1 Generalities

With the assumption that the coherently integrated time series $S^{ci}[m]$ for atmospheric returns can be regarded as a stationary Gaussian random process, it suffices to estimate the power spectrum for a description of this process without loss of information. The latter is usually referred to as the Doppler spectrum. More information on spectral estimation can be found in Percival and Walden (1993).

2 Periodogram

In RWP processing, a modified periodogram is used as a classical nonparametric estimator of the power spectrum. This method needs no further a-priori information and produces reasonable results for a large class of relevant processes, including ground clutter and some types of Radio Frequency Interference (RFI). The (leakage) bias of the periodogram estimate is reduced through data tapering, e.g. the time series is multiplied with a window sequence $w[n]$. A Hanning window is often employed for it is conveniently implemented in the frequency domain, but in general a variety of windows is at disposal, see Harris (1978).

For a reduction of the variance of the estimate, there are basically three options:

- The whole time series is transformed through a DFT and the estimate is smoothed across frequencies (lag window spectral estimator), see e.g. Muschinski et.al. (2005)
- The time series is broken up into N_s segments of equal length, the direct spectral estimate is computed for each segment and the N_s estimates are averaged together. This is called Welch's overlapped segment averaging (WOSA) estimator Welch (1967). It is popular due to its easy implementation and known as spectral or incoherent averaging in the RWP community, see e.g. Strauch et.al. (1984)
- A series of estimates is calculated using a set of orthogonal data tapers, which are then averaged together. This multitaper estimator was proposed by \citet{Thomson:82} and recently used by Anandan et.al. (2004).

3 WOSA

The WOSA approach without overlapping of the blocks is implemented as follows: For N_s segments of length N_p, single spectrum estimates are obtained for $l = 0, \ldots, N_s - 1$, with N_p discrete frequencies, $k = 0, \ldots, N_p - 1$ as

$$P[l,k] = \frac{1}{N_p} \left| \sum_{m=0}^{N_p-1} w[m] S^{ci}[l \cdot N_p + m] e^{-i \frac{2\pi k m}{N_p}} \right|^2,$$

and simple averaging then yields the estimate

$$P[k] = \frac{1}{N_s} \sum_{l=0}^{N_s-1} P[l,k]$$

The Doppler spectrum is usually given as a function of velocity instead of frequency. The conversion between frequency shift f and radial velocity v_r uses the well-known relation $f = 2v_r/\lambda$, where λ denotes the radar wavelength.

The dwell time for the estimation of a Doppler spectrum is $T_d = N_s \cdot N_p \cdot N_{ci} \Delta T$.

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