PS/LPI Note 86-19
8. 7. 1986

FUNDAMENTAL AND HIGHER ORDER MODE MEASUREMENTS ON THE RF CAVITY FOR EPA

S. Bartalucci - A. Susini

Introduction

The insertion of lossy material in the EPA RF cavity was proposed for global damping of parasitic modes. A series of measurements was done on a test cavity by looking at the spectrum of the parasitic modes and their Q-values for various damping mechanisms [1]. The possibility of global damping was clearly proved.

Successively, the introduction of large coupling port for the RF drive loop and the addition of tuning mechanisms should in principle change the field distribution of the higher order modes, as much as the use of an amplifier cavity has generated other modes. So it was quite evident that a series of measurements on the cavity in its final configuration was required. The measurements which have been performed on the actual EPA cavity are shown below. Unfortunately not all possible measurements have been made, as indicated in the following table:

lossy material including ferrit	Cavity alone			Cavity + amplifier		
	full	various levels	empty	full	various levels	empty
tap water	x		x	x	x	x
dem. water	x			x		x

Q measurements of the higher order modes

The measuring set-up is basically the one described in ref. [1]. The feed probe was located at the gap and the response was taken either from top or bottom monitoring loops. For Q-measurements the 3 dB method was used and we made sure that both feed and monitoring loops were loosely coupled to the cavity.

By this arrangement the circular modes are poorely excited. Remembering that these modes are also highly damped by the longitudinal slots and absorbing ferrites [2] it can be inferred that most of the peaks appearing at the network analyzer are generated by longitudinal modes. Therefore, no special precaution has been taken for the mode identification.

The agreement with URMEL is good only up to 300 Mc, because the introduction of large coupling port for the RF drive loop and the addition of tuning mechanisms changes the field distribution of the higher order modes, as much as the use of an amplifier cavity can introduce other modes.

It has been remembered that the presence of ferrite rings at both sides of the accelerating gap gives already a substantial damping of the parasitic modes without affecting in a measurable way the fundamental one [1]. The damping is enhanced when adding a layer of water, contained in an annular box at the shortened end of the cavity, where some parasitic modes have relatively high electric fields. The results are different with ordinary and demineralised water, especially at low frequency, whereas above 2/300 Mc. they tend to be identical. Also an imperfectly filled water box increases the damping as an asymmetry is created in the field distribution which causes some energy at the longitudinal modes to be lost in the ferrite through the longitudinal slits.

Q measurement at higher modes

We measured the Q as function of the water level in the box. The results are shown in Table I and compared with theoretical predictions. The frequencies of the higher order modes as computed with the code URMEL are reported in column 1.

The corresponding threshold values for the Q are shown in column 2, as far as coupled bunch instabilities are concerned. These have been calculated with the code BBI [3], referred to an ideal, isolated, symmetric cavity. The measured values for the frequencies and the Q's at various levels of tap water are shown in the other columns. We found that, even with a small quantity of water (a few litres), the Q decrease is impressive. At water level of 20 cm from the bottom (the outer diameter of the box is about 80cm), only a few broad peaks were observed, with Q values well below threshold.

The situation does not change very much by adding more water so that a global damping of all modes is successfully achieved with a limited quantity of water, what in turn means a limited power loss at the fundamental mode. The same holds for the region between 500 and 1000 MHz, as shown in Table II. Here the effect is stronger, probably due to higher electric fields at the end of the cavity. Anyhow at frequencies aboves 500 MHz the parasitic modes seem less dangerous as calculations have shown [3].

Also, we investigated the effects of demineralised water, which has lower losses at the fundamental frequency and does not produce sediments in the box. The global damping effect is clearly unsatisfactory: as an example, a peak at 270 MHz remained with a Q ≃ 100, even after the box had been completely filled. Also various other modes with Q > 100 were observed. In particular, we noticed a mode a 762 MHz with a Q ≃ 825, probably introduced by the amplifier, which the demineralised water was unable to damp out.

We should perhaps remark that the dieletric-loss factor for the demineralised water used at CERN is about tan $\delta = 0.005$ at 20 MHz, while for tap water tan $\delta = 0.64$ [4], so that in this latter case dielectric losses are considerably higher.

Q measurements at the fundmental mode

A summary of the Q measurements at 19.08 MHz for various conditions is shown in Table III. Clearly the demineralised water proved ineffective, so that the cavity will be operated with tap water, which enables us to control the Q and hence the shunt impedance in a rather simple way. A calibration of the Q value against water height in the box is also shown in Table IV.

RF Losses

We remember the RF power requirements depend on the gap shunt impedance, i.e. the product of the above Q's time the cavity characteristic impedance. This latter value has been calculated with SUPERFISH: 41 ohm. No measurements have been performed to check this calue.

Conclusion

The last measurements on the final cavity confirm the previous results about the possibility of globally damping all unwanted modes. For this purpose the use of tap water seems an effective tool in the low frequency region, also because power dissipation is still tolerable (≈ 8 kW at maximum gap voltage with h = 20 cm). Furthermore, the option of reducing the Q, and hence the shunt impedance, may be useful in case of strong beam loading, in order to enhance the Robinson stability threshold.

TABLE I

			Q with tap water		
f (theory) MHz	Q (threshold)	F (meas.) MHz	empty	10 cm	20 cm
100	180	109	312	130	< 100
200	160	202 209	354 597	264 294	very broad
270	30	270	319	55	-
330	180	not seen (weak coupling?)			
430	650	398	122	-	-
470	130	487	625	325	
490	350	500	576		
520	> 1000	536	144		

TABLE II

	Q (meas.) with tap water			
F (meas.) MHz	empty	10 cm	20 cm	Comments
570	142	-	-	broad, indistinct structure
668	602	-	-	
687	636	-	-	
721	879	-	-	
733	417	408	-	
739	583	-	-	
764	749	291	-	introduced by the amplifier
854	342	-	-	
1075	184	-	-	

TABLE III

Cavity	empty	tap water (full)	dem. water (full)
isolated	6413	3247	6061
with amplifier	4740	2621	4489

TABLE IV

Tap water level (cm)	0	10	20	30	40	50	60	full
Q of cavity + ampli.	4740	3995	3722	3289	3027	2825	2724	2621

References

[1] M. Bell, F. Caspers, K. Hübner, R. Poirier, A. Susini, PS/RF/Note 85-2

[2] S. Giordano, IEEE Transactions on Nucl. Psci. NS-30, 1983

[3] K. Hübner, CERN/PS/lPI Note 84-28

[4] H. Ullrich, private communication

Distribution:

M. Bell
D. Blechschmidt
R. Cappi
J.P. Delahaye
F. Caspers
A. Fiebig
B. Frammery
R. Garoby
K. Hübner
H. Kugler
A. Lévy-Mandel
J.H.B. Madsen
G. Nassibian
R. Poirier
J.P. Potier
L. Rivkin
H. Ullrich
J.D. Warner