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THE HIGH FREQUENCY LIMIT TO FOURIER ANALYSIS. A REMINDER OF THE NYQUIST FREQUENCY

This note is a reminder to astronomers using Fourier Analysis (to determine the frequencies present in variable star data) that one cannot extract from a continuously sampled data set any frequency greater than $1/2\Delta$ where Δ is the sampling interval. The reason for this is that aliases arise due to beating between the sampling frequency, $1/\Delta$, and any real frequency, f, present in the data. Thus, in the power spectrum of data varying with the frequency f, peaks will occur at f, $1/\Delta + f$, $1/\Delta - f$, $2/\Delta + f$, $2\Delta - f$, etc. The high frequency limit to any meaningful frequency search exists where the real frequency f and the lowest frequency alias $1/\Delta - f$ overlap, that is, when $f = 1/\Delta - f$ which yields the Nyquist frequency of $f = 1/2\Delta$.

I have illustrated this problem in Figures 1 and 2 which are amplitude spectra of artificial data. These data have sampling interval of $\Delta = 0.05$ hour (or a sampling frequency of 20 hour^{-1}) and a time span of 5 hours. In Figure 1 there is a real frequency of 1 hour^{-1} present in the data with an amplitude of 10 m mag. In Figure 2 there is a real frequency at 7 hour^{-1}. Note that the amplitude spectra shown in Figures 1 and 2 would look identical if the real frequency in the original data were at the frequency of any of the aliases. Also note that the aliases under discussion here occur for continuously sampled data sets and are not the same as the aliases which arise in the Fourier analysis of astronomical data with time gaps. Aliases caused by time gaps in the data are simply cycle count ambiguities across the gaps.

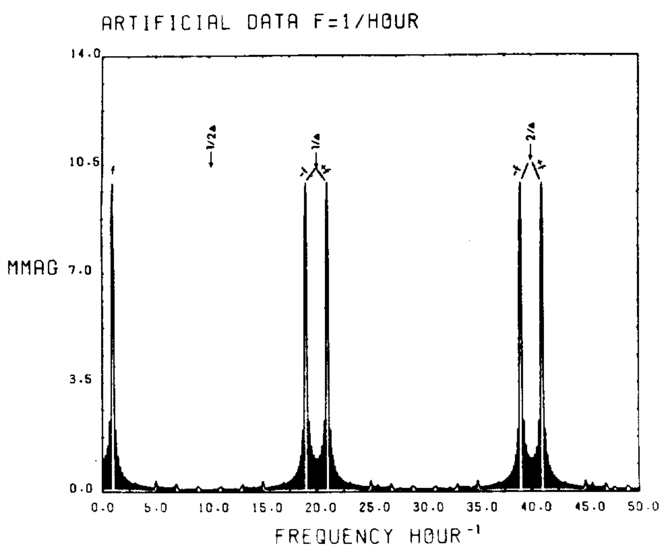

Figure 1

An amplitude spectrum of 5 hours of artificial data sampled at a frequency of $1/\Delta$ = 20 $hour^{-1}$ which gives a Nyquist frequency of $1/2\Delta$ = 10 $hour^{-1}$. The data were generated with a frequency of 1 $hour^{-1}$ with an amplitude of 10 m mag. The noise is due to three decimal truncation of the generated magnitudes.

The impetus for the note comes from two recent issues of *IBVS* in which astronomers have performed Fourier analyses beyond the Nyquist frequency and obtained results which are very probably wrong. Burki *et al.* (1982) Fourier analysed data sampled at "1 measurement per night" for HR3562 and derived "three significant periods" all less than 2 days which is the Nyquist

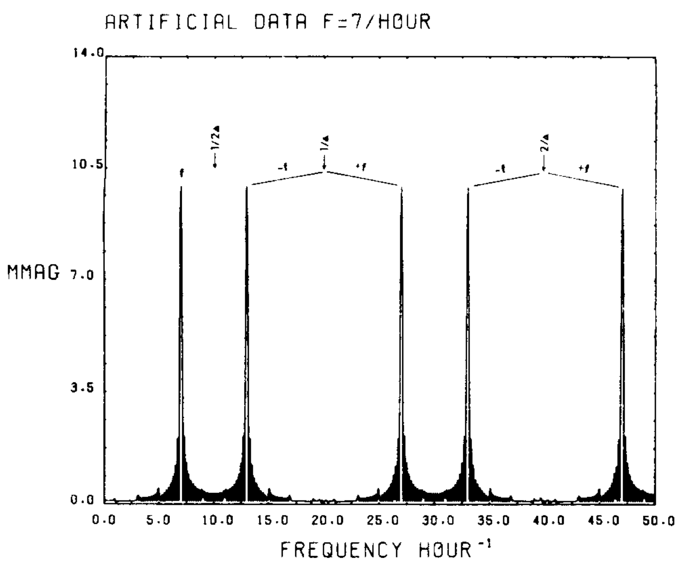

Figure 2

An amplitude spectrum of the same data set as in figure 1 except with a generating frequency of 7 hour^{-1}. One can easily see from these two figures that the highest frequency which can be unambiguously extracted from such a diagram is the Nyquist frequency where the real frequency and the lowest frequency alias overlap.

limit to their analysis. Musielok and Kozar (1982) suggest periods of 5.4 and 5.9 minutes for data they have on 21 Com. Yet, if their 450 measurements obtained during 30 hours of observation are uniformly spaced, then their data spacing is about 4 minutes/measurement which limits their search to periods greater than 8 minutes.

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