FREQUENCY SPECTRUM GENERATED BY AGS BOOSTER POWER SWING, HEAVY ION CYCLE

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Booster Technical Note

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INTRODUCTION

LILCO is studying the effects of the AGS Booster power swing on its power grid. The study is being conducted by GE systems Development and Engineering, Schenectady, New York. In notes, dates November 10, 1987, prepared for a GE-LILCO Progress Review Meeting, the author notes LILCO system resonances that are excited by the heavy ion cycle.

The data used by GE for their study, is the power flow required for continuous operation of the Booster, namely a continuous 13MW power swing and a period of one second. The data used by GE came from BNL reports, used to analyze the power line flicker generated by this pulsating load. It is a worse case study and does not represent the Booster cycle.

The Booster must be synchronized with the AGS, which is operated with a period of 3 seconds, when accelerating heavy ions. Thus the Booster duty cycle is 1/3 with a peak power swing of 13MW.

The time of one second used to cycle the Booster magnets is arbitrary and can be increased to a maximum of three seconds. The peak power swing and the power spectrum are modified by the Booster duty cycle and period. The spectrum is critical for the GE study of the LILCO grid.

SPECTRUM ANALYSIS

The power spectrum has been determined for the Booster magnet power supplies, subject to the following operational specifications. See Figure 1 for the power cycle.

Peak Energy Stored in Magnet	= 2.25 Mega Joules
Energy Recovered from Magnet	= 1 Mega Joule
Energy Loss Per Cycle	= 1.25 Mega Joules
Period	= T seconds
Booster Duty Cycle	= k

The power spectrum is expressed as:

$$p(t) = \frac{1.25}{T} + \sum_{n=1}^{\infty} A_n \text{Cos} \left(\frac{2\pi n}{T} \right) t + B_n \sin \left(\frac{2\pi n}{T} \right) t$$

where

$$A_n = \frac{1}{T} \int_o^T p\ (t) \cos \frac{2\pi n}{T} t\ dt$$

$$B_n = \frac{1}{T} \int_o^T p\ (t) \sin \frac{2\pi n}{T} t\ dt$$

The coefficients A_n and B_n have been evaluated as

$$A_n = \frac{5T}{(KTn\pi)^2} \cos Kn\pi + \frac{4T}{(KTn\pi)^2} \cos 2\ Kn\pi + \frac{13}{KTn\pi} \sin Kn\pi - \frac{9T}{(KTn\pi)^2}$$

$$B_n = - \frac{13}{(KTn\pi)} \cos Kn\pi + \frac{5T}{(KTn\pi)^2} \sin Kn\pi + \frac{4T}{(KTn\pi)^2} \sin 2Kn\pi$$

BOOSTER SPECTRUM

Th Booster power spectrum has been evaluated for a period T of 3 second and a duty cycle of 1/3, 2/3, and 1. The results are given in the graph of Figure 2. The spectral lines given represents power and is calculated as $\sqrt{A_n^2+B_n^2}$.

In addition the power spectrum for a period T of one second and continuous operation (unity duty cycle) has been calculated and is given in Figure 3. This spectrum represents the power flow used by GE in their initial study of the resonance of the LILCO grid.

The dominant resonance of the LILCO grid is at a frequency of 1hz. The Booster power for this frequency is reduced from an initial value of 4.26MW to a value that lies between 1.42MW to .46MW, depending on the duty cycle k. This is given by the graph of Figure 4 in which the power spectral line at 1hz is plotted as a function of k, the period is fixed at 3 seconds. If the Booster is operated with a duty cycle of 2/3, the spectral line at 1hz is 0.69 and the dominant response is reduced by a factor of 6.2.

A PERIODIC OPERATION OF BOOSTER

The power spectrum can be further reduced by operating the AGS with a random or pseudorandom period. The AGS cycle is initiated by one of the 24 phase of the AC supply ramping the magnet. The spectrum is continuous rather than discrete, as shown in Figure 5. The LILCO response is dependent on the system Q at the resonant frequency and the spectral density of the power spectrum.

For systems characterized by a high Q, the resonant response is reduced to a level below that of fixed period systems. Typically the Q ranges between 20 and 60 and the response will be reduced by a factor of 0.6 to 0.2.

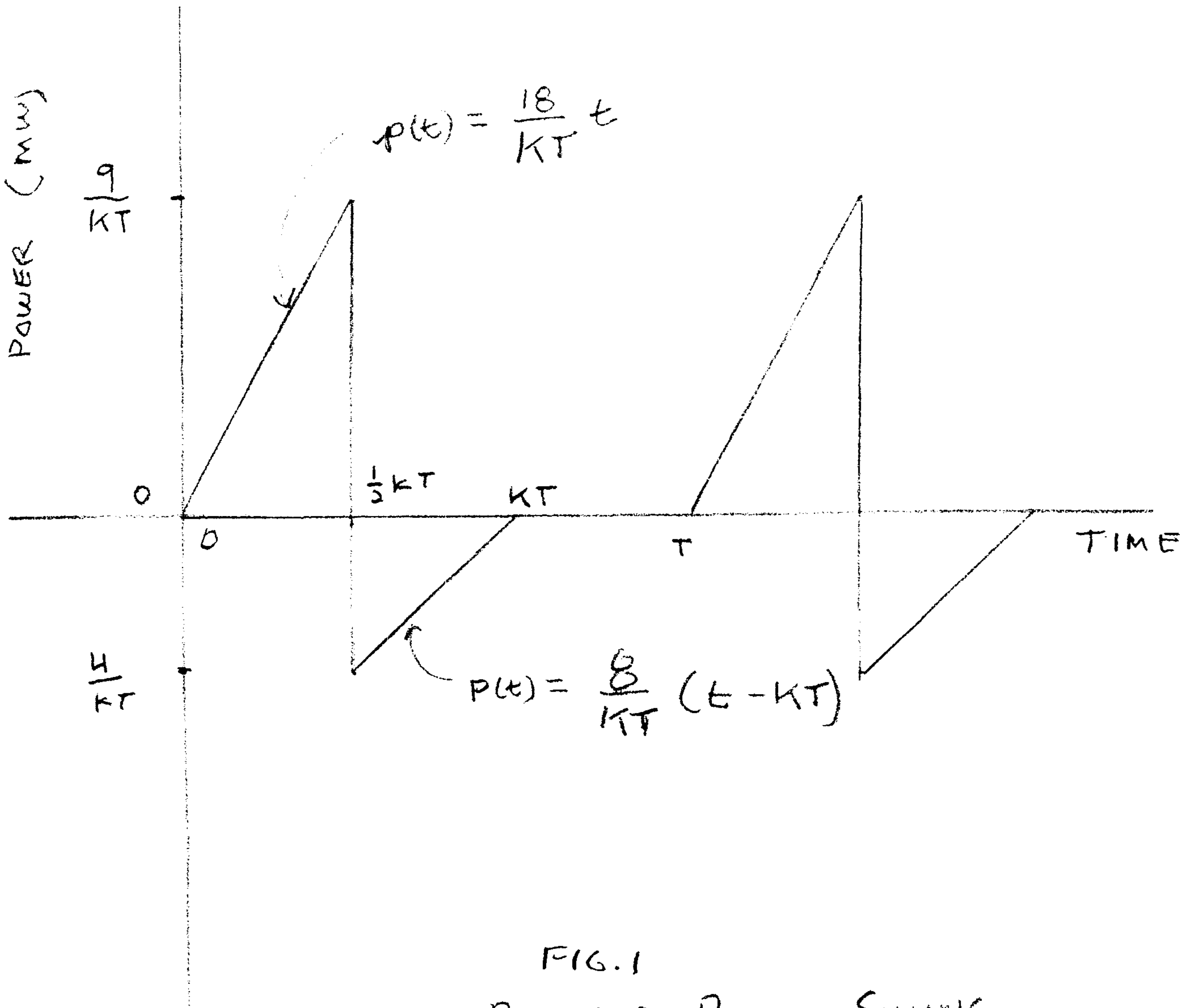

FIG. 1
BOOSTER POWER SWING

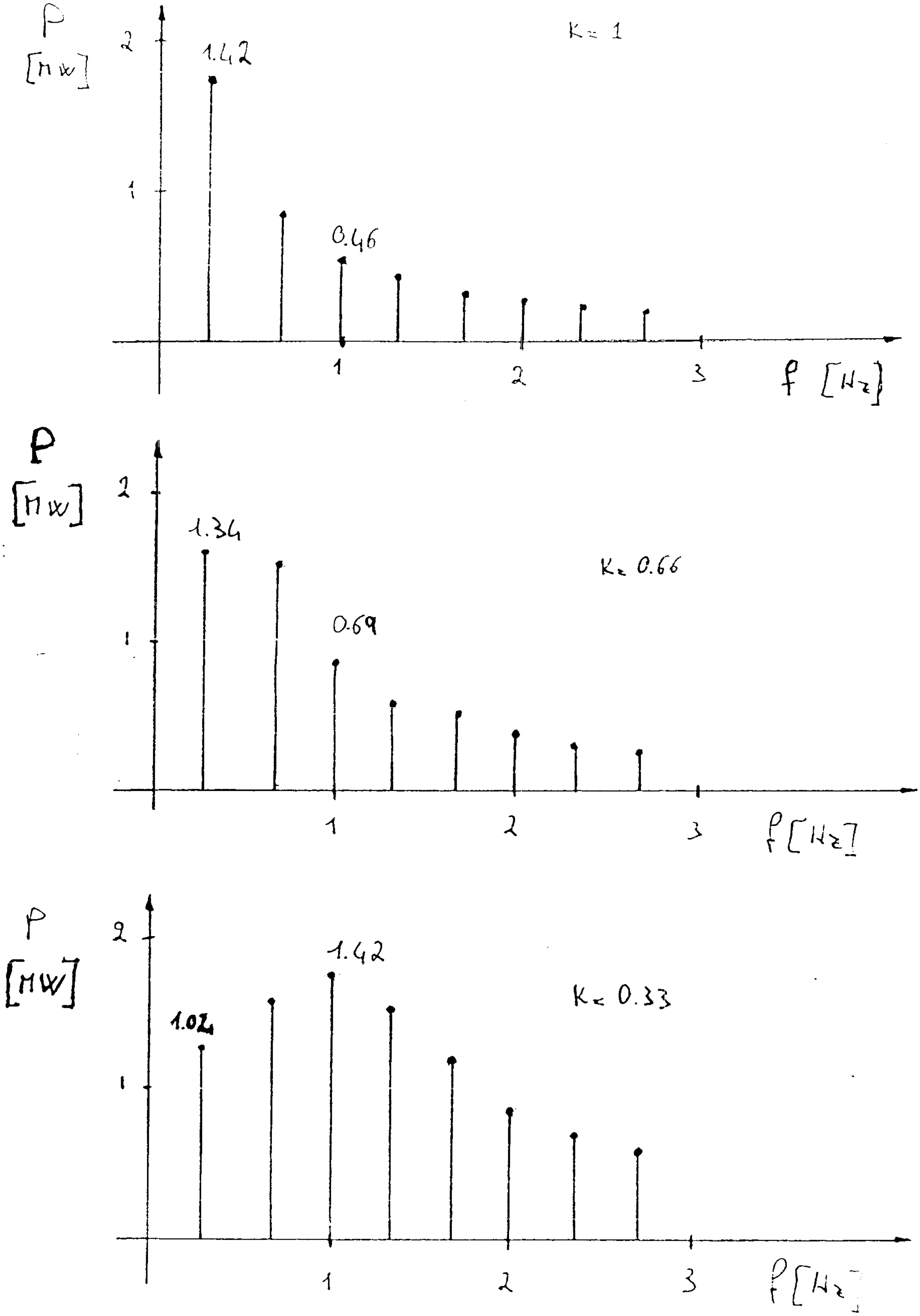

Fig 2 - Spectrum of Booster Power Swing for T= 3 sec.

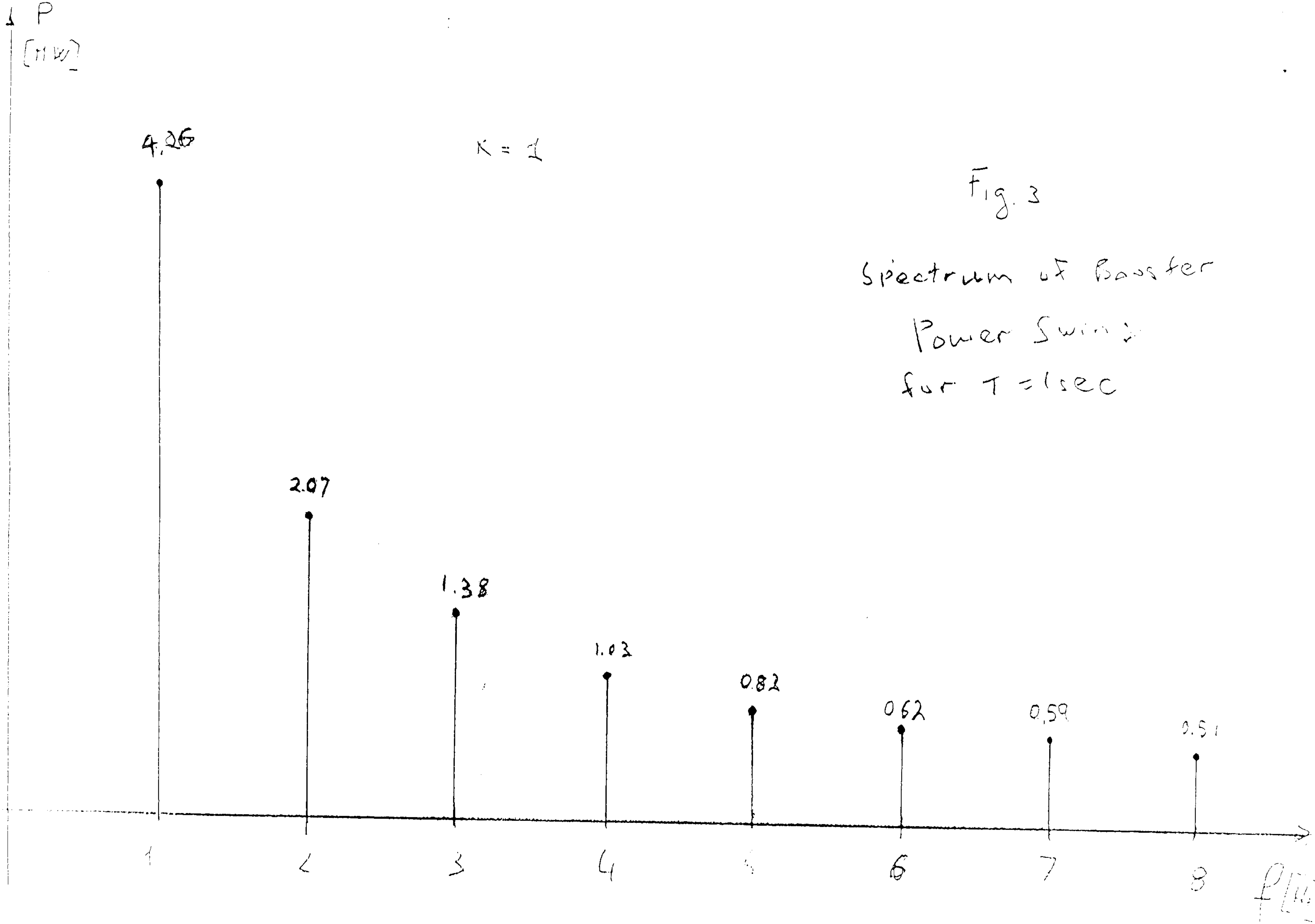

Fig. 3
Spectrum of Booster Power Swing for T = 1 sec

k	$f_n(k)$
$1\ 10^{3}$	0.835022
0.05	0.885978
0.099	1.003949
0.148	1.155502
0.197	1.286822
0.246	1.379483
0.295	1.422236
0.344	1.412396
0.393	1.356052
0.442	1.261095
0.491	1.140314
0.54	1.007046
0.589	0.874035
0.638	0.752071
0.687	0.649073
0.736	0.56956
0.785	0.514503
0.834	0.481559
0.883	0.465824
0.932	0.461046
0.981	0.460936

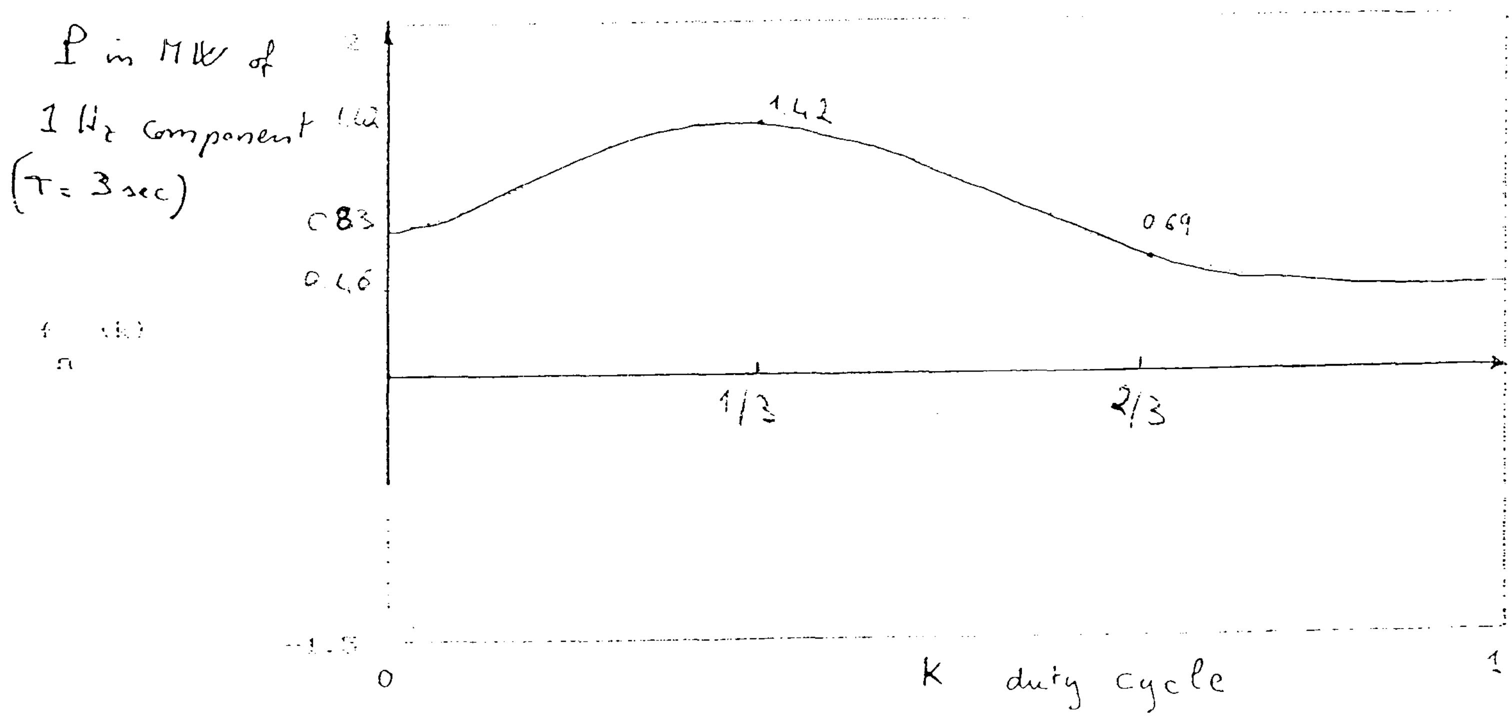

Fig. 4 - Amplitude of 1 Hz component of the Booster Power Spectrum as a function of K.

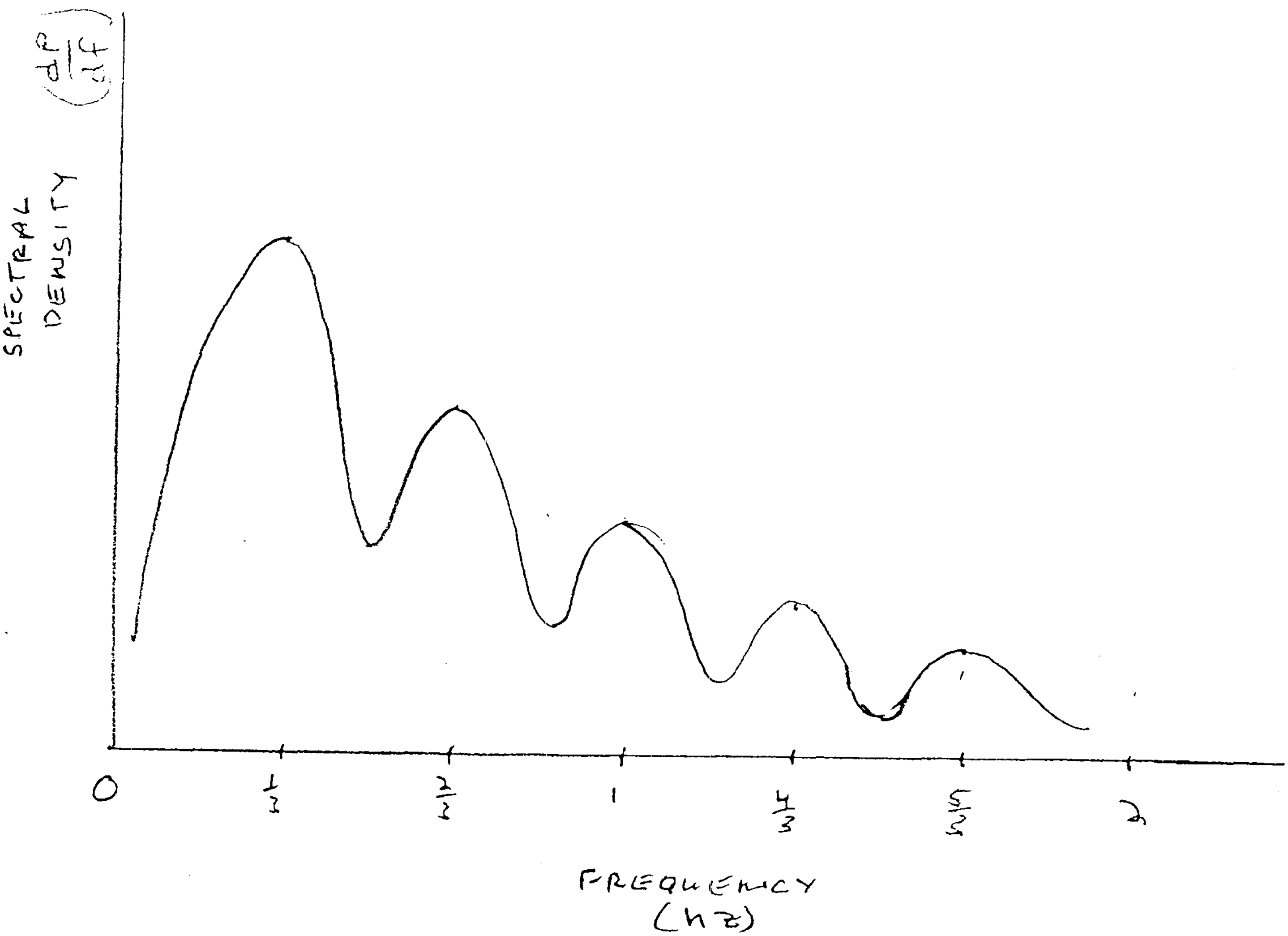

Figure 5

Booster Power Spectrum For Pseudo-random Operation of AGS