STRUCTURE TUNING AND ITS EFFECT ON HIGHER ORDER MODES[1]

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Abstract

Coarse tuning of multi-cell linac structures is required to achieve the correct accelerator mode frequency and a flat field profile at room temperature. Fine tuning is required to adjust the frequency during operation at low temperatures. Our newly fabricated 1300 MHz CERN/DESY type structures incorporate longitudinal stiffening bars for reduction of microphonic effects. In this paper we evaluate the use of longitudinal rods as a means of coarse tuning and achieving a flat field profile, and report the effect of fine tuning by end cell deformation on Higher Order Modes.

Introduction

We have recently constructed a four cell 1300 MHz CERN/DESY structure incorporating RF measurements and tuning in the fabrication procedure[1]. The individual half cells and beam tubes for the structure were made by die-forming. Room temperature coarse tuning of this structure is accomplished by increasing or decreasing cell lengths using three threaded support rods (Fig. 1) that also play a role in stiffening the structure to reduce microphonic effects. Helium temperature fine tuning is accomplished by adjusting the length of one of the end half cells.

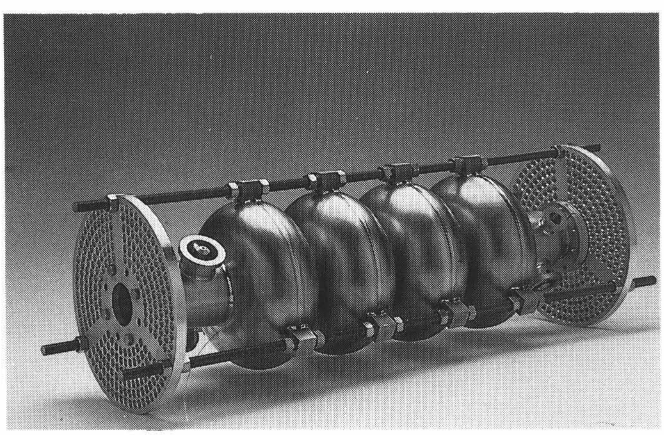

Fig. 1. Four cell CERN/DESY structure with longitudinal rods and end plates.

Tuning of the accelerator mode frequency and profile may produce changes in the Higher Order Mode (HOM) frequencies and profiles. These can have important effects by altering the impedance of some HOMs, and by changing the external loading provided by HOM couplers. In this paper, we evaluate our fabrication tolerances and our coarse and fine tuning schemes with respect to their effect on mode frequencies and field profiles.

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Fabrication Procedure and Tolerances

The fabrication procedure used in construction of the four cell structure has been described elsewhere[1]. As it includes RF measurements and tuning of individual half cell frequencies before making the final equatorial welds, one can expect good control of mode frequencies and field profiles. To achieve a fractional cell frequency tolerance of $\pm$ 1 X 10^{-4} and a fractional structure frequency tolerance of $\pm$ 5 X 10^{-5}, it is necessary to control the final equatorial weld shrinkage to $\pm$ 0.002 inches. Subsequent tuning, using the longitudinal rods shown in Fig. 1, can yield a flat field profile and a structure frequency within $\pm$ 1 X 10^{-5} of the target.

Due to a non-recurring problem in making the final equatorial welds, the fractional cell frequency tolerance was not met. The individual cell frequencies in the as-fabricated structure were determined by measuring the electric field profile in the accelerator mode (Fig. 2a) and modelling the structure as a chain of weakly coupled LCR circuits. Using perturbation theory one can calculate, for each of the four cells, the frequency error that produced the measured electric field profile[2]. The fractional frequency errors were $\pm$ 3 X 10^{-4}.

As fabricated, the field unflatness in the accelerator mode, expressed as the difference between the highest and lowest peak fields on axis divided by the average of the four fields, was 9.1%. If one calculates the total voltage gained by an electron divided by the peak electric field, one finds this ratio has degraded, in the as-fabricated structure, by a factor of 0.96 compared to an ideal structure.

Field profile distortion in the HOMs, expressed as the fractional asymmetry of the highest peak in the profile, is comparable to that seen in the accelerator mode. Although many of the HOMs are well behaved, one longitudinal mode exhibits peak field asymmetry of 8% (Fig. 2c). The trapped mode peak field asymmetry is 2%.

Tuning the Accelerator Mode

As discussed in a previous paper[1], we have installed three threaded support rods on our structure which can be used to tune the cell frequencies by increasing or decreasing cell lengths. As can be seen in Fig. 1, the rods are anchored to the equator of each cell and to end plates which are bolted to the beam tubes. Since these rods are fastened by a combination of nuts and compression fittings, tuning is easily performed by adjustment of the nuts.

Due to the small number of cells involved in this structure, tuning was performed by adjusting each cell length while repeatedly monitoring the field profile and total frequency of the structure. After only one iteration of this process, the field had been flattened to 1% flatness in the electric field with a fractional frequency error less than $\pm$ 10^{-5} (Fig. 2a).

To gauge the effect of this tuning on the frequencies and field profiles of the higher order modes of the structure, we obtained frequency and field profile data for all higher order modes below the beam tube cutoff frequencies before and after tuning. URMEL[3] calculations were also performed to determine the expected shape of the field profiles. The measured profiles before tuning (solid line) and after tuning (dotted line) are presented for some of the longitudinal modes in Fig. 2 and some of the dipole modes in Fig. 3. The modes presented are the ones that showed the most significant changes in their field profiles during tuning. Coincidentally, this set of modes includes the highest R/Q' dipole mode (Fig. 3b), and the dipole mode with the lowest beam breakup threshold current, I_s (Fig. 3c). The higher order mode frequency changes resulting from tuning were less than 1 MHz for all longitudinal modes, and less than 3 MHz for all dipole modes.

As can be seen from Figs. 2 and 3, the tuning procedure that led to a flat field profile in the accelerator mode, did not improve the field profile in the higher order modes. The changes in higher order mode profiles were small and most often they resulted in a profile more asymmetrical than before tuning. The field profile of the trapped mode did not change significantly.

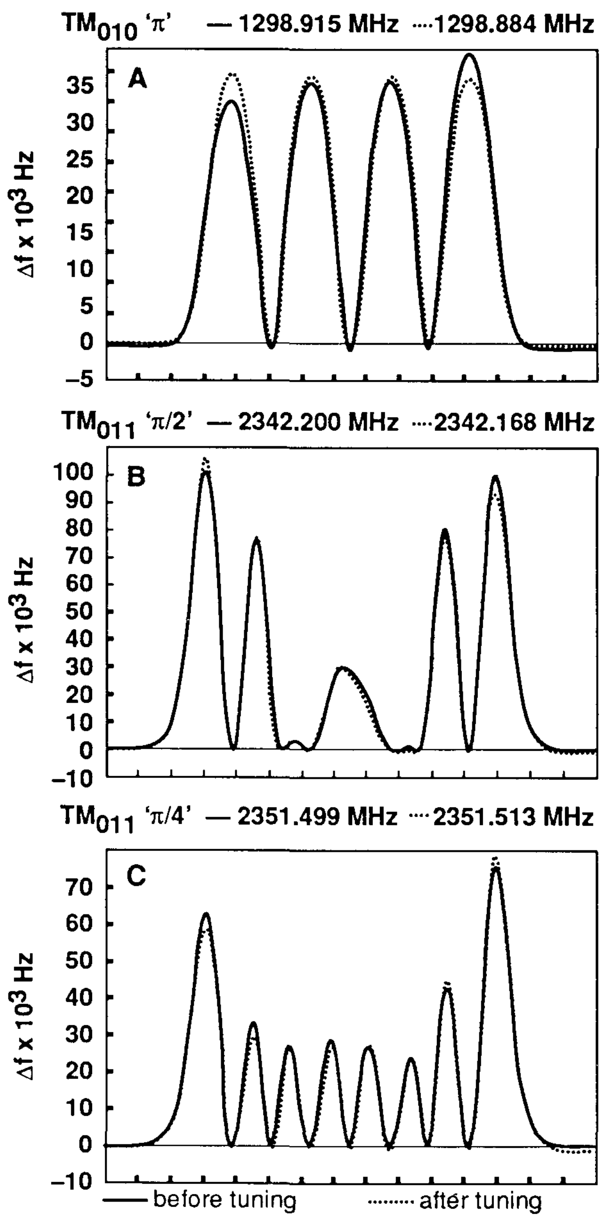

Fig. 2. Field profiles of some longitudinal modes before and after tuning of the accelerator mode(2a).

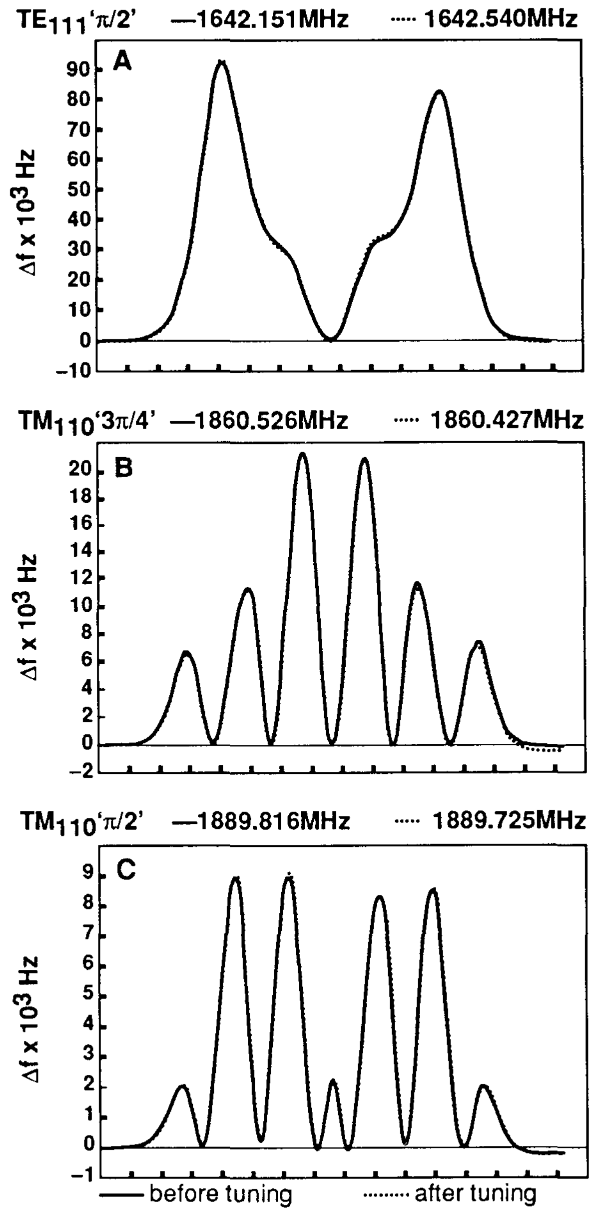

Fig. 3. Field profiles of some dipole modes before and after tuning of the accelerator mode.

End Half Cell Tuning

When the structure is cooled to helium temperature for operation, small frequency changes will be required to achieve the correct working frequency. One scheme for doing this is to tune one of the end half cells of the structure by deforming it in the longitudinal direction. This tuning will have the undesired effect of causing field profile unflatness in the accelerator mode, and causing frequency shifts and field profile changes in the higher order modes.

To investigate these effects, we compressed the right hand end half cell .027 inches, causing a shift in the accelerator mode frequency of -100 kHz, and recorded the structure mode frequencies and field profiles before and after this change. With an expected uncertainty in structure frequency at helium temperature of ± 1 X 10^{-5}, we will provide a tuning capability of ± 2 X 10^{-5} or ± 26 kHz. This is a factor of four smaller than the change produced in these measurements. The field profiles for the same six modes shown previously are given in Figs. 4 and 5. The modes that showed the most change in field profile are the accelerator mode (TM_{010} π-mode, 1299 MHz) and the TM_{011} $\pi/4$-mode at 2351 MHz. The frequency shifts for all modes below beam tube cutoff are less than 0.5 MHz.

From the measurements, one can calculate the degradation one might expect from tuning the structure frequency by 26 kHz. The field unflatness in the accelerator mode profile as a result of tuning the mode by 26 kHz is 3%. The field asymmetry generated in the TM_{011} '$\pi/4$' mode is 7%.

We have paid special attention to the effects of tuning one end half cell on the external coupling to the trapped mode and found no significant change in coupling as a result of tuning the accelerator mode by 200 kHz. We also terminated the structure with a beam pipe extension containing a movable short and measured the coupling to the trapped mode as the short was moved out from the end of the beam pipe. Once again, no noticeable change in coupling was measured.

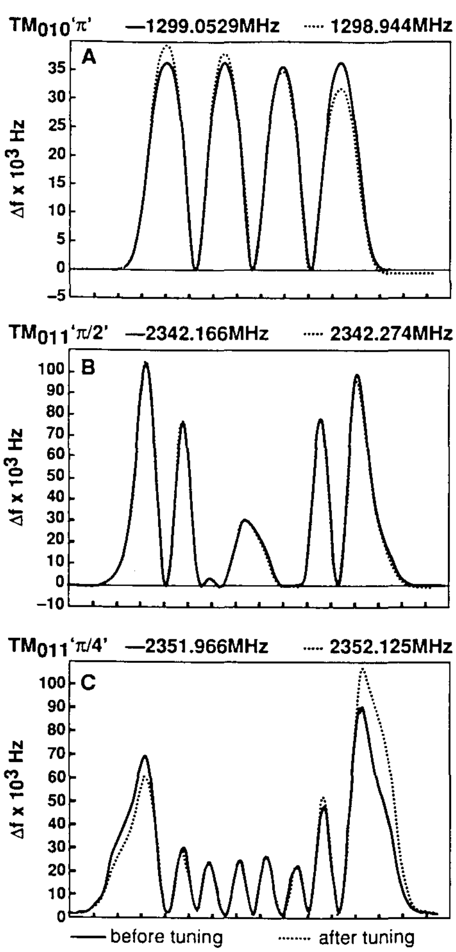

Fig. 4. Profiles of selected longitudinal modes before and after end cell tuning.

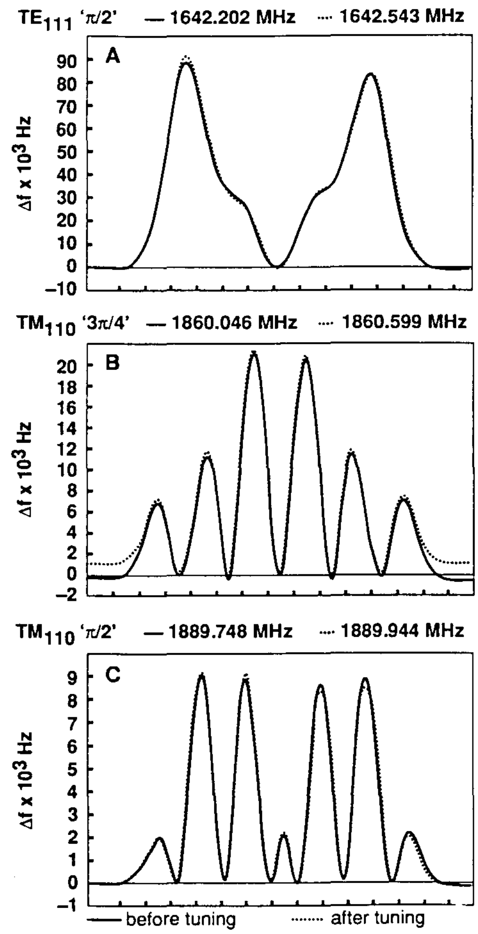

Fig. 5. Profiles of selected dipole modes before and after end cell tuning.

Conclusions

We have shown in our four cell structure that tuning of the accelerator mode by means of longitudinal rods is both simple and effective in achieving a specified accelerator mode frequency within ± 10^{-5} and a field profile flat within 1%. Field profile asymmetries in the HOMs of the as-fabricated structure are comparable to those in the accelerator mode. Tuning of the structure to flatten the accelerator mode profile does not remove asymmetries in the HOMs.

End half cell tuning of the accelerator mode frequency by ± 2 X 10^{-5} in a four cell structure leads to a marginally acceptable degradation of the field profile in the accelerator mode and the HOMs. For structures of more than four cells, fine tuning should involve both end cells to avoid unacceptable distortion of the mode.

References

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