Two-Dimensional (2D) Digital Signal Processing Examples

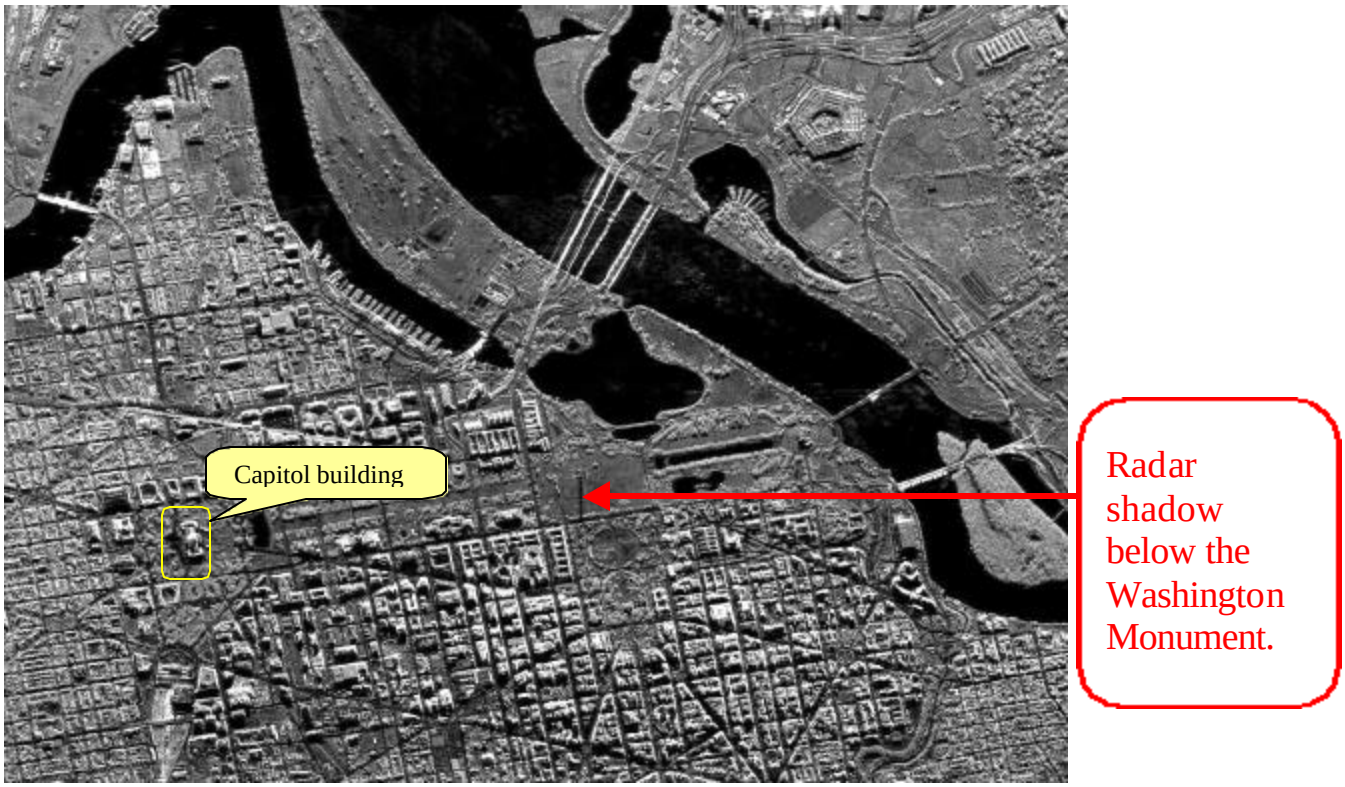

Figure 1. Synthetic Aperture Radar (SAR) image of Washington D.C. produced by 2D DSP. SAR images look the same, regardless of the time of **day or night**, or weather conditions. (The radar image looks basically the same at 11 am or 11 pm, on a clear day or a foggy day)

Two-Dimensional (2D) digital signal processing (2D DSP) is used to produce Synthetic Aperture Radar (SAR) images from microwave radar echoes. The first several stages of the processing primarily involve digital filters and sampling rate changes. The last stage of the processing is implemented by a two-dimensional (2D) FFT. The output of the 2D FFT is a 2D matrix of complex numbers. Each complex number corresponds to a picture element (pixel) in the output image. The magnitude of each 2D FFT output complex number is converted to a gray level (brightness, as an indication of microwave reflectivity) for each pixel. There are usually 256 possible gray levels, corresponding to one byte, for each pixel. The pixels are usually compressed with an algorithm such as JPEG for efficient storage.

The above image in Figure 1 was compressed in the JPEG format to reduce the size of this document. JPEG is based on the discrete cosine transform (DCT), which is similar to the discrete Fourier transform (DFT). JPEG is now used for images on Internet web pages. When you go to a web page that includes an image, your web browser downloads the JPEG coeffcients and then computes the inverse discrete cosine transform (IDCT) to reconstruct the image. The FFT is used to efficiently compute the IDCT.

2D DSP, JPEG, and the DCT are included in EE 652.

2D Digital Signal Processing: Medical Imaging Examples

Medical images are produced using the same DSP algorithms as in Synthetic Aperture Radar (SAR) systems. In particular, the last step in the signal processing is a 2D FFT.

G. Hounsfield, a radar engineer, received the Nobel Prize in Medicine for applying SAR signal processing algorithms to medical data. He did "technology transfer" from radar to medicine. The previous medical imaging technology used x-ray film to produce blurry images of bones. Hounsfield applied radar digital signal processing algorithms to medical data to produce detailed images of 2D slices through bones and soft tissue. Some examples of medical images produced by digital signal processing are shown below.

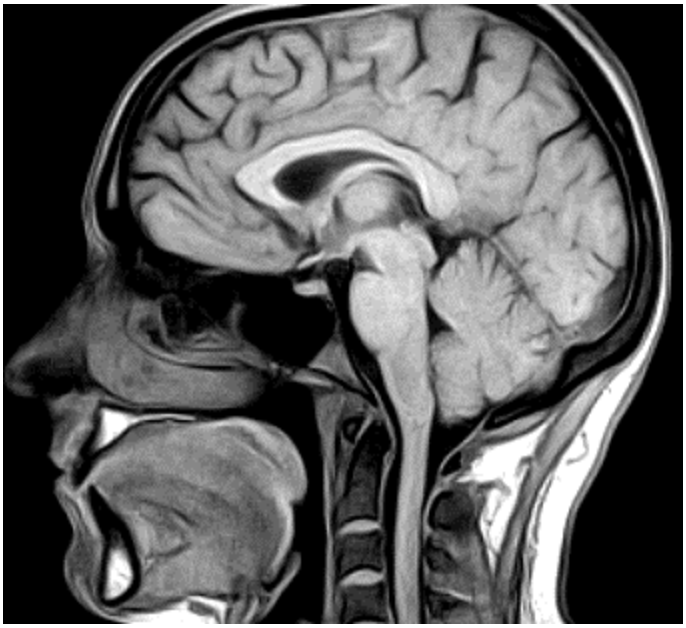

Fig. 2. Magnetic Resonance Image (MRI) showing a vertical slice through the center of a head. The soft tissue comprising the spinal cord is visible inside the bony spine.

(3a) 

(3b) 

Fig. 3a. X-ray Computerized Tomogram (x-ray CT) of a horizontal slice through a spine. Tomogram means "slice." It is produced by a 2D FFT of digitally filtered x-ray data.
Fig. 3b. 3D view of a spine constructed from multiple 2D x-ray CT slices taken at different elevations.

IEEE Radar Engineer of the Year Award