BNL-104136-2014-TECH

AGS.SN260;BNL-104136-2014-IR

Stopband Measurements in the AGS (II)

W. van Asselt

April 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

11/14/89

Number 260

AGS Studies Report

Date(s) Spring, 1988 Time(s) Various

Experimenter(s) W. van Asselt and C. Gardner

Reported by W. van Asselt and C. Gardner

Subject Stopband Measurements in the AGS (II)

I. Introduction

This is the second in a series of reports on studies of the $2Q_H = 17$, $2Q_V = 17$, $3Q_H = 26$, $Q_H + 2Q_V = 26$, $3Q_V = 26$, and $Q_V + 2Q_H = 26$ resonances in the AGS at low field. The aim of these studies is to determine whether or not the present schemes for correcting these resonances will be adequate when protons are injected into the AGS at the Booster momentum of 2.25 GeV/c. The techniques employed will be useful during the commissioning of resonance correction schemes for the booster.

In the first study[1] the $2Q_H = 17$ and $3Q_H = 26$ resonances were investigated. The conclusions of this study were as follows:

1. The measurements of the QN17 corrections required to cancel the fields present in the machine which excite the $2Q_H = 17$ resonance yield essentially the same result at 1 and 2 GeV/c momentum, and indicate that the QN17 correction scheme should be adequate at the Booster momentum of 2.25 GeV/c.

2. When the horizontal tune was moved to 8 + 2/3, no beam loss was observed and it was therefore not necessary to apply any SN26 corrections. However, the setting of the auxiliary power supply (DLFSC) used to null the remnant fields in the drive sextupoles was not noted and presumably this supply was adjusted so that no fields were present to excite the $3Q_H = 26$ resonance. This should be confirmed in a subsequent study.

3. Beam loss due to excitation of the $2Q_H = 17$ resonance was observed even when the measured tune was outside the stopband region calculated from Equation (2) of Reference 1. This is presently not understood and requires further investigation.

4. The 60 Hz structure seen on the L-20 current transformer signal as beam was lost due to excitation of the $2Q_H = 17$ resonance (see Photo #4 of Reference 1) was found to be due to a bad nu-quad power supply which was subsequently repaired. The 60 Hz ripple on this supply was much larger than it was supposed to be and was presumably moving the horizontal tune in and out of the $2Q_H = 17$ resonance stopband.

In this second report, we continue our investigation of the $2Q_H$ = 17 and $3Q_H = 26$ resonances and try to answer some of the questions raised in the previous study. The $3Q_V = 26$ resonance is also investigated.

II. Study Conditions

The conditions under which the present study was carried out were similar to those of the previous study.[1] A 500 ms long flattop at 2000 or 4000 Gauss clock counts (1 or 2 GeV/c momentum) started approximately 100 ms from T_o and the QN17, SN26, SN25, and 17S26 corrections were programmed on the flattop as described in Reference 1. In addition, the horizontal chromaticity was programmed to reduce the tune spread on the flattop. The beam intensity on the flattop was 5 to 7 x 10^{11} ppp.

III. Correction of the $3Q_H = 26$ Resonance

Here an expression for the total $3Q_H = 26$ excitation coefficient in the machine is developed and compared with measurements.

The SN26 correction scheme discussed in References 2 and 3 corrects the $3Q_H = 26$ and $Q_H + 2Q_V = 26$ resonances simultaneously. The real and imaginary parts of the excitation coefficient for the $3Q_H = 26$ resonance produced by this scheme are respectively

$$CX = -0.970\ A \frac{N_c}{2000}, \quad SX = -0.970\ A \frac{N_s}{2000} \qquad (1)$$

where N_c and N_s are the commands issued to COS26X and SIN26X,

$$A = 4C\left(\frac{eS}{cP}\right)\ B^{3/2}, \qquad (2)$$

S is the integrated strength per amp of each sextupole in the scheme, P is the momentum, and B is the beta maximum in the number 7 and 13 straight sections. (Equations (1-2) follow from Equations (57-60) of Reference 3 and Table V of Reference 2).

In addition to the high-current power supply, the auxiliary power supply labeled DLFSC is connected to the string of four drive sextupoles at C13, F13, I13, L13, and excites them with currents I, −I, I, and −I, respectively. Taking C7 to be the point of zero betatron phase (as in the SN26 correction scheme) and using Equation (26) of Reference 3, we find that the real and imaginary parts of the $3Q_H = 26$ excitation coefficient produced by the drive sextupoles are

$$CX = A\ I\ \mathrm{Cos}\ \omega = -0.588\ A\ \frac{N}{1000}\ ,$$
$$SX = A\ I\ \mathrm{Sin}\ \omega = -0.809\ A\ \frac{N}{1000} \qquad (3)$$

where A is given by (2), I = N/1000 is the current (in amps) delivered by the DLFSC power supply, and $\omega \simeq 26\ \pi/20$.

Now let CX_o and SX_o be the real and imaginary parts of the $3Q_H$ = 26 excitation coefficient present in the machine when the SN26 and DLFSC corrections are turned off. Defining N_{co} and N_{so} to be the amounts of SN26 correction equivalent to CX_o and SX_o we have (using Equation 1)

$$CX_o = -0.970\ A\ \frac{N_{co}}{2000}\ , \quad SX_o = -0.970\ A\ \frac{N_{so}}{2000}\ . \qquad (4)$$

Then, adding Equations (1), (3), and (4), we obtain the real and imaginary parts of the total excitation coefficient present in the machine:

$$CX = -\frac{A}{2000}\left[0.970(N_c + N_{co}) + 2(0.588)N\right]$$
$$SX = -\frac{A}{2000}\left[0.970(N_s + N_{so}) + 2(0.809)N\right] \qquad (5)$$

If N, N_c, and N_s are adjusted so that the total excitation coefficient is zero, then it follows from Equation (5) that

$$N_c = -1.21N - N_{co}$$
$$N_s = -1.67N - N_{so}. \qquad (6)$$

To verify Equations (6), the horizontal tune was moved to 8+2/3 on the 2 GeV/c flattop and for various settings of DLFSC the SN26 corrections were adjusted so that beam loss due to excitation of the $3Q_H = 26$ resonance was eliminated. The sensitivity of these measurements was enhanced by adjusting the chromaticity on flattop to minimize the tune spread. Figure 1 shows the tune meter FFT spectrum measured on the flattop with the horizontal tune at 8+2/3. (The revolution frequency was 339 kHz, which together with the peak at 226 kHz gives 2/3 for the fractional part of the tune.) Photo #1 shows the beam loss observed when the horizontal tune was moved to 8+2/3 on the flattop with DLFSC set at 950 and with no SN26 corrections applied. Photo #2 shows that this beam loss is eliminated with the SN26 corrections COS26X = 1500, SIN26X = 800. (In each photo, the top, second, third, and bottom traces show respectively the backleg voltage, L20 current transformer, nu-quad shunt voltage, and a signal which indicates when the SN26 correction scheme levels are switched to the values requested on the flattop.) These measurements were repeated with DLFSC set at 150 and at 1750. The values of the SN26 corrections required to eliminate the beam loss in each case are given in Table I.

TABLE I

DLFSC (N)	COS26X (N_c)	SIN26X (N_s)
150	2400 ± 150	1900 ± 150
950	1500 ± 150	800 ± 150
1750	600 ± 150	-500 ± 150

Figures 2 and 3 are plots of the data from Table I. The slopes,

$$\frac{dN_c}{dN} = -1.13 \pm 0.13, \quad \frac{dN_s}{dN} = -1.50 \pm 0.13, \qquad (7)$$

of the lines fitted to these data are in good agreement with the calculated values given in Equations (6). Using the intercepts of the fitted lines in Equations (6), we have

$$N_{co} = -2570 \pm 150, \quad N_{so} = 2160 \pm 150 \qquad (8)$$

which give the excitation coefficient present in the machine (expressed in terms of the SN26 corrections -- see Equation 4) with no corrections applied.

Since the power supplies used in the SN26 correction scheme can provide a maximum of 3 Amps (which corresponds to 3000 counts), it is clear from our measurements that without the DLFSC correction, the SN26 correction scheme is not capable of completely correcting the fields present in the machine which excite the $3Q_H = 26$ resonance. Furthermore, it is clear from Figures 2 and 3 that these fields are not entirely due to the remnant fields of the drive sextupoles. If this were the case, then at some setting of DLFSC, both SIN26X and COS26X would be zero.

In addition to the measurements made on the 2 GeV/c flattop, a measurement of the amount of SN26 correction required to eliminate beam loss with DLFSC set at 950 was made at 1 GeV/c and was found to be the same as that required at 2 GeV/c. Thus, at these low momenta, the amount of correction required for the $3Q_H = 26$ resonance appears to be independent of momentum. We conclude that if the DLFSC correction is used with the SN26 correction, then these corrections should be adequate for the correction of the $3Q_H = 26$ resonance at the Booster momentum of 2.25 GeV/c.

IV. Some Qualitative Observations of the $2Q_H = 17$ Resonance

The top and second traces in photograph #3 show the nuquad shunt voltage and the L20 current transformer signal. During each of the steps in the nuquad current the horizontal tune was measured, and was found to be 8.646, 8.620, 8.580, and 8.544 on the first, second, third, and fourth steps (from left to right). The FFT spectra for these measurements are shown in Photos #5 - #8. As the measured tune approaches 8.5, the width of the corresponding peak in the FFT spectrum decreases, presumably because particles in the wings of the tune distribution have moved into the stopband region and are lost.

If the chromaticity is nonzero, then as the particles undergo synchrotron oscillations, the particles furthest from the center of the rf bucket will undergo the largest excursions from the central tune and will be the first to be lost as the tune is moved toward 8.5. As the tune is moved closer to 8.5, particles closer to the center of the bucket will be lost and the area of the bucket occupied by beam will decrease. This is consistent with what is seen in Photo #4. Here a mountain range display of the wall monitor signal is shown in which the bottom and subsequent traces show the beam bunches during the four steps in the nuquad current. The bunches clearly become narrower as the tune is moved toward 8.5. Now, since the synchrotron frequency is lowest for the particles furthest from the center of the bucket, these particles will move in and out of the stopband region less frequently than the particles closer to the center. One therefore expects the rate of beam loss to increase as the tune is moved closer to 8.5. This is consistent with what is seen on the L20 current transformer signal in Photo #3.

V. An Attempt to Excite or Correct the $3Q_V = 26$ Resonance

There are four skew sextupoles in the ring with which one can simultaneously correct the $3Q_V = 26$ and $Q_V + 2Q_H = 26$ resonances (see Reference 2). With the vertical tune at 8 + 2/3, these magnets were excited on the 1 GeV/c flattop in the configuration required to correct the $3Q_V = 26$ resonance, and were found to have little if any effect on the beam loss or survival. It has been noted in the past, however, that these magnets do have a discernable effect on beam survival at high intensity, and for this reason, they continue to be a part of the stopband correction system for the AGS.

References

1. W. van Asselt and C. Gardner, "Stopband Measurements in the AGS (I)", AGS Studies Report 238, April 1, 1988.

2. C. Gardner, "A Review of the Low Field Correction System Presently Employed in the AGS", AGS/AD/Op. Note No. 17, February 4, 1988.

3. C. Gardner, "Effective Placement of Stopband Correction Elements in an AGS Lattice", AGS/AD/Tech. Note No. 321, May 30, 1989. (Revised September 29, 1989).

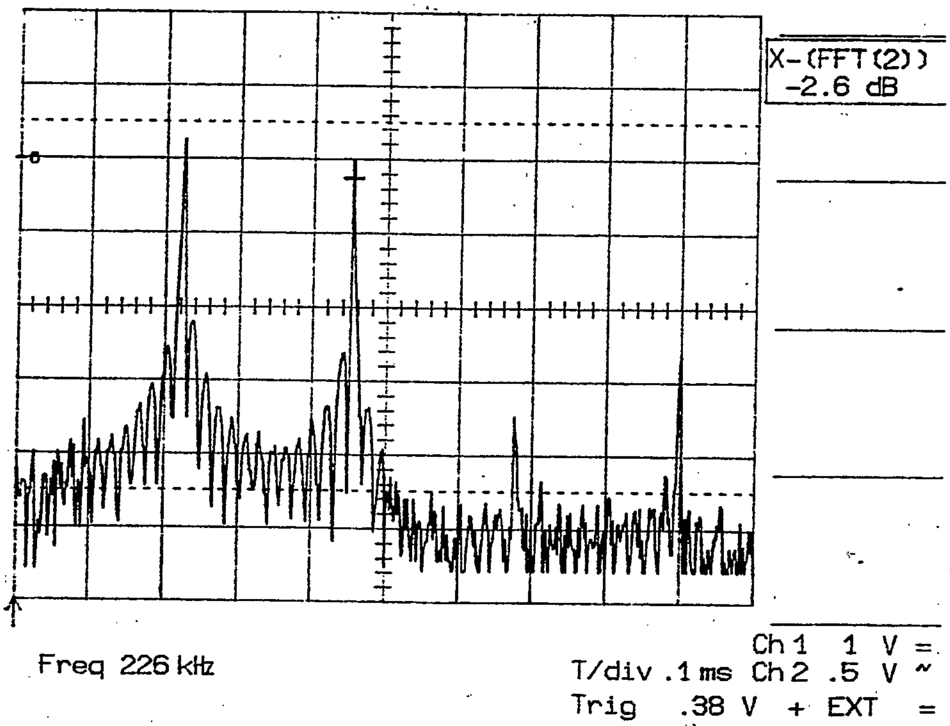

Figure 1

Backleg

L20

Nuquad

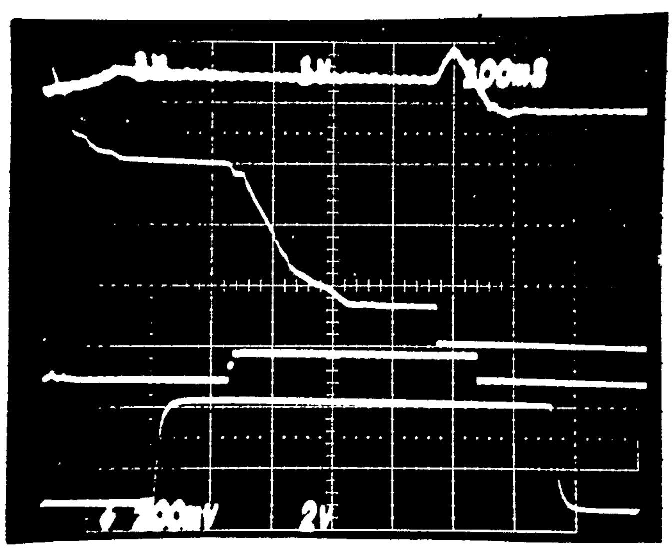

Photo 1

$Q_H = 8\frac{2}{3}$

DLFSC = 950

COS 26X = 0

SIN 26X = 0

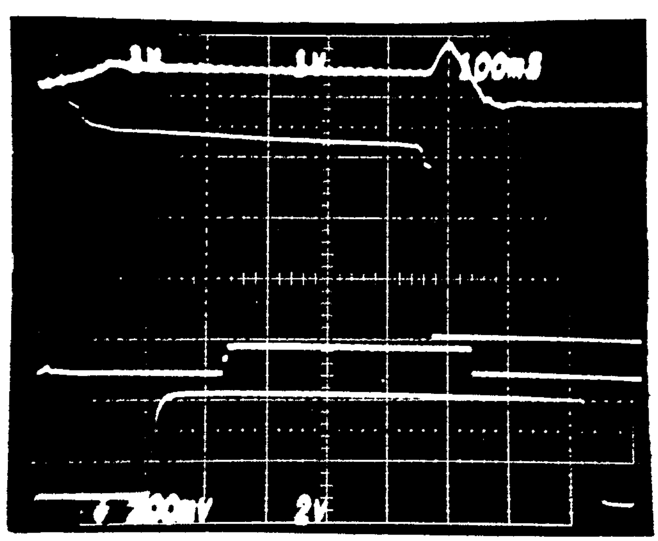

Photo 2

$Q_H = 8\frac{2}{3}$

DLFSC = 950

COS 26X = 1500

SIN 26X = 800

CORRECTION OF 3QH=26 RESONANCE WITH DLFSC AND SN26
SLOPE= -1.125000 +/- 0.132583
INTERCEPT= 2568.750100 +/- 152.853710

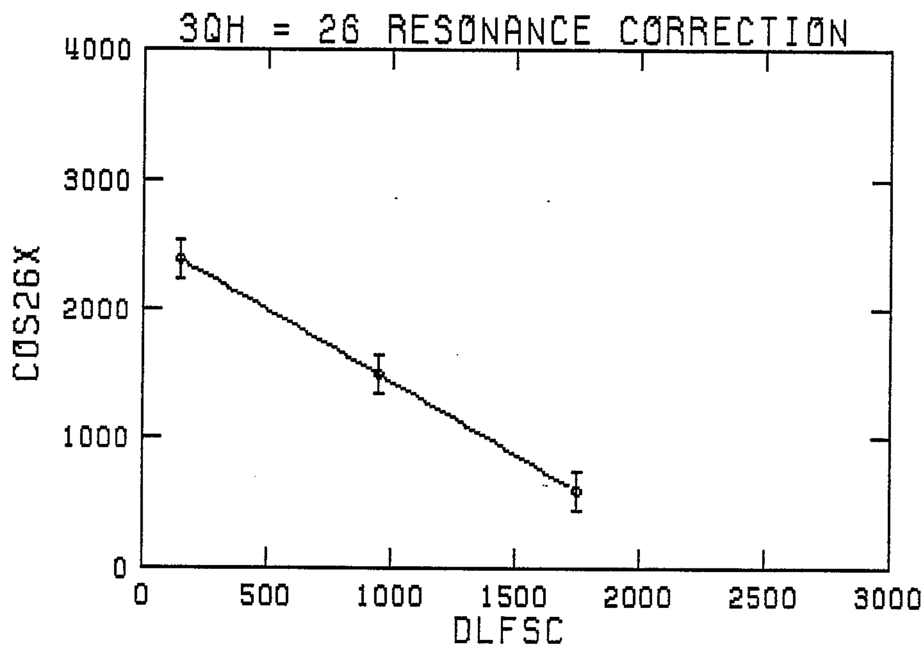

Figure 2

CORRECTION OF 3QH=26 RESONANCE WITH DLFSC AND SN26
SLOPE= -1.500000 +/- 0.132583
INTERCEPT= 2158.333400 +/- 152.853710

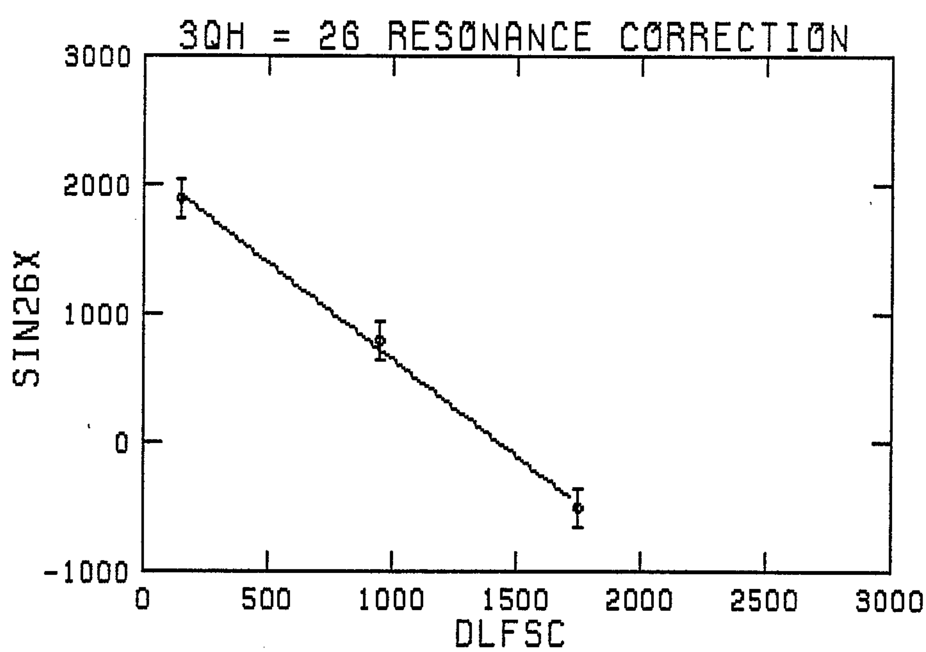

Figure 3

Nuquad Shunt

L20

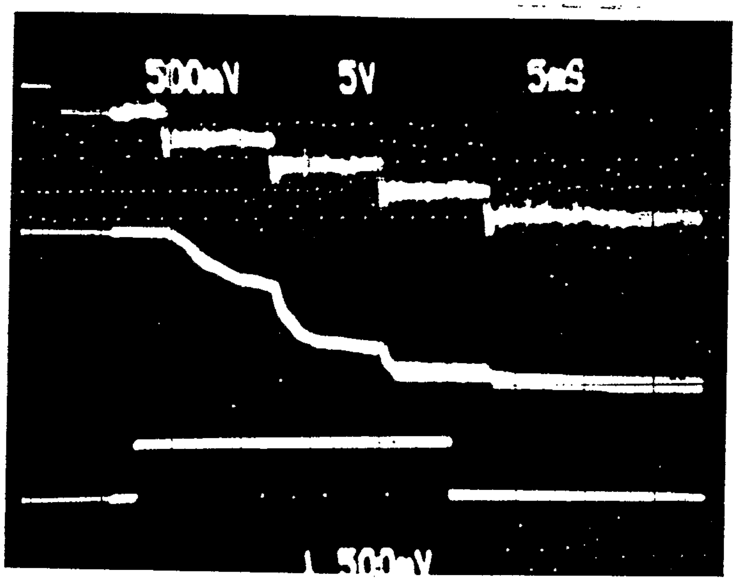

Photo 3

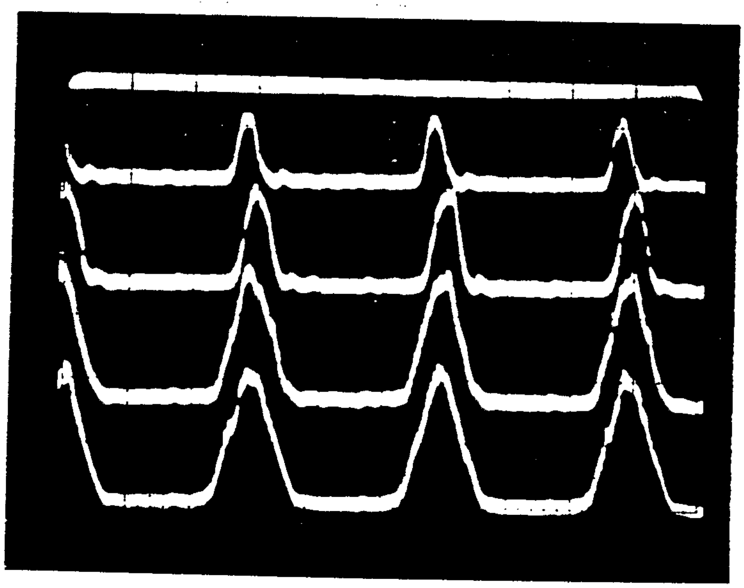

Photo 4

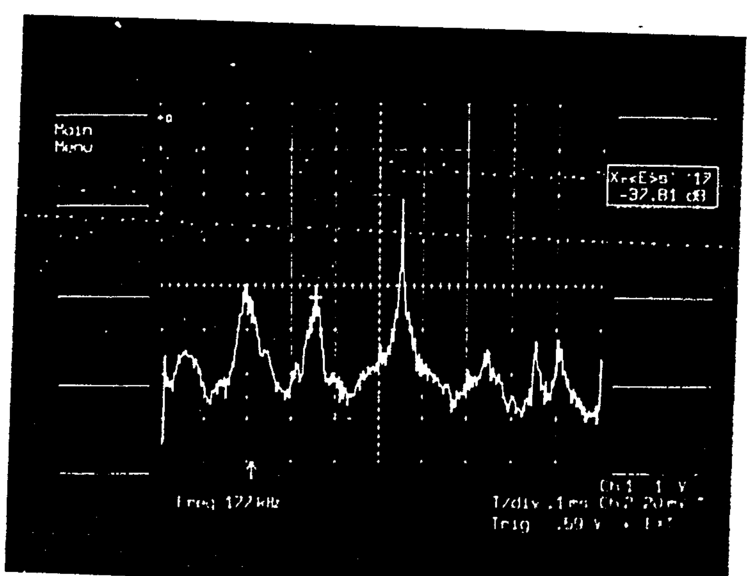

Photo 5

$Q_H = 8.646$

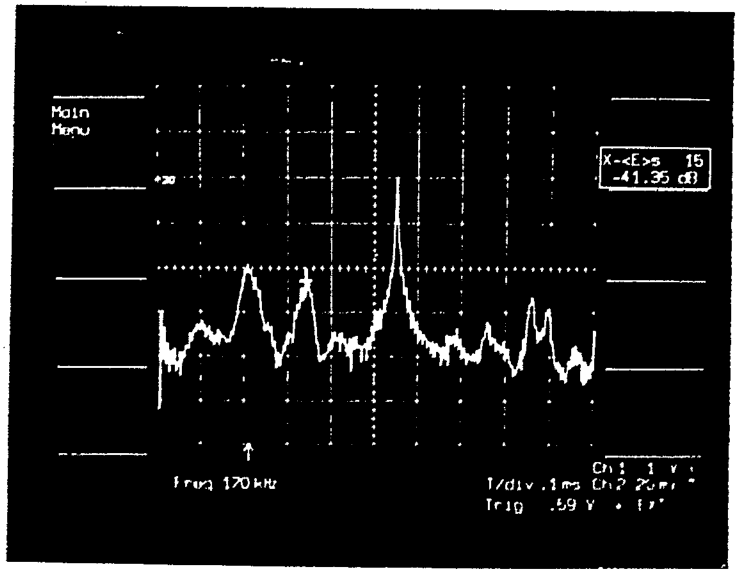

Photo 6

$Q_H = 8.620$

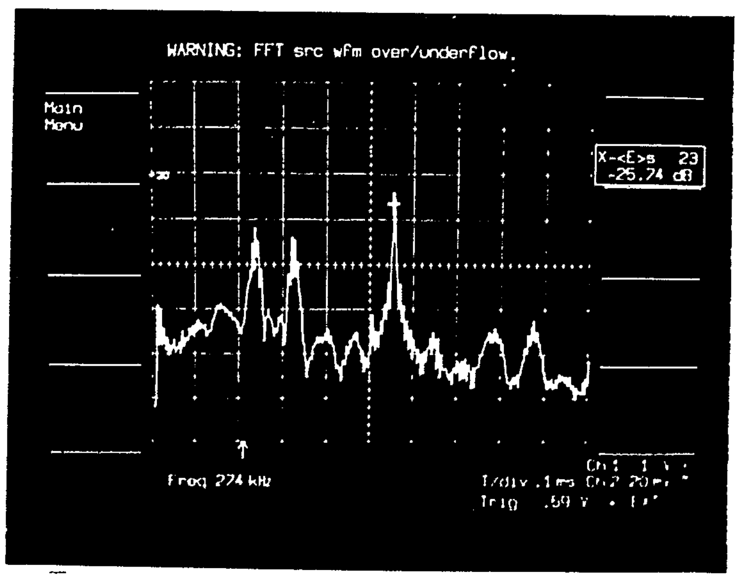

Photo 7

$Q_H = 8.580$

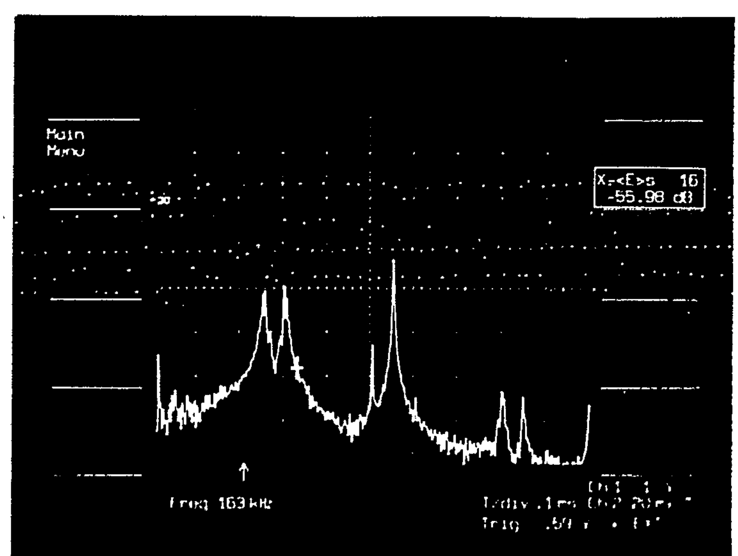

Photo 8

$Q_H = 8.544$