RF CHARACTERIZATION OF DTL PROTOTYPE

Shweta Roy, S V L S Rao, Rajni Pande, Piyush Jain, Sumit Garg, Gireesh Singh,
S. Krishnagopal and P. Singh
LEHIPA Project, Physics Group
Bhabha Atomic Research Centre, Mumbai-400085

Abstract

The detailed physics design of the 352.21 MHz Drift-Tube Linac (DTL) for the Low Energy High Intensity Proton Accelerator (LEHIPA) [1] has been performed. To validate this design, a 1.2 m long DTL prototype, comprising the first 16 cells, was fabricated. It consists of an MS tank electroplated with copper, 17 drift tubes and 3 tuners made of aluminium. The effect of tuners on the resonant frequency was studied. A bead pull test was performed to measure the field and the effect of tuners on the field flatness was also studied. Detailed simulation studies have been done in order to understand the effect of various DTL dimensions on the resonant frequency. The results of the measurements and simulations are presented in this paper.

INTRODUCTION

The DTL, at 352.21 MHz, has been designed to accelerate the proton beam from 3 MeV to 20 MeV. The total length of the DTL is 12.86 m and it will be built in eight tanks, each of length about 1.51 m. Each tank will consist of 3 tuners, 2 vacuum ports and two RF ports. Postcouplers will be used for field stabilization. To validate these simulations it was decided to fabricate a 1.2 m long prototype of the DTL containing the first 16 cells of the first DTL tank.

Fig. 1. A photograph of the DTL prototype.

The 1.2 m long DTL was simulated in MDTFISH [2]. The frequency was found to be 352.206 MHz for a tank diameter of 52 cm without 3D features. It was planned to put 3 tuners of diameter 12 cm each in this 1.2 m prototype of the DTL. The tuning range of the tuners has been calculated [3] using CST Microwave Studio [4] and is found to be around 2.8 MHz. Nominally the tuners will be inserted half-way, *i.e.* to a depth of 5.5 cm, so that the frequency can be tuned in both the directions. The diameter of the DTL cavity, corrected for stems and tuners inserted half-way, is calculated to be 52.6 cm. The DTL prototype has one vacuum port and two RF ports. The shifts in frequency due to vacuum and RF ports have been calculated to be 7 kHz and 20 kHz respectively, which are negligible. No post couplers were provided in this prototype. The DTL prototype is shown in Fig. 1.

RF MEASUREMENTS

Frequency measurements were done on the DTL prototype using a Vector Network Analyzer. The measured frequency in air with all tuners flush was 348 MHz. The resonant frequency with all the 3 tuners inserted at 10.5 cm was found to be 350.745 MHz. The Q-value was measured to be 2,500. The measured and simulated frequency shifts as a function of tuner depth are shown in Fig. 2. It can be seen that the agreement is good and the slopes of the lines are almost equal.

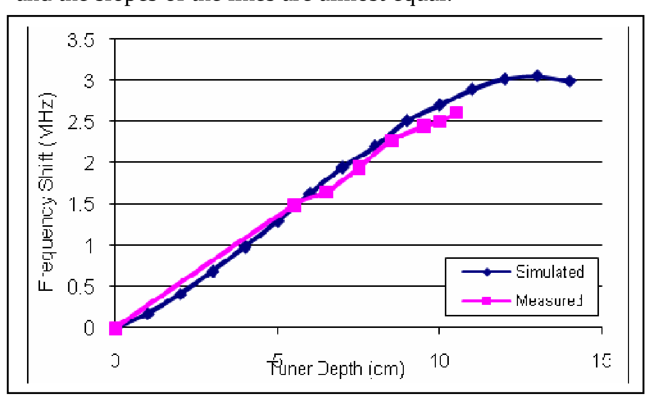

Fig. 2. Measured and simulated frequency as a function of tuner depth.

In order to understand the difference between the designed frequency and measured frequency in the DTL prototype, more simulations were done to study the effect of various DTL dimensions which could have been different in the fabricated DTL prototype. Simulations were also done to take into account the change in frequency due to the medium being air instead of vacuum which was assumed in the original simulations. The effects of tank diameter, drift tube diameter and bore radius on the frequency were studied using SUPERFISH and CST Microwave Studio. The frequency decreases linearly with tank diameter as shown in Fig. 3. The rate of change of frequency calculated with SUPERFISH and CST MWS are -4.7 MHz/cm and -4.9 MHz/cm.

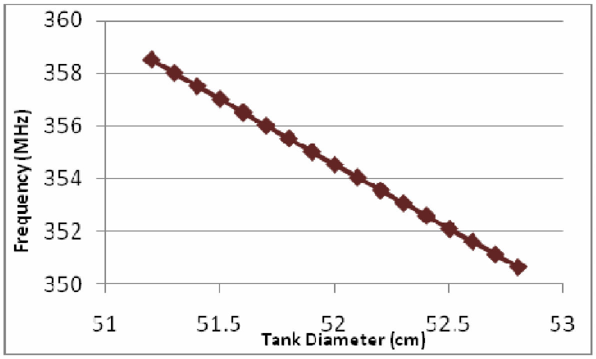

Fig.3. Frequency vs. tank diameter (CST MWS).

The resonant frequency decreases linearly by -8.6 MHz/cm, with varying drift tube diameter. By increasing the bore radius, the resonant frequency increases linearly by 2.46 MHz/cm. The effect of varying stem radius on frequency was also studied. The frequency increases linearly with stem radius by 1.71 MHz/cm. The effect of resonant frequency on relative permittivity on resonant frequency has been studied using SUPERFISH and is plotted in Fig. 4.

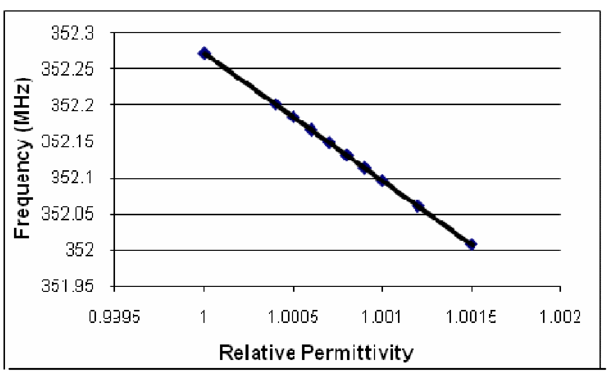

Fig. 4. Frequency as a function of relative permittivity of the medium.

The frequency of the 1.2 m prototype simulated in MDTFISH was 352.206 MHz. The drift tube dimensions in the fabricated prototype were not exactly the same as the simulated one. The simulations were done with the fabricated dimensions and the frequency was found to be 352.2710 MHz. The simulated frequency with air as the medium was found to be 352.165 MHz. The frequency corrected for the actual tank diameter, stem and tuner radius and with air as the medium is calculated to be 351.729 MHz. The simulation model in CST MWS assumes symmetry in all cells and the two end drift tubes had half stems connected to them, whereas in the actual case, the end half stems are not present. This produces a frequency shift of about 59 kHz. Taking into account all the above corrections, the frequency of the fabricated prototype should have been 351.67 MHz with all three tuners inserted to a depth of 5.5 cm, i.e., half-way in. However the frequency with this tuner position has been measured to be 349.49 MHz. In order to compensate this 2.18 MHz difference in frequency, either the tank diameter should be reduced by 0.445 cm or the drift tube diameter should be reduced by 0.253 cm.

BEAD PULL MEASUREMENTS

In order to measure the electric field on the axis, bead pull measurements were done on the DTL prototype. A dielectric bead was passed along the axis of the DTL and phase measurements were done using a VNA. The phase shift of S_{21} is translated to frequency shift using the formula

$$Q\frac{\Delta\omega}{\omega} = \frac{1}{2}\tan\varphi$$

where Q is the quality factor of the cavity.

The field in each gap is then calculated using the Slater Perturbation theorem. The field flatness was studied by changing the depth of the tuners. The tuner positions were adjusted to obtain a flat field in all the gaps. Fig. 5 shows E/E_{avg} as a function of gap number for various tuner positions. The field flatness was found to be within ±2% for tuner insertions of 3.75 cm, 2.95 cm, and 10.05 cm and for 3.5 cm, 1.5 cm, 8.5 cm. The field in first and last gap was about 4 % off from the average value.

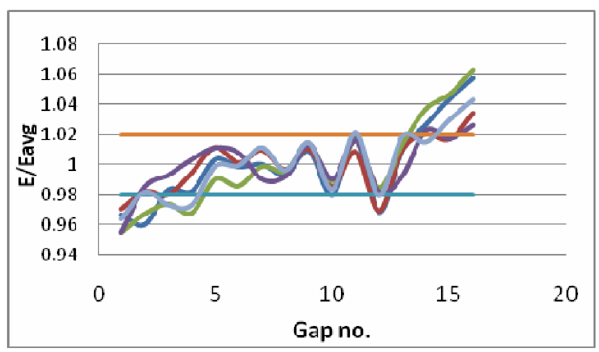

Fig. 5. E/E_{avg} vs. gap number.

REFERENCES

[1] P. Singh *et al.*, Accelerator development in India for ADS programme, Pramana-J.Phys., **68,** 331 (2007).

[2] J. H. Billen and L. M. Young, *POISSON SUPERFISH*, LA-UR-96-1834, LANL.

[3]Shweta Roy *et al.*, Frequency Analysis and Field Stabilization of LEHIPA DTL Prototype, InPAC 2009.

[4] CST Microwave Studio software.