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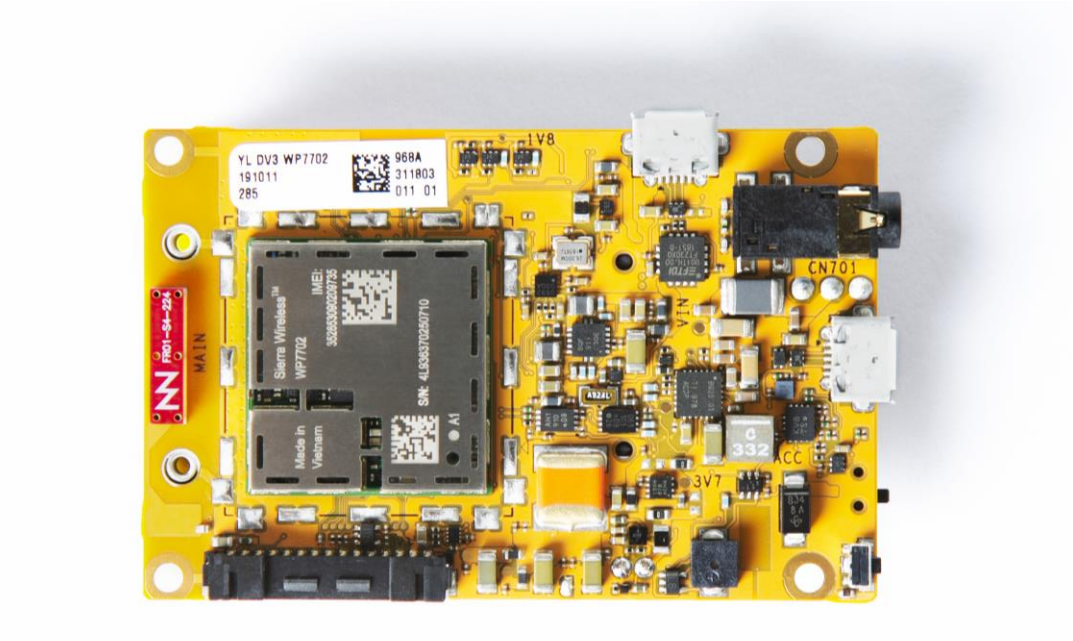
RUN mXTEND™: OPTIMIZE THE ANTENNA OF YOUR mangOH® YELLOW OPEN PLATFORM

APPLICATION NOTE
RUN mXTEND™ (NN02-224)

Optimize the antenna of your mangOH® Yellow open platform

- **Antenna Component:** RUN mXTEND™ NN02-224
- **Dimensions:** 12.0 mm x 3.0 mm x 2.4 mm
- **Frequency regions:** 698-960MHz and 1710-2690MHz



Discover how to boost the RF signal on a mangOH® Yellow platform

The **RUN mXTEND™ cellular embedded IoT antenna into** the mangOH® Yellow is an example of the **new generation of tiny antenna boosters available for multiband connectivity**. Integrating the antenna into the mangOH® Yellow fast prototyping super sensor ensures a fast and economic development of the new generation of IoT devices.

The miniature chip antenna component is connected to the RF transceiver through a matching network that shapes the frequency response of the wireless platform. To ensure a fast and economic development of the new generation of IoT devices, module and chip makers have created several prototyping kits, developing platforms and reference designs like the mangOH® Yellow fast prototyping super sensor.

The PCB of a new cellular IoT design based on mangOH® Yellow can be customized according to customer design needs. Discover within this application note how to boost the RF signal on the platform. This reference design presents easy and effective ways to modify the PCB in order to **boost the LTE antenna performance embedded in the cellular IoT device** based on mangOH® Yellow.

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1. PRODUCT DESCRIPTION mangOH® Yellow & RUN mXTEND™

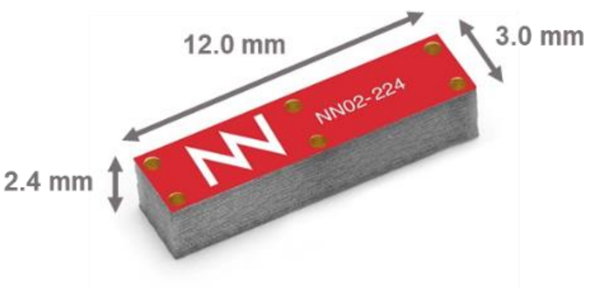
The mangOH® Yellow environment delivers all the hardware, software and cloud tools to ensure that a low power cellular IoT application is developed in a short period of time. The super smart edge open source solution has a compact form factor (65 mm x 42 mm, smaller than a credit card) and its open license allows engineers to reproduce the design as needed and prototype ideas quickly and go to market in weeks, not years. Build low-power IoT devices that can run for 10+ years.

mangOH® Yellow HIGHLIGHTS

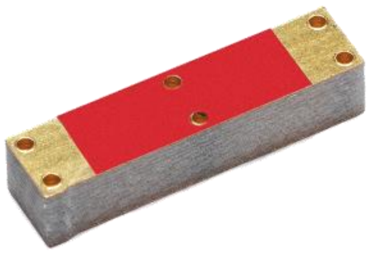
- Snap-in socket to add any CF3©-compatible modules, including wireless modules (2G to 4G & LTE-M/NB-IoT)
- Built-in Wi-Fi b/g/n and Bluetooth 5.0 BLE, Bluetooth Mesh, NFC tag
- Built-in antennas for cellular, GPS, Wi-Fi, Bluetooth and NFC
- Built-in accelerometer, gyroscope, magnetometer, pressure, humidity, acoustic mic, air index quality, temperature, and light sensors
- Battery charger and battery monitor
- Multiple LEDs, buzzer and touch button
- IoT Expansion Card slot to plug in any technology based on the IoT Expansion Card open standard
- 15 pin IO connector, SD card, 2-way audio connector
- 3D-printable case designs available

The mangOH® Yellow platform includes a tiny **RUN mXTEND™** antenna booster component, part of the Virtual Antenna™ family by Ignion.

TOP



BOTTOM



Material: The RUN mXTEND™ antenna booster is built on glass epoxy substrate.

The RUN mXTEND™ antenna booster (NN02-224) provides multiband performance in wireless devices throughout a large range of frequencies (698-8000 MHz) and it is specifically used in the mangOH® Yellow platform in the range of 698-960 MHz and 1710-2690 MHz. RUN mXTEND™ enables an IoT platform to feature worldwide coverage allowing operation in multiple IoT related communication standards such as NB-IoT, LTE-M, LoRa, Zigbee, SigFox, Neul, Thread, Z-Wave, Weightless, all mobile GSM/UMTS/LTE bands for 2G, 3G, 4G, 5G sub-6GHz, Bluetooth and Wi-Fi.

APPLICATIONS

- IoT devices
- Modules
- Routers
- Handsets and smartphones
- Tablets
- Digital cameras
- Smartwatches and wearables

BENEFITS

- High efficiency
- Small size
- Cost-effective
- Easy-to-use (pick and place)
- Off-the-Shelf standard product (no customization is required)
- No clearance beyond footprint.

The RUN mXTEND™ antenna booster belongs to a new generation of antenna solutions based on the Virtual Antenna™ technology developed by Ignion. The technology is mainly focused on replacing conventional antenna solutions by miniature, general purpose, and off-the-shelf components. This breakthrough technology has been specifically designed to fit a diverse set of wireless applications – IoT devices are just one of the many environments where this tiny antenna can be transformational.

2. HOW TO BOOST THE RF SIGNAL ON mangOH® Yellow PLATFORM

2.1. MATCHING NETWORK

The cellular embedded IoT antenna into the mangOH® Yellow is an example of the new generation of tiny antenna boosters available for multiband connectivity. The miniature chip **antenna component is connected to the RF transceiver through a matching network** that shapes the frequency response of the wireless platform.

Going from a mangOH® Yellow prototype to a final product does not require changing the antenna part: the **same off-the-shelf component will fit any device with just a little tune** of the matching network. Even the range of frequency bands can be modified with such a little change. This feature enables a fast development of the final product while making its BoM and Time-to-Market much more predictable than using old custom solutions.

If a mangOH® Yellow platform is used to design a completely new and different second IoT device, the antenna component will still be the same. A matching network retuning will make sure that the same chip antenna component fits the entire range of IoT product portfolio.
In the following chapter is explained how cellular connectivity can be optimized following some simple recommendations in a platform such as mangOH® Yellow.

2.2. BOOST THE LTE ANTENNA PERFORMANCE

The mangOH® Yellow sensor is an open-source hardware platform (gerbers and schematic are open to wireless designers), therefore the PCB of a new cellular IoT design based on mangOH® Yellow can be customized according to customer design needs.

This PCB change can not only meet mechanics criteria for a new device but also be designed in a way that radioelectric performance is improved. In this sense, **this section presents easy and effective ways to modify the PCB in order to boost the LTE antenna** performance embedded in the cellular IoT device based on mangOH® Yellow. Four changes are proposed and analyzed here (Figure 1):

1. Removing nearby grounded components.
2. Enlarging the clearance area around the antenna chip component.
3. Extending the size of the PCB.
4. Optimizing the position of the feeding line to the antenna chip component.

As shown in the graphs below, applying one or a combination of these changes can significantly improve the radiation performance of your mangOH® Yellow, with improvements that range from 1 and up to 10 dB in the low frequency region.

These results can be easily replicated using an electromagnetic CAD to model the main parts of the device: the antenna booster, the PCB including the ground plane and the substrate (FR4, 1mm thick with εr=4.15 and tanδ=0.014).

To measure the relative improvement of the different design changes, the following figure of merit Δ is proposed. **The total efficiency (ηt) averaged at 698MHz-960MHz and 1710MHz-2690MHz is calculated for each scenario** (Figure 1). Then, these averaged values are compared to the original device. The total efficiency ηt is the fraction of input power that is radiated to space. This efficiency depend on two factors: the system losses on one side ηr , which include losses due to plastic covers, components on the PCB, matching network and losses in the antenna booster itself, and the antenna impedance mismatch (S11) on the other side. Total efficiency is then defined as $\eta t=\eta r\cdot(1-|S11|2)$. For instance, if the power of the LTE module delivered to the antenna is Pout=23dBm and the total efficiency is ηt=50% (-3dB), the output radiated power (also known as total radiated power, TRP) is 23dBm-3dB=20dBm since TRP(dBm)=Pout(dBm)+10log10(ηt). Same argument applies to reception as the antenna is a reciprocal device.

Figure 1 - Cases considered in the analysis: screw connectors, change ground clearance, change feeding location, and change PCB size. Each scenario has a matching network at the excitation port which comprises lumped elements (capacitors and inductors). Only the original case has the screw connectors connected to the ground of the PCB; at the other cases, such screw connectors are floating (non-grounded).

With these considerations, the figure is merit Δ is then defined by eq. (1):

$$\Delta(dB) = 10\log\left(\frac{\overline{\eta}_{t\ new\ PCB}}{\overline{\eta}_{t\ original}}\right) \tag{1}$$

Being $\overline{\eta}_{t\ original}$ and $\overline{\eta}_{t\ new\ PCB}$ the average total efficiency in a given frequency range [f1,f2] for the original device and the new PCB case, respectively. Two frequency ranges are studied: the first one comprises [f1,f2]=[698MHz-960MHz] covering the low bands of LTE, and the second one comprises [f1,f2]=[1.71GHz-2.69GHz] covering the high-bands of LTE.

In this sense, a Δ=3dB increment means that total efficiency is increased by 3dB when compared to the original device. This figure of merit Δ is useful to determine the impact of each scenario when doing a new PCB design to get the best of the antenna performance in the device (Figure 2).

For each scenario, the matching network at the excitation port is optimized to maximize total efficiency with Microwave Office AWR Design tool by Cadence. Such matching networks comprise lumped inductor and capacitors including losses.

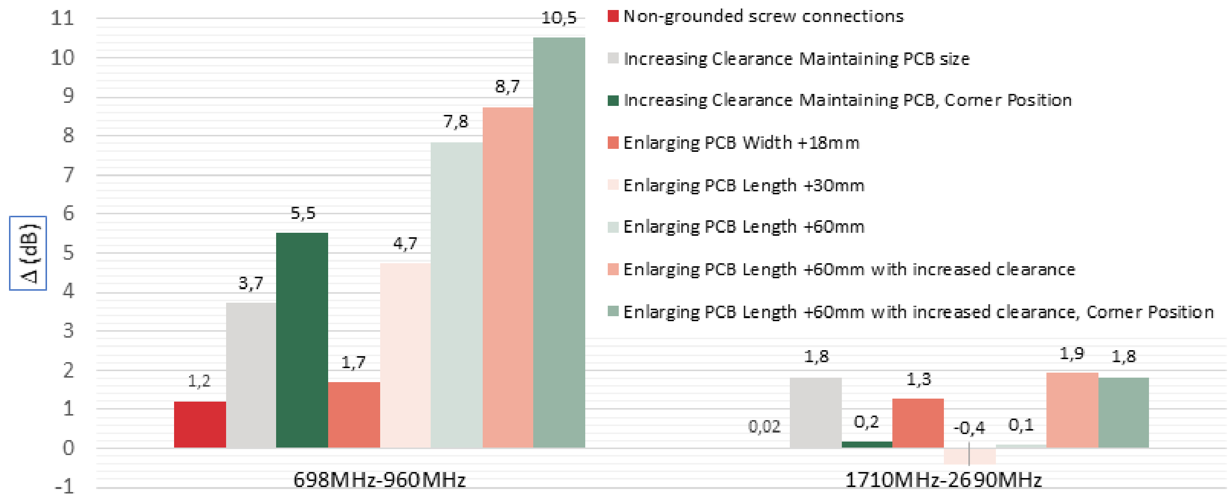


Figure 2 - Impact of the PCB size and ground clearance for the low frequency region (698MHz-960MHz) and the high frequency region (1710MHz-2690MHz). Original device PCB is 65 mm x 42 mm.

2.3. RESULTS AND DESIGN GUIDELINES

Results from Figure 2 reveal several interesting **design guidelines to be followed when optimizing the RF performance of a mangOH® Yellow platform**:

- Conducting portions close to the antenna should be avoided, but if those cannot be avoided, those portions should be non-grounded. In this present situation, when the screw connectors are non-grounded, the performance at the low frequency region is improved by Δ=1.2dB compared to the original situation where the screw connectors are grounded. From now on, all the remaining cases have non-grounded screw connectors.

- Increasing ground clearance while maintaining the PCB size (see legend at Figure 2) can increase performance Δ=3.7dB both at the low and Δ=1.8dB at the high frequency region. This ground clearance increment is due to a larger gap of the antenna booster to the ground plane. For this case, the gap between the antenna booster is increased from 2.8mm to 7.8mm.

- Increasing ground clearance while maintaining the PBC size and moving the feeding line to the corner, provides further improvement at the low frequency range of Δ=5.5dB.

- PCB width has also a positive effect, although slightly for the case under test. This increment, however, is not as significant as the ones obtained by increasing the ground clearance.

- Increasing PCB length has a positive impact in the 698-960MHz region whereas in the 1710MHz-2690MHz is almost the same. When increasing the ground plane for the original PCB size by 30 mm, the improvement at the low frequency region is 4.7dB and 7.8dB when enlarging 60mm.

- When combining the increase of ground clearance and PCB size, the performance is improved Δ=8.7dB and Δ=1.9dB at the low and high frequency regions, respectively.

- Finally, when combining the increase of ground clearance, PCB length, and antenna booster feeding line at the corner of the PCB, the positive effects are added, that is, performance is improved at both frequency regions, in particular Δ=10.5dB at the low frequency region and Δ=1.8dB at the high frequency region.

These are useful **design recommendations for optimizing performance at the conception phase of an IoT project** when the designer has still freedom to modify the PCB size. These design rules should be made at the very beginning of a design project. This will minimize and even avoid cumbersome PCB modifications while the project is in the development phase when all electronics, chipsets, and mechanics are already fixed. Therefore, **it is recommended always to think first about these design lines when designing a cellular IoT device based on mangOH® Yellow** to get the best of it.

Once the PCB size is fixed, **embedding a Virtual Antenna™** in an IoT device follows a simple design flow consisting of **three simple steps: 1) placing the antenna** booster in the PCB; **2) designing the matching network** for your PCB size; **3) testing and fine tuning the real device**, which makes the whole embedded antenna design process much faster, cheaper and easier than the traditional choice of developing a custom antenna.

If you need assistance to design your matching network, please contact support@ignion.io, or try our free-of-charge[1] **NN Wireless Fast-Track** design service, you will get your chip antenna design including a custom matching network for your device in 24h[1]. Other related to NN's range of R&D services is available at: https://www.ignion.io/rdservices/

[1] See terms and conditions for a free NN Wireless Fast-Track service in 24h at: https://www.ignion.io/fast-track-project/

Ignion products are protected by Ignion patents.

Ignion is an ISO 9001:2015 certified company. All our antennas are lead-free and RoHS compliant.

ISO 9001: 2015 Certified

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