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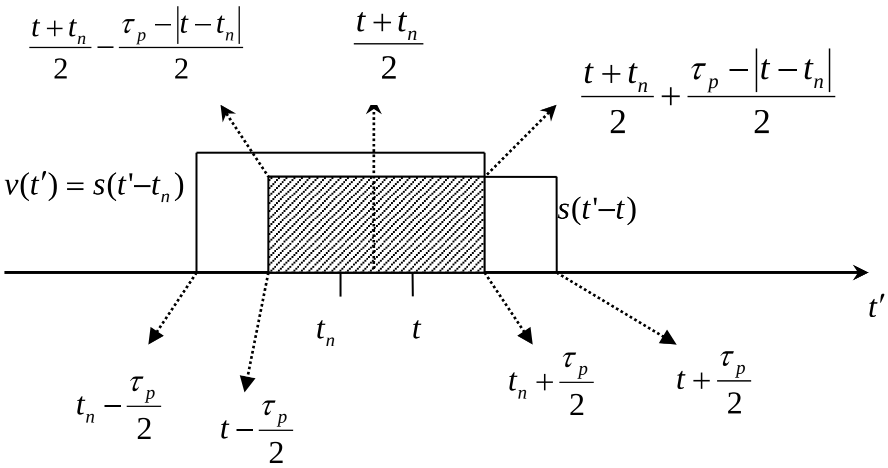
A SAR antenna transmits the following chirp signal,

$$s(t) = \exp[j2\pi(f_c t + Kt^2/2)], \qquad |t| < \tau_p/2.$$

1. Define phase $\phi(t)$, frequency $f(t) = \dot{\phi}(t)/2\pi$, and chirp bandwidth B_R of the above signal. (10 points)

The returned signal from a point target is a delayed chirp signal, $v(t) = s(t - t_n)$, where $t_n = 2R/c$ is the 2-way travel time of the pulse from the sensor to the target. The range compression is performed by the following matched filtering:

$$g(t) = \int_{-\infty}^{\infty} s^*(t' - t)v(t')dt'.$$



2. Prove that the above matched filtering results in

$$g(t) \approx \exp(j2\pi f_c t)\exp(-j4\pi R/\lambda)\frac{\sin\lfloor \pi K\tau_p(t-t_n)\rfloor}{\pi K(t-t_n)},$$

and find the range time resolution δt. (30 points)

As the satellite moves forward, many pulses are to be transmitted and backscattered from the point target. Each returned pulse is then range-compressed and sampled at $t = t_n$. The carrier structure of the signal is stripped away by the linear operation of complex demodulation. The range-compressed signal of each pulse transmitted at slow time *s*, is then (see the figure below)

$$\hat{g}(s) = \exp[j\phi(s)] = \exp[-j4\pi R(s)/\lambda] \ .$$

The Taylor's series expansion of $R(s)$ centered at $s = s_c$ (the time at which the target is located at the beam center) is:

$$R(s) = R_c + \dot{R}(s_c)(s-s_c) + \ddot{R}(s_c)(s-s_c)^2/2 + \cdots\cdots.$$

3. Using the definition of Doppler frequency:

$$f_D(s) = \dot{\phi}(s)/2\pi \quad \text{and} \quad \dot{f}_D(s) = \ddot{\phi}(s)/2\pi, \quad \text{show that}$$

$$\hat{g}(s) \approx \exp(-j4\pi R_c/\lambda)\exp\{j2\pi[f_{Dc}(s-s_c) + f_R(s-s_c)^2/2]\}, \quad |s-s_c| < S/2$$.(10 points)

Here S is the *coherent integration time*, which means the duration the target is within the view of radar pulse. $f_{Dc} = f_D(s_c)$ is *Doppler centroid*, and $f_R = \dot{f}_D(s_c)$ is *Doppler rate*. The above signal can be interpreted as the returned pulse of the linear chirp pulse:

$$h(s) = \exp[j2\pi(f_{Dc}s + f_R s^2/2)], \quad |s| < S/2 \ .$$

Therefore, we can compress the signal with respect to *s* using matched filtering as:

$$\varsigma(s) = \int_{-\infty}^{\infty} h^*(s'-s)\hat{g}(s')ds' .$$

4. Prove that the above integration results in

$$\varsigma(s) \approx \exp[j2\pi f_{D_c}(s-s_c)]\exp(-j4\pi R_c/\lambda)\frac{\sin[\pi f_R S(s-s_c)]}{\pi f_R(s-s_c)},$$

and find the *azimuth time resolution* (δs). (30 points)

5. Describe an ideal, earth-observing remote sensing system. (20 points)

Thank you.