Yagi-Uda Antennas

(section 10.3.3 of *Antenna Theory, Analysis and Design* (4th Edn) by Balanis)

Figure 1 Yagi-Uda antennas on traffic lights (Courtesy of Mr. J. Wolf)

Figure 2 Yagi-Uda antennas on pay telephones in Mexico

Advantages:

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

Characteristics

- 4.3 dBi ≤ Typical Directivity (Gain) ≤ 19 dBi
- 30 Ω ≤ Typical Input Impedance ≤ 70 Ω (w/out feed)
- Bandwidth: ≈ 2%
- Typical frequency bands where utilized are the HF (3-30 MHz), VHF (30-300 MHz), and UHF (300-1000 MHz)
- Transmission line feeds:

  Coaxial utilizing a Gamma match, Omega match, or modified Gamma match.

  or

  Twin-lead utilizing a folded dipole or T-match.

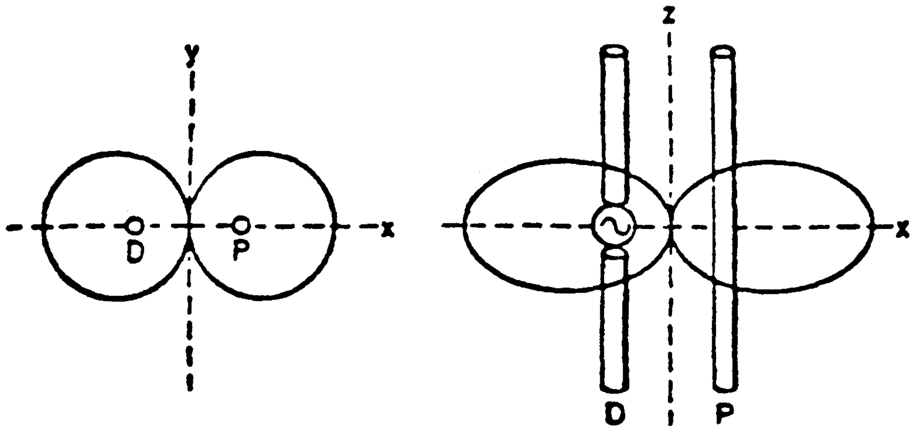
- Optimal Designs available

History or Origin of Yagi-Uda Antennas

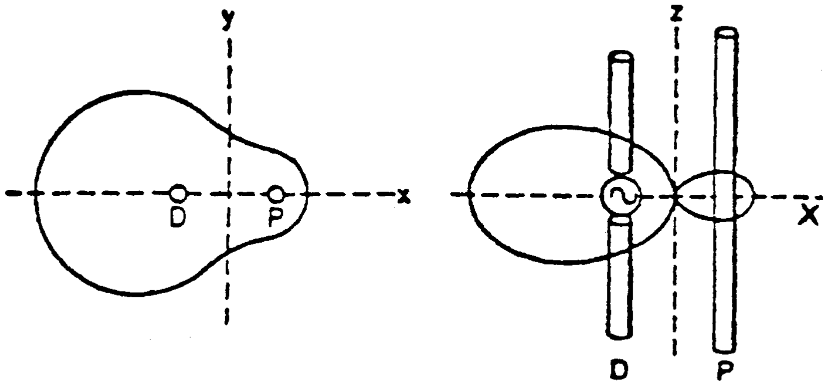
- Originated in 1920's in Japan
  - ➢ S. Uda, "Wireless Beam of Short Electric Waves," *J. IEE.* (Japan), pp. 273-282, March 1926, and pp. 1209-1219, November 1927. (In Japanese)
  - ➢ H. Yagi, "Beam Transmission of Ultra Short Waves," *Proc. IRE*, Vol. 26, pp. 715-741, June 1928. Republished, *Proc. IEEE*, Vol. 72, No. 5, pp. 634-645, May 1984.
- Extensive experimental work, theoretical analysis, and numerical analysis done from the 1930's to 1970's

R.M. Fishender
C.C. Lee
H.W. Ehrenspeck
H. E. Green
R.J. Mailloux
G.A. Thiele
D.K. Cheng
N.K. Takla
E.R. Wiblin
L.-C. Shen
H. Poehler
W. Wilkinshaw
D. Kajfez
P.A. Tirkas
C.A. Shen
P.P. Viezebicke

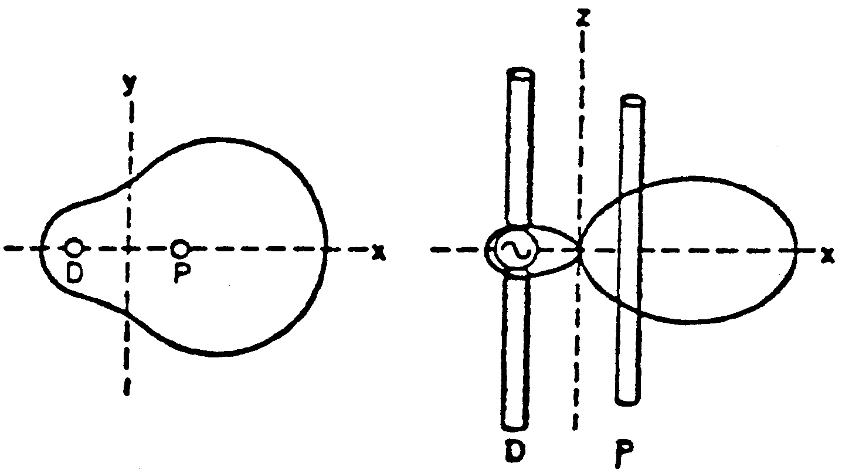
Far-field patterns for a resonant (reactance is zero) Driven dipole (D) with Parasitic element (P), i.e., a two-element dipole array. Variables include diameters, lengths, and spacings (typically ~0.1λ to 0.25λ).



Parasite in Resonance
(length ≈ λ/2, real
input impedance)



Parasite lengthened by 5%
(Reflector, input impedance
is real + inductive reactance)



Parasite shortened by 5%
(Director, input impedance
is real + capacitive reactance)

Dipole input impedances

- Resonances occur when the reactance is zero while the resistance is NOT at a peak or infinity. For example, near $\ell/\lambda \sim 0.5$ and 1.5.
- Anti-resonances occur when the resistance is at a peak or infinity while the reactance is zero/finite. For example, near $\ell/\lambda \sim 0.75$ and 1.

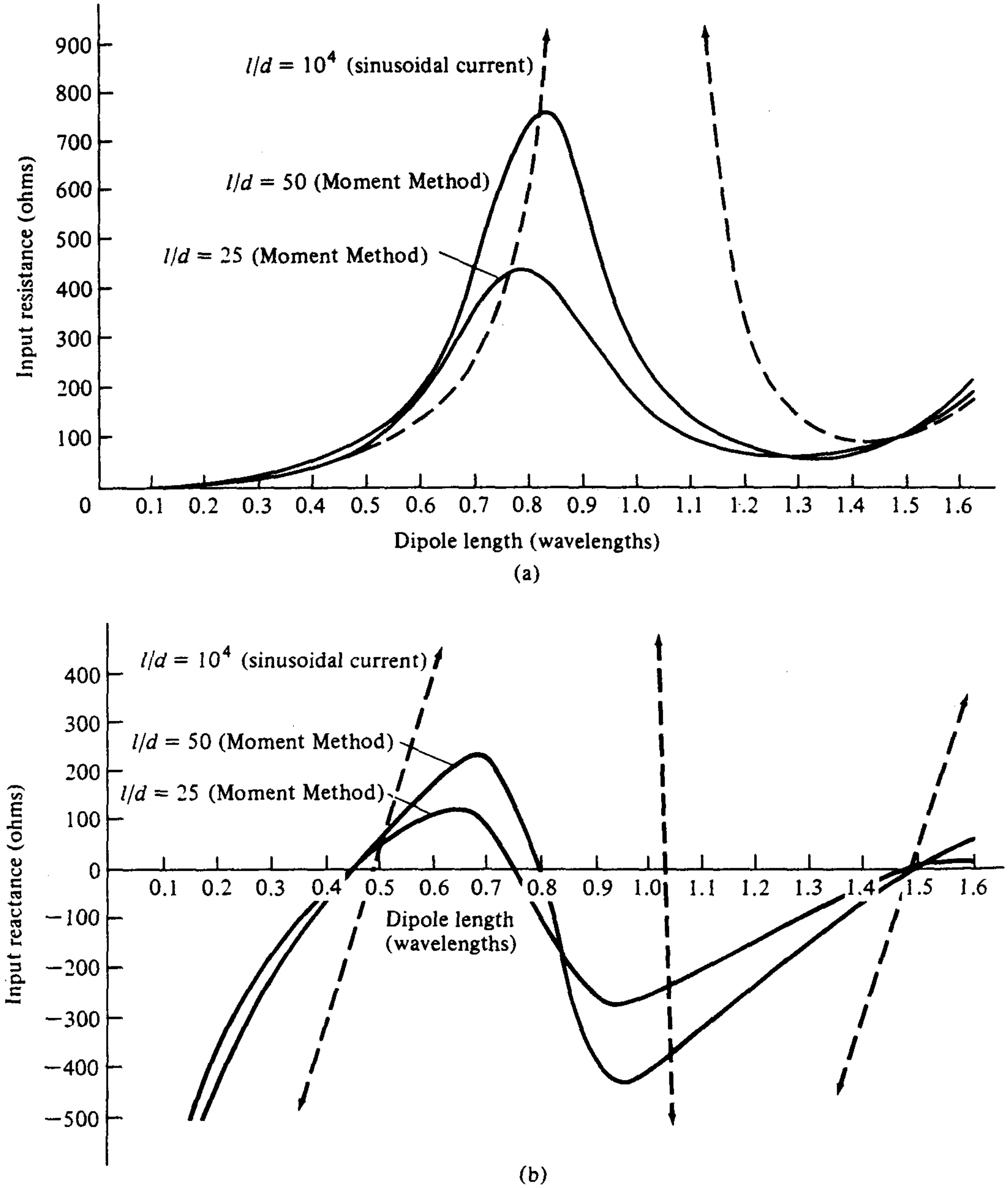
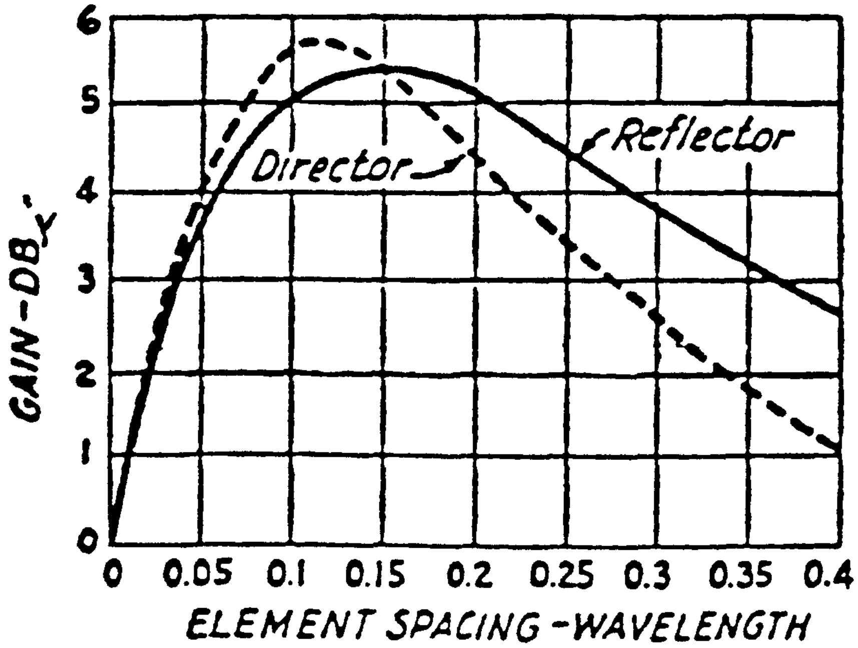
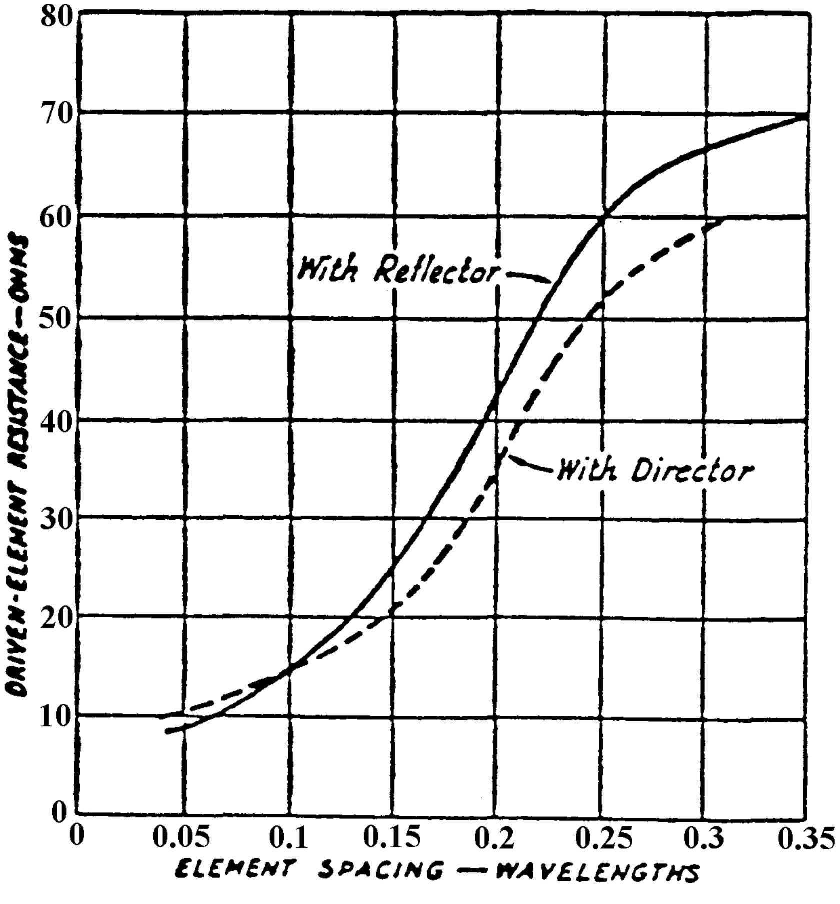


Figure 8.8 (a) Input resistance of wire dipoles. (b) Input reactance of wire dipoles. [Antenna Theory, Analysis and Design, Balanis, 1982, p. 334.]

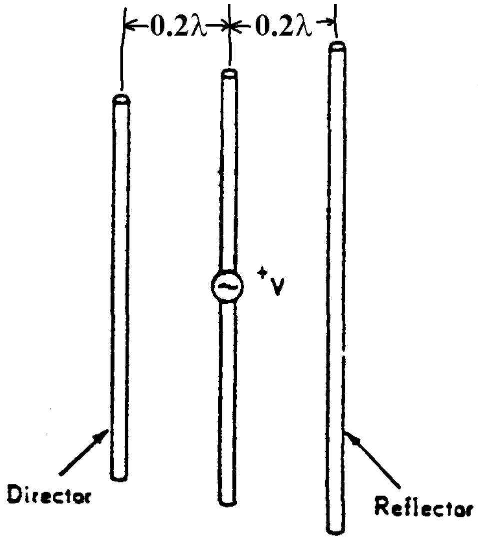
Maximum Gain of Two-element array versus spacing



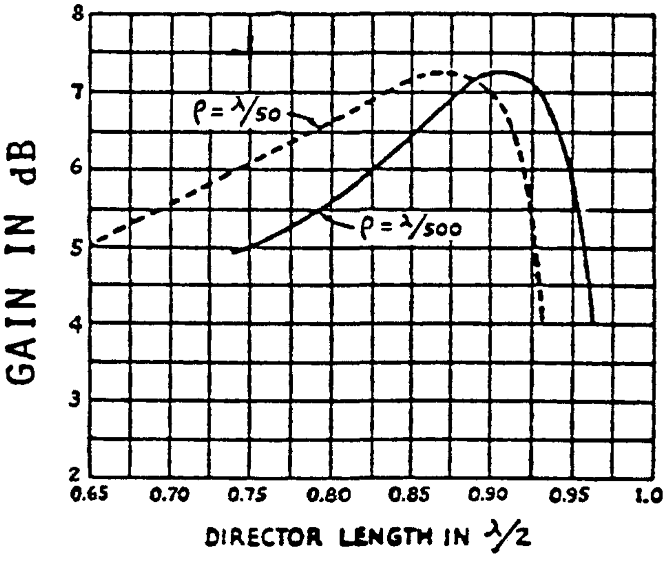
Corresponding Radiation Resistance of Two-element array versus spacing
[Note: Much less than 73 Ω for isolated dipole.]



Three-element Yagi-Uda array

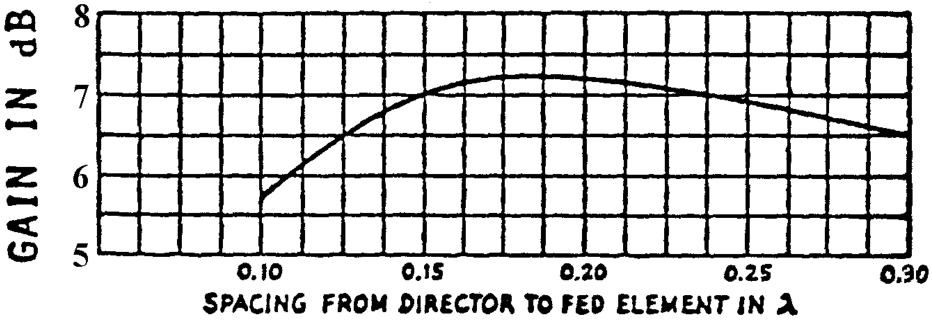


Gain as a function of Director length for two (2) director thicknesses/diameters ρ (0.2λ spacing between all the elements)



Gain as a function of **director spacing**

(0.2λ spacing between the driven element and the Reflector)



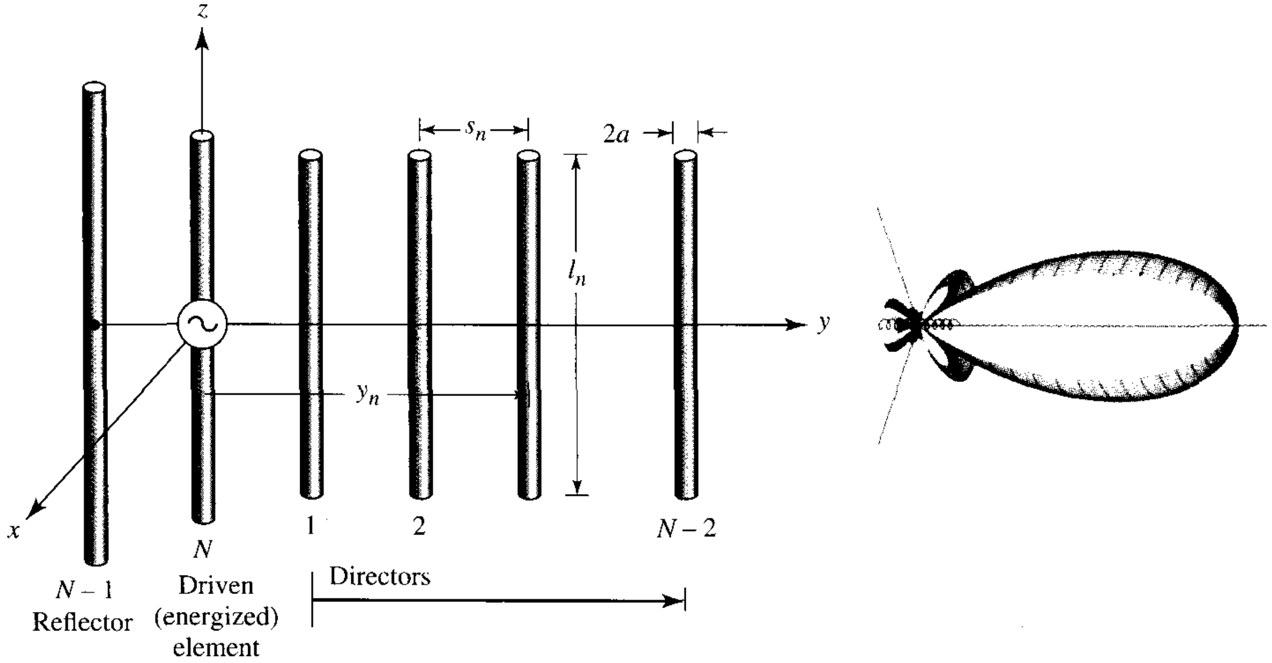
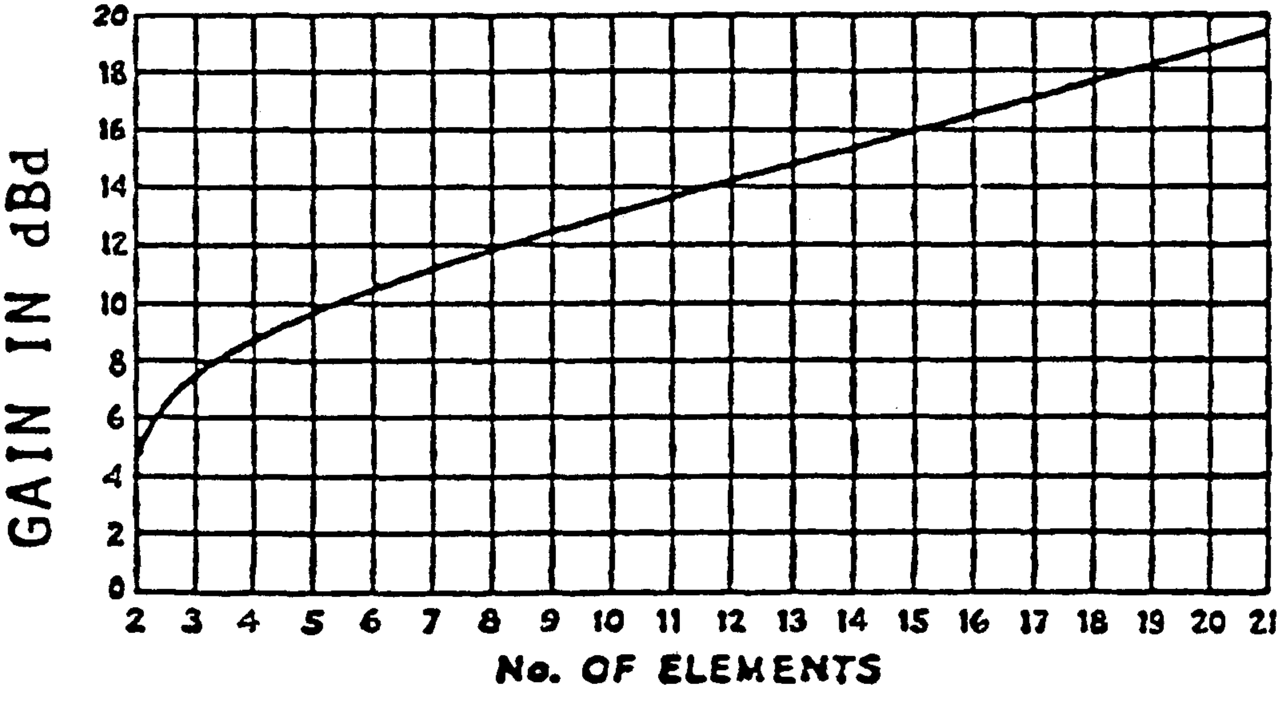


Figure 10.19 Yagi-Uda antenna configuration
[*Antenna Theory, Analysis and Design* (4th Edn) by Balanis]



Gain versus number of elements
[Note: dBi = dBd + 2.15]

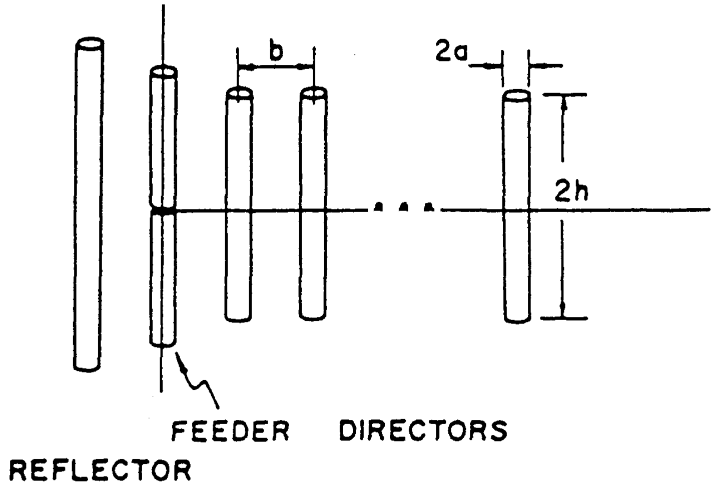


Fig. 1. The Yagi array.

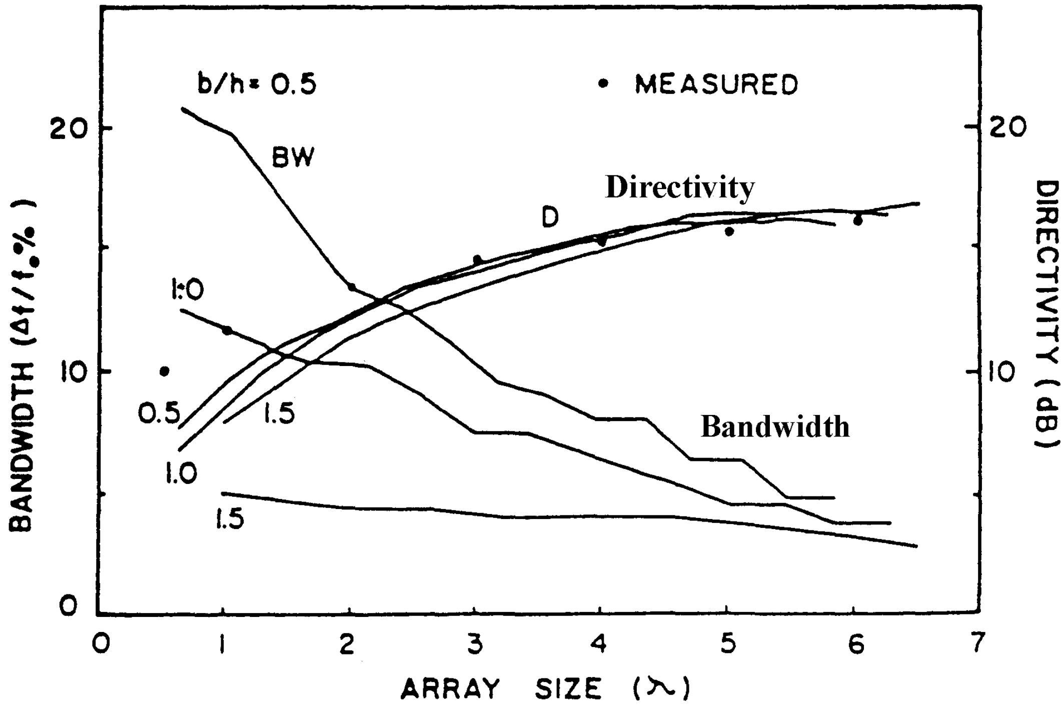


Fig. 2. Bandwidth and directivity versus array size ($N b / \lambda$) with three different spacings between elements. The bandwidth decreases and the directivity increases with increasing array size. Bandwidth is determined by the spacing while the directivity is very insensitive to it.

[Source: L.-C. Shen, "Directivity and Bandwidth of Single-Band and Double-Band Yagi Arrays," IEEE Trans. Antennas Prop., pp. 778-780, Nov. 1972.]

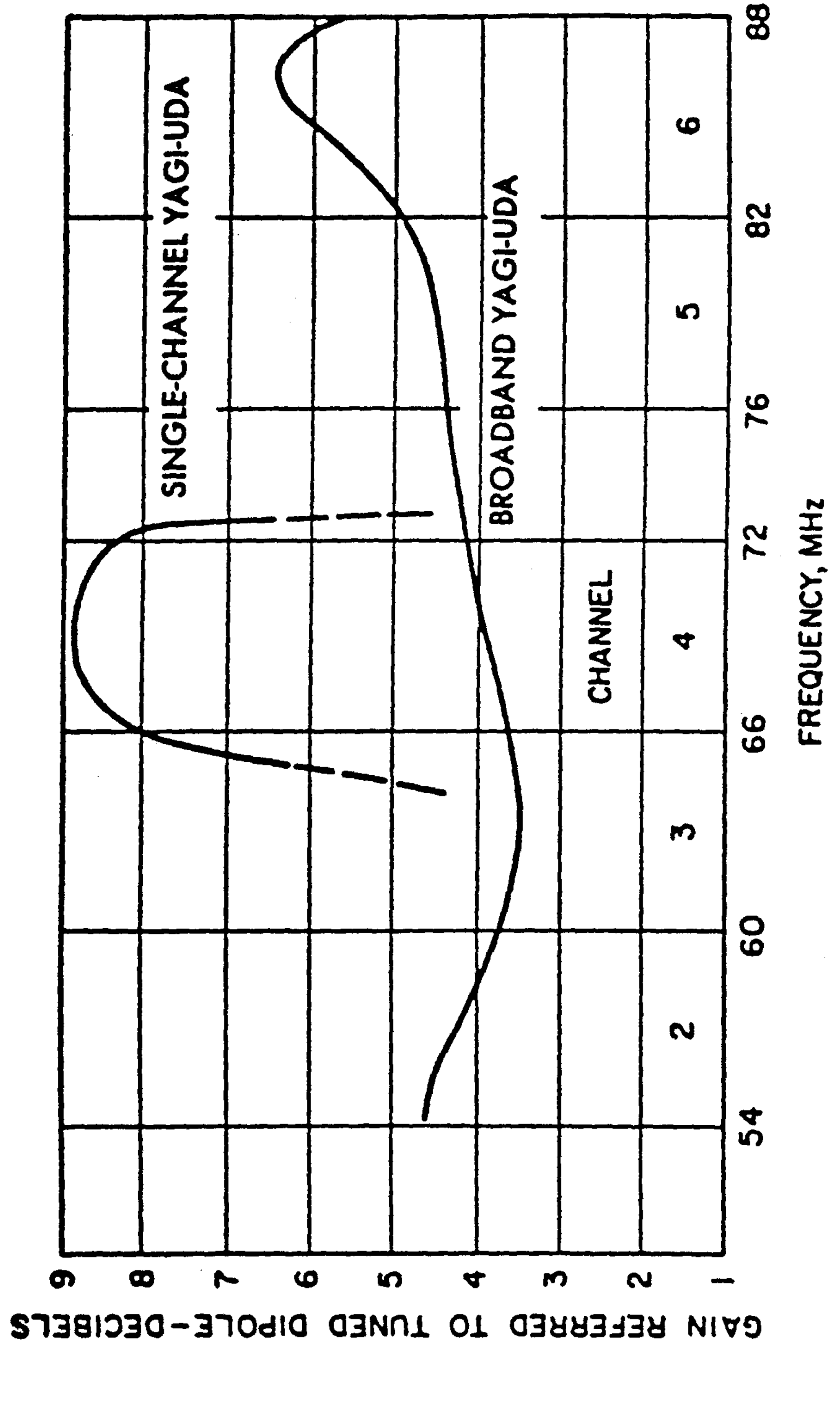
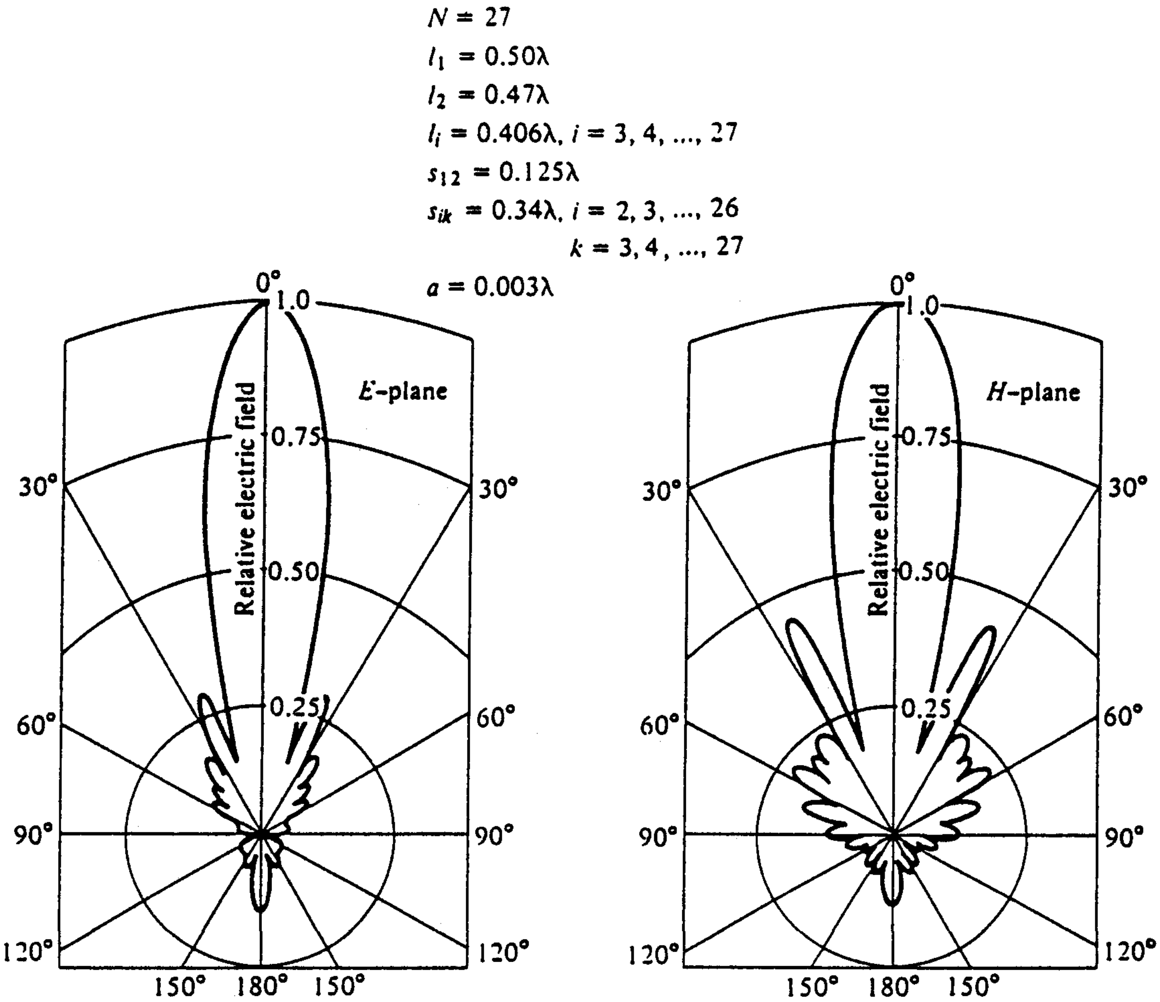


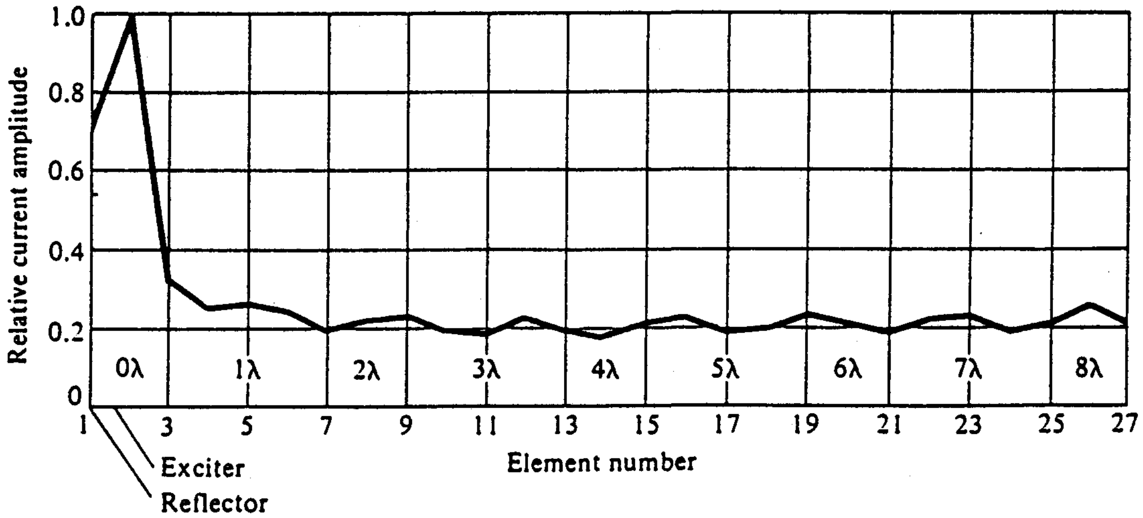
FIG. 29-11 Measured gain of five-element Yagi-Uda. (*a*) Single-channel Yagi-Uda. (*b*) Broadband Yagi-Uda.

- Can trade gain for bandwidth or vice versa.



(a) E-plane pattern

(b) H-plane pattern



(c) Current distribution

Figure 9.14 E- and H-plane patterns and relative current amplitudes of a 27-element Yagi-Uda array. (SOURCE: G. A. Thiele, "Analysis of Yagi-Uda-Type Antennas," *IEEE Trans. Antennas Propag.*, vol. AP-17, pp. 24–31, January 1969. © (1969) IEEE)

Table 9.4 DIRECTIVITY OPTIMIZATION FOR SIX-ELEMENT YAGI-UDA ARRAY (PERTURBATION OF *DIRECTOR SPACINGS AND ALL ELEMENT LENGTHS*), $a = 0.003369\lambda$

	lengths						spacings					DIRECTIVITY (dBi)
	l_1/λ	l_2/λ	l_3/λ	l_4/λ	l_5/λ	l_6/λ	s_{21}/λ	s_{32}/λ	s_{43}/λ	s_{54}/λ	s_{65}/λ	
INITIAL ARRAY	0.510	0.490	0.430	0.430	0.430	0.430	0.250	0.310	0.310	0.310	0.310	10.93
ARRAY AFTER SPACING PERTURBATION	0.510	0.490	0.430	0.430	0.430	0.430	0.250	0.289	0.406	0.323	0.422	12.83
OPTIMUM ARRAY AFTER SPACING AND LENGTH PERTURBATION	0.472	0.452	0.436	0.430	0.434	0.430	0.250	0.289	0.406	0.323	0.422	13.41

SOURCE: C. A. Chen and D. K. Cheng, "Optimum Element Lengths for Yagi-Uda Arrays," *IEEE Trans. Antenna Propag.*, **vol. AP-23, pp.** 8–15, January 1975. © (1975) IEEE.

2-D E-Plane Radiation Patterns

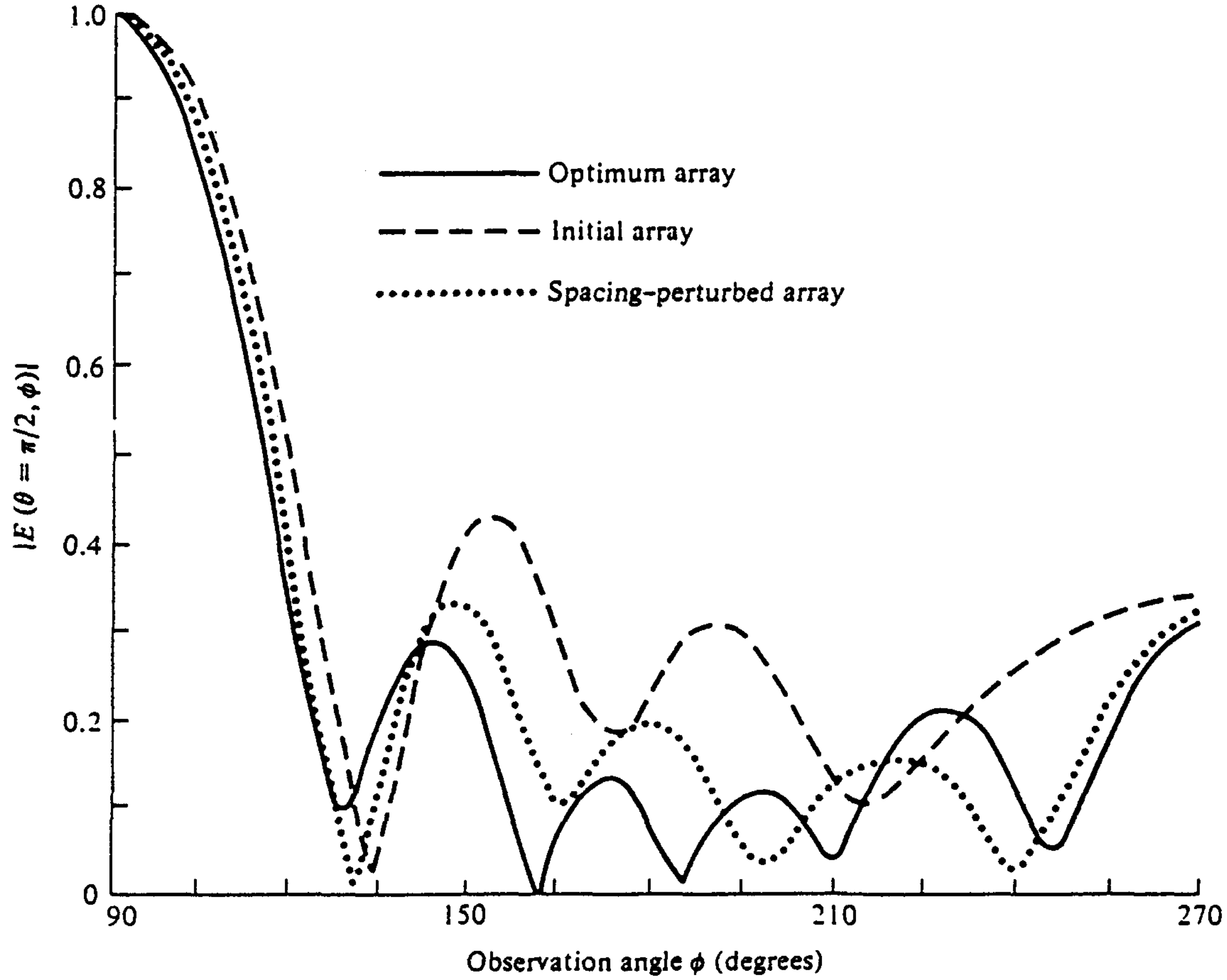


Figure 9.15 Normalized amplitude antenna patterns of initial, perturbed, and optimum six-element Yagi-Uda arrays (Table 9.4). (SOURCE: C. A. Chen and D. K. Cheng, "Optimum Element Lengths for Yagi-Uda Arrays," *IEEE Trans. Antennas Propag.*, vol. AP-23, pp. 8–15, January 1975. © (1975) IEEE)