FEATURES

Wing4TRAX's main features are listed in table below:

Technical specifications	Details
Module dimensions	35 x 17.5 x 2.9 mm
Operating temperature	-40°C to +85°C
Operating voltage (VDD)	1.8V to 3.6V (3.0V typical)
RF chip (8 bits µC + RF front end)	AX8052F143
PA voltage (VDD_ANA)	Regulated from VDD to 1.8V (1)
Tx consumption @433.92 MHz	51 mA typ. @+13dBm
Tx consumption @866.5 MHz	49 mA typ. @+13dBm
Tx consumption @921.5 MHz	47 mA typ. @+13dBm
Rx consumption	11 mA
WOR consumption	13.9 µA
Programmable TX power	From -10dBm to +13dBm
ETSI 433 MHz band channel mapping	17 channels of 100KHz
ETSI 868 MHz band channel mapping	68 channels of 100KHz
FCC 915 MHz band channel mapping	68 channels of 100KHz
ARIB 920 MHz band channel mapping	32 channels of 100KHz
Sensitivity @433.92 MHz	Down to -109dBm @BER 10^{-3}
Sensitivity @866.5 MHz	Down to -113dBm @BER 10^{-3}
Sensitivity @921.5 MHz	Down to -110dBm @BER 10^{-3}
Operating range (open space)	Up to 1km with external antenna
Medium access method	ETSI compliant LBT + AFA
RF communication	Unicast, broadcast, mesh routing
RF data rate (raw bit / payload byte)	20Kbps / ~1.1Kbyte per second
Host communication	UART 19200, n, 8, 1
Digital inputs / outputs	Up to 12 (5V tolerant)
Analog inputs (10 bits ADC)	2 channels (0..1V) @20ksample/s
Smart kernel (PHY layer + bootloader)	MAC + NET layers upgradable thru UART

(1) Power amplifier (PA) runs from the regulated VDD_ANA supply and not directly from the battery voltage VDD. This has the advantage that the current and output power do not vary much over supply voltage and temperature

1.6 PINOUT DEFINITION

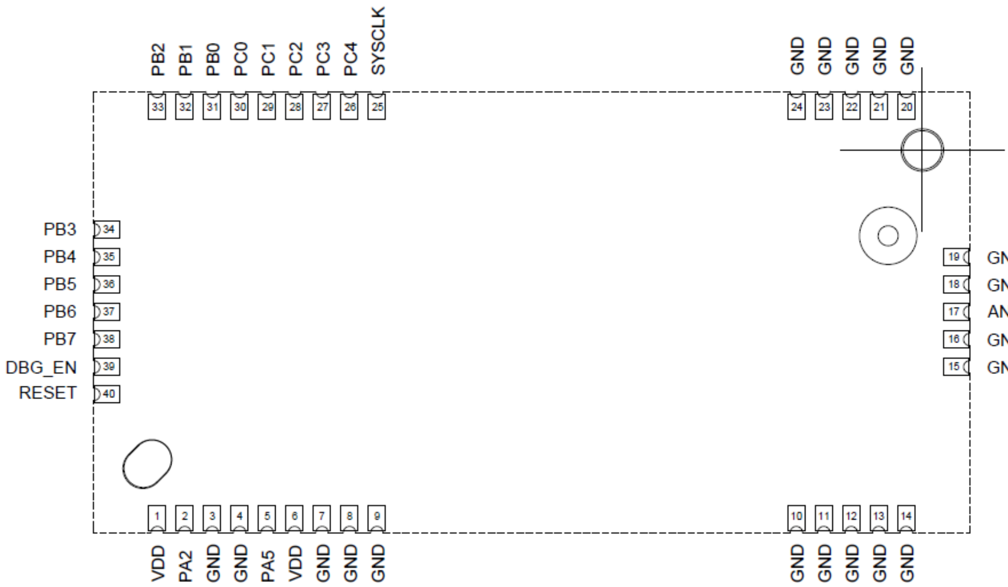
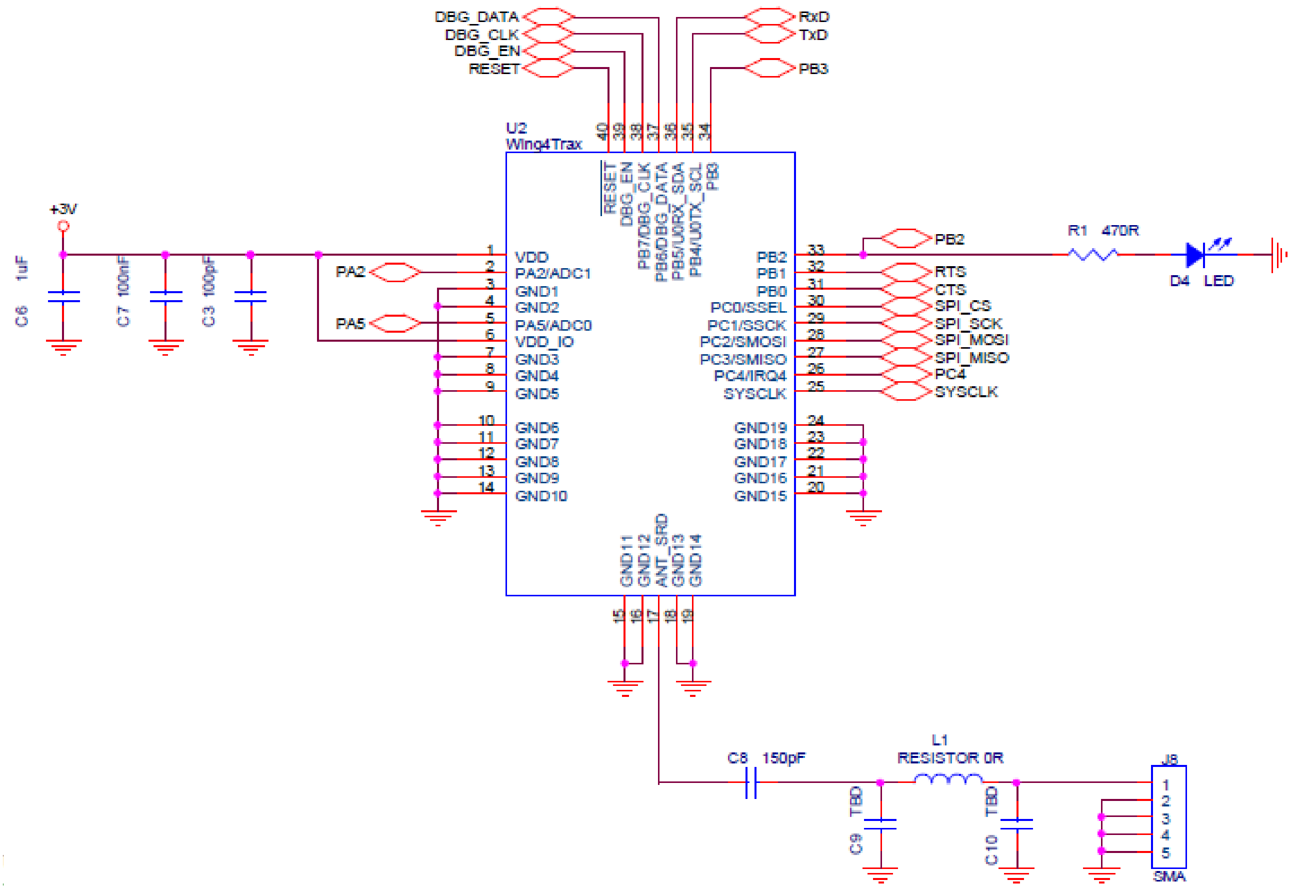


Figure 1: top view pins numbering & naming

Pin	Type	RST value	Description
1 - VDD	Power supply	X	Source voltage between 2.3V & 3.6V – also pin 6
2 - PA2	Analog input	X	Channel 2 – 10bits ADC – [0..1V] range
3 - GND	Ground	X	Also pins 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24
5 - PA5	Analog input	X	Channel 5 – 10bits ADC – [0..1V] range
17 - ANT	Antenna RX-TX	X	Connect to a 50Ω antenna thru a 150pF coupling capacitor
25 - SYSCLK	Digital output	Hi-Z	Optional I2C clock line (SCL) or general purpose clock output
26 - PC4	Digital IO	Hi-Z	Optional I2C data line (SDA) or EXT_IRQ input (EXTIRQ_EVENT)
27 - PC3	Digital IO	Hi-Z	Optional SPI MISO input or GPIO (PINC_3 in & PORTC_3 out bits)
28 - PC2	Digital IO	Hi-Z	Optional SPI MOSI output or GPIO (PINC_2 in & PORTC_2 out bits)
29 - PC1	Digital IO	Hi-Z	Optional SPI SCK output or GPIO (PINC_1 in & PORTC_1 out bits)
30 - PC0	Digital IO	Hi-Z	Optional SPI SS output or GPIO (PINC_0 in & PORTC_0 out bits)
31 - PB0	Digital input	Hi-Z	Optional UART CTS or general purpose (HOSTCTS_EVENT on PINB_0)
32 - PB1	Digital output	0 / 1	Optional UART RTS or general purpose (PORTB_1 out bit)
33 - PB2	Digital output	0	General purpose (PORTB_2 out bit)
34 - PB3	Digital input	Hi-Z	General purpose (GPINPUT_EVENT on PINB_3) & DEEPSLEEP wakeup
35 - PB4	Digital output	1	UART TXD for host interface
36 - PB5	Digital input	Hi-Z	UART RXD for host interface
37 - PB6	Digital output	0	General purpose (PORTB_6 out bit)
38 - PB7	Digital output	0	General purpose (PORTB_7 out bit)
39 – DBG_EN	Digital input	Pull-down	DEBUG only - Leave this pin unconnected
40 – RESET_N	Digital input	Pull-up	Internal 65KΩ pull-up – if not used, leave this pin unconnected

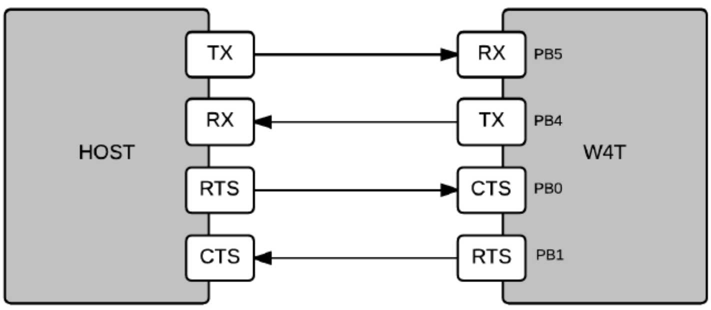
2 Functional interfaces

2.1 Typical design



2.2 Host CPU

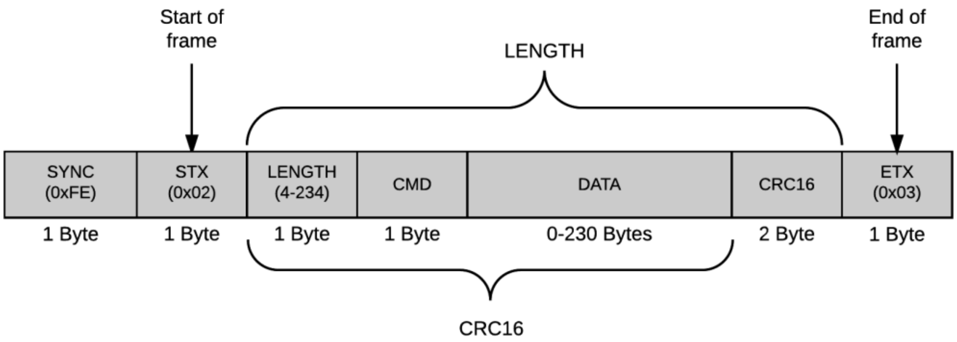
Communication between the host controller and Wing4TRAX module is based on a standard UART working in half-duplex mode, as illustrated below:



Default factory UART setup is 19200 bauds, no parity, 8 data bits and 1 stop bit

By default, hardware flow control thru RTS/CTS handshaking signals is deactivated and RTS signal is set to 0 after reset; in this case, PB0 pin can be used as a general purpose input and PB1 as output
RTS/CTS handling can be activated thanks to a specific command issued by the host and RTS signal is set to 1 after reset; in this case PB0 and PB1 pins are reserved and driven by Wing4TRAX kernel

Frame format in both directions is as follows:



Communication protocol details can be found in specification [R1]

2.3 Antenna

ANT pin must be connected to a single pole antenna via a ceramic capacitor to avoid DC coupling with GND

A capacitor value between 100pF and 220pF (150pF typical) is commonly used

An additional inductance can be mounted between ANT pin and the capacitor to improve impedance matching with the chosen antenna, as well as two foot capacitors to build a Π filter if extra filtering is required. Feel free to contact us if you need more information about antenna design

2.4 GPIOs

Wing4TRAX offers a large panel of GPIOs on both ports B and C

Port B mapping is statically defined by the kernel, with 2 inputs and 4 outputs (UART RXD & TXD not counted), meaning that direction of signal cannot be changed by the user; level change on PB0 and PB3 can be sensed by the kernel which generates events intercepted by user application. PB3, when tied low, is also the sole pin by which the Wing4TRAX can exit the minimum consumption mode (DEEPSLEEP)

Port C & SYSCLK mapping can be dynamically defined by user application, with the possibility to interface multiple slave devices, thru SPI bus and/or I2C bus, or thru discrete lines; the following table lists possible alternate functions for port C & SYSCLK user pins:

Name	SPI	I2C	IN	OUT
PC0	SS	-	√	√
PC1	SCK	-	√	√
PC2	MOSI	-	√	√
PC3	MISO	-	√	√
PC4	-	SDA	EXT_IRQ	√
SYSCLK	-	SCL	-	√

SYSCLK is a special function pin, giving the opportunity to output permanent states 0 or 1 (0Hz clock), a software programmable clock (e.g. 100KHz for I2C bus) or a hardware XTAL clock @32.768KHz with a precision of +/-20ppm at @+25°C

2.5 ADC

Wing4TRAX features 2 external channels of analog-to-digital conversion on Port A pins PA2 and PA5

Conversion full scale is achieved with 1V voltage, and in any case, voltage applied on these pins shall not exceed power supply voltage applied on VDD (pins 1 and 6)

In addition, Wing4TRAX provides 2 internal channels for application supervision:

- An embedded temperature sensor with a precision of +/-2°C, over the full temperature range
- Voltage applied on VDD pin calculated using the following formula:

$$VDD\_Value = (ADC\_Value \times 0.0390625) - 4.5$$

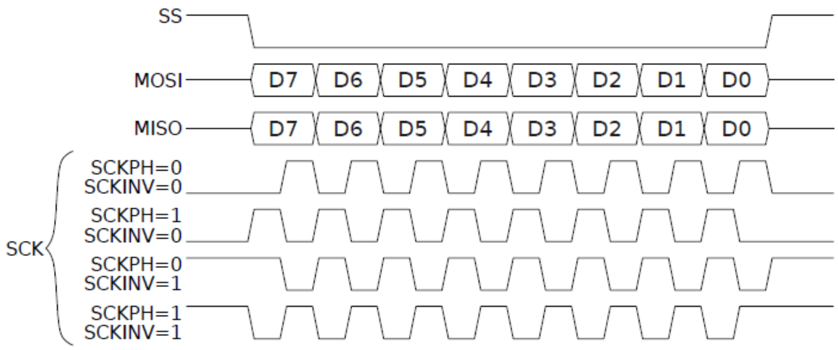
Even if all conversions are performed with 10 bits resolution, the 2 LSBs are shifted out and results are transferred to the application in 8 bits format (signed for temperature and unsigned for others)

2.6 SPI

SPI interface is only available in the configuration where the Wing4TRAX is the bus master

Slave Select (SS) signal is fully controlled by application, because active/inactive voltage to be applied to the Chip Select (CS) pin varies with slave device manufacturer; if more than one SPI device must be interfaced, free Port B outputs can be used too, as well as PC4 and SYSCLK, but with I2C interface exclusion

SPI clock can reach up to 5MHz and Wing4TRAX implements by default a clock setup without inversion (0V when inactive) and MOSI/MISO data lines latch on clock rising edge; other setup is available on demand, as illustrated below:



2.6 I2C

I2C interface is only available in the configuration where the Wing4TRAX is the bus master

Optionally, SCL and SDA lines can be internally pulled up with 65KΩ, but most of the time this value is too weak for normal bus operation under VDD voltage and external resistors are required

I2C clock signal SCL can reach up to 200KHz

2.7 EXT_IRQ

If not used by I2C interface, PC4 pin is available as an external interrupt source

EXT_IRQ function is sensitive to rising or falling edges of signal applied to pin PC4, and each change can be intercepted by the Wing4TRAX kernel and notified to the application thanks to EXTIRQ_EVENT

3 Hardware Interfaces

3.1 Absolute Maximum Ratings

Stresses above those listed values below may cause permanent damage to the device

Exposure to absolute maximum rating conditions for extended periods may affect device reliability

Symbol	Description	Conditions	Min.	Max.	Unit
V_{DD}	Supply voltage		-0.5	+5.5	V
I_{DD}	Supply current		-	200	mA
P_{WRT}	Total power consumption		-	800	mW
P_{WRA}	Maximum input power on ANT pin	Wing4TRAX in RX mode	-	10	dBm
I_{DC}	DC current into any pin except ANT		-10	+10	mA
I_{OUT}	Output current		-	40	mA
V_{DC}	Input voltage any pin except ANT		-0.5	+5.5	V
T_{AMB}	Operating temperature		-40	+85	°C
T_{STG}	Storage temperature		-65	+150	°C
V_{ESD}	Electrostatic handling		-2	+2	kV

3.2 DC characteristics

Symbol	Description	Conditions	Min.	Typ.	Max.	Unit
Supplies						
T_{AMB}	Operational ambient temperature		-40	25	+85	°C
V_{DD}	Power supply and I/O voltage		1.8	3.0	3.6	V
V_{BOT}	Brown-out threshold		-	1.3	-	V
I_{DSLEEP}	Deep Sleep current		-	100	-	nA
I_{SLEEP}	Sleep current	8.25Kb RAM retained	-	2.2	-	µA
$I_{STANDBY}$	Standby current		-	85	-	µA
I_{RUN}	Microcontroller running current		-	3	-	mA
I_{RFRX}	RF receiver consumption		-	9.5	-	mA
I_{RFTX}	RF transmitter consumption		-	45	-	mA
I_{RFOSC}	RF XTAL oscillator consumption	48MHz	-	500	-	µA
I_{TMOSC}	Time XTAL oscillator consumption	32.768KHz	-	700	-	nA
I_{ADC}	ADC current	312.5 ksample/s	-	1.1	-	mA
I_{WOR}	Typical Wake-On-Radio duty cycle	360ms, 20Kbps	-	13.9	-	µA
Digital inputs						
V_{T+}	Schmitt trigger low to high threshold	VDD = 3.0V	-	1.4	-	V
V_{T-}	Schmitt trigger high to low threshold		-	1.13	-	V
V_{IL}	Input voltage low		-	-	0.8	V
V_{IH}	Input voltage high		2.0	-	-	V
V_{IPA}	Input voltage range port A		-0.5	-	VDD	V
V_{IPBC}	Input voltage range ports B and C		-0.5	-	5.5	V
I_L	Input leakage current		-10	-	+10	µA
R_{IPU}	Programmable internal pull-up resistor		-	65	-	kΩ

Digital outputs						
I_{OHPBC}	Output current high ports B and C	V_{OH} = 2.4V	8	-	-	mA
I_{OLPBC}	Output current low ports B and C	V_{OL} = 0.4V	8	-	-	mA
$I_{OHSYSCLK}$	Output current high SYSCLK pin	V_{OH} = 2.4V	4	-	-	mA
$I_{OLSYSCLK}$	Output current low SYSCLK pin	V_{OL} = 0.4V	4	-	-	mA
I_{OZ}	Tri-states output leakage current		-10	-	+10	µA
Analog inputs						
F_{ADCSR}	ADC sampling rate		30		500	kHz
F_{ADCSRT}	ADC sampling rate temperature sensor		10	15.6	30	kHz
B_{ADCRES}	ADC resolution		-	10	-	Bits
C_{IPA}	Input capacitance on PA2 and PA5 pins		-	-	2.5	pF
B_{ADCERR}	ADC non linearity error		-1	-	+1	LSB
B_{ADCOFF}	ADC offset		-	3	-	LSB
V_{ADCFS}	ADC full swing input		0	-	1	V
Temperature sensor						
T_{RNG}	Temperature range		-40	-	+85	°C
T_{RES}	Temperature resolution		-	0.1607	-	°C/LSB
T_{ERR}	Temperature error		-2	-	+2	°C

3.3 RF CHARACTERISTICS

Symbol	Description	Conditions	Min.	Typ.	Max.	Unit
Generic						
P_{TXRNG}	Programmable transmitter power	50Ω measurement	-10	-	+13	dBm
P_{TXTEMP}	Transmitter power drift versus T°	-40°C to +85°C	-0.5	-	+0.5	dB
P_{TXVDD}	Transmitter power drift versus VDD	1.8V to 3.6V	-0.5	-	+0.5	dB
F_{IPRECS}	Frequency absolute precision	@25°C	-10	-	+10	ppm
F_{DTEMP}	Frequency drift versus temperature	-40°C to +85°C	-15	-	+15	ppm
F_{AGING}	Frequency aging	1 year	-1	-	+1	ppm
S_{BR}	Signal bit rate		-	20	-	Kbps
F_{SKMI}	Modulation index (GMSK)		-	0.5	-	-
F_{SKGBT}	Gaussian pulse shaping		-	0.5	-	-
$F_{CHSPACE}$	Channel spacing	AGFS dependent	100	-	250	KHz
F_{CHNUM}	Number of channels		12	-	68	-
433 MHz band						
F_{R433}	Frequency range		433.05	-	434.79	MHz
P_{TX433_2}	Harmonic 2 TX power	See note 1	-	-37	-	dBm
P_{TX433_3}	Harmonic 3 TX power		-	-34	-	dBm
S_{RX433_1}	RX sensitivity @433.12 MHz	BER = 10^{-3}	-	-108	-	dBm
S_{RX433_2}	RX sensitivity @433.92 MHz		-	-108	-	dBm
S_{RX433_3}	RX sensitivity @434.72 MHz		-	-109	-	dBm
B_{RX433_1}	RX blocking @433.92 MHz	Offset = +/-2 MHz	-	71	-	dB
B_{RX433_2}		Offset = +/-10 MHz	-	86	-	dB

868 MHz band						
F_{R868}	Frequency range		863	-	870	MHz
P_{TX868_2}	Harmonic 2 TX power	See note 2	-	-50	-	dBm
P_{TX868_3}	Harmonic 3 TX power		-	-58	-	dBm
S_{RX868_1}	RX sensitivity @863.05 MHz	BER = 10^{-3}	-	-111.5	-	dBm
S_{RX868_2}	RX sensitivity @866.50 MHz		-	-113	-	dBm
S_{RX868_3}	RX sensitivity @869.95 MHz		-	-112.5	-	dBm
B_{RX868_1}	RX blocking @866.5 MHz	Offset = +/-2 MHz	-	71	-	dB
B_{RX868_2}		Offset = +/- 10 MHz	-	85	-	dB
915 MHz band						
F_{R915}	Frequency range		902	-	928	MHz
P_{TX915_2}	Harmonic 2 TX power	See note 3	-	38	-	dBµV/m
P_{TX915_3}	Harmonic 3 TX power		-	45	-	dBµV/m
S_{RX915_1}	Sensitivity @915.05 MHz	BER = 10^{-3}	-	-112	-	dBm
S_{RX915_2}	Sensitivity @918.275 MHz	BER = 10^{-3}	-	-111	-	dBm
S_{RX915_3}	Sensitivity @921.50 MHz	BER = 10^{-3}	-	-110	-	dBm
S_{RX915_4}	Sensitivity @924.725 MHz	BER = 10^{-3}	-	-109	-	dBm
S_{RX915_5}	Sensitivity @9271.95 MHz	BER = 10^{-3}	-	-108	-	dBm
B_{RX915_1}	RX blocking @921.5 MHz	Offset = +/-2 MHz	-	70	-	dB
B_{RX915_2}		Offset = +/- 10 MHz	-	84	-	dB
Miscellaneous						
P_{RXWKP}	RX wake-up period		-	360	-	ms
D_{TXPRMB}	TX preamble duration		-	-	390	ms
$R_{PAYLOAD}$	Effective payload rate (throughput)	Per second		1.1		KByte

Note 1: EN 300 220-2 measurement conditions §7.8.2.1, at 867.84 MHz for harmonic 2 and 1.30176 GHz for harmonic 3 (433.92 MHz carrier power set at +13dBm)

Note 2: EN 300 220-2 measurement conditions §7.8.2.1, at 1.733 GHz for harmonic 2 and 2.5995 GHz for harmonic 3 (866.5 MHz carrier power set at +13dBm)

Note 3: FCC part 15.247 test method (15.109, 15.209, 15.215b, 15.247), at 1.843 GHz for harmonic 2 and 2.764 GHz for harmonic 3 (921.5 MHz carrier measured with 114 dBµV/m at 3m)

3.4 MECHANICAL CHARACTERISTICS

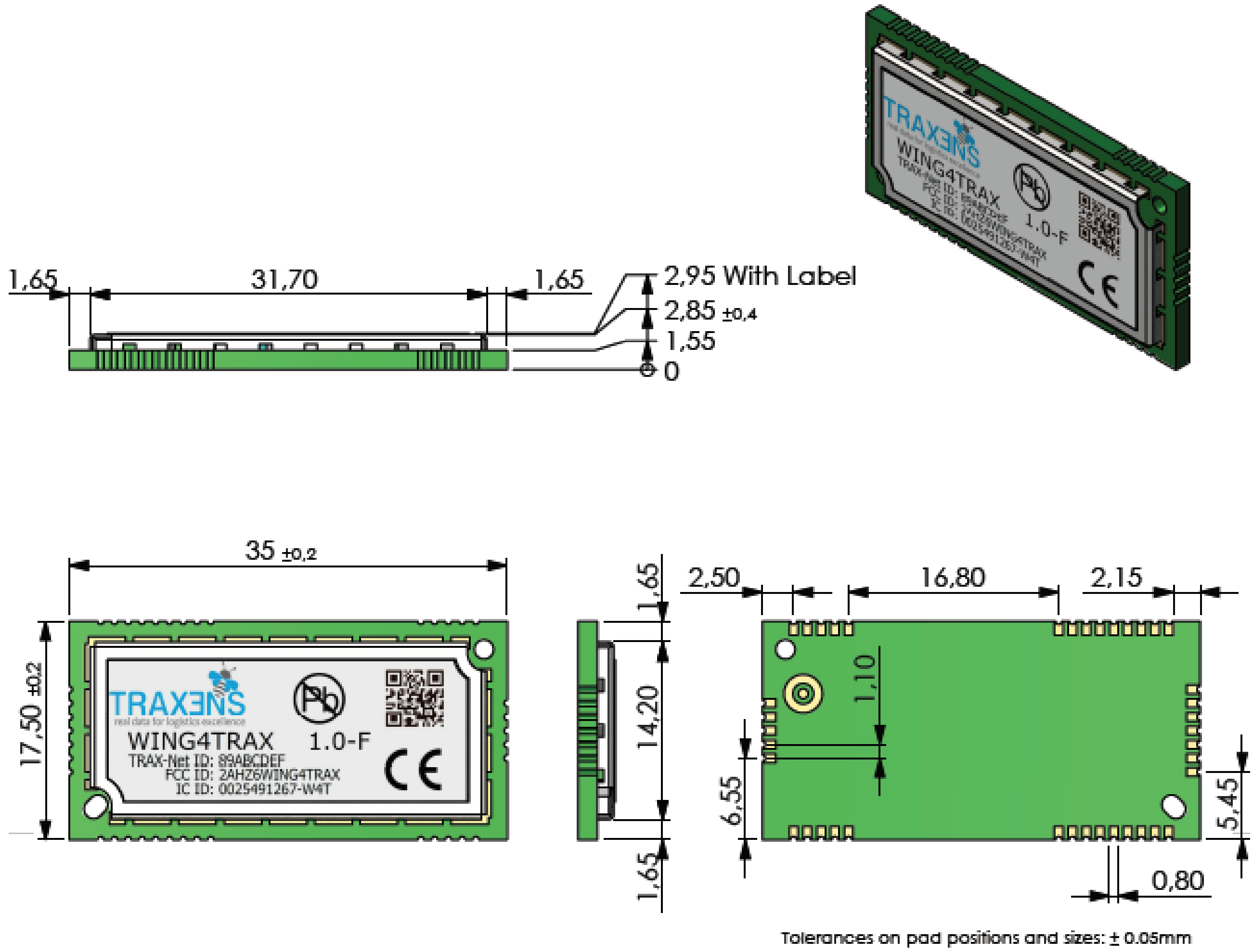


Figure 2: mechanical dimensions

Mechanical tolerances:

- PCB dimensions on X & Y axis: +/- 0.2 mm
- PCB + shield thickness: +/- 0.4 mm
- Pad position and size: +/- 0.05 mm

3.5 Footprint characteristics

Layout precautions: module bottom layer in contact with host PCB must be considered as a KEEP OUT area; except for host pads, avoid copper plan, tracks and via on the host PCB layer in contact with the module

Note: KiCAD or ALTIUM Designer footprints are available on request

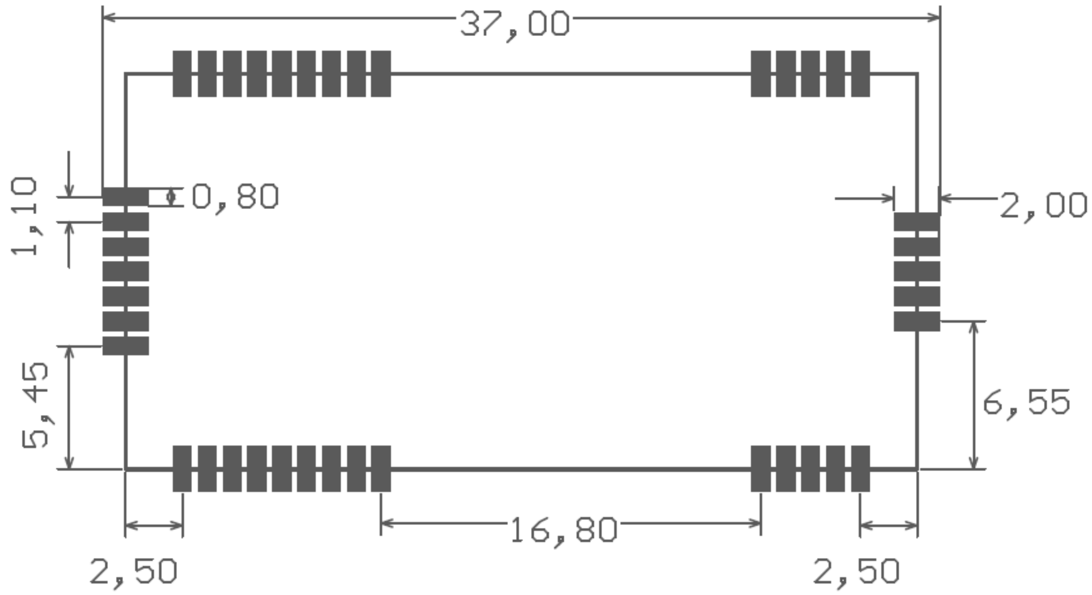


Figure 3: footprint dimensions

4 DECLARATIONS OF CONFORMITY

The gain of the system antenna(s) used with Wing4TRAX (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed 6dBi (in 433 MHz, 868 MHz and 915 MHz bands) for mobile and fixed or mobile operating configurations.

4.1 R&TTE CONFORMITY FOR 433 MHZ AND 863 MHZ BANDS

Name: Wing4TRAX

Reference: W4T-V1.0-REV.F

This device complies with EN 300 220-1 v2.4.1 and EN 300 220-2 v2.4.1

According to the R&TTE Directive (1999/5/CE)

4.2 FCC CONFORMITY FOR 915 MHZ BAND

This RF module (Model: WING4TRAX – FCC ID: 2AHZ6WING4TRAX) is limited to OEM installation only, in mobile or fixed applications; separate approval is required for all other operating configurations, including portable configuration with respect to Part 2.1093

It can only be used in devices certified by TRAXENS under the following conditions:

- The antenna(s) must be installed such that a minimum separation distance of 20cm is maintained between the antenna and user's/nearby person's body at all times
- The device must not be co-located with any other antenna or transmitter

OEM integrators shall not provide installation and/or removal instructions to end-users.

End-user's operating manual delivered with finished products shall include the following information:
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation

Finished products integrating this RF module (Model: WING4TRAX) shall bear the following label:
This device contains RF module (FCC ID: 2AHZ6WING4TRAX)

Prior to any distribution or installation, all products integrating the Wing4TRAX module shall be certified by TRAXENS; changes or modifications applied afterwards and not expressly approved by TRAXENS SAS could void the user's authority to operate the equipment.

Note: the grantee is not responsible for any changes or modifications not expressly approved by the party responsible for compliance. Such modifications could void the user's authority to operate the equipment

4.3 CSA CONFORMITY FOR 915 MHZ BAND

Canada, Industry Canada (IC) Notices
This device complies with Industry Canada license-exempt RSS-210 standard(s). Operation is subject to the following two conditions:

- This device may not cause interference, and
- This device must accept any interference, including interference that may cause undesired operation of the device

Radio Frequency (RF) Exposure Information
The radiated output power of the Wing4TRAX Module is below the Industry Canada (IC) radio frequency exposure limits. The Wing4TRAX Module should be used in such a manner such that the potential for human contact during normal operation is minimized.
This device has been evaluated and shown compliant with the IC RF Exposure limits under mobile exposure conditions (antennas are greater than 20cm from a person's body).

IMPORTANT: Manufacturers of portable applications incorporating the Wing4TRAX module are required to have their final product certified and apply for their own FCC Grant and Industry Canada Certificate related to the specific portable device. This is mandatory to meet the SAR requirements for portable devices.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Canada, avis d'Industrie Canada (IC)
Cet appareil numérique de classe B est conforme aux normes canadiennes RSS-210. Son fonctionnement est soumis aux deux conditions suivantes:

- cet appareil ne doit pas causer d'interférence
- cet appareil doit accepter toute interférence, notamment les interférences qui peuvent affecter son fonctionnement

Informations concernant l'exposition aux fréquences radio (RF)
La puissance de sortie émise par l'appareil sans fil Wing4TRAX Module est inférieure à la limite d'exposition aux fréquences radio d'Industrie Canada (IC). Utilisez l'appareil sans fil Wing4TRAX Module de façon à minimiser les contacts humains lors du fonctionnement normal.
Ce périphérique a été évalué et démontré conforme aux limites d'exposition aux fréquences radio (RF) d'IC lorsqu'il est installé dans des produits hôtes particuliers qui fonctionnent dans des conditions d'exposition à des appareils mobiles (les antennes se situent à plus de 20 centimètres du corps d'une personne).

IMPORTANT: les fabricants d'applications portables contenant le module Wing4TRAX doivent faire certifier leur produit final et déposer directement leur candidature pour une certification FCC ainsi que pour un certificat Industrie Canada délivré par l'organisme chargé de ce type d'appareil portable. Ceci est obligatoire afin d'être en accord avec les exigences SAR pour les appareils portables.

Tout changement ou modification non expressément approuvé par la partie responsable de la certification peut annuler le droit d'utiliser l'équipement

5 Integration Guidelines

5.1 Design Checklist

5.1.1 Schematics

The following are the most important points for a simple schematic check:

- ✓ DC supply must provide a nominal voltage at **VDD** pins above the minimum operating range limit.
- ✓ DC supply must be capable of providing up to 75 mA current, providing a voltage at **VDD** pins above the minimum operating range limit and with a maximum 150 mV voltage drop from the nominal value.
- ✓ **VDD** supply should be clean, with very low ripple/noise: provide the suggested series ferrite bead and bypass capacitors, in particular if the application device integrates an internal antenna.
- ✓ **VDD** voltage must ramp from 0.1V maximum and then rise with a slope of at least 0.1V/ms to the normal operating voltage.
- ✓ Check that voltage level of any connected pin does not exceed the specific operating range.
- ✓ Provide appropriate access to UART **RxD** and **TxD** lines for debugging (resp. PB5 and PB4).
- ✓ Capacitance and series resistance must be limited on each line of the SPI interface, if the interface is used.
- ✓ Add a proper pull-up resistor to a proper supply on each I2C interface line, if the interface is used.
- ✓ Capacitance and series resistance must be limited on each line of the I2C interface.
- ✓ Connect all the pins referred as **GND** to the ground.
- ✓ Provide proper precautions for ESD immunity as required on the application board.
- ✓ Any external signal connected to the UART interface, SPI interface, I2C interface and GPIOs must be tri-stated when the module is in power-down mode, when the external reset is forced low and during the module power-on sequence (at least for 100 ms after the start-up event), to avoid latch-up of circuits and let a proper boot of the module.
- ✓ All unused pins can be left floating on the application board, except the **PB3** pin if the module has to be put in DEEP_SLEEP mode

5.1.2 Layout

The following are the most important points for a simple layout check:

- ✓ Check 50 Ω nominal characteristic impedance of the RF transmission line connected to the **ANT** pad (main RF input/output).
- ✓ Follow the recommendations of the antenna producer for correct antenna installation and deployment (PCB layout and matching circuitry).
- ✓ Ensure no coupling occurs with other noisy or sensitive signals (primarily SPI and/or I2C interfaces).
- ✓ **VDD** line should be as wide and as short as possible (i.e. width of 0.25mm min.)
- ✓ Provide the suggested series ferrite bead and bypass capacitors close to the **VDD** pins implementing the recommended layout and placement, especially if the application device integrates an internal antenna.
- ✓ Route **VDD** supply line away from sensitive analog signals.
- ✓ Ensure proper grounding.
- ✓ Consider "No-routing" areas for the Module footprint (see section § 3.5).

- ✓ Optimize placement for minimum length of RF line and closer path from DC source for **VDD**.
- ✓ Keep routing short and minimize parasitic capacitance on the SPI lines to preserve signal integrity.

5.1.3 Antenna

- ✓ Antenna should have a 50 Ω impedance, VSWR less than 3:1 (recommended 2:1) on operating bands in deployment geographical area.
- ✓ Follow the recommendations of the antenna producer for correct antenna installation and deployment (PCB layout and matching circuitry).
- ✓ Follow the additional guidelines for products marked with the FCC logo (United States only) reported in section §5.2
- ✓ The antenna connected to the **ANT** pad should be DC isolated with a ceramic COG/NPO capacitor of 150pF.

5.2 Layout Recommendations

5.2.1 Guidelines per pin function

The following design guidelines must be met for optimal integration of Wing4TRAX module on the final application board

Rank	Function	Pin(s)	Attention to pay	Remark
1st	RF antenna	ANT	**VERY HIGH**	Design for 50 Ω characteristic impedance
2nd	Main DC supply	VDD	HIGH	**VDD** line should be wide and short. Route away from sensitive analog signals
3rd	Ground	GND	HIGH	Provide proper grounding
4th	Analog pins	PA2, PA5	HIGH	If ADC0 and/or ADC1 lines are used Avoid coupling with noisy signals
5th	High-speed digital pins	PC1..PC3	HIGH	If SCK, MOSI and MISO lines are used Avoid coupling with sensitive signals
6th	Digital pins & supplies	PB0..PB7, PC0, PC4, SYSCLK, DBG_EN, RESET_N	Medium	Follow common practice rules for digital pin routing

5.2.2 RF antenna connection

The **ANT** pin provided by Wing4TRAX module is very critical in layout design.
Proper transition between **ANT** pad and the application board must be provided, implementing the following design-in guidelines for the layout of the application PCB close to the **ANT** pad:

- On a multi-layer board, the whole layer stack below the RF connection should be free of digital lines
- Increase GND keep-out (i.e. clearance) for **ANT** pad to at least 175 µm up to adjacent pads metal definition, as described in Figure 4
- Add GND keep-out (i.e. clearance) on buried metal layers below **ANT** pad and below any other pad of component present on the RF line, if top-layer to buried layer dielectric thickness is below 200

µm, to reduce parasitic capacitance to ground (see Figure 4 for the description of the GND keep-out area below **ANT** pad)

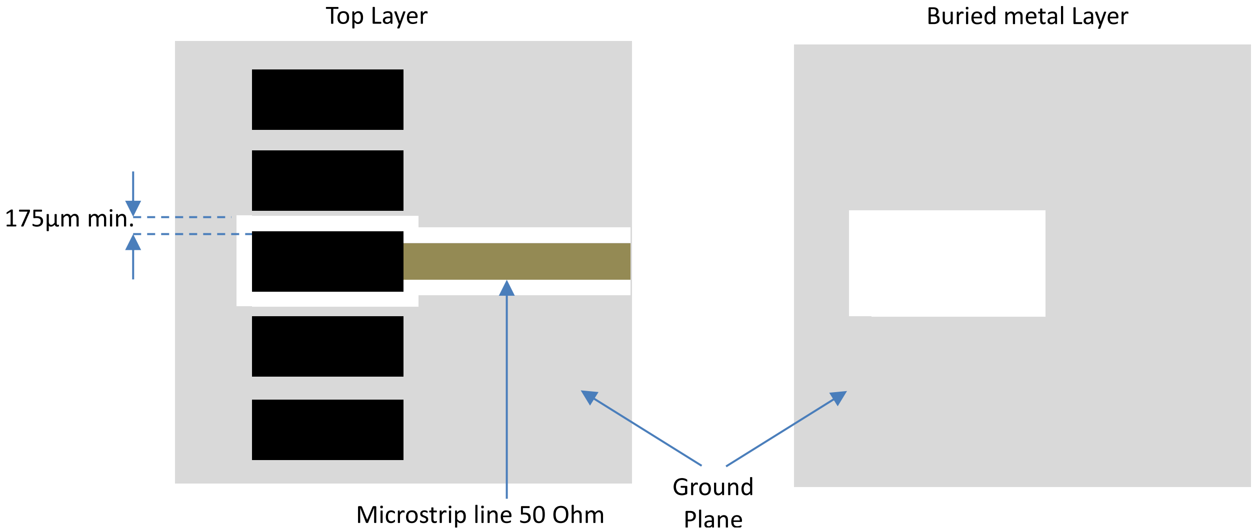


Figure 4: GND keep-out area on top layer around and on buried layer below ANT pad

The transmission line from the **ANT** pad up to antenna connector or up to the internal antenna pad must be designed so that the characteristic impedance is as close as possible to 50 Ω.

- The transmission line up to antenna connector or pad may be a microstrip (consists of a conducting strip separated from a ground plane by a dielectric material) or a strip line (consists of a flat strip of metal which is sandwiched between two parallel ground planes within a dielectric material). In any case must be designed to achieve 50 Ω characteristic impedance
- Microstrip lines are usually easier to implement and the reduced number of layer transitions up to antenna connector simplifies the design and diminishes reflection losses. However, the electro-magnetic field extends to the free air interface above the stripline and may interact with other circuitry
- Buried striplines exhibit better shielding to external and internally generated interferences. They are therefore preferred for sensitive application. In case a stripline is implemented, carefully check that the via pad-stack does not couple with other signals on the crossed and adjacent layers

Figures 5 below provide two examples of proper 50 Ω coplanar waveguide designs. The first transmission line can be implemented in case of 2-layer PCB stack-up herein described, the second transmission line can be implemented in case of 4-layer PCB stack-up herein described:

- With a 2-layer PCB stack using FR-4 material (ε_r = 4.6) of 1.55mm height between top and bottom layers, 18µm of copper thickness for the top layer, a 50 Ω microstrip line can be achieved with a line of 1.0mm width and a clearance of 0.175mm from GND

- With a 4-layer PCB stack using FR-4 material (ε_r = 4.6) of 0.36mm height between top and first inner layers, 18µm of copper thickness for the top layer, a 50 Ω microstrip line can be achieved with a line of 0.6mm width and a clearance of 0.34mm from GND

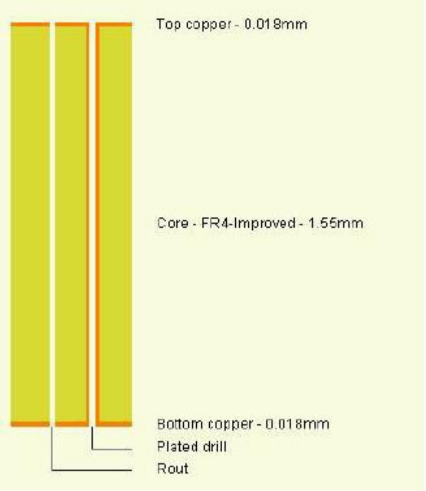
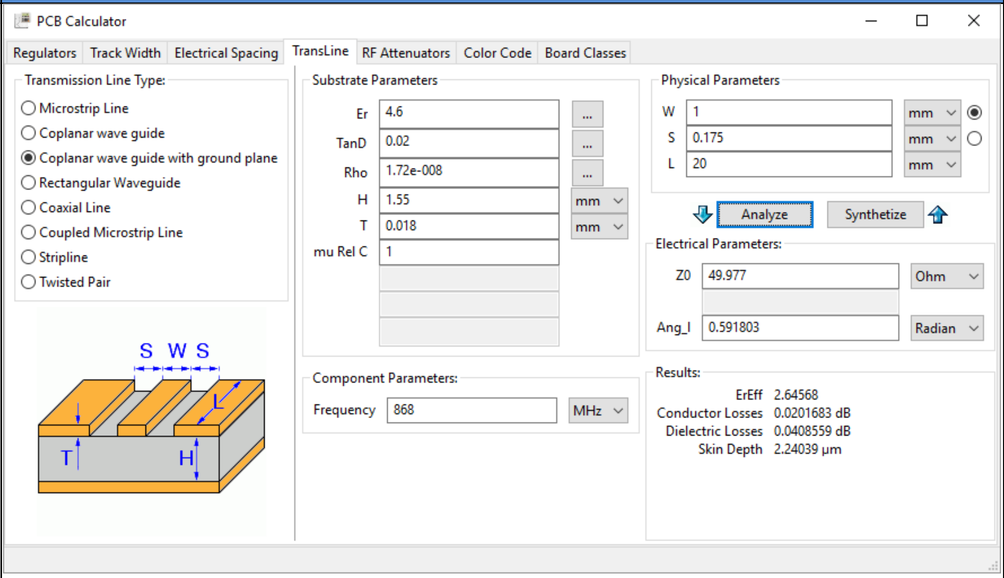
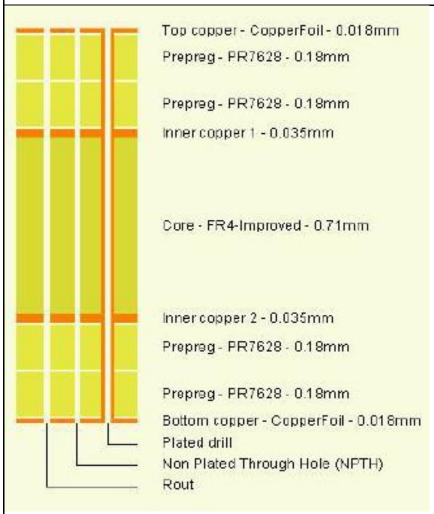
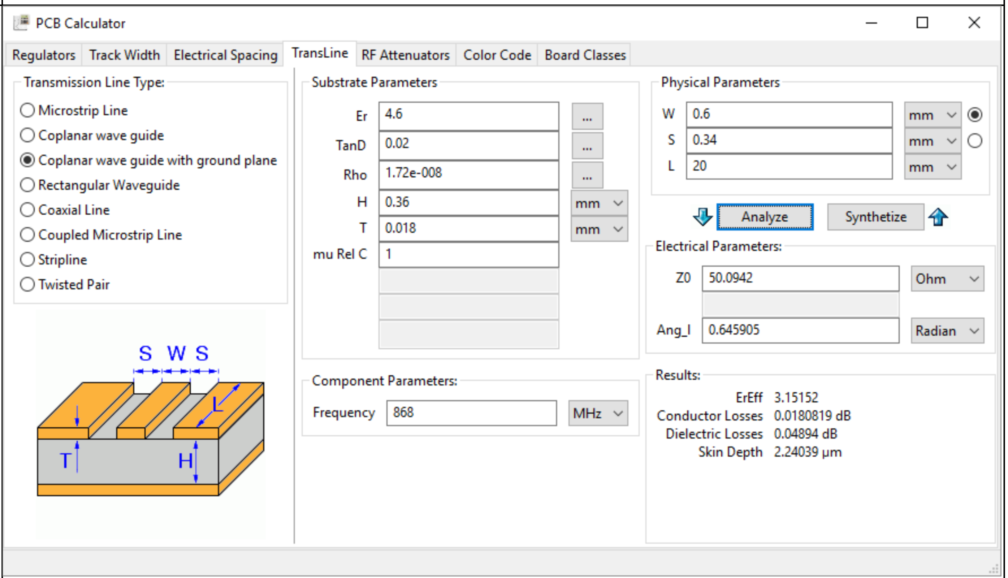
Board buildup	Coplanar waveguide transmission line parameters
	
	

Figure 5: 50 Ω coplanar waveguide transmission line calculation with different PCB buildup

If the two examples do not match the application PCB layup, the 50 Ω characteristic impedance calculation can be made using the HFSS commercial finite element method solver for electromagnetic structures from ANSYS Corporation, or using freeware tools like AppCAD from Agilent or TXLine from Applied Wave Research, taking care of the approximation formulas used by the tools for the impedance computation.

To achieve a 50 Ω characteristic impedance, the width of the transmission line must be chosen depending on:

- the thickness of the transmission line itself (e.g. 18 µm in the example of Figure 5)
- the thickness of the dielectric material between the top layer (where the transmission line is routed) and the inner closer layer implementing the ground plane (e.g. 360 µm or 1550 µm in Figure 5)

- the dielectric constant of the dielectric material (e.g. dielectric constant of the FR-4 dielectric material in Figure 5 given at $\varepsilon_r = 4.6$)
- the gap from the transmission line to the adjacent ground plane on the same layer of the transmission line (e.g. 175 µm or 340 µm in Figure 5)

Additionally to the impedance matching at 50 Ω, the following guidelines are recommended for the RF line design:

- Minimize the transmission line length; the insertion loss should be minimized as much as possible, in the order of a few tenths of a dB
- The transmission line should not have abrupt change to thickness and spacing to GND, but must be uniform and routed as smoothly as possible
- The transmission line must be routed in a section of the PCB where minimal interference from noise sources can be expected
- Route RF transmission line far from other sensitive circuits as it is a source of electromagnetic interference
- Avoid coupling with **VDD** routing and analog lines
- Ensure solid metal connection of the adjacent metal layer on the PCB stack-up to main ground layer
- Add GND via around transmission line (e.g. repetitive pattern of via spaced by 2.54mm)
- Ensure no other signals are routed parallel to transmission line, or that other signals cross on adjacent metal layer
- If the distance between the transmission line and the adjacent GND area (on the same layer) does not exceed 5 times the track width of the microstrip, use the "Coplanar Waveguide" model for 50 Ω characteristic impedance calculation
- Do not route microstrip line below discrete component or other mechanics placed on top layer
- When terminating transmission line on antenna connector (or antenna pad) it is very important to strictly follow the connector manufacturer's recommended layout
- GND layer under RF connectors and close to buried via should be cut out in order to remove stray capacitance and thus keep the RF line 50 Ω. In most cases the large active pad of the integrated antenna or antenna connector needs to have a GND keep-out (i.e. clearance) at least on first inner layer to reduce parasitic capacitance to ground. Note that the layout recommendation is not always available from connector manufacturer: e.g. the classical SMA Pin-Through-Hole needs to have GND cleared on all the layers around the central pin up to annular pads of the four GND posts.
- Ensure no coupling occurs with other noisy or sensitive signals

Additional guidelines for products marked with the FCC logo - United States only

Wing4TRAX module can only be used with a host antenna circuit trace layout according to these guidelines; a host system designer must follow the guidelines to keep the original Grant of Wing4TRAX module. Strict compliance to the layout reference design already approved (described in the following guidelines) is required to ensure that only approved antenna shall be used in the host system.

If in a host system there is any difference from the trace layout already approved, it requires a Class II permissive change or a new grant as appropriate as FCC defines.

Compliance of this device in all final host configurations is the responsibility of the Grantee.
The approved reference design for Wing4TRAX modules has a structure of 2 layers described below.

The top layer provides a microstrip line to connect the **ANT** pin of the Wing4TRAX module to the antenna connector. The **ANT** pin of the Wing4TRAX module must be soldered on the designed pad which is connected to the antenna connector by a microstrip. The characteristics of the microstrip line (coplanar wave guide) are the following:

- Thickness = 0.018 mm
- Width = 1.0 mm
- Length = 20 mm
- Gap (signal to GND) = 0.175 mm

The microstrip line must be designed to achieve 50 Ω characteristic impedance
The dimensions of the microstrip line must be calculated in a host system according to PCB characteristics provided by PCB manufacturer.
Additional coupling and filtering components between the **ANT** pin pad and the antenna connector shall be placed all along the microstrip line, in a way that preserves as much as possible integrity of the line; a special attention must be paid to the placement of components mounted in parallel to the microstrip line in order to avoid generation of unexpected stubs

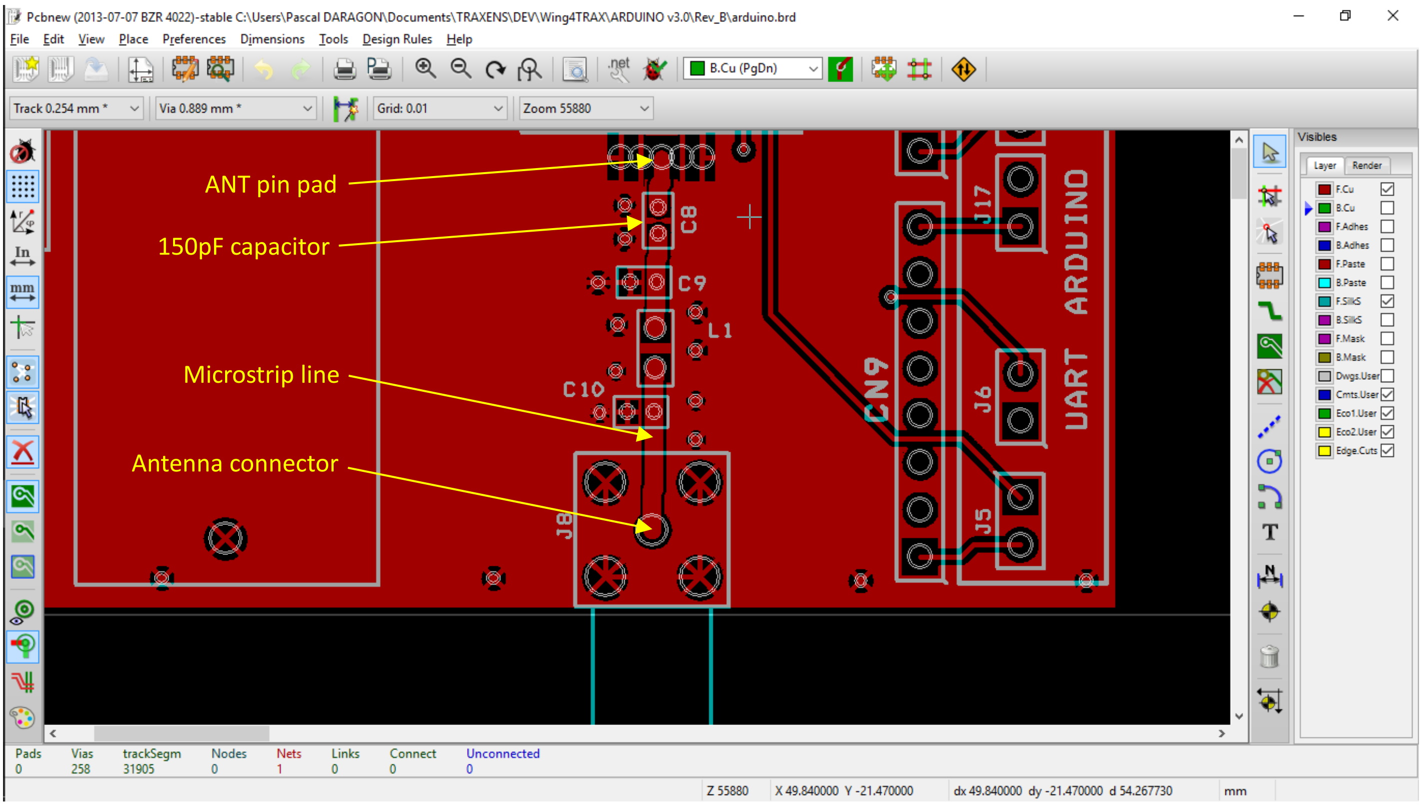


Figure 6: Layer 1 (top layer) of TRAXENS approved interface board for Wing4TRAX module

The thickness of the dielectric from Layer 1 (top layer) to Layer 2 (bottom layer) is 1.55 mm.

The Layer 2 (bottom layer) is designed for signals routing, components placement and GND plane.
Layer 2 thickness is 0.018 mm.

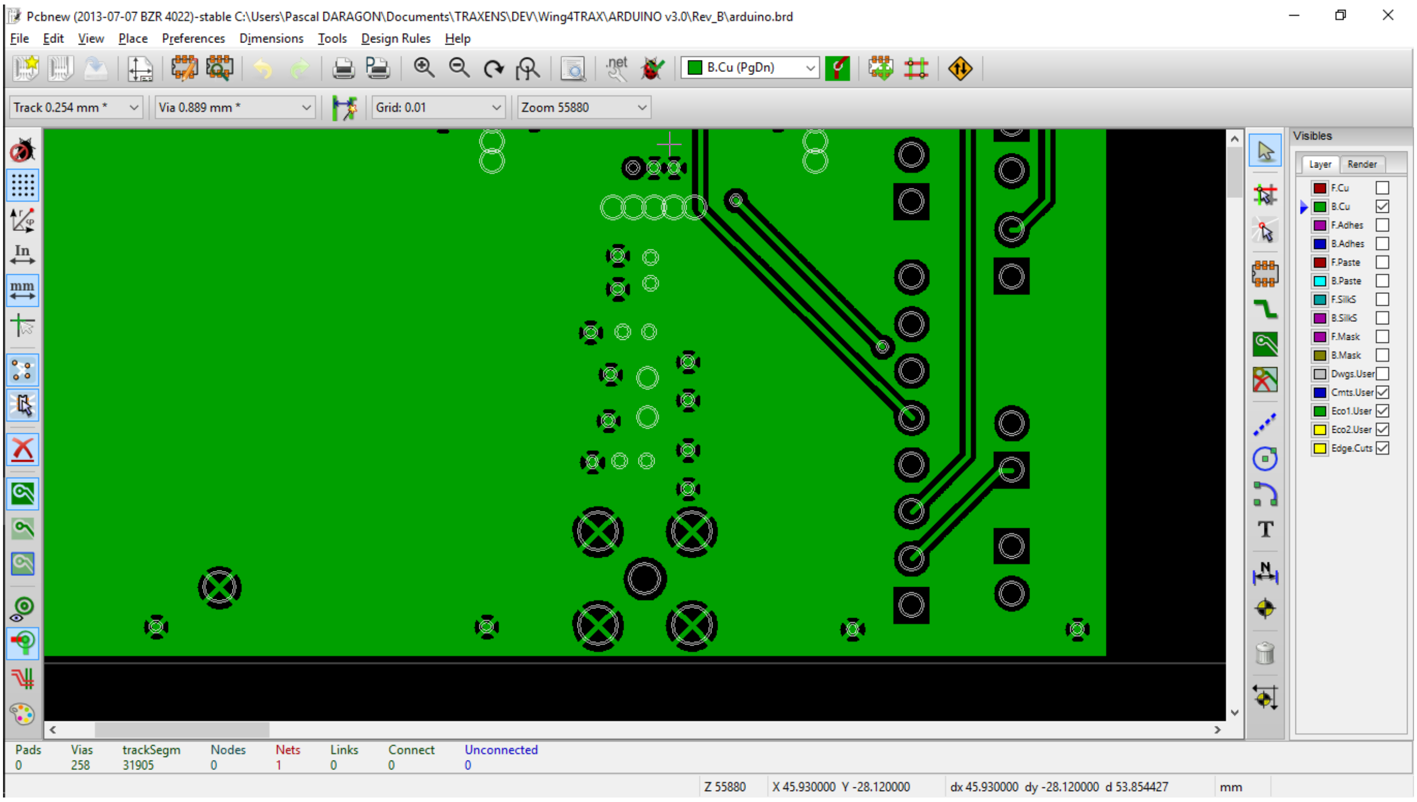


Figure 7: Layer 2 (bottom layer) of TRAXENS approved interface board for Wing4TRAX module

- The antenna gain must not exceed the levels reported in the section §4 introduction to preserve the original TRAXENS FCC ID.
- The antenna must be installed and operated with a minimum distance of 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.
- Under the requirements of FCC Section 15.212(a)-iv, the module must contain a permanently attached antenna, or contain a unique antenna connector, and be marketed and operated only with specific antenna(s).
- In accordance with FCC Section 15.203, the antenna should use a unique coupling connector to the approved reference design for Wing4TRAX module, to ensure that the design will not be deployed with antenna of different characteristic from the approved type.
- The use of standard SMA type connector is not permitted, as its standard usage allows easy replacement of the attached antenna. However RP-SMA (Reverse-Polarized-SMA) connector type fulfills the minimum requirements to prevent exchangeability of antenna on the reference design.

5.3 ANTENNA CHARACTERISTICS

Antenna characteristics are essential for good functionality of the module. Antenna radiating performance has direct impact on the reliability of connections over the Air Interface. A bad termination of the **ANT** pin can result in poor performance of the module.

The following parameters should be checked:

Item	Recommendations
Impedance	50 Ω nominal characteristic impedance
Frequency Range	Wing4TRAX module supports 3 sub-GHz ISM bands: 1. 433.05.. 434.79MHz 2. 863.. 869 MHz 3. 902.. 928 MHz
Input Power	20mW peak
VSWR	<2:1 recommended, <3:1 acceptable
Return Loss	S_{11} < -10dB recommended, S_{11} < -6dB acceptable

Sub-GHz ISM bands antennas are typically available as:

- Linear monopole: typical for fixed applications (e.g. TRAX-Net gateway). The antenna extends mostly as a linear element with a dimension comparable to $\lambda/4$ of the lowest frequency of the operating band. Magnetic base may be available. Cable or direct RF connectors are common options. The integration normally requires the fulfillment of some minimum guidelines suggested by antenna manufacturer
- PIFA: typical for mobile applications (e.g. TRAX-Box mounted onto a container). It consists of a monopole antenna running parallel to a ground plane and grounded at one end. The antenna is fed from an intermediate point a distance from the grounded end. The design has two advantages over a simple monopole: the antenna is shorter and more compact, and the impedance matching can be controlled by the designer without the need for additional matching components. However, the design is complex and we recommend to rely on TRAXENS expertise in this field before considering to implement this technology
- Patch-like antenna: better suited for integration in compact designs (e.g. USB key). These are mostly custom designs where the exact definition of the PCB and product mechanical design is fundamental for tuning of antenna characteristics

For integration observe these recommendations:

- Ensure 50 Ω antenna termination, minimize the V.S.W.R. or return loss, as this will optimize the electrical performance of the module. See section §5.2.2
- Select antenna with best radiating performance. See section §5.3.2
- If a cable is used to connect the antenna radiating element to application board, select a short cable with minimum insertion loss. The higher the additional insertion loss due to low quality or long cable, the lower the connectivity
- Follow the recommendations of the antenna manufacturer for correct installation and deployment
- Do not include antenna within closed metal case

- Do not place the main antenna in close vicinity to end user since the emitted radiation in human tissue is limited by S.A.R. regulatory requirements
- Do not use directivity antenna since the electromagnetic field radiation intensity is limited in some countries
- Take care of interaction between co-located RF systems since the Wing4TRAX transmitted power may interact or disturb the performance of companion systems
- Place antenna far from sensitive analog systems or employ countermeasures to reduce electro-magnetic compatibility issues that may arise

5.3.1 Antenna termination

The Wing4TRAX module is designed to work on a 50 Ω load. However, real antennas have no perfect 50 Ω load on all the supported frequency bands. Therefore, to reduce as much as possible performance degradation due to antenna mismatch, the following requirements should be met:

- With a network analyzer, connect the antenna through a coaxial cable to the measurement device; S_{11} parameter indicates the power which is reflected by the antenna back to the module output.
- A good antenna should have a S_{11} below -10 dB over the entire frequency band. Due to miniaturization, mechanical constraints and other design issues, this value may not be achieved; a S_{11} value of about -6 dB is therefore acceptable.

Picture below shows an example of this measurement, with a good value of S_{11} in the 860-930MHz band and an acceptable value in the 433MHz band (Frequency span = 150MHz, starting at 50MHz)

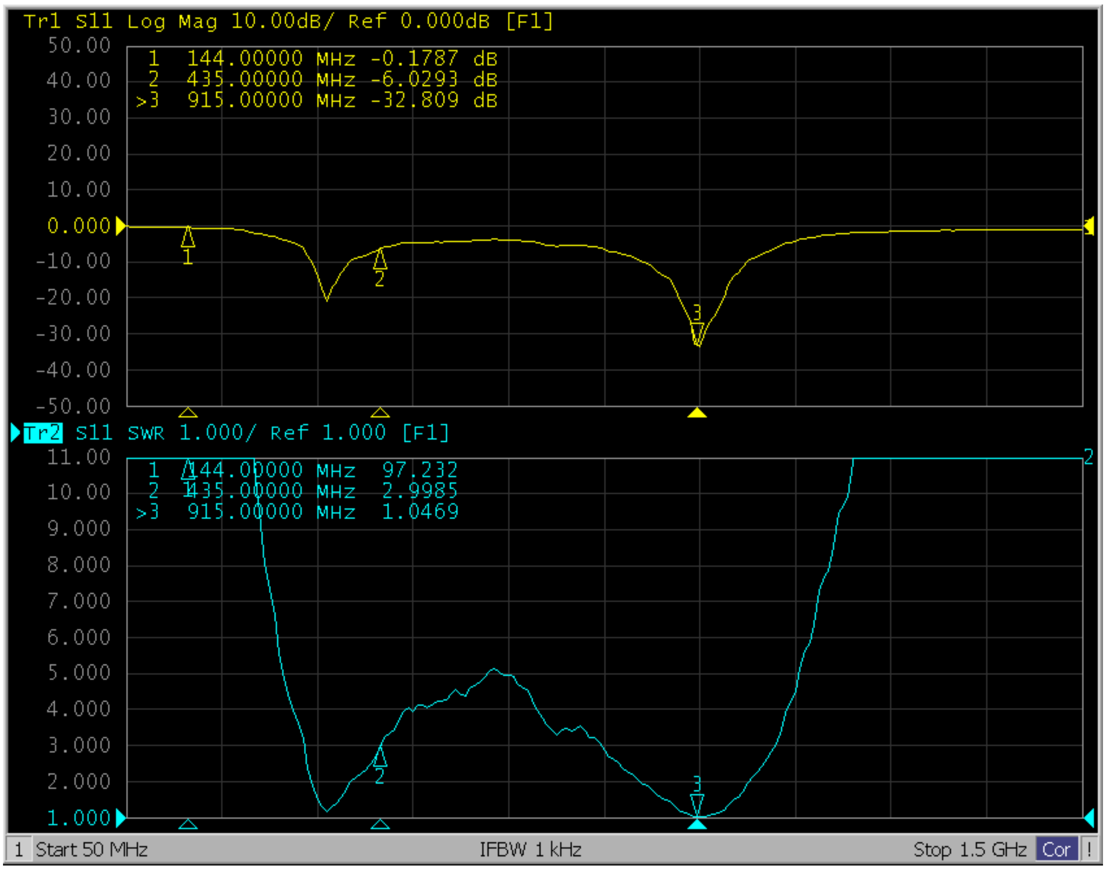


Figure 8: S_{11} measurement with a Nagoya NA-915-2 monopole antenna

5.3.2 ANTENNA RADIATION

An indication of the antenna's radiated power can be approximated by measuring the S_{21} parameter from a target antenna to the measurement antenna, using a network analyzer with a wideband antenna. Measurements should be done at a fixed distance and orientation, and results compared to measurements performed on a known good antenna.

For good antenna radiation performance, antenna dimensions should be comparable to a quarter of the wavelength. Different antenna types can be used for the module, many of them (e.g. patch antennas, monopole) are based on a resonating element that works in combination with a ground plane. The ground plane, ideally infinite, can be reduced down to a minimum size that must be similar to one quarter of the wavelength of the minimum frequency that has to be radiated (transmitted/received).

Numerical samples are given below (below calculated size, the antenna efficiency is reduced):

- for a frequency = 450MHz ⇒ wavelength λ = 66 cm ⇒ minimum antenna size = 16.5 cm
- for a frequency = 900MHz ⇒ wavelength λ = 33 cm ⇒ minimum antenna size = 8.3 cm

Picture below shows 3D radiation patterns for an omnidirectional antenna, designed to work over the 3 ISM bands, with a gain of 2dBi in lower band and 2.5dBi in upper bands:

Radiation patterns at 430-435-440 MHz	Radiation patterns at 860-900-930 MHz

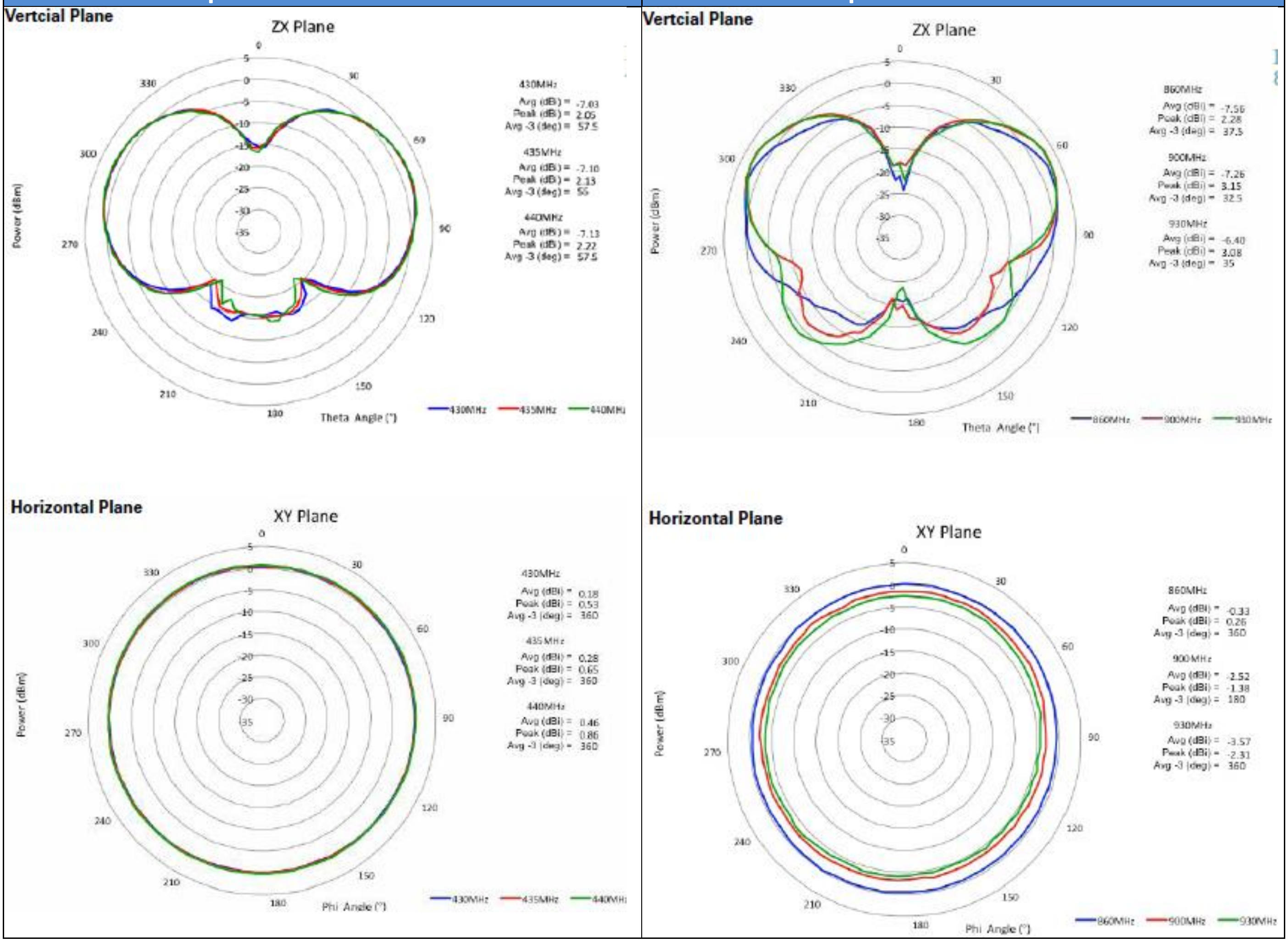


Figure 9: radiation patterns of PULSE RO3ISMNM omnidirectional & wideband antenna

6 Product Testing

6.1 TRAXENS manufacturing tests

TRAXENS focuses on high quality for its products. All units produced are fully tested. Defective units are analyzed in detail to improve the production quality.
This is achieved with automatic test equipment, which delivers a detailed test report for each unit. The following measurements are done:

- Digital self-test (firmware download, network UID and version information programming)
- Measurement of voltages and currents in different power saving modes
- Functional tests (serial interface communication, frame synchronization clock)
- Digital tests (GPIOs, digital interfaces)
- Analog tests (external ADCs, internal temperature sensor & reference voltage)
- Measurement and calibration of RF characteristics in all supported bands (receiver sensitivity vs BER, RSSI verification, tuning of frequency synthesizer, calibration of transmitter)
- Verification of RF characteristics after calibration (power levels and spectrum performance are checked to be within tolerances when calibration parameters are applied)

Figure 10: Wing4TRAX manufacturing test bench

6.2 Tests policy for OEM manufacturer

Because of the testing done by TRAXENS with 100% coverage, an OEM manufacturer does not need to repeat firmware tests or measurements of the module RF performance or tests over analog and digital interfaces in their production test.
An OEM manufacturer should focus on:

- Module assembly on the device; it should be verified that:
  - Soldering and handling process did not damaged the module components
  - All module pins are well soldered on the host board
  - There are no short circuits between pins
- Component assembly on the device; it should be verified that:
  - Communication with host controller can be established
  - The interfaces between module and device are working (for those used)
  - RF performance tests of the device including antenna are conform to expectations

Dedicated tests can be implemented to check the device. For example, the measurement of module current consumption when set in a specified status can be performed to detect a short circuit when compared with a "Golden Device" result.
Specific test commands [refer to R2] can be used to perform functional tests (communication with host controller, reading of network UID, GPIOs, ADCs, etc.) and to perform RF performance tests.

6.2.1 "GO/No GO" tests

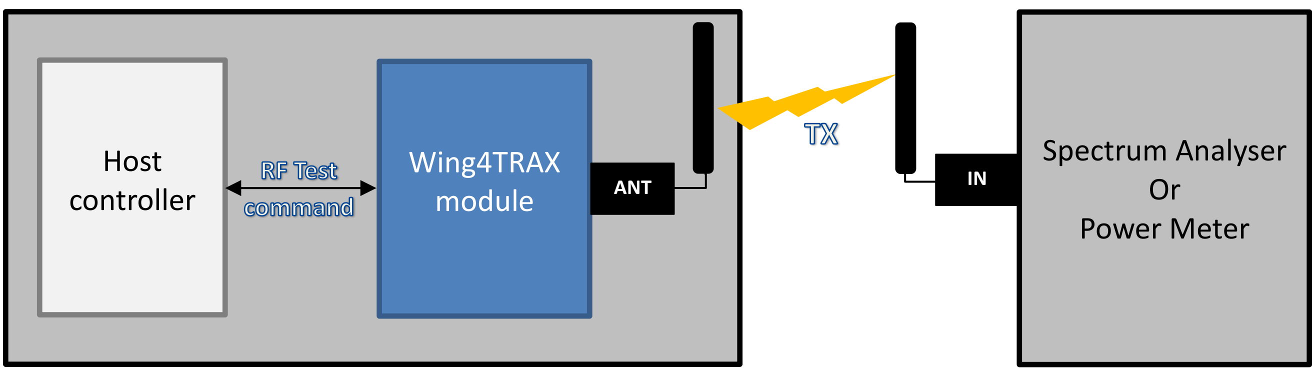
A "GO/No GO" test is intended to simply compare the signal quality with a "Golden Device", in a position where it can communicate in P2P mode with another "Golden Device", with a stable and well known level of signal (refer to CMD_MAC_SHORT_SEND and CMD_MAC_GET_RSSI commands in R1)

This test is suitable to quickly check the communication between host controller and the Wing4TRAX module, power-good functionality and RF path integrity from the module to the device antenna.

6.2.2 Functional RF tests

Overall RF performance test of the device including antenna can be performed with basic instruments such as a spectrum analyzer (or RF power meter) and a signal generator using test commands [refer to R2].
The test command set gives a simple interface to set the module into TX and RX test modes, ignoring TRAX-Net signaling protocol. Each command can set the module:

- In transmitting mode, in a specified channel and power level without modulation
- In receiving mode, in a specified channel to returns the measured power level



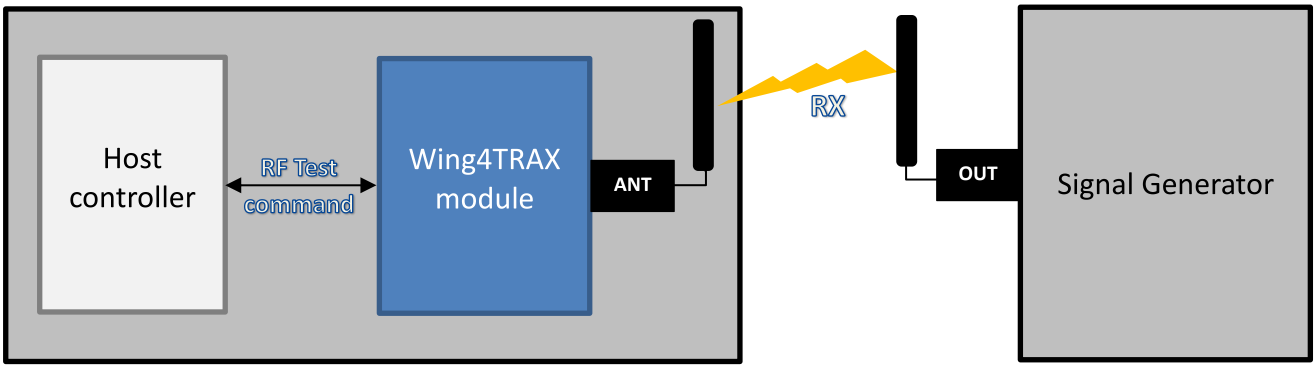


Figure 11: synoptic of OEM test platform for radiation measurement

This feature allows the measurement of the transmitter and receiver power levels to check component assembly related to the module antenna interface and to check other device interfaces from which depends the RF performance.

To avoid module damage during transmitter test, a proper antenna according to module specifications or a 50 Ω termination must be connected to ANT pin.

To avoid module damage during receiver test the maximum power level received at ANT pin must meet module specifications.

- Emission tests can generate interference that can be prohibited by law in some countries. The use of this feature is intended for testing purpose in controlled environments by qualified user and must not be used during the normal module operation.
- Follow instructions suggested by TRAXENS documentation
- TRAXENS assumes no responsibilities for the inappropriate use of this feature.

7 Disclaimers

7.1 Document Status

This manual is in initial version. Supplementary data will be published at a later date. TRAXENS reserves the right to change its content without notice in order to improve the design and supply the best possible product.

Please check with TRAXENS for the most recent data before initiating or completing a design.

Contact : support@traxens.com

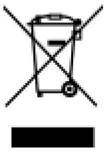
7.2 ESD

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

7.3 Warranty

TRAXENS warrants that its products shall conform to TRAXENS's specifications and remain free from defects materials and workmanship under normal, proper and intended use for a period of one (1) year from date of purchase, provided that proof of purchase be furnished with any returned equipment.

7.4 Disposal of waste by users in private households within the European Union



This symbol on the product or on its packaging indicates that this product must not be disposed off with your other household waste. Instead, it is your responsibility to dispose of your waste by taking it to a collection point designated for the recycling of electrical and electronic appliances.

Separate collection and recycling of your waste at the time of disposal will contribute to conserving natural resources and guarantee recycling that respects the environment and human health. For further information concerning your nearest recycling center, please contact your nearest local authority/town hall offices, your household waste collection company or the distributor where you bought the product.