Yagi-Uda Antenna
Theory, Design and Results

Thomas Fahrni and Andreas Müller
1. Yagi-Uda Antenna – Theory
2. Antenna Design
3. Construction
4. Test Set-up
5. Results
History

- Invented by Shintaro Uda and Hidetsugu Yagi in 1926
- Relatively unknown until World War 2
- Now used for amateur radio, TV, satellite comm., ..

Typical Yagi Antenna
Yagi-Uda Antenna – Theory

Theory

Dipole
- Two conductors of length $\approx \lambda/4$
- One connected to signal, the other to ground
- The only driven element in the system, no electrical connection to directors or reflector

Directors
- Lengths smaller than dipole, continuously decreasing
- Excited by the field of the dipole
- Make antenna directional

Reflector
- Larger than dipole
- Prevents antenna from sending backwards
**Antenna Design**

**Fixed parameters**
- Frequency: 2.45 GHz
  ≈ Channels 8 and 9
- 9 Directors

**Calculated parameters**
- Element lengths
- Element positions
- Calculated with online JavaScript application

<table>
<thead>
<tr>
<th></th>
<th>Position [mm]</th>
<th>Length [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector</td>
<td>0</td>
<td>57.8</td>
</tr>
<tr>
<td>Dipole</td>
<td>24.47</td>
<td>54.68</td>
</tr>
<tr>
<td>D1</td>
<td>33.65</td>
<td>47.03</td>
</tr>
<tr>
<td>D2</td>
<td>55.68</td>
<td>45.98</td>
</tr>
<tr>
<td>D3</td>
<td>81.98</td>
<td>45.00</td>
</tr>
<tr>
<td>D4</td>
<td>112.58</td>
<td>44.13</td>
</tr>
<tr>
<td>D5</td>
<td>146.84</td>
<td>43.38</td>
</tr>
<tr>
<td>D6</td>
<td>183.55</td>
<td>42.74</td>
</tr>
<tr>
<td>D7</td>
<td>222.09</td>
<td>42.18</td>
</tr>
<tr>
<td>D8</td>
<td>262.47</td>
<td>41.7</td>
</tr>
<tr>
<td>D9</td>
<td>304.69</td>
<td>41.28</td>
</tr>
</tbody>
</table>
## Antenna Construction

### Requirements
- Low cost
- Non-metallic construction
- Adjustable element positions

### Materials Used
- $16\text{mm}$ wood rod
- Plastic pipe clamps to mount elements
- $2.5\text{mm}$ copper wire / $3\text{mm}$ aluminium sticks
- Plenty of hot glue

### Result
- Cost: about 20 CHF
**Test Set-up**

<table>
<thead>
<tr>
<th>Analysis with VNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shows resonance frequency, input impedance, SWR</td>
</tr>
<tr>
<td>Incredibly useful for tuning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis Signal Generator and Spectrum Analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sender: signal generator (tuned to 2.43 GHz) + antenna</td>
</tr>
<tr>
<td>commercial 2.4 GHz dipole antenna (reference)</td>
</tr>
<tr>
<td>our Yagi antenna</td>
</tr>
<tr>
<td>Receiver: spectrum analyzer + commercial 2.4 GHz dipole</td>
</tr>
<tr>
<td>Sender antenna rotated in 10 degree steps</td>
</tr>
</tbody>
</table>
Results – Radiation Pattern

Radiation pattern

Gain [dB]

0° 45° 90° 135° 180° 225° 270° 315°
Results

Key Parameters
- Gain: About 20 dBi
- Resonance frequency: ~2.43 GHz
- Input impedance (after tuning): $49 - i6\Omega$
- Found AP at 5.5 km distance :-)

Lessons Learned
- Element lengths and spacings are critical
- Yagi has good directivity
- Professional equipment very helpful during construction