RUN mXTEND™ – MAINTAINING PEAK PERFORMANCE IN YOUR SMARTWATCH

APPLICATION NOTE
RUN mXTEND™ (NN02-224)
LOOKING TO MAINTAIN PEAK PERFORMANCE IN YOUR SMARTWATCH?

RUN mXTEND™ (NN02-224) – AN for a Smartwatch WIFI/BLUETOOTH (2400-2500 MHz)

Ignion specializes in enabling effective mobile communications. Using Ignion technology, we design and manufacture optimized antennas to make your wireless devices more competitive. Our mission is to help our clients develop innovative products and accelerate their time to market through our expertise in antenna design, testing and manufacturing.

Ignion products are protected by Ignion patents.

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

ISO 9001: 2015
TABLE OF CONTENTS

1. PRODUCT DESCRIPTION NN02-224 4
2. EVALUATION BOARD 5
   2.1. QUICK REFERENCE GUIDE 5
   2.2. EVALUATION BOARD (2.4-2.5 GHz) 5
   2.3. MATCHING NETWORK 6
   2.4. VSWR AND TOTAL EFFICIENCY 7
   2.5. RADIATION PATTERNS (2.4 – 2.5 GHz), GAIN AND EFFICIENCY 8
3. HUMAN HAND IMPACT 9
   3.1. SET-UP 9
   3.2. MATCHING NETWORK 10
   3.3. VSWR AND TOTAL EFFICIENCY 11
   3.4. RADIATION PATTERNS, GAIN AND EFFICIENCY 12
1. PRODUCT DESCRIPTION NN02-224

The RUN mXTEND™ antenna booster has been specifically designed for providing multiband performance in wireless devices, enabling worldwide coverage by allowing operation in multiple communication standards such as Bluetooth, ISM, WIFI, and WLAN.

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

APPLICATIONS
- Smartwatch
- Wearables
- M2M
- IoT
- Modules
- Meters
- Remote Sensors

BENEFITS
- High efficiency
- Small size
- Cost-effective
- Easy-to-use (pick and place)
- Multiband behaviour (worldwide standards)
- Off-the-Shelf Standard Product (no customization is required)

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 and standard components.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 674491
2. EVALUATION BOARD

2.1. QUICK REFERENCE GUIDE

<table>
<thead>
<tr>
<th>Technical features</th>
<th>2.4 – 2.5 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Efficiency</td>
<td>&gt; 75%</td>
</tr>
<tr>
<td>Peak Gain</td>
<td>2.2 dBi</td>
</tr>
<tr>
<td>VSWR</td>
<td>&lt; 2:1</td>
</tr>
<tr>
<td>Radiation Pattern</td>
<td>Omnidirectional</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
</tr>
<tr>
<td>Weight (approx.)</td>
<td>0.19 g</td>
</tr>
<tr>
<td>Temperature</td>
<td>-40 to +125 °C</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 Ω</td>
</tr>
<tr>
<td>Dimensions (L x W x H)</td>
<td>12.0 mm x 3.0 mm x 2.4 mm</td>
</tr>
</tbody>
</table>

Table 1 – Technical Features. Measures from the Evaluation Board (Figure 1).

2.2. EVALUATION BOARD (2.4-2.5 GHz)

This Evaluation Board EB_NN02-224-SW-2400 integrates a coplanar grounded transmission line to connect the RUN mXTEND™ antenna booster with the SMA connector. Its dimensions make it suitable for becoming an antenna system solution for smartwatches. The RUN mXTEND™ provides operation in the frequency region which covers from 2.4 GHz to 2.5 GHz, through a single input/output port.

![Figure 1 – EB_NN02-224-SW-2400. Evaluation Board providing operation from 2.4 GHz to 2.5 GHz.](image)

This product and its use are protected by at least one or more of the following patents: US 9,130,259 B2; US 9,276,307 B2 and patent applications US62/328073, http://www.ignion.io/patents. Additional information about patents related to this product is available at www.ignion.io/virtual-antenna/.
2.3. MATCHING NETWORK

The specs of a Ignion standard product are measured in their Evaluation Board, which is an ideal case. In a real design, components nearby the antenna, LCD’s, batteries, covers, connectors, etc. affect the antenna performance. This is the reason why it is highly recommended placing pads compatible with 0402 and 0603 SMD components for a matching network as close as possible to the feeding point. Do it in the ground plane area, not in the clearance area. This provides a degree of freedom to tune the RUN mXTEND™ antenna booster once the design is finished and taking into account all elements of the system (batteries, displays, covers, etc.).

Please notice that different devices with different ground planes and different components nearby the RUN mXTEND™ antenna booster may need a different matching network. To ensure optimal results, the use of high Q and tight tolerance components is highly recommended (Murata components). Please, if you need assistance contact support@ignion.io for more information related to the antenna booster matching service.

<table>
<thead>
<tr>
<th>Value</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 nH</td>
<td>LQW15AN2N3B80</td>
</tr>
<tr>
<td>3.3 nH</td>
<td>LQW15AN3N3B80</td>
</tr>
</tbody>
</table>

**Figure 2** – Matching Network implemented in the Evaluation Board (Figure 1).

For additional information, please visit www.ignion.io or contact info@ignion.io.

If you need assistance to design your matching network, please contact support@ignion.io, or try our free-of-charge¹ NN Wireless Fast-Track design service, you will get your chip antenna design including a custom matching network for your device in 24h¹. 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/
2.4. VSWR AND TOTAL EFFICIENCY

VSWR (Voltage Standing Wave Ratio) and Total Efficiency versus Frequency (GHz).

**Figure 3** – VSWR and Total Efficiency for the 2.4 – 2.5 GHz frequency range (from the Evaluation Board (Figure 1)).
2.5. RADIATION PATTERNS (2.4 – 2.5 GHz), GAIN AND EFFICIENCY

Measurement System Set-Up
Evaluation Board in Plane XY

ϕ = 0° Plane XZ at 2.45 GHz
ϕ = 90° Plane YZ at 2.45 GHz

<table>
<thead>
<tr>
<th>Gain</th>
<th>Peak Gain</th>
<th>2.2 dBi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Gain across the band</td>
<td>1.9 dBi</td>
<td></td>
</tr>
<tr>
<td>Gain Range across the band (min, max)</td>
<td>1.7 → 2.2 dBi</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Peak Efficiency</th>
<th>81.2 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Efficiency across the band</td>
<td>78.6 %</td>
<td></td>
</tr>
<tr>
<td>Efficiency Range across the band (min, max)</td>
<td>74.5 – 81.2 %</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 – Antenna Gain and Total Efficiency from the Evaluation Board (Figure 1) within the 2.4 – 2.5 GHz frequency range. Measures made in the Satimo STARGATE 32 anechoic chamber.
3. HUMAN HAND IMPACT

In general terms, the interaction of the human body with a radiating system affects its performance mainly introducing efficiency decrements and detuning effects. In a smartwatch solution, this interaction is strong since the smartwatch is directly set around the wrist of the human hand at a reduced distance. This section will analyze the impact of the human hand (Figure 4) over the evaluation board (Figure 1) considering different distances at the frequency region which covers from 2.4 GHz to 2.5 GHz.

![Figure 4 – Phantom hand used to assess the performance of the evaluation board (Figure 1) when regarding the human hand interaction.](image)

3.1. SET-UP

The evaluation board (Figure 1) is placed over a phantom hand emulating the electromagnetic properties of the human body at the frequency range of 2.4-2.5GHz at different distances (Figure 5).

![Figure 5 – Different distances between the phantom hand and the evaluation board that provide operation from 2.4GHz to 2.5GHz.](image)
3.2. MATCHING NETWORK

Please note that the matching network topology has been maintained for each configuration. The component values have been re-adjusted in each case for compensating the detuning effects introduced by the proximity of the phantom hand (Figure 5).

![Matching Network Diagram]

**Figure 6** – Topology of matching network mounted at the different solutions.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Z₁</th>
<th>Z₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0mm</td>
<td>1.5 nH</td>
<td>0 Ω</td>
</tr>
<tr>
<td>3mm</td>
<td>1.8 nH</td>
<td>3.3 nH</td>
</tr>
<tr>
<td>6mm</td>
<td>1.8 nH</td>
<td>3.4 nH</td>
</tr>
</tbody>
</table>

**Table 3** – Values of the components for each distance.

<table>
<thead>
<tr>
<th>Value</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z₁</td>
<td>LQW15AN1N5C80</td>
</tr>
<tr>
<td></td>
<td>LQW15AN1N8C00</td>
</tr>
<tr>
<td>Z₂</td>
<td>LQW15AN3N3B80</td>
</tr>
<tr>
<td></td>
<td>LQW15AN3N4B80</td>
</tr>
</tbody>
</table>

**Table 4** – Values and part numbers of the components used for the matching networks.
3.3. VSWR AND TOTAL EFFICIENCY

VSWR (Voltage Standing Wave Ratio) and Total Efficiency versus Frequency (GHz).

**Figure 7** – VSWR and Total Efficiency for the 2.4 – 2.5 GHz frequency range (from the evaluation board (Figure 5)).

<table>
<thead>
<tr>
<th>Distance</th>
<th>2.4-2.5GHz</th>
<th>$\eta_a^2$ (2.4GHz)</th>
<th>$\eta_a$ (2.5GHz)</th>
<th>$\eta_a$ (min)</th>
<th>$\eta_a$ (max)</th>
<th>$\eta_a$ (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Space</td>
<td>&lt; 2:1</td>
<td>76.0</td>
<td>75.5</td>
<td>74.5</td>
<td>81.2</td>
<td>78.6</td>
</tr>
<tr>
<td>0mm</td>
<td>&lt; 2:1</td>
<td>13.8</td>
<td>16.1</td>
<td>13.8</td>
<td>16.1</td>
<td>15.1</td>
</tr>
<tr>
<td>3mm</td>
<td>&lt; 2.5:1</td>
<td>21.6</td>
<td>24.4</td>
<td>21.6</td>
<td>26.9</td>
<td>25.0</td>
</tr>
<tr>
<td>6mm</td>
<td>&lt; 2.5:1</td>
<td>32.1</td>
<td>33.6</td>
<td>32.1</td>
<td>39.5</td>
<td>37.0</td>
</tr>
</tbody>
</table>

**Table 5** – VSWR and Total Efficiency comparison considering the different distances.

$\eta_a$ refers to the total efficiency of the antenna system which considers both ohmic and impedance losses.
3.4. RADIATION PATTERNS, GAIN AND EFFICIENCY

<table>
<thead>
<tr>
<th>Measurement</th>
<th>XY Plane at 0mm, 3mm, 6mm</th>
<th>Z Plane at 0mm, 3mm, 6mm</th>
</tr>
</thead>
</table>

- **Gain**
  - Peaks: -3.5 dBi, 0.3 dBi, 3 dBi
  - Average Gain: -3.9 dBi, -0.3 dBi, 2.6 dBi
  - Range: -4.5<->-3.5 dBi, -1.2<->0.3 dBi, 1.7<->3.0 dBi

- **Efficiency**
  - Peaks: 16.1 %, 26.9 %, 39.5 %
  - Average Efficiency: 15.1 %, 25.0 %, 37.0 %
  - Range: 13.8 – 16.1 %, 21.6 – 26.9 %, 32.1 – 39.5 %

**Table 6** – Antenna Gain and Total Efficiency from the Evaluation Board (Figure 1) within the 2.4 – 2.5 GHz frequency range. Measures made in the Satimo STARGATE 32 anechoic chamber.
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