Trasco RFQ Cavity Design and Model Measurements

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Summary

- Reasons for an RFQ cold model: how was it designed?
- E-Field Measurement: Experimental Technique and Experimental Apparatus
- First Measurements
- RFQ Transverse Section: a Possible Solution

RFQ Cold Model

- Bench for Cavity Perturbation and Electric Field Stabilization Tests

  - no electrodes modulation needed
  - low power

- 3 Segments 1m long; 12 tuners per segment

  - 3 tuners per sector (A_{ij}, i=1 to 4, j=1 to 3)

- Mechanical tolerances required: better than 0.05 mm

- Construction, Assembling and Handling

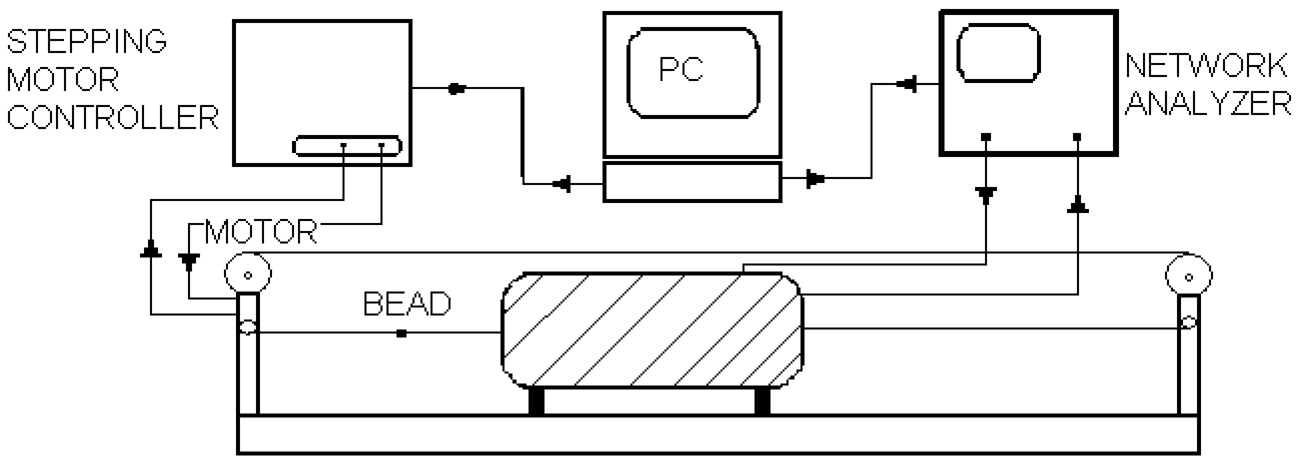
  - Easy machining
  - Flexibility
  - End cell and coupling cell electrodes dimensions are over-estimated; during tests they can be easily machined in order to get the right frequency

Experimental Technique

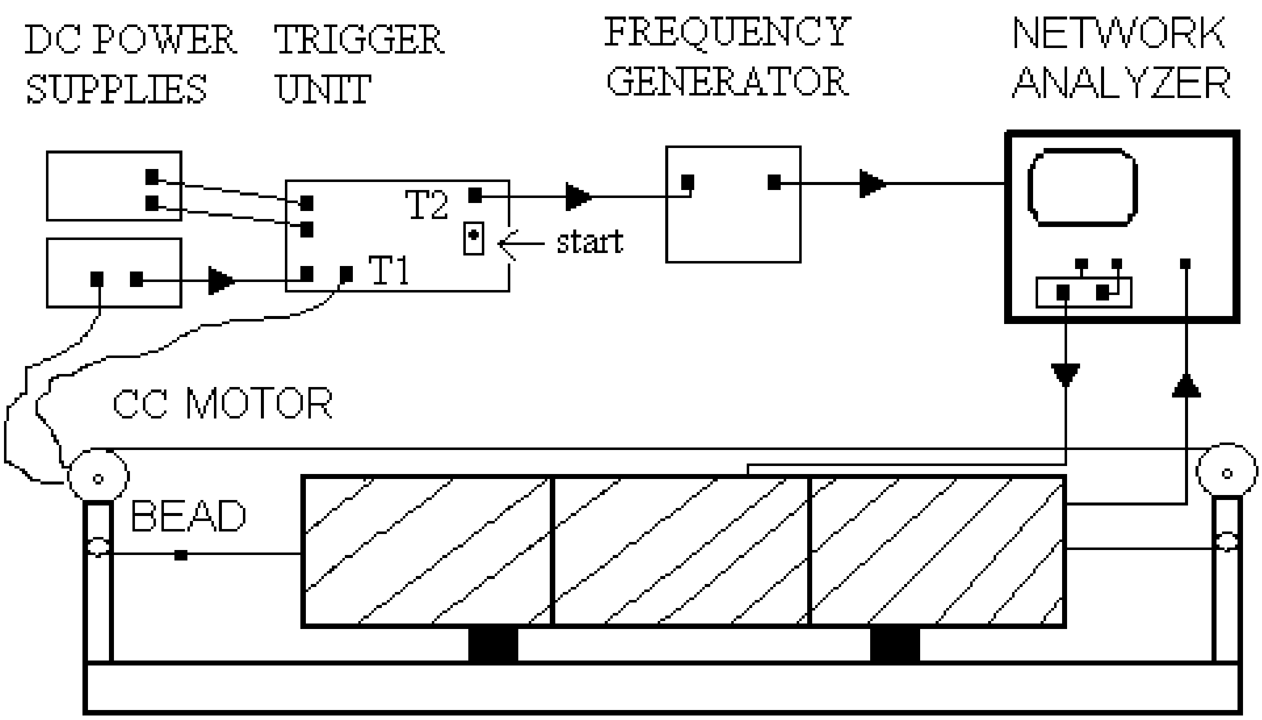
- Resonant Perturbation
  - a perturbing object inside a cavity cause a change in the stored energy and a shift in the resonance frequency
  - dielectric perturbing bead: $\frac{\Delta\omega}{\omega} = -\frac{K}{U} E^2$, where U is the cavity energy in the non perturbed case
- Measurement
  - direct measurement of frequency
  - phase shift measurement: $\Delta\phi = 2Q\frac{\Delta\omega}{\omega} = -\frac{K_1}{U} E^2$
  - Field flatness: $\frac{\Delta E}{E} = 0.5\frac{\Delta(\Delta\phi)}{\Delta\phi}$

Experimental Apparatus

- Frequency Shift measurement
  - bead pulling system
  - network analyzer
  - stepping motor+ motor controller
  - pc
  - temperature stabilizing system
- Advantages
  - very high resolution



- Phase Shift measurement
  - bead pulling system
  - network analyzer
  - cc motor
  - trigger system
- Advantages
  - faster: in our case 10 sec/m; we are interested in low Fourier space harmonics
  - no need of temperature stabilizing system
  - no need of motor controller or pc
  - phase variation along the structure is plotted on the N.A. screen



Experimental Results

- Phase Plot: what do we measure?
- Segments and Tuner tests
- End Cell and Coupling Cell Tuning
  - we must tune at the frequency ν_0=352.0 MHz with the tuners at the nominal position

Phase Plot: what do we measure?

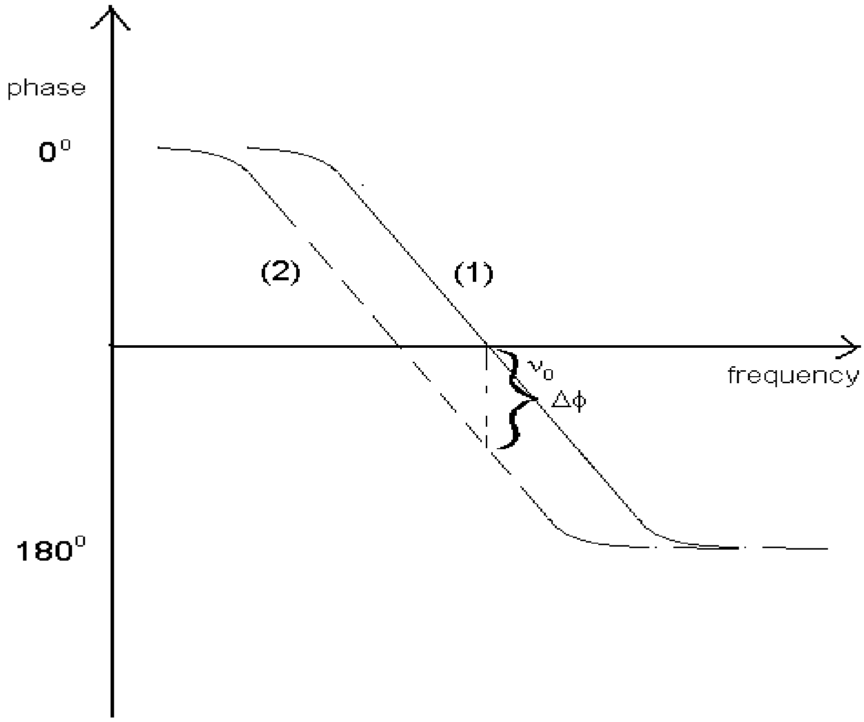


FIG.1 Phase shift with respect to excitation of a resonator

1) We measure the mode frequency ν_0 in the unperturbed case (without bead);
2) we fix the N.A. in zero span mode then we start the motor allowing the bead going through the RFQ;
3) bead is placed inside RFQ touching 2 of the for electrodes. No wire oscillations is permitted.
4) due to the dielectric bead, phase plot shifts towards lower frequency then a smaller phase is related to the frequency ν_0;
5) electric field (square module) variation along the structure is directly shown on N.A. screen

Segments and Tuner tests

- Spectrum for the 1st segment: no end cell tuning
  - ν_{1dip}= 345.190 MHz, ν_{1quad}= 350.587 MHz,
    ν_{2dip}= 379.149 MHz, ν_{2quad}= 379.456 MHz
    Q_{1quad}=1655
  - $\nu_{2quad} = \sqrt{1+\frac{1}{4}\cdot\left(\frac{\lambda}{l}\right)^2}\,\nu_{1quad}$ = 381.33 MHz: *0.5% error*
- Tuner test: 0.01 MHz/mm per tuner
  - Good agreement with Sfish simulation: 12 tuners per segment were forseen, 3 per RFQ section (i=1to 4 sectors, j=1to 3 tuners). In order to have the resonant frequency $\nu_{1quad} = 352.0\,\mathrm{MHz}$, all tuners should be inserted for 13 mm (initial or 'nominal' tuner position) when tuning has been accomplished.
- Comparison among segments: resonant frequency
  - ν_{1st}= 350.625 MHz, ν_{2nd} = 350.525 MHz,
    ν_{3th}= 350.615 MHz

1st Segment End Cell Tuning

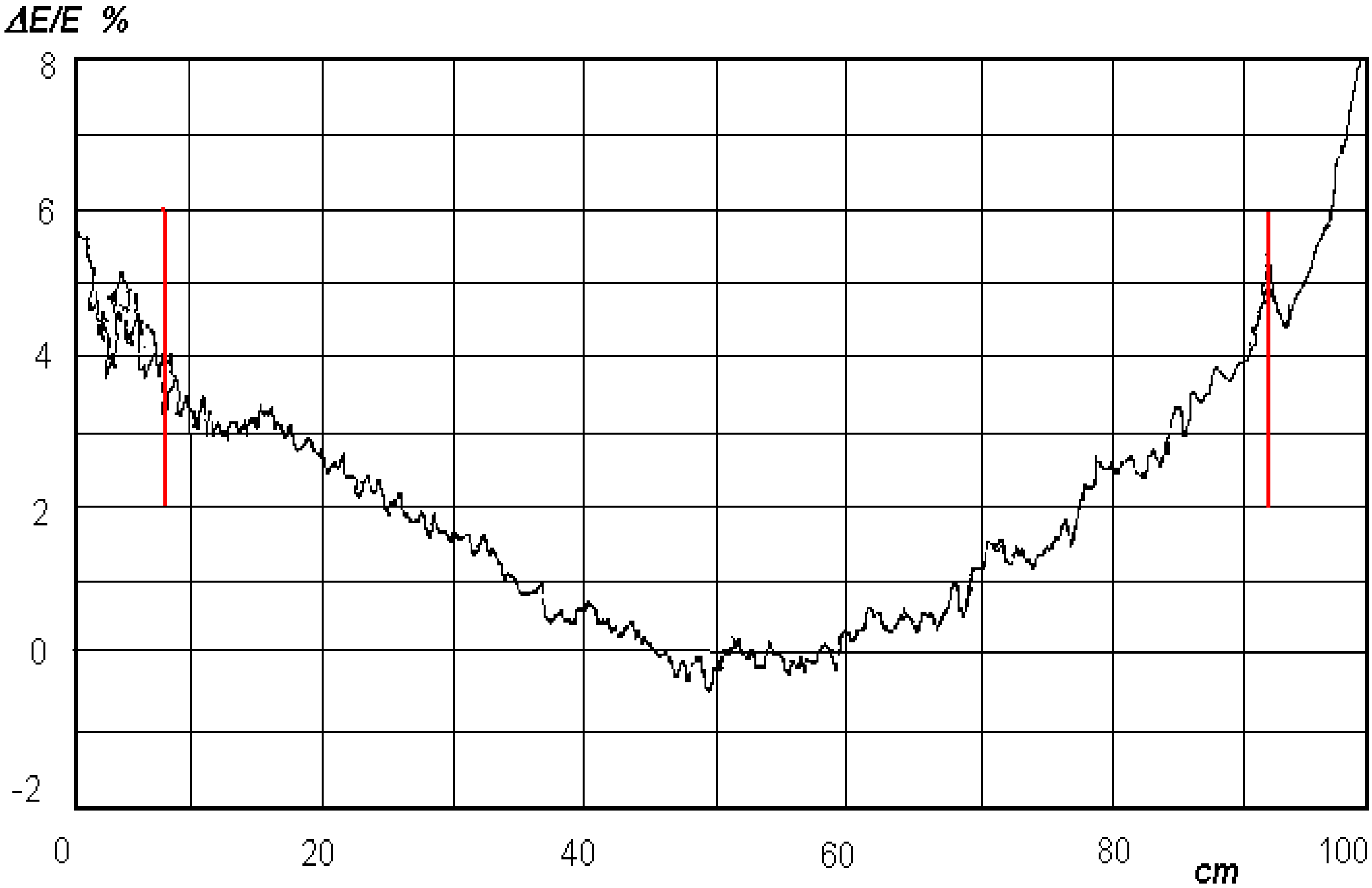


FIG.2 Longitudinal variation of E-field intensity ΔE/E. Mode Frequency is ν_0=350661275 Hz. Orange lines shows the end of end cell electrodes

- Tuners: A_{ij}= 5.3cm
- Mode frequency is lower than it should be
- End cells are tuned at a too low frequency with respect the rest of RFQ segment. Actually, the higher is the measured field in a given position along the structure, the bigger is the phase difference between the unperturbed (without bead) and the perturbed case;
- Tuners near end cells should be inserted more

1st Segment End Cell Tuning

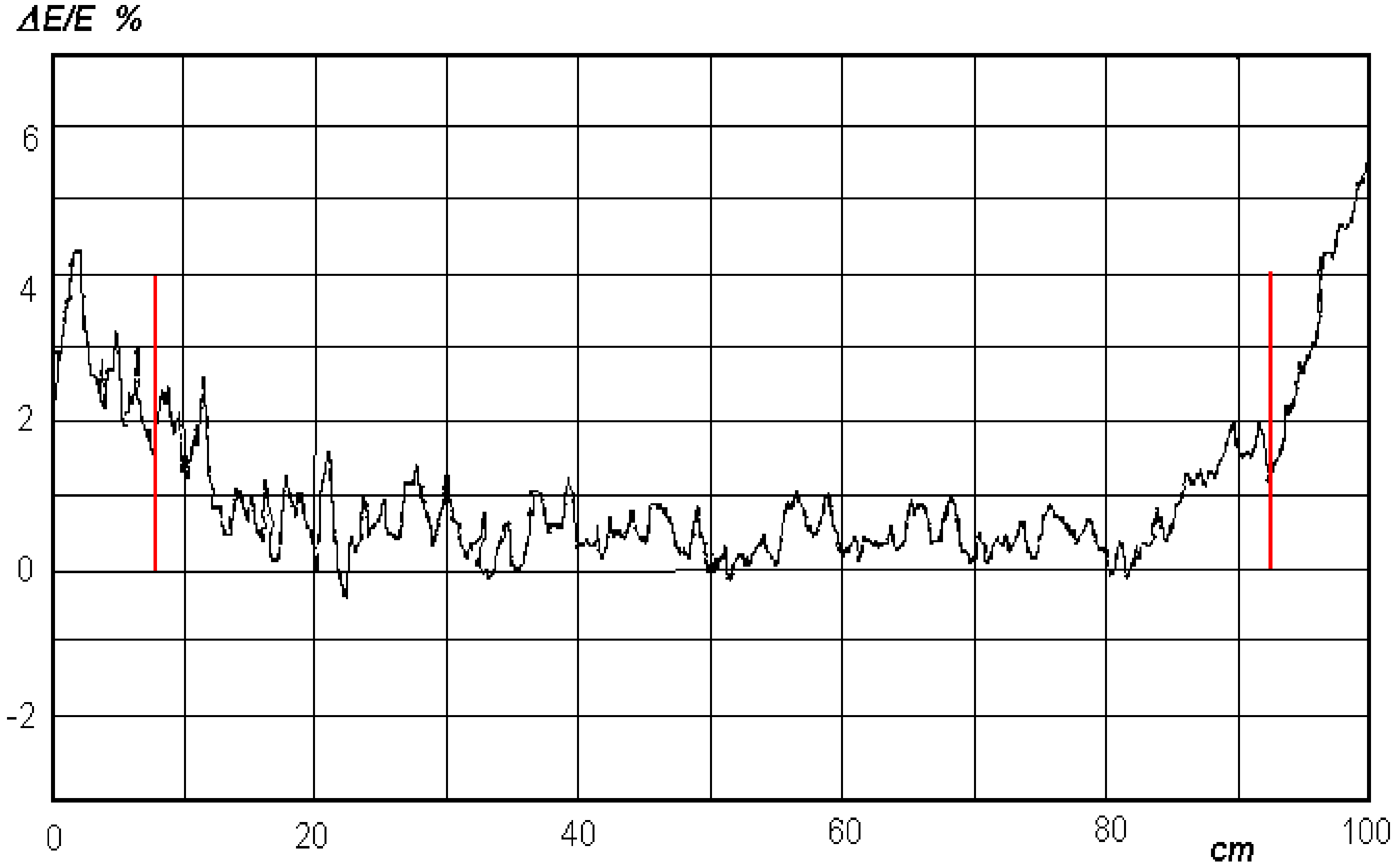


FIG.3 Longitudinal variation of E-field intensity. Center Frequency 352459950 Hz. In the following we will consider the part in between the orange lines as regards ΔE/E calculation

- Tuners: A_{i1}= A_{i3}= totally inserted, A_{i2}=5.6cm (i=1 to 4)
- Mode frequency is higher than it should be
- Flatness $\frac{\Delta E}{E} \approx 1.9$ %
- We must increase end cell frequency. We cut end cell electrodes in order to decrease capacitance between electrodes and end plates

Segments End Cell Tuning

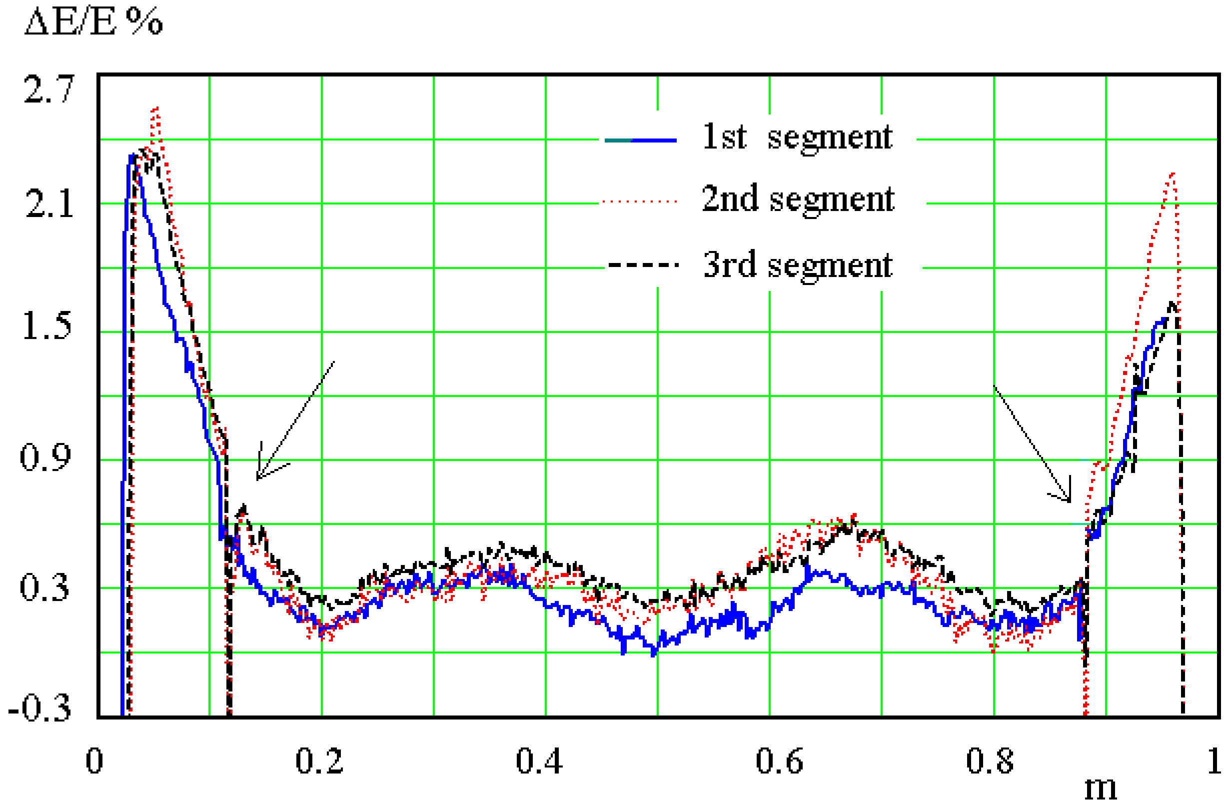


FIG. 5 Center Frequencies: n_1=352046000 Hz, n_2=352045000 Hz, n_3=352046000

- End cell Electrodes: 4mm shorter
- 1st segment: Tuners: A_{i1}= 5cm, A_{i2}= 5.6cm, A_{i3}= 5.20cm

  Flatness $\frac{\Delta E}{E} \approx 0.40\%$
- 2nd segment: Tuners: B_{i1}= 4.75cm, B_{i2}= 5.6cm B_{i3}= 5.05cm

  Flatness $\frac{\Delta E}{E} \approx 0.56\%$
- 3rd segment: Tuners: C_{i1}= 5.05cm, C_{i2}= 5.5cm C_{i3}= 5.15cm

  Flatness $\frac{\Delta E}{E} \approx 0.44\%$

2 Segments with a Coupling Cell

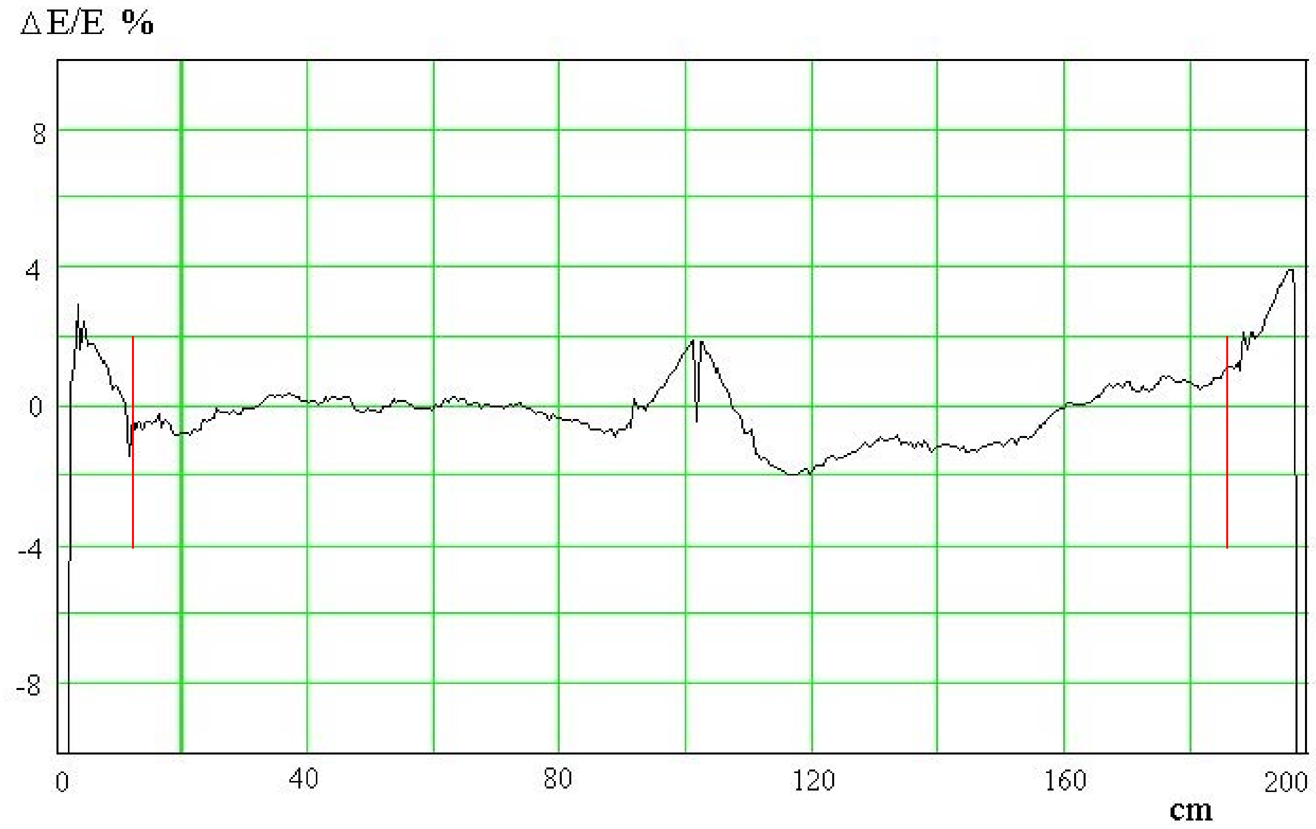


FIG.6 Center Frequency 352099250 Hz

- Tuners: A_{i1}= 4.8cm, A_{i2}= 4.9cm A_{i3}= 4.7
  B_{i1}= 4.7cm, B_{i2}= 5.0cm B_{i3}= 5.5cm
- Flatness: $\frac{\Delta E}{E} \approx 4.0\%$

3 Segments with 2 Coupling Cells

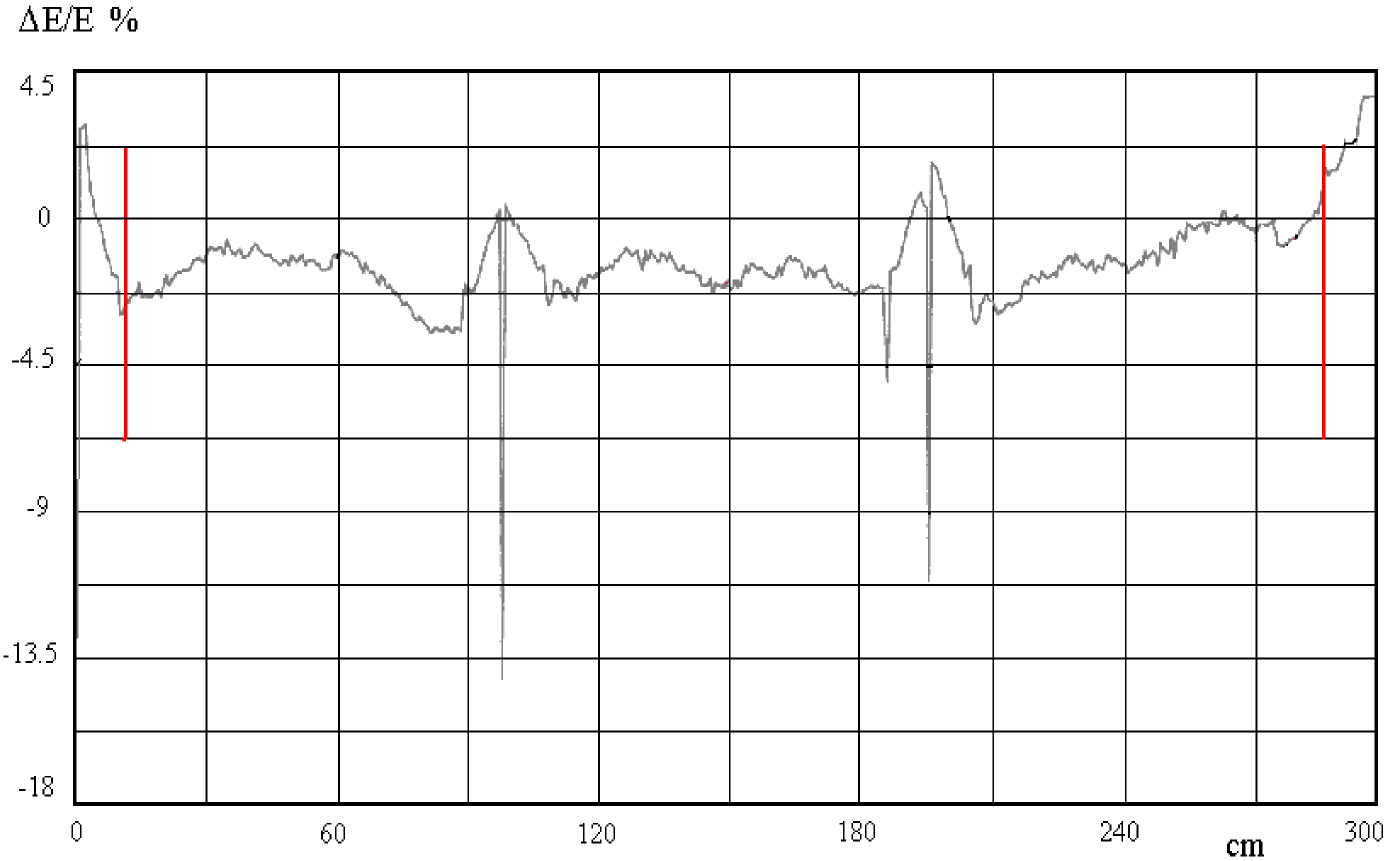


FIG.5 Center Frequency 352096500 Hz

- Tuners: A_{i1}= 4.8cm, A_{i2}= 4.9cm A_{i3}= 4.7
  B_{i1}= 4.7cm, B_{i2}= 5.0cm B_{i3}= 5.5cm
  C_{i1}= 5.1cm, C_{i2}= 5.3cm C_{i3}= 4.7
- Flatness: $\frac{\Delta E}{E} \approx 3.1\%$

Conclusions

We have tuned “end cells” and “coupling cells” at the required frequency with electric field flatness $\frac{\Delta E}{E} = 3.1\,\%$