Design of Yagi-Uda Antennas

(section 10.3.3 of *Antenna Theory, Analysis and Design* (2^{nd} Edn) by Balanis)

Figure 1 Yagi-Uda Antennas on Traffic Lights (Courtesy of Mr. J. Wolf)

Advantages:

- ✓ Lightweight,
- ✓ Durable,
- ✓ Simple construction,
- ✓ Low cost,
- ✓ Many desirable performance characteristics

Typical characteristics/parameters:

- 4.3 dBi ≤ Typical Directivity (Gain) ≤ 19 dBi
- 15 Ω ≤ Typical Input Impedance ≤ 70 Ω (w/out feed)
- Bandwidth ≤ 2%
- Typical frequency bands where utilized are: HF (3-30 MHz), VHF (30-300 MHz), and UHF (300-1000 MHz)
- Transmission line feeds:
  - Coaxial using a Gamma match, Omega match, or modified Gamma match at the driven element.
  - Twin-lead using a T-match at the driven element or with a folded dipole as the driven element.
- Pre-determined designs are available.
- Also, computer-aided design tools, which allow the antenna to be optimized for particular performance characteristics, are available. For example, several shareware programs that use NEC (Numerical Electromagnetics Code), a Method of Moments code, as an engine are freely available on the internet.

Yagi-Uda Antenna Design Procedure

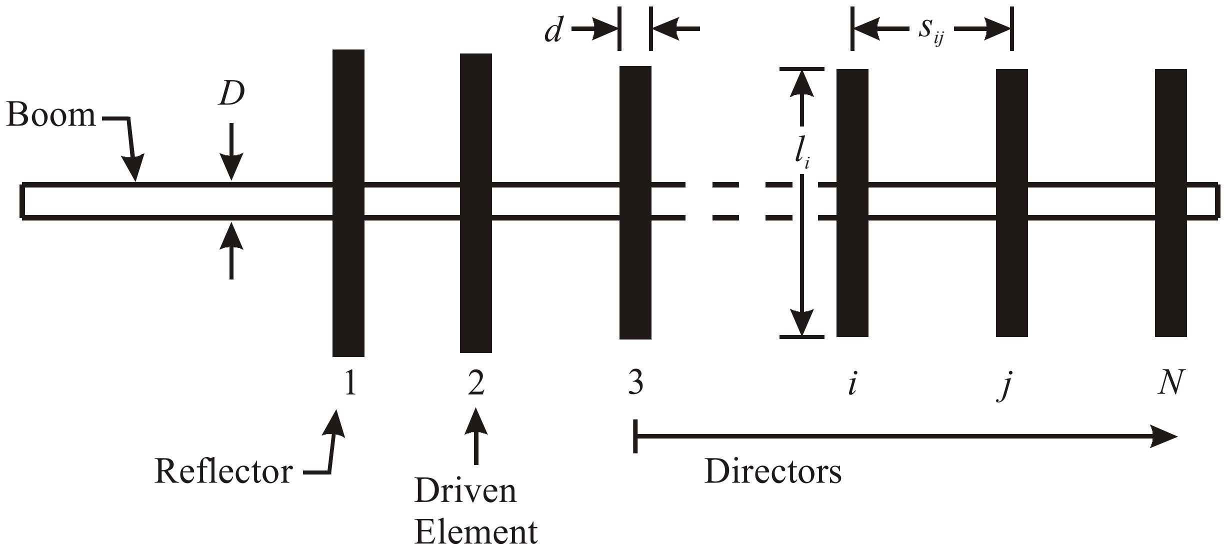

Figure 2 Yagi-Uda Antenna Layout

Notes:

- Design procedure based on: P.P. Viezbicke, "Yagi Antenna Design," NBS Technical Note 688, U.S. Department of Commerce/National Bureau of Standards, December 1976.

- This design procedure utilizes a table (Table 10.6) and two figures (Fig. 10.25 & 10.26) taken from the NBS Tech. Note.

- The directivities given by Table 10.6 are in dBd, $\text{dBi} = \text{dBd} + 2.15\,\text{dB}$.

- The design(s) described by Table 10.6 assume that the antenna uses a certain diameter for the elements and has a dielectric boom. If a different diameter is used, element length adjustments are made using Figure 10.25. If a metal boom is used, element length adjustments are made using Figure 10.26.

Design Steps:

1. Select or specify design parameters:
   a. Desired directivity (gain)
      - Six values ranging from 9.25 to 16.35 dBi available (see Table 10.6)

   b. Design Frequency (center frequency of 1-2% bandwidth)
   c. Desired input impedance R_0 (real) based on desired or given transmission line.

2. Select diameter d of elements and diameter D of metallic supporting boom (optional, only necessary if a metallic boom is to be used) based on mechanical considerations (e.g., strength, rigidity) and parts availability.

3. Calculate design wavelength- $\lambda = c/f$. Use this to calculate s_{12} (reflector-driven element spacing) and s_{ij} [driven-director & director-director spacing(s)] using Table 10.6 values.

4. Calculate d/λ. Is $0.001 \leq d/\lambda \leq 0.04$? If not, go to step 2 and reconsider selection of d.

5. If a metal boom is used (otherwise, go to next step), calculate D/λ. Is $0.001 \leq D/\lambda \leq 0.04$? If not, go to step 2 and reconsider selection of boom diameter D.

Table 10.6 OPTIMIZED UNCOMPENSATED LENGTHS OF PARASITIC ELEMENTS FOR YAGI-UDA ANTENNAS OF SIX DIFFERENT LENGTHS

$d/\lambda = 0.0085$		LENGTH OF YAGI-UDA (IN WAVELENGTHS)					
$s_{12} = 0.2\lambda$		0.4	0.8	1.20	2.2	3.2	4.2
LENGTH OF REFLECTOR (l_1/λ)		0.482	0.482	0.482	0.482	0.482	0.475
LENGTH OF DIRECTORS, λ	l_3	0.442	0.428	0.428	0.432	0.428	0.424
	l_4		0.424	0.420	0.415	0.420	0.424
	l_5		0.428	0.420	0.407	0.407	0.420
	l_6			0.428	0.398	0.398	0.407
	l_7				0.390	0.394	0.403
	l_8				0.390	0.390	0.398
	l_9				0.390	0.386	0.394
	l_{10}				0.390	0.386	0.390
	l_{11}				0.398	0.386	0.390
	l_{12}				0.407	0.386	0.390
	l_{13}					0.386	0.390
	l_{14}					0.386	0.390
	l_{15}					0.386	0.390
	l_{16}					0.386	
	l_{17}					0.386	
SPACING BETWEEN DIRECTORS (s_{ij}/λ)		0.20	0.20	0.25	0.20	0.20	0.308
DIRECTIVITY RELATIVE TO HALF-WAVE DIPOLE (dB)		7.1	9.2	10.2	12.25	13.4	14.2
DESIGN CURVE (SEE FIGURE 10.25)		(*A*)	(*B*)	(*B*)	(*C*)	(*B*)	(*D*)

SOURCE: Peter P. Viezbicke, *Yagi Antenna Design*, NBS Technical Note 688, December 1976.

Table 1 Available tubing/pipe/rod sizes

Nominal Diameter		Outer Diameter*	
(inches)	(cm)	(inches)	(cm)
3/32	0.238125	3/32	0.238125
1/8	0.3175	1/8	0.3175
5/32	0.397	5/32	0.397
3/16	0.476	3/16	0.476
7/32	0.556	7/32	0.556
1/4	0.635	1/4	0.635
9/32	0.714	9/32	0.714
5/16	0.794	5/16	0.794
11/32	0.873	11/32	0.873
3/8	0.9525	3/8	0.9525
13/32	1.032	13/32	1.032
7/16	1.111	7/16	1.111
1/2	1.27	1/2	1.27
1/2	1.27	9/16	1.429
1/2	1.27	5/8	1.5875
3/4	1.905	7/8	2.223

* For brass tubing/pipe/rods, the nominal and outer diameters are the same (i.e., wall thickness negligible). For copper pipes, the wall thickness is substantial and should be measured as it varies between manufacturers.

6. If $d/\lambda = 0.0085$, go to step 11 (no element diameter length corrections required). If $d/\lambda \neq 0.0085$, the elements lengths must be corrected. Plot the lengths of the reflector (element 1) and first director (element 3) from Table 10.6 on the appropriate design curves on Figure 10.25 (should fall on or near vertical line drawn from $d/\lambda = 0.0085$). Label these points l_1'' and l_3'' respectively.

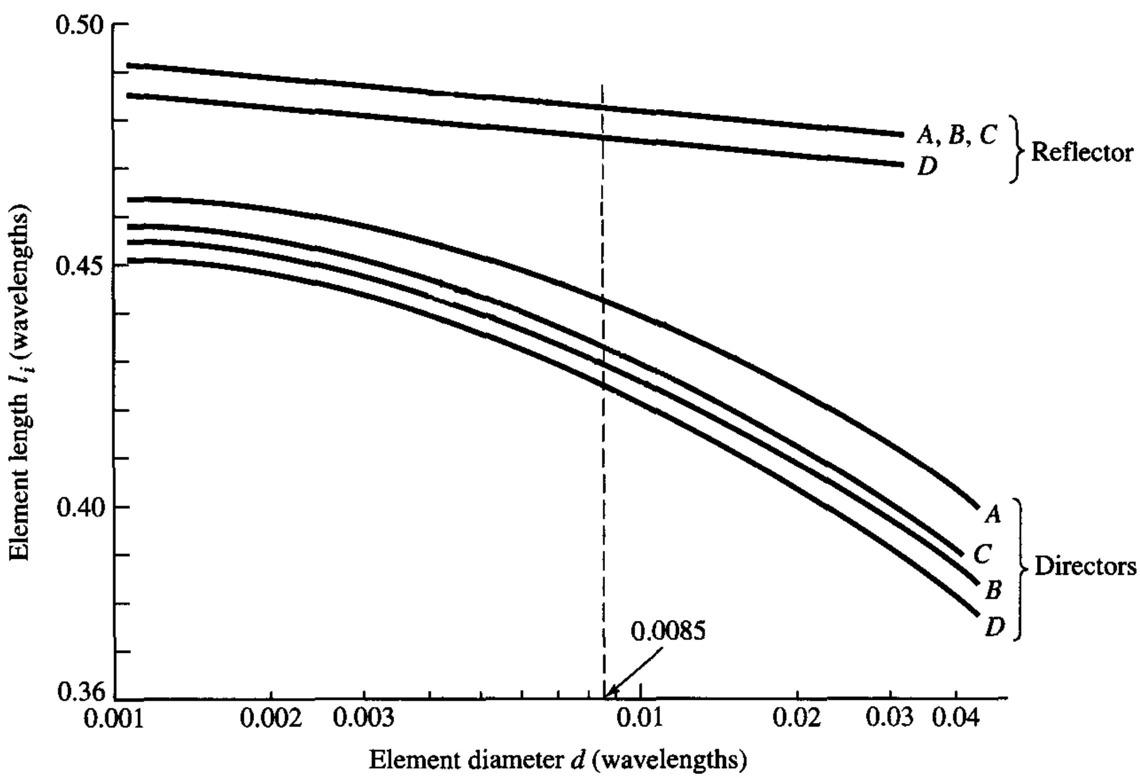

Figure 10.25 Design curves to determine element lengths of Yagi-Uda arrays. (SOURCE: P. P. Viezbicke, "Yagi Antenna Design," NBS Technical Note 688, U.S. Department of Commerce/National Bureau of Standards, December 1976)

7. Draw a vertical line from the actual d/λ through the appropriate reflector and director design curves, where this line intersects the curves is the corrected lengths of the reflector l_1' and first director l_3'. To read the values, draw horizontal lines from the intersections to the left axis of the figure. The length l_3' should be used for any other directors that are the same original length as l_3.

8. Measure and label the arc length Δl between l_3'' and l_3' along the design curve.

9. Plot the remaining original optimized director lengths from Table 10.6 on the appropriate director design curve on Figure 10.25 and label l_i'' (Note: point(s) will not fall on the vertical line drawn from $d/\lambda = 0.0085$).

10. To find the corrected (for element diameter) length(s) for the remaining directors, move Δl from l_i'' (same direction as between l_3'' and l_3') to the corrected length l_i'. To read the value(s), draw horizontal line(s) from l_i' to the left axis of the figure.

11. If a metal boom is used (else, skip to next step), the element lengths must be lengthened to compensate for it. On Figure 10.26, draw a vertical line from D/λ through the curve. Draw a horizontal line from the intersection to the left axis of the figure and read the compensation length. The final lengths of the elements (label l_i) are found by adding this length to the original (Table 10.6) or the corrected (for element diameter) element lengths.

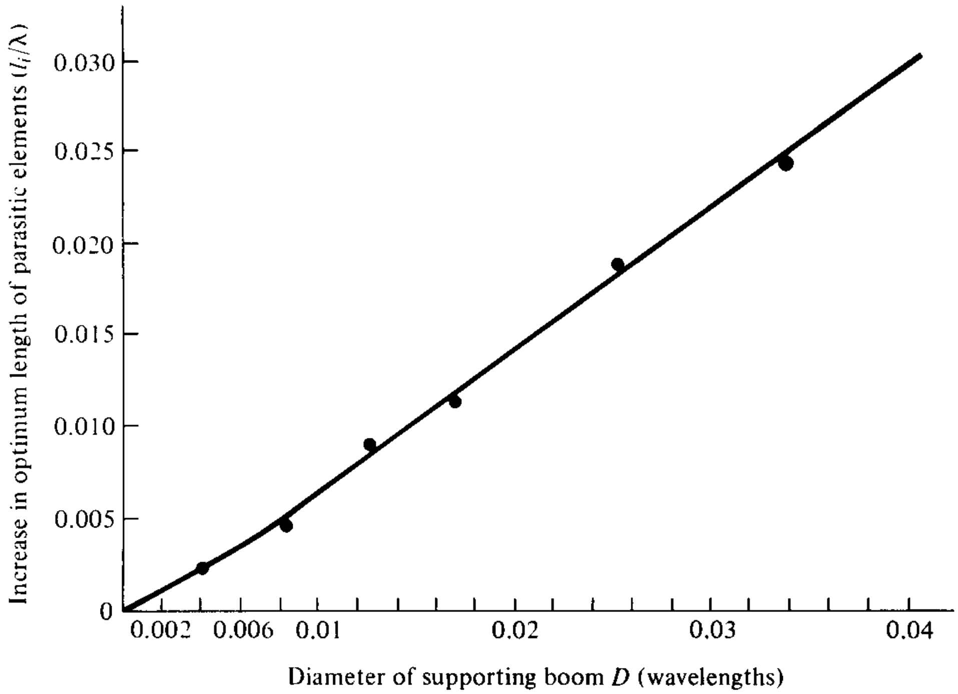

Figure 10.26 Increase in optimum length of parasitic elements as a function of metal boom diameter. (SOURCE: P. P. Viezbicke," Yagi Antenna Design," NBS Technical Note 688, U.S. Department of Commerce/National Bureau of Standards, December 1976)

12. Design matching network (e.g., Gamma match, …) to connect the antenna to the selected transmission line. The length of the driven element l_2 is empirically adjusted to achieve a match at the design frequency. Typically, it has a length between that of the reflector and the first director.