

# DEVELOPMENT OF NON-RESONANT PERTURBING METHOD FOR TUNING TRAVELING WAVE DEFLECTING STRUCTURES

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## Abstract

For traveling wave accelerating structures, the tuning method assisted by bead pull technique based on non-resonant perturbation field distribution measurement has been widely applied. The method is also suitable for deflecting structures, but some key considerations of the field components of HEM11 mode and the selection of bead are discussed. A cage type of perturbing object has been made and applied on non-resonant perturbation measurements. The measurements on an S-band traveling wave deflecting structure are presented.

## INTRODUCTION

Non-resonant perturbing method has been widely used on accelerating structure for field distribution measurement and guiding tuning procedure. For the purpose of tuning deflecting structure, non-resonant perturbing technology has been developed and applied for field distribution measurement in deflecting structure. As described in ref [1], non-perturbation method, which make the field measurement procedure fast, especially for long-period structure, and it uses direct measurements of the field distribution in the structure. For measurement and tuning travelling wave deflecting structure, the bead pull measurement based on non-resonant perturbation theory has been developed and will be applied.

## NON-RESONANT PERTURBATION THEORY

According to the non-resonant perturbation theory [2], the reflection coefficients are measured at the input port of the structure in the absence of the perturbation object and in its presence. When the perturbing bead moves along a line from input port to output port, the magnitude and phase distribution of the electromagnetic field could be collected, which could be applied to get the information for tuning of the structure after the post-processing.

In non-resonant perturbation theory, the reflection coefficient and the field distribution in the structure have the relationship as follows:

$$2P_i(\Gamma_p - \Gamma_a) = -j\omega(k_e E_a^2 - k_m H_a^2) \quad (1)$$

Where  $\Gamma_p$  and  $\Gamma_a$  are the reflection coefficients in the input port in the presence and absence of the perturbing object, respectively.  $E_a$  and  $H_a$  are the complex vectors of the electric and magnetic field at the position of the bead in the structure, respectively. It is well known that, for traveling wave

accelerating structure, the TM01 mode is used for beam acceleration, and the electric field  $E_z$  is the unique field component on axis. Then Eq. 1 becomes scalar equation, name as Eq. 2

$$\Delta S_{11} = S_{11p} - S_{11a} = \frac{-j\omega k_e}{P_i} E_z^2 = K_{ez} E_z^2 \quad (2)$$

Where  $\Delta S_{11p}$  and  $\Delta S_{11a}$  are reflection coefficients in the presence and absence of perturbation object, respectively, acquired from the NetWork Analyzer.  $E_z(z)$  is the electric field on axis, as the perturbing object goes through the structure along  $z$ , it is obvious that the amplitude of  $E_z$  is proportional to the square root of the amplitude of  $\Delta S_{11}$ , and the phase of  $E_z$  is the half of the phase of  $\Delta S_{11}$ , the information of measuring for tuning is collected.

For a deflecting structure, the operating mode is HEM11, which is a hybrid of TE11 and TM11 mode [3], and the field components have been calculated in [4]. Then Eq. 1 becomes a complicated equation, named as Eq. 3

$$\Delta S_{11} = \sum_{i=x,y,z} (K_{ei} E_i^2 - K_{mi} H_i^2) \quad (3)$$

Where  $E_i$  and  $H_i$  are electric and magnetic field in different directions, respectively,  $K_i$  is defined as form factor of perturbing object. Further consideration, Eq. 3 can be expressed as,

$$\Delta S_{11} = \sum [(K_{ei}|E_i^2| \cos 2\varphi_i + j|E_i^2| \sin 2\varphi_i) - (K_{mi}|H_i^2| + j|H_i^2| \sin 2\varphi_i)] \quad (4)$$

Where  $\varphi_i$  and  $\psi_i$  are the phase of electric and magnetic field. Eq. 4 indicate that, it is a multi-element complex equation, becomes difficult and complicated for measuring and guiding tuning multi-cell deflecting structure. A fast and reliable method for measurement is desperately needed.

In the travelling wave structure, the magnitude of  $E_y$  and  $H_x$  nearly homogeneous on the axis cell by cell, but the positions of  $E_y$  and  $H_x$  at their maximum are iris center and cavity center, respectively. For other four field components, except  $E_z$  exist in coupler cavity, the distribution of  $E_z$ ,  $E_x$ ,  $H_y$ , and  $H_z$  could be ignored in the structure on axis. Figure 1 shows the magnitude and phase distribution of  $E_y$  and  $H_x$  along  $z$ . The magnitude and phase distribution in Figure 1(b) and (c), comparing with schematic drawing of structure in Figure 1(a), indicate that the electric field  $E_y$  has maximum magnitude and flat phase shift in the iris center, on the contrary,  $H_x$  in the cavity center.

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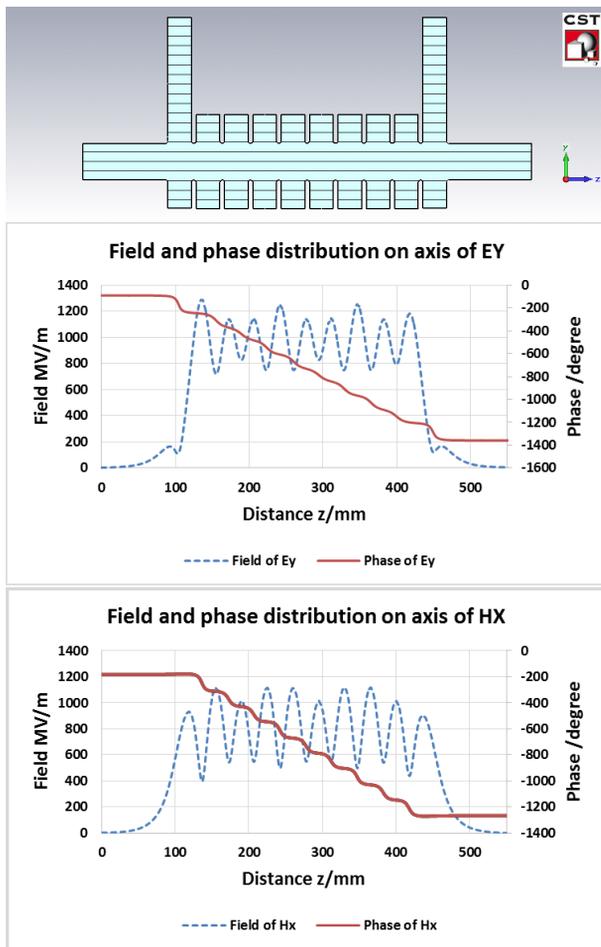


Figure 1: Magnitude and phase distribution of EY and HX along z on axis.

According to the non-resonant perturbation theory, apply Eq. 2 to field  $E_Y$  and  $H_X$  in deflecting structure, the reflection coefficient could be calculated with the field data of  $E_Y$  and  $H_X$  from CST, respectively.

### SELECTION OF PERTURBING OBJECT

For more conveniently and quickly to measuring and tuning multi-cell deflecting structure, the perturbing object should satisfy the relation,

$$K_i \gg K_j \quad (5)$$

$$i = x \text{ or } y \text{ or } z \quad j \neq i$$

When a perturbing object with this feature moving along structure, the measurement results equivalent to the situation of accelerator structure. As discussed above, the main field component  $E_Y$  could be chosen to perturb, and the simulation result as shown in Figure 3.

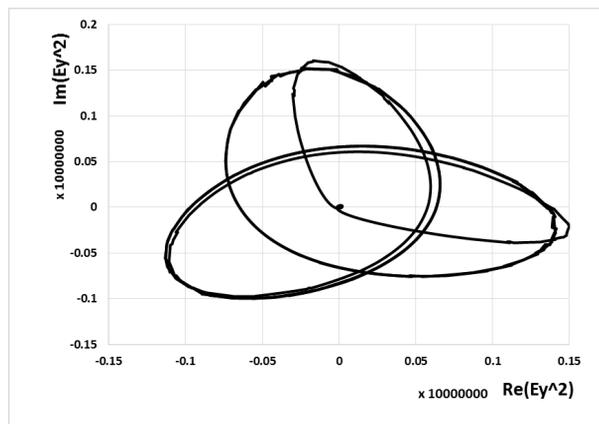


Figure 2: single field component simulation results of  $\Delta S_{11}$  on the condition of matched.

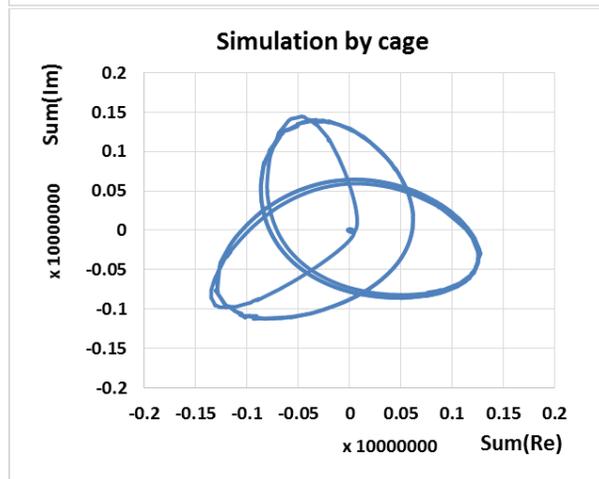
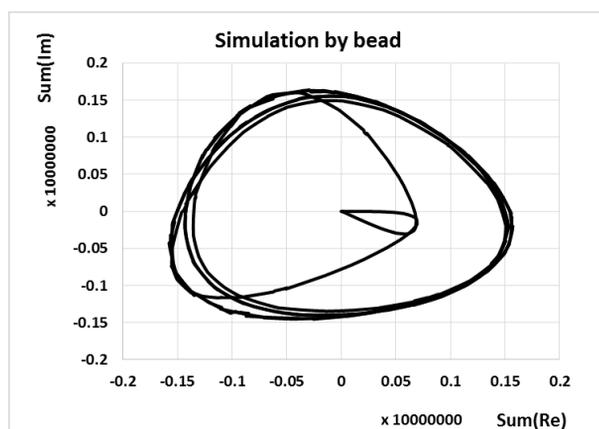


Figure 3: Simulation of bead pull measurement.

Considering the dimension of perturbing object, the field components which are exist off axis should be included. The field  $E_Z$  is exist off axis and has the same characteristic of  $H_X$ . As discussed above, when the perturbing object moves through the structure, the field  $E_Y$  is the main considering component, but the impact by the existence of  $E_Z$  and  $H_X$  on the results has to be considered. When the shape factor Key as defined before, compared with others, is greater

enough to ignore the impact of  $E_Z$  and  $H_X$ , the measurement formula becomes simple as Eq. 2. A new type of perturbing object for high order mode measurements had been proposed in [5], and several experiments of HOMs measurement have been proved its effective on L-band structure [6]. The cage type perturbing object, with several metal wires surrounded on the Teflon. The element of the metal wire, include the length  $L$ , diameter  $d$  and the number of the metal wire  $N$ , have a great influence on measurement. It is called cage because of its shape, and the scaling results are shown in Table 1.

Table 1: Scaling Results of Perturbing Object

Field Component	$k_i(10^{-8})$	$k_i/k_1$
$E_{  }$	12.39	1.000
$E_{\perp}$	3.152	0.254
$H_{  }$	0.000	0.000
$H_{\perp}$	0.000	0.000

## FIELD DISTRIBUTION MEASUREMENT

In order to avoid orientation error for the cage with very high direction resolution, we use two paralleled threads for supporting the perturbing cage, and the schematic drawing is shown in Figure 4. The field distribution on axis is measured, which is shown in Figure 5.

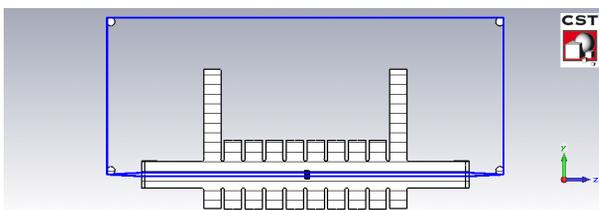
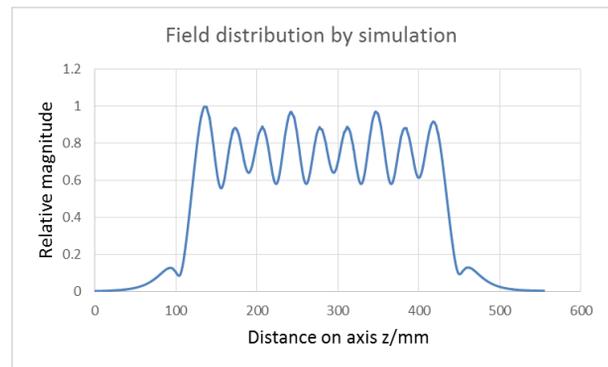


Figure 4: Bead-pull based on cage with parallel threads.

## SUMMARIES

The simulation and analysis of field distribution in deflecting structure are completed, a perturbing object with high direction resolution is necessary. Several cage type perturbing objects have been made and selected to measuring field distribution in s-band deflecting structures, and the results show that the cage type perturbing objects applied to measure and guide tuning for multi-cell travelling wave deflecting structure are successful.



centering

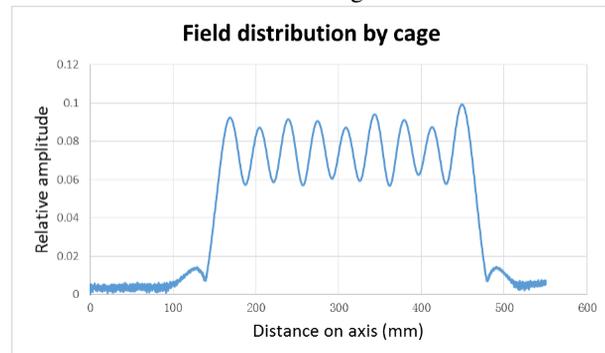


Figure 5: Field ( $E_Y$ ) distribution of s-band deflecting structure.

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