Virtual Education Lab: The effect of the prime number and the number of periods on the polar resopnse

There are many choices to be made when designing a diffusor. In the last post, we discussed selecting a prime number and a frequency bandwidth. In Figure 1, we show a reflection phase grating with two periods of a QRD based on N=17. However, typically more than two periods are needed to provide sufficient coverage. Therefore, we have to consider the effect of the prime times the well width, Nw, and the number of periods on the polar responses, from which the diffusion coefficient is determined. The goal is to provide uniform coverage.

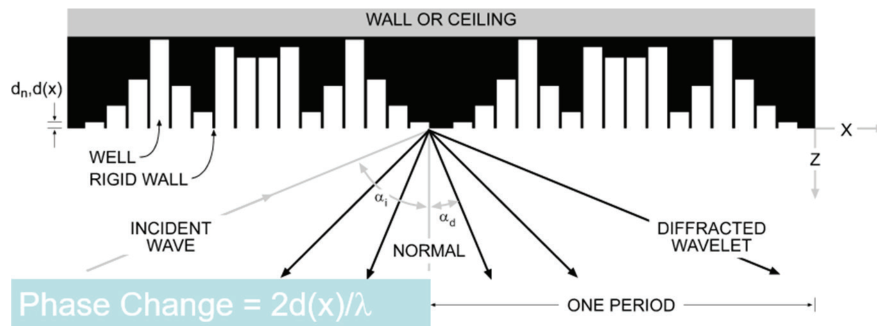

Figure 1. Two periods of a QRD based on N=17.

As we show in Figure 2, the polar reponse of the QRD is determined by the prime number N and the number of periods, P. In A, we show the polar response for N=17 and two periods, P=2, for a given well width. The effect of this choice yields broad diffraction lobes with equal energy in the 5 diffraction directions, m=-2, -1, 0, 1, 2, which are determined by the following grating lobes formula:

$$\sin\theta = \frac{m\lambda}{Nw} - \sin\Psi; m = 0, \pm1, \pm2, \ldots$$

The diffraction directions, θ, are determined by the angle of incidence, Ψ , the wavelength, λ, and the width of the scattering device, Nw. m is an integer describing the order of diffraction, with 0 being the specular direction. Ψ is typically zero, since we are in the far field.

As the number of periods increases in B from P=2 to 25, the energy is now focused into the diffraction directions. The diffraction lobes become narrower, thus decreasing the diffusion coefficient because the goal is uniform diffusion as shown in D, where there are no gaps in the spatial response.

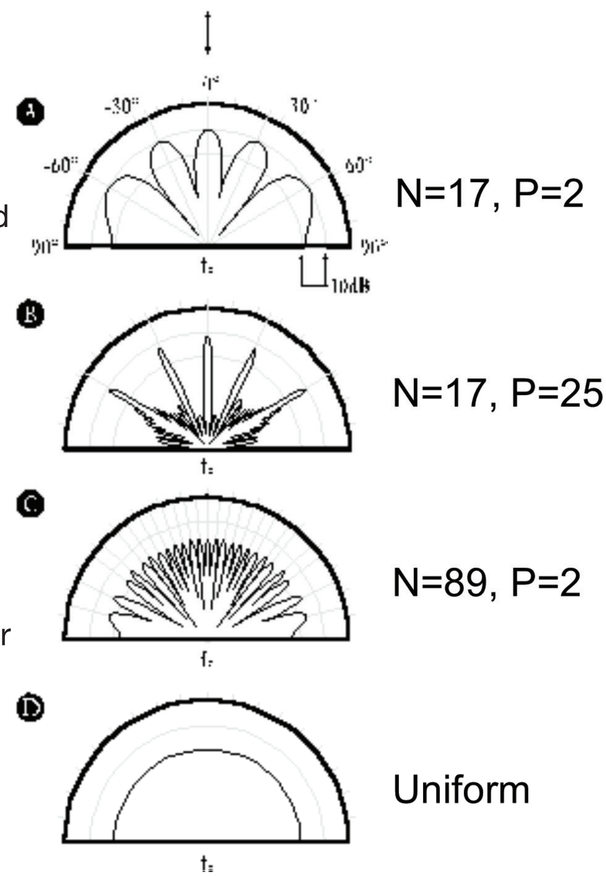

Figure 2. Polar responses for different values of prime number N and the number of periods P

In C, we see the effect of increasing the prime from N=17 to 89. In this case, we increased Nw significantly and since it is in the denominator of the diffraction grating equation, the number of diffraction lobes, m, can increase significantly before sinθ exceeds 1. We are more closely approaching uniform diffusion, however, the cost of manufacturing a diffusor with 89 wells becomes prohibitive. Let's review the variables:

1. The prime number of wells, N, which togethwe with the well width, w, determines Nw, the width of the diffusor and the number of grating lobes.
2. The lower and upper frequencies which determine the maximum depth and well width, w, respectively.
3. The number of repeat periods needed to cover a specific area, which determines the width of the diffraction lobes and the diffusion coefficient.

In summary, increasing N beneficially offers more grating lobes, whereas increasing the number of periods, P, has the negative effect of focusing the diffracted energy into specific directions which creates spatial gaps in the polar responses and decreases uniformity and consequently the diffusion coefficient. In later posts, we will explain how to resolve this periodicity problem, along with two other limitations of reflection phase gratings, which we will describe.

In the next post, we will describe how to design a 1D primitive root diffusor.

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