TUNING METHOD FOR THE 2π/3 TRAVELLING WAVE STRUCTURES

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Abstract

To build a constant gradient travelling wave structure, one must perform cold tests under a press in order to tune the different cells individually. For the tests to be valid, the test cells must be terminated by shorting planes located in planes of symmetry in which the electric field vector is normal in such a way that the standing wave "trapped" between them is an exact representation of the instantaneous travelling wave one wishes to study. For the TW structure, the cavities are placed three by three under the press. We then try to reduce the contribution of "mixed cells" by adding to one wavelength at 2π/3 mode two-quarter wavelengths. This is possible when the end cells mode at the same frequency is π/2 instead of 2π/3. These end cells are not included in the final assembly. The setting process will be analysed.

INTRODUCTION

Under the press, we have metallic shorting planes at both ends and the frequency control of TW cavities is performed in a standing wave mode. Fig. 1 shows the measurement setting for the cavities' frequency controls under the press together with the equipments needed.

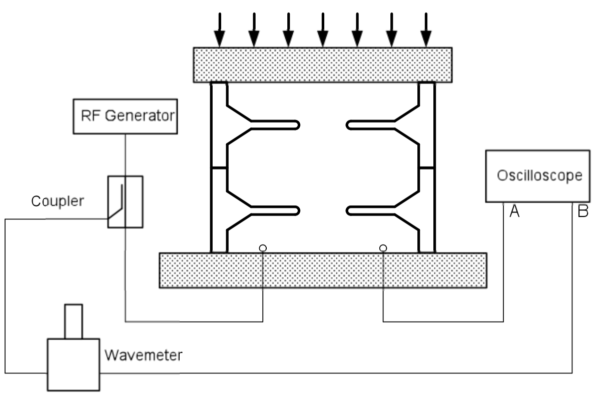

Figure 1: Measurement setting under the press

The frequency controls are made during the process of building TW as well as SW structures. Frequency adjustments on individual cells are of great help as they limit the tuning on the assembled structure to slight localised adjustments. Fig. 1 shows the simplest case of the π/2 mode, for the TW cavities of our structures, where the resonant end cells are made of the two mechanical parts unified as a unique cell in the final assembly. The propagating modes for these three volumes can only be 0, π/2 and π.

For the π/2 mode, the central volume has no field and does not contribute to the frequency determination. The final structure assembly, obtained by reversal of the mechanical parts corresponds to the sequence in the natural order.

In this propagating mode, we can then eliminate the contribution of mixed cells and tune the cavities volumes one by one.

The RF generator covers a frequency band larger than the dispersion curve; we can then observe the three peaks on channel A. We compare it with the desired fixed frequency peak on channel B. The Cavities are then rectified by micromachining and the final tuning, for the TW cavities, is obtained with the plungers positioned at mid-course.

TUNING METHOD

For Three Cavities

For the TW structure, the cavities are put three by three under the press. The propagating modes for these four volumes can only be 0, π/3, 2π/3 and π. Fig. 2 shows the geometry together with the electrical field vectors for the 2π/3 mode [1].

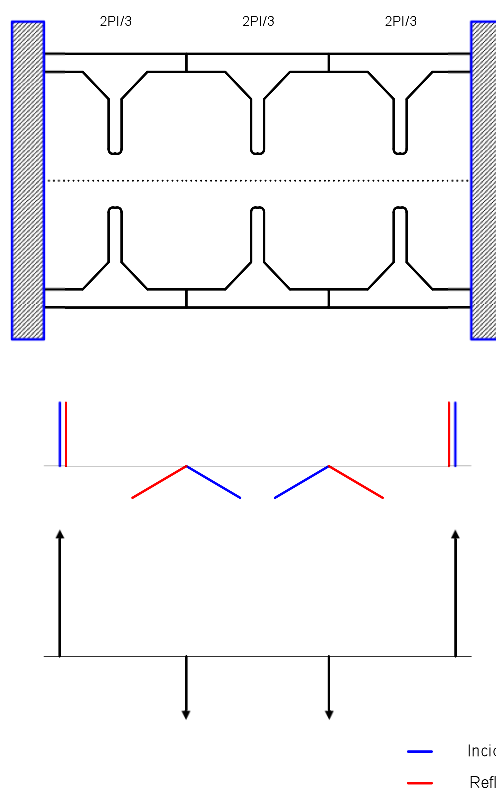

Figure 2: Tuning method for three cavities.

For this propagating mode the electric field is present in all cavities volumes. For a first setting adjustment of the three cavities together, we compare the third peak of channel A to the desired fixed frequency peak on channel

B. In this propagating mode, we cannot eliminate the contribution of mixed cells and we must tune the cavities volumes three by three.

For Five Cavities

We then try to reduce the contribution of "mixed cells" by adding to one wavelength at $2\pi/3$ mode (in the right order of the cavities without reversal of the mechanical parts) two-quarter wavelengths above and below. This is possible when the end cells mode at the same frequency is $\pi/2$ instead of $2\pi/3$. These end cells are not included in the final assembly.

Fig. 3 shows the geometry together with the electrical field vectors for this last setting.

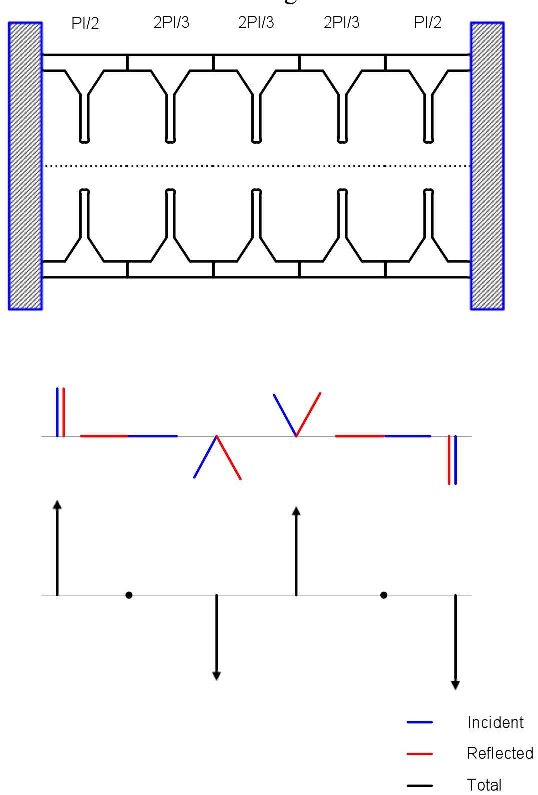

Figure 3: Tuning method for five cavities.

For this mixed propagation mode, the electric field is eliminated in the mixed volumes (volume 2, between the first and the second cavities, and volume 5, between the fourth and the last cavities).

We first adjust the two end cells frequency at the $\pi/2$ mode then we fill in between the three cavities. We compare the fourth peak of channel A to the desired fixed frequency peak on channel B.

This method, with five cavities, has been in use for many years in our laboratory at CGR-MeV and now at PMB plant. However two volumes, between cavities two and four, are checked at the same time. The method provides no means to check individually the frequencies. Compensation between the two volumes can occur.

SUPERFISH SIMULATIONS

This last setting with five cavities under the press was simulated by the well known SUPERFISH code [2].

This code is used extensively to determine RF properties for cylindrically symmetric cavities.

The curve of Fig. 4 represents, for the forth peak of the dispersion curve, the electric field shape along the axis of the five cavities. The diagram represents the geometry as well as the field lines of the setting.

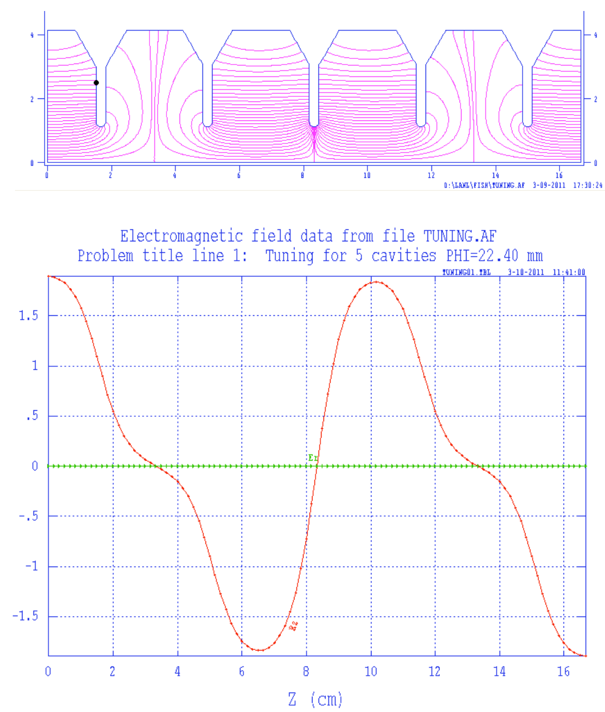

Figure 4: Geometry and electric field for five cavities.

We first simulate the end cells geometry in order to obtain a working frequency equal to 2998.540 MHz for the $\pi/2$ mode. Then we simulate the one period three cells, by adjusting a symmetrical geometry in order to obtain the same working frequency for the $2\pi/3$ mode. Finally, we simulate the whole setting.

Table 1 gives the different mode frequencies obtained with SUPERFISH together with the calculated phase shift per cell. For the fourth mode, the phase shift is equal to $\pi/2$ for the end cells and equal to $2\pi/3$ for the standard cells.

Table 1: Mode Frequencies

Mode	End cell shift °	Standard cell shift °	Freq (MHz)
1	0	0	2954.800
2	0	60	2965.910
3	53.1	84.6	2980.200
4	90	120	2998.520
5	117	162	3020.000
6	180	180	3022.920

SETTING PROCESS

Our in-house code SECTION provides along a travelling wave structure the filling time, the group velocity, the circulating power, the shunt impedance, the electric field and the energy gain. The code uses the beam loading theory, based upon diffusion equation [3] and the S band measurements mainly the ALS structures [4].

Our standard accelerating structure is a travelling wave 2π /3 mode section designed with a constant gradient. The iris diameter varies from 22.4 mm to 16 mm, giving a group velocity c/v_g from 51 to 149 over 96 cells including the couplers cavities ones. The curve of Fig. 5 represents the coupling iris diameter along the structure. For this structure, we have 3 sets of end cells at 20.60, 18.80 and 16.04 mm.

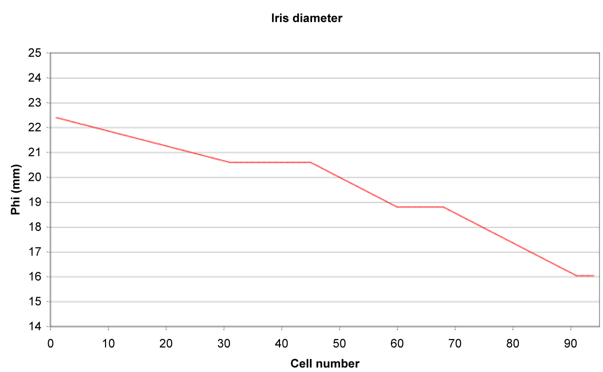

Figure 5: Iris diameter along the structure.

We first tune the cavities three by three under the press. We then reduce the contribution of "mixed cells" by adding to three cavities two end cells. We start this procedure from a constant iris diameter at 20.60 mm and we move to both sides of the structure. The cavities are then tuned two by two.

After the final tuning on the bench for a working frequency equal to 2997.750 MHz for the 2π/3 mode, we disassemble the cavities and we measure the π/2 mode frequencies for the entire structure cell by cell.

The curves of Fig. 6 represent the iris diameter, the measured π/2 mode frequencies and an approximation law (curve in green) of these last frequency measurements.

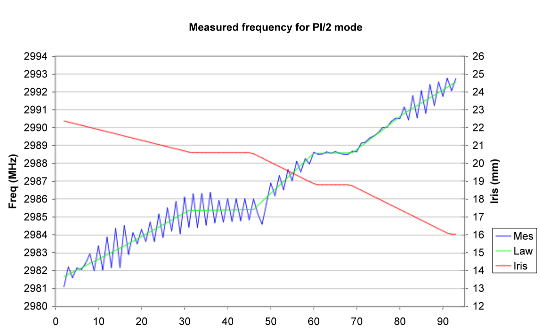

Figure 6: Measured π/2 frequency versus iris diameter.

This last curve is obtained by averaging the measured frequencies.

We can observe an oscillation of the measurements around the last curve obtained. This is probably due, as the tuning of the cells is done two by two, to a small shift in frequency that one compensates from cell to cell.

For a constant impedance structure, as the coupling iris diameter is constant along the whole structure, the frequency shift between the π/2 mode and 2π/3 mode is constant.

In our case, with a constant gradient structure, the frequency shift between these two modes depends on the coupling iris diameter. For a working frequency of 2997.750 MHz for the 2π/3 mode, the measured frequencies are respectively 2981.640 MHz and 2992.550 MHz for an iris coupling diameter of 22.40 mm and 16.04 mm i.e. frequencies shift of 16.110 MHz and 5.200 MHz.

CONCLUSION

This setting process has been done on our last injector for BESSY II [5].

The measured π/2 mode frequencies of all the cells allowed us to obtain an averaged law that will improve, for future injectors, the tuning method for our 2π/3 travelling wave structures.

In fact, we will be able to shorten the tuning time by approaching the definitive volumes in an adjustment based on this π/2 mode frequency where the tuning is performed cell by cell with a better frequency approach.

ACKNOWLEDGEMENT

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REFERENCES

[1] G. Loew and R. Neal, “Accelerating structures”, page 93, Linear Accelerators edited by P. Lapostolle and A. Septier, 1970 North Holland publishing company Amsterdam.

[2] R. Holsinger and K. Halbach, “Properties of the cylindrical RF cavity evaluation code SUPERFISH”, Proc. Of 1976 Proton Linac Conf., Atomic Energy of Canada Limited, Report No. AECL-2600, 122 1976.

[3] J. Leiss, “Beam loading and transient behaviour in travelling wave electron linear accelerators”, page 151, Linear Accelerators edited by P. Lapostolle and A. Septier, 1970 North Holland publishing company Amsterdam.

[4] D. Tronc et al, “Les sections accélératrices”, page 1194, L’onde électrique Vol 49, Fasc. 11-n° :513, December 1969.

[5] A. Setty et al, "Beam dynamics of the 50 MeV preinjector for the Berlin synchrotron BESSY II", IPAC10, Kyoto, Japan, May 2010.