**Beam steering.** The beam of an array antenna may be steered rapidly in space without moving large mechanical masses by properly varying the phase of the signals applied to each element. Consider an array of equally spaced elements. The spacing between adjacent elements is $d$, and the signals at each element are assumed of equal amplitude. If the same phase is applied to all elements, the *relative* phase difference between adjacent elements is zero and the position of the main beam will be broadside to the array at an angle $\theta = 0$. The main beam will point in a direction other than broadside if the relative phase difference between elements is other than zero. The direction of the main beam is at an angle $\theta_0$ when the phase difference is $\phi = 2\pi(d/\lambda) \sin \theta_0$. The phase at each element is therefore $\phi_c + m\phi$, where $m = 0, 1, 2, \ldots, (N-1)$, and $\phi_c$ is any constant phase applied to all elements. The normalized radiation pattern of the array when the phase difference between adjacent elements is $\phi$ is given by

$$G(\theta) = \frac{\sin^2 [N\pi(d/\lambda)(\sin \theta - \sin \theta_0)]}{N^2 \sin^2 [\pi(d/\lambda)(\sin \theta - \sin \theta_0)]} \tag{8.9}$$

The maximum of the radiation pattern occurs when $\sin \theta = \sin \theta_0$.

Equation (8.9) states that the main beam of the antenna pattern may be positioned to an angle $\theta_0$ by the insertion of the proper phase shift $\phi$ at each element of the array. If variable, rather than fixed, phase shifters are used, the beam may be steered as the relative phase between elements is changed (Fig. 8.2).

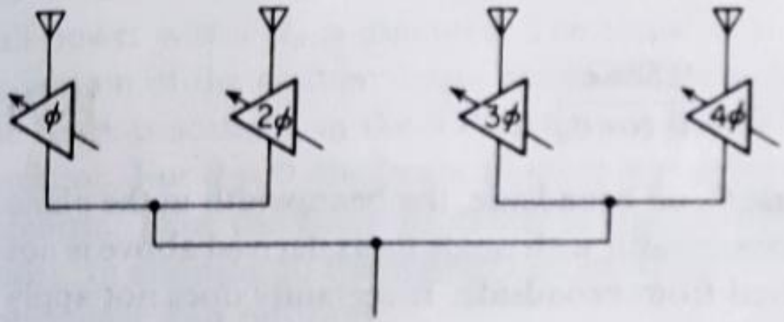


**Figure 8.2** Steering of an antenna beam with variable phase shifters (parallel-fed array).

Using an argument similar to the nonscanning array described previously, grating lobes appear at an angle $\theta_g$ whenever the denominator is zero, or when

$$\pi \frac{d}{\lambda}(\sin \theta_g - \sin \theta_0) = \pm n\pi \tag{8.10a}$$

or

$$|\sin \theta_g - \sin \theta_0| = \pm n \frac{\lambda}{d} \tag{8.10b}$$

If a grating lobe is permitted to appear at $-90°$ when the main beam is steered to $+90°$, it is found from the above that $d = \lambda/2$. Thus the element spacing must not be larger than a half wavelength if the beam is to be steered over a wide angle without having undesirable grating lobes appear. Practical array antennas do not scan $\pm 90°$. If the scan is limited to $\pm 60°$, Eq. (8.10) states that the element spacing should be less than $0.54\lambda$. Note that antenna elements used in arrays are generally comparable to a half wavelength in physical size.