



# A NOVEL BRIDGE COUPLER FOR SSC COUPLED CAVITY LINAC

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## Abstract

A novel magnetically coupled multi-cavity bridge coupler is proposed for SSC Coupled-Cavity-Linac (CCL). The bridge coupler is a five cell disc-loaded waveguide with a small central aperture (used for measurement) and two large curved coupling slots near the edge on each disc. The two coupling slots on the adjacent disc are rotated  $90^\circ$  in orientation to reduce the direct coupling. This type of structure is capable of producing very large coupling ( $> 10\%$  in our longest bridge coupler). Also because of the small opening on the discs, the high-order-modes are very far ( $> 300$  MHz) above the operating mode. Thus for long bridge couplers, the magnetic coupled structure should provide maximum coupling with minimum mode mixing problem. In this paper both physics and engineering issues of this new bridge coupler are presented.

## I. INTRODUCTION

In the new design of the SSC side Coupled Cavity Linac (CCL)<sup>1</sup>, inter tank spaces are increased significantly and most bridge coupler lengths are over 40 cm. The conventional TM<sub>010</sub> single cavity bridge coupler used in LAMPF and Fermilab will have severe mode mixing problem at this length, also its group velocity is too low and coupling is too weak. Three types of new bridge couplers were proposed for consideration<sup>2,3,4</sup>. After computer simulation and cold model tests, the Magnetically Coupled multicavity Bridge Coupler (MCBC) is chosen because it is least subject to mode mixing problems and also provides large nearest neighbor coupling.

## II. SIMULATION AND MEASUREMENT

The MCBC is a five cell disc loaded wave guide with two coupling slots near the edge of the discs, as shown in Fig. 1. The geometry of a disc is shown in Fig. 2. The length of the coupling slot has a first order effect on the coupling, but the slot width only has a second order effect. MAFIA is used to select the slot length, width and radial location. The goal is to have large nearest neighbor coupling  $K_1$  without introducing large second nearest neighbor coupling  $|K_2|$  (a large  $|K_2|$  will produce an asymmetric dispersion curve and reduce the group velocity). Fig. 3 show the  $K_1$  and  $K_2$  as functions of radial

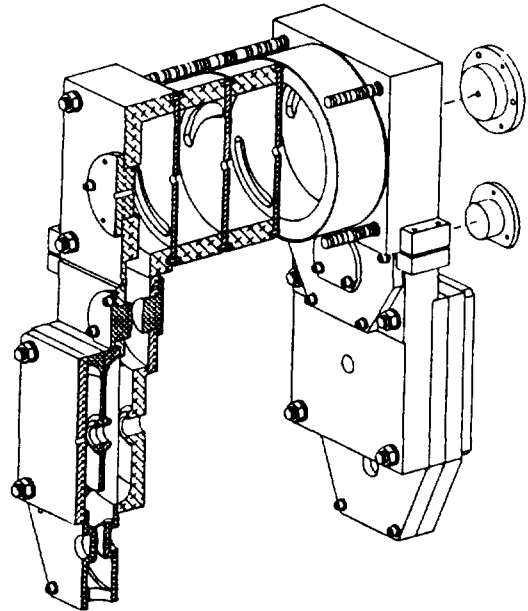


Figure 1: Geometry of the magnetically coupled bridge coupler

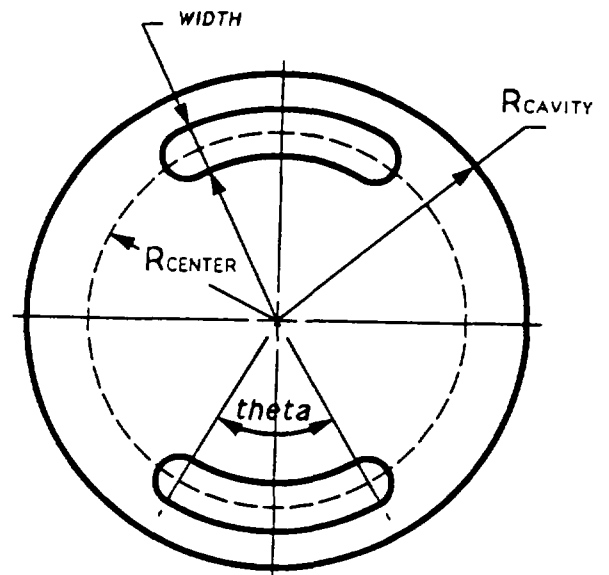


Figure 2: Geometry of coupling slots

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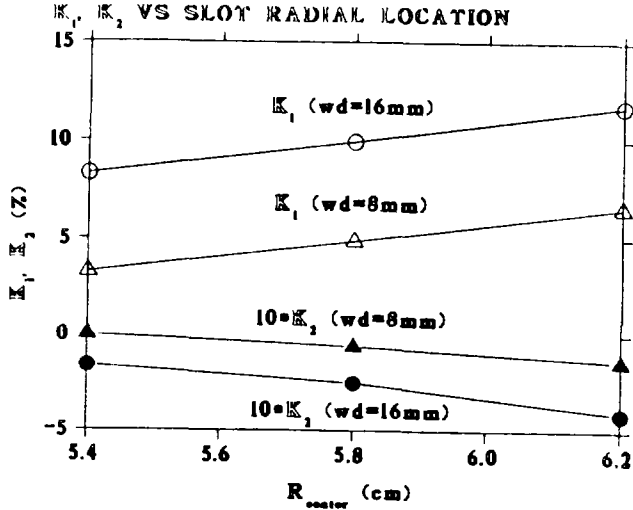


Figure 3:  $K_1$  and  $K_2$  vs slot radial location. Slot center angle=60°, width=8 and 16 mm. (MAFIA)

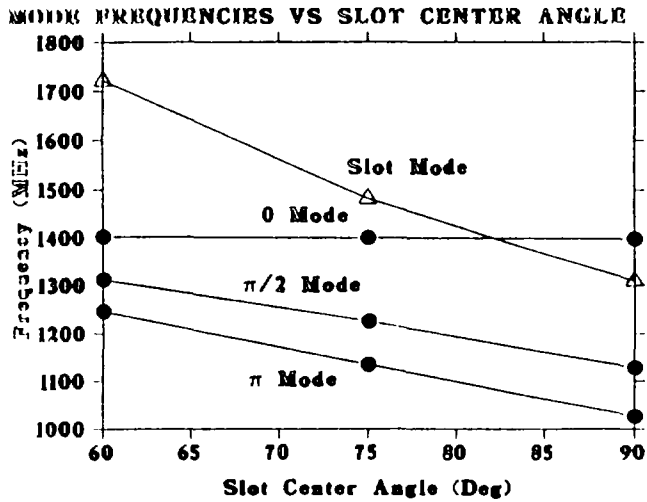


Figure 4: 0,  $\pi/2$  and  $\pi$  mode frequencies vs slot center angle. Slot width=16 mm,  $R_{center}=62$  mm. (MAFIA)

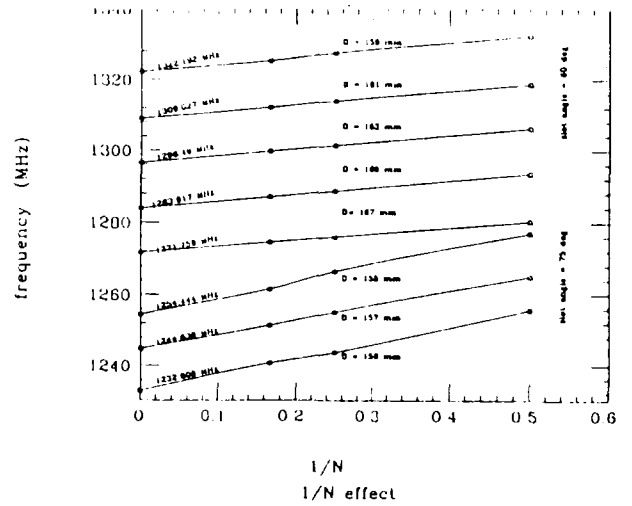


Figure 5: Measured  $\pi/2$  frequencies for different radius as functions of  $1/n$ , where  $n$  is total cavity number.

Tot cell No.	$F_{\pi/2,acc}$	$F_{\pi/2,coup}$	$\Delta F_{\pi/2}$
2	1272.98	1295.17	22.19
6	1280.25	1288.26	8.01
10	1281.77	1286.67	4.90
22	1283.03	1285.29	2.26

Table 1: Mode frequencies vs total cavity number (MAFIA)

location for different slot widths. Fig. 4 show the 0,  $\pi/2$ ,  $\pi$  and slot mode frequencies as functions of slot center angle  $\theta$ . It can be seen if  $\theta$  is over 60°, the dispersion curve becomes apparent asymmetric ( $f_0 - f_{\pi/2} > f_{\pi/2} - f_{\pi}$ ). Also the slot mode frequency becomes low and may get into the pass band. For our design parameters a reasonable choice is: slot angle  $\theta = 60^\circ$ , slot width  $hh = 16$  mm and slot radial location  $R_{center} = 62$  mm. Without affecting  $K_1$ ,  $|K_2|$  can be reduced if the coupling slots on adjacent discs are rotated 90° in orientation so that the slots do not directly “see” each other. The resulting structure is still a single periodic structure, although under the half cell termination, it looks like a double periodic structure and has a stop band. This, the so-called  $1/n$  effect, is caused by the images of the coupling slots on the termination plates, as a result the two end cavities will have a different  $\pi/2$  mode frequency as the middle cavity. The  $1/n$  effect will disappear for infinite long structure. Table 1 shows the MAFIA results of mode frequencies vs total cavity number  $n$ . We can see how  $1/n$  effect is reducing as increase of  $n$ : as  $n$  increases, the difference of the two  $\pi/2$  mode frequencies reduces. Fig. 5 shows the cold model measurements of the  $\pi/2$  frequencies with  $n=2$ ,  $n=4$  and  $n=6$ . With these 3 frequencies, we can obtain  $f_{\pi/2}$  for  $n=\infty$ <sup>5</sup>.

The dispersion relation for a singly periodic structure is

$$f = f_c / \sqrt{1 + K_1 \cos \phi + K_2 \cos 2\phi} \quad (1)$$

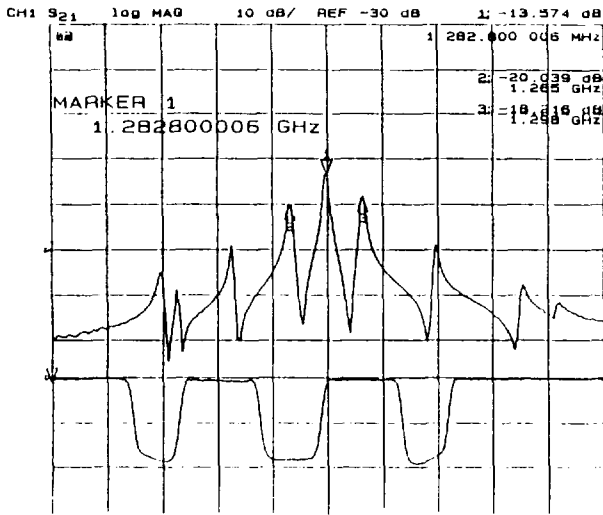


Figure 6: Top figure: Measured mode frequencies of the bridge coupler cold model. Bottom figure: The field level in the bridge coupler by beadpull measurement. The cold model consists of five bridge cells, two coupling cells and two half accelerating cells.

if  $K_2$  is taken into account. This equation has two unknowns  $K_1$  and  $K_2$ . With three measured frequencies  $f_0$  ( $\phi = 0$ ),  $f_{\pi/2}$  ( $\phi = \pi/2$ ) and  $f_\pi$  ( $\phi = \pi$ ), we can get the exact solution for  $K_1$  and  $K_2$ . From Fig. 5, with  $60^\circ$  slot center angle,  $K_1$  is about 13% and  $|K_2|$  is less than 1%.

The area of the coupling slots is very small compared to the area of the entire disc. The bridge coupler is acting like five short cavities to high order modes so these mode frequencies are distributed far from each other. Fig. 4 shows that the closest high order mode is about 300 MHz above the top of the pass band of TM01 mode if  $\theta = 60^\circ$ . The magnetically coupled bridge coupler, while providing large nearest neighbor coupling, is least likely to have any mode mixing problem even for our longest bridge coupler ( $l_{\text{bridge}} = 46.1$  cm) and it should provide zero power flow phase shift. This is the biggest advantage the magnetic coupled structure has over other structures<sup>2</sup>.

There are 63 bridge couplers in the CCL and their length varies from 37.2 cm to 46.1 cm. If we choose to have an equal cavity length for all five cavities in a bridge coupler, then for 63 different cavity lengths we will also have 63 different cavity radii. A better scheme is: within a module, fixing the three middle cavity length (the three middle cavities have the same length), and let the length increase of the bridge coupler take place at the two end cells. From module to module, the length of the middle cavities only increases two times from 7cm to 9 cm. The resulting cavity lengths of this arrangement looks very reasonable and are listed in Table 2.

A big advantage of this scheme is that there are only 3 middle cavity lengths thus only 3 cavity radii need to be determined for 63 bridge couplers. The end cavities will have the same radius as the center cavities and their frequencies are adjusted by the two end posts as frequency tuner, which is shown in Fig. 1.

Unit: [cm]	MOD. 1,3,4	MOD. 2,5,6	MOD. 7,8,9
$L_{\text{bridge}}$	30.79 - 36.33	37.22 - 41.20	41.71 - 46.13
$L_{\text{mid,cell}}$	7.00	8.00	9.00
$L_{\text{end,cell}}$	4.89 - 7.67	6.61 - 8.60	7.36 - 9.56

Table 2: Cavity Length vs Module No.

Under this scheme, the determination of the bridge coupler dimension is divided into three steps: (I) optimization of the coupling slot geometry (Fig. 3 and Fig. 4). For maximum exchangeability the same slot geometry will be used for all 63 bridge couplers; (II) determination of the three middle cavity radius (Fig. 5), these three middle cavities are considered as a part of an infinite structure; (III) set the radius of the end cells to be the same as the mid-cells and determine the end post length to obtain the right end cell frequency.

This method works quite well. We have built a bridge coupler cold model for Tank1-Tank2 of Module I and all cavity dimensions are determined by this method. Without any tuning, the  $\pi/2$  mode frequency measured is within 2.5 MHz of the required operating frequency. This means very little tuning is needed. By adjusting the post lengths at the end walls of bridge cavity and gaps of the coupling cavities, we can easily obtain the right  $\pi/2$  mode frequency, as shown in Fig. 6. The measured  $K_1$  value is about 13.6%, the predicted value is 13%, which is again a very good agreement.

### III. CONCLUSION

Magnetically coupled structure is least subject to mode mixing problems and is the most suitable structure for long bridge couplers. The first measurement results of the bridge coupler cold model are very encouraging.

### IV. ACKNOWLEDGMENT

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### V. REFERENCES

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