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6. Input Noise Approximations in Tracker Modeling*

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INTRODUCTION AND RESULTS

This study was conducted to investigate the validity of approximating random Gaussian-distributed inputs used in human response modeling by sums of discrete sinewaves. An ideal rectangular power density spectrum was simulated using both filtered Gaussian white noise (Butterworth Filter) and sums-of-discrete sinewaves spaced as in reference 1. These two input spectrums were used with three different input cutoff frequencies ($\omega_c = 1.5, 2.5,$ and 4.0 rad/sec) in the same compensatory tracking task ($Y_o = K/j\omega$) and the resultant normalized tracking error (NTE) and qualitative operator observations to investigate the apparent discrepancies in human operator characteristics. A block diagram of the experimental setup is shown in figure 1. A comparison of normalized tracking error and input cutoff frequency is given in figure 2 for the discrete and continuous spectra. An analysis of variance was performed at each input cutoff frequency ($\omega_c = 1.5, 2.5,$ and 4.0 rad/sec) to determine if the differences were statistically significant. The results of the analysis of variance based on a confidence level of 0.95 show that the discrete and continuous spectra are statistically similar at the two lower breakpoints but there is a statistically significant difference at $\omega_c = 4.0$ rad/sec.

There are at least two explanations that can be offered for the differences in response at 4.0 rad/sec. The first is that the Butterworth filter is not a perfect approximation of the ideal rectangular spectra and thus there is power in the crossover region. The second explanation is based

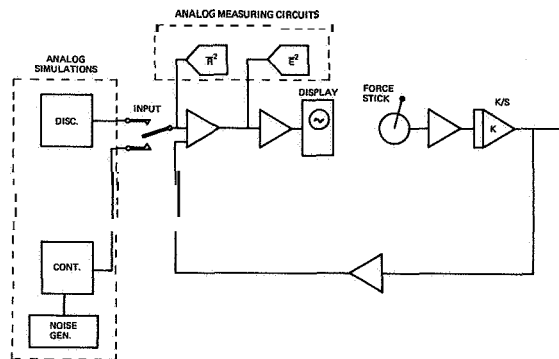


FIGURE 1.—Analog computer simulation: compensatory tracking task.

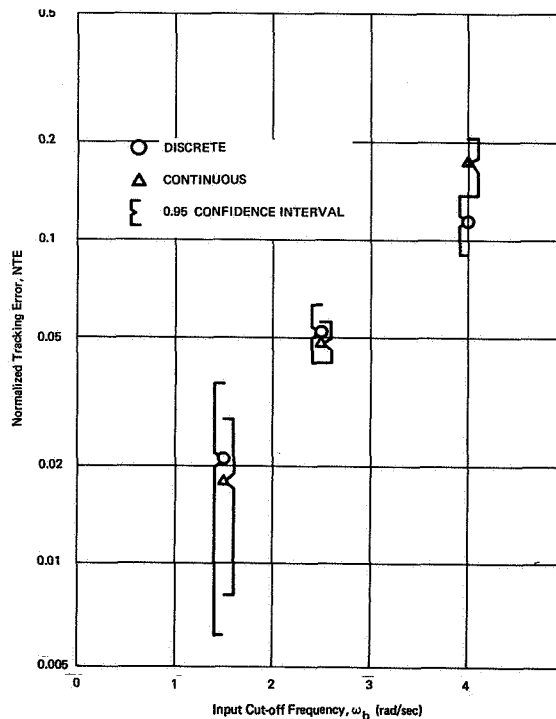


FIGURE 2.—Comparison of NTE: discrete vs continuous rectangular input spectra.

* The work described herein is the M.S. thesis work of Paul F. Torrey (ref. 4).

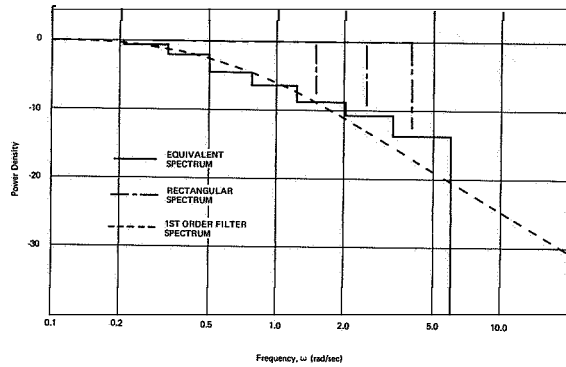


FIGURE 3.—Equivalent power density spectrum for discrete rectangular input.

on the logarithmic frequency distribution of the discrete sinewaves. As shown in figure 3 the equivalent spectrum of the discrete spectrum and the first order filter spectrum are approximately the same. Thus, there may be a better filter than the eighth order Butterworth filter for the continuous input.

To support these explanations and to validate these results with other research efforts, we compared the normalized tracking error and normalized crossover frequency for the three input cutoff frequencies ($\omega_c = 1.5, 2.5, \text{ and } 4.0 \text{ rad/sec}$). Figure 4 is a plot of NTE vs $\tau_e \omega_c$ where the solid lines are calculated for a continuous rectangular input spectrum. Data from references 1 and 2 as well as parameter track data obtained in this study are also displayed in figure 4. Figure 5 is a plot of NTE vs $\tau_e \omega_c$ where the solid lines are calculated for a continuous first order filter spectrum. Again data from references 1 and 2 as well as parameter track data obtained in the present study is presented in figure 5. Note the good correspondence between the reference 2 and 3 data and the data taken in this study with the dashed line on figure 5. The dashed line is the loci of minimum points for NTE vs $\tau_e \omega_c$ and is the loci of operating points predicted in references 1 and 3.

CONCLUSIONS

There is a statistical difference in the tracking behavior at the 4.0 rad/sec cutoff frequency between the filtered Gaussian white noise inputs and sums-of-discrete sinewaves inputs. Based on

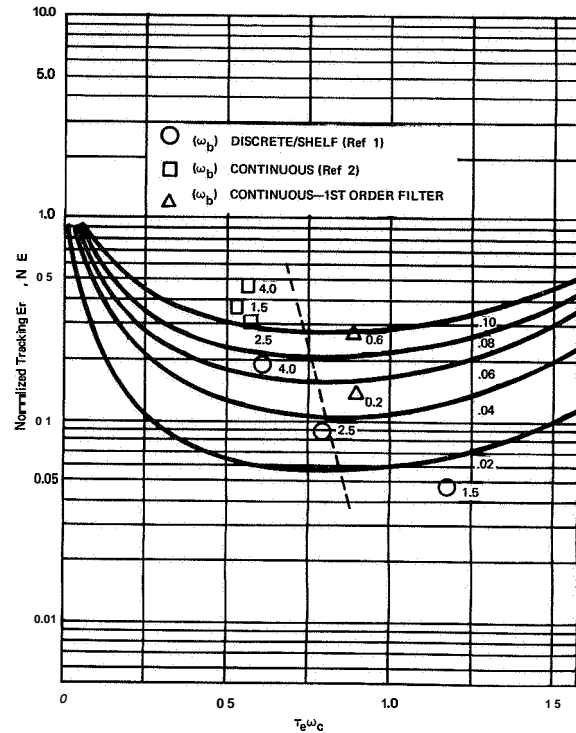


FIGURE 4.—NTE vs $\tau_e \omega_c$: rectangular input spectrum (from ref. 1).

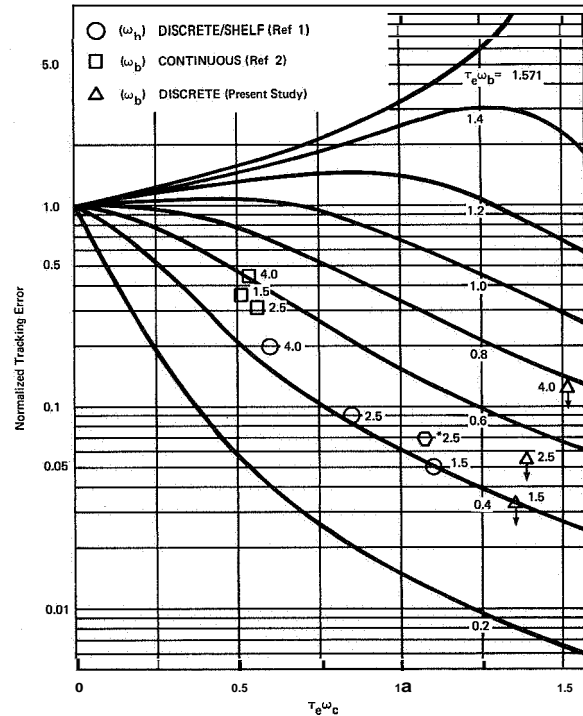


FIGURE 5.—NTE vs $\tau_e \omega_c$: first order filter input spectrum.

tracking behavior data from other investigations and data gathered in this study it was found that the discrete and continuous input tracking data compared favorably when the power in the crossover region was taken into account. Any power in the crossover region has a pronounced effect on pilot parameters. The best correspondence between discrete and continuous input tracker behavior was found using a continuous input with a first order filter.

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