This application note describes three designs of printed antenna for use with the NXP JN516x series of wireless microcontrollers used in IEEE802.15.4-based systems, such as ZigBee networks.
### Revision history

<table>
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<th>Rev</th>
<th>Date</th>
<th>Description</th>
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<tr>
<td>1.0</td>
<td>20150522</td>
<td>Initial version</td>
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Contact information

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1. Introduction

The NXP JN516x wireless microcontrollers are designed for use in the nodes of low-power wireless networks based on the IEEE802.15.4 protocol standard. These networks may employ higher level networking protocols built on top of IEEE802.15.4, such as ZigBee PRO or ZigBee-RF4CE. The antenna for use with a JN516x device must be selected by the developer and this application node describes three designs for a suitable high-performance PCB antenna:

- Meander antenna - see Section 2
- Inverted-F antenna (IFA) - see Section 3
- Dipole antenna - see Section 4

2. Meander antenna

The meander antenna simulations have been done with ADS from Cadence and EMPro from Agilent.

2.1 Two-layer printed antenna

2.1.1 PCB characteristics

Substrate FR4.
Substrate thickness = 1.0 mm.
Er = 4.6, Er TanD = 0.01.
Copper thickness = 17 µm.
2.1.2 Antenna layout

Fig 1. Meander antenna layout diagram

Table 2. Meander antenna layout dimensions

<table>
<thead>
<tr>
<th>Reference (in diagram)</th>
<th>Distance (mm)</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>0.5</td>
</tr>
<tr>
<td>B</td>
<td>7.7</td>
</tr>
<tr>
<td>C</td>
<td>1.6</td>
</tr>
<tr>
<td>D</td>
<td>4.5</td>
</tr>
<tr>
<td>E</td>
<td>17.7</td>
</tr>
<tr>
<td>F</td>
<td>1.1</td>
</tr>
</tbody>
</table>
2.1.3 Counter poise

The counter poise is made of metallic tin plate with a thickness of 0.3 mm.

Fig 2. Counter poise dimensions

2.1.4 Assembled view

Fig 3. 3D view of meander antenna with its counter poise
2.2 Simulation results

2.2.1 S parameters

Fig 4. S11 parameter

2.2.2 S11 results

S11(2.350 GHz) = −4.31 dB.
S11(2.400 GHz) = −4.51 dB.
S11(2.510 GHz) = −4.6 dB.
2.2.3 S11 Smith chart

![S11 Smith chart](image)

Fig 5. S11 Smith chart
Fig 6. S11 Smith chart
2.2.4 3D radiation

The maximum gain is in the theta direction.

Fig 7. Total gain for all directions
Maximum gain 1.2 dBi at 13°

Fig 8. Gain in theta direction
Fig 9. Gain in phi direction
2.2.5 Radiation efficiency

Table 3. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Efficiency</th>
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<tr>
<td>1 GHz</td>
<td>40.6%</td>
</tr>
<tr>
<td>2.4 GHz</td>
<td>87.1%</td>
</tr>
<tr>
<td>3 GHz</td>
<td>28.2%</td>
</tr>
</tbody>
</table>
3. Inverted-F antenna (IFA)

The Inverted-F antenna simulations have been done with ADS from Cadence.

3.1 One-layer printed antenna

3.1.1 PCB characteristics

Substrate FR4.
Substrate thickness = 1.6 mm.
\( \varepsilon_r = 4.6, \tan \delta = 0.01. \)
Copper thickness = 35 µm.

3.1.2 Antenna layout

![Inverted-F antenna layout diagram](image)

Table 4. Inverted-F antenna layout dimensions

<table>
<thead>
<tr>
<th>Reference (in diagram)</th>
<th>Distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>20.3</td>
</tr>
<tr>
<td>C</td>
<td>4.4</td>
</tr>
<tr>
<td>D</td>
<td>15.2</td>
</tr>
<tr>
<td>E</td>
<td>6.3</td>
</tr>
<tr>
<td>F</td>
<td>10.3</td>
</tr>
<tr>
<td>G</td>
<td>1.145</td>
</tr>
<tr>
<td>H</td>
<td>1.85</td>
</tr>
<tr>
<td>I</td>
<td>1.05</td>
</tr>
<tr>
<td>J</td>
<td>21</td>
</tr>
</tbody>
</table>
3.2 Simulation results

3.2.1 S parameters

![Diagram showing S11 parameter](image)

Fig 12. S11 parameter

3.2.2 S11 results

\[ S11[2.366 \text{ GHz}] = -19.6 \text{ dB.} \]
\[ S11[2.447 \text{ GHz}] = -19.8 \text{ dB.} \]
\[ S11[2.551 \text{ GHz}] = -44.9 \text{ dB.} \]
3.2.3 S11 Smith chart

![S11 Smith chart](image)

Fig 13. S11 Smith chart

3.2.4 3D radiation

The maximum gain is in the theta direction.

![3D radiation](image)

Fig 14. Total gain for all directions
Fig 15. Gain in theta direction
3.2.5 Radiation efficiency

Table 5. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Efficiency</th>
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<tbody>
<tr>
<td>1 GHz</td>
<td>18%</td>
</tr>
<tr>
<td>2.4 GHz</td>
<td>25%</td>
</tr>
<tr>
<td>3 GHz</td>
<td>20.1%</td>
</tr>
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Fig 16. Gain in phi direction
4. Dipole antenna

The dipole antenna simulations have been done with ADS from Cadence.

4.1 One-layer printed antenna

4.1.1 PCB characteristics

Substrate FR4.

Substrate thickness = 1.6 mm.

Er = 4.6, Er TanD = 0.01.

Copper thickness = 35 μm.

4.1.2 Antenna layout

Table 6. Dipole antenna layout dimensions

<table>
<thead>
<tr>
<th>Reference (in diagram)</th>
<th>Distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>22.2</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>2.2</td>
</tr>
<tr>
<td>D</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Fig 17. Dipole antenna layout diagram*
4.2 Simulation results

4.2.1 S parameters

**Fig 18.** S22 parameter

4.2.2 S22 results

- $S_{22}(2.367 \text{ GHz}) = -3 \text{ dB}$.
- $S_{22}(2.426 \text{ GHz}) = -5.8 \text{ dB}$.
- $S_{22}(2.547 \text{ GHz}) = -1.5 \text{ dB}$.
4.2.3 S22 Smith chart

Fig 19. S22 Smith chart

4.2.4 3D radiation

The maximum gain is in the theta direction.

Fig 20. Total gain for all directions
Fig 21. Gain in theta direction
4.2.5 Radiation efficiency

Table 7. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GHz</td>
<td>26%</td>
</tr>
<tr>
<td>2.4 GHz</td>
<td>22.54%</td>
</tr>
<tr>
<td>3 GHz</td>
<td>41.8%</td>
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6. List of figures

Fig 1. Meander antenna layout diagram .................. 4
Fig 2. Counter poise dimensions.......................... 5
Fig 3. 3D view of meander antenna with its counter poise.................................................. 5
Fig 4. S11 parameter ........................................ 6
Fig 5. S11 Smith chart ...................................... 7
Fig 6. S11 Smith chart ...................................... 8
Fig 7. Total gain for all directions ......................... 9
Fig 8. Gain in theta direction................................ 10
Fig 9. Gain in phi direction.................................. 11
Fig 10. Directivity versus Theta.......................... 12
Fig 11. Inverted-F antenna layout diagram .......... 13
Fig 12. S11 parameter ...................................... 14
Fig 13. S11 Smith chart ...................................... 15
Fig 14. Total gain for all directions ....................... 15
Fig 15. Gain in theta direction............................. 16
Fig 16. Gain in phi direction............................... 17
Fig 17. Dipole antenna layout diagram ................ 18
Fig 18. S22 parameter ...................................... 19
Fig 19. S22 Smith chart ...................................... 20
Fig 20. Total gain for all directions ....................... 20
Fig 21. Gain in theta direction............................. 21
Fig 22. Gain in phi direction............................... 22
7. List of tables

Table 1. Reference board summary................................ 3
Table 2. Meander antenna layout dimensions .............. 4
Table 3. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz ................................................................. 12
Table 4. Inverted-F antenna layout dimensions .......... 13
Table 5. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz ................................................................. 17
Table 6. Dipole antenna layout dimensions ............... 18
Table 7. Radiation efficiency at 1 GHz, 2.4 GHz and 3 GHz ................................................................. 22
8. Contents

1. Introduction ......................................................... 3
2. Meander antenna ................................................. 3
   2.1 Two-layer printed antenna.................................. 3
   2.1.1 PCB characteristics ............................................ 3
   2.1.2 Antenna layout ................................................... 4
   2.1.3 Counter poise ..................................................... 5
   2.1.4 Assembled view ................................................. 5
   2.2 Simulation results ............................................... 6
   2.2.1 S parameters ...................................................... 6
   2.2.2 S11 results ......................................................... 6
   2.2.3 S11 Smith chart .................................................. 7
   2.2.4 3D radiation ........................................................ 9
   2.2.5 Radiation efficiency .......................................... 12
3. Inverted-F antenna (IFA) ................................... 13
   3.1 One-layer printed antenna................................ 13
   3.1.1 PCB characteristics .......................................... 13
   3.1.2 Antenna layout ................................................. 13
   3.2 Simulation results ............................................. 14
   3.2.1 S parameters .................................................... 14
   3.2.2 S11 results ....................................................... 14
   3.2.3 S11 Smith chart ................................................ 15
   3.2.4 3D radiation ...................................................... 15
   3.2.5 Radiation efficiency .......................................... 17
4. Dipole antenna ................................................... 18
   4.1 One-layer printed antenna................................ 18
   4.1.1 PCB characteristics .......................................... 18
   4.1.2 Antenna layout ................................................. 18
   4.2 Simulation results ............................................. 19
   4.2.1 S parameters .................................................... 19
   4.2.2 S22 results ....................................................... 19
   4.2.3 S22 Smith chart ................................................ 20
   4.2.4 3D radiation ...................................................... 20
   4.2.5 Radiation efficiency .......................................... 22
5. Legal information .............................................. 23
   5.1 Definitions ........................................................ 23
   5.2 Disclaimers....................................................... 23
6. List of figures ..................................................... 24
7. List of tables ...................................................... 25
8. Contents ............................................................. 26

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