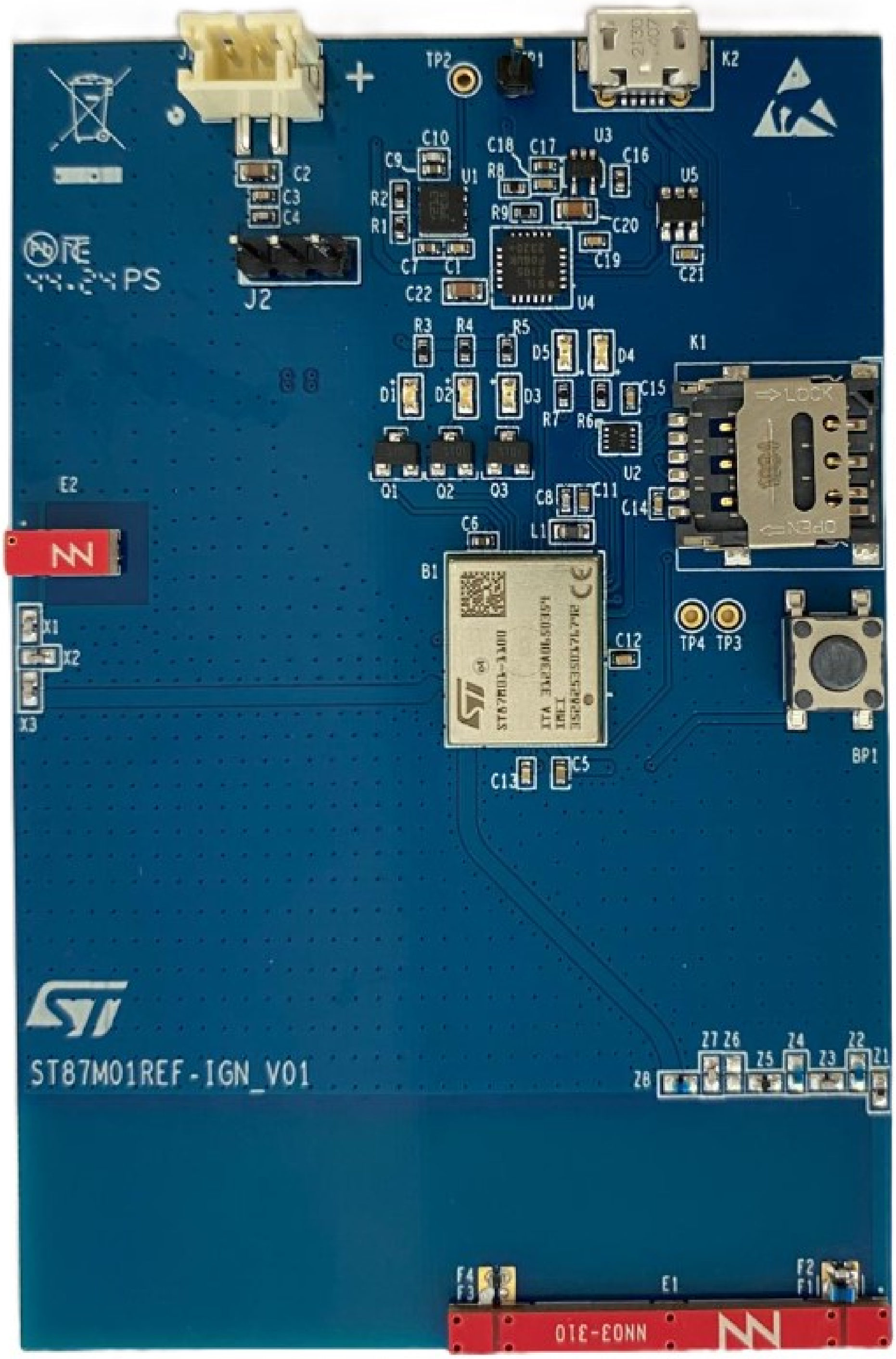
ST87M01REF-IGN_V01 - ST87M01 reference design with chip antennas

Introduction

The ST87M01 NB-IoT module is a state-of-the-art solution designed to meet the growing demands for reliable and efficient wireless communication. This application note provides a comprehensive overview of the reference design specifically developed for the ST87M01 module, which integrates the high-performance NN03-310 and NN03-320 IGNION antennas. It focuses on the key features, application diagram, board layout, bill of material, RF performance of the reference design.

The ST87M01REF-IGN_V01 reference design is engineered to facilitate the evaluation of the ST87M01 module's capabilities. The NN03-310 NB-IoT chip antenna and NN03-320 GNSS chip antenna are renowned for their efficiency, compact design, and robust performance across a wide range of frequencies, making them suitable companions for the ST87M01 module.

Figure 1. ST87M01REF-IGN_V01 reference design



1 General information

1.1 Acronyms and terms

Table 1. Definitions of terms

Term	Definition
CPWG	Coplanar Waveguide with Ground
FR4	Flame Retardant woven glass reinforced epoxy resin
GND	Ground
RL	Return Loss
TRP	Total Radiated Power
UART	Universal Asynchronous Receiver/ Transmitter
USB	Universal Serial Bus

1.2 Reference documents

The documents listed in Table 2 provide further information.

Table 2. Document references

Reference	Document
[1]	ST87M01 datasheet (see www.st.com)
[2]	NN03-310 NB-IoT IGNION chip antenna datasheet (see www.ignion.io)
[3]	NN03-320 GNSS IGNION chip antenna datasheet (see www.ignion.io)
[4]	User Manual EVKITST87M01-1 (see www.st.com)
[5]	FR4 double-sided (see www.isola-group.com)

2 ST87M01REF-IGN_V01 reference design overview

2.1 Overview

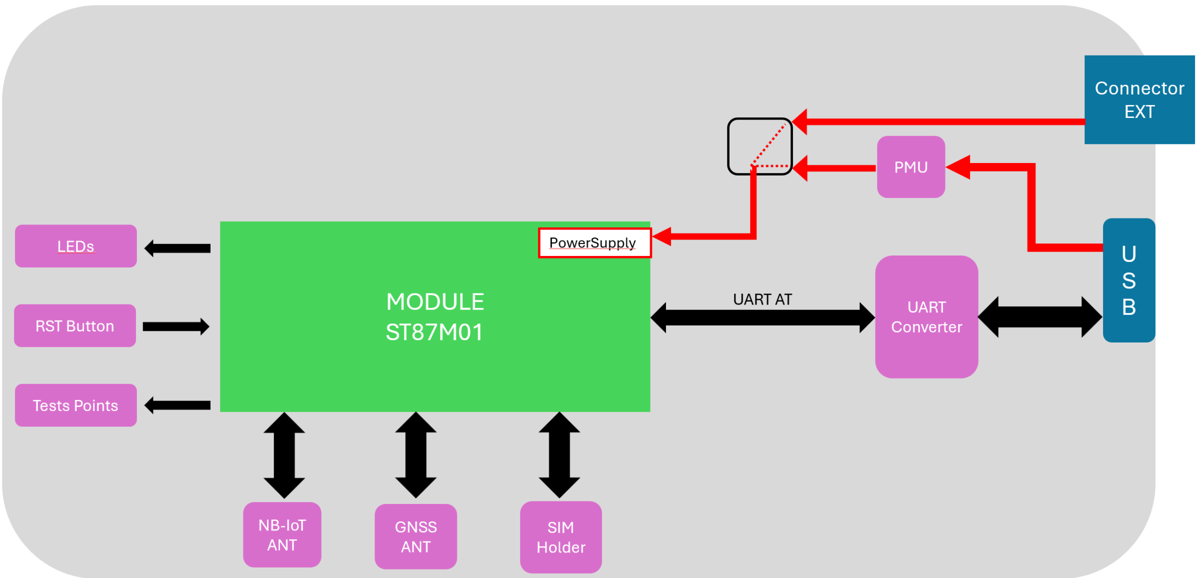
The reference design ST87M01REF-IGN_V01 for the ST87M01 module is designed to provide a comprehensive platform for testing the module's performance using IGNION chip antennas. This section provides detailed information about the board layout, schematic, and key components.

The reference design ST87M01REF-IGN_V01 is fabricated on a 60 mm x 90 mm x 1.6 mm thick, 2 layers FR4 PCB, and is fully assembled in accordance with the last standards for SMD components.

2.2 Block diagram

To have an overview of the reference design's architecture and functionality, Figure 2 shows its block diagram. This diagram provides a high-level visual representation of the various components and their interconnections:

Figure 2. Block diagram board



- The ST87M01 module is powered either via USB or by a battery through dedicated connectors
- An USB-to-UART converter allows communication with the ST87M01 module over USB using AT commands
- The board includes LEDs to monitor UART activity and the functionality of the ST87M01 module
- A reset button is provided to reset the ST87M01 module
- NN03-310 NB-IoT and NN03-310 GNSS IGNION chip antennas are used for wireless communication in the reference design
- The SIM holder ensures that the SIM card is securely placed on the reference design
- Test points for testing and troubleshooting are also provided

3 ST87M01REF-IGN_V01 schematic

For further details, or to request the electrical schematic and the Gerber files of the ST87M01REF-IGN_V01 board, please contact our sales and marketing departments.

3.1 Bill of material

Table 3 below lists the Bill of Material (BOM) used in the ST87M01REF-IGN_V01 reference design:

Table 3. Bill of material

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
BP1	WS-TASV SMT tacts switch	430182043816	-	Wurth Elektronik	430182043816
B1	ST87M01 NB-IoT and GNSS module	ST87M01-110x	-	STMicroelectronis	STMicroelectronis
C2	Chip multilayer ceramic capacitors for general purpose	10µF	0603	Murata	GRM188R61C106MA73D
C3	Chip multilayer ceramic capacitors for general purpose	0.1µF	0402	Murata	GRM155R71C104KA88D
C5,C11,C12	Chip multilayer ceramic capacitors for general purpose	10µF	0402	Murata	GRM155R61A106ME11
C1,C18,C19,C21, C14,C15,C13	Chip multilayer ceramic capacitors for general purpose	0.1µF	0402	Murata	GRM155R61H104KE14
C6	XR5 SMD multilayer ceramic chip capacitors	1µF	0402	Kemet	C0402C105K4PACTU
C7,C9,C16,C17	Chip multilayer ceramic capacitors for general purpose	1µF	0402	Murata	GRM155R61E105KE11
C4,C10	High Q chip multilayer ceramic capacitors for general purpose	33pF	0402	Murata	GJM1555C1H330JB01
C22,C20	Chip multilayer ceramic capacitors for general purpose	4.7µF	0603	Murata	GRM185R61C475KE11
C8	Chip multilayer ceramic capacitors for general purpose	100pF	0402	Murata	GRM1555C1H101JA01
D5,D3	Red Led - SMD WL-SMCW	150060RS75000	0603	Wurth Elektronik	150060RS75000
D4,D2,D1	Green Led - SMD WL-SMCW	150060VS75000	0603	Wurth Elektronik	150060VS75000
E1	TRIO mXTEND™ Ignion NB-IoT antenna	NN03-310	30mm x 3mm x 1mm	Ignion	NN03-310
E2	DUO mXTEND™ Ignion GNSS antenna	NN03-320	7mm x 3mm x 2mm	Ignion	NN03-320

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
J1	CONN SMT VERT 2POS 2MM	B2B-PH-SM4-TBT	-	JST	B2B-PH-SM4-TBT
J2	3 position WR-PHD pin header	61300311121	-	Wurth Elektronik	61300311121
K2	Micro USB bottom mount receptacle, B type	105017-0001	Micro USB	Molex	105017-0001
K1	SIM card socket	G85D1160022HHR	-	Amphenol ICC	G85D1160022HHR
L1	EMI suppression ferrite bead	140Ω	0603	Wurth Elektronik	742792621
Q2,Q1,Q3	N-channel power MOSFET	STR2N2VH5	SOT-23-3	STMicroelectronis	STR2N2VH5
R8	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
R1	Thin film resistors	24KΩ	0402	Yageo	RT0402BRD0724KL
R2	Thin film resistors	51KΩ	0402	Yageo	RT0402BRD0751KL
R7,R6,R4,R3,R5	Thick film resistors	1KΩ	0402	Yageo	RC0402JR-131KL
R9	Thick film resistors	4.7KΩ	0402	Yageo	RC0402JR-074K7L
TP2,TP3,TP4	1 position WR-PHD pin header	N.M.	-	Wurth Elektronik	61300111121
TP1	1 position WR-PHD pin header	61300111121	-	Wurth Elektronik	61300111121
U1	500 mA low quiescent current and low noise voltage regulator	LD39050PUR	DFN6	STMicroelectronis	LD39050PUR
U3	Power switch ICs - power distribution	FPF2004	DFN6	ON Semi	SC-70-5
U4	USB to UART converter	CP2105-F01-GM	QFN-24	Silicon Labs	CP2105-F01-GM
U5	TVS diodes / ESD suppression diodes	USBLC6-2SC6	SOT-23-6	STMicroelectronis	USBLC6-2SC6
U2	EMI filter circuits	EMIF03-SIM02M8	QFN-8	STMicroelectronis	EMIF03-SIM02M8

The following components:

- F1, F2, F3, F4
- Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8
- X1, X2, X3

are present in the schematic but not shown in Table 3. These are part of the NB-IoT and GNSS matching networks, and their values vary depending on the NB-IoT band used (please refer to Section 3.3). All these matching network components are strictly dependent on the PCB dimensions.

3.2 Power supply

The power supply is designed according to the EVKITST87M01-1.

To power the reference design board, it is possible to choose between USB or battery input:

Table 4. Power supply

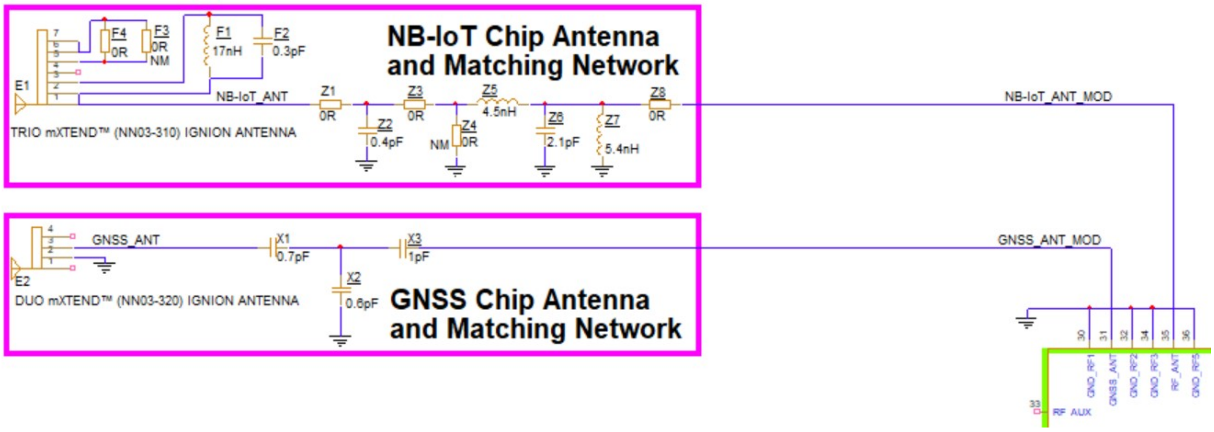
Power supply configuration	USB	Battery
Connector	K2	J1

Power supply configuration	USB	Battery
J2 configuration	short pin2 with pin3	short pin1 with pin2
Input Voltage [V]	*5V_USB*	*VBAT*
Output voltage [V]	2.5	3

3.3 NB-IoT and GNSS chip antennas and matching networks

Figure 3 shows the connections and components of the NB-IoT and GNSS antenna matching networks:

Figure 3. NB-IoT and GNSS antennas and matching networks



Description of components and connections:

- E1 is the NN03-310 NB-IoT IGNION chip antenna (see [1] ST87M01 datasheet (see www.st.com))
- E2 is the NN03-320 GNSS IGNION chip antenna (see [2] NN03-310 NB-IoT IGNION chip antenna datasheet (see www.ignion.io))
- F1, F2, F3, F4, Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8 and X1, X2, X3 are the matching network components. Depending on the NB-IoT bands to be covered, these components may have different values:

Table 5. Matching network components (for bands 12 (85), 4, 2, 66, 28)

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
F1	Wire wound RF inductor	17nH	0603	Murata	LQW18AN17NG80
F2	High Q chip multilayer ceramic capacitors for general purpose	0.3pF	0402	Murata	GJM1555C1HR30WB01
F3	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
F4	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z1	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z2	High Q chip multilayer ceramic capacitors for general purpose	0.4pF	0402	Murata	GJM1555C1HR40WB01
Z3	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z4	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
Z5	Wire wound RF inductor	4.5nH	0403	Murata	LQW15AN4N5G80
Z6		2.1pF	0402	Murata	GJM1555C1H2R1WB01
Z7	Wire wound RF inductor	5.4nH	0402	Murata	LQW15AN5N4G80

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
Z8	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
X1		0.7pF	0402	Murata	GJM1555C1HR70WB01
X2		0.6pF	0402	Murata	GJM1555C1HR60WB01
X3		1pF	0402	Murata	GJM1555C1H1R0WB01

Note: Bands: 12 (85), 4, 2, 66,28 (Frequency Operation Range: 698 – 748 MHz and 1710 – 2200 MHz)

Table 6. Matching network components (for bands 5, 13, 14, 26, 1, 4, 66)

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
F1	Wire wound RF inductor	15nH	0603	Murata	LQW18AN15NG80
F2		0.3pF	0402	Murata	GJM1555C1HR30WB01
F3	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
F4	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z1		13pF	0402	Murata	GJM1555C1H130FB01
Z2	Wire wound RF inductor	5nH	0402	Murata	LQW15AN5N0B80
Z3		2.5pF	0402	Murata	GJM1555C1H2R5WB01
Z4		1.5pF	0402	Murata	GJM1555C1H1R5WB01
Z5	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z6	Wire wound RF inductor	5.6nH	0402	Murata	LQW15AN5N6B80
Z7	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
Z8	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
X1		0.7pF	0402	Murata	GJM1555C1HR70WB01
X2		0.4pF	0402	Murata	GJM1555C1HR40WB01
X3		1pF	0402	Murata	GJM1555C1H1R0WB01

Note: Bands: 5, 13, 14, 26, 1, 4, 66 (Frequency Operation Range: 746 – 894 MHz and 1710 – 2200 MHz)

Table 7. Matching network components (for bands 3, 8, 20, 5)

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
F1	Wire wound RF inductor	10nH	0603	Murata	LQW18AN10NG80
F2		0.6pF	0402	Murata	GJM1555C1HR60WB01
F3	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
F4	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z1	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL
Z2	Wire wound RF inductor	5nH	0402	Murata	LQW15AN5N0B80
Z3		3.1pF	0402	Murata	GJM1555C1H3R1WB01
Z4	Wire wound RF inductor	7nH	0402	Murata	LQW15AN7N0G80
Z5	Thick film resistors	0Ω	0402	Yageo	RC0402FR-070RL

Reference	Description	Value / Generic part number	Package	Manufacturer	Manufacturer's ordering code / Orderable part number
Z6	Thick film resistors	N.M.	0402	Yageo	RC0402FR-070RL
Z7		1.5pF	0402	Murata	GJM1555C1H1R5WB01
Z8	Wire wound RF inductor	2.3nH	0402	Murata	LQW15AN2N3G80
X1		0.7pF	0402	Murata	GJM1555C1HR70WB01
X2		0.6pF	0402	Murata	GJM1555C1HR60WB01
X3		1pF	0402	Murata	GJM1555C1H1R0WB01

Note: Bands: 3, 8, 20, 5 (Frequency Operation Range: 791 – 960 MHz and 1710 – 1880 MHz)

- All the part numbers listed in Table 5, Table 6 and Table 7 above are mandatory
- The pin number 35 of the ST87M01 is connected to the NB-IoT matching network by a 50 Ω trace (see Section 4.2)
- The pin number 33 of the ST87M01 is connected to the GNSS matching network by a 50 Ω trace (see Section 4.2)

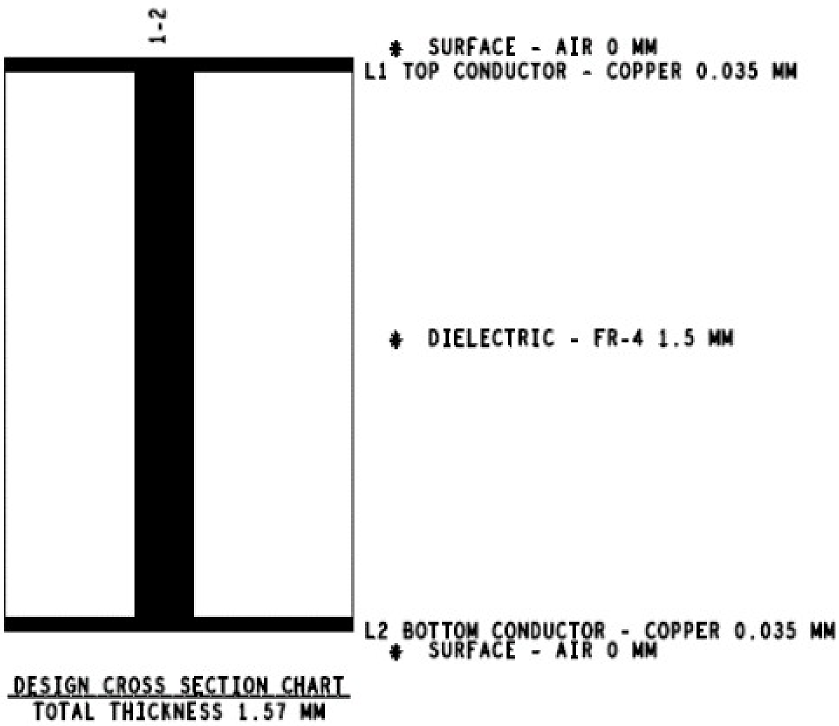
4 PCB layout

4.1 PCB layout stack-up

The reference design is developed with specific considerations to ensure optimal performance for NB-IoT and GNSS applications. The stack-up is as follows:

- **Material**: www.isola-group.com
- **Thickness**: 1.6 mm
- **Copper Thickness**: 35 µm
- **Finish**: Gold
- **Solder Mask**: Blue
- **Via Holes**: 0.2 mm plated

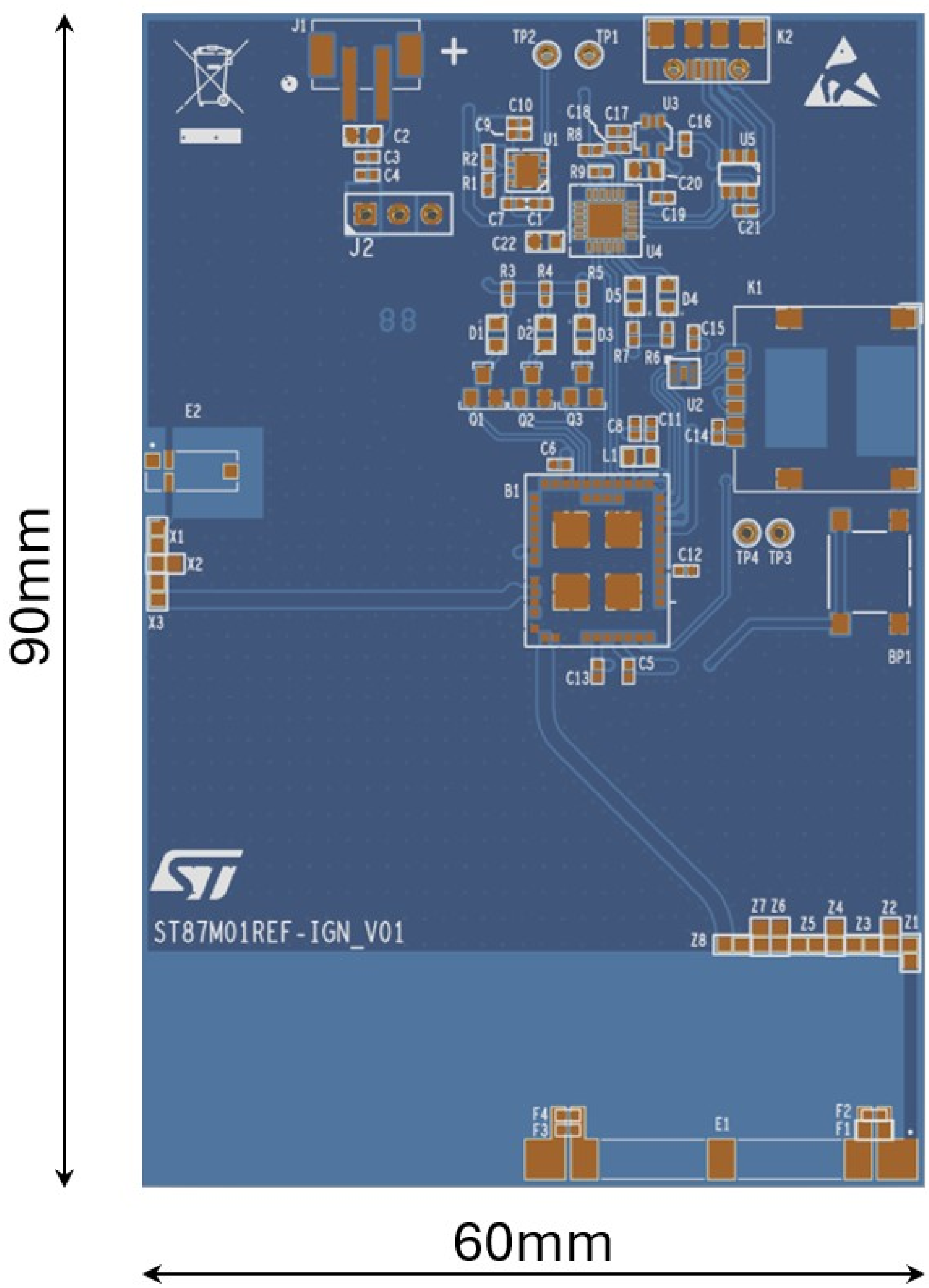
Figure 4. Stack-up



4.2 Top layer

The PCB dimensions are 90x60 mm. A top layer view is shown in Figure 5:

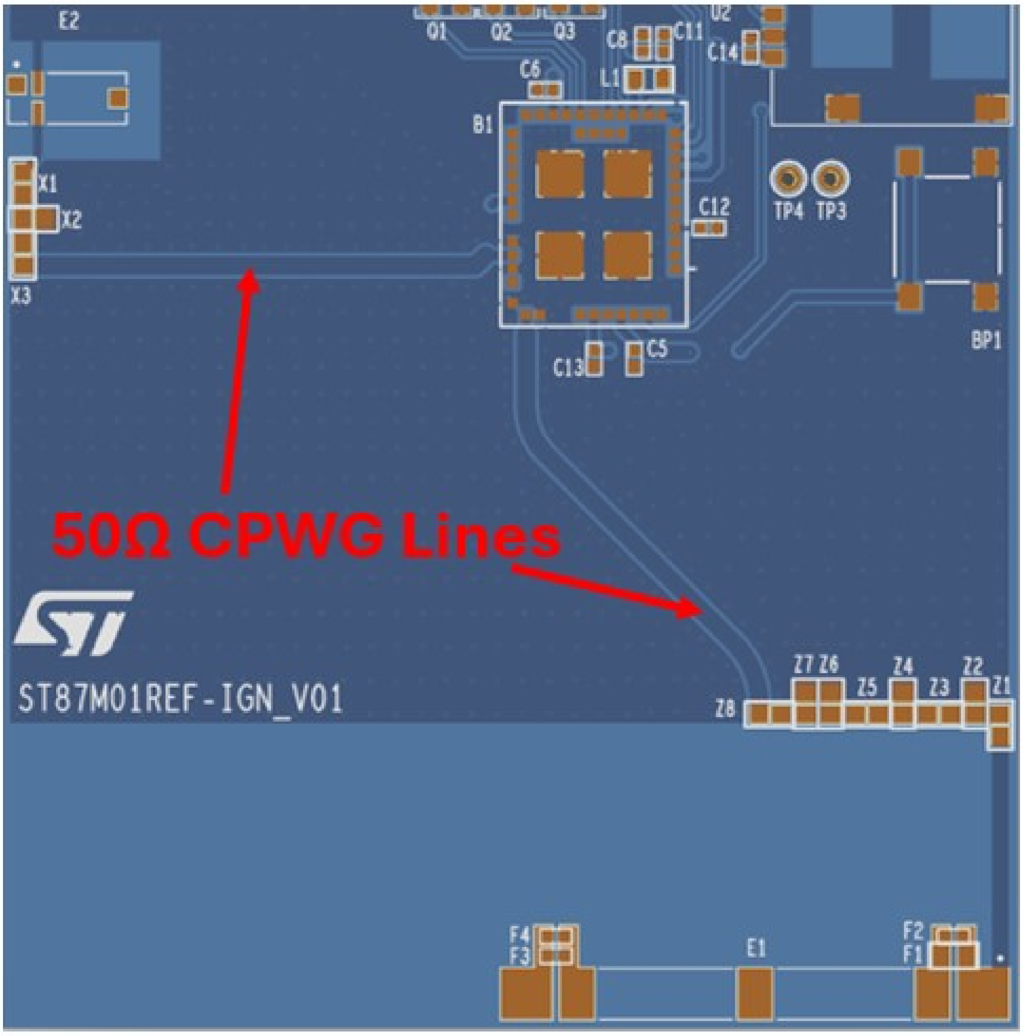
Figure 5. Top layer + components footprint



Most of the top layer is designed as a GND (Ground) area, which provides a stable reference plane for the signal traces.

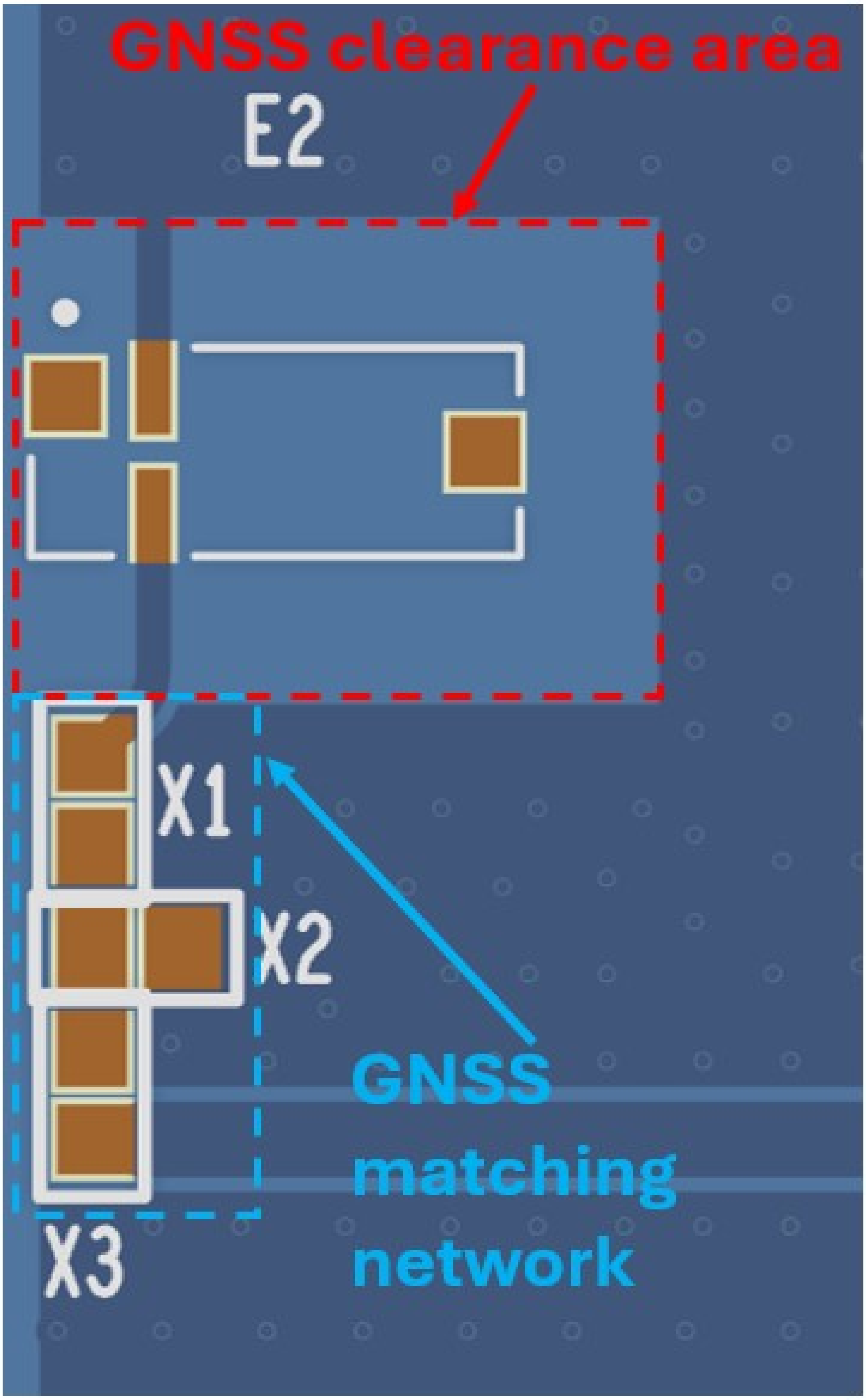
Controlled impedance lines must be used to connect the NB-IoT and GNSS antennas to the ST87M01 module. These lines are implemented as coplanar waveguide with ground (CPWG) microstrip traces to ensure a consistent 50 Ω impedance, which is crucial for maintaining signal integrity:

Figure 6. **Controlled impedance 50 Ω lines**



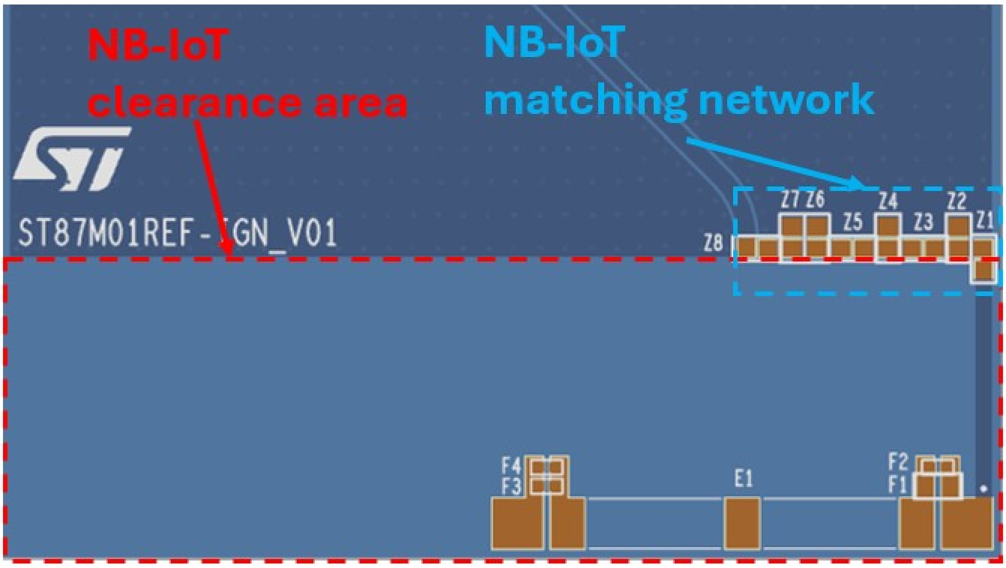
The **NN03-320 Ignion GNSS antenna** is positioned on the left side of the top layer. The clearance area dimensions must be respected for good antenna performance. The GNSS matching network is placed very close to the antenna input:

Figure 7. GNSS clearance area and matching network



The **NN03-310 IGNION NB-IoT antenna** is positioned at the bottom right of the top layer. Again, the clearance area dimensions must be respected to ensure good antenna performance (see Gerber files for details). The NB-IoT matching network is also placed close to the antenna input:

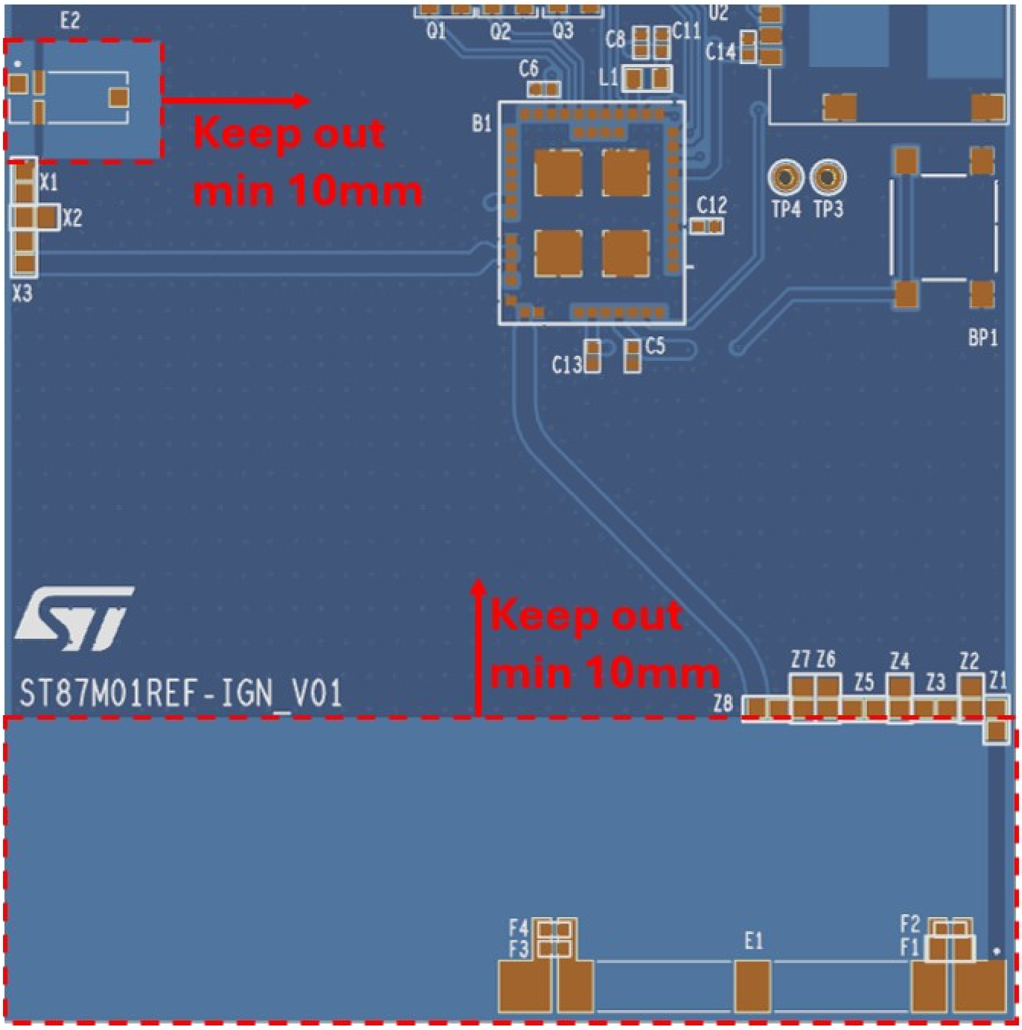
Figure 8. NB-IoT clearance area and matching network



For both GNSS and NB-IoT clearance areas, no components should be placed within these zones, except for those recommended by the antenna manufacturer, to ensure optimal antenna performance.

A keep-out zone of at least 10 mm is recommended between the antenna clearance areas and the electronic components:

Figure 9. Keep out areas



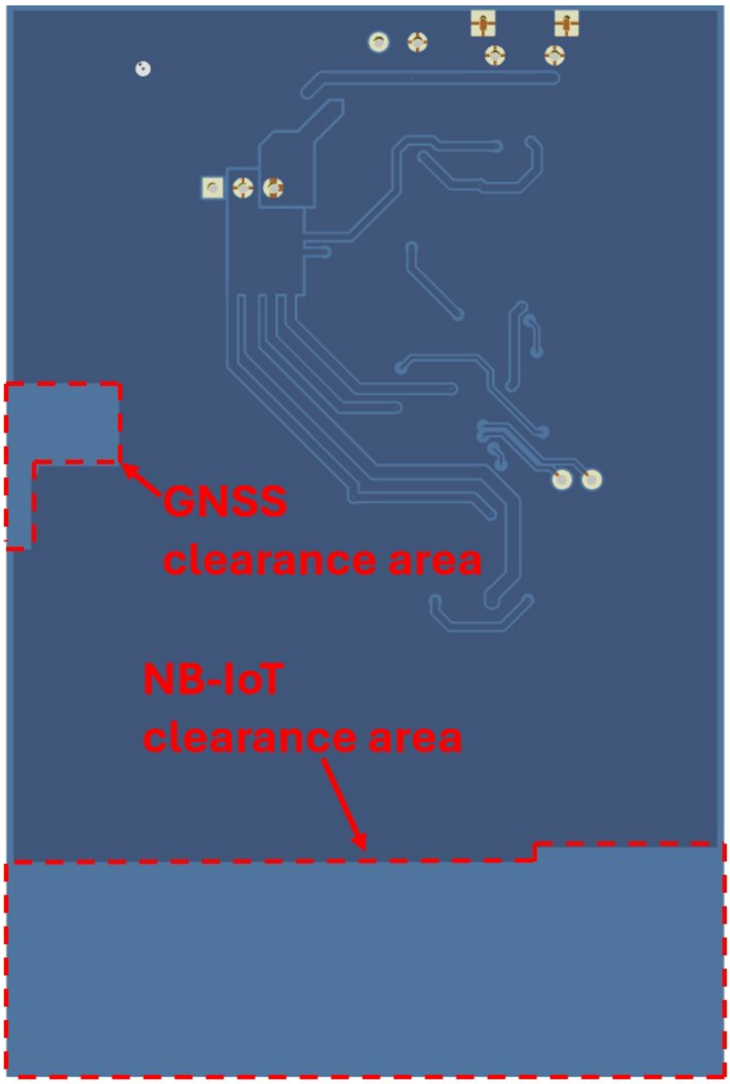
4.3 Bottom layer

Like the top layer, a large portion of the bottom layer is designated as the GND area, ensuring a continuous ground plane.

The bottom layer contains various signal traces and power lines that connect different components on the top layer. These traces are carefully routed to minimize crosstalk and maintain signal integrity.

Top layer clearance areas are mirrored on the bottom layer:

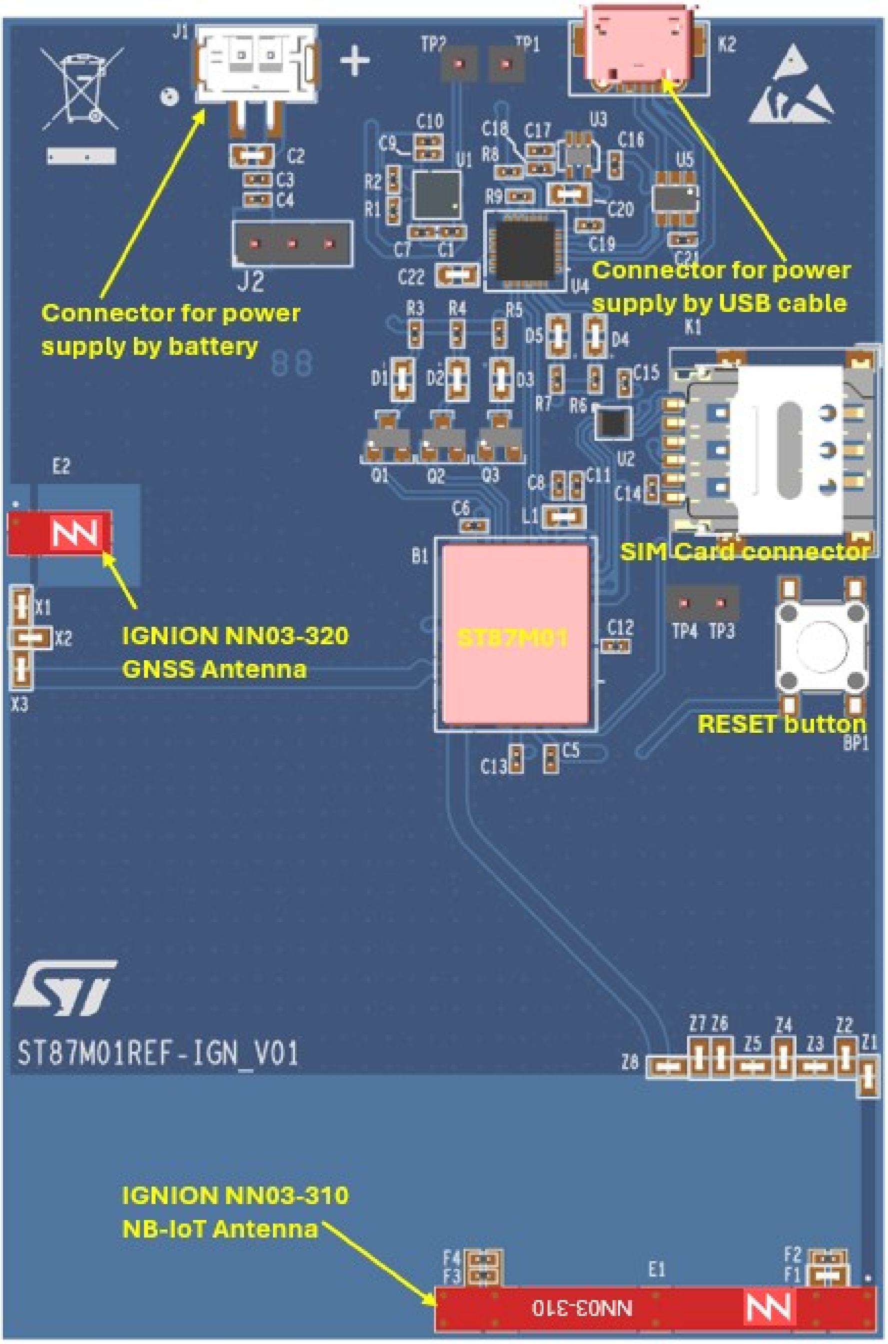
Figure 10. Bottom layer



4.4 PCB with components

Figure 11 shows a TOP view of the board with all the mounted components, and the key components are highlighted in a yellow colour for easier identification:

Figure 11. Board with mounted components



No components are mounted in the bottom layer.

5 Evaluation of the RF performance in passive mode

The RF performances explained in this section are related to the NB-IoT and GNSS antenna performances of the ST87M01REF-IGN_V01. They are:

- Return loss (S11-parameter)
- Tolerance analysis of the matching network components
- Maximum gain
- Radiation pattern (2D & 3D)
- Antenna efficiency

5.1 DUT preparation

RF measurements were performed on an unpopulated board, with only the two antennas and their respective matching networks mounted (see Section 3.3 for the components corresponding to the covered bands). Two coaxial pigtails were soldered at the beginning of the two 50 Ω CPWG lines, one for measuring the NN03-310 NB-IoT antenna performance, and the other for measuring the NN03-320 GNSS antenna performance:

Figure 12. Unpopulated board and points where solder the pigtails (1)

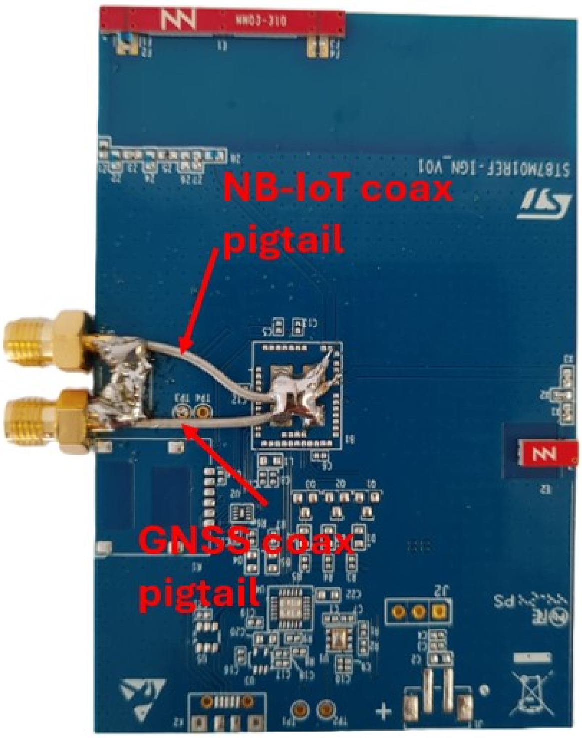
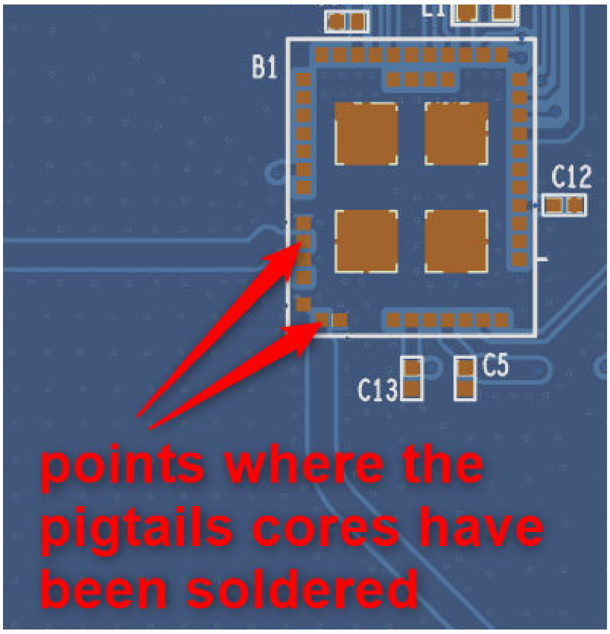


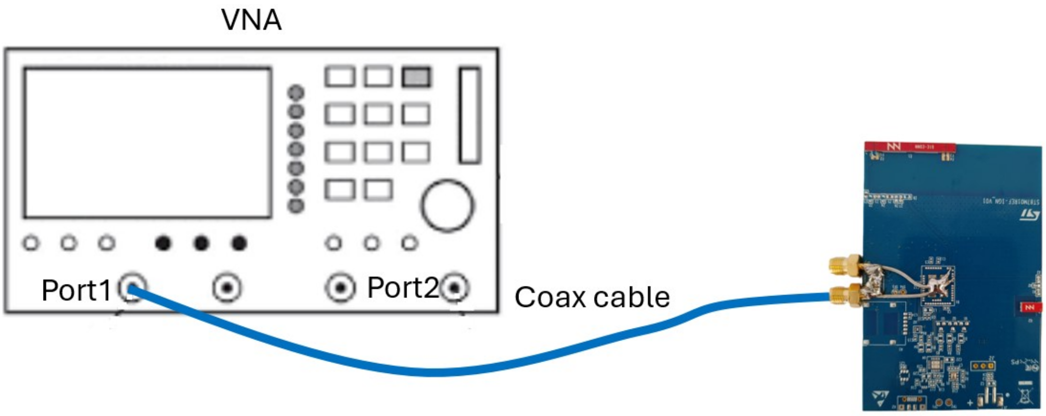
Figure 13. Unpopulated board and points where solder the pigtails (2)



5.2 Set-up

The setup used to measure the S11-parameters (RL) and perform components tolerance analysis consisits of a VNA, a coax cable, and the DUT:

Figure 14. **Setup to measure the S11-parameters**



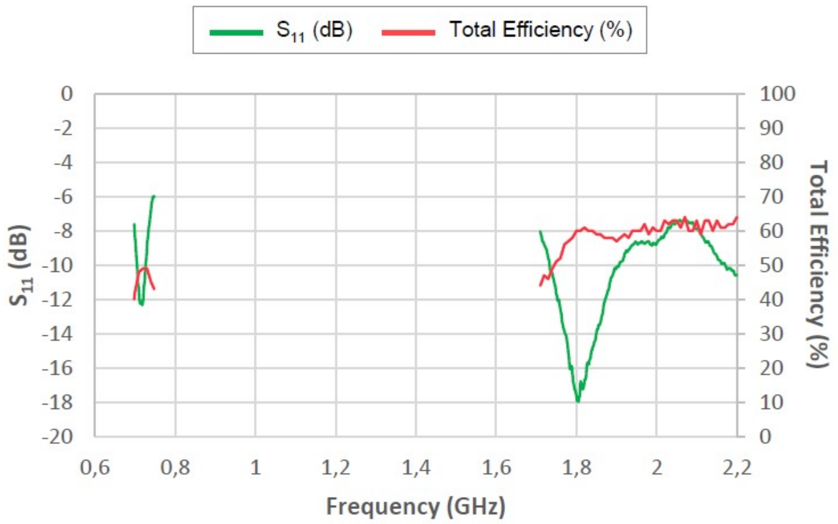
Here is a photo showing where the radiation pattern, the efficiency, and the maximum gain were measured:

Figure 15. **Photo courtesy of Ignion**

5.3 S11-parameters and antenna efficiency measurements

Here are the measurements related to the solution with the matching network components from Table 5:

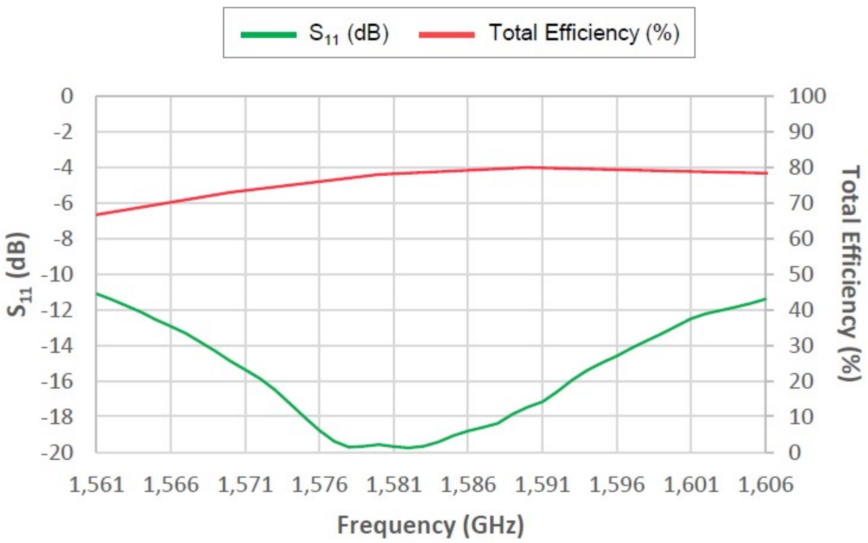
Figure 16. S-param and efficiency for the bands 12 (85), 4, 2, 66, 28



Total efficiency results summary for NB-IoT band

Frequency (MHz)	698	748	Average (698 - 748)	1710	2200	Average (1710 – 2200)
Total Efficiency (%)	40.0	43.0	**45.1**	44.0	64.0	**58.9**

Figure 17. S-param and efficiency for GNSS band

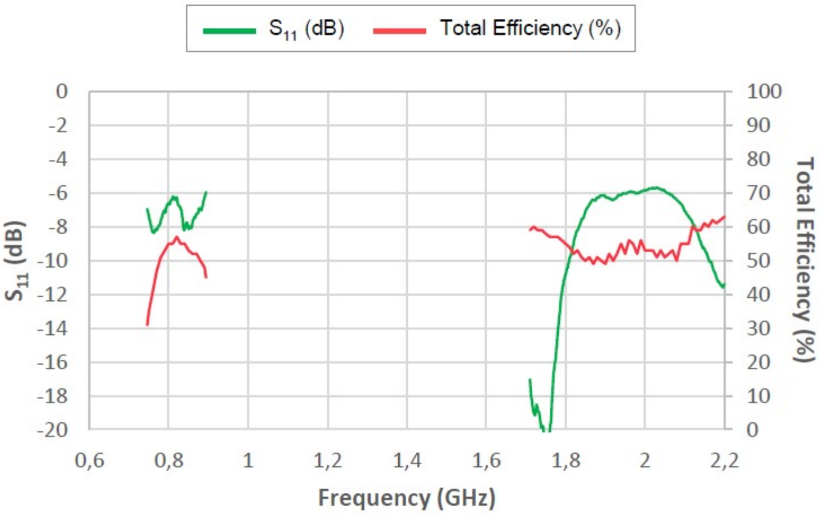


Total efficiency results summary for GNSS band

Frequency (MHz)	1561	1606	Average (1561 - 1606)
Total Efficiency (%)	66.0	78.0	**75.7**

Here are the measurements related to the solution with the matching network components from Table 6:

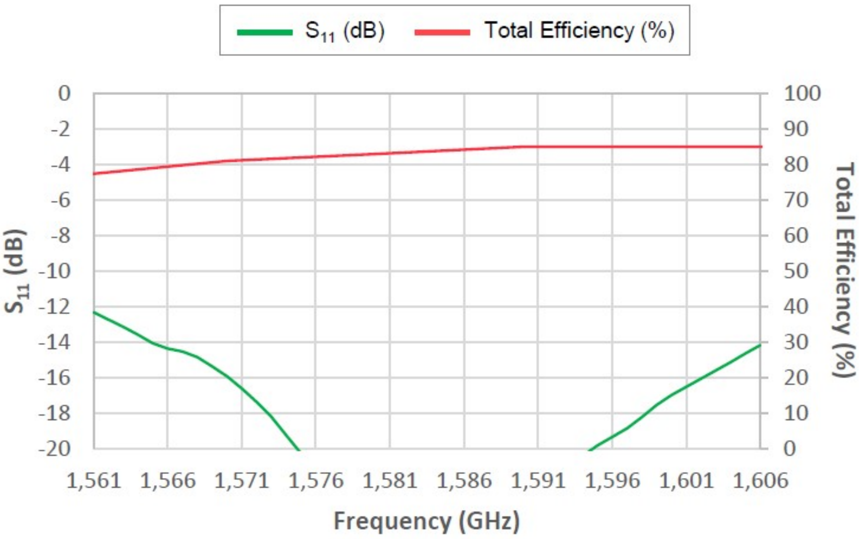
Figure 18. S-param and efficiency for the bands 5, 13, 14, 26, 1, 4, 66



Total efficiency results summary for NB-IoT band

Frequency (MHz)	746	894	Average (746 - 894)	1710	2200	Average (1710 – 2200)
Total Efficiency (%)	31.0	45.0	**49.1**	59.0	63.0	**55.0**

Figure 19. S-param and efficiency for GNSS band

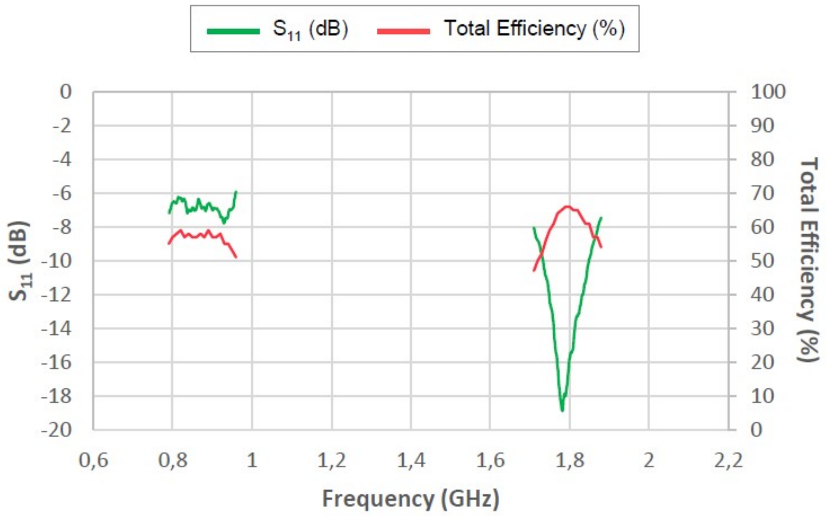


Total efficiency results summary for GNSS band

Frequency (MHz)	1561	1606	Average (1561 - 1606)
Total Efficiency (%)	77.0	85.0	**82.7**

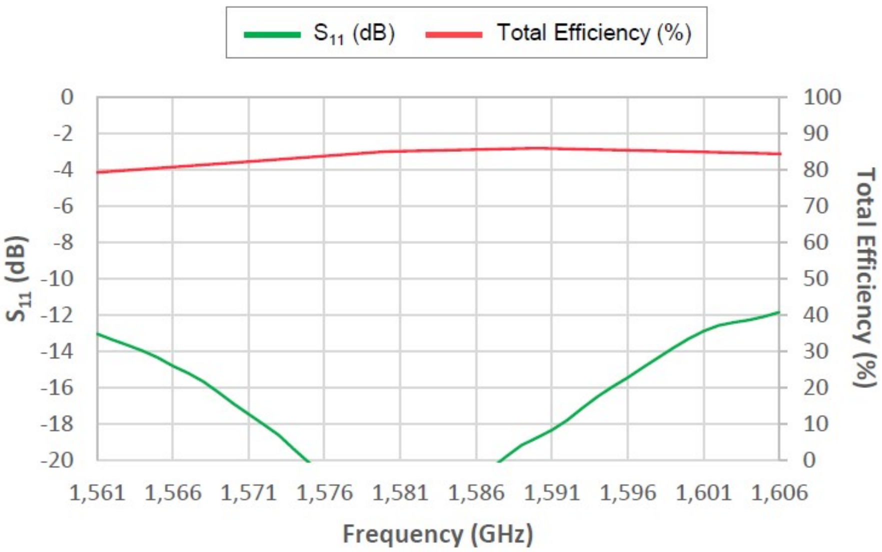
Here are the measurements related to the solution with the matching network components from Table 7:

Figure 20. S-param and efficiency for the bands 3, 8, 20



Total efficiency results summary for NB-IoT band						
Frequency (MHz)	791	960	Average (791 - 960)	1710	1880	Average (1710 – 1880)
Total Efficiency (%)	55.0	51.0	**56.6**	47.0	54.0	**59.4**

Figure 21. S-param and efficiency for GNSS band



Total efficiency results summary for GNSS band			
Frequency (MHz)	1561	1606	Average (1561 - 1606)
Total Efficiency (%)	79.0	84.0	**83.5**

5.4 Tolerance analysis of the matching network components

The tolerance analysis of the matching network components shows the typical deviation in return loss that can be expected under normal conditions. Two sample boards were evaluated for this analysis.

Here are the measurements related to the solution with the matching network components from Table 5:

Figure 22. Return loss deviation for the Bands 12 (85), 4, 2, 66, 28

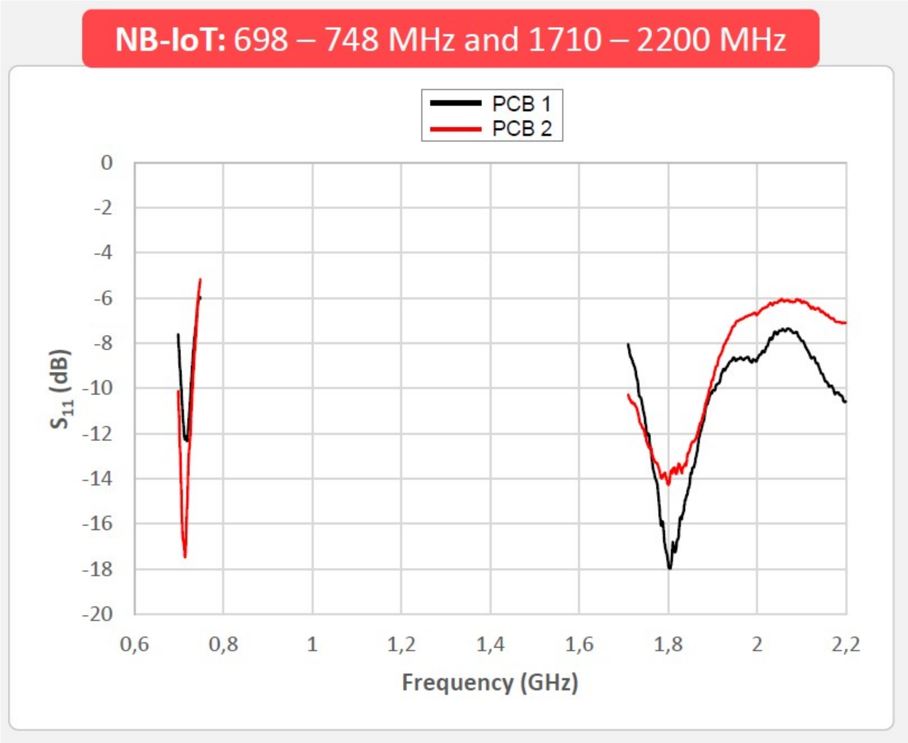
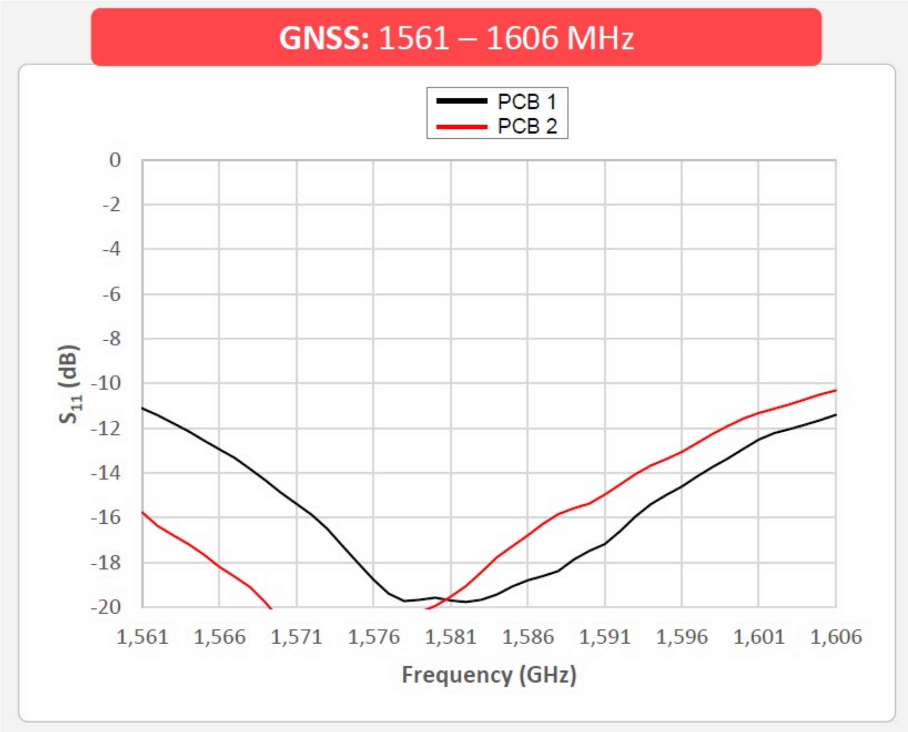


Figure 23. Return loss deviation for GNSS band



Here are the measurements related to the solution with the matching network components from Table 6:

Figure 24. **Return loss deviation for the Bands 5, 13, 14, 26, 1, 4, 66**

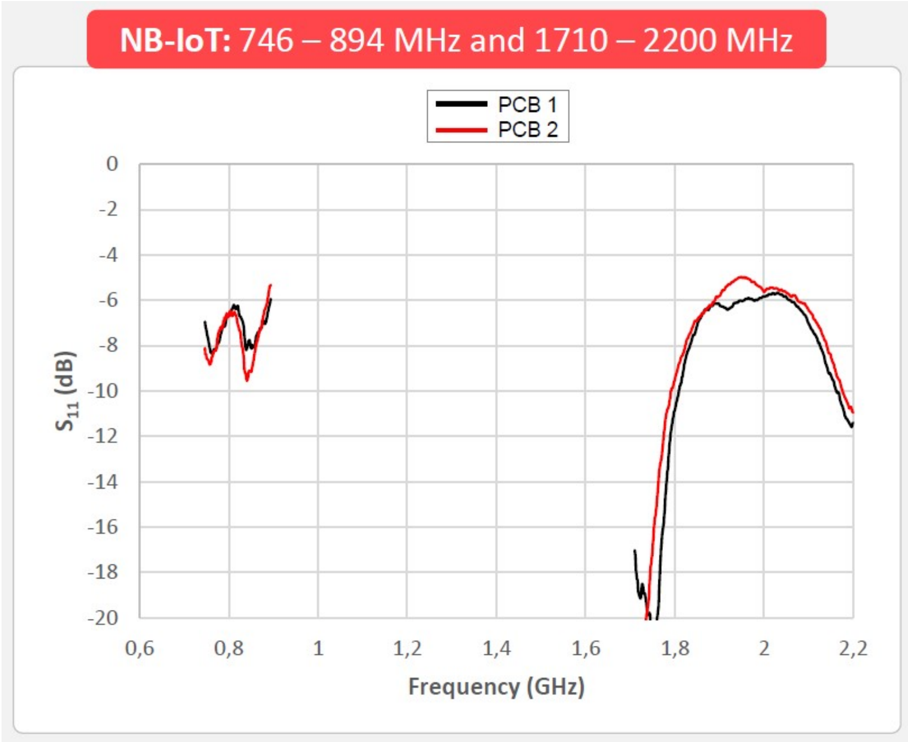
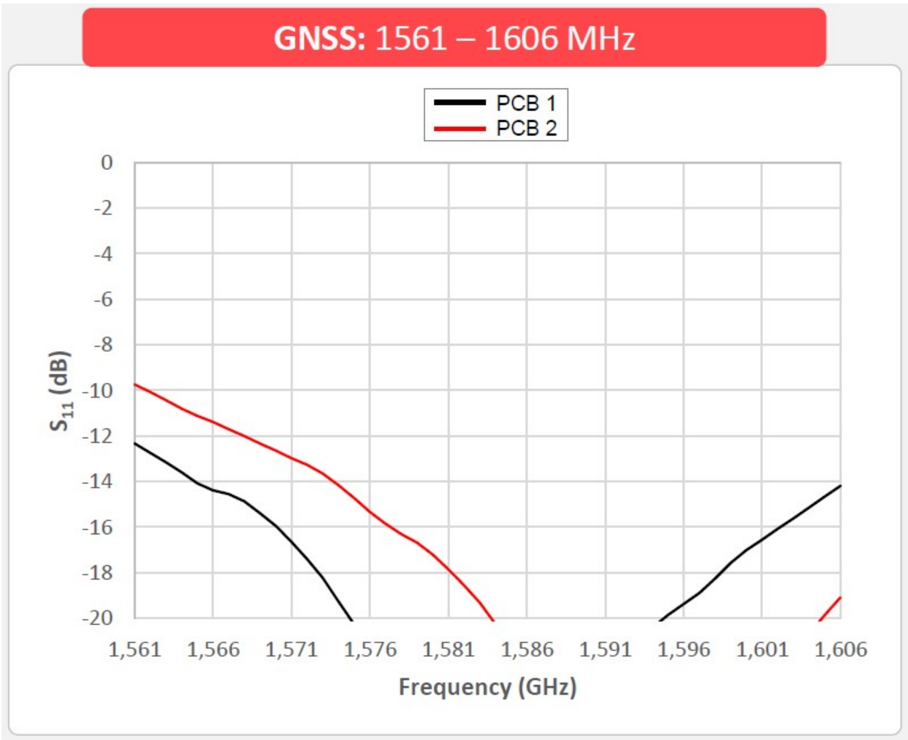


Figure 25. **Return loss deviation for GNSS band**



Here are the measurements related to the solution with the matching network components from Table 7:

Figure 26. **Return loss deviation for the bands 3, 8, 20**

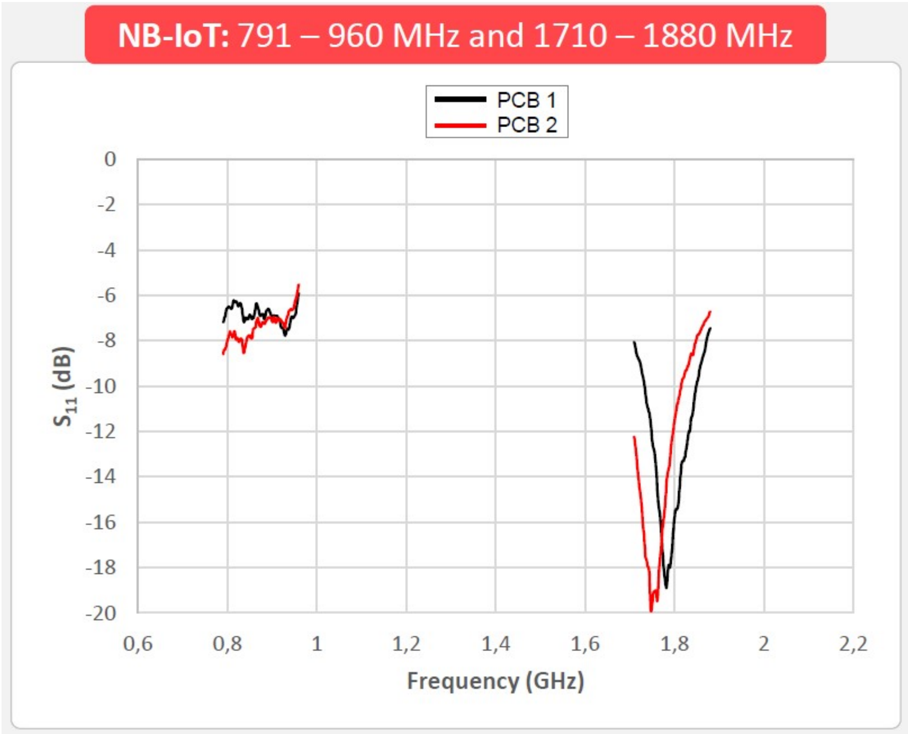
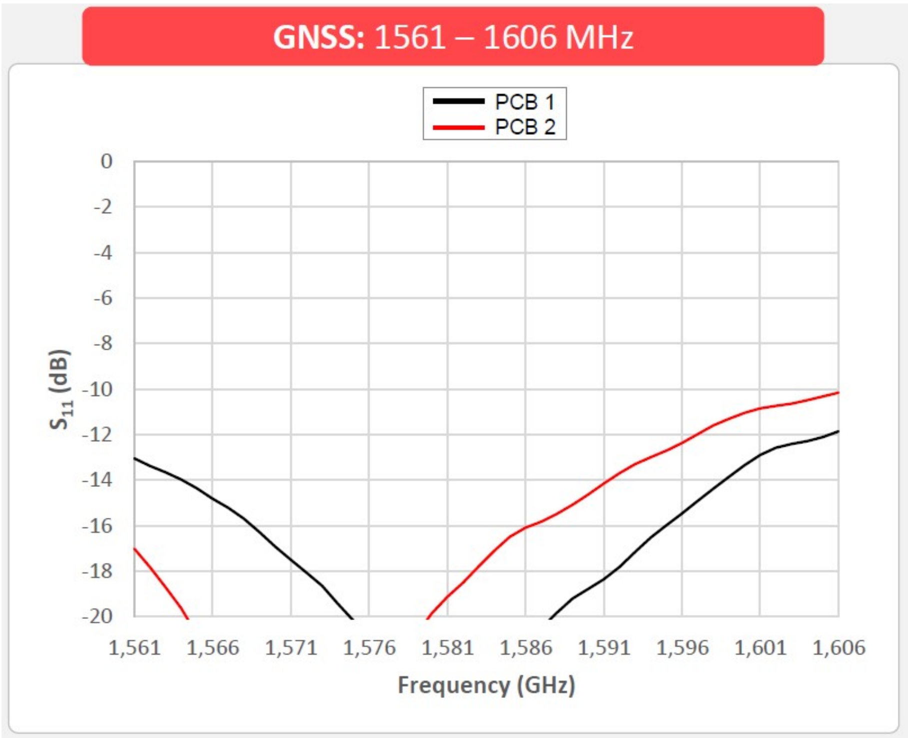


Figure 27. **Return loss deviation for GNSS band**



For all three solutions, no significant deviation has been observed.

5.5 Maximum gain

Here are the measurements related to the solution with the matching network components from Table 5:

Figure 28. **Maximum gain for the NB-IoT antenna**

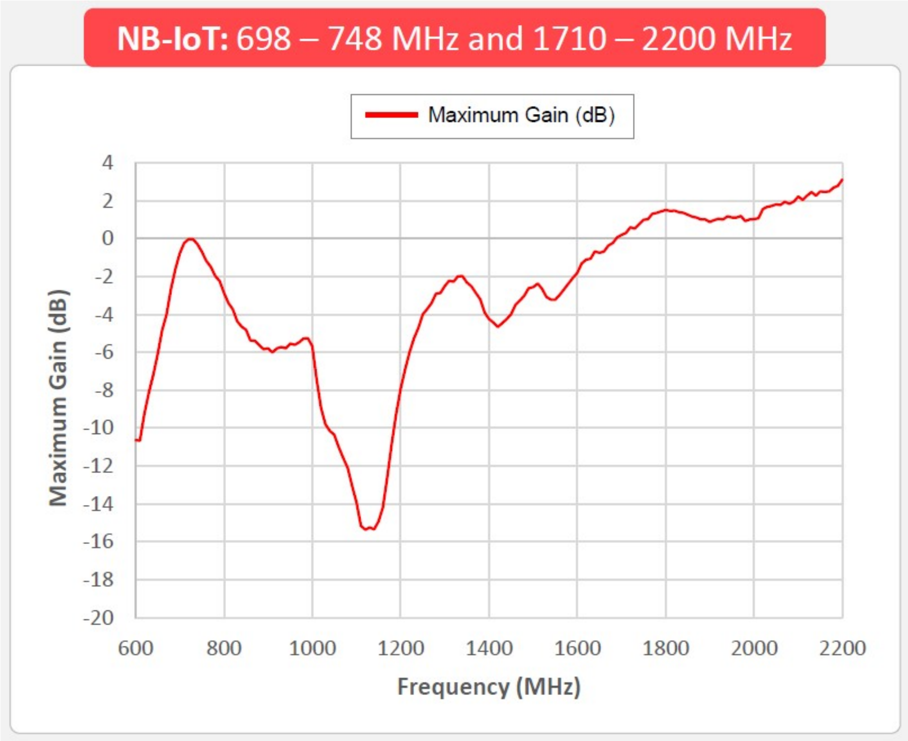
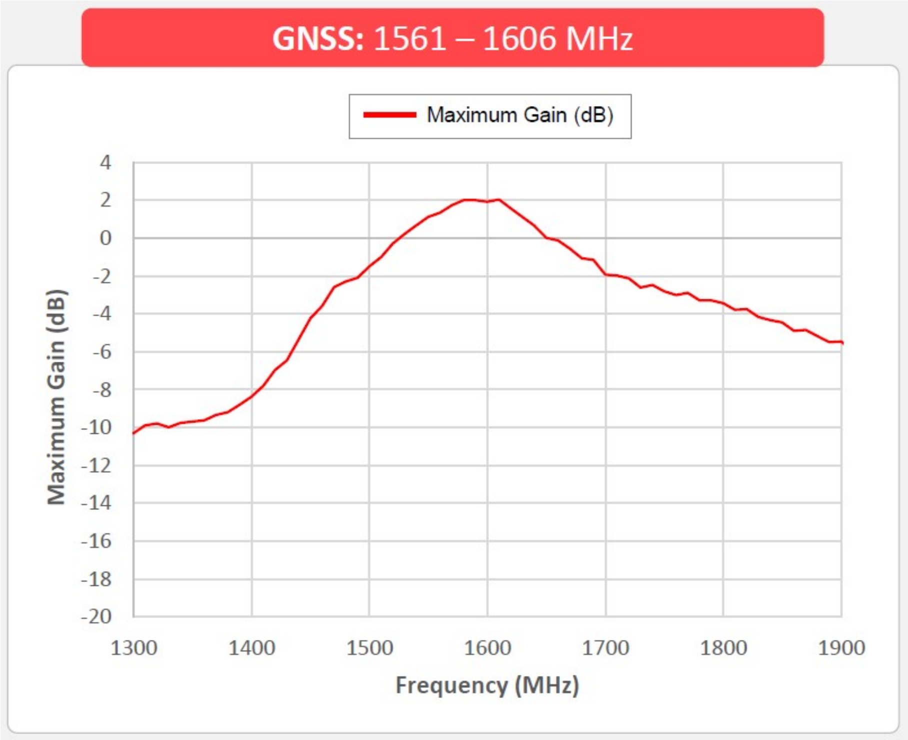


Figure 29. **Maximum gain for the GNSS antenna**



.

Here are the measurements related to the solution with the matching network components from Table 6:

Figure 30. **Maximum gain for the NB-IoT antenna**

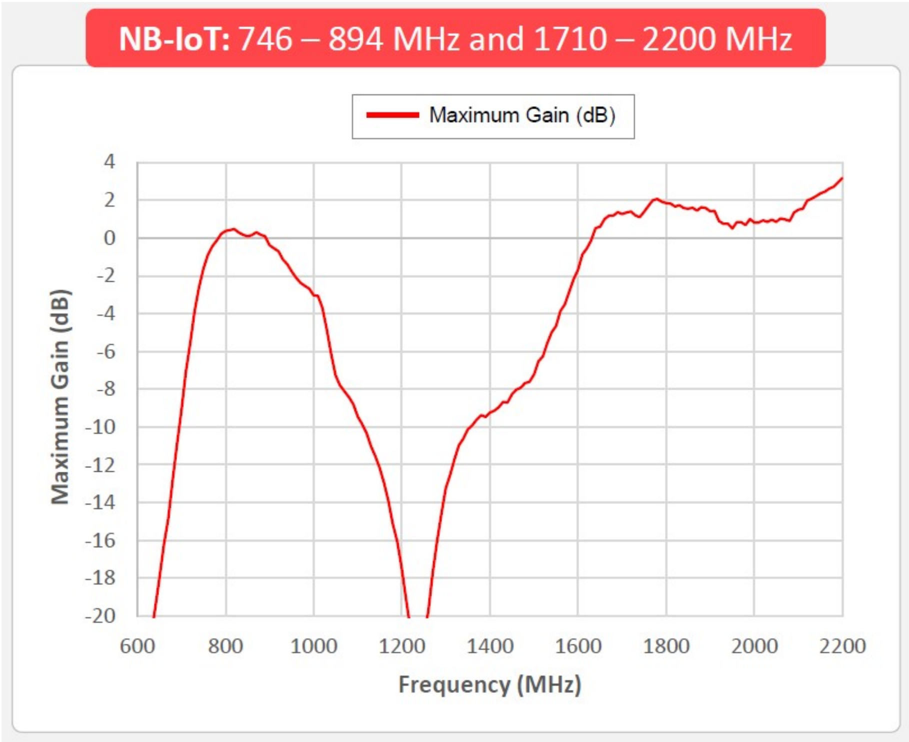
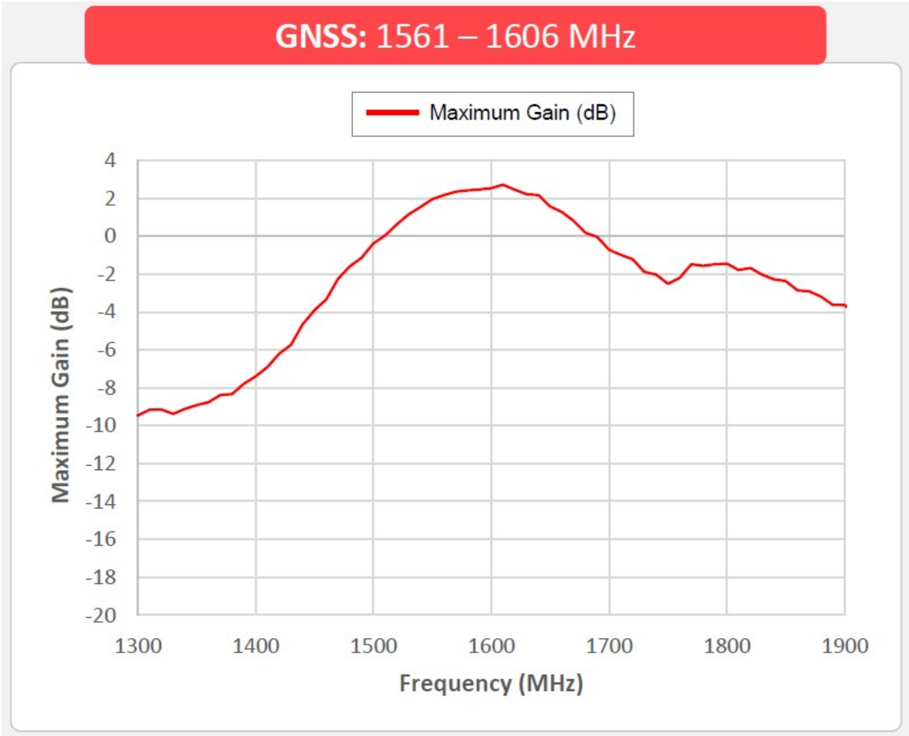


Figure 31. **Maximum ain for the GNSS antenna**



Here are the measurements related to the solution with the matching network components from Table 7:

Figure 32. **Maximum gain for the NB-IoT antenna**

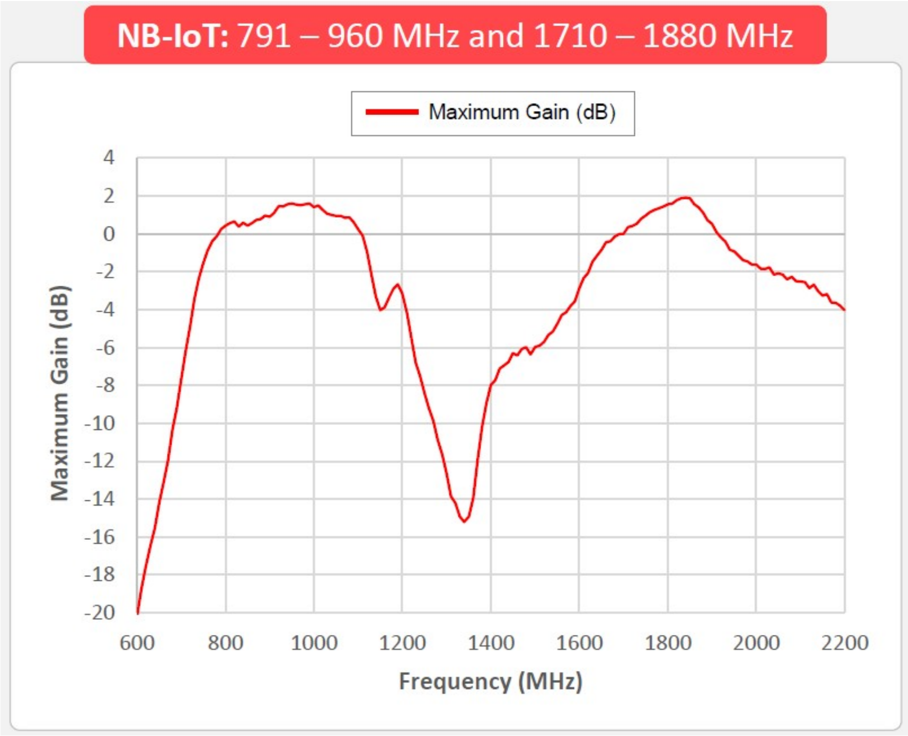
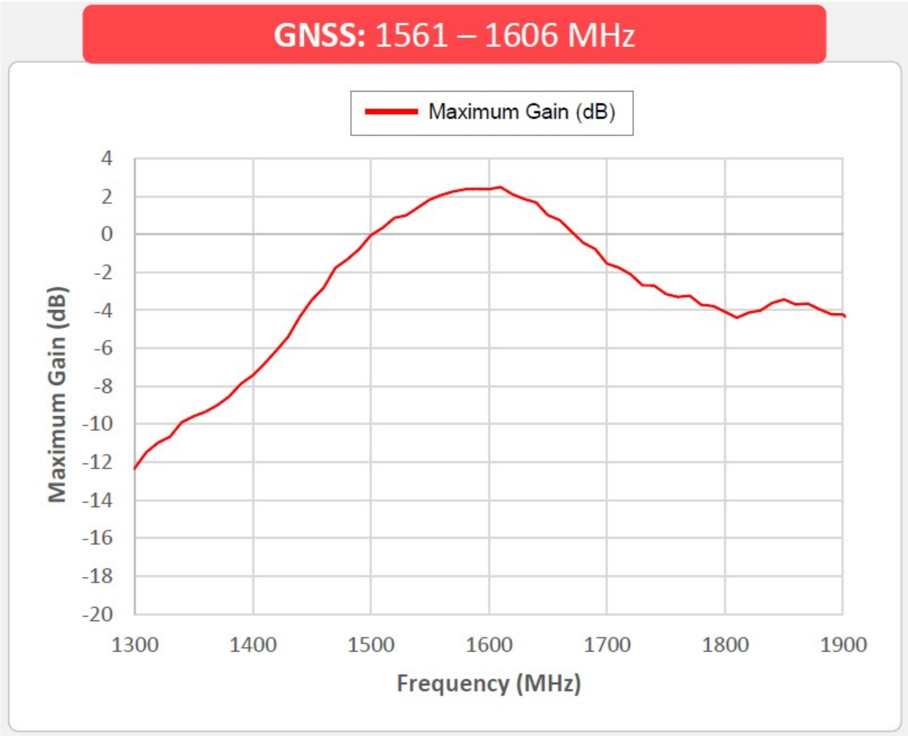


Figure 33. **Maximum gain for the GNSS antenna**



5.6 2D radiation pattern

The 2D radiation pattern graphs reported here show the gain at various angles for the vertical polarization.

Here are the measurements related to the solution with the matching network components from Table 5:

Figure 34. Axis for 2D radiation pattern

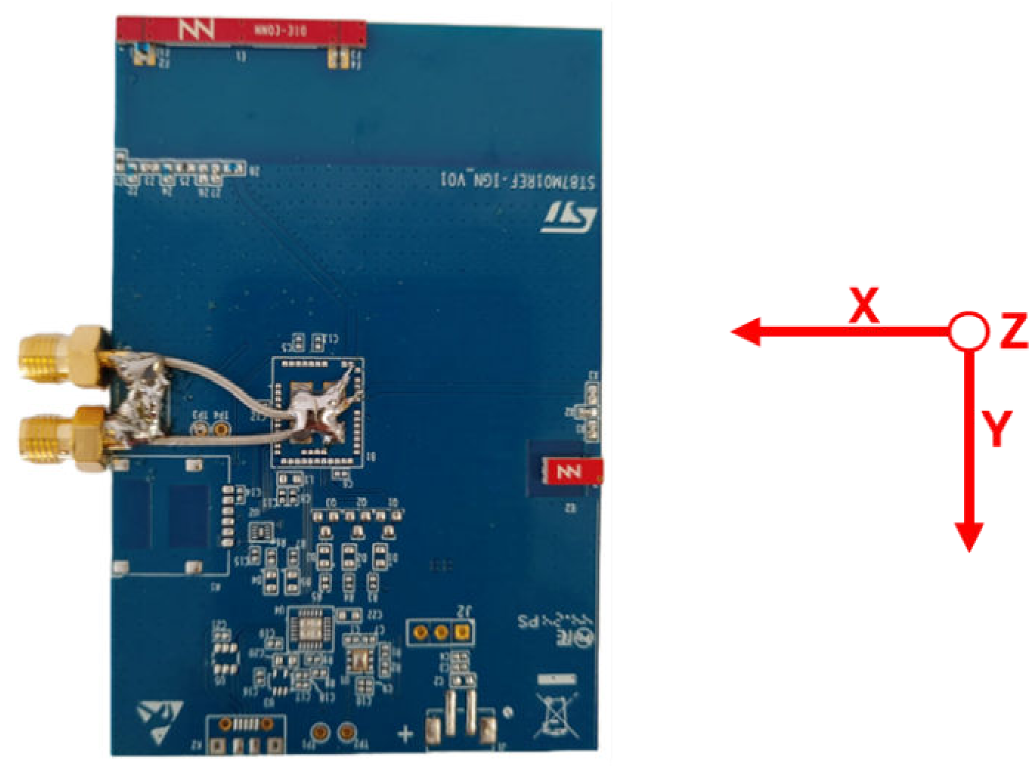
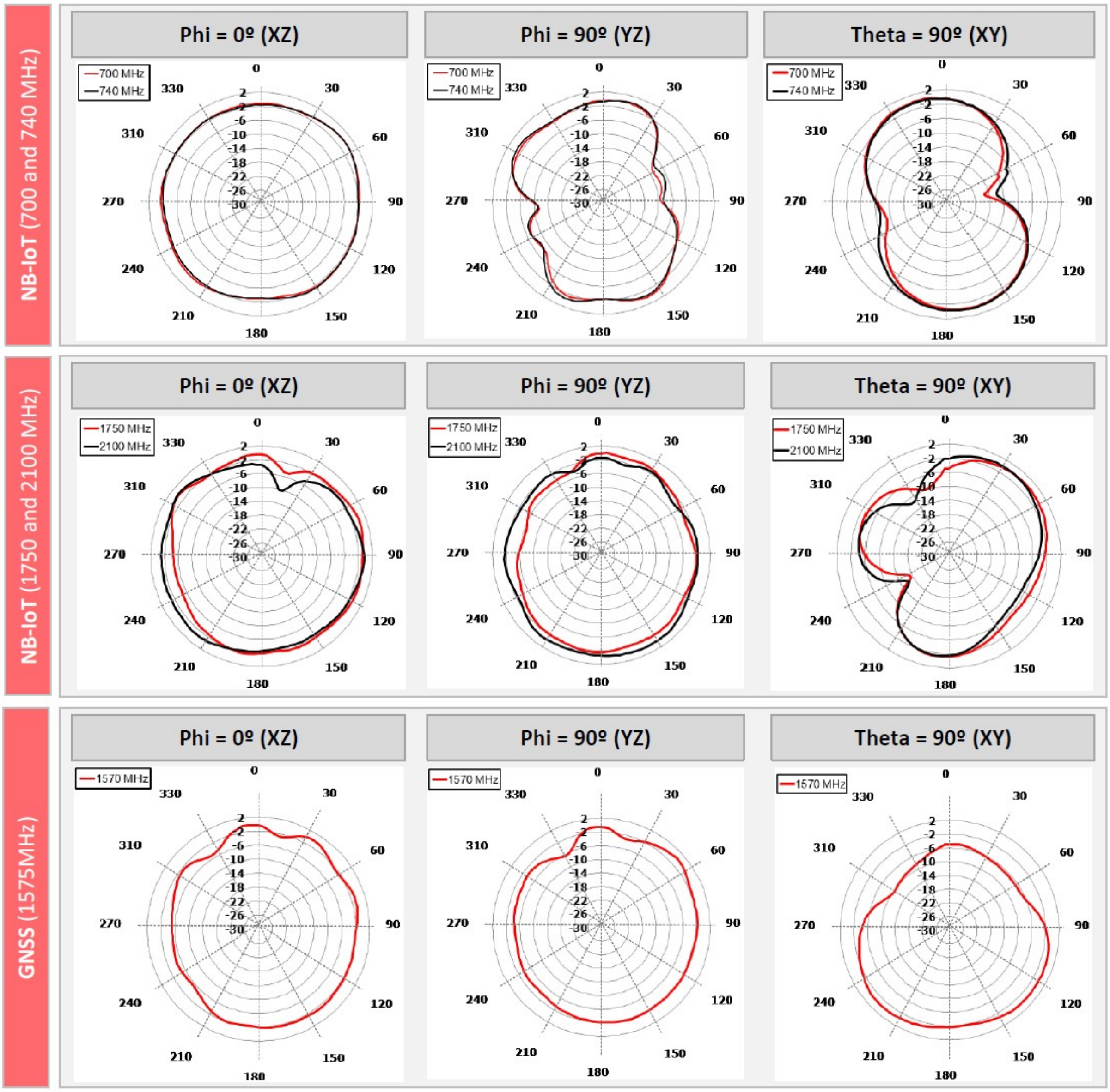
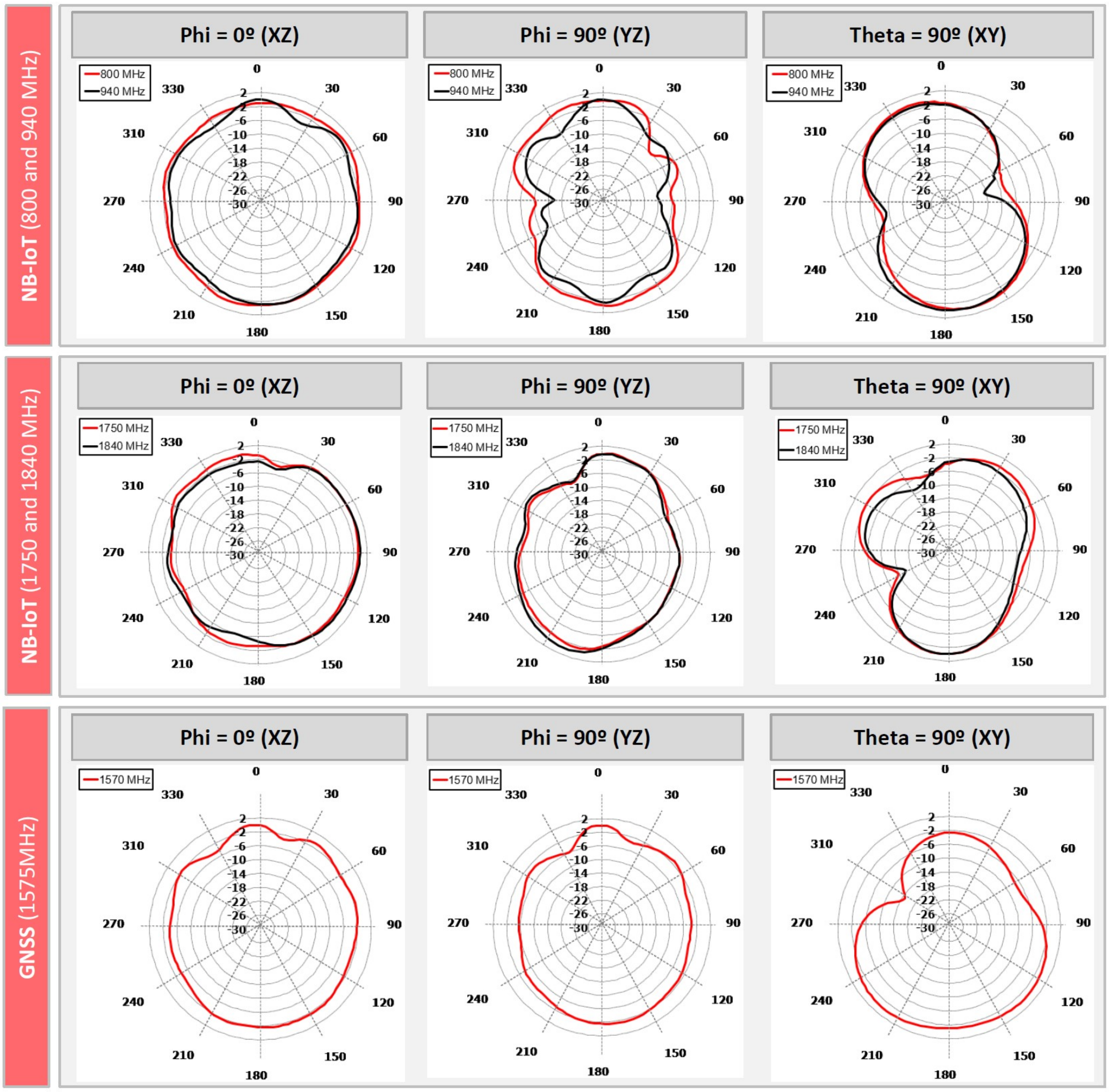


Figure 35. Radiation patterns for the NB-IoT and GNSS antennas



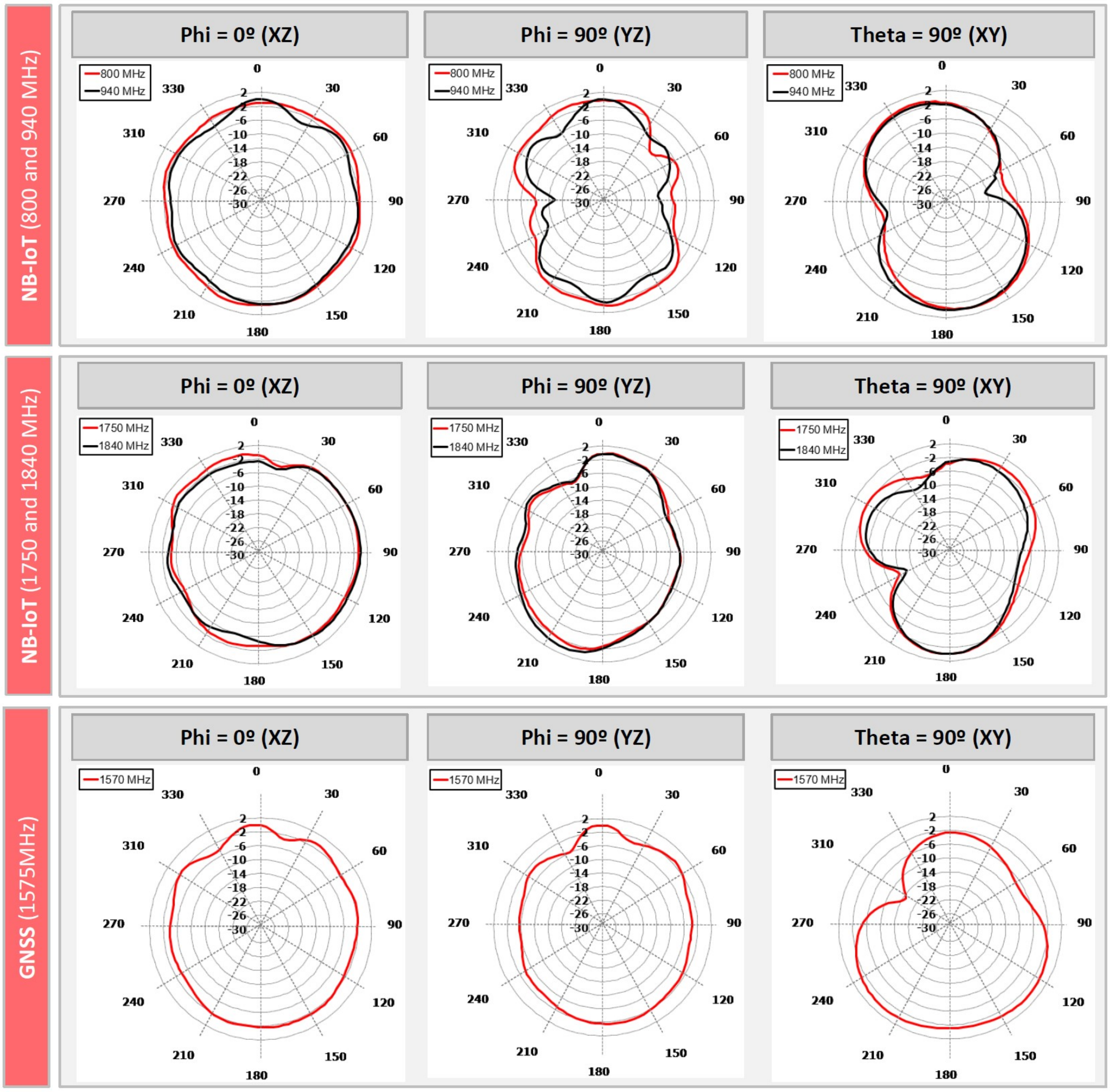
Here are the measurements related to the solution with the matching network components from Table 6:

Figure 36. Radiation patterns for the NB-IoT and GNSS antennas



Here are the measurements related to the solution with the matching network components from Table 7:

Figure 37. Radiation patterns for the NB-IoT and GNSS antennas



5.7 3D radiation pattern

Here are the 3D radiation patterns related to the solution with the matching network components from Table 5 for three frequencies:

Figure 38. 3D radiation patterns @ 720 MHz

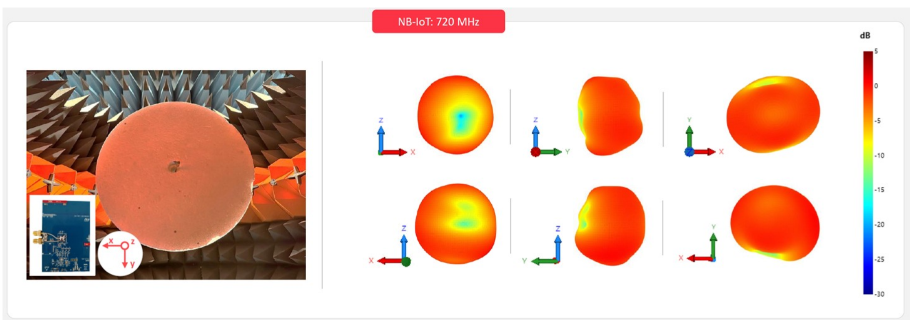


Figure 39. **3D radiation patterns @ 1800 MHz**

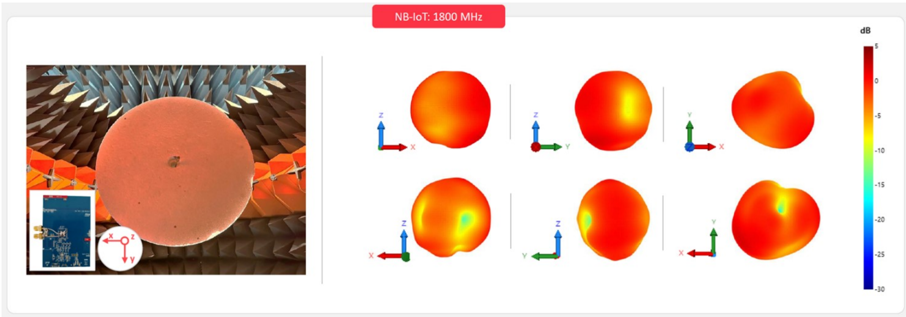
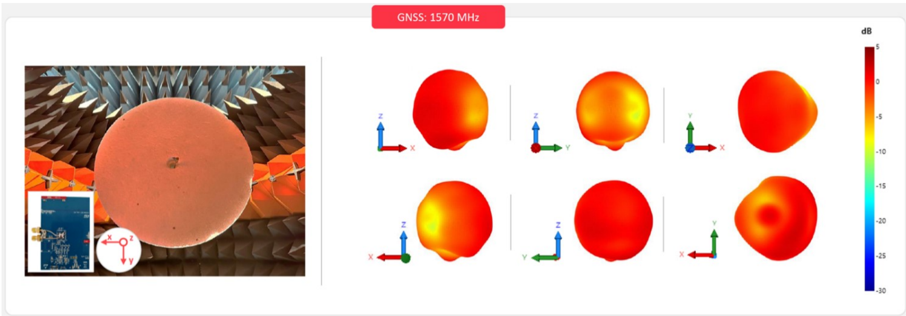


Figure 40. **3D radiation patterns @ 1570 MHz**



6 Evaluation of the RF performances in active mode: TRP

The RF performance in active mode refers to the NB-IoT performance of the ST87M01REF-IGN_V01 board when the ST87M01 module is communicating with a radio communication tester. In particular, the Total Radiated Power (TRP) was measured for each solution across different channels.

6.1 TRP results

The following table shows the TRP measurements for solution 1 (board with the matching network components from Table 5), solution 2 (board with the matching network components from Table 6) and solution 3 (board with the matching network components from Table 7):

Figure 41. TRP

		Total Radiated Power (TRP)		
		Channel (MHz)	Measured TRP (dBm)	Expected TRP* min – max (dBm)
Solution 1	Band 28	703	18.8	17.6 – 21.6
		725.5	20.3	
		747.9	20.3	
Solution 2	Band 1	1920	22.2	18.3 – 22.3
		1950	21.5	
		1979.9	21.2	
Solution 3	Band 5	824	19.9	18.6 – 22.6
		836.5	20.1	
		848.9	20.2	
	Band 20	832	19.7	18.6 – 22.6
		847	20.0	
		861.9	19.8	
	Band 8	880	20.8	18.6 – 22.6
		897.5	20,8	
		914.9	20.8	
	Band 3	1710	21.4	18.5 – 22.5
		1747.5	21.7	
		1784.9	22.1	

*Expected TRP is calculated through total efficiency (passive measurements) and theoretical power injected by the ST87M01 module (+21 dBm min, +23 dBm max)

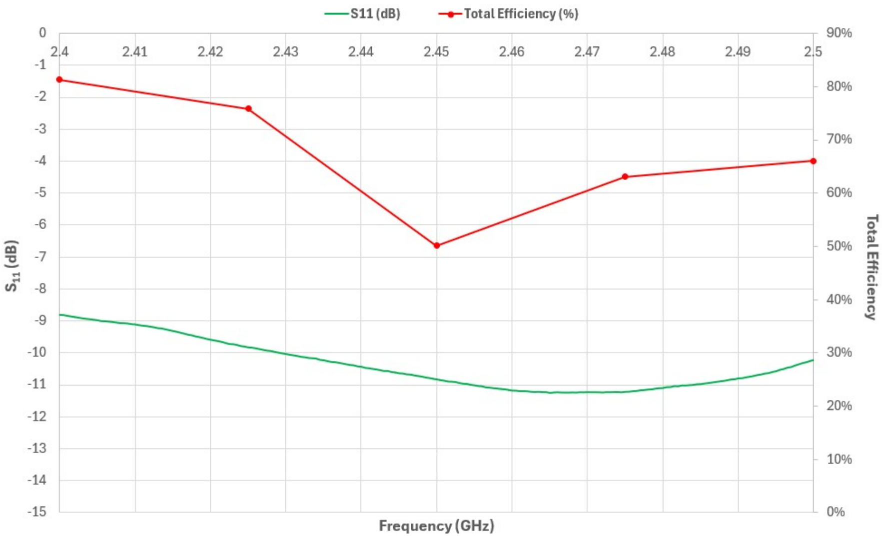
All measurements were performed for each covered NB-IoT band, at the lower, middle, and higher channels. The TRP results are aligned with the expected values.

7 Wi-Fi frequency range - RF performances

The NN03-310 Ignion chip antenna can also work at Wi-Fi frequencies. As usual, an appropriate matching network must be designed. For example, solution 1 (board with the matching network components from Table 5) already fits this.

Here are the return loss and antenna efficiency for the Wi-Fi frequency range of solution 1:

Figure 42. Return Loss and antenna efficiency for solution 1 - Wi-Fi frequency range



Revision history

Table 8. **Document revision history**

Date	Version	Changes
08-Sep-2025	1	Initial release.

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