

## NN Design Hub: NN Librarie[S]



Here you are the NN Librarie[S], the new design tool by Fractus Antennas (NN) that helps you design the antenna for your wireless device using any standard RF CAD software. Just select your PCB size and the mXTEND™ antenna type, download the file from our website and import the library file into your preferred design software.

Based on our Virtual Antenna™ technology, all files in NN Librarie[S] form a group of [S] parameters for several wireless platforms, with different PCB/ground plane form factor and clearance area dimensions. By choosing the file with the closer specs to your device you can implement your matching network easy and fast in just a few clicks.

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## 1. WHAT IS A LIBRARY FILE?

### 1.1. LIBRARY FILE DEFINITION

The new tool, NN Librarie[S], provides a collection of [S] parameter files for every specific mXTEND™ antenna component (i.e., a Virtual Antenna™ component) as mounted on a variety of wireless platforms with different form factors and printed circuit board (PCB) sizes. Each library file is associated to a different ground plane and a recommended clearance area, so the user can make a choice of the most suitable one depending on the form factor of his wireless device. Upon uploading the corresponding library file into any RF/Microwave circuit design software the user can readily implement a matching network to match the device to its frequency or frequencies of operation and then complete the whole antenna integration work. So, embedding an antenna component into a new wireless device becomes as simple as including any other electronic part into a circuit design.

### 1.2. LIBRARY FILE PLATFORM

You can find below, in *Figure 1*, an example of a basic platform you use in any file within the NN Librarie[S]. It includes a PCB ground plane layer mounted on an FR4 dielectric substrate of 1mm thickness and an mXTEND™ antenna component (e.g. a Virtual Antenna™ booster) located on a clearance area, that is, the area on the ground plane layer surrounding the antenna component where the ground plane conductor is removed. The mXTEND™ antenna component is in some platforms placed at a corner of the PCB in the clearance area, as shown in the left picture from *Figure 1*, and in other platforms, the mXTEND™ component is placed at more distance from the corner (see the platform to the right in *Figure 1*).

The mXTEND™ antenna component is connected to the matching network by a feeding line, as indicated in *Figure 1*. This feeding line features an L-shape for the platforms where the NN mXTEND™ component is not placed at the PCB corner (*Figure 1*). The feeding line features a 2mm width for all platform cases and for those where the feeding line features an L-shape the feeding line measures 5mm from the corner of the PCB to the mXTEND™ antenna component.

*Figure 1* also shows the dimensions of the platform, being  $A \times C$  the board dimensions and  $w \times h$  the clearance area dimensions. The mXTEND™ antenna component is connected to a matching network on the ground plane by means of a feeding line, as described before. A feeding area containing several pads and ports for allocating the matching network is included at the connection point between the feeding line and the ground plane edge.

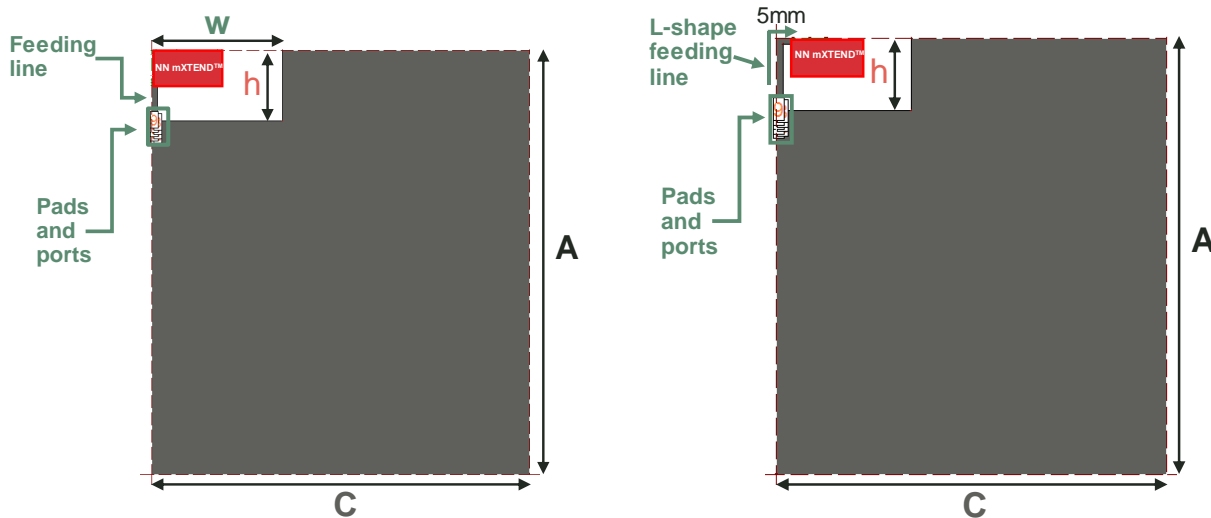


Figure 1 – Example of an NN platform used for creating a library file.

A library file provides the [S] parameters related to a platform as the one described before. These [S] parameters are obtained using an electromagnetic CAD software, all the simulations performed in the frequency range from 650MHz to 6GHz with a step of 10MHz. This is possible because the range of mXTEND™ antenna components are non-resonant, so they can be matched and used in any of the frequency bands within that range, even in multiple ones within such a frequency range.

### 1.3. LIBRARY FILE NAMING

Let’s see now how each library file is named. For an easy and convenient identification, every file is individually named using the following genal rule: **NN\_mXTEND™ Antenna Component\_BAxC\_Cwxh.s9p**

Each name helps identifying the file content as the different parts of the name correspond to a specific information related to the simulated platform. This information is provided in the following *Table 1*. It is worth noticing that the extension **.s9p** indicates that the [S] params are calculated at 9 ports defined in the feeding area of the platform as it is shown in the section 4 of this manual.

Library File Name				
NN	mXTEND™ Antenna Component	BAxC	Cwxh	.s9p
Fractus Antennas Logo	Antenna component name	B: Board	C: Clearance	File extension
		AxC: board dimensions	wxh: clearance dimensions	

Table 1 – Library file name by parts.

For instance, if we have the following data on the file:

Library File Name				
NN	mXTEND™ Antenna Component	BxAc	Cwxh	.s9p
Fractus Antennas Logo	<b>CUBE</b>	B: Board	C: Clearance	File extension
		AxC: <b>120X60</b>	wxh: <b>60X11</b>	

**Table 1.1.** – Example of a library file name by parts.

Then, the file name will be: **NN\_CUBE\_B120x60\_C60x11.s9p**

**Example of File Name**

*NN\_CUBE\_B120x60\_C60x11.s9p* contains the [S] params corresponding to an NN platform using a CUBE mXTEND™ integrated in a board of dimensions 120mm x 60mm featuring a clearance of 60mm x 11mm for allocating the CUBE mXTEND™ component.

**1.4. LIBRARY FILE CONTENT**

Each library file contains the information described below and structured as follows.

**Example of Library File Content: Header Information, Parameters Information**

*An example is provided below, it corresponds to the file NN\_CUBE\_B120x60\_C60x11.s9p file introduced before.*

*It is worth noticing that a line beginning with the ! character corresponds to a comment line that it is normally not interpreted by a matching-circuits design software that reads this type of files.*

**1.4.1. HEADER INFORMATION**

- The name of the library file
- The name, reference and size of the mXTEND™ antenna component used in the NN platform to which corresponds the library file
- A link to the NN's website providing more information about the mXTEND™ antenna specified in the previous point
- Board dimensions
- Clearance area dimensions
- Feeding line shape and dimensions: a first dimension, from the ground plane edge to the board corner, and second dimension only for L-shape lines, from the board corner to the mXTEND™ antenna component
- Possible applications for which the platform related to the library file can be used
- Frequency range at which the [S] params included in this library file are calculated
- The number of ports defined in the platform and for which the [S] parameters are calculated
- A paragraph related to the NN's patents and/or patents applications that protect this platform and the mXTEND™ antenna component as an NN product and their use
- Some additional information preceded by the word "*Touchstone*" about the platform ports. These lines are sometimes interpreted by some of the matching-circuits softwares able to import and use the library file

```

! FRACTUS ANTENNAS VIRTUAL ANTENNA LIBRARY
!
! NN_CUBE_B120x60_C60x11
! Cube mXTEND™: FR01-S4-250 5.0 mm x 5.0 mm x 5.0 mm
! https://www.fractusantennas.com/chip-antenna/
! Board: 120 mm x 60 mm
! Clearance Area: 60 mm x 11 mm
! Feeding line: L-shape; 11mm x 2mm and 5mm x 2mm
! Applications: Smartphone, Fleet management, IoT
! Frequency range 0.65GHz to 6GHz, step 10MHz
! Number of ports 9
!
! This product is protected by at least the following patent PAT. US 8,203,492 and other domestic and
! international patents pending. Any update on new patents linked to this product will appear in
! www.fractusantennas.com/virtual-antenna/, all rights reserved. Copyright, Fractus Antennas 2018.
!
!
! Touchstone port 1 = "Series Port"
! Touchstone port 2 = "Shunt Port"
! Touchstone port 3 = "Series Port"
! Touchstone port 4 = "Shunt Port"
! Touchstone port 5 = "Series Port"
! Touchstone port 6 = "Shunt Port"
! Touchstone port 7 = "Series Port"
! Touchstone port 8 = "Shunt Port"
! Touchstone port 9 = "Series Port"
!

```

**Example:** Header information.

## 1.4.2. PARAMETERS

### 1.4.2.1. Parameters general information

Following the header, the lines concern the representation of the [S] parameters. They are calculated by an EM CAD software at the 9 ports defined in the platform for each frequency included in the simulation. This is because each platform in the NN Librarie[S] enables implementing a matching network, normally with up to 8 components, or even more in some solutions, on a ladder structure and those ports enable inserting a series or a shunt component for matching, as shown in section 4.

For each port, the frequency is provided in GHz at the beginning of each paragraph of [S] params. Each [S] parameter is represented by its magnitude and angle, as indicated by the “M” and the “A” found in the following example lines included in a library file. The “R 50” text from the example lines provided below indicates that the [S] params are calculated regarding an impedance  $Z=50\Omega$  (only resistance component).

```
! IE3D S-Parameters Output Version 2.0
# GHZ S MA R 50
! Nport = 9
!
```

**Example:** Parameters general information.

### 1.4.2.2. Frequency, magnitude and angle

The last information provided is the **frequency**, the **magnitude** and the **angle** representing each [S] parameter related to each of the 9 ports of the structure.

Each line of [S] params includes 9 [S] parameters related to each port calculated for the corresponding frequency, indicated at the beginning of each paragraph, as already mentioned. In total, 9x9 [S] params are calculated and provided for each frequency at each [S] paragraph.

```
6.500000000000000e-001 2.50068754269855e-001 1.52214978070981e+002 7.61850929784291e-001
-5.44468308925773e+000 4.66963165069729e-001 1.72162180454406e+002 2.93191507483463e-
001 -8.10754730165073e+000 1.74510844131583e-001 1.71986476312820e+002
1.18437307738526e-001 -9.52593599010154e+000 5.66572190450041e-002
1.75180486768357e+002 6.19975571595999e-002 -1.23266198912485e+001 9.50771242509153e-
```

**Example:** Line of text with frequency, magnitude and angle for the first 9 [S] parameters.

As shown with this example and as explained before, for each frequency a paragraph with 9 lines of [S] parameters, so 9x9, i.e. 81 [S] parameters, are found in a library file for each frequency band.



## 2. AVAILABLE mXTEND™ ANTENNA COMPONENTS

The range of products by Fractus Antennas are named mXTEND™. Please, find below the whole range of available NN's Virtual Antenna™ 'boosters', used in the wireless platforms included in our NN Librarie[S]. You can also find below their part number and dimensions together with the possible bands covered in solutions already implemented with those pieces. Notice that the acronym standing out in bold and capital letters is the name of the mXTEND™ antenna component used to create the library file names, as explained in chapter 1.3.

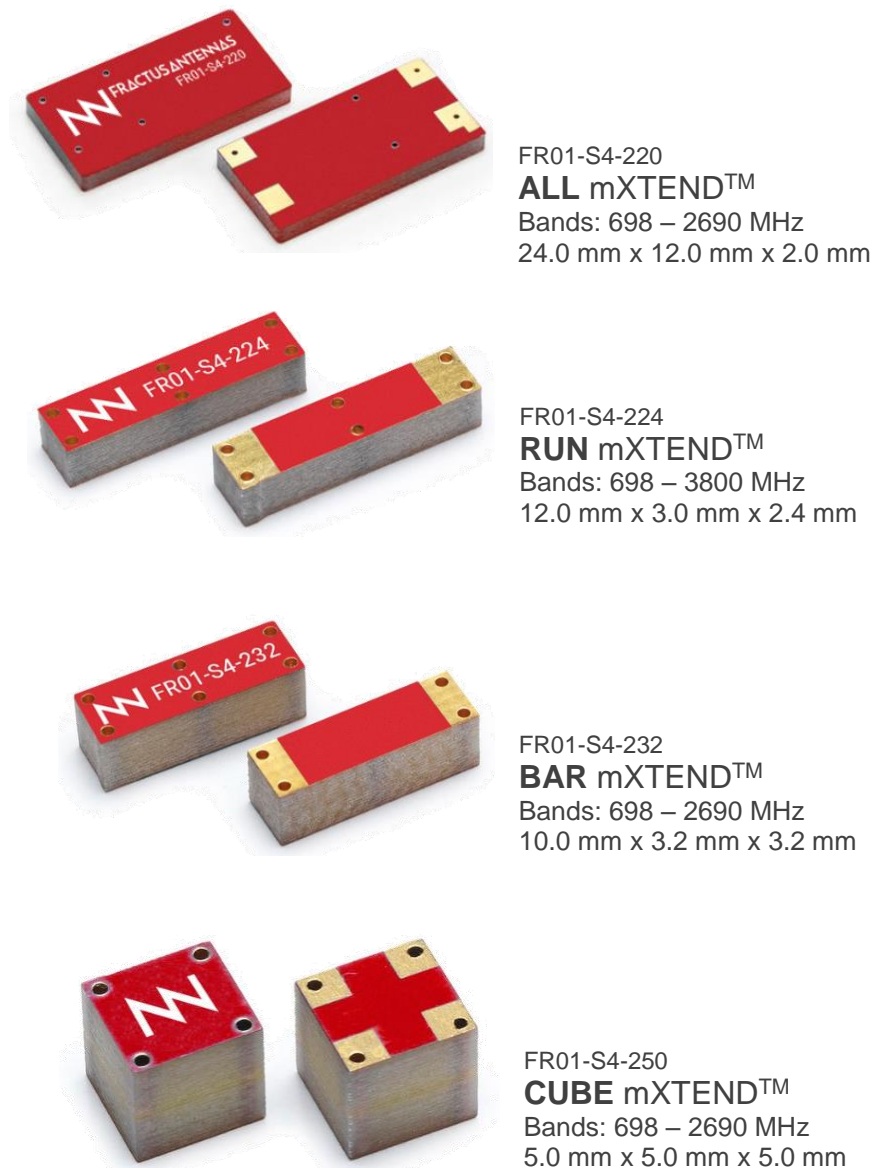


Figure 2 – NN mXTEND™ antenna components available in the NN Librarie[S].

### 3. CHOOSE THE RIGHT LIBRARY FILE FOR YOUR APPLICATION

The table below provides the different platforms available for direct download. Each possible platform has a library file name assigned that you can find on the right-side column. The dimensions of the board together with those of the clearance area available in the board for allocating the NN mXTEND™ antenna component are included in the third and fourth columns.

**Choose the right file: Size, Space and Clearance**

*A quick look to the table allows you to choose a library file depending on your platform requirements, especially in terms of size and the available space for allocating the mXTEND™ antenna component, that is the clearance area.*

Application	NN mXTEND™ Antenna Component	Board Size AxC mm <sup>2</sup>	Clearance Size wxh mm <sup>2</sup>	Library File Name
Smart meter	RUN	145x130	45x24	NN_RUN_B145x130_C45x24.s9p
	ALL	145x130	45x24	NN_ALL_B145x130_C45x24.s9p
Smartphone	RUN	130x60	20x11	NN_RUN_B130x60_C20x11.s9p
Fleet Management Module	RUN	120x60	60x11	NN_RUN_B120x60_C60x11.s9p
	RUN	105x45	45x11	NN_RUN_B105x45_C45x11.s9p
	RUN	70x40	40x11	NN_RUN_B70x40_C40x11.s9p
	CUBE	120x60	60x11	NN_CUBE_B120x60_C60x11.s9p
	CUBE	105x45	45x11	NN_CUBE_B105x45_C45x11.s9p
	CUBE	70x40	40x11	NN_CUBE_B70x40_C40x11.s9p
IoT	RUN	90x90	90x11	NN_RUN_B90x90_C90x11.s9p
	RUN	90x70	70x11	NN_RUN_B90x70_C70x11.s9p
	RUN	85x55	55x11	NN_RUN_B85x55_C55x11.s9p
	RUN	70x55	55x11	NN_RUN_B70x55_C55x11.s9p
	RUN	50x55	55x11	NN_RUN_B50x55_C55x11.s9p
	RUN	50x40	40x11	NN_RUN_B50x40_C40x11.s9p
	RUN	50x20	20x11	NN_RUN_B50x20_C20x11.s9p
	CUBE	90x90	90x11	NN_CUBE_B90x90_C90x11.s9p
	CUBE	90x70	70x11	NN_CUBE_B90x70_C70x11.s9p
	CUBE	85x55	55x11	NN_CUBE_B85x55_C55x11.s9p
	CUBE	70x55	55x11	NN_CUBE_B70x55_C55x11.s9p
	CUBE	50x55	55x11	NN_CUBE_B50x55_C55x11.s9p
	CUBE	50x40	40x11	NN_CUBE_B50x40_C40x11.s9p
	CUBE	50x20	20x11	NN_CUBE_B50x20_C20x11.s9p
Wearable	RUN	30x30	14x5	NN_RUN_B30x30_C14x5.s9p
Routers/Repeaters	RUN	140x120	120x11	NN_RUN_B140x120_C120x11.s9p
	BAR	140x120	120x11	NN_BAR_B140x120_C120x11.s9p

**Table 2** – Platforms available in the NN Librarie[S].

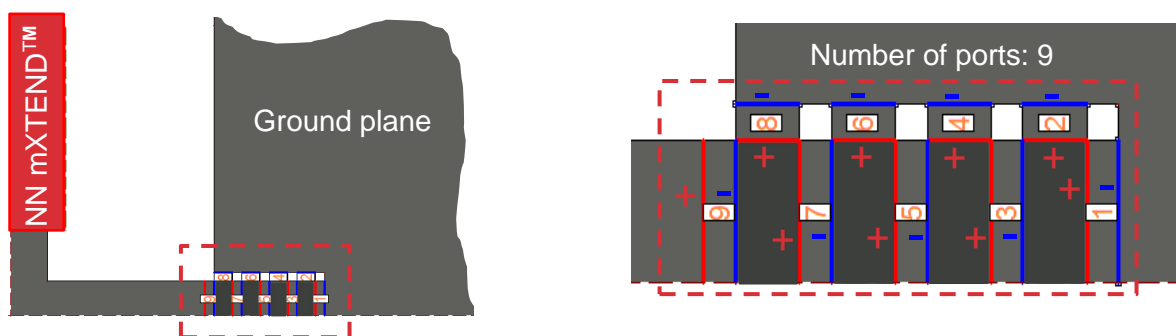
## 4. PLATFORM PADS AND PORTS

The pads and ports configuration related to a platform of this library is shown as below (*Figure 3*). Instead of defining one single port to allocate the matching network, different pads, more concretely 4 pads (colored in a darker grey), are included in the feeding area of the platform in order to use a realistic model that takes into account the pads effect in the input impedance of the structure.

The pads are 1x2 mm<sup>2</sup> and they are spaced apart by a gap of 0.5mm. In such a pads configuration, 9 corresponding ports are defined, some of them allocated in the gaps between the pads and other ports between a pad and the ground plane of the structure, as it is represented below in *Figure 3*.

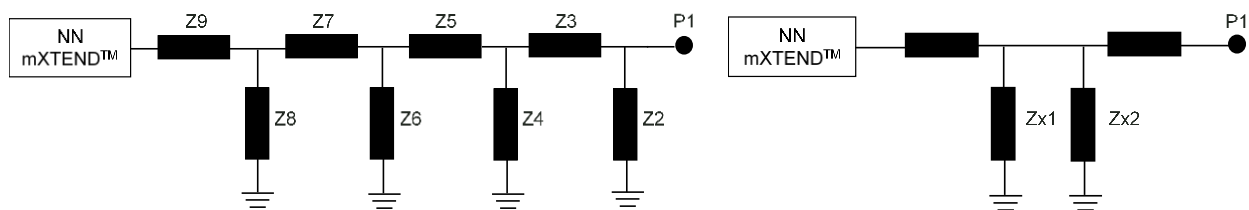
Particularly, port 9 is defined between a pad and a feeding line that is connected in its end to the mXTEND™ antenna. Ports 9, 7, 5, 3 and 1 are series ports and ports 8, 6, 4 and 2 are shunt ports connecting a pad to the platform ground plane. It is worth noticing that in the context of this document and for the platforms included in our library, a port does not necessary correspond to a feeding port.

In section 5 of this document you can find some examples where you can check that if the matching network designed requires components in all or most of the ports, port 1 will be the feeding port. If the matching network implemented does not require components in all the ports, the feeding port can be located at another port different from port 1, to avoid the transmission line effect resulting from connecting the remaining series pads with short-circuits or resistance components with resistance value equal to 0 until port 1. For the case of just a few ports needed for allocating the matching network it is suggested to use a port different from port 1 as feeding port.



**Figure 3** – NN platform pads and ports defined.

The matching network topology (*Figure 4*) represents a generic topology of a matching network whose components are allocated at the ports defined in the platform, so that  $Z_{2..9}$  corresponds to a component allocated in the '2..9' port. In this topology no component has been included at port 1, according to a real case of a matching network mounted on a real platform, where the feeding cable, connector or alike is going to fully occupy the port, without leaving place for allocating a component. But, it is possible to add in simulations a component  $Z_1$  at port 1 before closing the port with a feeding port. It is also worth noticing that two components arranged in a shunt configuration can also be used in a same port X, this configuration is shown in the right topology example from *Figure 4*.



**Figure 4** – Left: generic matching network topology allocated in the ports defined in an NN platform from the library.  $Z_{2..9}$  corresponds to a component placed at the '2..9' port. Right: topology example representing a shunt configuration of components allocated in the same 'x' port.

## 5. HOW TO USE A LIBRARY FILE: EXAMPLES

### 5.1. IoT – SMART METER

#### 5.1.1. STEP 1: LIBRARY FILE SELECTION

Let's say you have a new project and you need to design a new smart meter application within a frequency range from 698 MHz to 960 MHz and/or from 1.71 GHz to 2.17 GHz. You also know the platform used is featuring a 142 x 129 mm<sup>2</sup> board with a clearance of 45 x 25 mm<sup>2</sup>.

The information above is the only data you need to choose the most suitable library file. Use Table 2 to see available files and you must choose the one closer in specs to your specific project.

In this case the library file will be NN\_ALL\_B145x130\_C45x24.s9p. The antenna is an ALL mXTEND™ (see section 2 of this manual) placed at the corner of the PCB.

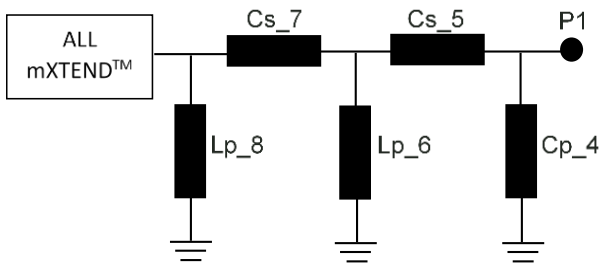
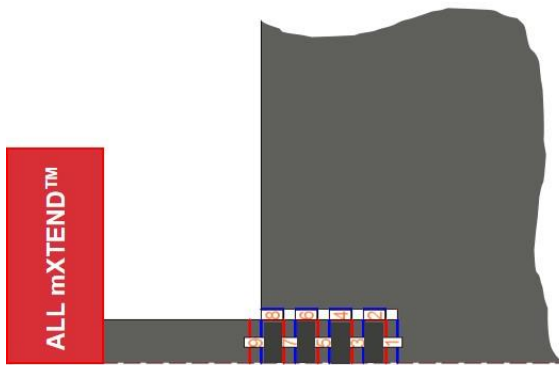
#### 5.1.2. STEP 2: MATCHING NETWORK IMPLEMENTATION

*Figure 5* shows a picture of a piece of the platform used for this case, showing the pads area and ports defined in the structures included in this library.

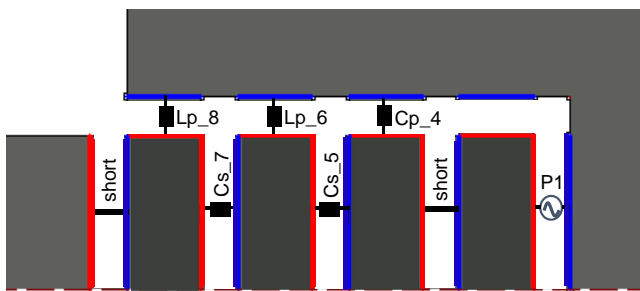
Below the platform you can find the matching network designed and used for matching this platform. The value and part numbers of the real components used for implementing it are specified in the table next to the topology.

As seen in *Figure 5*, the matching network designed is formed by five components: a shunt inductance, a series capacitance, another shunt inductance followed by another series capacitance, the matching network finishes with a shunt capacitance.

In this case the port used as feeding port is port 1. The bottom image in *Figure 5* represents how all the components are allocated in the nine ports defined in the platform when its [S] parameters library file is connected to the components of the five-components matching network described before. The ports not containing a component, either a short-circuit or a circuit component, as for example an inductor or a capacitor, allocate an open-circuit, which is represented by an empty port in the bottom image.



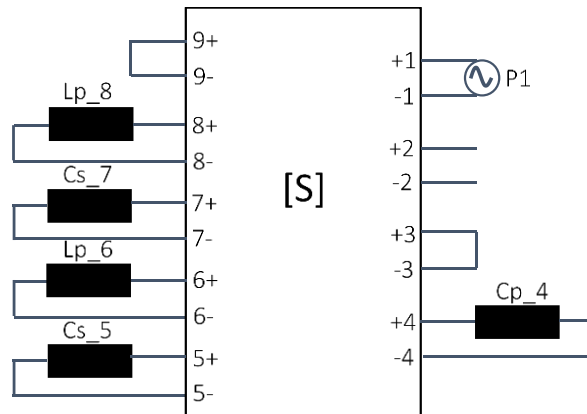
Value	Part Number
12nH	LQW18AN12NG10
1.4pF	GJM1555C1H1R4WB01
10nH	LQW18AN10NG10
2.6pF	GJM1555C1H2R6WB01
1.4pF	GJM1555C1H1R4WB01



**Figure 5** – Matching network designed together with its components position in the NN platform area assigned for allocating the matching network, regarding the ports defined on it.

Here you are a schematic of the [S] params representing the library file of this specific example, NN\_ALL\_\_B145x130\_C45x24.s9p.

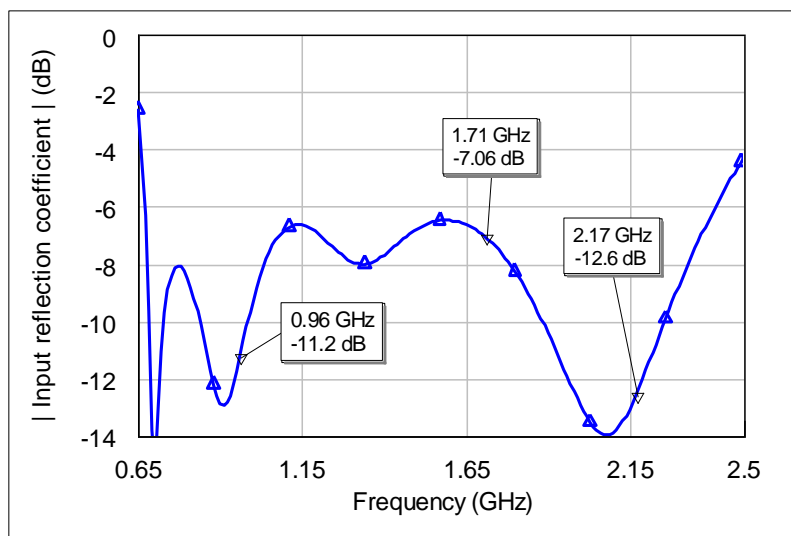
This schematic is a generic representation of how to implement the matching network circuit provided for this example with a software of matching circuits design. Each software will have its particularities on how to implement those [S] block to components connections, as well as on how to implement a short and an open-circuit.



**Figure 6** – [S] parameters block corresponding to the library file used, connected to the components of the matching network designed for this example.

### 5.1.3. STEP 3: RESULTS

The result of above matching network (*Figure 6*) is shown in the following *Figure 7*. It shows the input reflection coefficient for this smart metering example. The design is matched below -6dB in the frequency bands of interest, ranging from 698MHz to 960MHz and from 1.71GHz to 2.17GHz.



**Figure 7** – Input reflection coefficient related to the IoT/smart meter example here provided.

## 5.2. MOBILE – FLEET MANAGEMENT MODULE

### 5.2.1. STEP 1: LIBRARY FILE SELECTION

Imagine you need to design the antenna for a new fleet management application module and you need connectivity within a frequency range going from 824 MHz to 960 MHz and/or from 1.71 GHz to 2.17 GHz. The module features a 125 x 60 mm<sup>2</sup> board with a clearance of 61 x 13 mm<sup>2</sup>.

The information above is the only data you need to choose the most suitable library file. Use Table 2 to see available files and you must choose the one closer in specs to your specific project.

The corresponding library file providing the [S] params related to this platform is the NN\_RUN\_B120x60\_C60x11.s9p. The RUN mXTEND™ antenna booster is the chosen one and it is placed at 5 mm from the corner of the PCB. The RUN mXTEND™ is connected to the pads area, where the matching network is allocated, by an L-shape feeding line of 2mm width as it is seen in the top picture from *Figure 8*.

### 5.2.2. STEP 2: MATCHING NETWORK IMPLEMENTATION

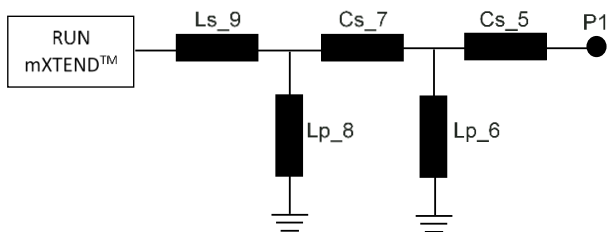
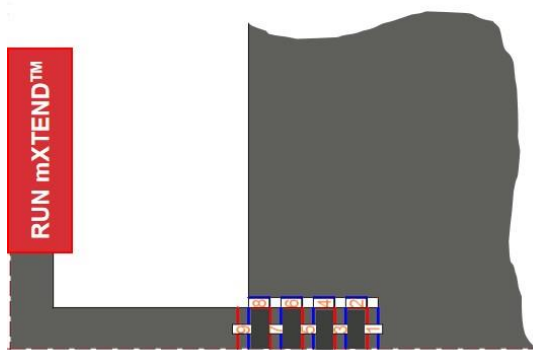
See in *Figure 8* the piece of the platform described before and used for this case, showing the pads area and ports defined in the structures included in this library.

Below the platform you can find the matching network designed and used along with the value and part numbers of the real components used for the design implementation.

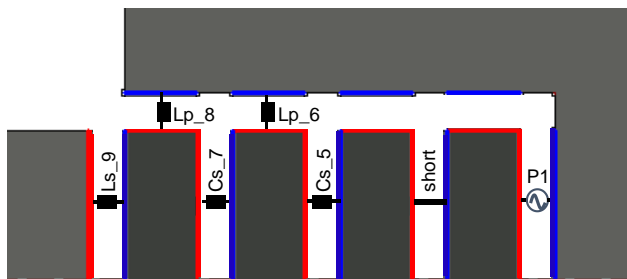
As seen in *Figure 8*, the matching network designed is composed of five components, a series inductance firstly, followed by a shunt inductance, a series capacitance, another second shunt inductance followed by another series capacitance. For this case the port used as feeding port is port 1 but port 3 or port 4 could also have been chosen.

The last image in *Figure 8* represents the location of the nine ports defined in the platform when its [S] parameters library file is connected to the components of the five-components matching network described before. The ports not containing a component, either a short-circuit or a circuit component, as for example an inductor or a capacitor, allocate an open-circuit, which is represented by an empty port in the bottom image.





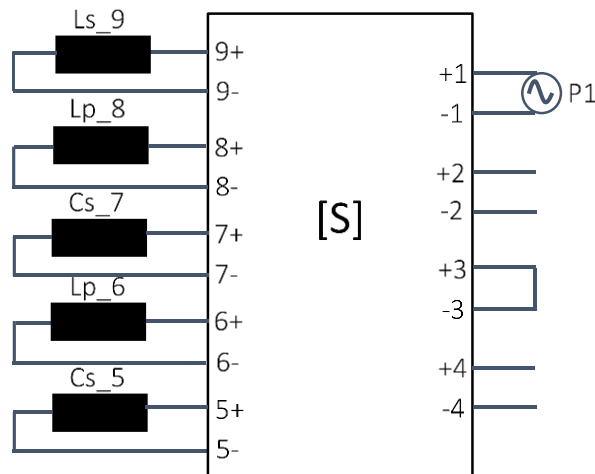
Value	Part Number
6.9nH	LQW15AN6N9G80
15nH	LQW18AN15NG80
0.9pF	GJM1555C1HR90WB01
10nH	LQW18AN10NG80
3pF	GJM1555C1H3R0WB01



**Figure 8** – Matching network designed, and its components position in the NN platform area assigned for allocating the matching network, regarding the ports defined on it.

Find below a schematic of the [S] params representing the library file of this specific example, NN\_RUN\_B120x60\_C60x11.s9p.

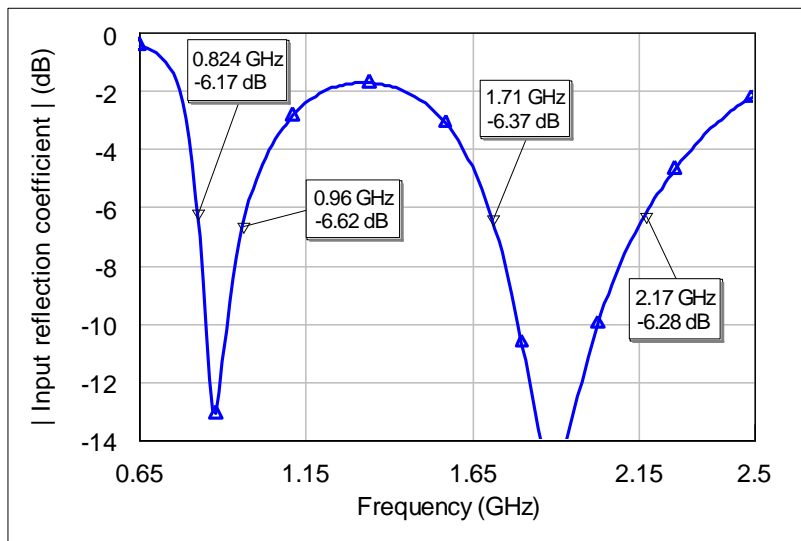
This schematic is a generic representation of how to implement the matching network circuit provided for this example with a software of matching circuits design. Each software will have its particularities on how to implement those [S] block to components connections, as well as on how to implement a short and an open-circuit.



**Figure 9** – [S] parameters block corresponding to the library file used, connected to the components of the matching network designed for this example.

### 5.2.3. STEP 3: RESULTS

The result of the above matching network shown in the next *Figure 10*. You can find the input reflection coefficient obtained after such a matching network. The design is matched below -6dB in the frequency bands of interest, going from 824MHz to 960MHz and from 1.71GHz to 2.17GHz for the target applications of this example.



**Figure 10** – Input reflection coefficient related to the Mobile/Fleet management example here provided.

## 5.3. ISM – WEARABLES

### 5.3.1. STEP 1: LIBRARY FILE SELECTION

If you need to cover ISM bands operating within the 2.4 GHz to 2.5 GHz range, here you are the example. This might be the case for instance of a wearable device establishing a short-range wireless link with a computer or mobile device. In this example, the platform used features a 32 x 32 mm<sup>2</sup> board with a clearance of 14 x 4 mm<sup>2</sup>.

The information above is the only data you need to choose the most suitable library file. Use Table 2 to see available files and you must choose the one closer in specs to your specific project.

In this case the library file you need to choose is NN\_RUN\_B30x30\_C14x5.s9p, the closest to your real situation.

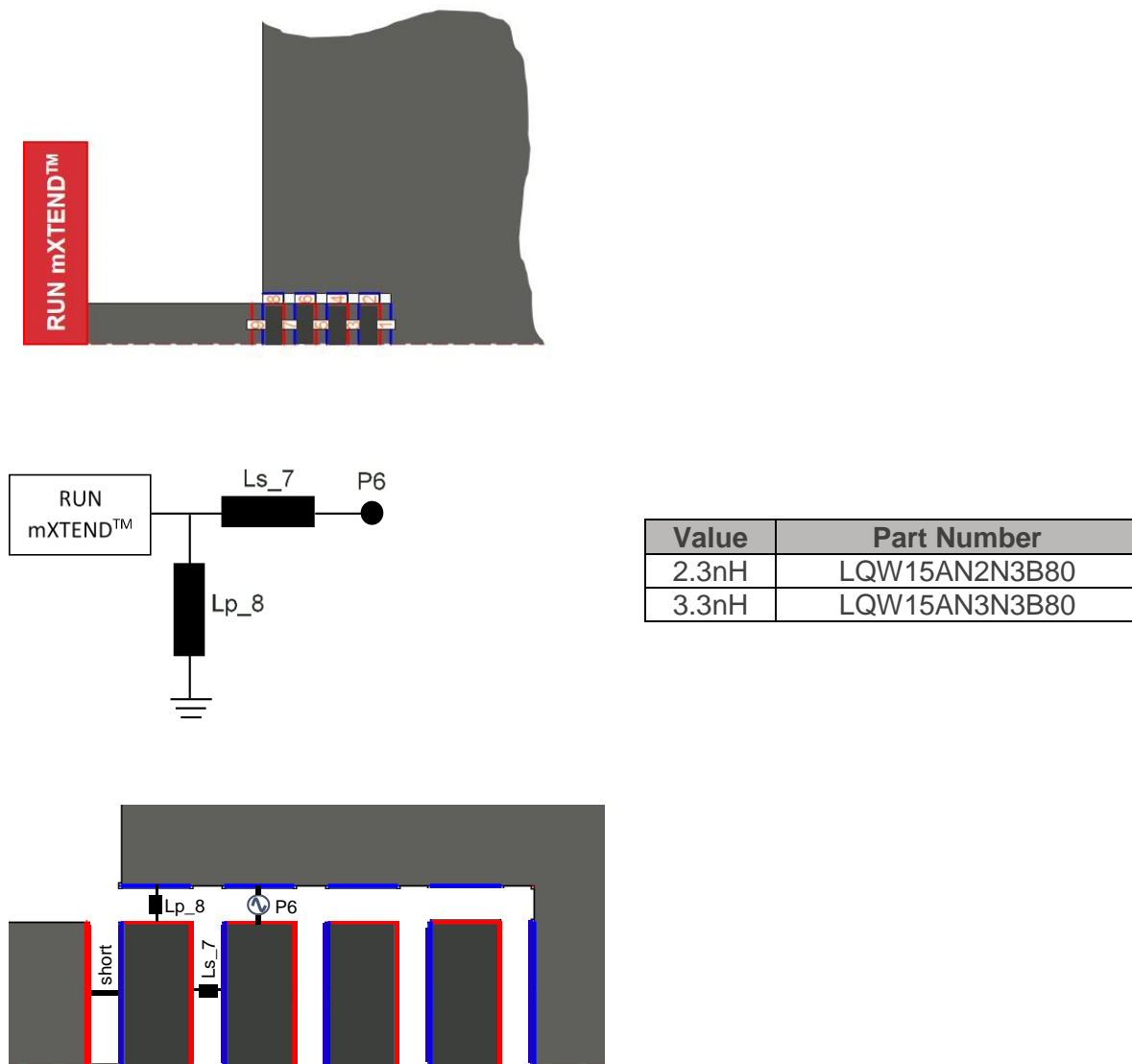
### 5.3.2. STEP 2: MATCHING NETWORK IMPLEMENTATION

*Figure 11* shows a picture of a piece of the platform used for this case, showing the pads area and ports defined in the structures included in this library.

Just below the platform you can find the matching network, also the value and part numbers of the real components used for implementing are below the topology.

As seen in *Figure 11*, the matching network designed formed by two components, a shunt inductance followed by a series inductance. For this case, the port used as feeding port is port 6 instead of port 1 to avoid the transmission line effect produced by the path between port 3 to port 1.

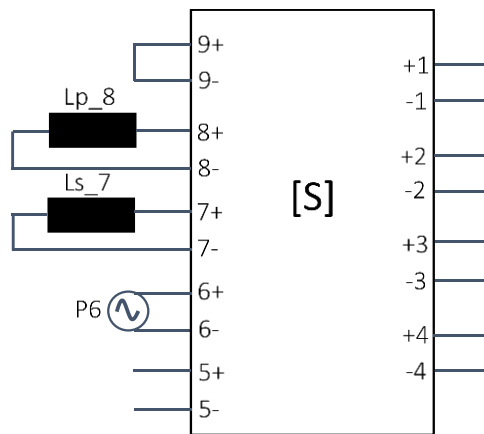
The last image in *Figure 11* represents how the components are allocated in the nine ports of the platform. The ports not containing a component, either a short-circuit or a circuit component such an inductor or a capacitor, allocate an open-circuit, are represented by an empty port in the picture to the right. If port 1 was chosen as feeding port, ports 5 and 3 would be short-circuited and then the corresponding path from port 7 to port 1 would have an impact on the input impedance evaluated at the feeding port 1. Allocating the components of the matching network designed as shown in the bottom picture avoids this effect. However, it does not mean that choosing port 1 as feeding port could not also be a possible implementation.



**Figure 11** – Matching network designed, and its components position in the NN platform area assigned for allocating the matching network, regarding the ports defined on it.

You can find now a schematic of the [S] params representing the library file for NN\_RUN\_B30x30\_C14x5.s9p.

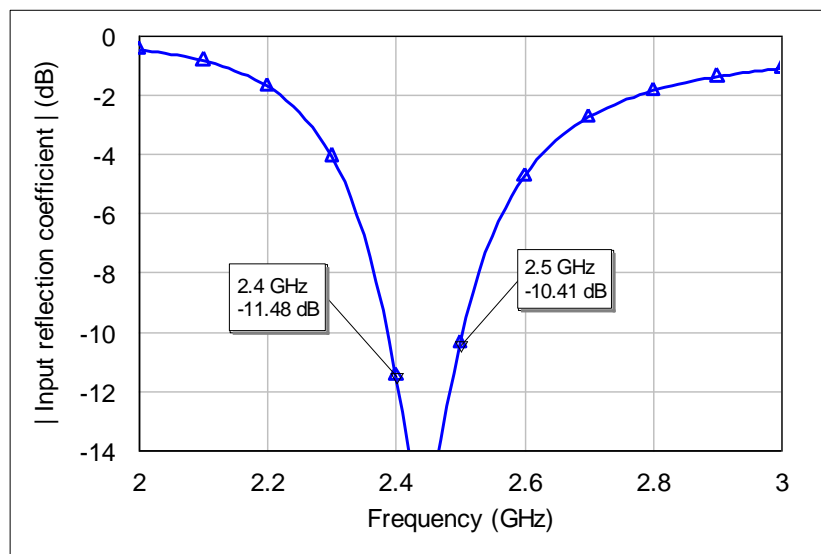
This schematic is a generic representation of how to implement the matching network circuit provided for this example with a software of matching circuits design. Each software will have its particularities on how to implement those [S] block to components connections, as well as on how to implement a short and an open-circuit.



**Figure 12** – [S] parameters block corresponding to the library file used, connected to the components of the matching network designed for this example.

**5.3.3. STEP 3: RESULTS**

In the following graph (*Figure 13*) you can find the input reflection coefficient obtained. The design is matched below -6dB, or even below -10dB, in the frequency range 2.4 GHz to 2.5 GHz.



**Figure 13** – Input reflection coefficient related to the ISM/wearables example here provided.

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