RF TUNING AND FABRICATION STATUS OF THE FIRST MODULE FOR J-PARC ACS

H. Ao*, T. Morishita, A. Ueno, K. Hasegawa, Y. Yamazaki, JAERI, Ibaraki, Japan
M. Ikegami, KEK, Japan, V. Varamonov, INR, Moscow, Russia

Abstract

J-PARC Linac starts with 180-MeV SDTL temporary, and it is upgraded to 400-MeV with 21 ACS (Annular Coupled Structure) modules and two ACS bunchers and two debunchers [1]. First buncher module is under fabrication, and second buncher and a few accelerating modules are also planed until FY2006. The first ACS module consists of two 5-cells ACS tanks and a 5-cells bridge cavity for the buncher module. Three RF tuners are installed to the bridge cavity for fine RF tuning. An operating frequency should be tuned to 972 MHz within the fine-tuning range before a brazing process in a factory. The tuning procedure has been studied with RF simulation analysis and cold-model measurements for ACS and bridge cells [2]. This paper describes RF tuning results, fabrication status and related development items.

INTRODUCTION

The first ACS (Annular Coupled Structure) module has been developed from Apr.2002. Final dimensions for machining were fixed in the summer of 2004 through various R&D, and then we started the mass product of cells for two 5-cells ACS tanks.

From the end of November 2004, two end-cells and two ACS half-cells were measured for RF properties, which were the first mass produced ACS cells for a first buncher. RF tuning procedures are following, first two end-cell are tuned for 971.9 MHz, secondly the frequency of two ACS half-cells are measured and it shows 973.4 MHz, and finally the two end-cell and two half-cell are stacked together to measure total frequency. It is 971.7 MHz, which is still lower than the minimum frequency of 971.9 MHz in the cell components.

The accelerating gap length and nose cone design of the end-cell are exactly same as that of periodical ACS cell. The frequency of the ACS end-cell should be designed to the operating frequency without a coupling slot, so that we arranged the position of the outer oblique wall just like as extending the volume of the end-cell. It compensates the magnetic flax into the coupling cell for the periodical ACS section. From the viewpoint of a total accelerating voltage, at the beam port side of the end-cell, the boundary condition of a beam port is not fixed as the periodical section and the electric field expands to a beam port. The value of E0T is calculated by MAFIA and compared to that of the periodical region.

* aohi@linac.tokai.jaeri.go.jp

We also discuss about the first RF measurements of these ACS cells. The machining process of the first RF tuning is under going in a factory.

FREQUENCY DROP AT END-CELL

We consider three case of the resonant frequencies for the end-cell only, the regular cell in the periodical structure and the combination of these cells. The frequency of the end-cell is adjusted to one of the regular cell as close as possible in MAFIA analysis. The frequency adjusting error between the end-cell and the regular cell are due to the roughness of the mesh size for the fine frequency tuning and the much computing time for iteration of the 3D analysis. Figure 1 shows the MAFIA drawings of the end-cell, the regular cell and the combination of these cells.

Table 1: MAFIA analysis for end-cell and regular-cell connection

MAFIA			Meas.
β	0.556	0.7114	$\beta = 0.556$
End and Regular	969.494	972.909	971.73
Regular only	970.077	972.843	973.38
End only	970.160	973.499	971.90
Ave.	970.119	973.171	972.64
drop	-0.625	-0.262	-0.91

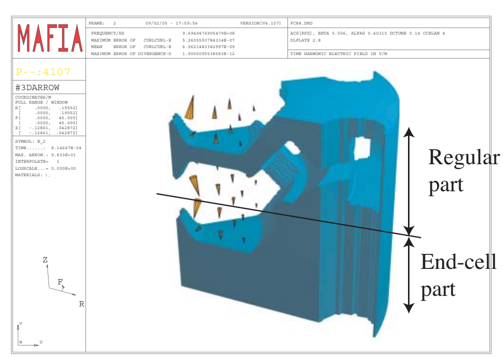

Figure 1: Input shape of MAFIA analysis

Figure 3 also shows the accelerating field (Ez) along the z-axis of the beam-line, it included the transit time factor T.

These analysis show the effective accelerating voltage

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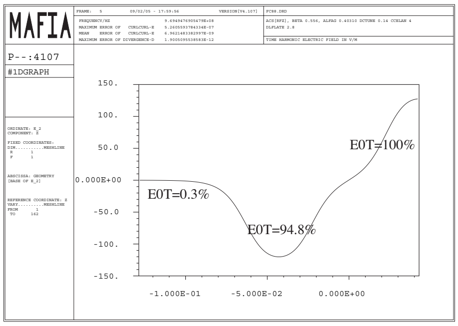

Figure 2: Field distribution E_z of $\beta = 0.556$

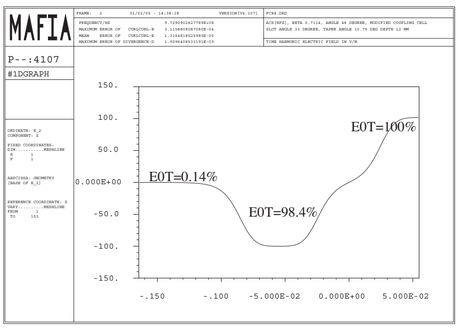

Figure 3: Field distribution E_z of $\beta = 0.7114$

E0T at the end-cell are 94.8% and 98.4% for beta=0.556 and 0.7114 respectively.

SETUP AND ANALYSIS OF RF MEASUREMENT

End-cell and short plate

We summarized the setup and the procedure of RF measurement. The two end-cells are stacked with themselves or two short plates. (See Fig.4)

Equations including an effect of a short plate, the measured frequencies are defined as follows:

$$\begin{aligned} f(\text{endA, shortA}) &= f(\text{endA}) + \Delta_{shortA} \\ f(\text{endB, shortA}) &= f(\text{endB}) + \Delta_{shortA} \\ f(\text{endA, endB}), &= \frac{f(\text{endA}) + f(\text{endB})}{2} \end{aligned}$$

Here, $f(1, \text{shortA})$ is the frequency of stacked cell and short plate, $f(1)$ is one of a cell-1 and Δ_{shortA} is one of a short plate. The other notations mean similarly. We also measured about the short-B. The effect of a short plate should be corrected, because that a short plate is not perfect plane, even though the surface of short-A and B were ground into 0.005 mm flatness. From these equations, we get

$$\begin{aligned} \Delta_{shortA} &= \frac{f(\text{endA, shortA}) + f(\text{endB, shortA})}{2} \\ &\quad - f(\text{endA, endB}) \end{aligned}$$

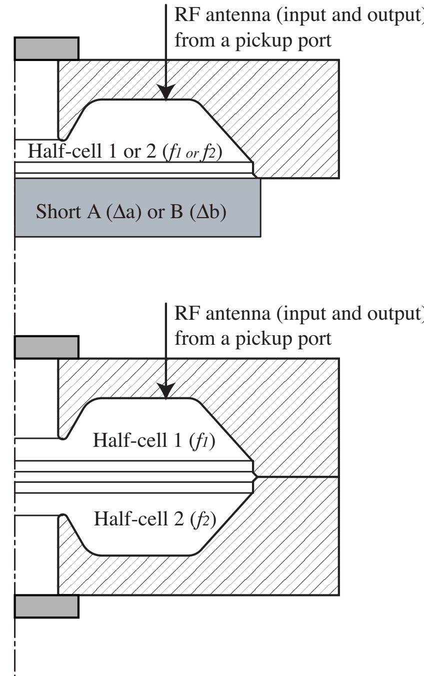

Figure 4: Setup of end-cell RF measurement

$$\begin{aligned} f(\text{endA}) &= f(\text{endA, shortA}) - \Delta_{shortA} \\ f(\text{endB}) &= f(\text{endB, shortA}) - \Delta_{shortA} \end{aligned}$$

From these measurements we fixed the frequencies of the short-A and B that are also used for measurement of a regular cell. Table 2 shows the frequencies of the buncher endcells and the short plates after frequency tuning.

Table 2: Measured frequencies of the end-cells and the short plates (All frequencies are corrected at 27°C vacuum.)

β=0.556			
End-cell A	971.90	Short plate A	-0.033
End-cell B	971.91	Short plate B	-0.030
			[MHz]

Regular cell

We have studied several types of measurement setups for a regular cell, consequently, we select following: for an accelerating cell, we stack a regular cell with a short plate, because that it has mirror symmetry at the center of an accelerating cell, and for the coupling cell, we use a detune method in an accelerating cell. Figure 5 shows the schematic view of the setup.

The total frequency is also defined as an average of each component:

$$f(\text{shortA, cell1, cell2, shortB}))$$

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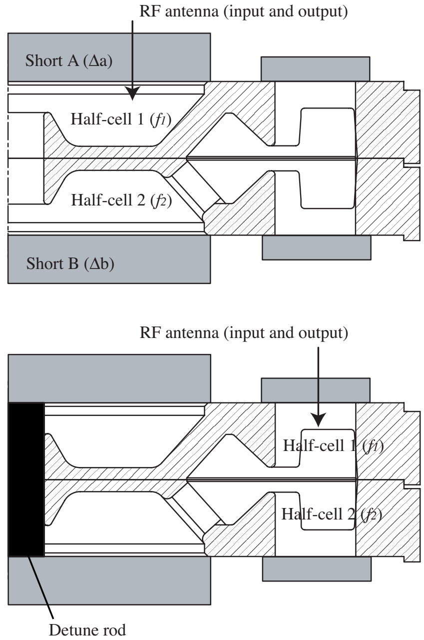

Figure 5: Setup of regular-cell RF measurement:(Upper) Accelerating mode, (Lower) Coupling mode with an electric and electric (EE) boundary

$$= \frac{f(\text{cell1}) + \Delta_{shortA} + f(\text{cell2}) + \Delta_{shortB}}{2}$$

The two short plates are used for all measurement, thus the notation $f(\text{shortA})$ and $f(\text{shortB})$ are omitted and $f(\text{cell1})$ is simplified to $f(1)$, then we get

$$f(1,2) = \frac{f(1) + f(2) + \Delta_{shortA} + \Delta_{shortB}}{2}$$

If we arrange the combination of cells, the half-cell frequencies are solved from follow equations:

$$f(1,2) = \frac{f(1) + f(2) + \Delta_{shortA} + \Delta_{shortB}}{2} \quad (1)$$

$$f(1,3) = \frac{f(1) + f(3) + \Delta_{shortA} + \Delta_{shortB}}{2} \quad (2)$$

$$f(2,3) = \frac{f(2) + f(3) + \Delta_{shortA} + \Delta_{shortB}}{2} \quad (3)$$

$$f(1,4) = \frac{f(1) + f(3) + \Delta_{shortA} + \Delta_{shortB}}{2} \quad (4)$$

From these equations, we get

$$f(1) = f(1,2) + f(1,3) - f(2,3) - \frac{\Delta_{shortA} + \Delta_{shortB}}{2} \quad (5)$$

$$f(2) = 2f(1,2) - f(1) - \Delta_{shortA} - \Delta_{shortB} \quad (6)$$

$$f(3) = 2f(1,3) - f(1) - \Delta_{shortA} - \Delta_{shortB} \quad (7)$$

There are four patterns of cell combination, even though the solution $f(1)$, $f(2)$ and $f(3)$ could be obtained without Eq.(4). This is because that the number of regular half-cell is always even, so it is easy to make a group of half-cell in arrangement.

The buncher cavity consist of two accelerating tanks, and the tank consists of eight half-cells and two end-cells. Thus, these half-cells were separated into two groups, and then the frequencies of the four patterns were measured. Table 3 summarizes these results.

Table 3: Initial half-cell frequencies of the regular cells

Cell ID	acc.mode	coup.mode (EE-boundary)
Tank No.1		
A1	973.33	980.66
B1	973.37	980.79
C1	973.38	980.59
D1	973.41	980.98
E1	973.36	980.68
B2	973.35	980.63
C2	973.35	980.89
F1	973.38	981.53
Tank No.2		
A2	973.38	980.85
B3	973.26	980.75
C3	973.42	980.90
D2	973.38	980.98
E2	973.31	980.81
B4	973.27	980.49
C4	973.48	981.16
F2	973.46	981.48

SUMMARY

We reproduce the end-cell frequency drop on the MAFIA analysis. The drop means that the frequency of 971.7 [MHz] including the two end-cells and two half-cells is lower than 971.9 MHz of the minimum frequency of the cell components. It is caused by an irregular field distribution, for example, $E_r, E_f \neq 0$ at the cross section of an accelerating gap center.

The $E0T$ values were analyzed. It shows -5.3% drop for a low beta. The field distribution should be checked after assembling.

The regular cell RF measurement and tuning for the buncher are going on. Accelerating mode frequency should be tuned for the operating frequency of 972 MHz. The tuning process will repeat several times for fine RF correction.

REFERENCES

[1] V. V. Paromonov, ”The Annular Coupled Structure Optimization for JAERI/KEK Joint Project for High Intensity Proton Accelerators”, KEK Report 2001-14(2001)

[2] H. Ao et al. ”Cold-model Tests and Fabrication Status for J-PARC ACS”, Proc. of the 2004 Linac Conf., August 2004