Design a six-element Yagi-Uda antenna for VHF television channel 13 using a copper-pipe boom with an outer diameter of 9/16 inch and brass elements with an outer diameter of 3/8 inch. Assume boom will need to extend 12" past center of reflector to allow antenna to be attached to an antenna mast, and 1" past center of last director for mechanical strength.

a) Tabulate design specifications (assume 75 Ω feeding transmission line)

Six-element VHF Channel 13 Yagi-Uda Antenna Specifications

Directivity/gain D_{max}	10.2 dBd = **12.35 dBi**	
Frequency range	**210 - 216 MHz**	f_c = 213 MHz
Input impedance R_0	**75 Ω**	

b) Show complete design procedure (e.g., design figures, spreadsheets, …) in a fashion similar to example given in class. **No matching network is required.**

Design Steps:

1. Select or specify design parameters:

   a. The directivity of a 6 element Yagi-Uda antenna, from Table 10.6, is 10.2 dBd = $10.2 + 2.15 =$ **12.35 dBi.** Note: For a Yagi-Uda antenna, gain ≈ directivity.

   b. Design Frequency- Channel 13 210-216 MHz , so **f = 213 MHz**.

   c. Desired input impedance- **R_0 = 75 Ω** (not required for design process, yet)

2. Select diameter d of elements and diameter D of metallic supporting boom

   Element diameter- **d = 3/8" = 0.9525 cm** (use brass pipe)

   Boom diameter- **D = 9/16" = 1.42875 cm** (use 1/2" I.D. copper pipe)

3. Calculate design wavelength λ. Use λ to calculate s_{12} (reflector-driven element spacing) & s_{ij} [driven-director & director-director spacing(s)] using Table 10.6 values.

$$\lambda = \frac{c}{f} = \frac{2.998\times10^{8}}{213\times10^{6}} = 1.4075117\text{ m} \quad \Rightarrow \quad \lambda = 140.7512\text{ cm}$$

s_{12} = 0.2λ = 28.1502 cm

s_{ij} = 0.25λ = 35.1878 cm

4. Calculate d/λ. Is $0.001 \le d/\lambda \le 0.04$?

   $d/\lambda = 0.9525/140.7512 \Rightarrow$ **$d/\lambda = 0.0067673$** $\Rightarrow$ Within $0.001 \le d/\lambda \le 0.04$ range.

5. If a metal boom is used, calculate D/λ. Is $0.001 \le D/\lambda \le 0.04$?

   $D/\lambda = 1.42875/140.7512 \Rightarrow$ **$D/\lambda = 0.010151$** $\Rightarrow$ Within $0.001 \le D/\lambda \le 0.04$ range.

6. Since $d/\lambda = 0.067673 \neq 0.0085$, the elements lengths must be corrected. Plot the lengths of the reflector (element 1) & first director (element 3) from Table 10.6 on design curves ***B*** on Figure 10.25. Label these points l_1'' and l_3'' respectively.

   On Design curves B at $d/\lambda = 0.0085$, plot- **$l_1'' = 0.482\lambda$ & $l_3'' = 0.428\lambda$**

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.

7. Draw a vertical line from d/λ = **0.067673** through reflector and director design curves ***B***, and read the corrected lengths of the reflector l_1' and first director l_3'. The length l_3' should be used for any other directors that are the same original length as l_3.

   Label and read the corrected (for element diameter) lengths-

   $l_1' = 0.483\lambda$ & $l_3' = l_6' = 0.434\lambda$.

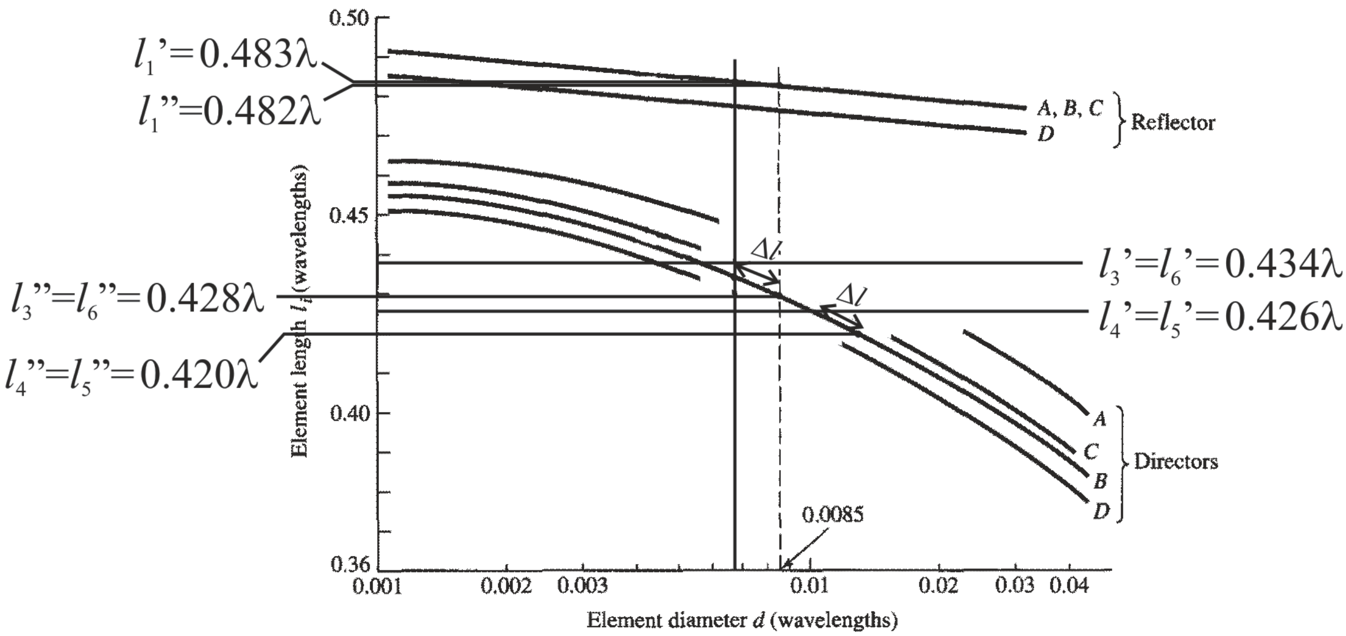

Figure 10.25 Design curves to determine element lengths of Yagi-Uda arrays. (SOURCE: P. P. Viezbicke, "Yagi Antenna Design," NBS Technical Note 688, U.S. Department of Commerce/National Bureau of Standards, December 1976)

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

   Using ruler, Δl = 0.56 cm.

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''

   On director design curve *B*, plot length of the second & third directors-

   $l_4'' = l_5'' = 0.420\lambda$

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'.

    Move Δl = 1.45 cm from $l_4'' = l_5'' = 0.420\lambda$, and read- **$l_4' = l_5' = 0.426\lambda$.**

11. The element lengths must be lengthened to compensate for a metal boom. On Figure 10.26, draw a vertical line from **$D/\lambda = 0.010151$** through the curve. Read the compensation length.

From Figure 10.26, read- **compensation length = 0.00644λ**

$$l_1 = l_1' + 0.00644\lambda = 0.483\lambda + 0.00644\lambda = 0.48944\lambda \;\Rightarrow\; l_1 = 68.889 \text{ cm}$$

$$l_3 = l_6 = l_3' + 0.00644\lambda = 0.434\lambda + 0.00644\lambda = 0.44044\lambda \;\Rightarrow\; l_3 = l_6 = 61.992 \text{ cm}$$

$$l_4 = l_5 = l_4' + 0.00644\lambda = 0.426\lambda + 0.00644\lambda = 0.43244\lambda \;\Rightarrow\; l_4 = l_5 = 60.866 \text{ cm}$$

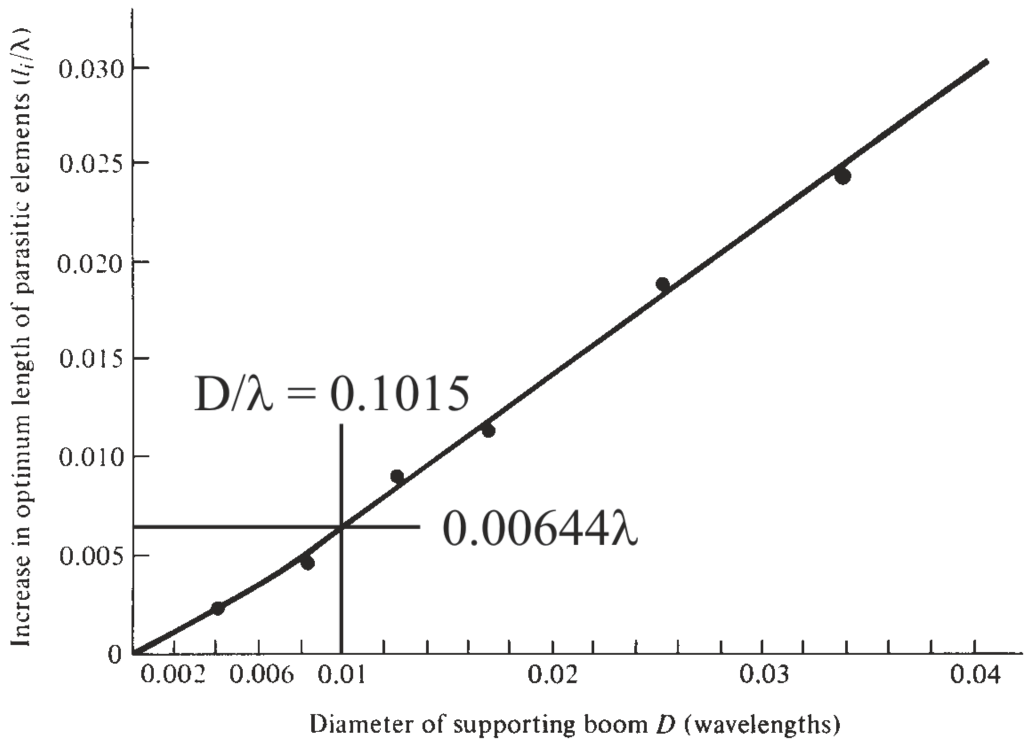

Figure 10.26 Increase in optimum length of parasitic elements as a function of metal boom diameter. (SOURCE: P. P. Viezbicke,“ Yagi Antenna Design,” NBS Technical Note 688, U.S. Department of Commerce/National Bureau of Standards, December 1976)

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.

$$l_3 = 61.992 \text{ cm} < l_2 < l_1 = 68.889 \text{ cm}$$

c) Make a **scale** drawing(s) of the final antenna designed including boom (transmission line may be omitted) that a machinist could take and use to build the antenna (use centimeters for all dimensions).

6 element, channel 13 Yagi-Uda antenna w/ boom

($s_{12} = 0.2\lambda = 28.1502\,\text{cm}$, $s_{ij} = 0.25\lambda = 35.1878\,\text{cm}$)