Fully 3D Printed 2.4 GHz Bluetooth/Wi-Fi Antenna

Paul Deffenbaugh
Josh Goldfarb, Xudong Chen, Dr. Kenneth Church

Thanks to: Ibrahim Nassar, Jonathan O’Brien
<table>
<thead>
<tr>
<th>Application</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Printed smartphones</td>
<td>1. Low time-to-market, on-demand manufacturing</td>
</tr>
<tr>
<td>2. Home products</td>
<td>2. Consumers may print at home, no trips to the store or delivery trucks</td>
</tr>
<tr>
<td>4. Printed satellites, space hardware</td>
<td>4. Ship bulk raw materials compactly to orbit, then print what is needed</td>
</tr>
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</table>
## “Full 3DP” vs. 3D Printing

<table>
<thead>
<tr>
<th>Conductive</th>
<th>Strong</th>
<th>Dielectric</th>
<th>Sticky</th>
</tr>
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<tbody>
<tr>
<td>Paste / Silver Ink</td>
<td>FDM / ABS</td>
<td>High-K Ceramic</td>
<td>Epoxy or Silicone</td>
</tr>
<tr>
<td>• Electrical</td>
<td>• Structural/case</td>
<td>• RF/microwave/wireless</td>
<td>• Bond small parts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Waterproof</td>
</tr>
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</table>

- **Heat Laser**
  - Cures inks, epoxies, silicones

- **High intensity UV**
  - Cures resins

- **Pick and Place**
  - Chips, LCR, LEDs
FDM = Fused Deposition Modelling

ABS plastic filament, 1.75 mm

Feed motor

Feed system

Thermal isolation

Heater, max 400 °C

Nozzle, <0.2 mm

nScrypt nFD

Stratasys Dimension Printer
SmartPump™
Direct Print Additive Manufacturing

Diagram showing pump body, valve rod, valve body, material flow inlet, patented dispensing tip, and valve bottom seal.
Printed Ceramic, Cured with UV

High viscosity ceramic/resin paste

365 nm, 4 watt LED

UV-protected nScrypt pump
Printable Epoxy or Silicone

Standard 2-part high strength epoxy

Conductive 2-part epoxy

RF/Microwave Silicone
Integrated Pick and Place
# State of the art

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3D Printed Antenna

ABS Filament

Silver Flake Thick Film Paste

FDM

nScrypt

3D Printed Antenna
Design

• Planar inverted “F” antenna
  • Requires thick dielectric or floating metal

• Quarter-Wave / Dipole
  • End-fire nulls

• Patch
  • Highly directional

• Inverted “F” Antenna
  • Simple, one-sided
Design

- Resonance
  - Quarter-wave
  - Ground sufficiently large

- Tuning
  - $Z_c = 50 \, \Omega$ (at point 3)
  - Width of inductor trace (item 2)
  - Feed point (item 3) located at $L/3.5$
CPW

Designed
Gap = 0.050 mm
Width = 2.0 mm
$Z_C = 50 \, \Omega$

As-Printed
Gap = 0.455 mm
Width = 2.0 mm
$Z_C = 80 \, \Omega$

- Microstrip tunes more easily
- CPW allows single-sided print
EPO-TEK H20e
Silver 2-part conductive epoxy
Good adhesion
Dupont CB-028
Silver flake conductive ink
Good conductivity
U.FL / IPX / UMCC

- Modern and popular

- Inexpensive

- Surface-mount, no vias needed

- Low-cost single-side mounting
Installation

- EPO-TEK H20e
  - 2-part conductive silver epoxy
  - Cured at 90°C for 2 hrs

- Loctite Quickset
  - 2-part, 5-minute
SWR

Blue solid: measured
Green dashed: model
Red dotted: design

Measured:
2.2 SWR at 2.45 GHz

Design:
2:1 SWR from 2.32 – 2.58 GHz
Return Loss

Blue solid: measured
Green dashed: model
Red dotted: design

Measured:
- 8dB at 2.45 GHz

Design:
-10 dB bandwidth is 14.4 %
Reflection

Blue solid: measured
Green dashed: model
Red dotted: design

-10 dB bandwidth is 14.4 %
Modelled Radiation

- 5.6 dB max gain
Measurement

<table>
<thead>
<tr>
<th>Antenna Type</th>
<th>Distance (m)</th>
</tr>
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<tbody>
<tr>
<td>Class 1 Bluetooth Spec.</td>
<td>100</td>
</tr>
<tr>
<td>Quarter-Wave Antenna</td>
<td>114</td>
</tr>
<tr>
<td>3D Printed Inverted F-Antenna</td>
<td>107</td>
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</tbody>
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Transceivers:
- Transceiver 1
- Transceiver 2
Final Credits

• The University of Texas, El Paso
  • Paul Deffenbaugh
  • Dr. Kenneth Church

• nScrypt, Orlando
  • Josh Goldfarb
  • Xudong Chen

• The University of South Florida
  • Ibrahim Nassar
  • Jonathan O’Brien