CHAPTER 10

Yagi beam antennas

The Yagi beam antenna (more correctly, the Yagi–Uda antenna, after both of the designers of Tohoku University in Japan 1926) is *unidirectional*. It can be vertically polarized or horizontally polarized with little difference in performance (other than the polarization!). The Yagi antenna can be rotated into position with little effort. Yet the Yagi antenna shows power gain (so it puts out and receives a stronger signal), reduces the interfering signals from other directions, and is relatively compact.

COMPOSITION OF A BEAM ANTENNA

The Yagi antenna is characterized by a single driven element which takes power from the transmitter (or is connected to the receiver), plus one or more *parasitic elements*. The parasitic elements are not connected to the driven element, but rather receive their power from the driven element by indirect means. The indirect means is that they intercept the signal, and then re-radiate them.

The minimalist two element beam antenna may be composed of either a driven element and a reflector, or a driven element and a director. The reflector and directors are known as parasitic elements.

The *parasitic reflector* is three to five per cent *longer* than the half wavelength driven element. It provides power gain in the direction away from itself. It is inductive in reactance and lagging in phase.

The *parasitic director* is three to five per cent *shorter* than the half wavelength driven element. It provides power gain in its own direction. It is capacitive in reactance and leading in phase.

The factors that affect the phase difference between the direct and reradiated signals is determined principally by the *element length* and the *spacing* between the elements. Proper adjustment of these factors determines the gain and the front-to-back ratio that is available.

The presence of a parasitic element in conjunction with a driven element tends to reduce the feedpoint impedance of the driven element for close spacings ($<\lambda/2$) and increase it for greater than $\lambda/2$ spacing. In general, beam antennas have element spacing of 0.1λ to 0.25λ (with 0.15λ to 0.19λ being common), so the impedance will be lower than the nominal impedance for a half wavelength dipole.

TWO-ELEMENT YAGI ARRAY

Figure 10.1 shows the two-element Yagi array antenna. This particular one uses a driven element and a director, so the direction of maximum signal is in the direction of the director. The gain of a two-element Yagi is about 5.5 dBd (gain above a dipole) for spacing less than 0.1λ and the parasitic element is a director. For the case where a reflector is used, the gain peak is 4.7 dBd at about 0.2λ spacing.

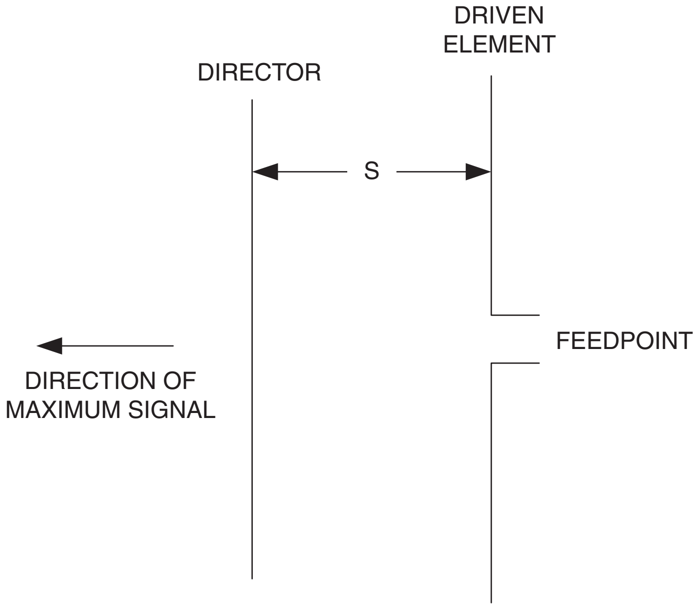

FIGURE 10.1

The difference between reflector and director usage is quite profound. The usual curve shows the director with higher gain, but it is more responsive to element spacing. The reflector has less gain, but is more tolerant of spacing errors.

The front-to-back ratio of the beam antenna is poor for two-element antennas. A compromise spacing of 0.15λ provides front-to-back ratios of 5 to 12 dB.

The feedpoint resistance of the antenna is clearly not 73 ohms as would be implied by the use of a half wavelength dipole for a driven element. The feedpoint impedance will vary roughly linearly from about 5 ohms at a spacing of 0.05λ to about 30 ohms for spacings of about 0.15λ. Above 0.15λ the differences between director and reflector implementations takes place. A reflector two-element beam feedpoint impedance will increase roughly linearly from 30 ohms at 0.15λ to about 45 ohms at 0.25λ spacing. The director implementation is a little less linearly related to spacing, but varies from about 30 ohms at 0.15λ to about 37 ohms at 0.25λ spacing.

Element lengths

The element lengths for a two-element Yagi beam are given below:

Director: $$\text{Director} = \frac{138.6}{F_{\text{MHz}}}$$

Driven element: $$\text{D.E.} = \frac{146}{F_{\text{MHz}}}$$

Spacing: $$\text{Spacing} = \frac{44.98}{F_{\text{MHz}}}$$

Where:
Director is the length of the director
D.E. is the length of the driven element in meters (m)
Spacing is the spacing between the elements in meters (m)
F_{MHz} is the frequency in megahertz.

These element lengths will result in 0.15λ spacing, which is considered about ideal.

THREE-ELEMENT YAGI BEAM

Figure 10.2 shows a Yagi antenna made up of a half wavelength driven element, a reflector and a director. The gain of the array and the front-to-back ratio peaks at a particular boom length (boom not shown), which is indicative of the spacing between the elements. Maximum gain occurs at a boom length of 0.45λ. An example of a three-element Yagi antenna built on a 0.3λ boom will provide 7 to 8 dBd forward gain, and a front-to-back ratio of 15 to 28 dB depending on the element tuning.

The feedpoint impedance of the three-element beam is about 18 to 25 ohms, so some means must be provided for adjusting the impedance to the 52 ohm coaxial cable.

Element lengths

Director: $\text{Director} = \frac{140.7}{F_{\text{MHz}}}$

Driven element: $\text{D.E.} = \frac{145.7}{F_{\text{MHz}}}$

Reflector: $\text{Reflector} = \frac{150}{F_{\text{MHz}}}$

Spacing: $\text{Spacing} = \frac{43.29}{F_{\text{MHz}}}$

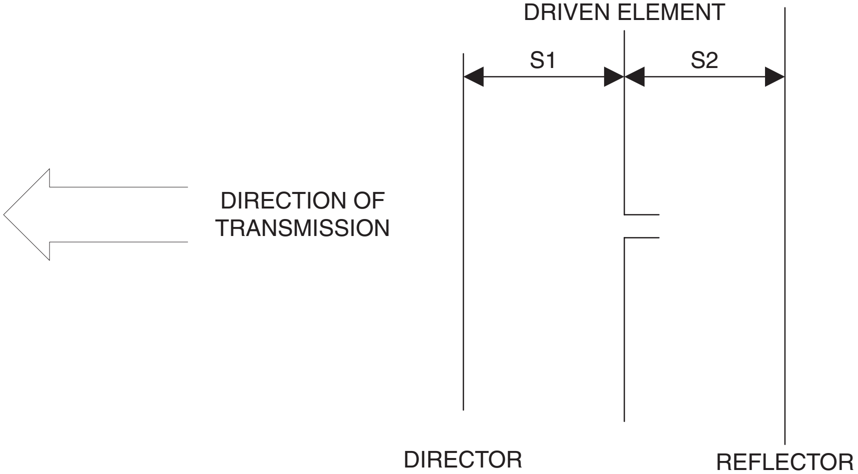

FIGURE 10.2

Where:

Director is the length of the director in meters (m)
D.E. is the length of the driven element in meters (m)
Reflector is the length of the reflector element in meters (m)
Spacing is the spacing of the elements in meters (m).

FOUR-ELEMENT YAGI ANTENNA

Figure 10.3 shows a four-element Yagi antenna. There is a tremendous increase in forward gain by adding a second director to the three-element case, but the front-to-back ratio is poorer unless the spacing is increased from 0.15λ to about 0.25λ. When all elements are spaced 0.15λ apart, the front-to-back ratio is only about 10 dB, but at 0.25λ the front-to-back ratio increases to 27 dB.

Element lengths

The dimensions calculated from the equations below will yield a forward gain of about 9.1 dBd, with a front-to-back ratio of about 27 dB.

Director: $$\text{Director} = \frac{138.93}{F_{\text{MHz}}}$$

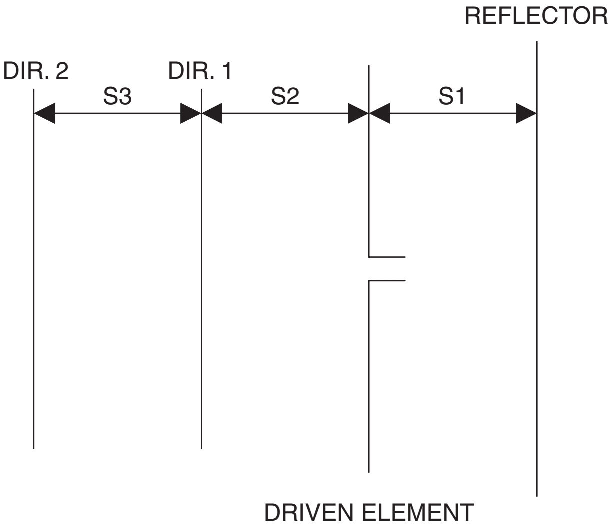

FIGURE 10.3

Driven element: $$\text{D.E.} = \frac{143.65}{F_{\text{MHz}}}$$

Spacing S1: $$\text{S1} = \frac{60.95}{F_{\text{MHz}}}$$

Spacings S2 and S3: $$\text{S2} = \text{S3} = \frac{75}{F_{\text{MHz}}}$$

Where:

Director is the length of the director element in meters (m)
D.E. is the length of the driven element in meters (m)
Reflector is the length of the reflector element in meters (m)
S1, *S2* and *S3* are in meters (m).

SIX-ELEMENT YAGI ANTENNA

Computer studies of Yagi antenna arrays demonstrate that five-element antennas are little more than four-element antennas, despite the extra director. But the addition of two additional directors adds significantly to the gain. The six-element antenna (Figure 10.4) shows a gain of nearly 10.5 dBd, and a front-to-back ratio of nearly 35 dB. Unfortunately, a six-element antenna is quite large, even with 0.15λ element spacing. At 14 MHz the antenna soars to about 16 meters boom length.

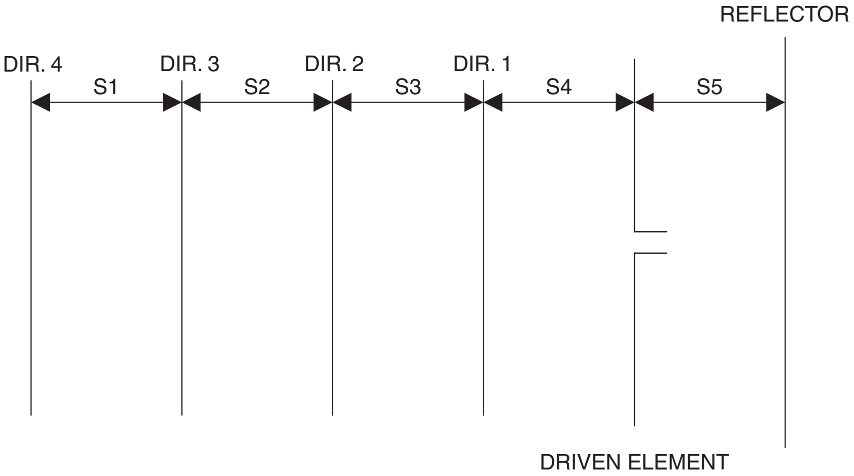

FIGURE 10.4

Element lengths

Director: $$\text{Director} = \frac{134.39}{F_{\text{MHz}}}$$

Driven element: $$\text{D.E.} = \frac{144.05}{F_{\text{MHz}}}$$

Reflector: $$\text{Reflector} = \frac{148.56}{F_{\text{MHz}}}$$

Element spacing: $$\text{Spacing} = \frac{44.8}{F_{\text{MHz}}}$$

Where:

Director is the length of the director elements in meters (m)
D.E. is the length of the driven element in meters (m)
Reflector is the length of the reflector element in meters (m)
Spacing is the spacing between the elements in meters (m).

IMPEDANCE MATCHING THE BEAM ANTENNA

The feedpoint impedance of most beam antennas is lower than the feedpoint impedance of a half wavelength dipole (72 ohms), despite the fact that the half wavelength dipole is a driven element. The feedpoint impedance may be as low as 18 to 20 ohms, and as high as 37 ohms. At 37 ohms there is a reasonable match to 52 ohm coaxial cable (1.41:1), but at 25 ohms the VSWR is more than 2:1. The typical solid-state transmitter will shut down and produce little RF power at this VSWR. What is needed is a means of matching the impedance of the beam to 52 or 75 ohm coaxial cable.

The *gamma match* is shown in Figure 10.5. It consists of a piece of coaxial cable connector such that its shield is to the center point on the radiating element (L), and its center conductor goes to the matching device. The dimensions of the gamma match of Figure 10.5 are as follows:

(L is the driven element length)

$$A = \frac{L}{10}$$

$$B = \frac{L}{70}$$

Where:

L, A and B are in meters (m).

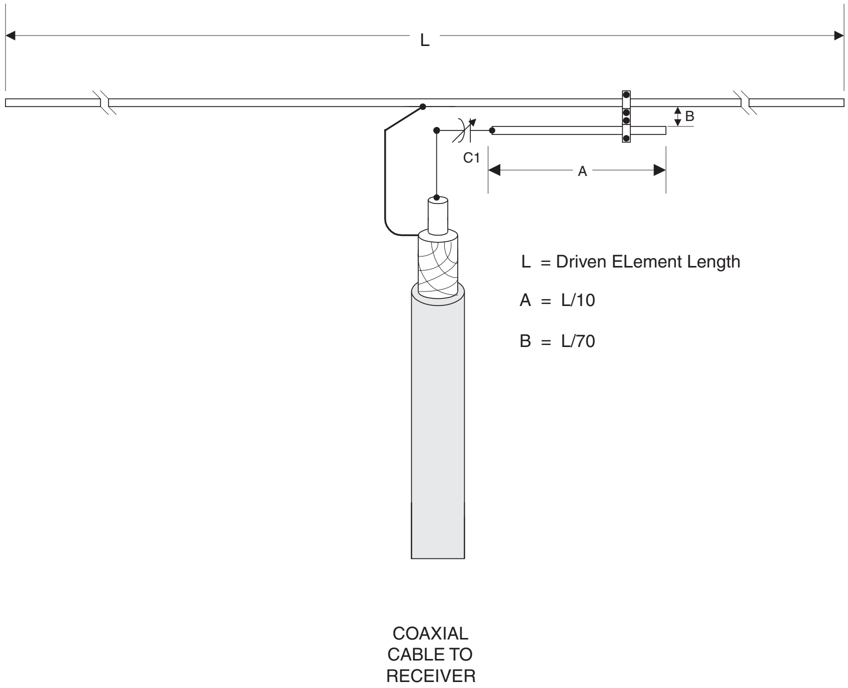
L
B
C1
A
L = Driven ELement Length
A = L/10
B = L/70
COAXIAL
CABLE TO
RECEIVER

FIGURE 10.5