RADAR IMAGING OF "OVERSPREAD" BODIES USING COHERENT FREQUENCY HOPPING; R. Jurgens, L. Robinett, M. Slade, D. Strobert; Jet Propulsion Laboratory; B. Flores; University of Texas at El Paso

The quest for higher quality radar images of planets, moons, and asteroids and comets using ground-based radar has been satisfied primarily by moving to shorter wave lengths where greater antenna gain is possible for a given collecting area. Higher transmitter power and lower receiver system temperatures have also helped, but larger and more precise antenna systems provide the greatest possible improvement. Shorter wavelengths, however, have the a draw back in that the bodies to be imaged become increasingly "overspread", i.e, the product of the Doppler frequency width and the range depth is a number greater than unity. Conventional delay-Doppler processing leads to serious aliases that render the image more or less useless depending upon how large this product is. The planet Mars presents the worst case where the overspread factor is about 600 at 3.5cm wavelength.

Recently Sulzer [1] and Hagfors and Kofman [2] have demonstrated that full disk imaging of overspread targets is possible using random modulation. In this technique, a matched processing filter is formed for each delay and Doppler pixel required in the image. Harmon et al. [3,4] have demonstrated that full disk imaging of Mars and Mercury is possible using random binary phase modulation. With this approach, a given pixel in the image results from a response to a specific region on the planet, and to all side-lobes of the resolving filter responding to other places on the planet. Thus the image is contaminated by "self-noise" as well as the usual the thermal background noise. The randomization of the coding results in a statistical side-lobe pattern that tends to average to a uniform background thus permitting the desired pixel to be seen.

We have studied the use of random frequency hop coding as a technique that provides some further advantages in that out-of-band interference is less than for binary phase encoding, and the level of the side-lobes can be controlled as discussed below. The implementation of this technique is easily accomplished with programmable digital oscillators that are being used for tuning the radar receiver system. Currently these oscillators can be coherently up-dated 1000 times a second, and modifications are planned to reach 10,000. The resolution and side-lobe level depend upon the modulation bandwidth, B, the number of frequency hop states, N, the baud period, T, and the number of coherently processed bauds, M. The number of hop states is a new additional parameter that can be adjusted to optimize the image quality. The product MT controls the frequency resolution, and B and T control the range resolution depending upon the selection of the BT product. The average side-lobe level depends upon all of the parameters in a fairly complicated manner. We are exploring this parameter space to optimize the imaging of Mercury, Mars, and the Galilean satellites.

We have calculated the variance of the side-lobes along the zero frequency axis considering N equally spaced hop frequencies from -B/2 to B/2. Each state is selected randomly from a uniform distribution. There are values of B for which the set of frequencies is orthogonal in the period T. These frequencies drive the variance to zero, however, this holds only along the zero frequency axis. Figure 1 shows a plot of the side-lobe level relative to the main peak plotted against B for three values of N, and with M set to 16 segments. The baud period is set to 1ms, and the coherence period MT is then 16ms corresponding to 62.5 Hz resolution. B_j is the modulation bandwidth, and the σ^2 correspond to values of N equal to 2, 4, and 8 hop states. We have not yet explored controlling the side-lobe structure off the zero frequency axis by use of non-uniformly weighted Fourier transforms, however, this is easily accomplished in the signal processing. The zero delay axis shows the usual $(\sin(x)/x)^2$ behavior.

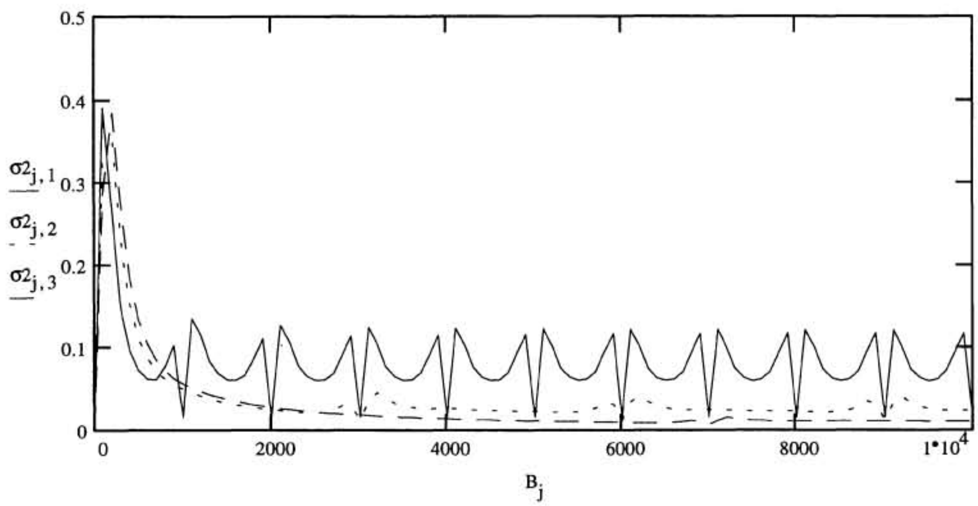

Figure 1

Relative side-lobe or variance for an unmatched frequency hop code using random uniformly distributed frequency hopping 2, 4, and 8 hop states. Other fixed parameters are: T = 1ms, and M = 16 coherently processed segments.

References:(1) Sulzer, M., Radio Science, 21, 1033-1040, 1986. (2) Hagfors, T, and W. Kofman, Radio Science, 26, 403-416, 1991. (3) Harmon, J.K., M.P. Sulzer, and P.J. Perillat, Icarus, 95, 153-156, 1992. (4) Harmon, J.K. and M.A. Slade, Science, 258, 640-643, 1992.