



BNL-105150-2014-TECH

Booster Technical Note No. 106;BNL-105150-2014-IR

Frequency spectrum generated by AGS Booster power swing, heavy ion cycle

M. Meth

January 1988

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

AD

Booster Technical Note

No.106

MARVIN METH

ALESSANDRO RATTI

JANUARY 27, 1988

ACCELERATOR DEVELOPMENT DEPARTMENT

Brookhaven National Laboratory

Upton, N.Y. 11973

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

Marvin Meth
Alessandro Ratti

January, 1988

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, dated 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:

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

where

$$A_n = \frac{1}{T} \int_0^T p(t) \cos \frac{2\pi n}{T} t dt$$

$$B_n = \frac{1}{T} \int_0^T p(t) \sin \frac{2\pi n}{T} t dt$$

The coefficients A_n and B_n have been evaluated as

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

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

BOOSTER SPECTRUM

The 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.

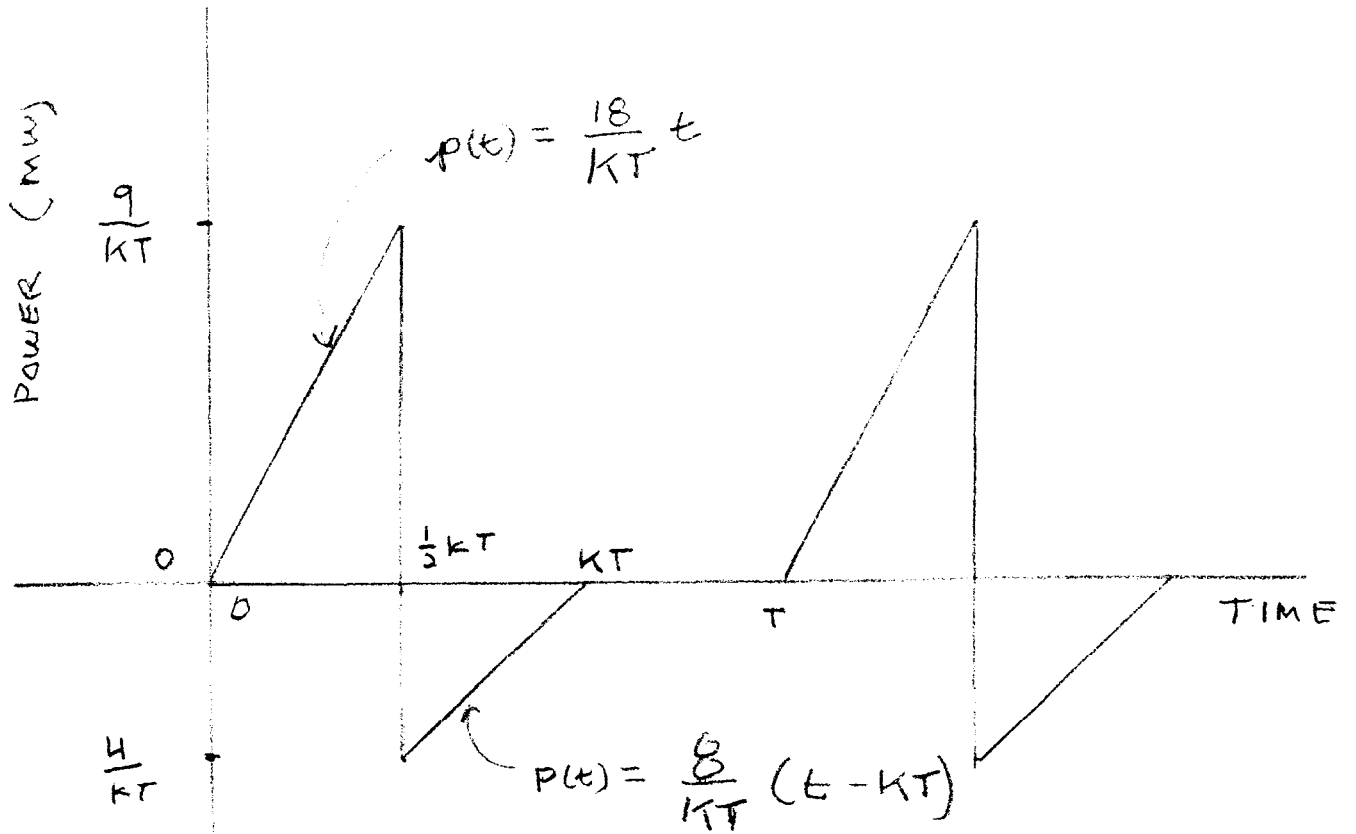


FIG. 1
BOOSTER POWER SWING

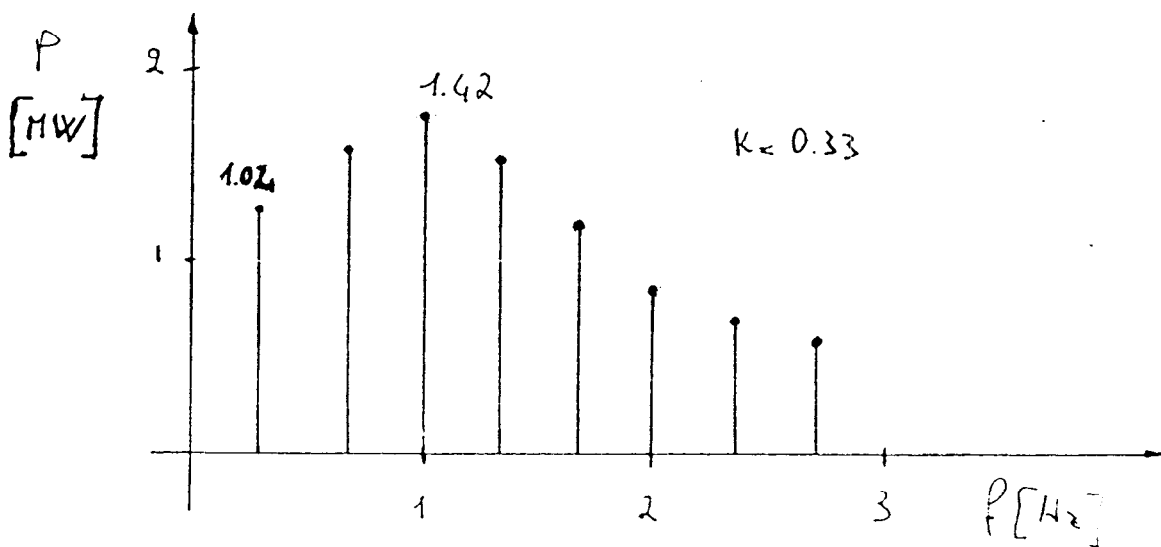
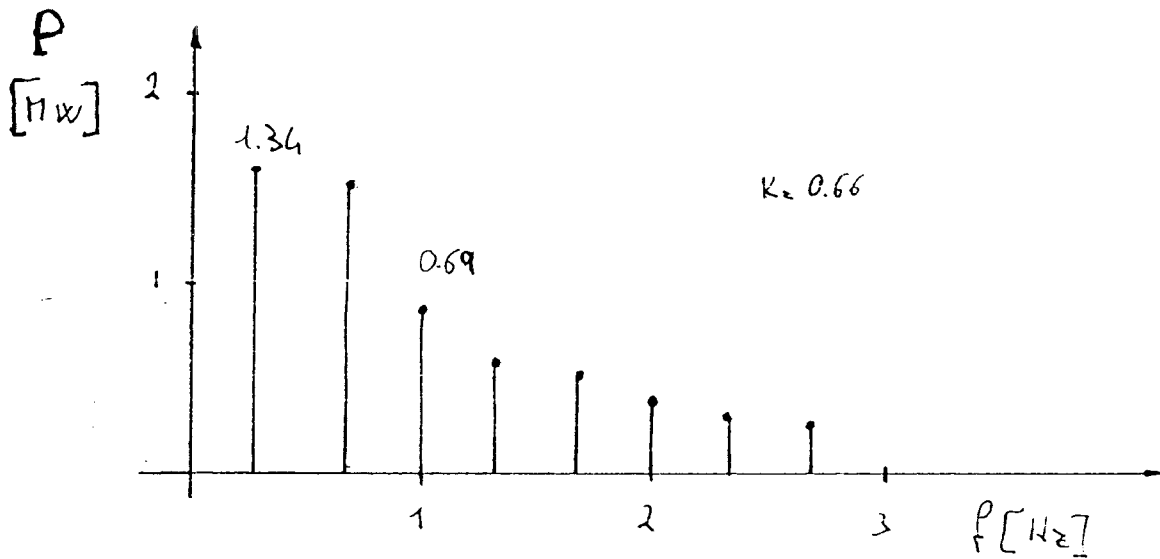
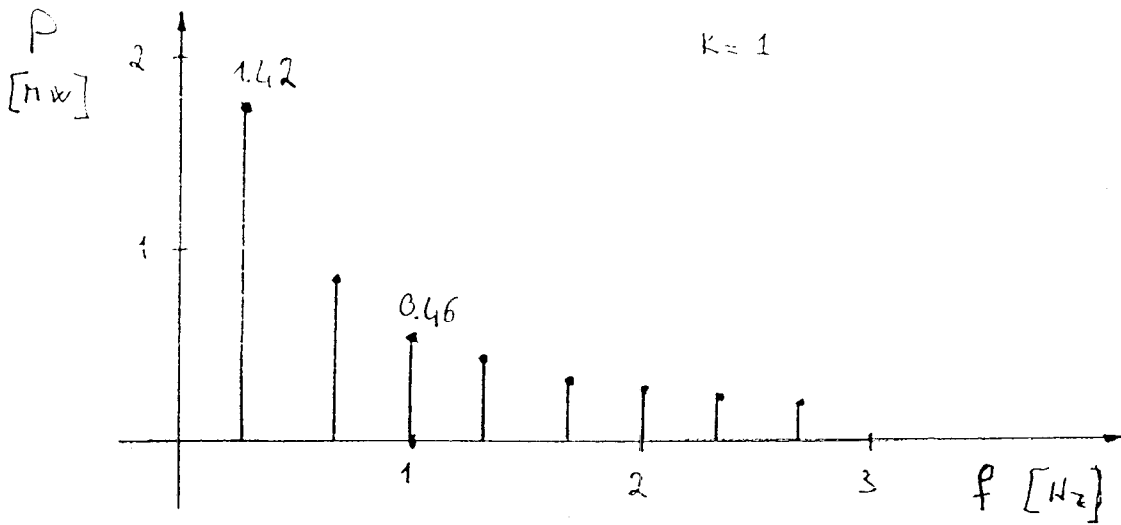


Fig 2 - Spectrum of Rooster Power Swing for $T = 3$ sec.

P [mW]

4.26

$K = 1$

Fig. 3

Spectrum of Booster
Power Switch
for $T = 1 \text{ sec}$

2.07

1.38

1.03

0.82

0.62

0.59

0.51

1

2

3

4

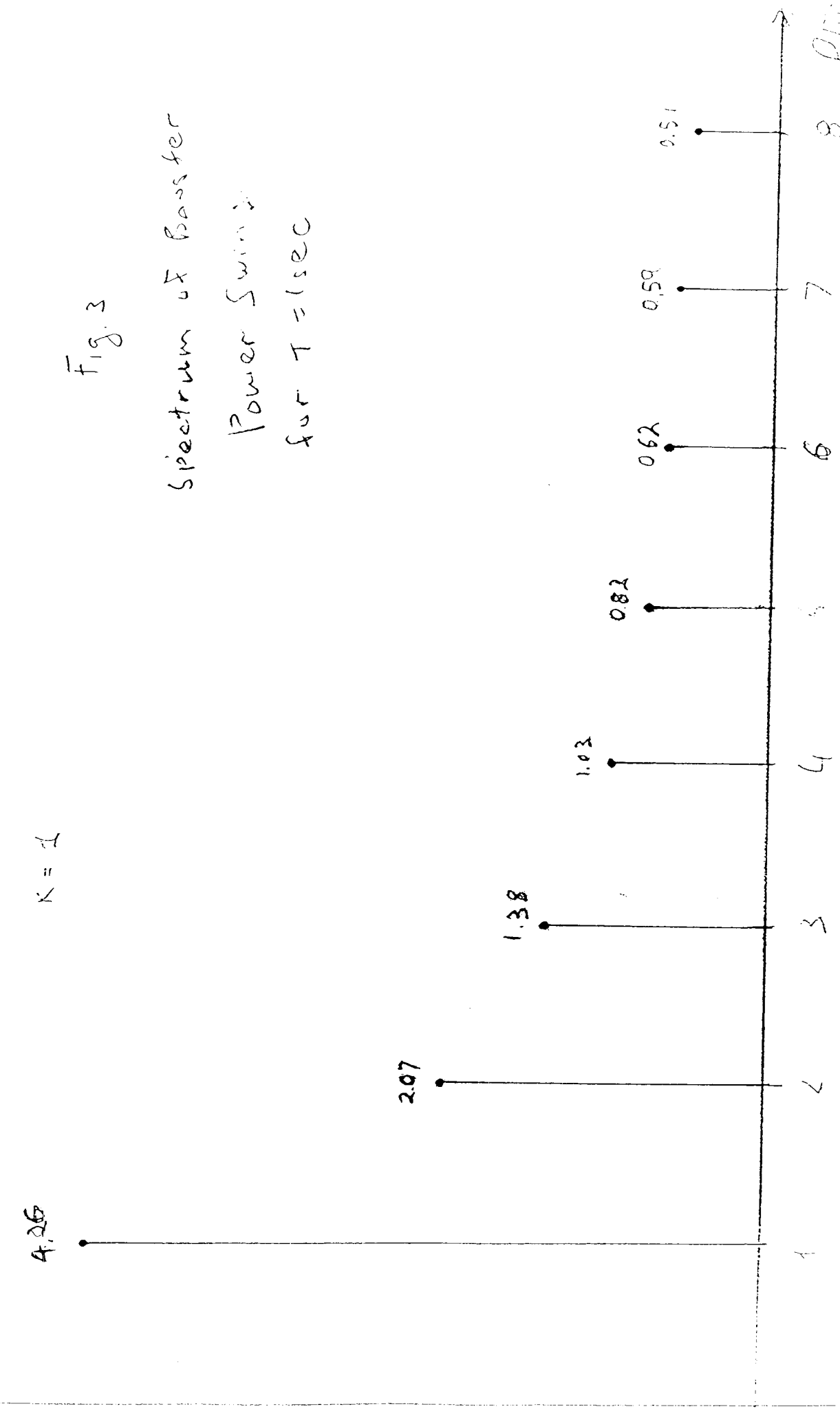
5

6

7

8

Plot



k	$f(k)$
0.10	0.835022
0.05	0.885978
0.099	1.003949
0.148	1.155502
0.197	1.336822
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

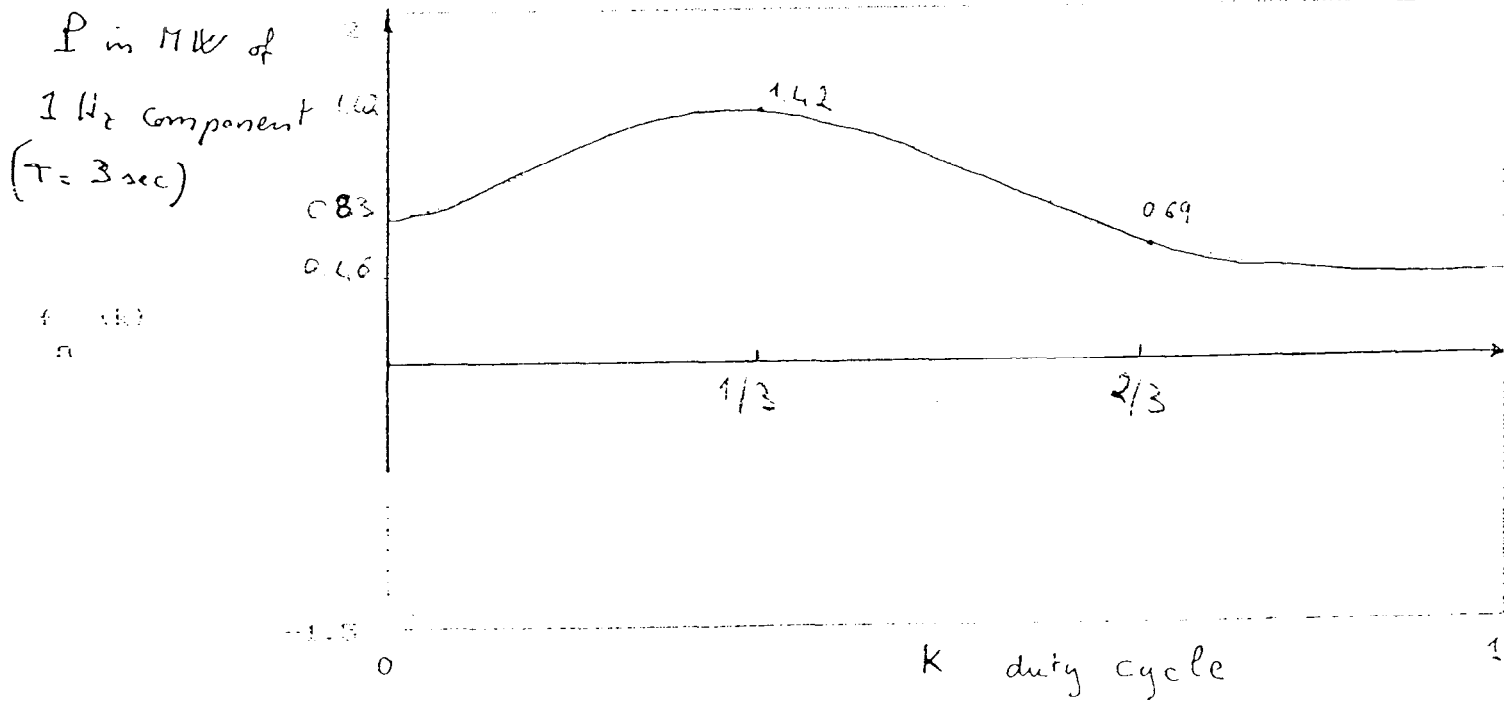


Fig. 4 - Amplitude of 1 Hz component of the Booster Power Spectrum as a function of k .

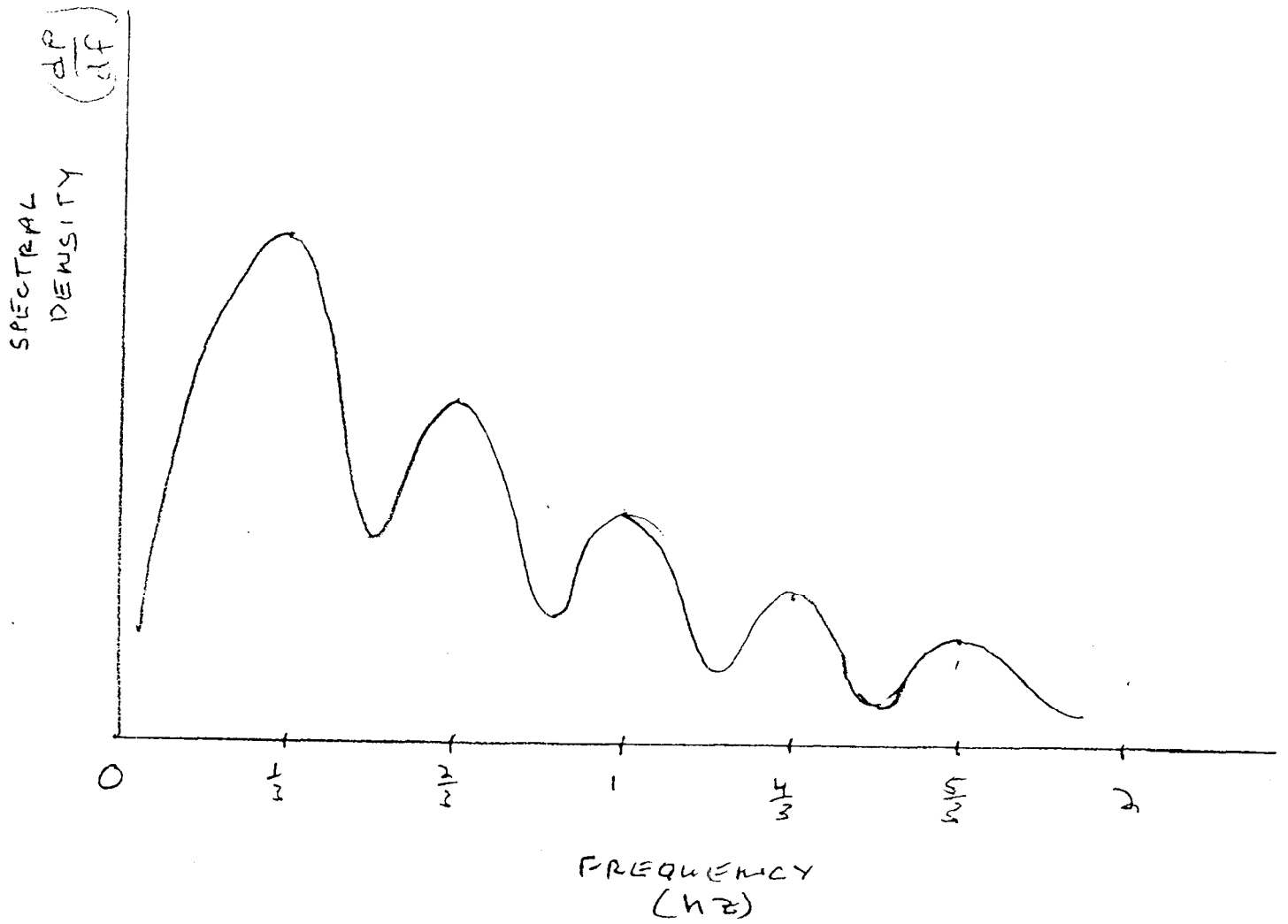


Figure 5

Booster Power Spectrum For Pseudo-random Operation of AGS