4G HIGH PERFORMANCE WITH A SMALL CHIP ANTENNA?
RUN mXTEND™ & SmarTune™

APPLICATION NOTE
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- **Antenna Component**: RUN mXTEND™ NN02-244
- **Dimensions**: 12.0 mm x 3.0 mm x 2.4 mm
- **Frequency regions**: 698-960 MHz & 1710-2690 MHz
  **Impedance Tuner**: SmarTune™ 32CK417R or 32CK301R by Cavendish Kinetics

By using RUN mXTEND™ along with the SmarTune™ Impedance Tuner the result is an active and versatile antenna system that supports all mobile frequency bands within the 698 MHz to 2690 MHz frequency range, while optimizing the antenna system performance and minimizing the antenna component size. The main feature of such a booster-tuner combination is that the mobile device can dynamically focus on a specific bandwidth within the entire frequency range to extract the maximum radiation of the mobile platform in every scenario of coverage and user operation.

**Ignion** products are protected by **Ignion patents**.

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

RUN mXTEND™ antenna booster NN02-224

**SmarTune™ Impedance Tuner**
32CK417R and 32CK301R

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1. PRODUCT DESCRIPTION NN02-224

The RUN mXTEND™ antenna booster (NN02-224) has been specifically designed for providing multiband performance in wireless devices, enabling worldwide coverage by allowing operation in multiple communication standards such as 2G, 3G, 4G, ISM, Zigbee, RFID, GPS, GLONASS, Bluetooth, WIFI, and WLAN, thanks to its flexibility. In this application note, its configuration to operate the 2G, 3G, 4G bands in combination with an impedance tuner is presented.

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

**APPLICATIONS**
- Handsets and Smartphones
- Tablets and PCs
- Modules
- Routers
- Headsets
- USB Dongles
- Navigators
- Digital Cameras and Smart Watches
- Metering (Gas, Electricity, Water…)
- Sensors (Parking, Speed Control, Optics…)
- IoT Devices

**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 patented Virtual Antenna™ technology owned by Ignion. The technology is mainly focused on replacing conventional antenna solutions by miniature and off-the-shelf chip antenna components that can be seamlessly deployed across a variety of different products and platforms.
2. CAVENDISH CHIP 32CK417R or 32CK301R

SmarTune™ Antenna Tuners are extremely precise and low-loss variable capacitors that tolerate high RF Voltages, making them ideal for tunable antennas, dynamic load adjustments, tunable filters, and analog RF applications that require high voltage operation. SmarTune™ Antenna Tuners are based on Cavendish Kinetics’ patented RF Micro-Electro-Mechanical Systems (MEMS) technology, which eliminates the high insertion loss and RF Voltage handling limitations of traditional Silicon-on-Insulator (SOI) or GaAs devices otherwise used in the RF front-end.

Cavendish Kinetics’ patented RF MEMS technology and process produce devices with unprecedented accuracy and reliability, maintaining full specification compliance even after 100 billion cycles.

The 32CK301R SmarTune™ Antenna Tuner is used in this application note. However, this product will be replaced by 32CK417R with a wider capacitor range.

The SmarTune Antenna Tuners are controlled through a MIPI RFFE interface. All functions are self-contained and executed by the logic in the controller.

**FEATURES 32CK417R and 32CK301R**

- Extremely compact
- Combining the tuneable capacitor and all required control logic in a small 2 mm² Wafer-Level-Chip-Scale Package (WL CSP)
- Easily controlled through the integrated MIPI RFFE controller
- 32CK417R: 0.5pF to 1.65 pF
- 32CK301R: 0.4pF to 1.0pF
- Very high-Quality Factor
- ESR ~ 0.3 Ohm at Cmax
- 5-bit resolution (32 capacitor states)
- SRF > 15GHz
- RF Power handling: +39dBm
- Cycling: > 10⁹ cycles
- High Linearity
- MIPI RFFE interface
- Small size: ~ 2mm² WL CSP
- Low power: 100μA typical
3. PERFORMANCE FOR DIFFERENT STATES OF THE IMPEDANCE TUNER

3.1. EVALUATION BOARD

This Evaluation Board EB_NN02-224-TA integrates a UFL cable to connect the RUN mXTEND™ antenna booster with the SMA connector. It has a 10-pin socket connecting the evaluation board to a PC using a parallel cable. The software SkyWalker by Cavendish-Kinetics is used to set the impedance tuner 32CK301R to any of its 32 possible states. This Evaluation Board is available under request.

Figure 1 – Evaluation board EB_NN02-224-TA with Cavendish chip 32CK301R providing operation from 698 MHz to 2690 MHz as a function of the selected state of the impedance tuner.

<table>
<thead>
<tr>
<th>Measure</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>131</td>
</tr>
<tr>
<td>B</td>
<td>120</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>11</td>
</tr>
</tbody>
</table>

**D**: Distance between the RUN mXTEND™ antenna booster and the ground plane.

**Material**: The evaluation board is built on FR4 substrate. Thickness is 1 mm.

**Clearance Area**: 11 mm x 60 mm (F x C)

**Tolerance**: ±0.2 mm

This product and/or its use is protected by at least one or more of the following patents and patent applications [http://www.ignion.io/patents](http://www.ignion.io/patents). Additional information about patents related to this product is available at [www.ignion.io/virtual-antenna/](http://www.ignion.io/virtual-antenna/).
3.2. VSWR AND EFFICIENCY

VSWR (Voltage Standing Wave Ratio) and Total Efficiency versus Frequency (GHz) for four states of the impedance tuner. Other 28 states can also be used for fine tune purposes. The proposed four states have been selected as to be compatible with carrier aggregation if needed as shown in section 3.4.

![Figure 2](image-url) – VSWR and Total Efficiency for the 700 – 2690 MHz frequency range (Figure 1).

<table>
<thead>
<tr>
<th>States</th>
<th>Av. $\eta_a$ 700 MHz</th>
<th>Av. $\eta_a$ 700 MHz</th>
<th>Av. $\eta_a$ 850 MHz</th>
<th>Av. $\eta_a$ 900 MHz</th>
<th>Av. $\eta_a$ 1800 MHz</th>
<th>Av. $\eta_a$ 1900 MHz</th>
<th>Av. $\eta_a$ 2100 MHz</th>
<th>Av. $\eta_a$ 2300 MHz</th>
<th>Av. $\eta_a$ 2500 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>S27</td>
<td>41.5</td>
<td>57.7</td>
<td>29.0</td>
<td>22.3</td>
<td>65.8</td>
<td>65.3</td>
<td>59.9</td>
<td>17.2</td>
<td>6.0</td>
</tr>
<tr>
<td>S08</td>
<td>19.0</td>
<td>53.6</td>
<td>54.0</td>
<td>41.5</td>
<td>71.5</td>
<td>63.8</td>
<td>59.1</td>
<td>60.4</td>
<td>26.2</td>
</tr>
<tr>
<td>S02</td>
<td>13.0</td>
<td>46.8</td>
<td>62.5</td>
<td>50.2</td>
<td>69.0</td>
<td>59.6</td>
<td>50.1</td>
<td>48.8</td>
<td>50.6</td>
</tr>
<tr>
<td>S00</td>
<td>11.5</td>
<td>44.1</td>
<td>65.4</td>
<td>53.7</td>
<td>68.4</td>
<td>58.5</td>
<td>47.7</td>
<td>42.5</td>
<td>57.2</td>
</tr>
</tbody>
</table>

Table 1 – Average total efficiency (%) for four different states of the impedance tuner. *) The number in the sub index indicates the LTE band.

3.3. MATCHING NETWORK

The specs of an 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 2** - Values and part numbers of the components used for the matching network.

<table>
<thead>
<tr>
<th>Value</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>8.0 nH</td>
</tr>
<tr>
<td>Z2</td>
<td>Impedance tuner</td>
</tr>
<tr>
<td>Z3</td>
<td>7.3 nH</td>
</tr>
<tr>
<td>Z4</td>
<td>11 nH</td>
</tr>
<tr>
<td>Z5</td>
<td>0.8 pF</td>
</tr>
<tr>
<td>Z6</td>
<td>13 nH</td>
</tr>
<tr>
<td>Z7</td>
<td>1.9 pF</td>
</tr>
<tr>
<td>Z8</td>
<td>2.5 nH</td>
</tr>
</tbody>
</table>

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/
3.4. CARRIER AGGREGATION

The evaluation board provides performance suitable for carrier aggregation (CA). CA in LTE-Advanced uses several frequency bands in order to increase the bitrate. Table 3 shows which state of the impedance tuner is recommended for each pair of inter-band carrier aggregation.

<table>
<thead>
<tr>
<th>CA configuration</th>
<th>Band#1</th>
<th>Band#2</th>
<th>State</th>
<th>Average Efficiency % (Band#1, Band#2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA_1A_5A</td>
<td>2100</td>
<td>850</td>
<td>S08</td>
<td>59.1 – 53.7</td>
</tr>
<tr>
<td>CA_1A_18A</td>
<td>2100</td>
<td>850</td>
<td>S08</td>
<td>59.1 – 56.0</td>
</tr>
<tr>
<td>CA_1A_19A</td>
<td>2100</td>
<td>850</td>
<td>S08</td>
<td>59.1 – 54.0</td>
</tr>
<tr>
<td>CA_2A_17A</td>
<td>1900</td>
<td>700</td>
<td>S27</td>
<td>63.3 – 41.8</td>
</tr>
<tr>
<td>CA_2A_29A</td>
<td>1900</td>
<td>700</td>
<td>S27</td>
<td>63.3 – 44.6</td>
</tr>
<tr>
<td>CA_3A_5A</td>
<td>1800</td>
<td>850</td>
<td>S00</td>
<td>68.4 – 64.8</td>
</tr>
<tr>
<td>CA_3A_7A</td>
<td>1800</td>
<td>2600</td>
<td>S00</td>
<td>68.4 – 57.2</td>
</tr>
<tr>
<td>CA_3A_8A</td>
<td>1800</td>
<td>900</td>
<td>S00</td>
<td>68.4 – 53.7</td>
</tr>
<tr>
<td>CA_3A_20A</td>
<td>1800</td>
<td>800</td>
<td>S00</td>
<td>68.4 – 64.1</td>
</tr>
<tr>
<td>CA_4A_5A</td>
<td>1700</td>
<td>850</td>
<td>S08 / S02</td>
<td>64.4 – 53.7 (S08) / 58.4 – 61.9 (S02)</td>
</tr>
<tr>
<td>CA_4A_7A</td>
<td>1700</td>
<td>2600</td>
<td>S00</td>
<td>56.8 – 57.2</td>
</tr>
<tr>
<td>CA_4A_12A</td>
<td>1700</td>
<td>700</td>
<td>S27</td>
<td>62.8 – 41.8</td>
</tr>
<tr>
<td>CA_4A_13A</td>
<td>1700</td>
<td>700</td>
<td>S08</td>
<td>64.4 – 50.4</td>
</tr>
<tr>
<td>CA_4A_17A</td>
<td>1700</td>
<td>700</td>
<td>S27</td>
<td>62.8 – 41.8</td>
</tr>
<tr>
<td>CA_4A_29A</td>
<td>1700</td>
<td>700</td>
<td>S27</td>
<td>62.8 – 44.6</td>
</tr>
<tr>
<td>CA_5A_12A</td>
<td>850</td>
<td>700</td>
<td>S27</td>
<td>28.7 – 41.8</td>
</tr>
<tr>
<td>CA_5A_17A</td>
<td>850</td>
<td>700</td>
<td>S27</td>
<td>28.7 – 41.8</td>
</tr>
<tr>
<td>CA_7A_20A</td>
<td>2600</td>
<td>800</td>
<td>S00</td>
<td>57.2 – 64.1</td>
</tr>
<tr>
<td>CA_8A_20A</td>
<td>900</td>
<td>800</td>
<td>S00</td>
<td>53.7 – 64.1</td>
</tr>
</tbody>
</table>

Table 3 - Configurations to support carrier aggregation (CA)
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Application Note

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