ANTENNA ARRAYS (CONT'D)

LAST LECTURE:

* ARRAY OF N ISOTROPIC SOURCES
* END-FIRE, BROADSIDE ARRAYS
* MAIN LOBE CONDITIONS, ARRAY FACTOR
* GRATING LOBES

ARRAY NULLS

A NULL OCCURS WHEN THE FIELDS FROM THE ARRAY OF SOURCES CANCEL EACH OTHER EXACTLY.

THIS OCCURS WHEN THE NUMERATOR OF THE ARRAY FACTOR IS ZERO;

$$\text{ARRAY FACTOR} = E_0 \left| \frac{\sin\left(\frac{N\theta}{2}\right)}{\sin\left(\frac{\theta}{2}\right)} \right| ,$$

$$\theta = k_0 d \cos(\phi) + \alpha .$$

THAT IS WHEN $\sin\left(\frac{N\theta}{2}\right) = 0$ OR WHEN

$$N\theta = 0, 2\pi q , \qquad q \in \mathbb{Z}$$

HENCE WE CAN WRITE;

$$N\theta = Nk_od\cos(\phi_n) - N\alpha = 2\pi q$$

ϕ_n - ANGLE OF BEAM NULL.

SO

$$\cos(\phi_n) = \left[\frac{q}{N}\frac{\lambda}{d} + \frac{\alpha}{k_od}\right]$$

THIS IS SIMILAR TO THE CONDITION FOR A MAIN LOBE;

$$\cos(\phi_b) = \left[\frac{m\lambda}{d} + \frac{\alpha}{k_od}\right]$$

THIS RESTRICTS THE VALUES THAT q CAN TAKE;

$$q \neq mN.$$

FOR EXAMPLE:

FOR A 15 ELEMENT ARRAY WITH A BROADSIDE BEAM ($\alpha = 0$) $m = 0$, AND WITH GRATING LOBES DEFINED BY $m = \pm 1, \pm 2$ DOES NOT HAVE NULLS AT $q = \pm 15, \pm 30$

FIRST NULL BEAMWIDTH (FNBW)

THE FIRST NULLS NEXT TO THE PRIMARY LOBE OCCUR WHEN $q = \pm 1$

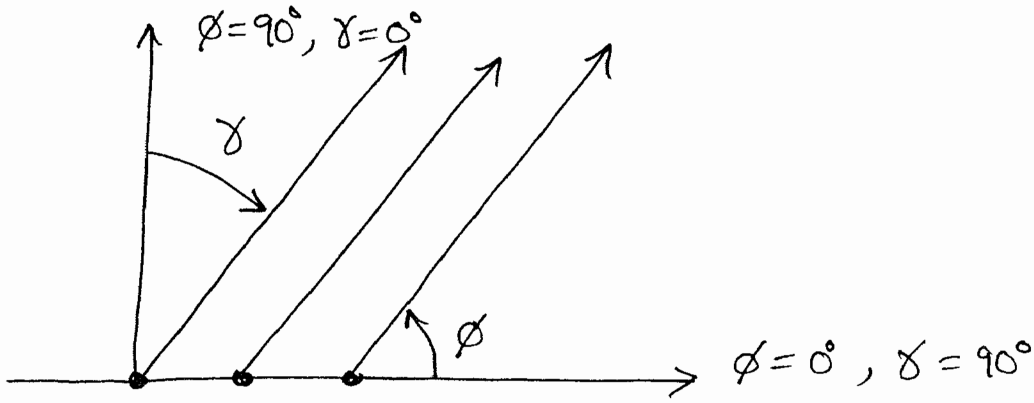
WE WILL CONSIDER THE BROADSIDE AND END-FIRE CASES SEPARATELY:

BROAD SIDE CASE

FOR THE BROADSIDE CASE ($\alpha = 0$), THE ANGLE OF THE FIRST NULL ϕ_{n1} IS DETERMINED BY;

$$\alpha = 0, \quad q = \pm 1 \quad \text{SO} \quad \cos(\phi_{n1}) = \pm \frac{\lambda}{Nd}.$$

WE CAN REPLACE ϕ_{n1} BY ITS COMPLEMENTARY ANGLE γ_{n1};



$$\cos(\phi_{n1}) = \sin(\gamma_{n1}) = \pm \frac{\lambda}{Nd}$$

HENCE FNBW IS $2\gamma_{n1}$

FOR A LONG BROADSIDE ARRAY WITH MANY ELEMENTS;

$$\gamma_{n1} \cong \sin(\gamma_{n1}) = \pm \frac{\lambda}{Nd}$$

THE FIRST-NULL-BEAMWIDTH IS;

$$FNBW \cong \frac{2\lambda}{Nd}.$$

END-FIRE CASE

FOR THE END-FIRE CASE, ($\alpha = k_0 d$) THE ANGLE OF THE FIRST NULL IS DEFINED AS;

$$\cos(\phi_{n1}) = \pm \frac{\lambda}{Nd} + 1$$

WRITING THE SERIES EXPANSION FOR
$\cos(\phi) = 1 - \frac{\phi^2}{2} + \ldots$

AGAIN, FOR SMALL ANGLES $\cos(\phi) \cong 1 - \phi^2/2$

SO: $$1 - \frac{\phi_{n1}^2}{2} \cong \pm \frac{\lambda}{Nd} + 1$$

HENCE THE FIRST NULL BEAMWIDTH IS;

$$FNBW \cong 2\phi_{n1} \cong 2\sqrt{\frac{2\lambda}{Nd}}$$

So, for a large, equal number of elements the endfire beamwidth is always greater than the broadside beamwidth.

In addition, if the beam angle is controlled via the drive current phase α, as the beam steers from broadside to endfire the main lobe will broaden.

SIDE LOBES

These occur when $\frac{\partial E_R}{\partial \phi} = 0$.

Giving lobes of lower magnitude than the major lobes.

For a uniform array it can be shown that the highest sidelobe will be only $\simeq$ 13dB lower than the main lobe - generally this is unacceptable.

The sidelobe levels can be reduced by using array elements of unequal amplitude

BROADSIDE ARRAYS WITH NON-UNIFORM AMPLITUDE DISTRIBUTIONS

WE WILL BRIEFLY CONSIDER;

* UNIFORM - (EASY ANALYTIC SOLUTION)
* BINOMIAL - (PASCAL'S TRIANGLE)
* OPTIMUM - (DOLPH - TCHEBYSCHEFF)
* EDGE - USED IN RADAR APPS.

CONTINUOUS ARRAY

IF WE CONSIDER AN ARRAY OF AN INFINITE NUMBER OF SOURCES SPACED BY AN INFINITESIMAL DISTANCE - WE HAVE EXACTLY THE SAME SITUATION AS WE DID WHEN WE CONSIDERED APERTURE DISTRIBUTIONS.

IMPLEMENTATION EXAMPLES

ALTHOUGH WE HAVE CONSIDERED ONLY LINEAR ARRAYS, THE THEORY CAN BE EXPANDED INTO A 2D ARRAY. SUCH ANTENNAS ARE CALLED <u>PLANAR</u> ARRAYS

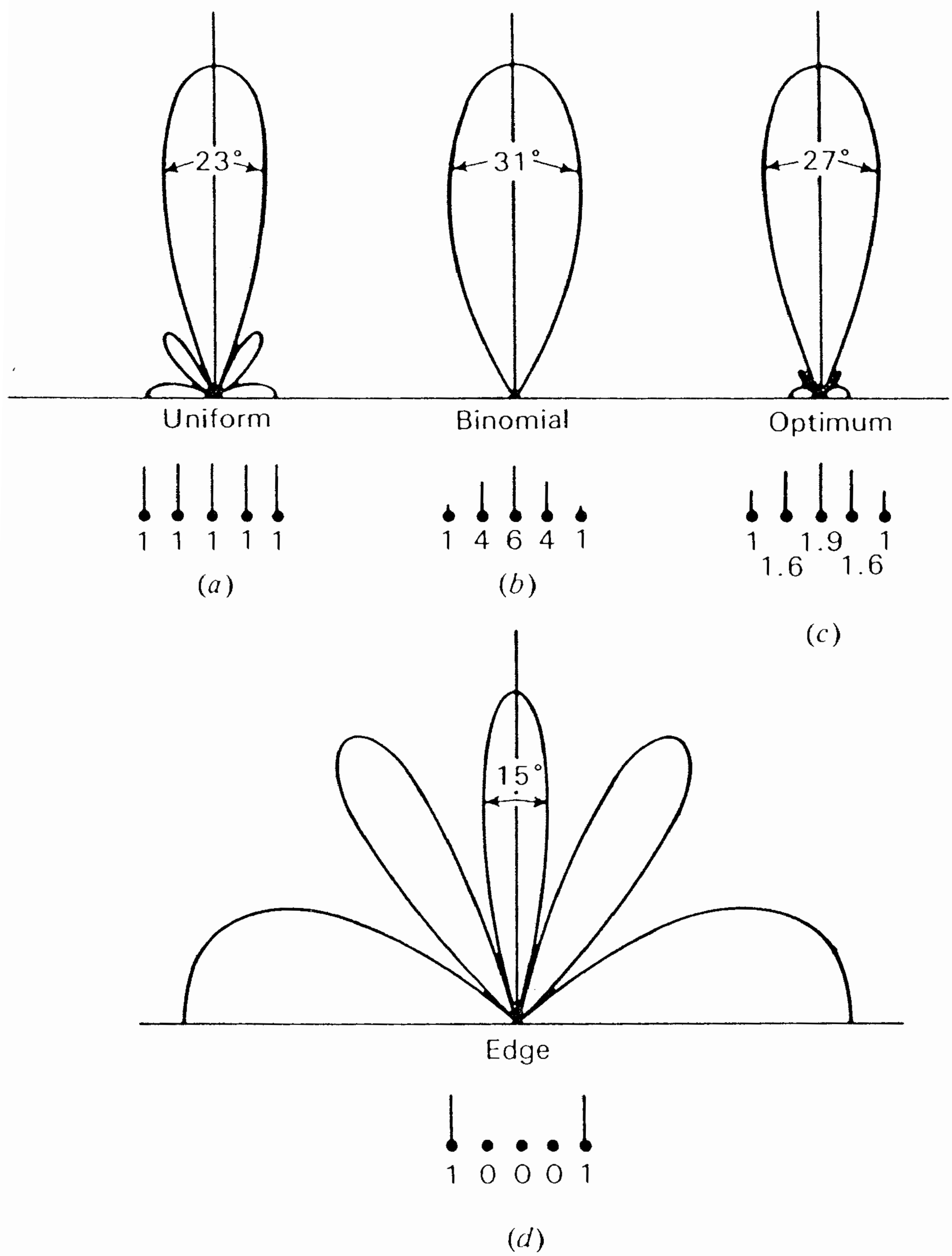
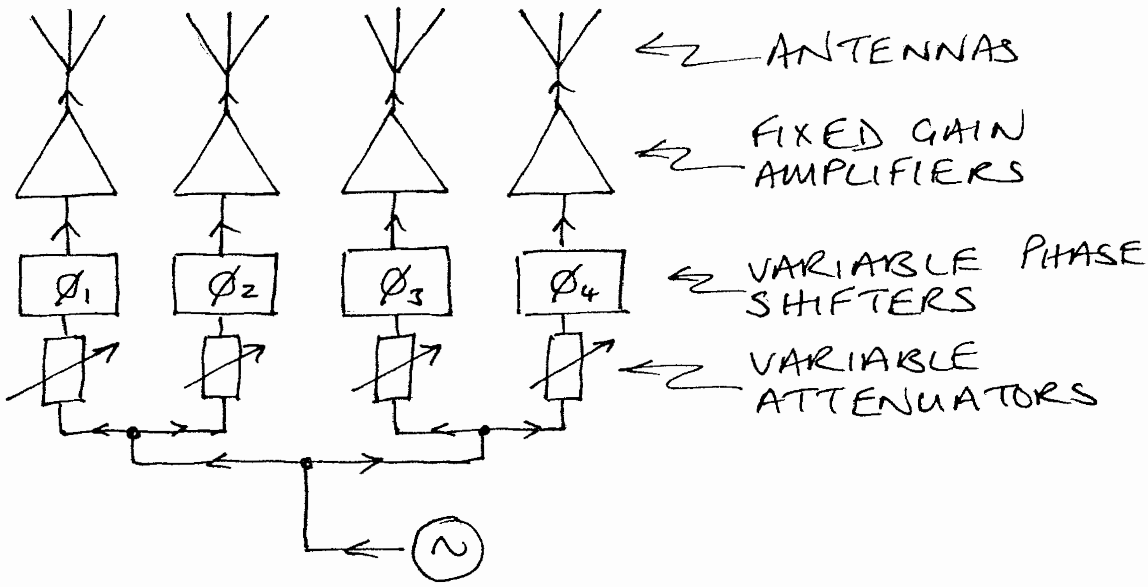


Figure 4-29 Normalized field patterns of broadside arrays of 5 isotropic point sources spaced $\lambda/2$ apart. All sources are in the same phase, but the relative amplitudes have four different distributions: uniform, binomial, optimum and edge. Only the upper half of the pattern is shown. The relative amplitudes of the 5 sources are indicated in each case by the array below the pattern, the height of the line at each source being proportional to its amplitude. All patterns are adjusted to the same maximum amplitude.

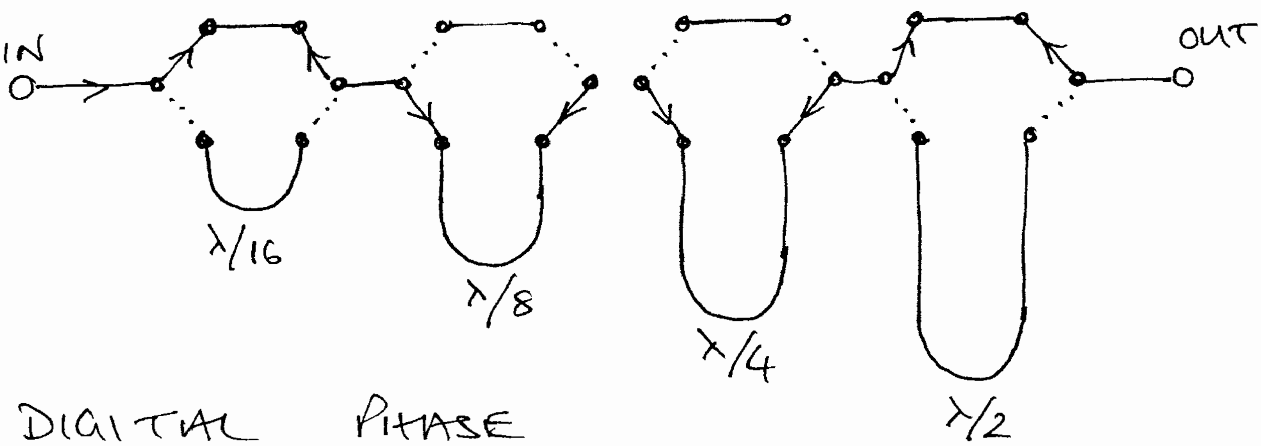
ARRAY ANTENNA IMPLEMENTATION



PHASE SHIFTERS

AT LOW POWER LEVELS CAN USE SWITCHED PATH PHASE SHIFTERS.

AT HIGH POWERS WE CAN USE FERRITE MATERIALS IN WAVE GUIDES.

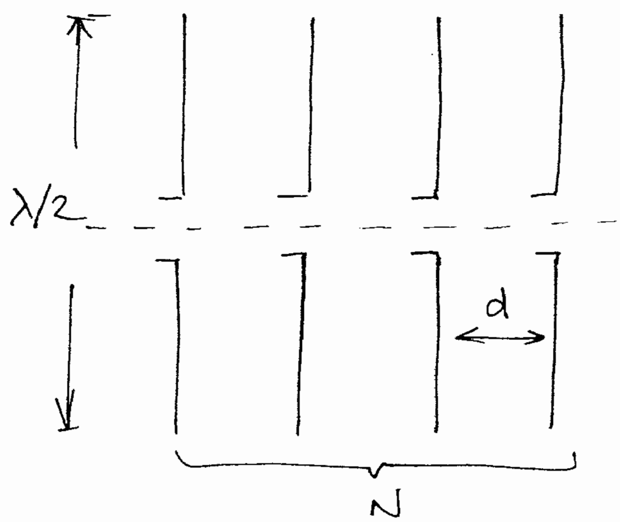


DIGITAL PHASE SHIFTER $\frac{3}{8}\lambda = 135^\circ$

$\frac{\lambda}{16}$ QUANTIZATION

PRACTICAL DIPOLE ARRAYS

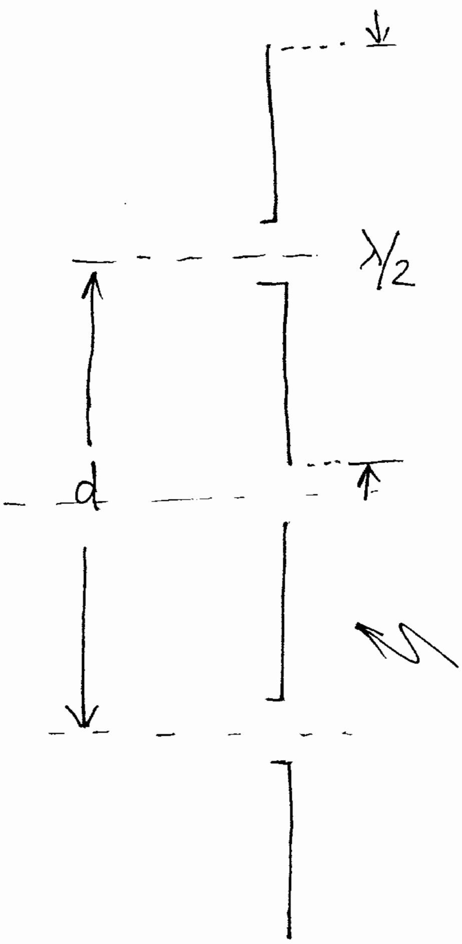
BROADSIDE DIPOLE ARRAY (CO-PHASED)



BEAMWIDTH $\simeq \frac{\lambda}{Nd}$ (RADS)

POWER GAIN $= N$
(RELATIVE TO A SINGLE DIPOLE)

COLLINEAR DIPOLE ARRAY (CO-PHASED)



BEAMWIDTH $\simeq \frac{\lambda}{Nd}$ (RADS)

POWER GAIN $= N$
(RELATIVE TO A SINGLE DIPOLE)

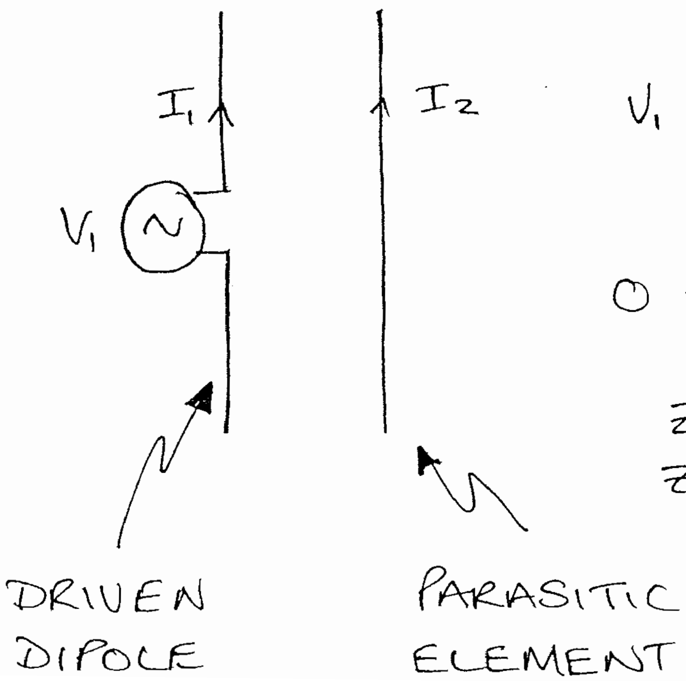
'N' DIPOLES

PARASITIC ELEMENTS

PARASITIC ELEMENTS FORM THE BASIS OF YAGI-UDA ARRAY.

IF A DIPOLE IN AN END-FIRE ARRAY OF ELEMENTS IS ENERGIZED IT CAN ALSO ENERGIZE AN ADJACENT ELEMENT OF THE ARRAY, SUCH AN ELEMENT IS CALLED A <u>PARASITIC</u> ELEMENT

THE DRIVEN AND PARASITIC ELEMENT ARE COUPLED VIA A MUTUAL INDUCTANCE EFFECT. – THE PARASITIC ELEMENT IS DRIVEN BY THE NEAR-FIELD ENERGY OF THE DRIVEN DIPOLE.



$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
(FOR THE DIPOLE)

$$0 = Z_{21} I_1 + Z_{22} I_2$$
(PARASITIC ELEMENT)

Z_{11}, Z_{22} – SELF IMPEDANCE

$Z_{12} = Z_{21}$ – MUTUAL IMPEDANCE

THE ARRAY CAN BE ANALYSED BY CONSIDERING THE IMPEDANCES Z_{11}, Z_{12}, Z_{21} AND Z_{22}

Z_{11} AND Z_{22} DEPEND ON THE LENGTH OF THE ELEMENTS.

$Z_{12} = Z_{21}$ DEPEND ON THE SPACING.

FOR EXAMPLE;

ELEMENT SPACING (λ)	$\lvert Z_{12} \rvert$ (Ω)	$\arg(Z_{12})$ (DEGREES)
0.10	70	+15
0.15	60	0
0.20	55	-20
0.25	50	-35

ELEMENT LENGTH (λ)	$\lvert Z_{22} \rvert$ (Ω)	$\arg(Z_{22})$ (DEGREES)
0.53	95	+40
0.50	73	0
0.47	74	-10
0.45	84	-30

+ve - INDUCTIVE   -ve - CAPACITIVE

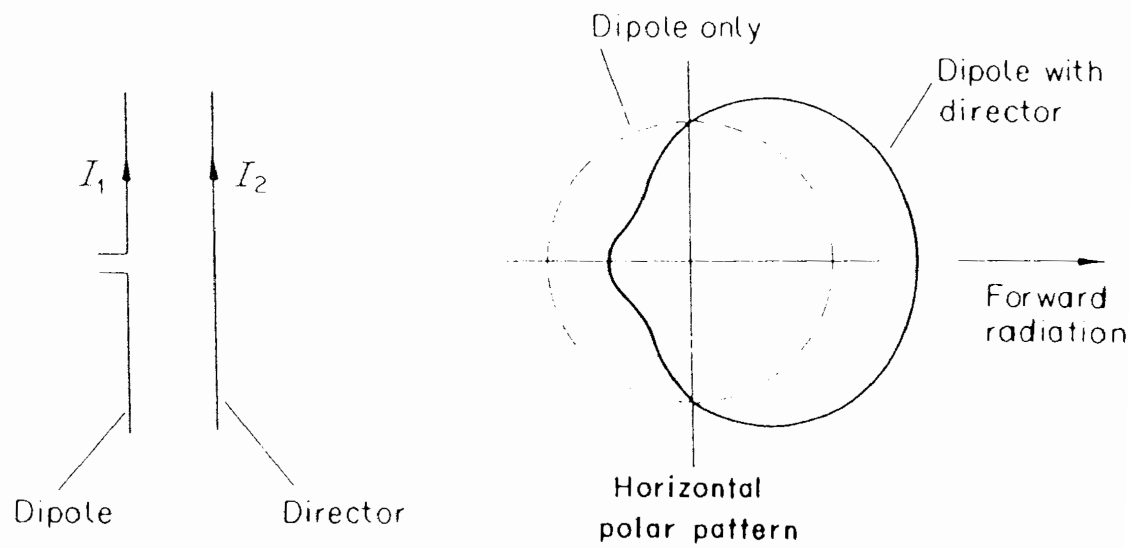


Fig 4.8

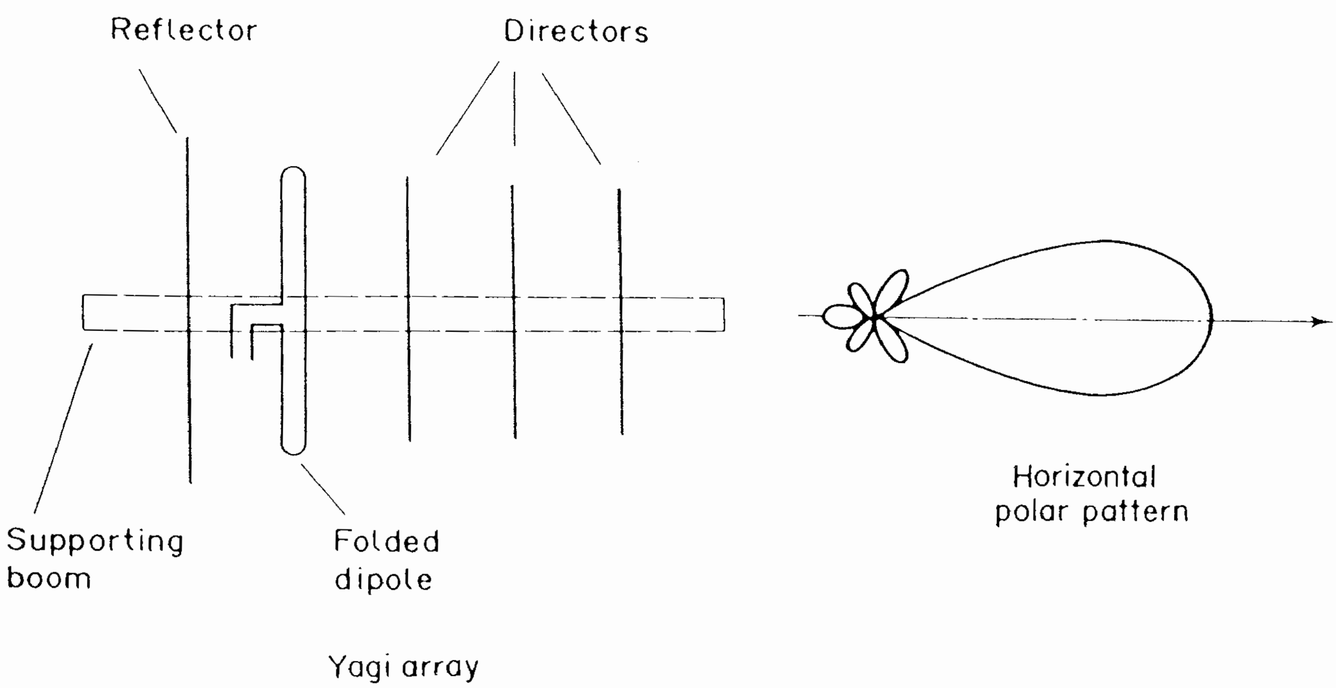


Fig 4.9

Table 4.3

Number of array elements	*Gain (dB) (relative to dipole)*
3	7
6	10
12	13
22	19