FIGURE 4.52 Top row: Perspective plot, image representation, and cross section of a typical ideal highpass filter. Middle and bottom rows: The same sequence for typical Butterworth and Gaussian highpass filters.
FIGURE 4.53 Spatial representation of typical (a) ideal, (b) Butterworth, and (c) Gaussian frequency domain highpass filters, and corresponding intensity profiles through their centers.
**FIGURE 4.54** Results of highpass filtering the image in Fig. 4.41(a) using an IHPF with $D_0 = 30, 60, \text{ and } 160.$
**FIGURE 4.55** Results of highpass filtering the image in Fig. 4.41(a) using a BHPF of order 2 with $D_0 = 30, 60,$ and $160$, corresponding to the circles in Fig. 4.41(b). These results are much smoother than those obtained with an IHPF.
FIGURE 4.56 Results of highpass filtering the image in Fig. 4.41(a) using a GHPF with $D_0 = 30, 60,$ and $160$, corresponding to the circles in Fig. 4.41(b). Compare with Figs. 4.54 and 4.55.
**TABLE 4.5**
Highpass filters. $D_0$ is the cutoff frequency and $n$ is the order of the Butterworth filter.

<table>
<thead>
<tr>
<th>Ideal</th>
<th>Butterworth</th>
<th>Gaussian</th>
</tr>
</thead>
</table>
| $H(u, v) = \begin{cases} 
1 & \text{if } D(u, v) \leq D_0 \\
0 & \text{if } D(u, v) > D_0 
\end{cases}$ | $H(u, v) = \frac{1}{1 + [D_0/D(u, v)]^{2n}}$ | $H(u, v) = 1 - e^{-D^2(u,v)/2D_0^2}$ |
FIGURE 4.57 (a) Thumb print. (b) Result of highpass filtering (a). (c) Result of thresholding (b). (Original image courtesy of the U.S. National Institute of Standards and Technology.)
FIGURE 4.58
(a) Original, blurry image.
(b) Image enhanced using the Laplacian in the frequency domain. Compare with Fig. 3.38(e).
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FIGURE 4.59  (a) A chest X-ray image. (b) Result of highpass filtering with a Gaussian filter. (c) Result of high-frequency-emphasis filtering using the same filter. (d) Result of performing histogram equalization on (c). (Original image courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School.)
FIGURE 4.63
(a) Bandreject Gaussian filter. (b) Corresponding bandpass filter. The thin black border in (a) was added for clarity; it is not part of the data.
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**FIGURE 4.64**
(a) Sampled newspaper image showing a moiré pattern.
(b) Spectrum.
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FIGURE 4.64
(c) Butterworth notch reject filter multiplied by the Fourier transform.
(d) Filtered image.
FIGURE 4.65
(a) $674 \times 674$ image of the Saturn rings showing nearly periodic interference.
(b) Spectrum: The bursts of energy in the vertical axis near the origin correspond to the interference pattern.
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FIGURE 4.65
(c) A vertical notch reject filter.
(d) Result of filtering. The thin black border in (c) was added for clarity; it is not part of the data. (Original image courtesy of Dr. Robert A. West, NASA/JPL.)
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**FIGURE 4.66**
(a) Result (spectrum) of applying a notch pass filter to the DFT of Fig. 4.65(a).
(b) Spatial pattern obtained by computing the IDFT of (a).