HOM Frequency Detuning in RF Cavity

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Introduction

When the total current in CESR was raised to about 300 ma a longitudinal instability threshold occurred which prevents a significant increase in the current. Experiments on CESR indicate that the main cause for the longitudinal instability is the H.O.M. in the cavities [1]. It has also been shown that by changing the cavities temperature the longitudinal instability threshold can be slightly raised [2]. In this paper an alternative method to shift the H.O.M. frequencies in a controlled way, without affecting the fundamental frequency, is proposed.

1 *Description*

The H.O.M. are coupled out by a loop coupler and dissipated by a water cooled 50 Ω LOAD (Figure 1). A narrow band notch filter is connected between the coupler and the load in order to reflect back the power of the fundamental frequency. Since the coupler's coupling is different for each mode some of the modes are damped better than others. These modes can cause longitudinal instabilities. It was shown experimentally that the instability current threshold depends on the bunch spacing. For example, for a single beam of 9 trains with 2 bunches per train and 14 nsec spacing between bunches, the threshold current was about 150 ma [3] while for 9 trains with 2 bunches/train with 10 nsec spacing between bunches the threshold current was above 300 ma [4]. It has also been shown that the instability current threshold can be slightly raised by changing the cavity temperature which shift all cavity modes including the fundamental frequency. This method was not very successful mainly because the tuner automaticlly changes the cavity impedance to bring the fundamental frequency back to its original value. This change in cavity impedance was also compensating some of the intended H.O.M. frequencies shift, making it not very sensitive to the temperature change. Another method of changing the cavity mode frequencies without moving the fundamental frequency is to connect a tuneable stub in parallel to the 50 Ω damping load. By doing this we add a tuneable reactive impedance to each of the modes through the coupler, see Figures 1,2, thus changing their frequencies. For each mode a different value of reactive impedance is added depending on its frequency and the coupling to the mode. Therefore, each mode frequency will be shifted by different amount. At the fundamental frequency the notch filter's transfer impedance is zero preventing any frequency shift. This can be done on each cavity cell and thus will allow us to tune the H.O.M.'s of each cell separately.

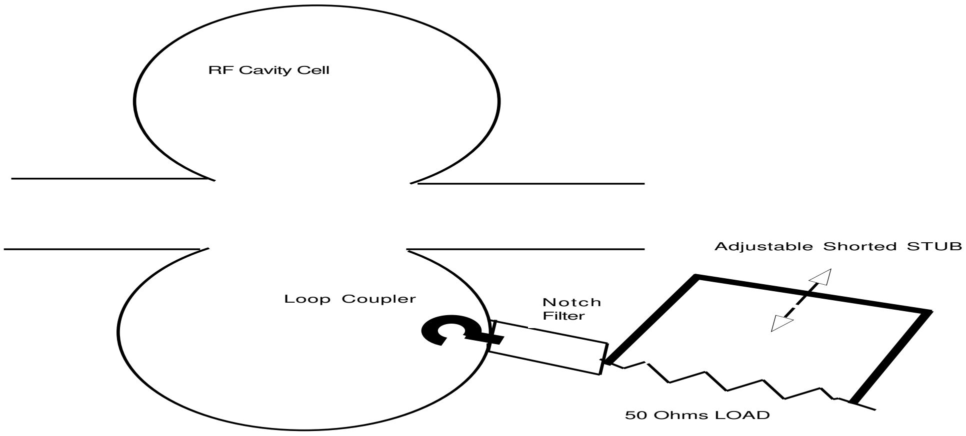

Figure 1: Schematic diagram of an RF cell with the adjustable stub mounted in parallel to the H.O.M. damping LOAD

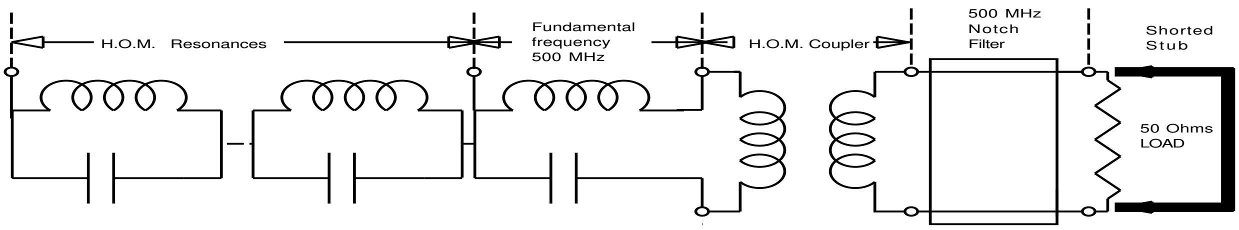

Figure 2: The Equivalent Circuit of the RF cell with its H.O.M. Coupling Loop Damping Load and the Stub

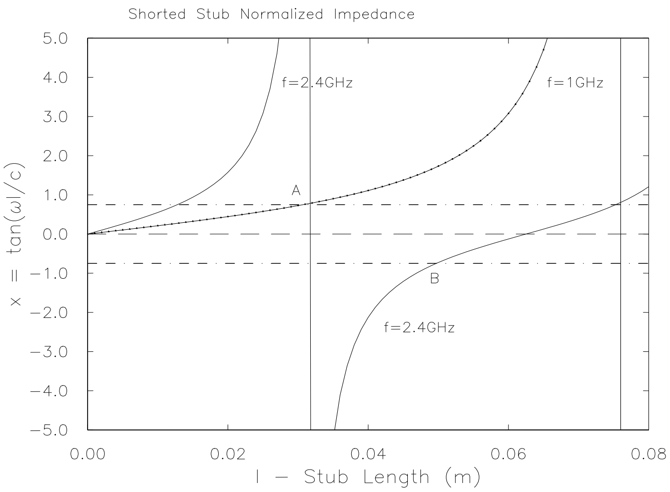

Figure 3: The Stub Normalized Reactance

2 *Stub Design*

While designing the stub the following parameters should be considered:

• The input impedance of the shorted stub is given by:

$$Zin = jZ_o tan\left(\frac{\omega l}{c}\right) \tag{1}$$

where Z_o is the characteristic impedance of the stub, ω is the radial frequency, l is the stub length and c is the speed of light. A simulation using URMEL shows that only modes between 1 GHz and 2.4 GHz have high enough quality factor Q to drive a longitudinal instability. The stub impedance for these frequencies is shown in Figure 3. The stub impedance for lowest and highest frequencies of interest, 1 GHz and 2.4 GHz correspondeningly, is shown in Figure 3.

The VSWR at the coupler, due to the added stub in parallel to the LOAD, should be less than 2.0 (30 % reflection) to avoid damage to the coupler ceramic window. In order to keep the VSWR less than 2 the added impedance of the stub must be larger than 50 Ω for all the frequency in between 1 $GHz - 2.4\ GHz$. It can be seen from Figure 3 that the minimum length of the stub is determined by the lowest frequency, point A, and maximum length is determined by highest frequency, point B. Thus the useful dynamical length for detuning the H.O.M. is about 2 cm. The dynamical range of the stub can be increased by using a stub with characteristic impedance larger than 50 Ω.

• A few hundreds KHz frequency shift should stabilize the beam in most cases.

• The contact resistance of the short to the inner and outer tubes of the stub should be small, since some of the H.O.M. damped power will be dissipated on it. Also the stub will need to be cooled.

3 *Low power measurements*

3.1 Measurements on the Stub

The output section of the coupler is a 50 Ω coaxial waveguide so it will match the 50 Ω LOAD. To check the mismatch in impedance between the coupler and the load due to the added stub we started by measuring the VSWR of the LOAD only and then compared it to the VSWR when the stub was connected in parallel to it. Figure 4 shows this comparison for a stub length of about

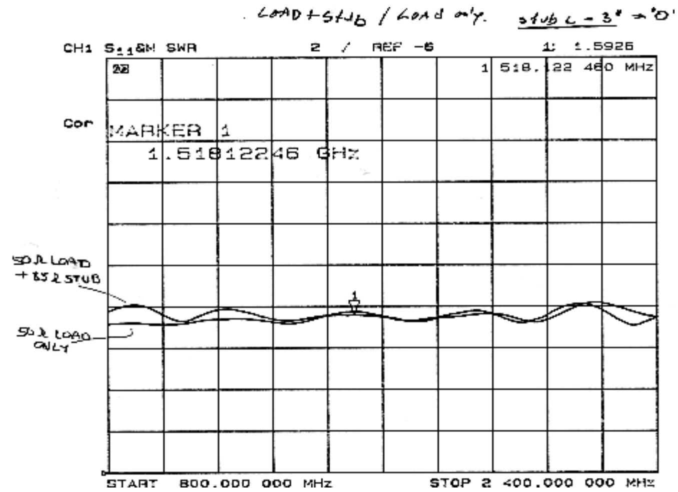

Figure 4: The VSWR when a 4 *cm* stub is added in parallel to the 50 *KWatts*, 50 Ω load compared with VSWR of the load only

mode frequency (*GHz*)	0.5	1.1	1.4 *detuned*	1.6	1.8
possible frequency shift (*KHz*)	0	100.	500.	50.	750.

Table 1: The measured changes in several H.O.M. frequencies due to changes in the stub length when the 1.4 GHz mode was detuned

4 *cm* which is the middle of the range, between point A and B. At this stub length the effect of the stub on the VSWR is negligible. In Figure 5 we show the VSWR for the case when the stub was shortened by 1 *cm*. As can be seen the VSWR of the lower frequencies increases. While in Figure 6 the VSWR for the case when the stub length was elongated by 1 *cm* to about 5 *cm* is shown. In this case the VSWR for the higher frequencies increases. In these two extreme cases the stub impedance was less than 50 Ω therefore the VSWR start to increase. This agrees with the calculations shown in Figure 3.

3.2 Measurements of Frequencies Shift of the H.O.M. in a Single Cell

We connected the stub and the load to the 500 *MHz* cavity cell through the notch filter and the coupler. We then excited the $m = 0$ H.O.M. in the cell by using one input probe in the center of the cell and the $m = 1$ H.O.M. by using two probes, located symmetrically off center in the cell, with the input power shifted by 180° between them. We recorded all the frequencies of the H.O.M. at a certain stub length. We picked one H.O.M. and shifted its frequency by changing the stub length. Leaving the stub in this new position, we measured the shift in the frequency of all other modes. In table 1 the results of such a measurement for the case when we detuned the 1.4 *GHz* mode is shown.Note, the fundamental frequency was not changed. A summary of the frequency shifts of the detuned modes only is brought in Table 2.

4 *Conclusion*

As we have shown, the frequency of the H.O.M. can be shifted significantly which will enable us to increase the beam current in CESR by raising the longitudinal instability threshold. The stub system is simple to build. It is also a passive system which does not require power sources or timing

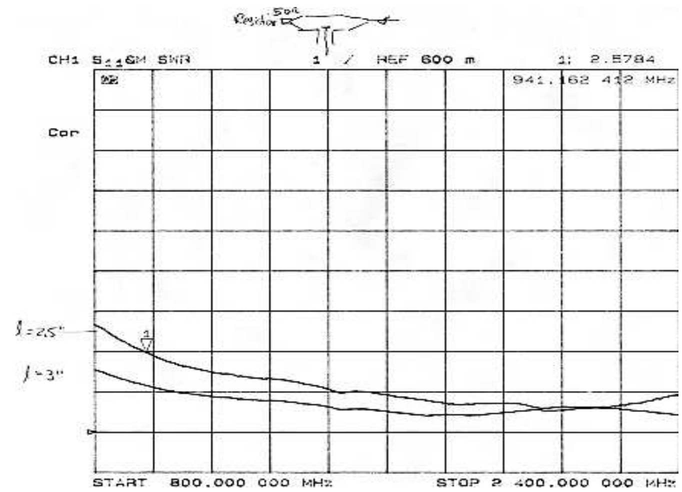

Figure 5: The increase in VSWR when the stub was shorten by 1 *cm* compared with the VSWR when the stub length was about 4 *cm*. In this experiment the stub was in parallel to a 50 Ω termination

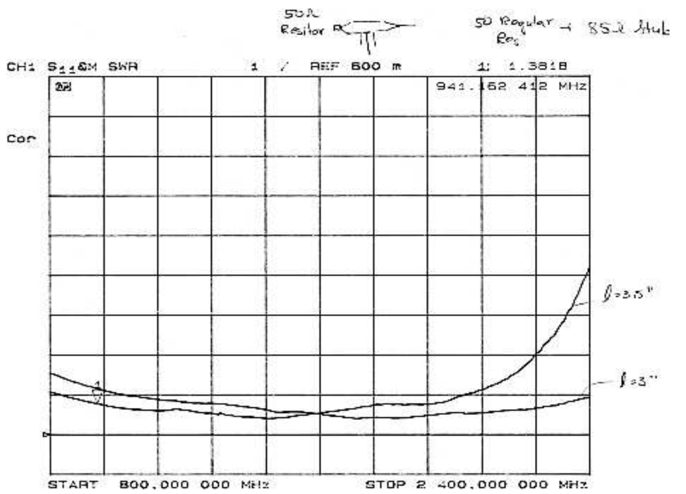

Figure 6: The increase in VSWR when the stub was elongated by 1 *cm* compared with the VSWR when the stub length was about 4 *cm*. In this experiment the stub was in parallel to a 50 Ω termination

mode frequency (GHz)	1.4	1.6	1.8
possible frequency shift (KHz)	500.	300.	750.

Table 2: The measured changes in the H.O.M. frequencies due to changes in the stub length

systems. In addition it will allow us to detune the H.O.M. of each cell separately to maximize the beam current.

References

[1] Machine Study. April 10, 1996

[2] Machine Study. September 17, 1996

[3] Machine Study. January 7, 1997

[4] Machine Study. October 25, 1996