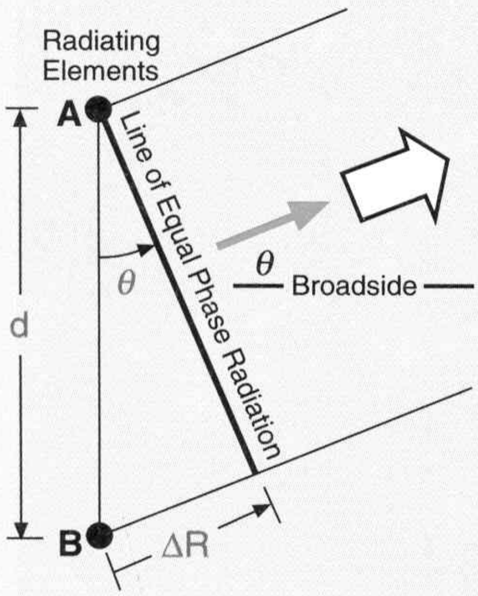
PHASE SHIFT NEEDED TO STEER THE BEAM

To steer the beam θ degrees off broadside, the phase of the excitation for element **B** must lead that for element **A** by the phase lag, $\Delta\phi$, that is incurred in traveling the distance, ΔR, from radiator **B**.



In traveling one wavelength (λ) a wave incurs a phase lag of 2π radians. So, in traveling the distance ΔR, it incurs a phase lag of

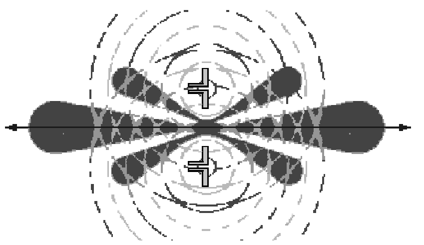
$$2\pi \frac{\Delta R}{\lambda} \text{ radians}$$

As can be seen from the diagram,

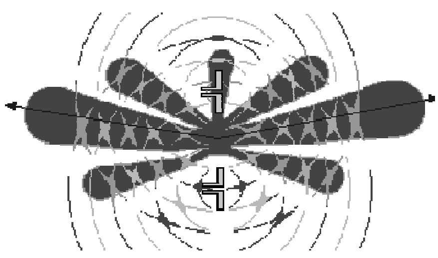
$$\Delta R = d \sin\theta$$

Hence, the element-to-element phase difference needed to steer the beam θ radians off broadside is

$$\Delta\phi = 2\pi \frac{d \sin\theta}{\lambda}$$



Radiation Pattern if Element A and B are in phase



Radiation Pattern if phase of Element B leads approx. 10° against phase of Element A

Note: The two radiator elements A and B (either dipole or dipole arrays fed in phase) are shown without the reflectors.

Some additional remarks according the Lichtenstein BC radar

The first technique used for angle tracking of targets by radar was to sense the target location with respect to the antenna axis by rapidly switching the antenna beam from one side of the antenna axis to the other.

The German Lichtenstein BC airborne intercept radar for instance used an array of 16 radiating elements arranged on the nose of aircraft normal to the line of flight. They could be switched in phase by sections of four elements to provide four beam positions (left – right for azimuth and up – down for elevation) for the lobbing operation.

The radar operator observed two oscilloscopes (one for azimuth and one for elevation) that displayed side by side the video returns from the four beam positions. When the target was on axis, the two pulses on both oscilloscopes were of equal amplitude, if the target moved off axis, the two pulses became unequal.
The radar operator, observing the existence of an error and its direction, he could tell the pilot to steer the airplane to regain a balance between the beam positions. This provided a manual tracking loop.

The continuous beam scanning was accomplished by a mechanical operated phase shifter with a rate of approx. 25Hz. See the explanation of beam steering by phase shifting.

The shortcoming of the early beam-scanning tracking radars was the time fluctuation of the echo signal amplitude. Other sources of echo-signal-amplitude such as target scintillation had caused false indications of tracking error too.
The undesired fluctuations that cause difficulty occur at about the same rate as the scan rate. Since target scintillation energy of aircraft in concentrated in the lower frequency range below approx. 100 Hz (particularly the troublesome propeller modulation), it would be desirable to increase the scan rate as high as possible. The maximum practical rate is one fourth of the pulse repetition frequency so that fur pulses provide a complete scan with one each up, down, right and left.
High scan rates are difficult to achieve with mechanical scanning devices, so a variety of techniques to scan electronically were used in later years.

However, the susceptibility of scanning and lobbing techniques to echo amplitude fluctuations was the major reason for developing a tracking technique that provides simultaneously all the necessary lobes for angle-error sensing. The output from the lobes may be compared simultaneously on a single pulse, eliminating any effect of time change of the echo amplitude.
This technique was initially called simultaneous lobbing – later so in the sixties the term **monopulse** came in use for it.