Advanced Planar Antenna Designs for Wireless Devices

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Introduction (1)

- **Wireless Communication devices**
  - Cellular phones (bar type, folder type)
  - Laptops or Tablet PCs
  - Personal digital assistants (PDAs)
  - WLAN in-building access points (on-ceiling, on-wall, on-desk)

- **Operating bands**
  - AMPS, GSM, DCS, PCS, UMTS, etc. (850, 900, 1800, 1900, 2050 MHz bands, etc.)
  - WLAN band (2.4, 5.2, 5.8 GHz)
  - Ultra-wide band (3.1~10.6 GHz)
Introduction (2)

Some Promising planar antenna types

- Planar inverted-F antennas (PI FAs)
- Very-low-profile monopoles (bent, folded)
- Printed monopole/dipole antennas
- Metal-plate antennas (constructed using line-cutting or stamping)
- Slot antennas (stamped from metal or integrated with system ground plane)
- Folded dipole antenna
- Ceramic chip antennas (SMT devices)
Conventional PIFAs

Conventional PIFAs comprise: a top patch, a shorting pin, and a feeding pin.

The top patch is mounted above a ground plane;
The shorting pin and feeding pin, connected at proper positions to the top patch, have the same length as the distance between the top patch and the ground plane.
Some dual-frequency top patches for PIFAs

These top patches are mainly printed on a thin dielectric substrate, and then supported above a ground plane.
PIFA - Folded top patch, stamped from a metal plate

Patch stamped from a single metal plate;
Then folded and attached to two sides of a dielectric slab.
PIFA- PIFA printed on an FPCB

PIFA unbent into a planar structure

flexible printed circuit board (FPCB)

bent structure (40 x 7 x 8 mm$^3$)

Patent pending
PIFA- PIFA printed on an FPCB

Length of the meandered radiating arm is ~ 95 mm, about 0.25\(\lambda\) at 900 MHz

BW (2.5:1 VSWR) covers the GSM and DCS bands;
Gain about 0.5-1.4 dBi for GSM band,
and about 1.3-3.2 dBi for DCS band
Very-Low-Profile Monopole 1-Planar monopole with slits

- **Inner sub-patch** resonates at $0.25\lambda$ for upper band;
- **outer sub-patch** at $0.25$ and $0.5\lambda$ for lower and upper bands.
Very-Low-Profile Monopole 2-Planar spiral monopole

Placing monopole in perpendicular to the circuit board

- Monopole size 7 x 30 mm²
- 7 mm to the system ground
- Covering GSM/DCS/PCS bands

TW Patent 171088
Very-Low-Profile Monopole 3-for folder-type handset (1)
Antenna printed on two sides of a dielectric substrate; BW (2:1 VSWR) covers the GSM/DCS/PCS bands

Gain level about 1 dBi for GSM band,
and about 2 dBi for DCS/PCS bands
Ground plane (length) effect on antenna performance

<table>
<thead>
<tr>
<th></th>
<th>Effect on $f_r$</th>
<th>Effect on BW</th>
<th>Effect on pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopole</td>
<td>Large (&gt; 15%)</td>
<td>large</td>
<td>large</td>
</tr>
<tr>
<td>Shorted monopole</td>
<td>Large (&gt; 15%)</td>
<td>large</td>
<td>large</td>
</tr>
<tr>
<td>PIFA</td>
<td>Small (~ 5%)</td>
<td>large</td>
<td>large</td>
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1. GP length varies from 40~200 mm (0.25~1.25$\lambda$), $f = 1800$ MHz ($\lambda$~160 mm)
2. For PIFA, max BW occurs when GP length $\sim 0.35\lambda$ (60 mm), 0.85$\lambda$ (140 mm), 1.35$\lambda$ (220 mm)
3. Period of null currents on GP is $\sim 0.5\lambda$ (80 mm)
Simulated Surface Current Distributions Using Ansoft HFSS

Dark regions indicate null currents and are spaced about 0.5λ
Simulated Radiation Patterns Using HFSS $f = 1800$ MHz

Radiation patterns dominated by the ground-plane length

$L = 40$ mm case shows a $0.5\lambda$ dipole-like pattern

$L = 80$ mm

$L = 120$ mm

$y-z$ plane  $x-z$ plane  $x-y$ plane
Simulated Radiation Patterns Using HFSS

$L = 200$ mm case shows 1.5$\lambda$ dipole-like patterns
For WLAN mobile units-
Surface-mount antenna

- Regular patch antennas (ceramic chip as a substrate)
- Monopoles (ceramic chip as a support for the monopole)
SMA- Ceramic Chip Antenna (1)

CP Design

- Ceramic chip
- Radiating patch
- Ground plane
- Feed

Protruded ground for easy connection to the system ground

US Patent 6140968
SMA- Ceramic Chip Antenna (2.1)

CP Design, dual side-feed, feed at A for RHCP, feed at B for LHCP; Gain level about 3.0 dBic (test board 50 mm x 50 mm) for GPS operation at 1575 GHz

ceramic chip ($\varepsilon_r = 45$)

TW Patent 171997
SMA- Ceramic Chip Antenna (2.2)

CP Design, dual side-feed ceramic chip antenna

TW Patent 171997
SMA- Ceramic Chip Antenna (2.3)
3D Model in Ansoft HFSS
SMA- Ceramic Chip Antenna (2.4) Current Plot

Ansoft HFSS simulation results
Helix monopole embedded within the ceramic chip

Meandered monopole embedded within the ceramic chip
Printed Dipoles/ Monopoles/ Slot Antennas/ PIFAs Applied to Notebook Computer

US Patents 6344825, 6297779, 6008774, 6295029, 6339400, 2001/ 0040529, 2002/ 0021250
WLAN Slot Antennas/ PIFAs Applied to Laptops

slot antenna
0.5 wavelength in length

PIFA
0.25 wavelength in length
WLAN 2.4/5.2 GHz Dual-Band Dual-Slot Antenna

Antenna gain level in both 2.4 and 5.2 GHz about 6.0~7.0 dBi

Patent pending
WLAN Metal-Plate Antenna (1)

Antenna size = 3 x 60 mm²; gain level ~3.6 dBi in 2.4 GHz band

Patent pending
WLAN Metal-Plate Antenna (2), dual-band operation

Antenna size = 1 x 3 x 60 mm³; gain level ~3.0/3.6 dBi in 2.4/5.2 GHz bands
WLAN Metal-Plate Array Antenna

Antenna size = 5 x 5 x 65 mm³;
Gain level > 4 dBi in 5 GHz band;
Antenna constructed from a single metal plate
WLAN Access-Point Antennas

- On-wall, on-ceiling, on-desk designs
- Printed dipole array for omni or diversity radiation
- Printed folded dipole (or loop) array for omni or diversity radiation
WLAN AP Antenna- Omnidirectional dipole array (1)

5 GHz AP dipole array:
1.5:1 VSWR: 5.15-5.35 GHz
Peak gain: > 5.5 dBi (Duroid sub)
Omnidirectional ripple: < 2 dBi
Size: 12 mm x 90 mm

Ports 1, 2: 0°, 1/4 power
Ports 3, 4: 180°, 1/4 power
WLAN AP Antenna-
Omnidirectional dipole array (2)

**BW covers 2.4/5.2 GHz bands**

**Gain level:** ~ 2.5 dBi for 2.4 GHz band;
~4.0 dBi for 5.2 GHz band (FR4 sub)

**Omnidirectional ripple:** < 2 dBi

**Size:** 12 mm x 160 mm
WLAN AP Antenna-Diversity dual-band dipole

*Port 1*

- $\phi = 90^\circ (+y)$
- $\theta = 0^\circ (+x)$
- 2442 MHz
- 10 dB

*Port 2*

- $\phi = 90^\circ (+y)$
- $\theta = 0^\circ (+x)$
- 5250 MHz

Azimuthal plane

$E_\theta$

$E_\phi$
WLAN AP Antenna - Omnidirectional folded dipole

5 GHz AP dipole array:
2:1 VSWR: 5.0-6.1 GHz
Peak gain: > 4.5 dBi (FR4 substrate)
Omnidirectional ripple: < 1.8 dBi
Size: 18 mm x 68 mm
WLAN AP Antenna - Omnidirectional folded dipole

Simulation results using Ansoft HFSS.
Conclusions

- Planar antennas are good candidates for wireless devices applications

- More promising planar antenna designs and applications are in progress