3.2 Yagi Uda antenna

Module:3 HF, UHF and Microwave Antennas

Course: BECE305L – Antenna and Microwave Engineering

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(Deemed to be University under section 3 of UGC Act, 1956)
CHENNAI

Module:3 HF, UHF and Microwave Antennas <u>7 hours</u>

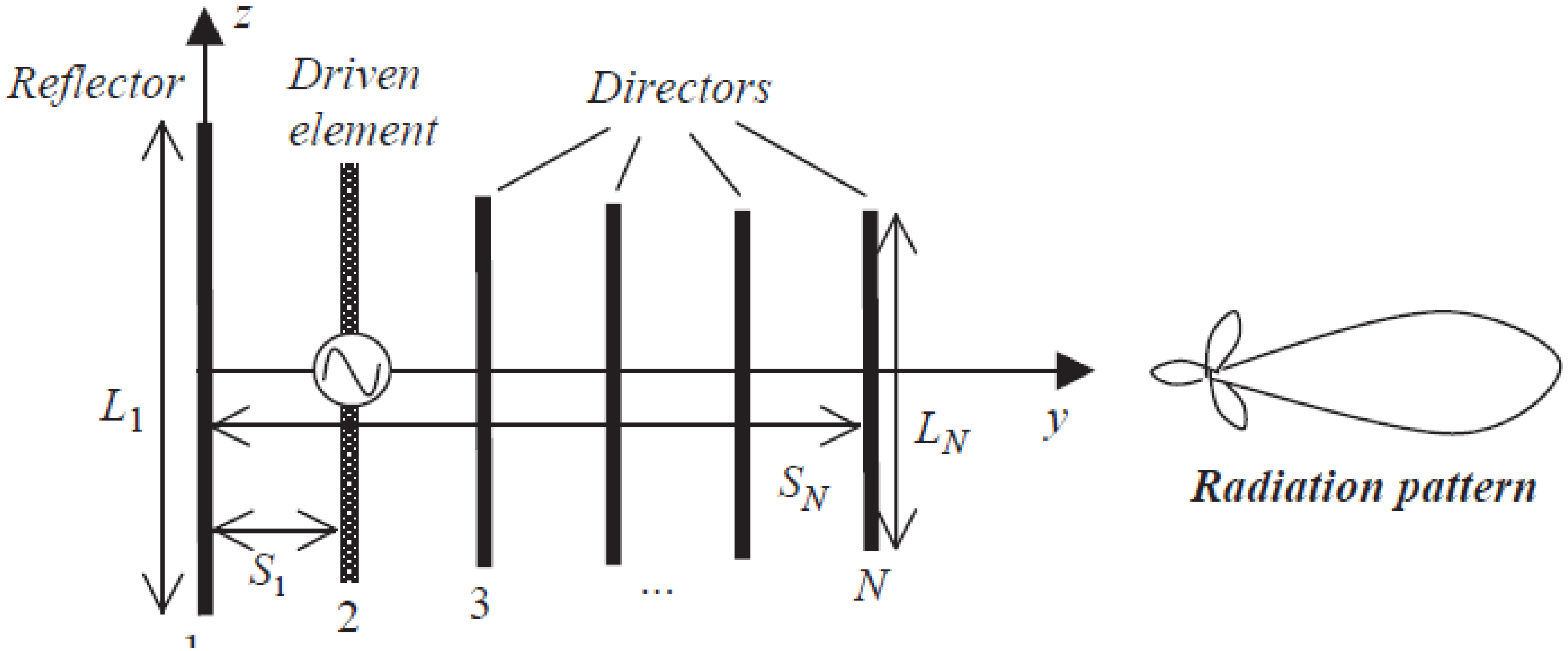
Wire Antennas - long wire, loop antenna - helical antenna. Yagi-Uda antenna, Frequency independent antennas - spiral and log periodic antenna - Aperture antennas – Horn antenna, Parabolic reflector antenna - Microstrip antenna

- Source of the contents: Antennas from theory to practice (Yi Huang)

1. Yagi-Uda antenna

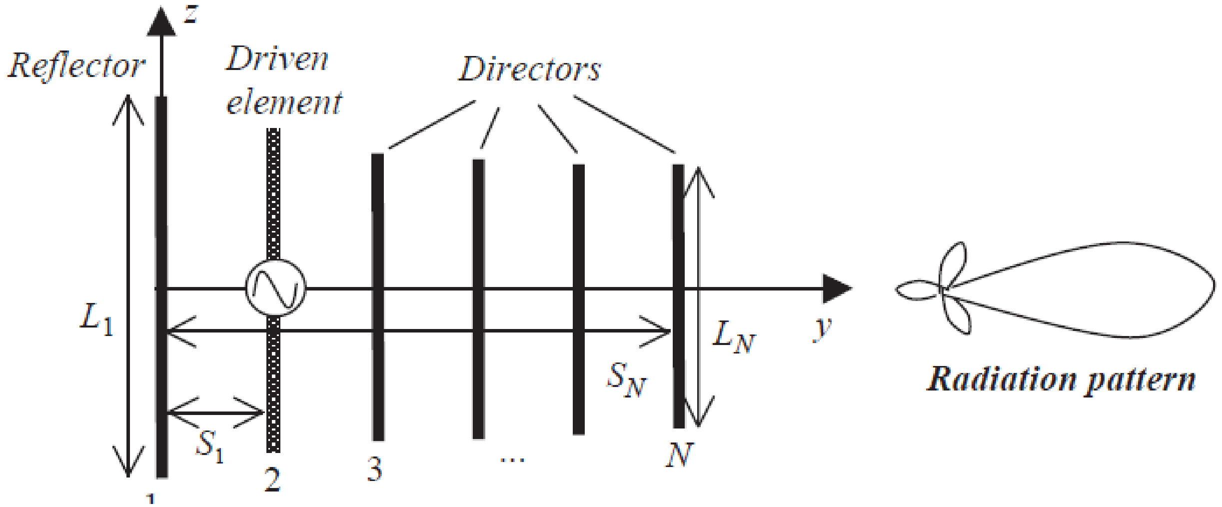
- *Yagi–Uda antenna* (also known as a *Yagi*) is another popular type of end-fire antenna widely used in the VHF and UHF bands (30 MHz to 3 GHz) because of its simplicity, low cost and relatively high gain.
- The most noticeable application is for home TV reception and these were found on the rooftops of houses.

1. Yagi-Uda



- The main feature of this type of antenna is that it consists of three different elements: **the driven element,** **reflector and** **director**
- Only one active element and feed port Other elements are parasitic

1. Yagi-Uda antenna

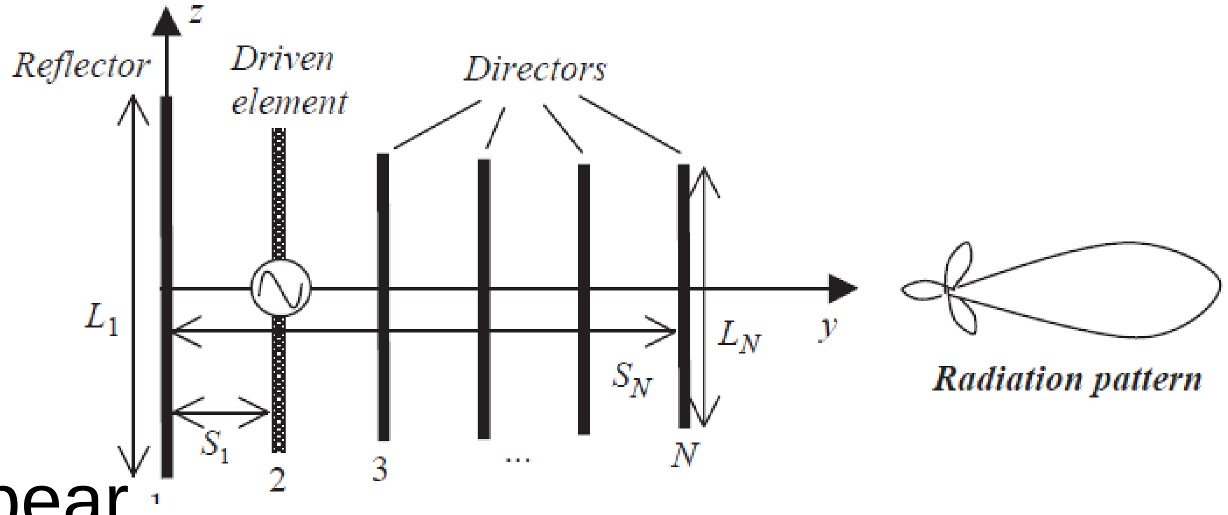


- **The driven element (feeder):** the very heart of the antenna. Determines the polarization and central frequency of the antenna. For a dipole, the recommended length is about 0.47λ to ensure a good input impedance to a 50Ω feed line.
- **The reflector:** normally slightly longer than the driven resonant element to force the radiated energy towards the front. (inductive reactance). Not much improvement by adding more reflectors to the antenna. (One is good)

The optimum spacing between the reflector and the driven element is between 0.15 and 0.25 wavelengths.

The length of the reflector has a large effect on the front-to-back ratio and antenna input impedance

1. Yagi-Uda antenna



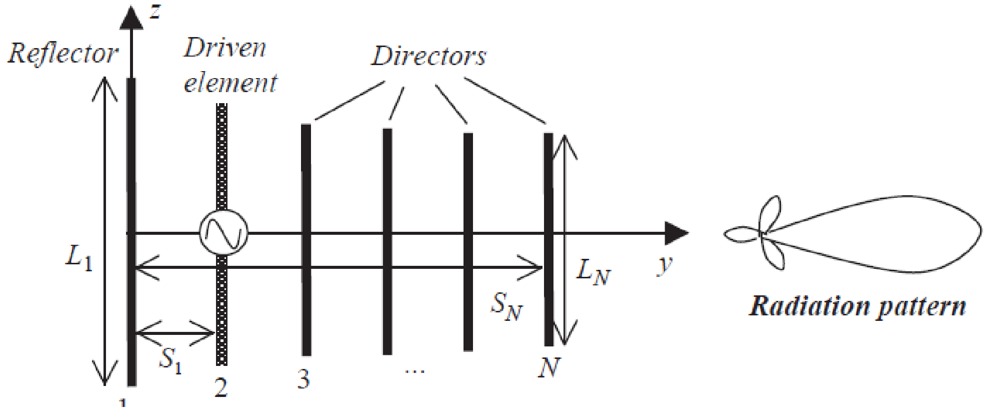
- **The directors:**

usually 10 to 20% shorter than the resonant driven element and appear to direct the radiation towards the front. They are of capacitive reactance.

Director to director spacing: 0.25 to 0.35 wavelengths,
larger spacing for longer arrays
smaller spacing for shorter arrays

- The number of directors determines the maximum achievable directivity and gain.

1.1 Yagi: Operation



- end-fire antenna
- The radiation towards the back seems to be blocked/reflected by the longer element,
  but not just by the reflector;
  the reflector and director produce push-and-pull effects on the radiation
- Induced currents are generated on the parasitic elements and form a traveling wave structure at the desired frequency.
- performance is determined by the current distribution in each element and the phase velocity of the traveling wave.

1.2 Current distribution

- Driven element current:
  determined by its length, frequency and interaction/coupling with nearby elements (mainly the reflector and first director),
- current distribution in parasitic elements is governed by the boundary condition: the total tangential electric field must be zero on the conducting surface.
- **dominant current** is on the **driven element**;
  the **reflector and the first director carry less current**, and
  the **currents on other directors are further reduced** and they appear to be of similar amplitude, which is typically less than 40% of that of the driven element

1.3 Radiation pattern

- For nth element: $$E(\theta)_n \approx j\eta \frac{I_n e^{j\beta r}}{2\pi r}\left(\frac{\cos(\beta l_n \cos\theta) - \cos(\beta l_n)}{\sin\theta}\right)$$
- Total field: $$E(\theta) \approx j\eta \frac{e^{j\beta r}}{2\pi r}\sum_{n=1}^{N} I_n \left(\frac{\cos(\beta l_n \cos\theta) - \cos(\beta l_n)}{\sin\theta}\right)\exp(j\beta S_{n-1}\cos\theta)$$

- One important figure of merit in a Yagi–Uda antenna is the *front-to-back ratio* of the pattern.
- It has been found that this is very sensitive to the spacing of the director

1.4 Yagi: Directivity ($D = 3.28N$)

- $D = 3.28N$
- coefficient 3.28 results from doubling the directivity (1.64) of a half-wave dipole.
  Unidirectional end fire: The radiation is redirected to just half of the space by the reflector and directors (very little to the other half), which is somewhat similar to the effect of a conducting ground plane.
- For N elements, the maximum is obtained when they are combined constructively as $3.28N$.
- simplest three-element Yagi–Uda antenna, $N = 3$, thus $D = 9.84 = 9.93$ dBi = 7.78 dBd.
  When the number is doubled to $N = 6$, 3 dB more gain can be obtained ($D = 12.93$ dBi = 10.78 dBd).

dBi is a measurement that compares the gain of an antenna with respect to an isotropic radiator (a theoretical antenna that disperses incoming energy evenly over the surface of an imaginary sphere.) dBd compares the gain of an antenna to the gain of a reference dipole antenna (defined as 2.15 dBi gain).

1.4 Yagi: Directivity ($D = 3.28N$)

- if three more directors are added to the antenna, the improvement in the directivity is just 1.76 dB.
- *the effect of the number of elements on the directivity is significant when N is small, but not significant when N is large*.
- the number of properly placed elements determines the directivity.
- directivity is determined by the number of elements, not the length of the boom.
- The boom should be insulated from the elements, otherwise compensation is required. Since the orientation of the boom is orthogonal to the antenna elements, the effects on the radiation pattern should be small.
- Boom: if it is of metal, affects input impedance

1.5 Yagi antenna design

- (the normalized diameter *d/λ* = 0.0085, spacing *S*1 = 0.2*λ*)

Boom length/λ	0.4	0.8	1.2	2.2	4.2	Note
L_1/λ	0.482	0.482	0.482	0.482	0.475	Reflector
L_2/λ			$\lambda/2$ folded dipole ~ 0.47			Driven element
L_3/λ	0.442	0.428	0.428	0.432	0.424	Director
L_4/λ		0.423	0.420	0.415	0.424	
L_5/λ		0.428	0.420	0.407	0.420	
L_6/λ			0.428	0.398	0.407	
L_7/λ				0.390	0.403	
L_8/λ				0.390	0.398	
L_9/λ				0.390	0.394	
L_{10}/λ				0.390	0.390	
L_{11}/λ				0.398	0.390	
L_{12}/λ				0.407	0.390	
L_{13}/λ					0.390	
L_{14}/λ					0.390	
L_{15}/λ					0.390	
Spacing/λ	0.20	0.20	0.25	0.20	0.308	Between directors
D in dBd	7.1	9.2	10.2	12.25	14.2	Measured
D in dBi	9.2	11.3	12.3	14.35	16.3	Measured
Estimated $D_{\max}$ *in dBi*	9.93	12.14	12.93	15.95	16.91	Equation (5.35)

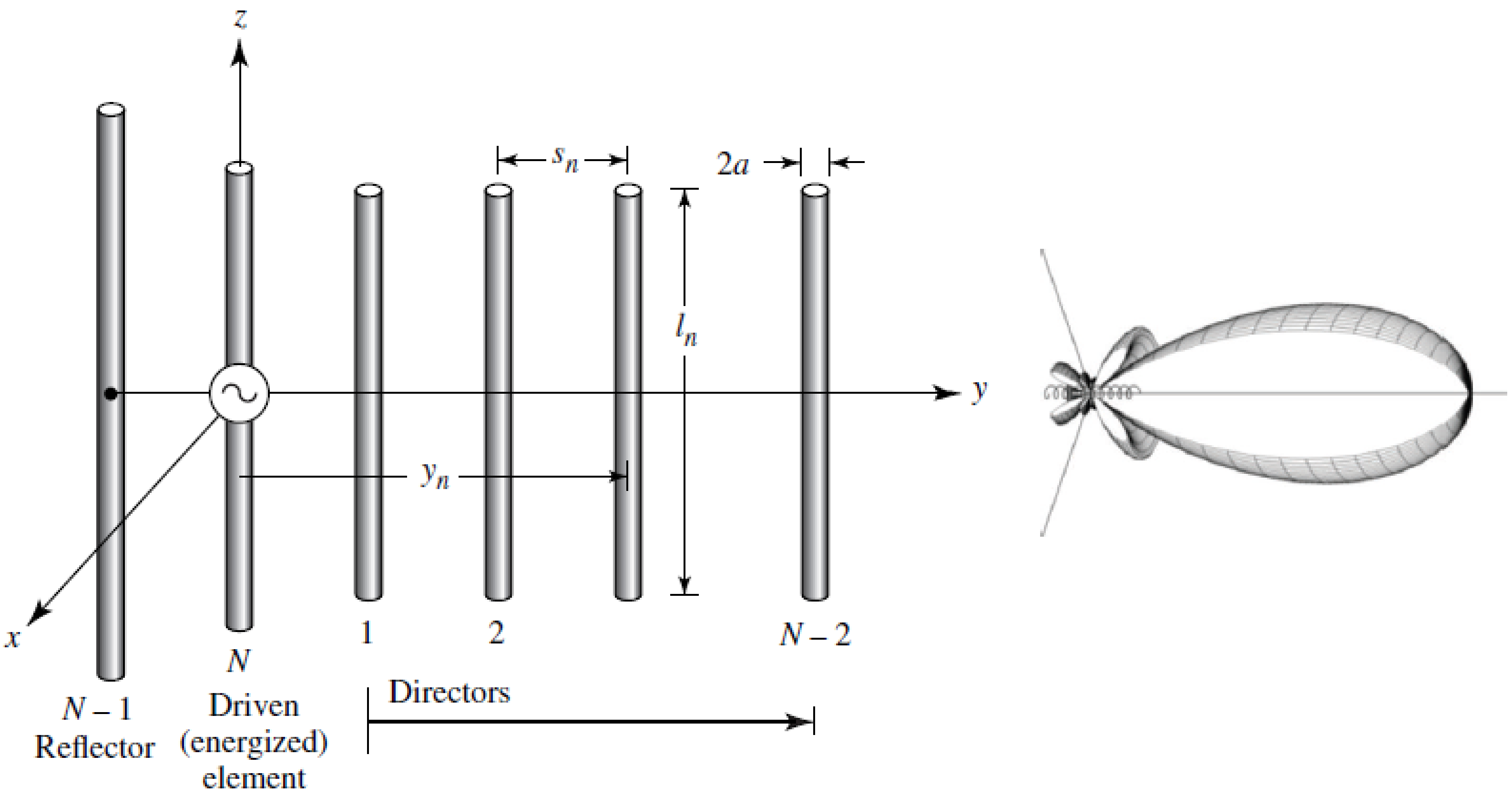

z
s_n
$2a$
l_n
y
y_n
x
N
1
2
N – 2
N – 1
Reflector
Driven
(energized)
element
Directors

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_{ik}/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 10.27)		(A)	(B)	(B)	(C)	(B)	(D)