An intuitive tour of parabolic reflector antennas

By K6MG
Introduction

• No equations will be used in this presentation, however several equations were harmed in the preparation

• Why a parabola reflector?

• The full parabola

• The offset parabola

• Multiple reflectors

• The ADE

• Reflectarray and Fresnel reflectors
Goal: directivity

Spherical wavefront

Planar wavefront

Wavefront: constant phase across the surface

Propagation through space and time
Conversion from spherical to planar wavefronts

- Parabola
- Focus
- Constant distance from the focus to the plane at all angles
• Diameter 4 units
• Focal length 1 unit
• F/D 0.25

• We are only interested in parabolas with F/D > 0.25 since smaller F/D becomes too deep

• Any parabola of interest can be made from this curve by truncating the diameter to get the desired F/D and scaling the units to the desired size
• Truncating the diameter for higher F/D results in a “shallower” curve: the focus stays at the same place but the parabola edges pull back toward zero

• At 0.25 F/D the edges are in the same plane as the focus

• The angle of incidence == the angle of reflection, at 0 degrees the surface of the parabola is perpendicular to the wavefront, at 90 degrees the surface of the parabola is 45 degrees to the wavefront
The offset parabola

Uses at most half of the parabolic curve

The “offset” can be >0 by starting the curve >0

The focal length is defined as the distance from the lower edge of the curve to the focal point

The tilt angle is the angle from vertical of the plane across the edges

The “diameter” is defined as the aperture of the incoming/outgoing planar wavefront
Things to notice

The tilt angle is a function of F/D for any given offset, only one tilt angle is possible for an F/D.

Offsets >0 require a larger segment of the curve to achieve the same aperture.

A zero offset parabola has exactly double the F/D of the equivalent full parabola, the focal length is the same as the full parabola.
Offset tilt vs. F/D

<table>
<thead>
<tr>
<th>Tilt Angle</th>
<th>F/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.5</td>
<td>1</td>
</tr>
<tr>
<td>15.25</td>
<td>0.95</td>
</tr>
<tr>
<td>16</td>
<td>0.9</td>
</tr>
<tr>
<td>17</td>
<td>0.85</td>
</tr>
<tr>
<td>18</td>
<td>0.8</td>
</tr>
<tr>
<td>19.25</td>
<td>0.75</td>
</tr>
<tr>
<td>20.8</td>
<td>0.7</td>
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<tr>
<td>22.6</td>
<td>0.65</td>
</tr>
<tr>
<td>24.5</td>
<td>0.6</td>
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<tr>
<td>27</td>
<td>0.55</td>
</tr>
<tr>
<td>30</td>
<td>0.5</td>
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</tbody>
</table>
### Inefficiencies

<table>
<thead>
<tr>
<th>Inefficiency</th>
<th>Prime focus</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illumination</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>Spillover</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>Blockage</td>
<td>0.90</td>
<td>0.97</td>
</tr>
<tr>
<td>Ohmic</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Surface</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Diffraction</td>
<td>0.95</td>
<td>0.98</td>
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**57%**  **69%**

**-2.4 db**  **-1.6 db**
Illumination and Spillover
Illumination and Spillover
Multiple Reflectors

**Newtonian** – flat sub-reflector

**Cassegrain** – hyperbolic sub-reflector

**Gregorian** – elliptical sub-reflector
Why??

• + Reduce feedline loss by moving the FP back toward the dish

• + Cassegrain and Gregorian multiply the F/D improving illumination efficiency of low F/D dishes

• - for small dishes blockage increases significantly

• - double diffraction, spillover and ohmic losses
Example Cassegrains

18” diameter main
2.75” diameter sub
2.5% sub blockage
40 GHz min

10 GHz min
10” diameter sub
31% sub blockage

36” diameter main
4” diameter sub
1.4% sub blockage
24 GHz min
Axially Displaced Ellipse (Gregorian)

Step 1: displace the parabola from the origin opening up a hole in the center
This creates a circular ring of focus rather than a point focus
In the example the parabola is displaced 0.5 from the origin
Step 2: use a rotated tilted *ellipse* to convert the focus ring to a focus point

Note that at the focus ring the wavefronts to the inner and outer edges of the displaced parabola cross

The crossing distributes the highest energy density of the feed to the outer edges of the parabola
### Inefficiencies

#### ADE vs. Offset

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- **82%** vs. **69%**
- **-0.9 db** vs. **-1.6 db**
Shaped multiple reflectors

Don’t have to use conic sections (Parabola, ellipse, hyperbolic) as long as the ray traced distance from the feedpoint to the planar wave is constant.

Shaping the sub-reflector and the main reflector enables better energy distribution to be achieved like the ADE.

Efficiencies of up to 85% have been measured.
Reflectarray

Don’t have to make all the path lengths equal!!!

It’s the constant phase at the plane that ensures directivity

Equal path lengths produce an in-phase wavefront at all frequencies

If we can operate narrow band other reflector structures become possible

For instance: a planar array of dipole reflectors that use passive or active phase tuning to produce an in-phase reflected wavefront
A Fresnel dielectric plate in front of a flat reflector can be used to generate the phase shifts needed to result in a planar wavefront.

The dielectric thickness is kept low in order to minimize absorption loss.

Efficiencies of $\leq 30\%$ are typical for this type of structure.
Conclusions

• There are a wide range of parabolic type reflector antennas with various tradeoffs:
  - Efficiency
  - Ease of construction

• Efficiencies higher than a good offset parabola while possible are less than 1 db