

Yagi-Uda Antennas

(section 10.3.3 of *Antenna Theory, Analysis and Design* (2nd 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

Characteristics:

- $4.3 \text{ dBi} \leq \text{Typical Directivity (Gain)} \leq 19 \text{ dBi}$
- $30 \Omega \leq \text{Typical Input Impedance} \leq 70 \Omega$ (w/out feed)
- Bandwidth: $\approx 2\%$
- Typical frequency bands where utilized are: HF (3-30 MHz), VHF (30-300 MHz), and UHF (300-1000 MHz)
- Transmission line feeds: Coaxial (w/ Gamma match, Omega match, or modified Gamma match)

or

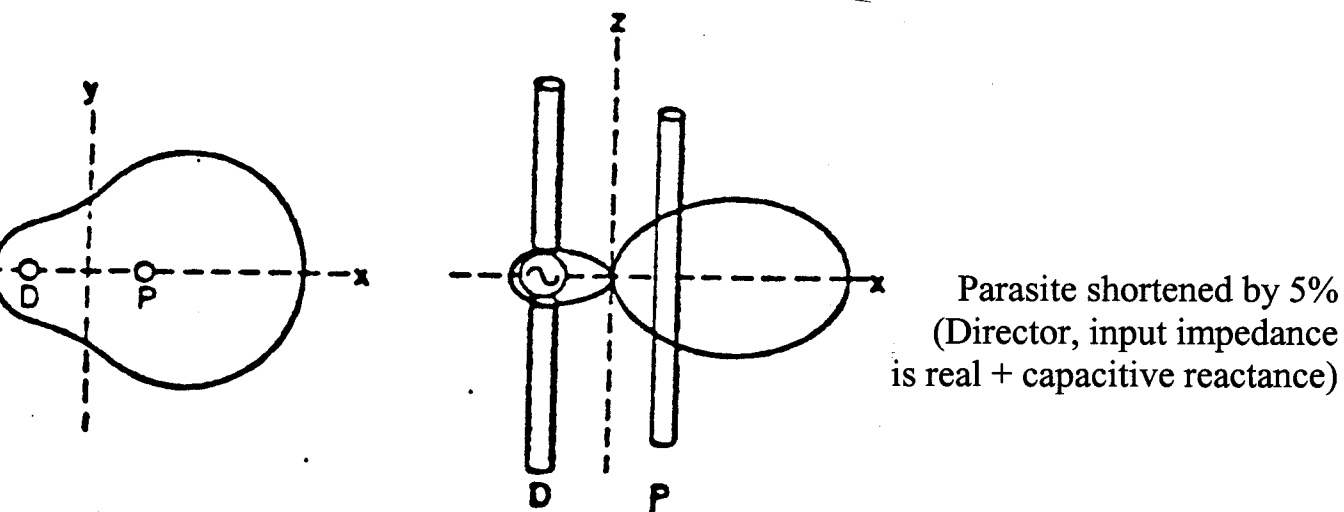
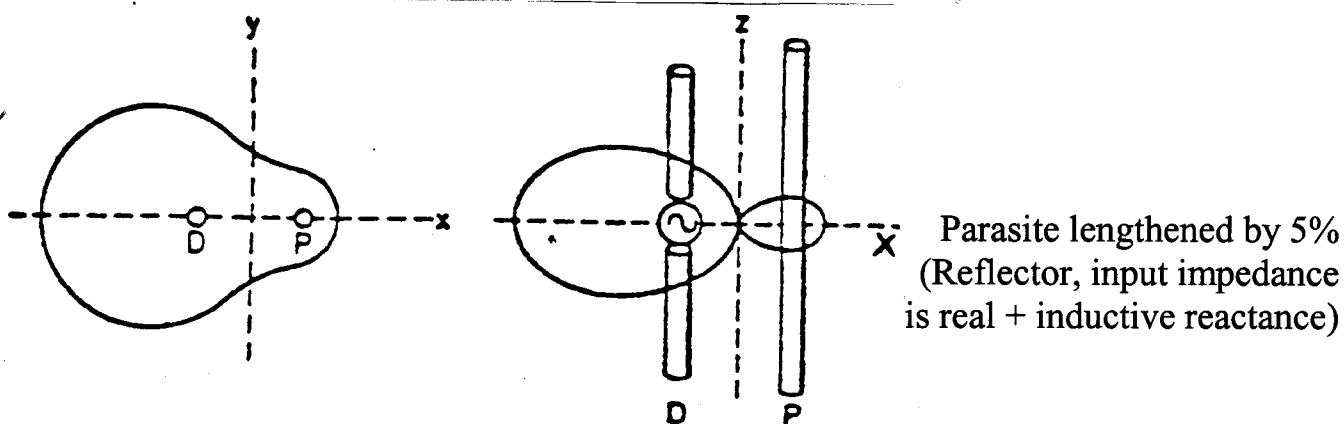
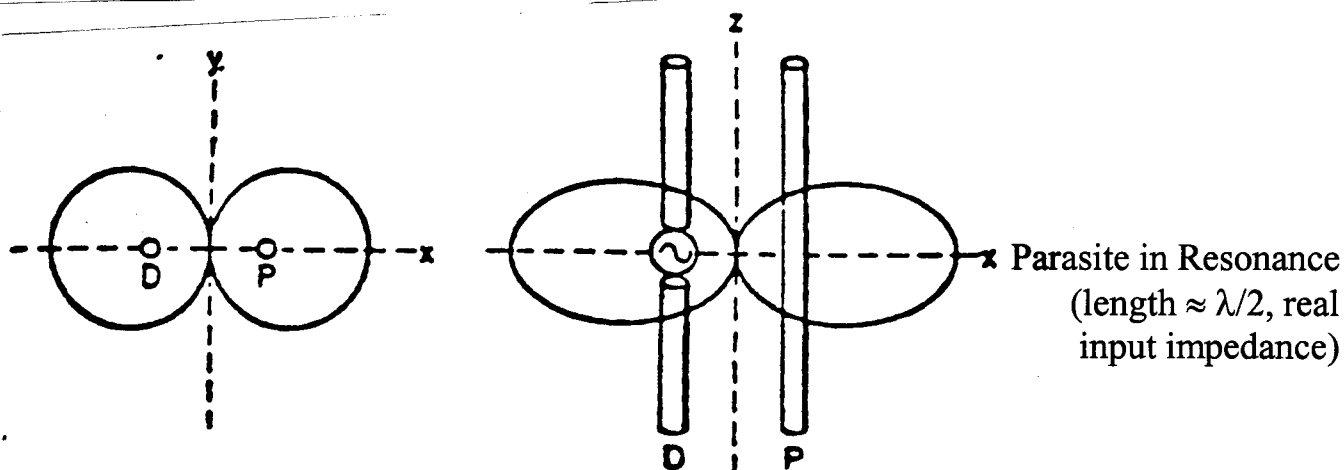
 Twin-lead (w/ folded dipole or T-match)
- Optimal Designs available

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

Far Field Pattern of Resonant (reactance is either zero or infinite) driven Dipole (D) with Parasitic element (P), i.e., a two-element dipole array. Variables include diameters, lengths, and spacings.



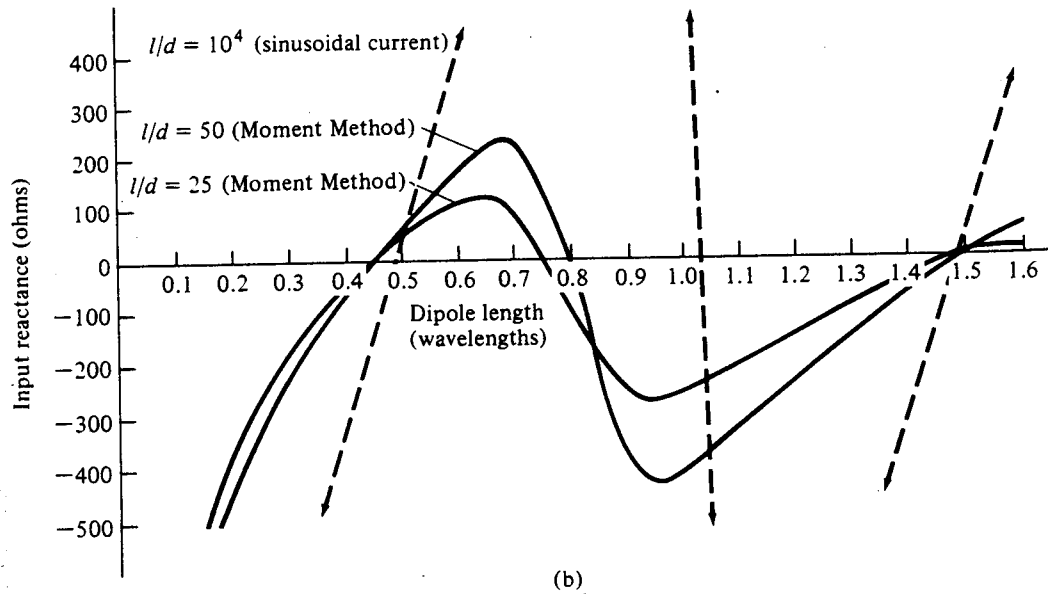
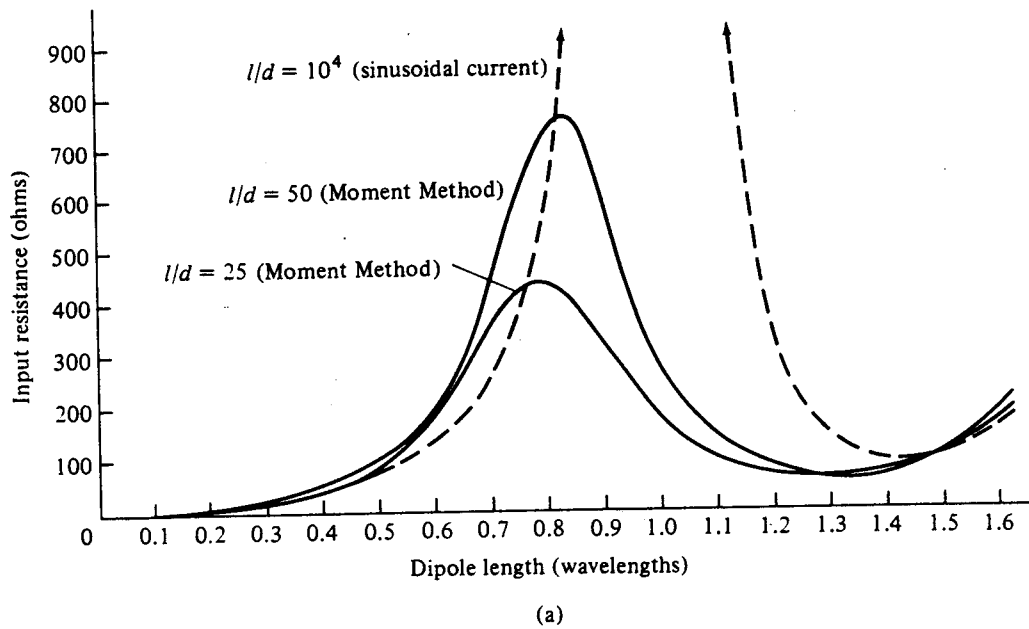
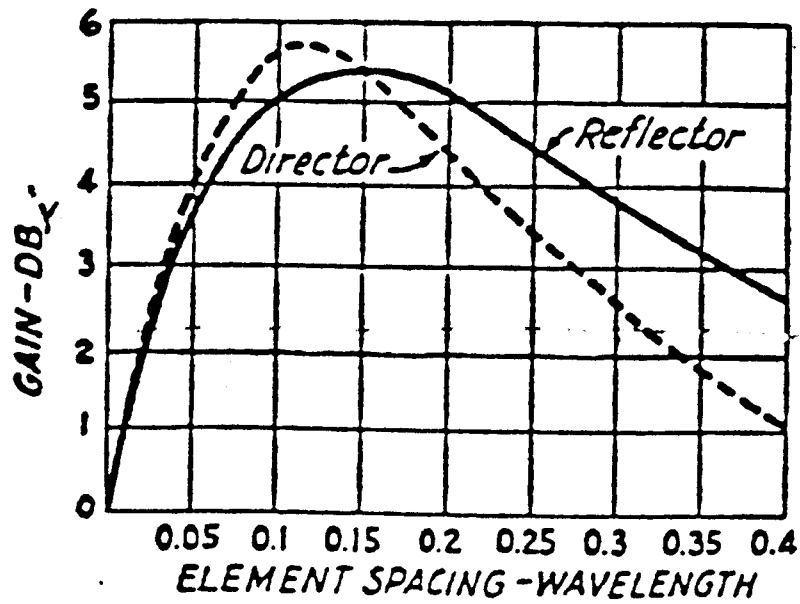


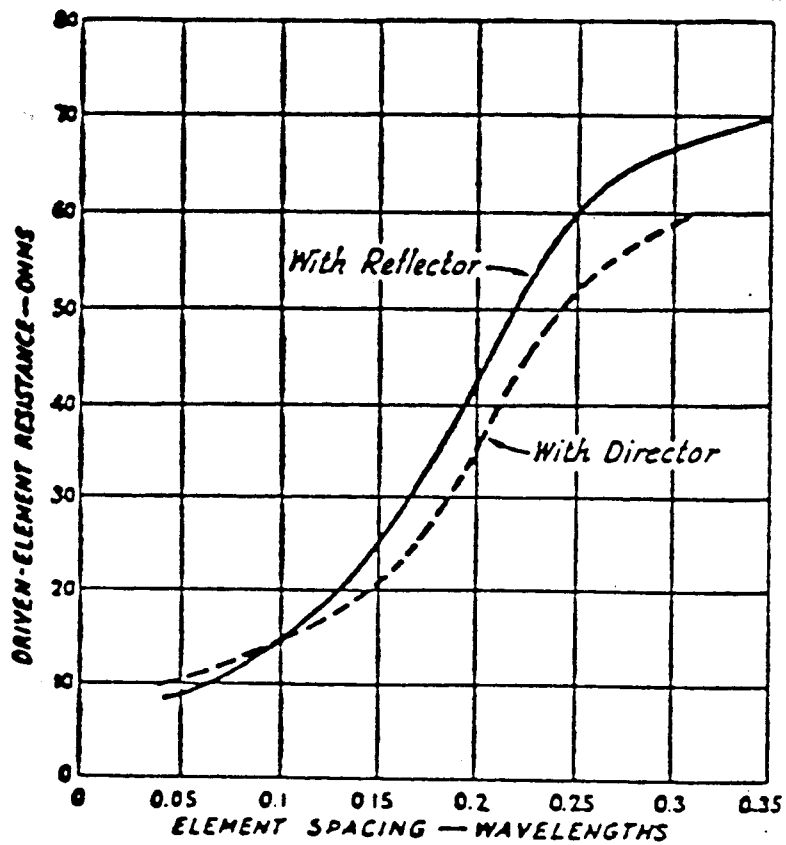
Figure 8.8 (a) Input resistance of wire dipoles. (b) Input reactance of wire dipoles.

(Balanis ©1982)

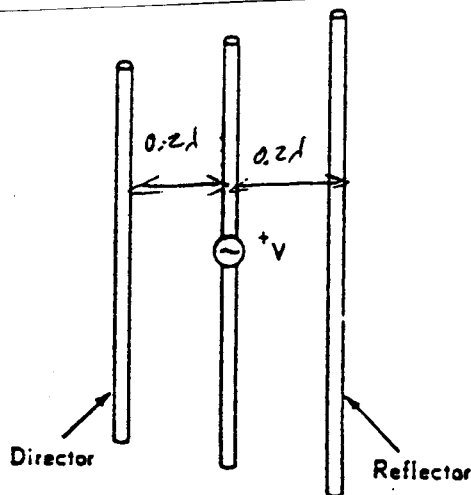
Maximum Gain of Two-element array versus spacing



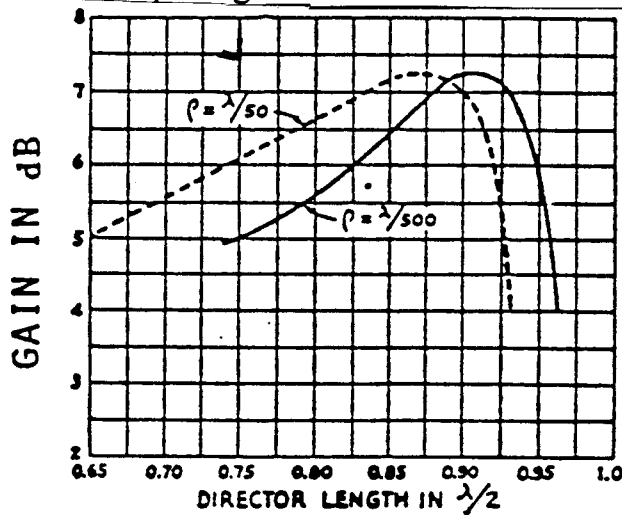
Corresponding Radiation Resistance of Two-element array versus spacing



Three-element array

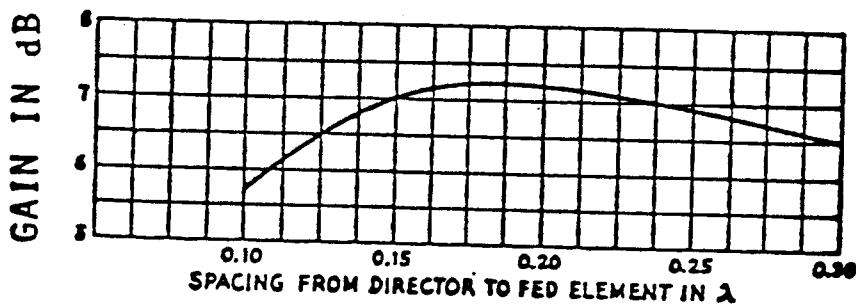


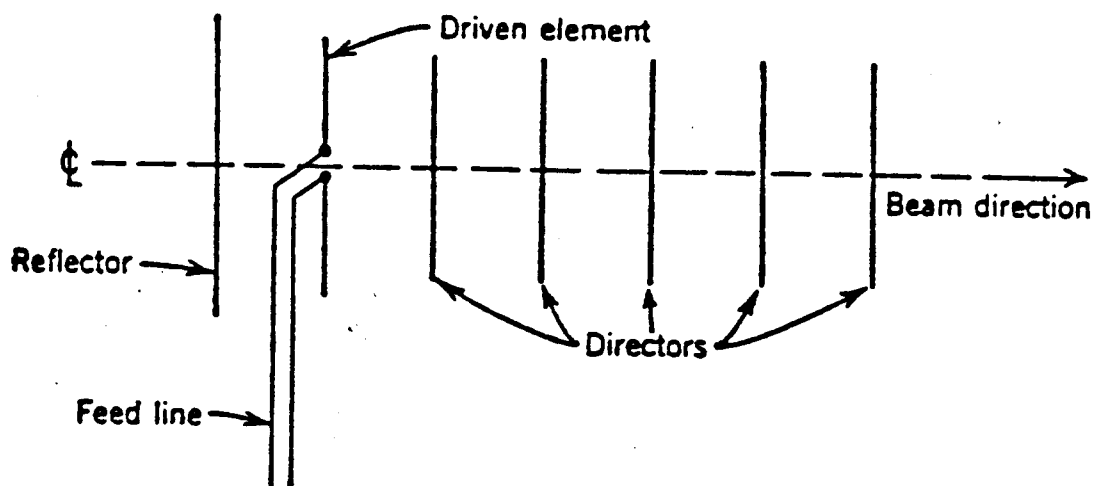
Gain as a function of Director length for two (2) director thicknesses
(0.2λ spacing between all the elements)



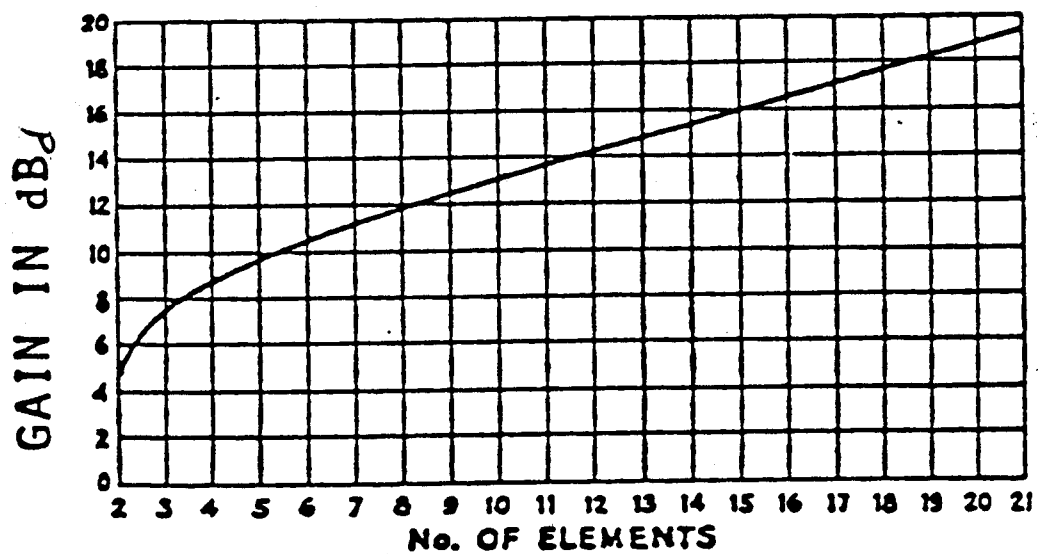
$\rho \equiv$ diameter of elements

Gain as a function of Director spacing
(0.2λ spacing between the driven element and the Reflector)





Yagi-Uda Antenna Configuration
(Fig. 10.17 of Balanis)



Gain versus number of elements

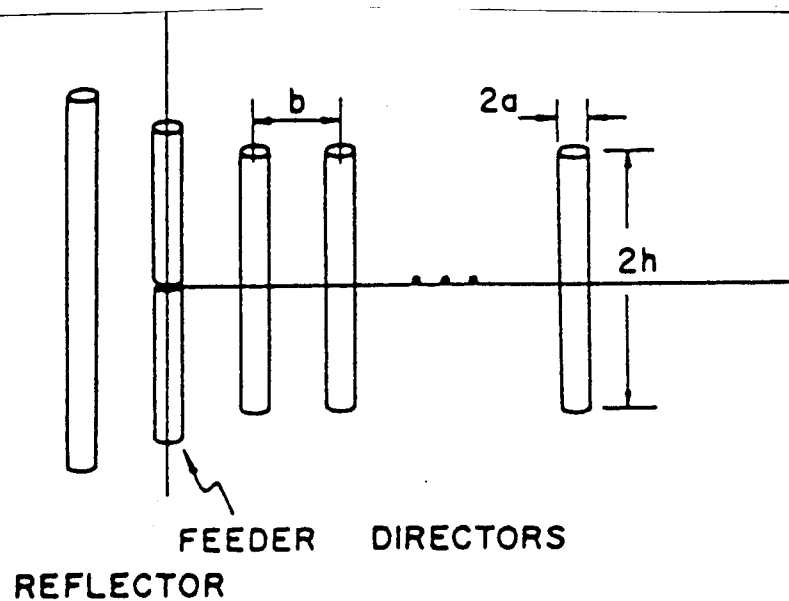


Fig. 1. The Yagi array.

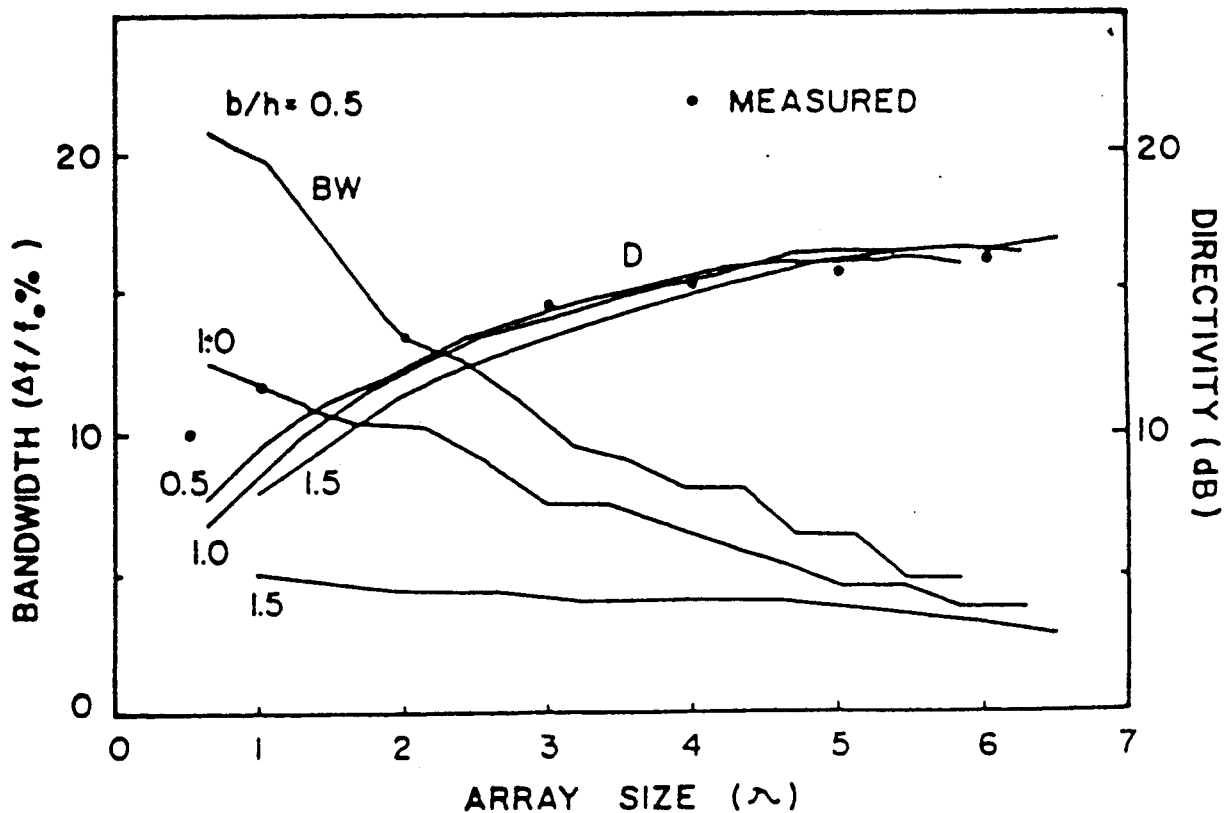


Fig. 2. Bandwidth and directivity versus array size (Nb/λ) with three different spacings between elements. The bandwidth decreases and the directivity increases with increasing array size. Bandwidth is determined by the spacing while the directivity is very insensitive to it. Shen, Liang-Chi, "Directivity and Bandwidth of Single-Band and Double-Band Yagi Arrays", IEEE Trans. Antennas Prop., pp 778-780, Nov. 1972

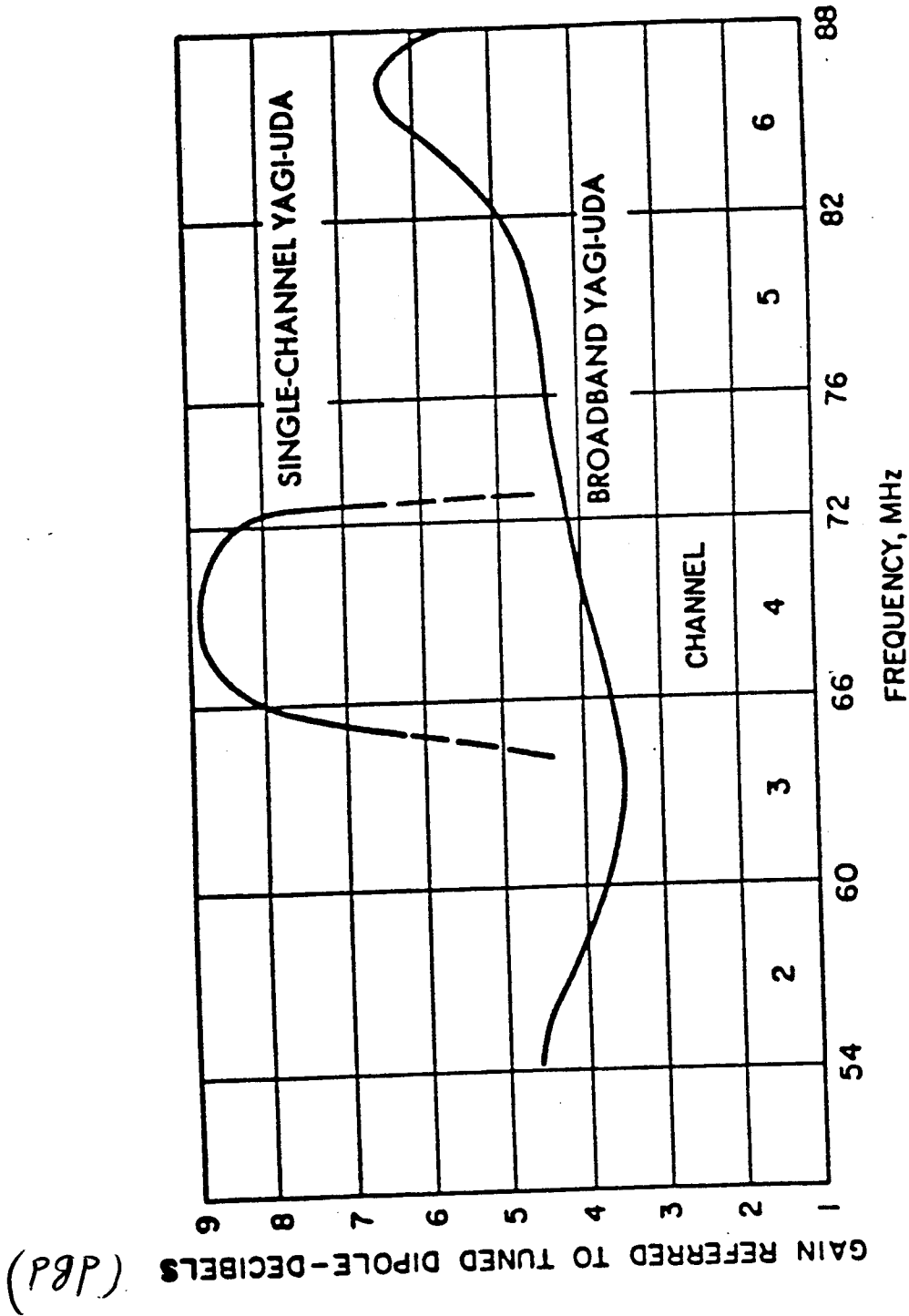
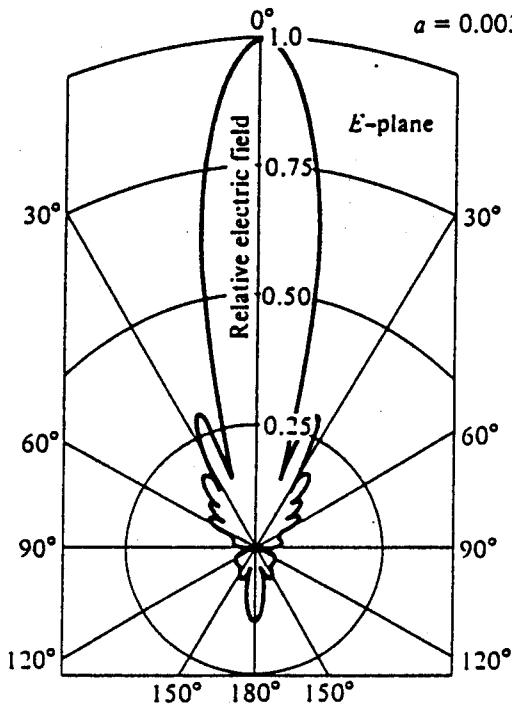


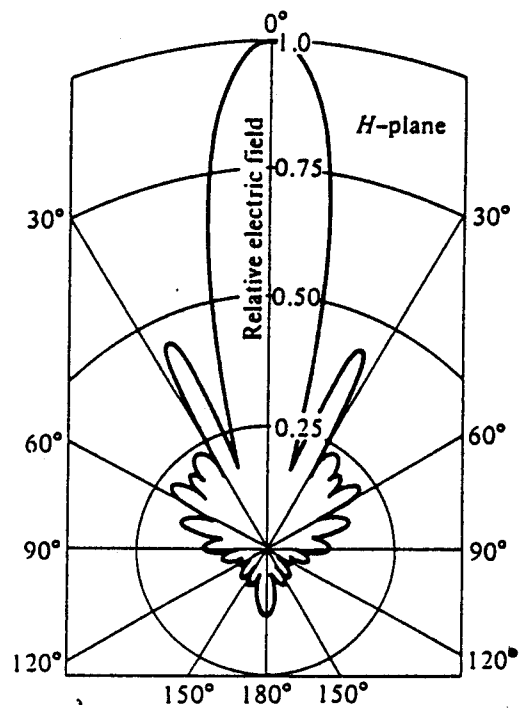
FIG. 29-11 Measured gain of five-element Yagi-Uda. (a) Single-channel Yagi-Uda. (b) Broadband Yagi-Uda.

$N = 27$
 $l_1 = 0.50\lambda$
 $l_2 = 0.47\lambda$
 $l_i = 0.406\lambda, i = 3, 4, \dots, 27$
 $s_{12} = 0.125\lambda$
 $s_{ik} = 0.34\lambda, i = 2, 3, \dots, 26$
 $k = 3, 4, \dots, 27$

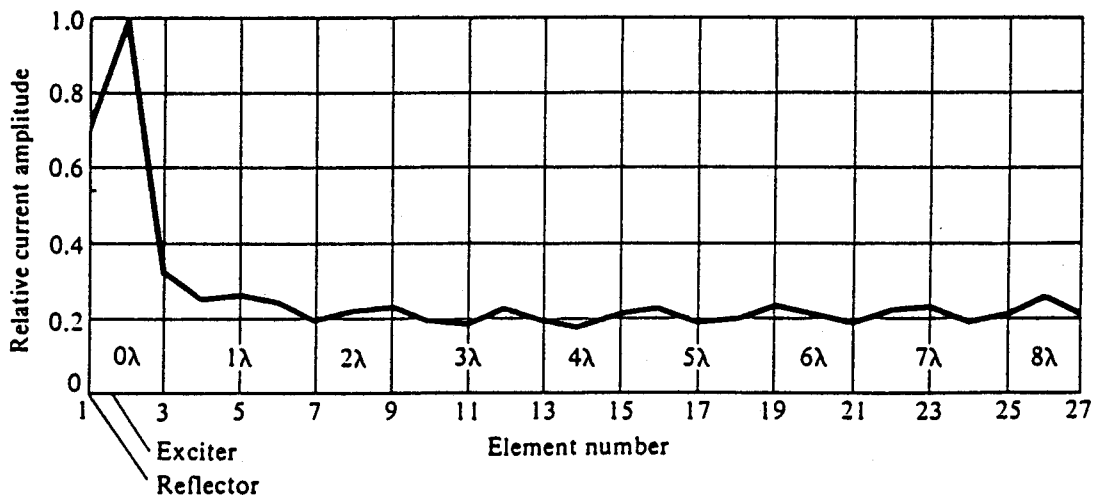
$a = 0.003\lambda$



(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), $a=0.003369\lambda = \text{radians}$

	lengths						spacings						DIRECTIVITY (dB) ← 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	DIRECTIVITY (dB)	
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.

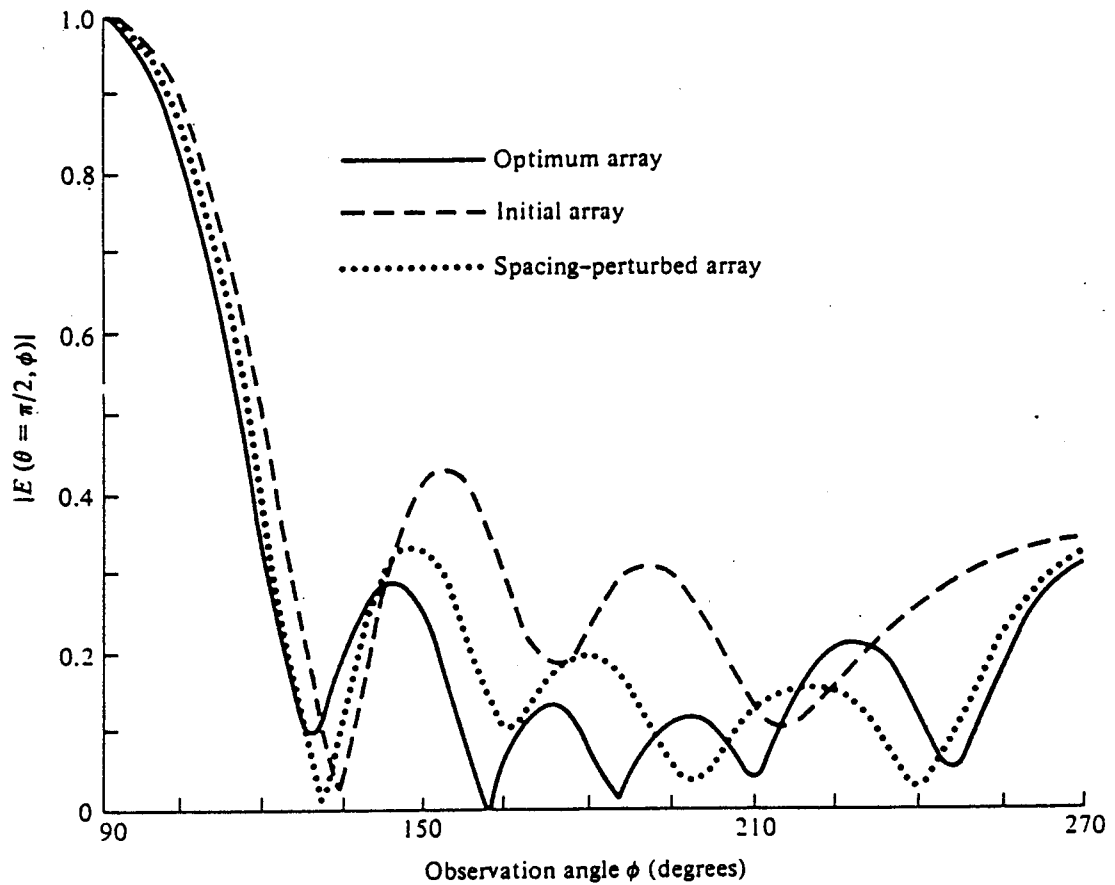


Figure 9.15 Normalized amplitude antenna patterns of initial, perturbed, and optimum six-element Yagi-Uda arrays (Table 9.4). (SOURCE: C. A. Chen and D. K. Cheng, "Optimum Element Lengths for Yagi-Uda Arrays," *IEEE Trans. Antennas Propag.*, vol. AP-23, pp. 8-15, January 1975. © (1975) IEEE)

