

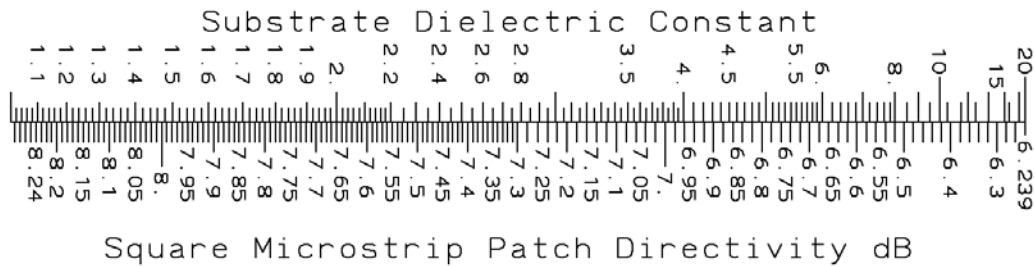
## Directivity of Microstrip Patches on Ground Plane

The directivity of a microstrip patch can be found from the cavity models of patches and integrated over the hemisphere to compute directivity. We obtain the same directivity for linearly and circularly polarized patches because a circularly polarized patch is a linear combination of two linearly polarized patterns. Integration over all values of  $\Phi$  produces the same integral for both cases.

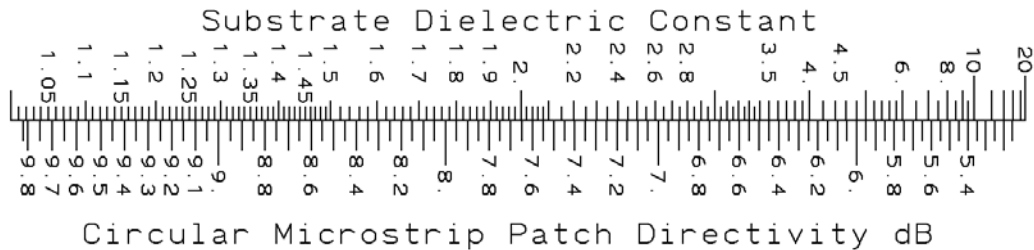
Table 6-1 [1, p. 290] lists the directivities computed for a large ground plane. The values are only given at 0.1 dB increments because closer values are unnecessary. In an actual application the microstrip patches will be mounted on a finite ground plane and the values will change. Table 6-1 is sufficient for estimates. Table 6-1 has been reduced to Scales 6-1 and 6-2 that give directivity of the patches and the corresponding substrate dielectric constant. These are interpolated from tables of maximum magnetic current given size [2, pp. 80-92]

Table 6-1 Estimated Directivity of Square and Circular Microstrip Patches on a Large Ground Plane.

Dielectric Constant	1.0	2.0	3.0	4.0	6.0	8.0	10.	16.
Square Patch (dB)	8.4	7.7	7.2	7.0	6.7	6.5	6.4	6.3
Circular Patch (dB)	9.8	7.6	6.7	6.2	5.8	5.5	5.4	5.1



**Scale 6-1** Estimated directivity of square patch on a large ground plane for either linearly or circularly polarized antenna



**Scale 6-2** Estimated directivity of circular patch on a large ground plane for either linearly or circularly polarized antenna

Least squares approximations to Table 6-1 can be computed. We use the variable:  $g = \log(\epsilon_r)$ . For a square patch we calculate the following approximation for directivity.

$$\text{Directivity (dB)} = 8.2651 - 0.18852g - 10.3483g^2 + 18.1983g^3 - 12.8228g^4 + 3.33296g^5$$

A circular patch on a large ground plane has a similar equation.

$$\text{Directivity (dB)} = 9.8445 - 7.12855g - 4.46486g^2 + 18.2167g^3 - 15.4406g^4 + 4.34745g^5$$

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The following two graphs show the errors of these two equations and illustrate that the least squares equations produce values below measurement errors.

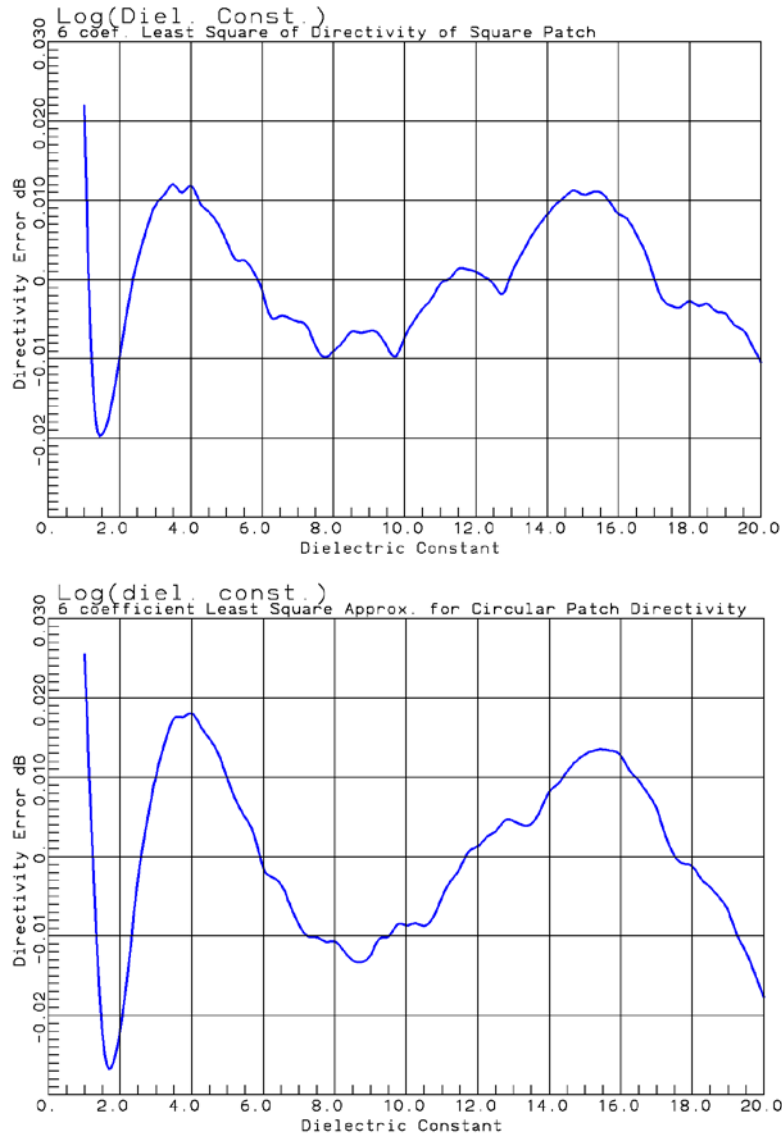
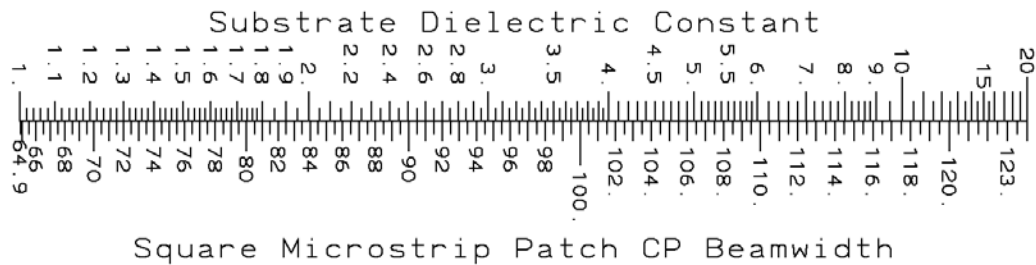
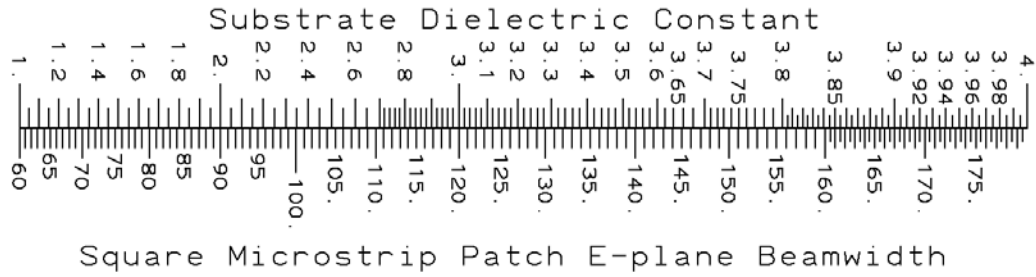


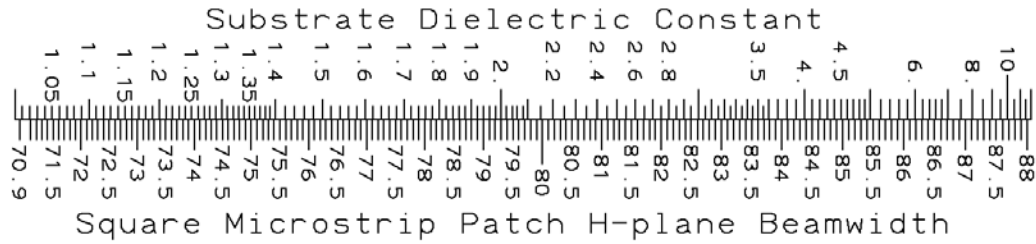
Figure 6-5 [1, pp. 291-292] illustrates the effect of mounting a patch on a finite circular ground plane and shows that the results given above have limited value.



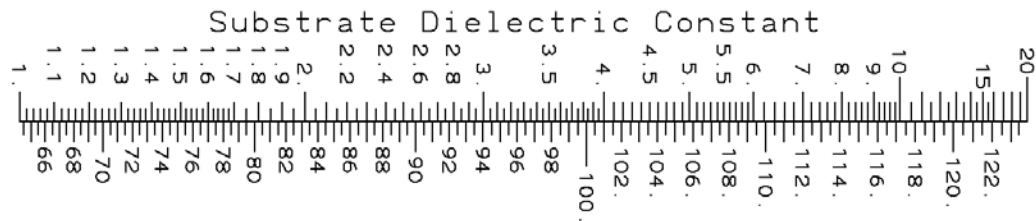
Scale 6-3 Beamwidth of square patch fed with circular polarization on infinite ground plane



**Scale 6-4** E-plane Beamwidth of Square Patch on infinite ground plane



**Scale 6-5** H-plane Beamwidth of Square Patch on infinite ground plane



**Scale 6-6** Beamwidth of circular patch fed with circular polarization on infinite ground plane



**Scale 6-7** E-plane Beamwidth of Circular Patch on infinite ground plane



**Scale 6-8** H-plane Beamwidth of Circular Patch on infinite ground plane

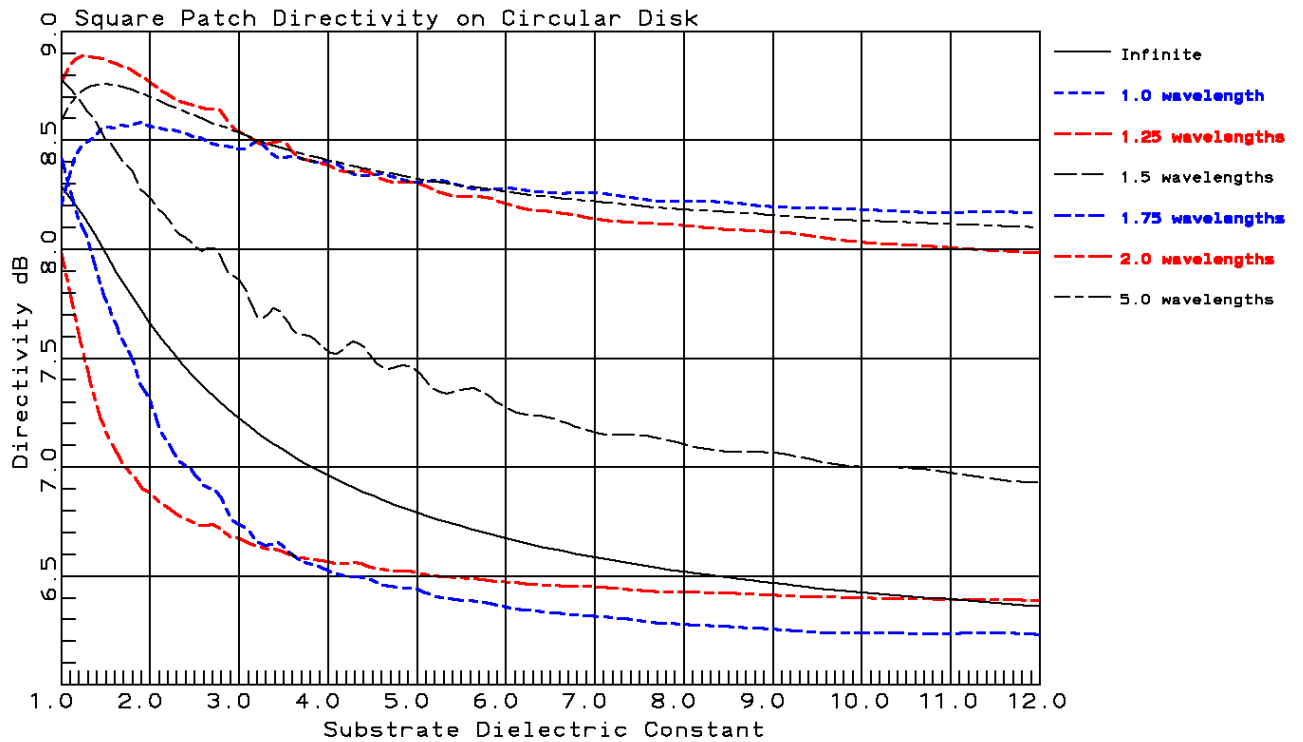


Figure 6-1 Square Patch Directivity Mounted on Circular Ground Plane

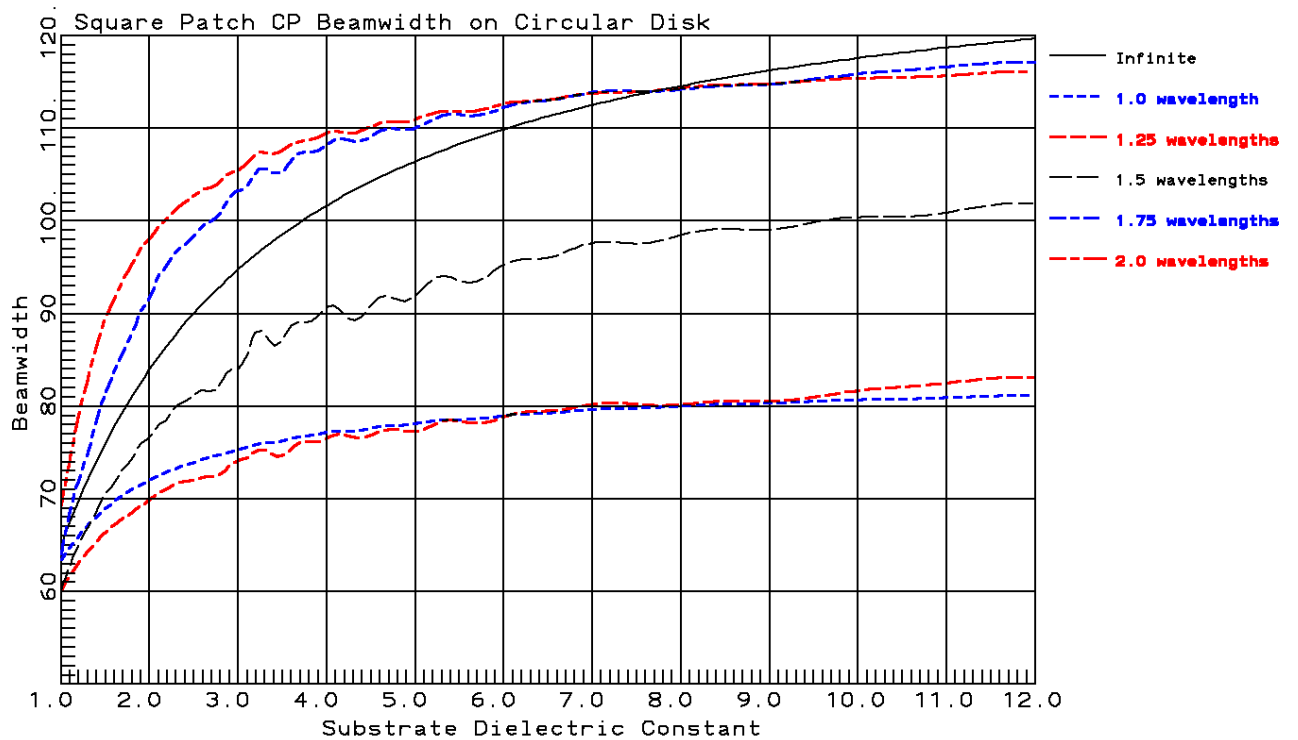


Figure 6-2 Square Patch Circular Polarization Beamwidth Mounted on Circular Ground Plane

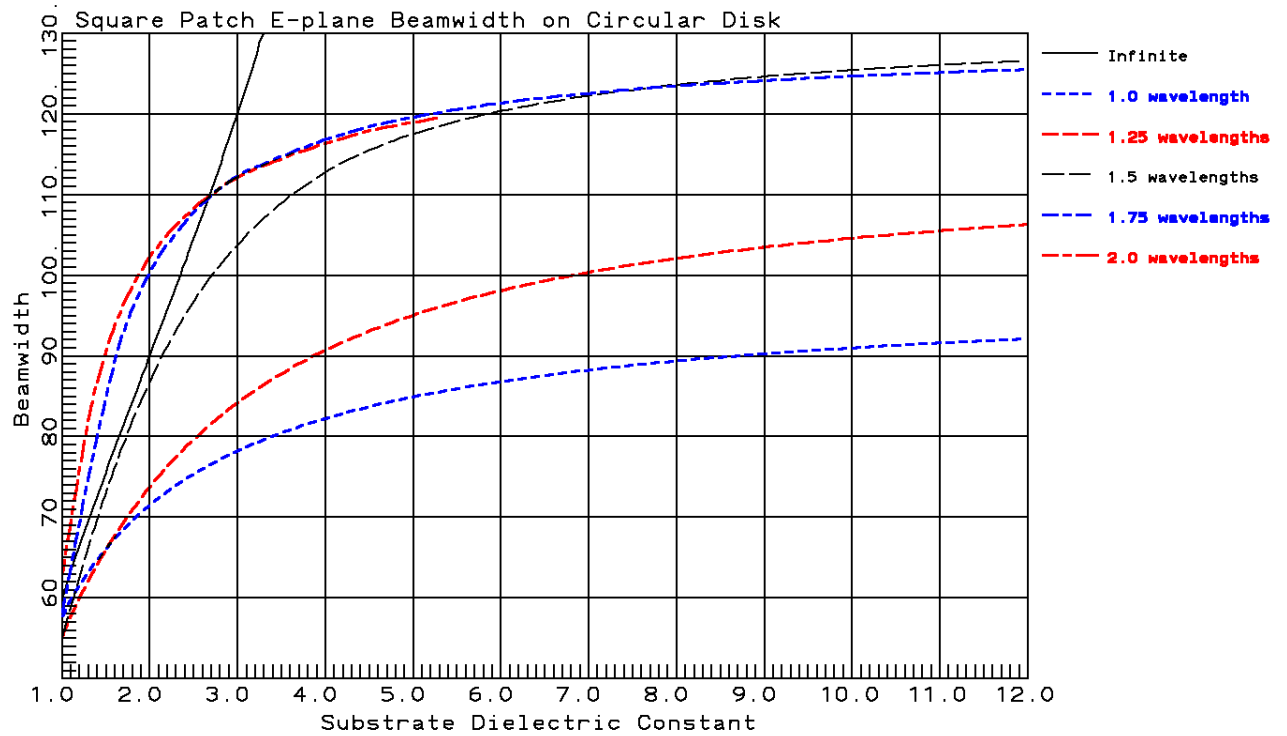


Figure 6-3 Square Patch *E*-Plane Beamwidth Mounted on Circular Ground Plane

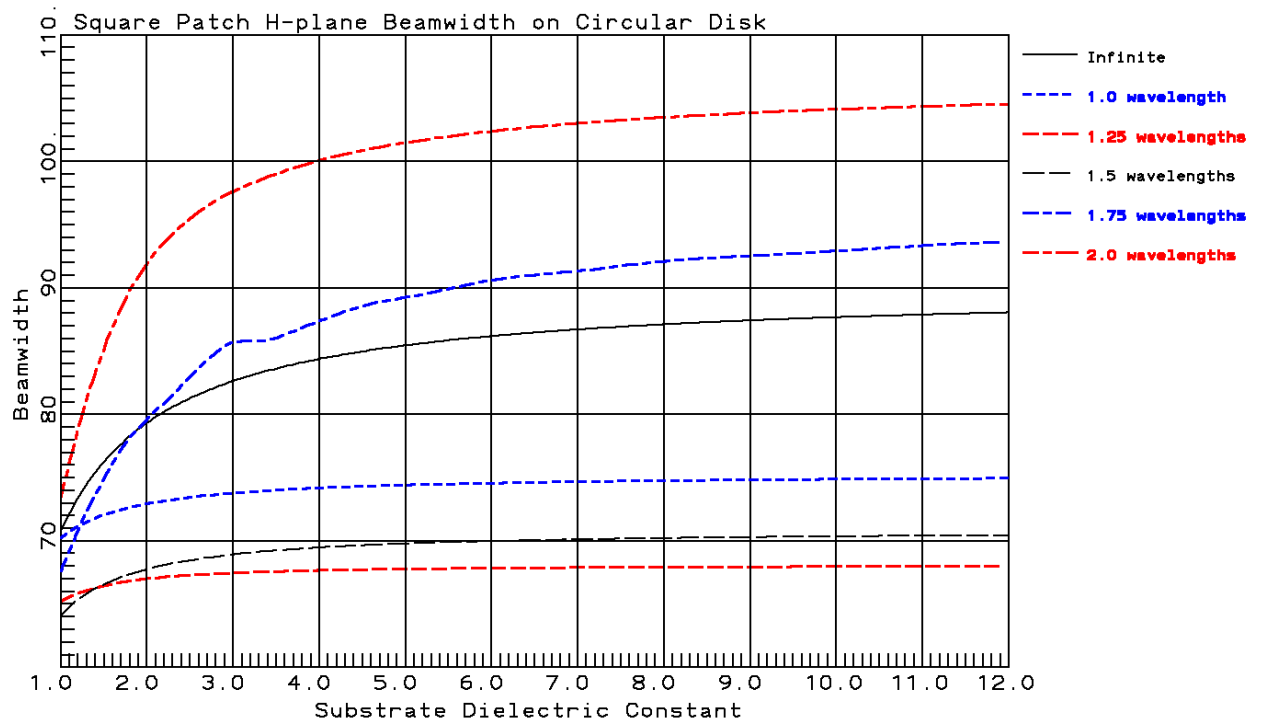
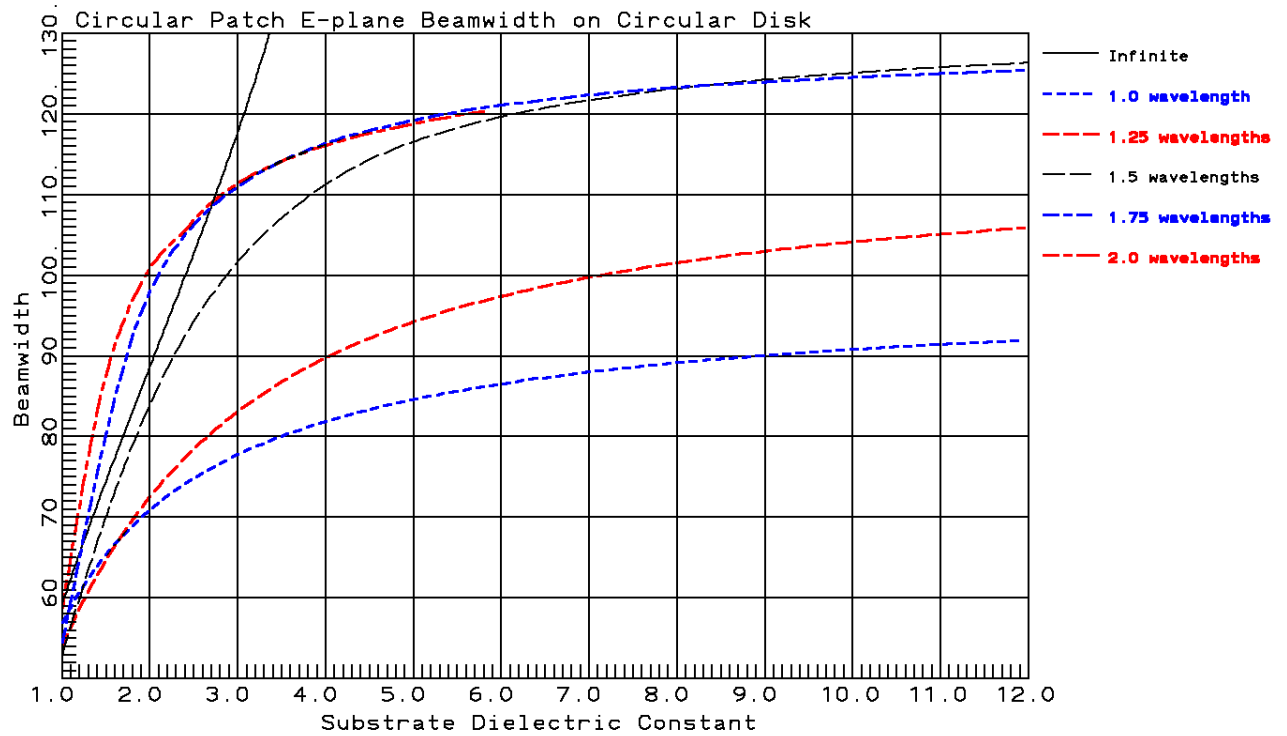
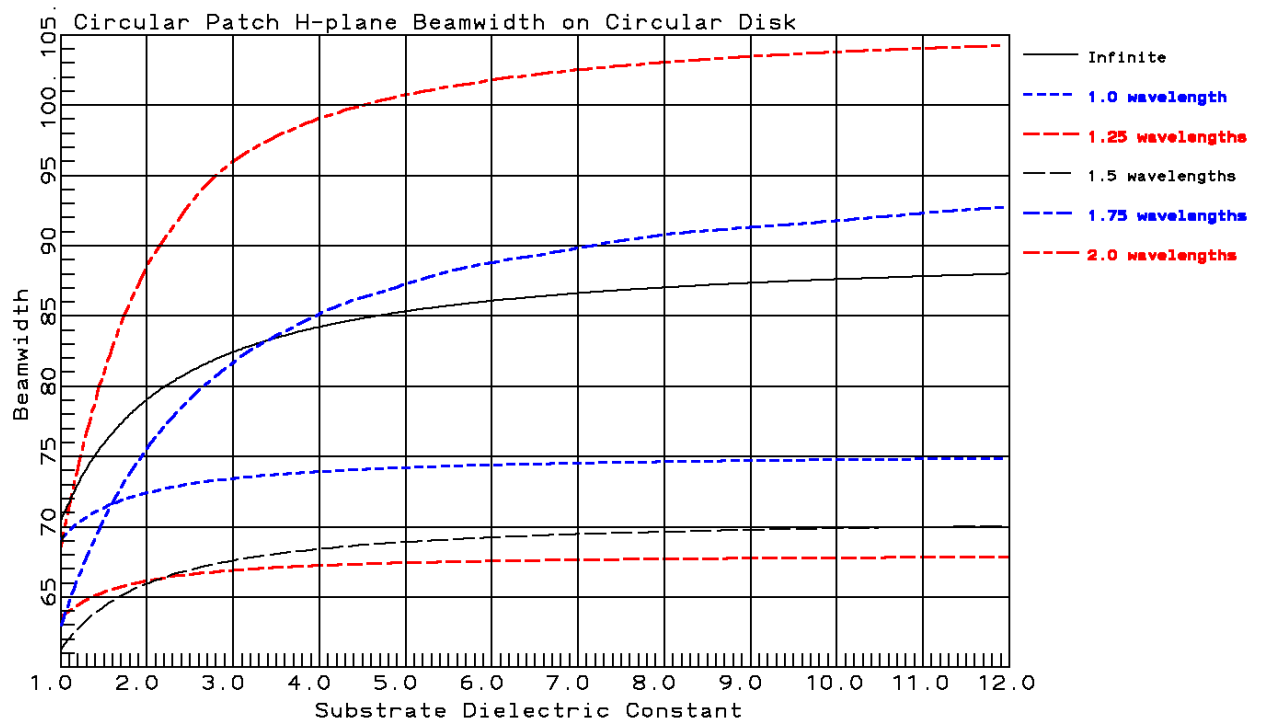


Figure 6-4 Square Patch *H*-Plane Beamwidth Mounted on Circular Ground Plane



**Figure 6-5** Circular Patch *E*-Plane Beamwidth Mounted on Circular Ground Plane



[1] T. A. Milligan, *Modern Antenna Design*, 2<sup>nd</sup> edition, Wiley, Hoboken, NJ, 2005.

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[2] L. Diaz and T. Milligan, *Antenna Engineering using Physical Optics*, Artech House, Boston, 1996.