IMPROWMENT OF THE AGS AGC LOOP

E. Onillon

April 1994

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Accelerator Division
Technical Note

AGS/AD/Tech. Note No. 394

IMPROVEMENT OF THE AGS AGC LOOP

E. Onillon and J.M. Brennan

April 8, 1994

Improvement of the AGS AGC loop
E. Onillon - M. Brennan

1. Introduction

The rf feedback system of the new power amplifier for the AGS cavities has an important effect on the amplitude modulation frequency response of the cavities. This changes the open loop response of the AGC system for the cavities. The loop compensator for the AGC system was first set up without rf feedback operating. This report describes how the loop compensator was modified to accomodate the presence of the rf feedback. A practical solution has been obtained that is compatible with and without rf feedback.

2. The AGC loop

The cavity voltage is measured with capacitive dividers attached to the accelerating gaps. The magnitude measured voltage is determined through an rf magnitude calculating circuit. This signal is compared to the reference voltage V_{ref}. The difference is then amplified before being modulating the rf voltage. The resulting signal is then sent to the cavity power amplifier (fig .1). The loop amplifier contains a circuit which scales is gain according to $G(s) = \dfrac{G_0(s)}{V_{ref}}$.
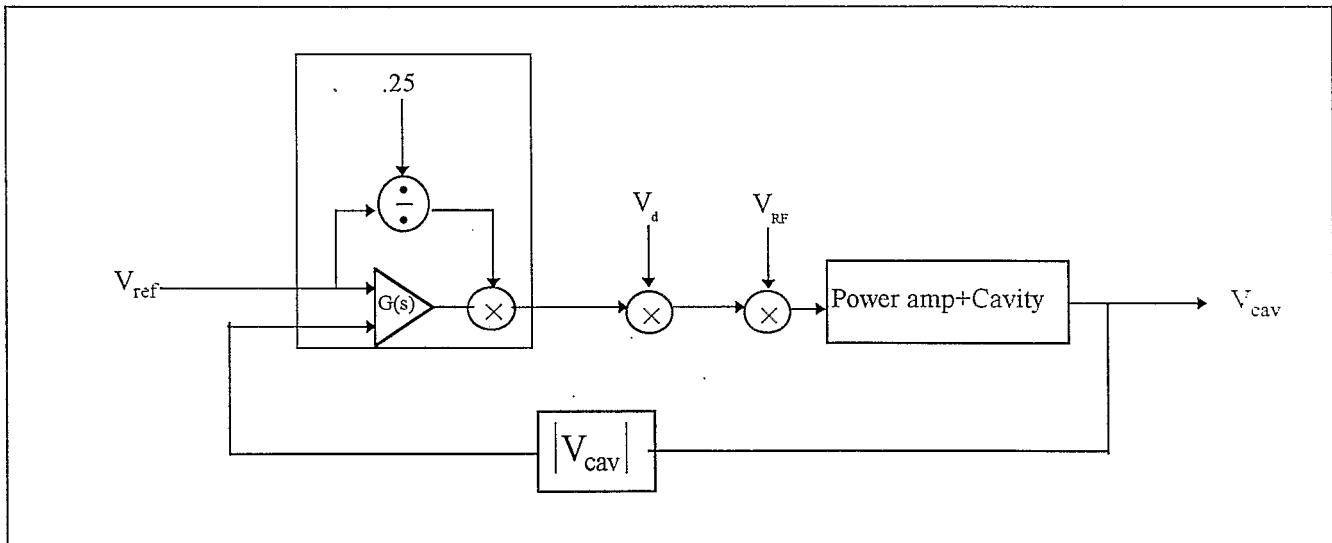

Fig. 1 AGC loop principle

2.1   The open loop

The open loop transfer function, fitting the system response has been determined with and without rf feedback on the cavity. This excludes the loop amplifier. When there is no feedback, the loop behaves like a low pass filter at 24.45 kHz, with a 5 µs delay:

$$H(s) = \frac{153.6 \ 10^3}{s + 153.6 \ 10^3} \ e^{-5 \ 10^{-6} s}$$

The effect of the rf feedback is to increase the frequency of this pole. The system acts has a pure delay of 5 µs up to 100 kHz:

$$H(s) = e^{-5 \ 10^{-6} s}$$

The Bode diagrams of these open loops are given on fig. 2 and fig. 3. The loop should have a good behavior in both cases.
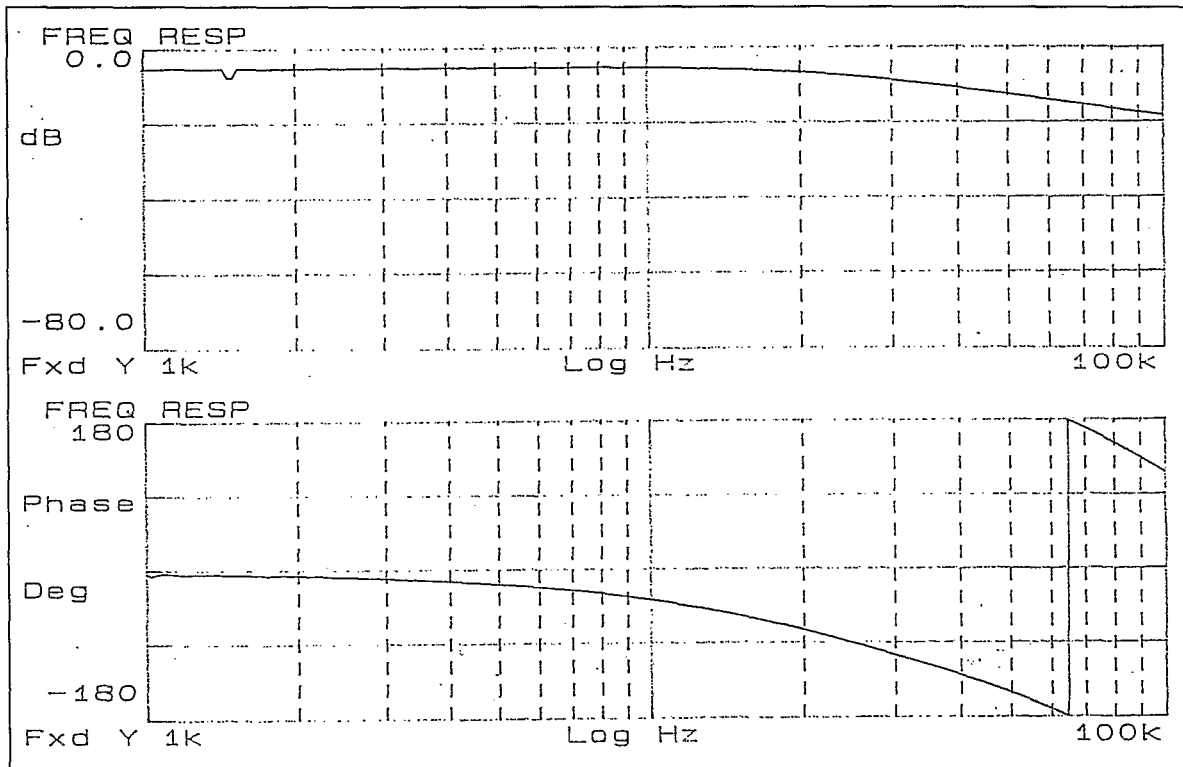

Fig. 2 Open loop without cavity feedback
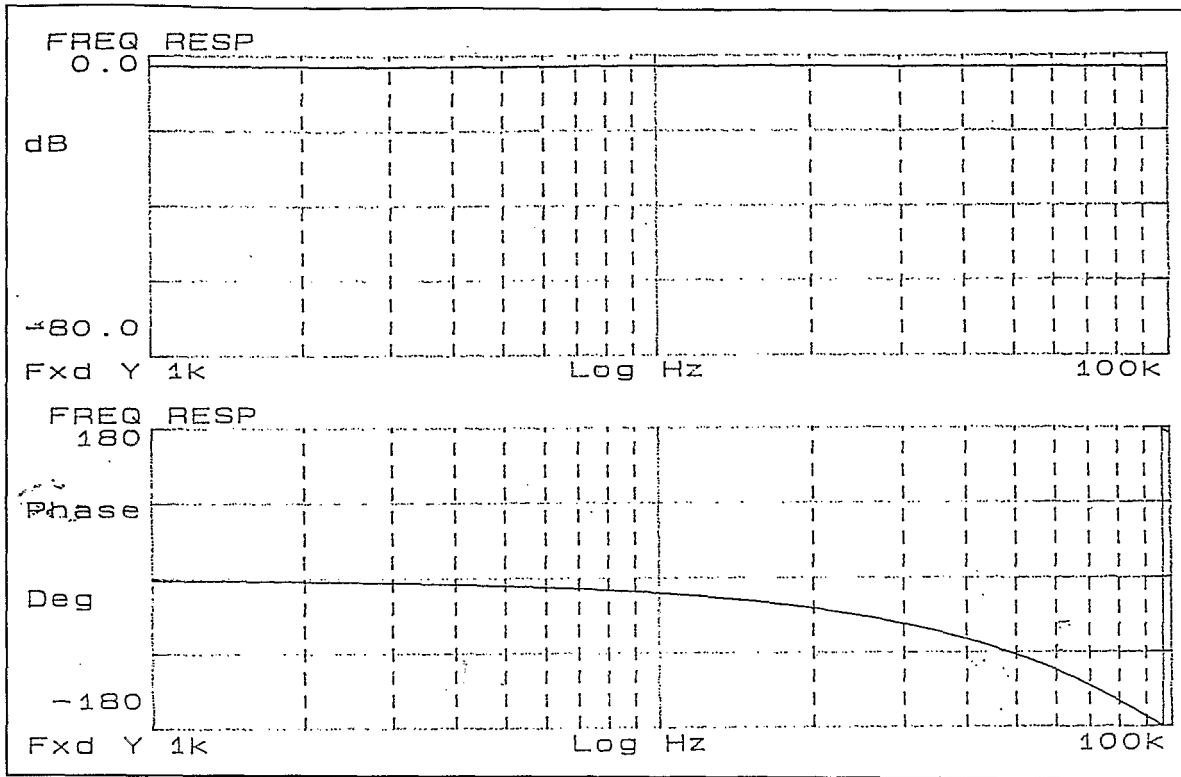
Fig. 3 Open loop with cavity feedback

2.2   The actual loop amplifier

The actual loop amplifier is a PI compensator given by:

$$G(s) = K\left(1 + \frac{1}{T_i s}\right)$$

The parameters are: $\begin{cases} T_i = 4.7\mu s \\ K_{pot} = 100 \end{cases}$

K_{pot} is the proportional constant read on the potentiometer. It is proportional to K.

The Bode plot of the open loop is given fig. 4. The phase margin is 25° and the amplitude margin 1.8 dB. This corresponds to a 60% overshoot.
The close loop shows a peak which proves that the system is not stable enough (fig. 5).

X=74.559kHz
Ya=-1.8583 dB
 M: FREQ RESP
   50.0

dB

  -10
FxdXY 1k   Log Hz   100k

 M: FREQ RESP
   0.0

Phase

Deg

 -180
FxdXY 1k   Log Hz   100k

Fig. 4 Open loop

X=6.6834kHz
Ya=-117.72mdB
 FREQ RESP
   30.0

dB

  -10
FxdXY 1k   Log Hz   100k
Yb=-12.817 Deg
 FREQ RESP
   0.0

Phase

Deg

 -180
FxdXY 1k   Log Hz   100k

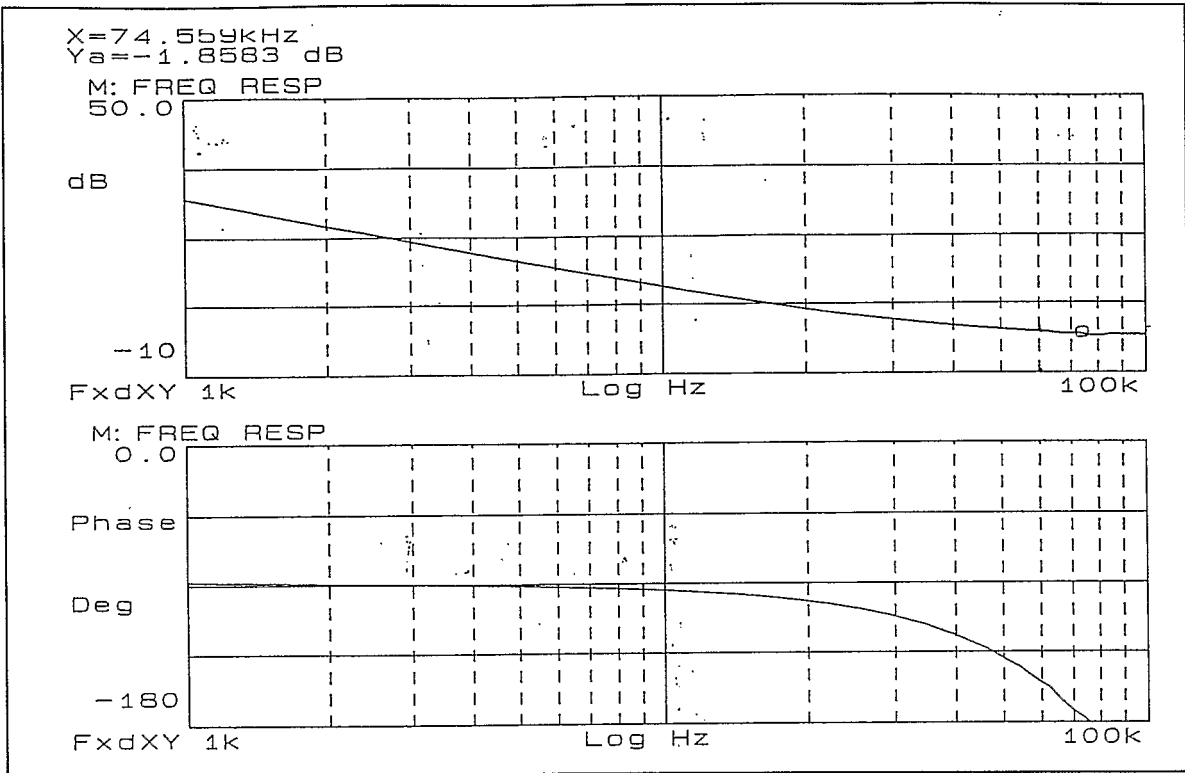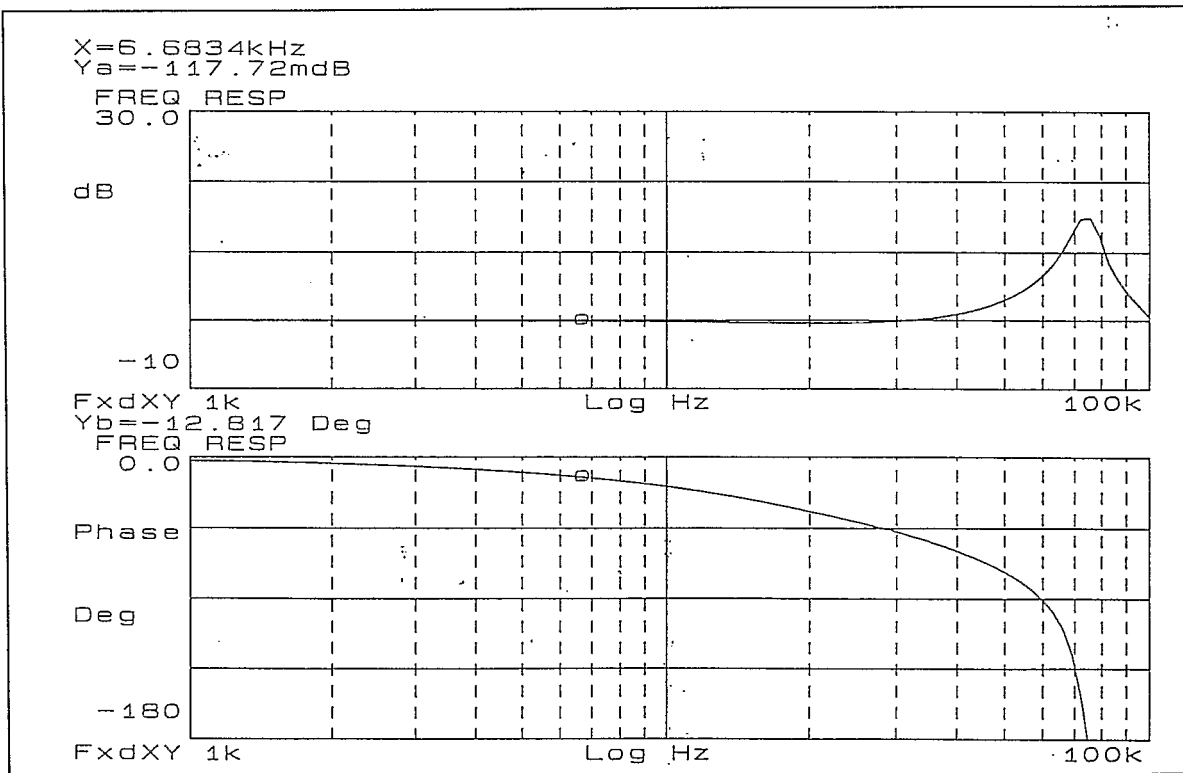**Fig. 5 Close loop**

2.3   Improvement of the loop

The use of a PI for the loop amplifier can provide a good solution, whether there is a cavity feedback or not.

The general behavior of the open loop F(s) is given fig. 6.

At low frequency, the PI provides gain. The phase is then equal to -90°. The amplitude of the open loop is 0 dB for $f \approx \dfrac{K}{2\pi T_i}$. At high frequency, if the cavity feedback is on, the magnitude is constant and is equal to $20\log(K)$. If there is no feedback, the pole of the system prevails.

The magnitude is translated by $20\log(K)$. The phase is unchanged at high frequency.

The K parameter is determined by the amplitude margin one wants when the feedback is on. The phase margin and the gain at low frequency is then fixed by adjusting the T_i parameter.
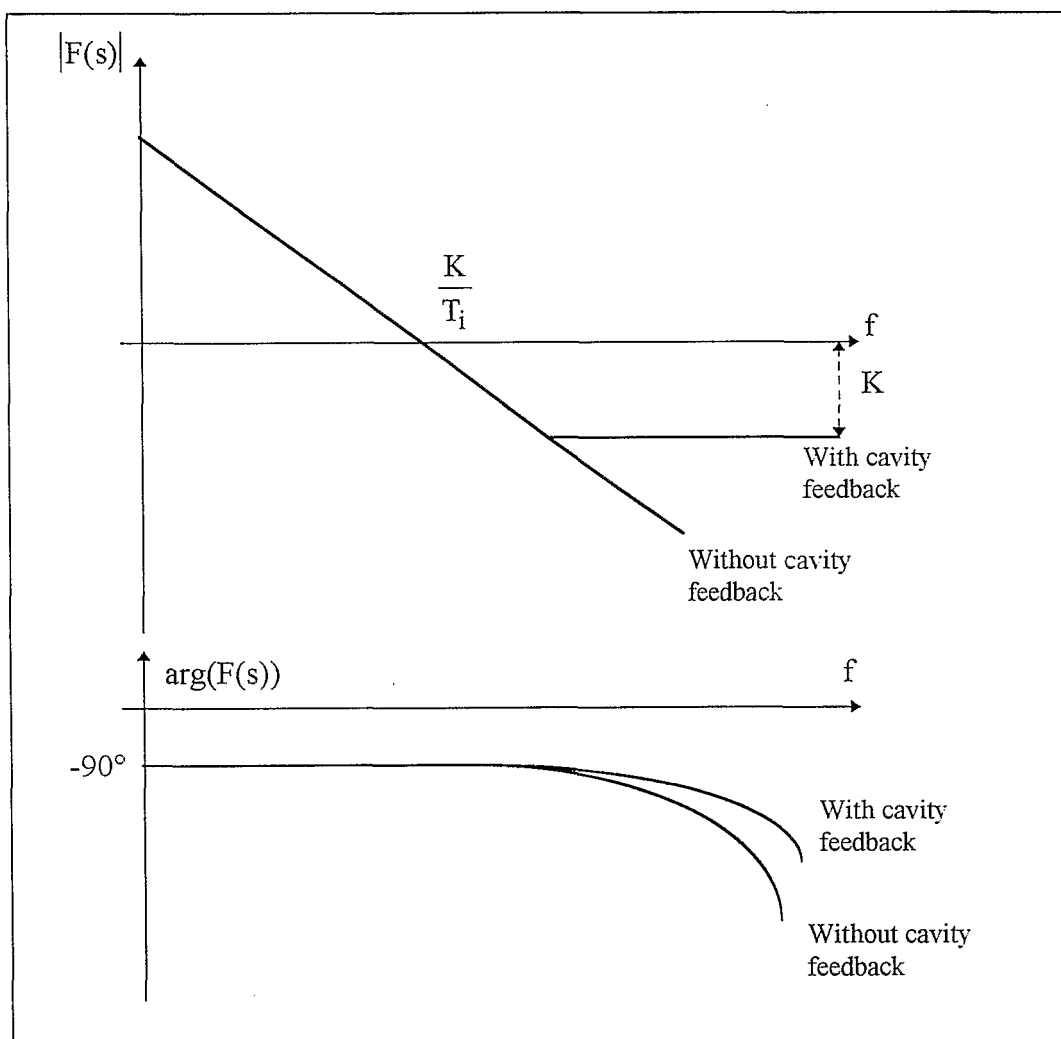

Fig. 6 Open loop with a PI compensator

A simulation (fig. 7) has been performed under Matlab^{TM} with $\begin{cases} K = 0.11 \\ T_i = 2.2 \ \mu s \end{cases}$.

When the cavity feedback is on, the phase margin is 77° and the amplitude margin 17 dB. If it is off, the phase margin is 61° and the amplitude margin 14 dB. The amplitude is zero in both cases for 8 kHz.

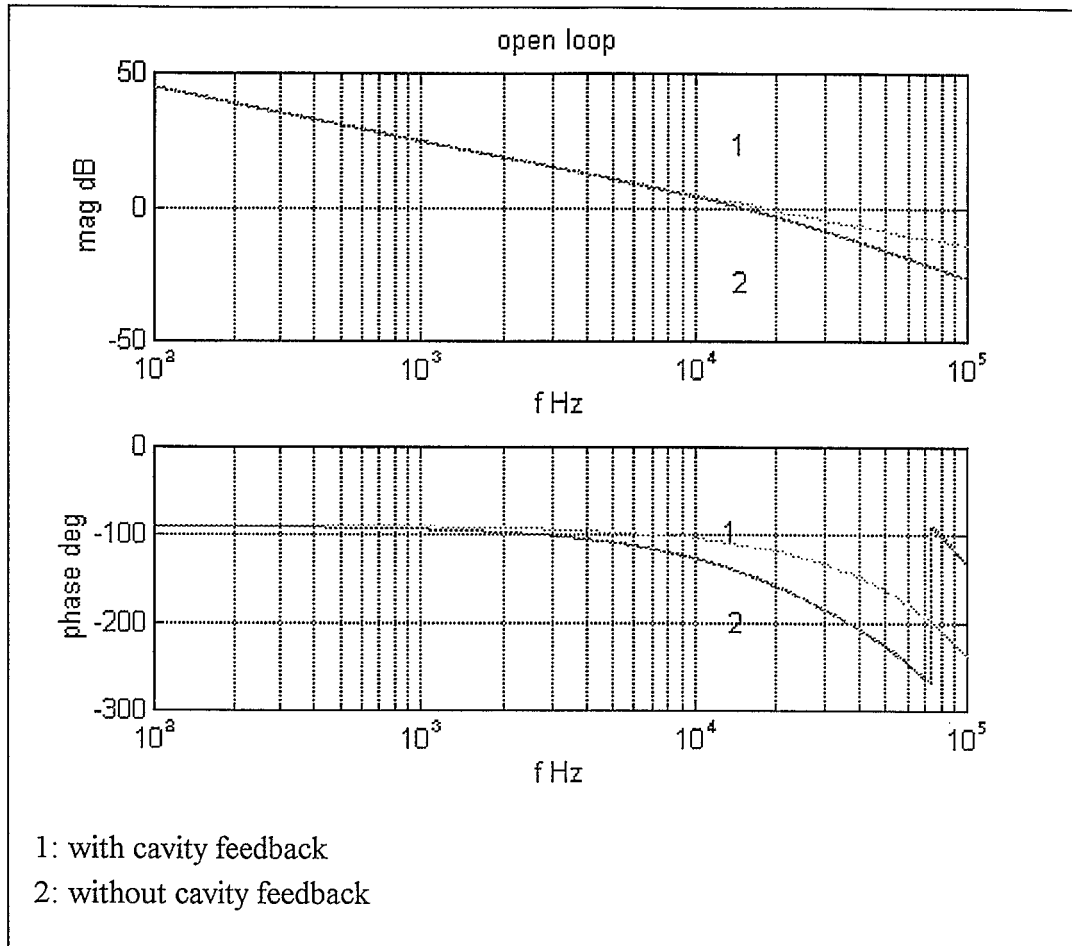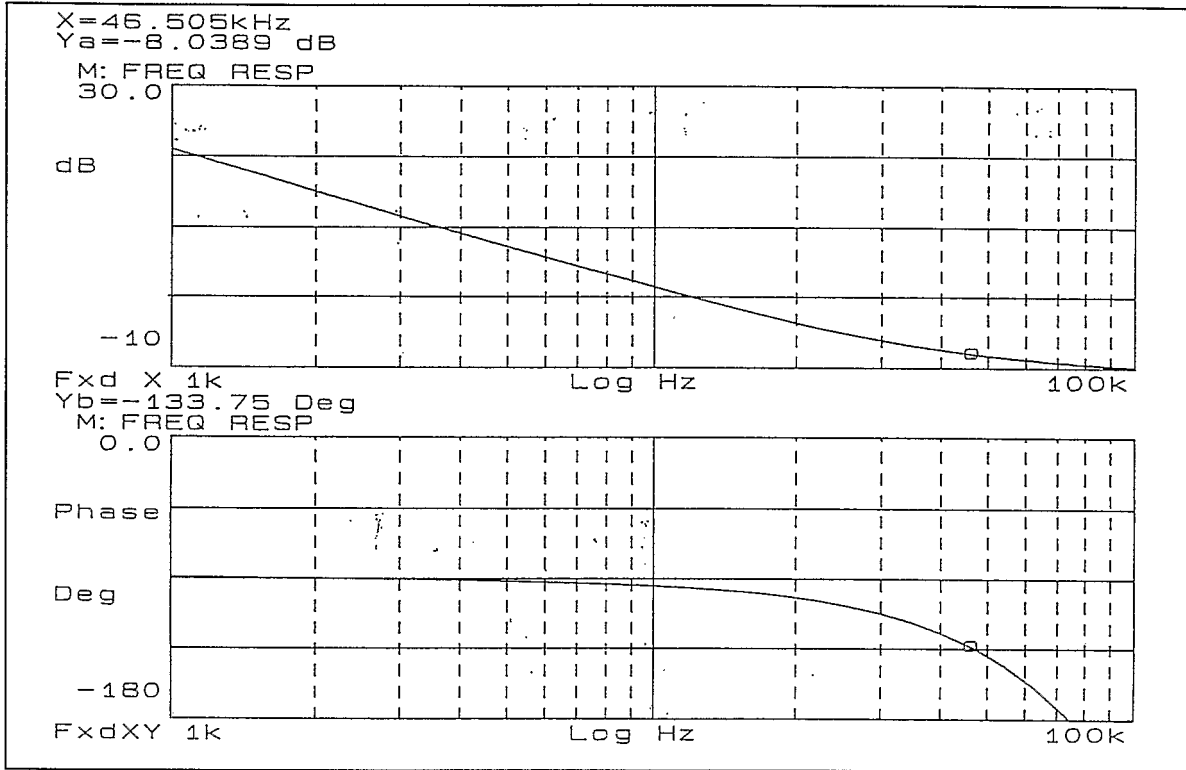1: with cavity feedback
2: without cavity feedback

Fig. 7 Open loop with and without cavity feedback

2.4 Practical study

Starting with the case where $\begin{cases} T_i = 4.7\mu s \\ K_{pot} = 100 \end{cases}$, to increase the amplitude margin, the gain is decreased by 60%. The integrator constant is unchanged:

$$\begin{cases} T_i = 4.7\mu s \\ K_{pot} = 40 \end{cases}$$

The resulting Bode plot is given fig. 8.


```
X=46.505kHz
Ya=-8.0389 dB
  M: FREQ RESP
    30.0

 dB



    -10
Fxd X 1k                         Log Hz            100k
Yb=-133.75 Deg
   M: FREQ RESP
     0.0

 Phase


 Deg


   -180
FxdXY 1k                         Log Hz            100k
```

Fig. 8 Open loop, increased amplitude margin

The amplitude margin is now 10 dB and the phase margin 83°.

To increase the gain at low frequency, the integrator constant is decreased: $\begin{cases} T_i = 2.3\ \mu s \\ K_{pot} = 40 \end{cases}$.
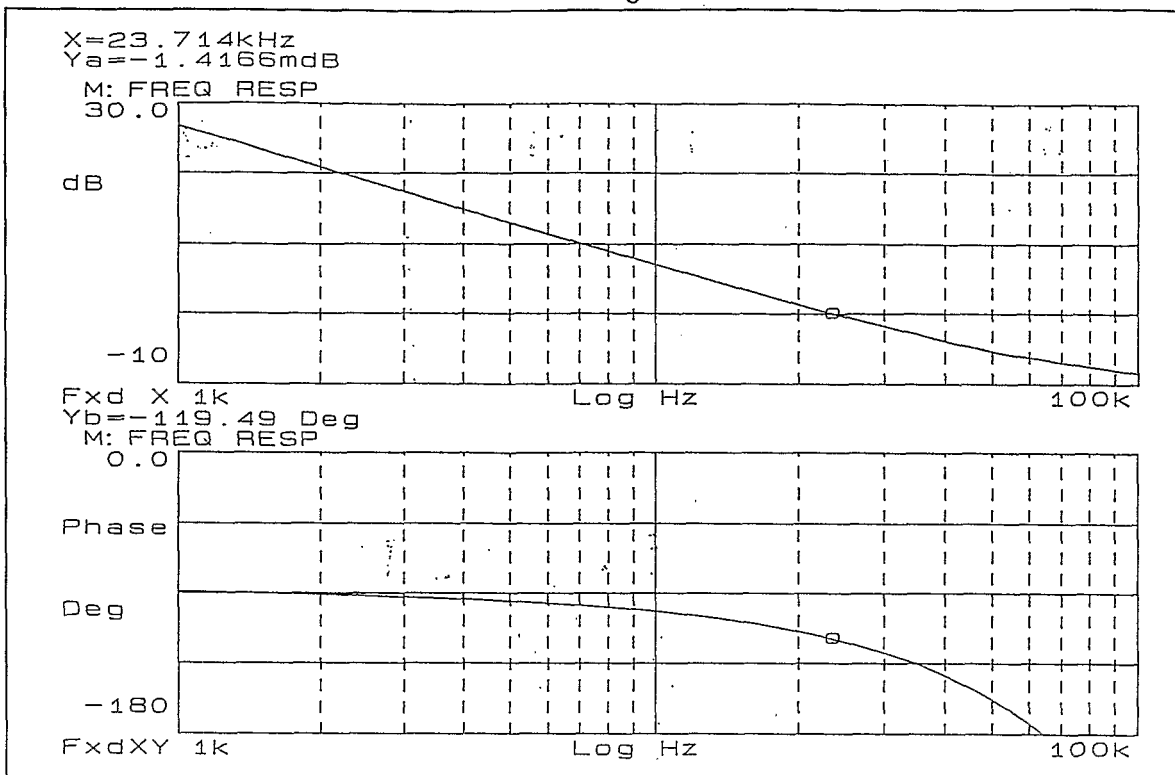
The result is drawn on fig. 9.

Fig. 9 Open loop, increased phase margin

The amplitude margin is 7 dB and the phase margin 70°. The gain at 6 kHz $\left(2\omega_s\right)$ is 11 dB, and the amplitude is 0 dB at 23.7 kHz.

With these settings, the overshoot will be 4%. The Bode diagram of the close loop is drawn on fig. 10. The peak which appeared at the beginning has now disappeared.
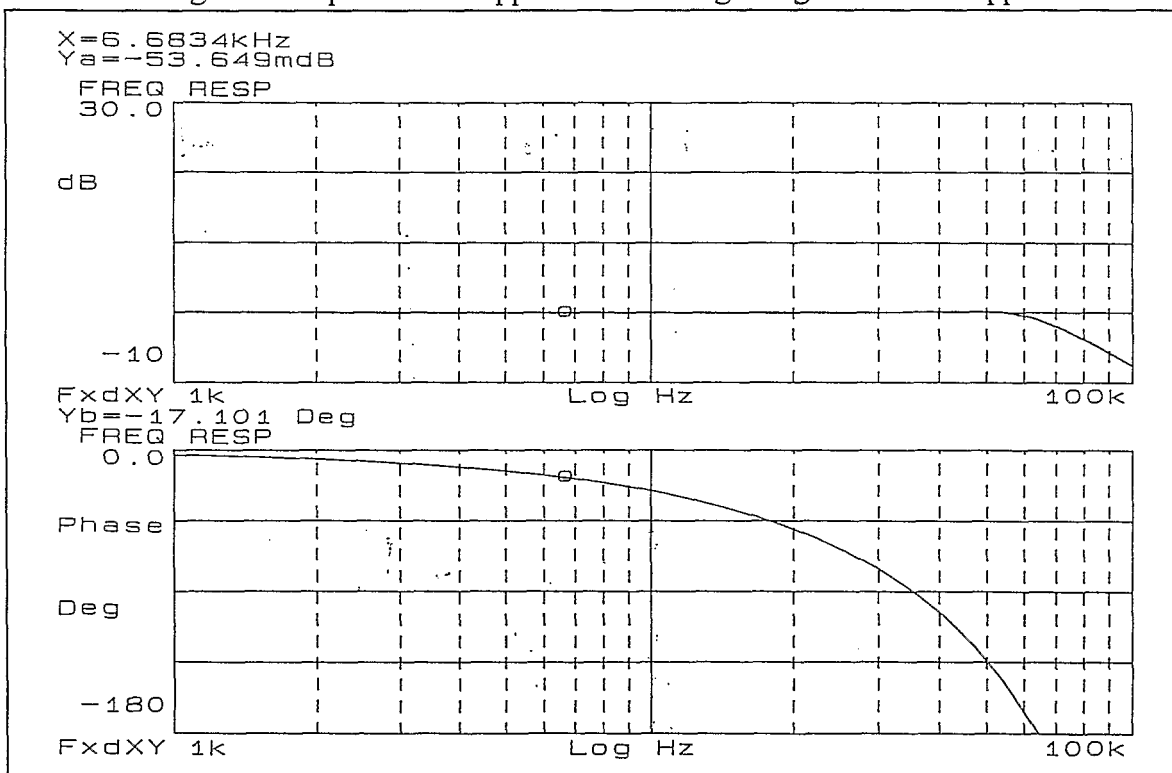

Fig. 10 Close loop, final case

3. Conclusion

The AGC loop has now better phase and amplitude margins, which provides a good stability. Moreover, it has 10 dB gain at twice the synchrotron frequency, which is important for suppressing coherent quadrupole oscillations. Furthermore, the quadrupole mode damper requires good response of the AGC system at twice the synchrotron frequency.