

Example 2- FM radio LPDA Design

➤ Based on work of R. E. Carrel.

1. Select or specify design parameters

a. Desired directivity (gain)

8 dBi

b. Frequency range (f_{high} and f_{low})

$f_{\text{low}} = 85 \text{ MHz}$, $f_{\text{high}} = 110 \text{ MHz}$

c. Desired input impedance R_0 (real)

$R_0 = 75 \Omega$

2. Use graph [Balanis 3rd Edn., Figure 11.13, p. 631], which shows contours of constant directivity versus σ (relative spacing) and τ (scale factor), to select σ and τ for the desired directivity.

$\sigma = 0.159$ and $\tau = 0.865$

3. Calculate the apex half angle α using-

$$\alpha = \tan^{-1} \left(\frac{1 - \tau}{4\sigma} \right) = \tan^{-1} \left(\frac{1 - 0.865}{4(0.159)} \right) \Rightarrow \underline{\alpha = 11.984^\circ}$$

apex angle $\Rightarrow \underline{2\alpha = 23.968^\circ}$

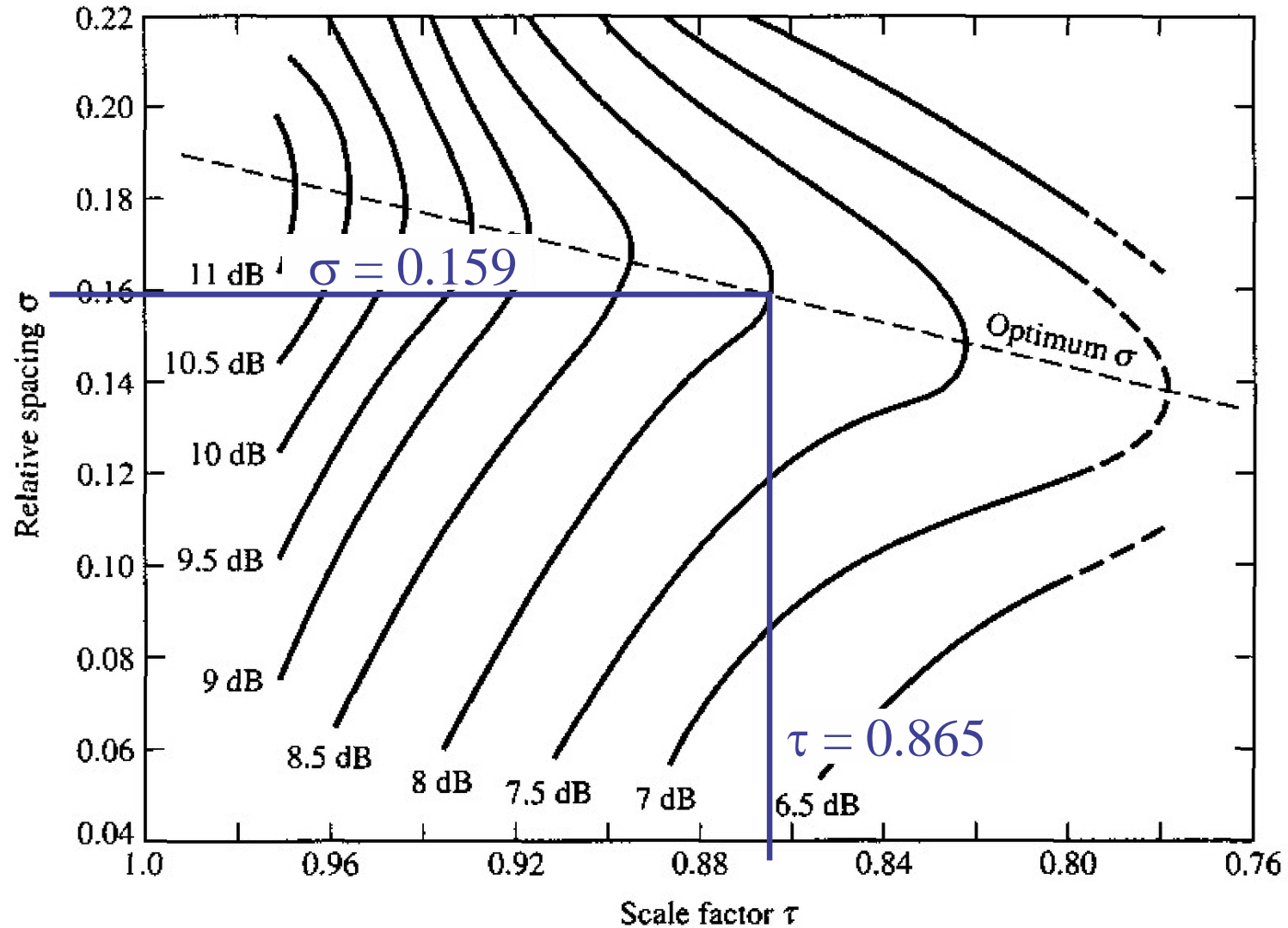


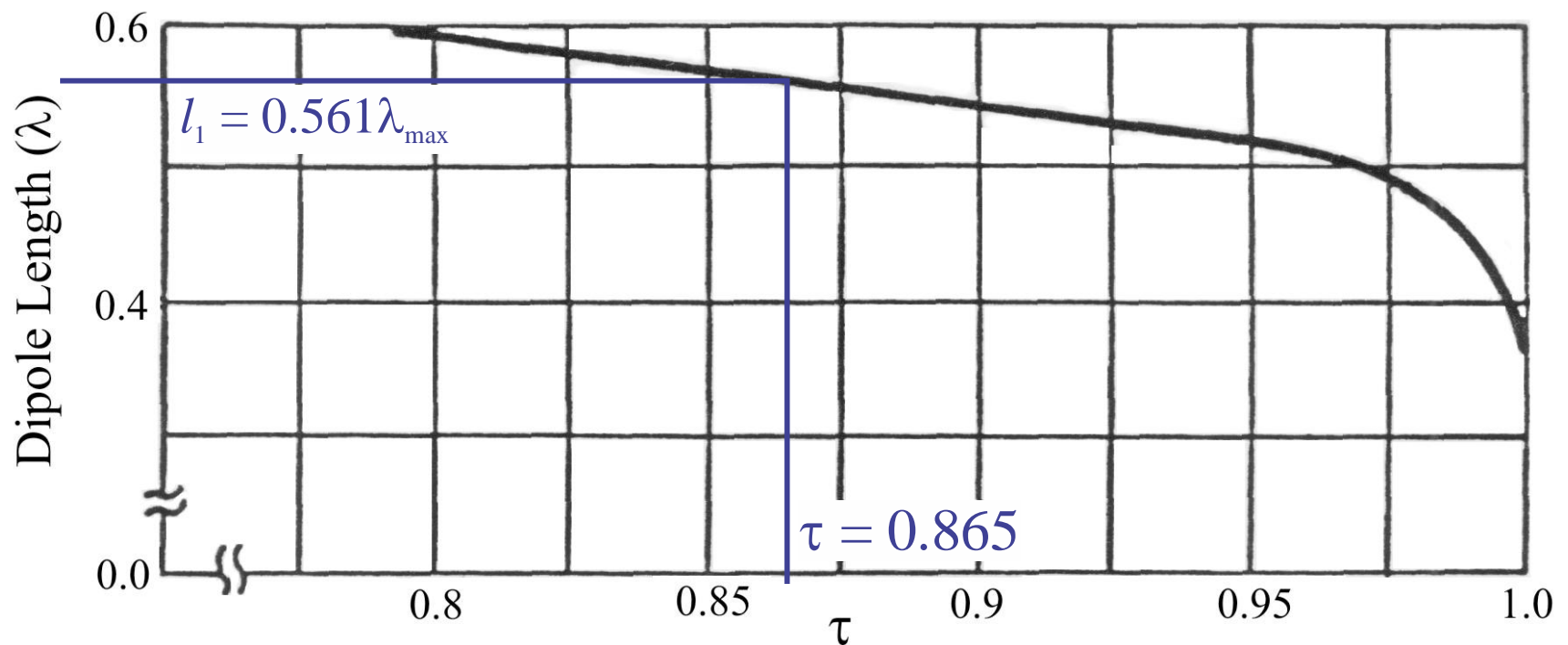
Figure 11.13 Computed contours of constant directivity versus σ and τ for log-periodic dipole arrays. [Balanis 3rd Edn., p. 631]

4. Find length l_1 (Note: start count of elements with longest) of the **longest** element of LPDA

- take length in wavelengths from graph if using optimum σ and τ ;

$$\lambda_{\max} = c/f_{\text{low}} = 3 \times 10^8 / 85 \times 10^6 = 3.5294 \text{ m} \Rightarrow \underline{l_1 = 0.561 \lambda_{\max} = 198 \text{ cm}}$$

- else, use $\lambda_{\max} / 2$ where $\lambda_{\max} = c / f_{\text{low}}$ is the wavelength at the lowest frequency in the desired frequency range. (N/A)

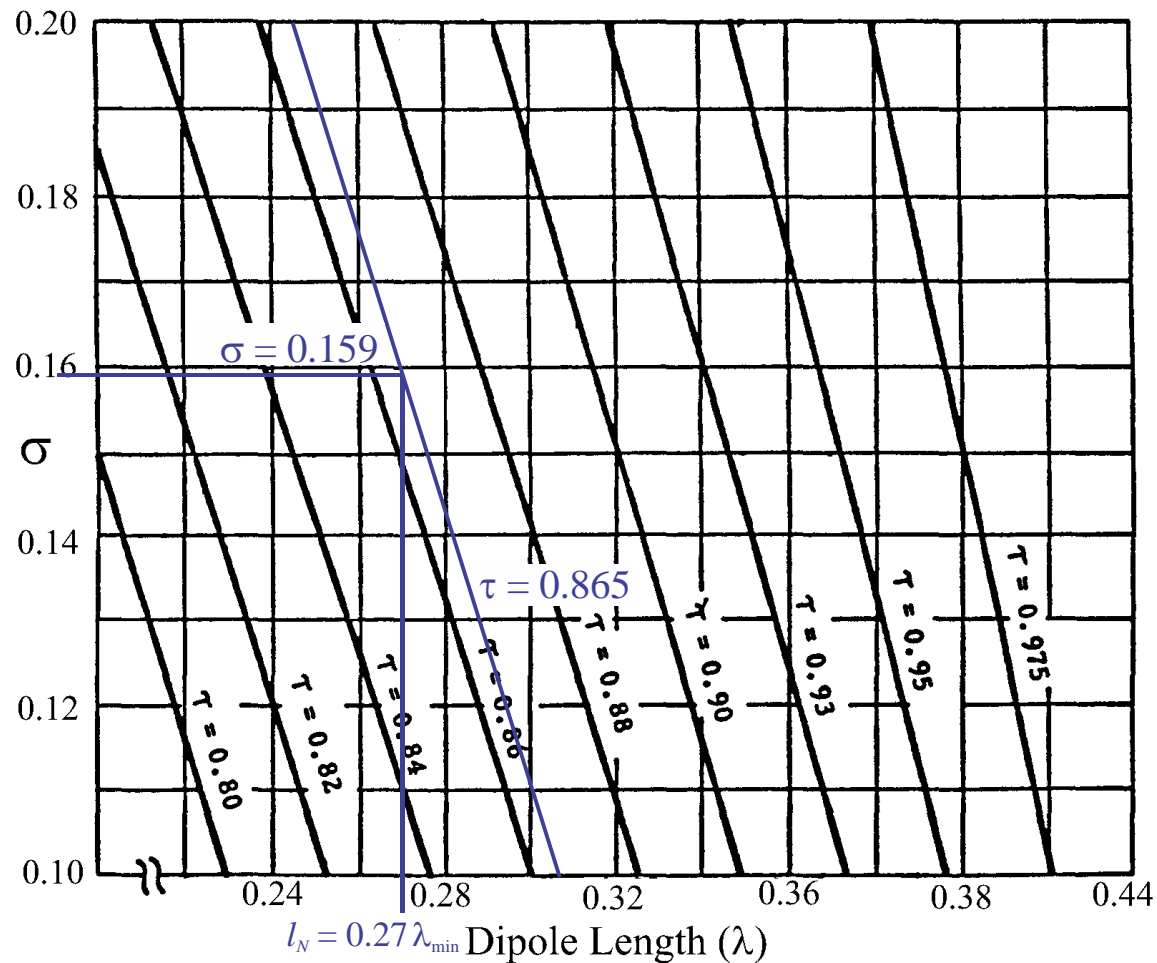


Measured length, normalized by λ_{\max} , of longest dipole in LPDA versus optimum σ and τ .

5. Find length l_N of the **shortest** element of the LPDA

- take length in wavelengths from graph where $\lambda_{\min} = c / f_{\text{high}}$ is the wavelength at the highest frequency in the desired frequency range.

$$\lambda_{\min} = c/f_{\text{high}} = 3 \times 10^8 / 110 \times 10^6 = 2.7273 \text{ m} \Rightarrow \underline{l_N = 0.27 \lambda_{\min} = 73.64 \text{ cm}}$$



Estimated length, normalized by λ_{\min} , of shortest dipole in LPDA versus σ and τ .

6. Calculate location R_1 of **longest** element (as measured from the apex)-

$$R_1 = \frac{l_1}{2} \cot(\alpha) = \frac{198}{2 \tan(11.984^\circ)} \Rightarrow \underline{R_1 = 466.4 \text{ cm}}$$

7. Calculate the total bandwidth B_s , includes additional bandwidth B_{ar} due to active region, using the specified bandwidth B -

$$B = f_{\text{high}} / f_{\text{low}} = 110 \text{ MHz} / 85 \text{ MHz} = \underline{1.29412}$$

$$B_{ar} = 1.1 + 7.7 (1-\tau)^2 \cot(\alpha) = 1.1 + 7.7 (1-0.865)^2 \cot(11.984^\circ) = \underline{1.76112}$$

$$B_s = B_{ar} \cdot B = 1.76112 \cdot 1.29412 = \underline{2.2791}$$

8. Calculate the approximate number N of elements required for design

$$N = 1 + \log_{10}(B_s) / \log_{10}(1/\tau) = 1 + \log_{10}(2.2791) / \log_{10}(1/0.865) = 6.68 \Rightarrow \underline{N \approx 7}$$

9. Calculate the approximate distance L_T between the longest and shortest elements.

$$L_T = \frac{l_1}{2} (1 - 1/B_s) \cot(\alpha) = \frac{198}{2} \left(1 - \frac{1}{2.2791}\right) \cot(11.984^\circ) \Rightarrow \underline{L_T = 261.76 \text{ cm}}$$

10. Calculate the location R_2 (from the apex) and length l_2 of the second longest element using the scale factor τ , R_1 , and l_1 -

$$R_2 = R_1 \tau = 466.4(0.865) \Rightarrow \underline{R_2 = 403.44 \text{ cm}}$$

and

$$l_2 = l_1 \tau = 198(0.865) \Rightarrow \underline{l_2 = 171.27 \text{ cm}}$$

11. Recursively calculate the location R_{n+1} and length l_{n+1} of the $n+1^{\text{th}}$ element(s) using the scale factor τ , R_n , and l_n -

$$\text{e.g., } R_{n+1} = R_n \tau = R_n (0.865) \quad \& \quad l_{n+1} = l_n \tau = l_n (0.865).$$

Stop when l_{n+1} is less than or equal to l_N (calculated in step 5.).

12. Count actual number of elements and calculate actual length of LPDA (compare to approximate calculations in steps 8. & 9.).

- Steps 10-12 done using MS-Excel spreadsheet shown on next page.

Steps 10. & 11.		Calculate: $R_{n+1} = R_n * \tau$ and $l_{n+1} = l_n * \tau$	
		where $\tau =$	0.865
n	l_n (cm)	R_n (cm)	
1	198	466.4	
2	171.270	403.436	
3	148.149	348.972	
4	128.148	301.861	
5	110.848	261.110	
6	95.884	225.860	
7	82.940	195.369	
8	71.743	168.994	Stop since $l_8 < l_N = 73.64$ cm
Step 12.	Actual # of elements & antenna length	$N_{\text{approx}} = 7$ LT = 261.76 cm	$N_{\text{actual}} = 8$ $L_{\text{actual}} = R_1 - R_8 = 297.406$ cm

13. Select a length to diameter ratio $K = l/d$ for the elements of the LPDA. This choice is a compromise between mechanical strength for the largest and smallest elements, available tubing sizes, and the selected diameter of the boom.

Choose boom diameter **$D = 7/8'' = 2.223$ cm**

If $d_1 = 5/8'' = 1.5875$ cm, then $K_1 = l_1/d_1 = 198/1.5875 = 124.7 \Rightarrow \mathbf{K = 125}$.

Check if this works on smallest element-

$$d_8 = l_8/K = 71.7/125 = 0.574 \text{ cm (OK)}$$

14. Calculate the diameter $d_n = l_n / K$ for each element. Then, select the closest available tube/pipe/rod diameter to the calculated value.
 15. Calculate the actual length to diameter ratio K_n for each element and the average length to diameter ratio K_{ave} after quantization. Check for unusually large deviations from desired K (may want to go back to step 13. and select another value of K).
- Steps 14-15 done using MS-Excel spreadsheet shown below.

Step 13.		Select $K = 125$				
Step 14. & 15.		$d_n = l_n / K$		$K_{actual} = l_n / d_{quantized}$		
n	l_n (cm)	Exact d_n (cm)	Quantized		Actual K_n	$\Delta K =$ $K_n - K$
			d_n (cm)	d_n (in)		
1	198	1.584	1.5875	5/8	124.724	-0.28
2	171.270	1.370	1.4290	9/16	119.853	-5.15
3	148.149	1.185	1.1110	7/16	133.347	8.35
4	128.148	1.025	1.0320	13/32	124.175	-0.83
5	110.848	0.887	0.8730	11/32	126.974	1.97
6	95.884	0.767	0.7940	5/16	120.761	-4.24
7	82.940	0.664	0.6350	1/4	130.614	5.61
8	71.743	0.574	0.5560	7/32	129.034	4.03
Average $K =$					126.185	

16. Calculate the approximate average characteristic impedance of the active region elements-

$$Z_a = 60 \ln(2 X K_{ave} / \pi) = 60 \ln[2(0.58996)126.185/\pi] \Rightarrow \underline{Z_a = 231.508 \Omega}$$

$$\text{where } X = 8 \tau \sigma / (1 + \tau) = 8(0.865)0.159 / (1 + 0.865) = 0.58996.$$

17. Find the characteristic impedance of the unloaded transmission line Z_0 for the desired input impedance R_0 -

$$Z_0 = \frac{R_0^2}{4Z_a X} + R_0 \sqrt{\left(\frac{R_0}{4Z_a X}\right)^2 + 1} = \frac{75^2}{4(231.5)0.59} + 75 \sqrt{\left(\frac{75}{4(231.5)0.59}\right)^2 + 1}$$

$$= 10.296 + 75.7035 = \underline{86.000 \Omega}$$

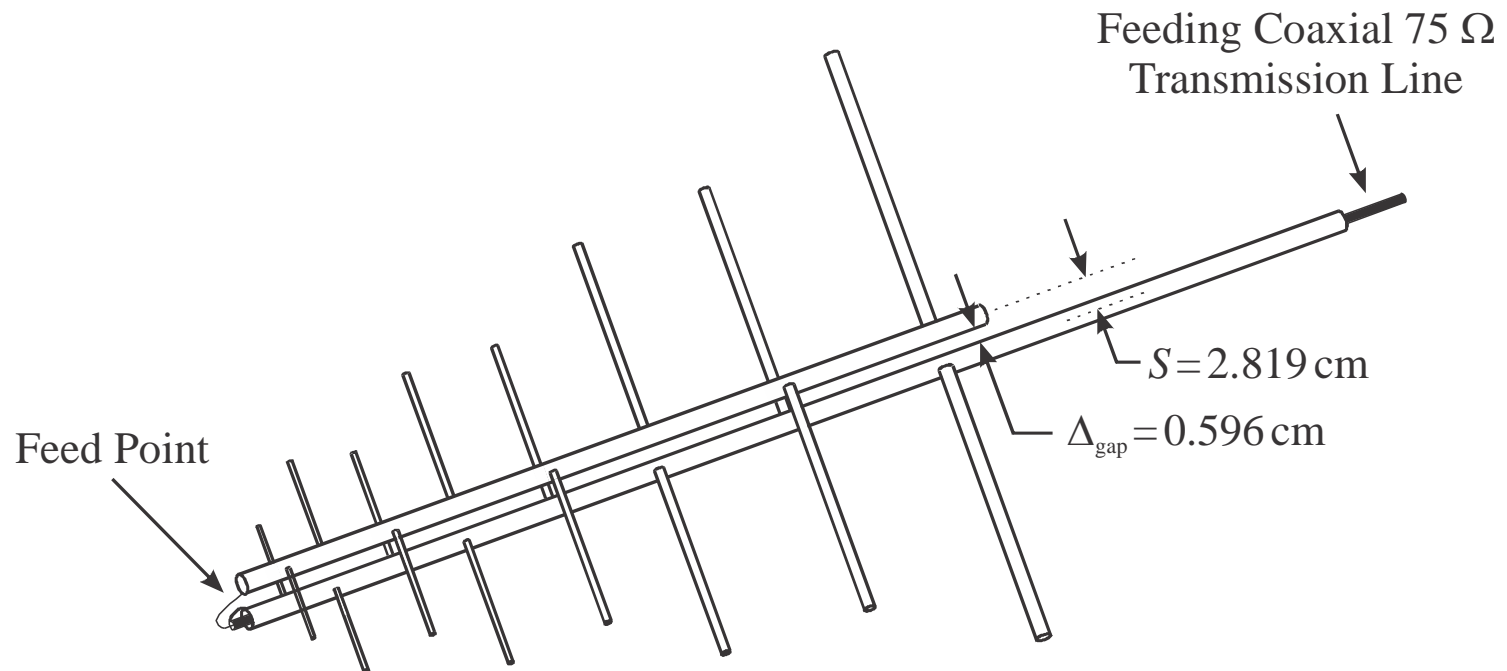
18. Calculate the **center-to-center** spacing S of the booms using the unloaded, cylindrical, twin-lead transmission line formula-

$$S = D \cosh(Z_0/120) = 2.223 \cosh(86/120) \Rightarrow \underline{S = 2.819 \text{ cm}}$$

where D is the diameter of the booms (assumed to be identical). The air gap Δ_{gap} between the inner surfaces of the booms is-

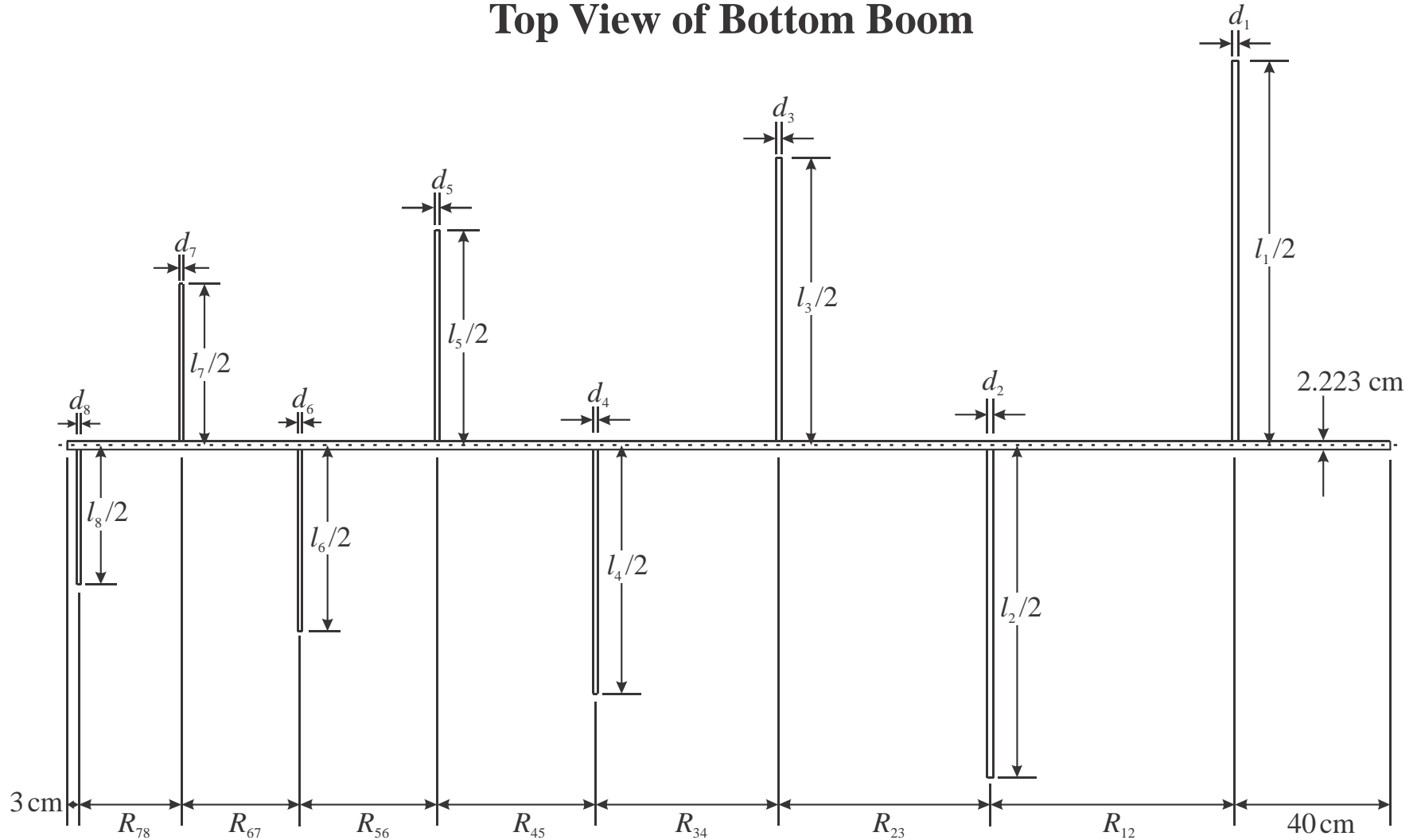
$$\Delta_{\text{gap}} = S - D = 2.819 - 2.223 \Rightarrow \underline{\Delta_{\text{gap}} = 0.596 \text{ cm} = 5.96 \text{ mm.}}$$

Perspective View of 8 Element LPDA for FM radio



Not to scale. Dimensions shown on following views of bottom and top booms

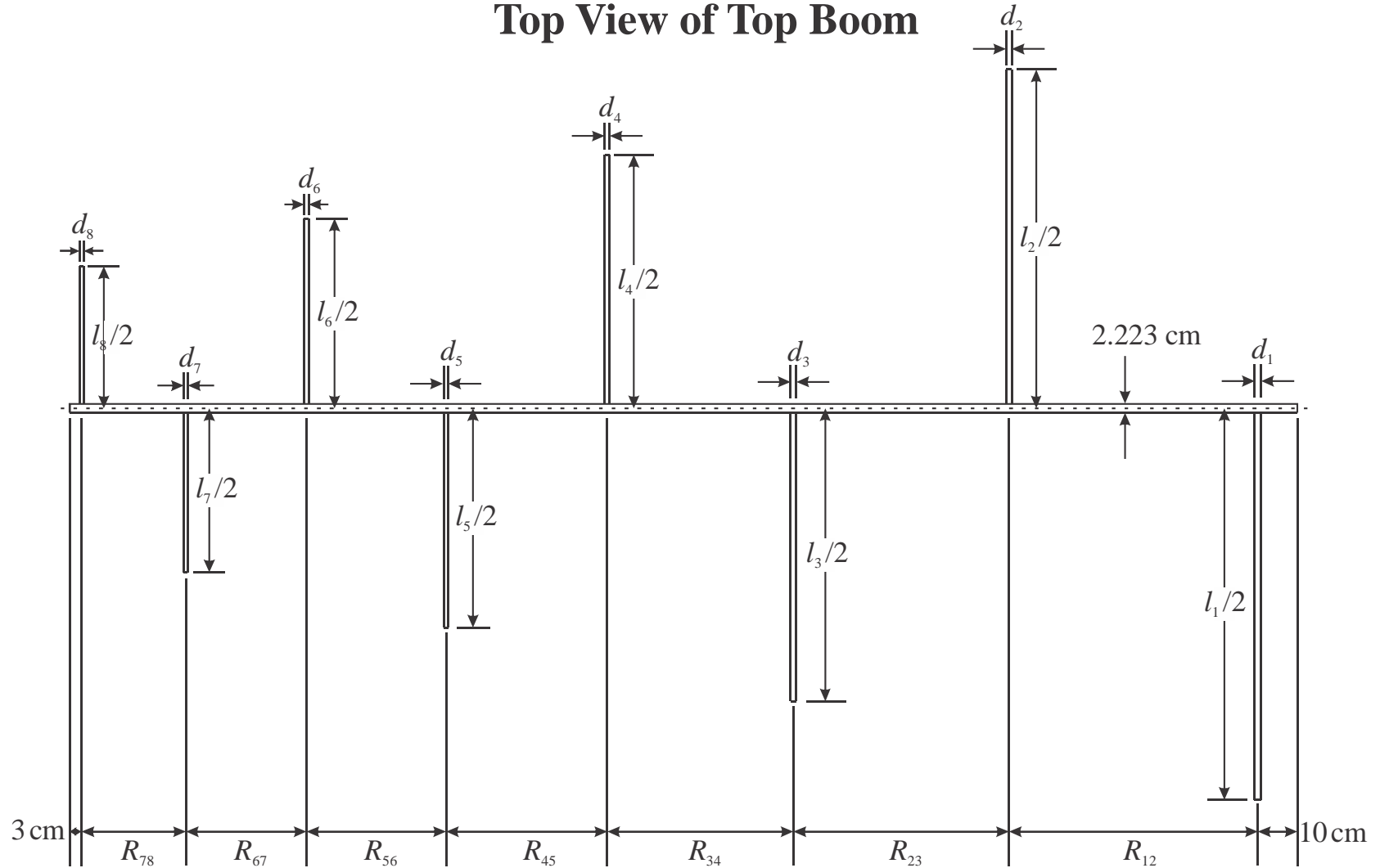
Top View of Bottom Boom



n	ln (cm)	dn (cm)	Rn (cm)	element-element spacing (cm)
1	198	1.5875	466.4	
2	171.270	1.4290	403.436	R1 - R2
3	148.149	1.4290	348.972	R2 - R3
4	128.148	1.2700	301.861	R3 - R4
5	110.848	1.1110	261.110	R4 - R5
6	95.884	1.1110	225.860	R5 - R6
7	82.940	1.0320	195.369	R6 - R7
8	71.743	0.9525	168.994	R7 - R8

scale 0.03" = 1 cm

Top View of Top Boom



n	ln (cm)	dn (cm)	Rn (cm)	element-element spacing (cm)	
1	198	1.5875	466.4		
2	171.270	1.4290	403.436	R1 - R2	62.964
3	148.149	1.4290	348.972	R2 - R3	54.464
4	128.148	1.2700	301.861	R3 - R4	47.111
5	110.848	1.1110	261.110	R4 - R5	40.751
6	95.884	1.1110	225.860	R5 - R6	35.250
7	82.940	1.0320	195.369	R6 - R7	30.491
8	71.743	0.9525	168.994	R7 - R8	26.375

scale 0.03" = 1 cm