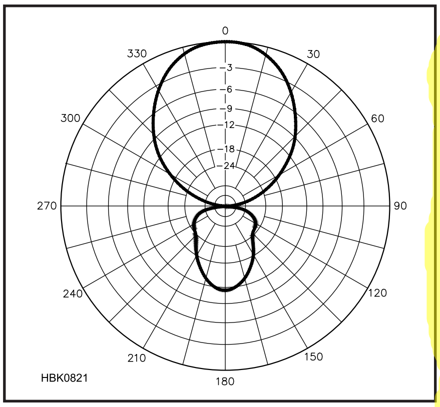

Fig 21.63 — Azimuthal pattern of a typical three-element Yagi in free space. The Yagi's boom is along the 0° to 180° axis.

The azimuth pattern for the same antenna is provided in **Fig 21.63**. (This is a free-space pattern, so the pattern is taken in the plane of the antenna. Remember that azimuth patterns taken over a reflecting surface must also specify the elevation angle at which the pattern was measured or calculated.) Most of the power is concentrated in the main lobe at 0° azimuth. The lobe directly behind the main lobe at 180° is often called the *back lobe* or *rear lobe*. The front-to-back ratio (F/B) of this antenna is just less than 12 dB — the peak power difference, in decibels, between the main lobe at 0° and the rearward lobe at 180°. It is infrequent that two 3 element Yagis with different element spacing and tuning will yield the same lobe patterns. The patterns also change with frequency of operation. The pattern of Fig 21.63 is shown only for illustrative purposes.

21.6.1 Parasitic Excitation

In a Yagi antenna only one element (the *driven element*) is connected to the feed line. The additional elements are *coupled* to the driven element because they are so close. (Element-to-element spacing in a Yagi antenna is generally on the order of $\frac{1}{10}$ to $\frac{1}{8}$ wavelength.) This *mutual coupling* results in currents being induced in the non-driven elements from the radiated field of the driven element. These elements are called *parasitic elements* and the Yagi antenna is therefore a *parasitic array*. (An antenna in which multiple elements all receive power from the transmitter is called a *driven array*.) The currents induced in the parasitic elements also result in radiated fields, just as if the current were the result of power from a feed line. This is called *re-radiation*, and it has a 180° phase shift from the current-inducing field. The combination of the field radiated by the driven element, the fields from the parasitic elements, and the physical spacing of the elements results in the fields having the proper phase relationship so as to focus the radiated energy in the desired direction and reject it in other directions.

The parasitic element is called a *director* when it reinforces radiation along a line pointing to it from the driven element, and a *reflector* in the opposite case. Whether the parasitic element is a director or reflector depends on the parasitic element tuning, which is usually adjusted by changing its length. The structure on which the elements are mounted is called the *boom* of the antenna.

21.6.2 Yagi Gain, Front-to-Back Ratio and SWR

The gain of a Yagi antenna with parasitic elements varies with the spacing and tuning of the elements. Element tuning is a function of length, diameter and *taper schedule* (the steps in length and diameter) if the element is constructed with telescoping tubing. For any given number of elements and the spacing between them, there is a tuning condition that will result in maximum gain. However, the maximum front-to-back ratio seldom, if ever, occurs at the same condition that gives maximum forward gain. The impedance of the driven element in a parasitic array, and thus the SWR, also varies with the tuning and spacing.

It is important to remember that all these parameters change as the operating frequency is varied. For example, if you operate both the CW and phone portions of the 20 meter band with a Yagi antenna, you probably will want an antenna that *spreads out* the performance over most of the band. Such designs typically must sacrifice a little gain in order to achieve good F/B and SWR performance across the band.

Gain and F/B performance generally improve with the number of elements. In Yagi antennas with more than three elements (a driven element and one director and reflector), the additional elements are added as directors, since little additional benefit is obtained from multiple reflectors. Wider spacing also improves gain and F/B up to a certain point, depending on a number of factors, beyond which performance begins to fall. Optimizing element spacing is a complex problem and no single spacing satisfies all design requirements. For the lower HF bands, the size of the antenna quickly becomes impractical for truly *optimal* designs, and compromise is necessary.

21.6.3 Two-Element Beams

A two-element beam is useful — especially where space or other considerations prevent the use of a three-element, or larger, beam. The general practice is to tune the parasitic element as a reflector and space it about 0.15 λ from the driven element, although some successful antennas have been built with 0. 1-λ spacing and director tuning.

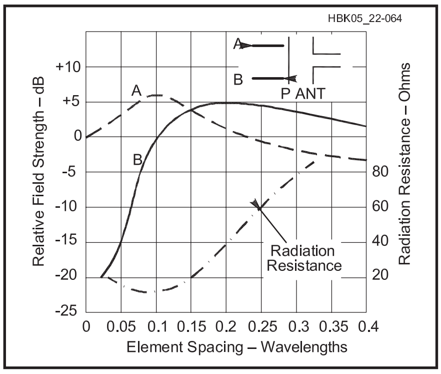

Fig 21.64 — Gain vs element spacing for a two-element Yagi, having one driven and one parasitic element. The reference point, 0 dB, is the field strength from a half-wave antenna alone.

Gain vs element spacing for a two-element antenna is given in **Fig 21.64** for the special case where the parasitic element is resonant. It is indicative of the performance to be expected under maximum-gain tuning conditions. Changing the tuning of the driven element in a Yagi or quad will not materially affect the gain or F/R. Thus, only the spacing and the tuning of the single parasitic element have any effect on the performance of a 2 element Yagi.

In Fig 21.64, the greatest gain is in the direction A (in which the parasitic element is acting as a director) at spacings of less than 0.14 λ, and in direction B (in which the parasitic element is a reflector) at greater spacings. The front-to-back ratio is the difference in decibels between curves A and B. The figure also shows variation in radiation resistance of the driven element.

These curves are for the special case of a self-resonant parasitic element, but are representative of how a two-element Yagi works. At most spacings the gain as a reflector can be increased by slight lengthening of the parasitic element; the gain as a director can be increased by shortening. This also improves the front-to-rear ratio.

Most two-element Yagi designs achieve a compromise F/R of about 10 dB, together with an acceptable SWR and gain across a frequency band with a percentage bandwidth less than about 4%.

21.6.4 Three-Element Beams

A theoretical investigation of the three-element case (director, driven element and reflector) has indicated a maximum gain of about 9.7 dBi (7.6 dBd). A number of experimental investigations have shown that the spacing between the driven element and