RHIC/RF-33

RHIC Project
BROOKHAVEN NATIONAL LABORATORY

RHIC/RF Technical Note No. 33

ANALYSIS OF BEAMPIPE TRANSITIONS FOR THE RHIC rf CAVITIES

S. Kwaitkowski, C. Quiery, J. Rose

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Introduction

BNL RHIC facility has two 3.8km long synchrotrons able to accept protons or heavy ions beam from AGS, accelerate them to final energy (250GeV/n for protons and 100GeV/n for fully stripped gold) and store for several hours. Each accelerating system consists two quarterwave cavities placed back to back and connected with use of stainless bellows. The inner diameter of the beam pipe inside the 28MHz prototype cavity changes from 6.2 cm(accelerating gap area) to 12cm (an inner diameter of the beam pipe inside the 28MHz prototype cavity). The topic of this analysis is to find out how harmful trapped modes in the inner conductor volume could be for the accelerating beam.

1. Accelerating Cavity Longitudinal modes.

Since the cutoff frequency of the cylindrical waveguide with the radius 6.2cm for TM_{01} mode is 1847MHz and the first possible resonance (E_{010}) in 12 cm pipes is 950 MHZ there will be many resonances trapped inside the inner conductors of the 28MHz accelerating cavities. The cross section of the inner conductor of the prototype cavity is shown in Fig.1. The analysis is performed on the trapped volume of a cavity pair and so the results shown are per ring (two cavities per ring).

The first modes have the indexes' E_{010} to E_{01n}, since the length of the involuntary formed cavity (2.2m) is much longer than the diameter. First 10 longitudinal modes have been calculated using URMEL code and the results are given in Table 1.

MODE No.	Frequency [MHZ]	Rsh [kΩ]	Qo [ ]	R/Q [Ω]
1	951	560	40870	13.7
2	958	175	51470	3.4
3	966	8	50000	0.16
4	979	466	48500	9.6
5	996	47	48450	0.97
6	1018	37	48680	0.76
7	1044	537	49270	10.9
8	1074	139	49820	2.79
9	1108	1	50000	0.002
10	1144	8	50000	1.6

TABLE 1.

The impedance limit for 28MHz accelerating cavity longitudinal modes have been determined [1]. Figure 2 shows the beam pipe longitudinal modes plotted against the impedance limit curve.

2. Accelerating Cavity Perpendicular modes.

The longitudinal impedance of the first twenty dipole modes has been calculated using the code URMEL. The transverse impedance was then calculated as

$$R_{\perp} = \frac{2 * c * R_{\parallel}}{a^2 * \omega}$$

where R‖ is integrated at the beampipe radius "a".

The results (for the modes with the $R_{\perp} > 100 k\Omega/m$) are given in Table 2.

Mode No	Frequency [MHZ]	R⊥ [MΩ/m]	Q [ ]
9	962	0.24	53700
10	1008	0.3	57400
13	1159	0.13	69300
15	1267	0.2	75800
16	1322	2.84	77800
17	1385	12.99	58600
18	1409	8.87	57200
19	1435	6.17	85900

Table 2

3) Storage Cavity interconnects

The HOM impedances of the 197.1 MHZ storage cavities has been described elsewhere in detail [2], [3]. There is however, a trapped volume in the interconnect region between either adjacent cavities or between the cavities and the 5 inch RHIC beampipe which can support HOM's. This geometry is shown in figure 3. The step is only a little over 10 mm in radius and should have little or no effect on the beam. It is therefore recommended that no taper be installed to simplify the interconnect region and eliminate unnecessary vacuum seals. If analysis or beam measurements show that this step is harmful to the beam a liner can be installed at a later date.

Conclusion:

There is no danger for the accelerating beam coming from the longitudinal HOM's trapped inside the inner conductor of the 28MHz cavity, however the transverse impedances are very strong and may lead to transverse instabilities, either bunch to bunch or head/tail. Since the cost of the "liner" (device which will keep the diameter of the beam pipe inside the 28 MHZ constant and equal 12.4 cm) is only 1% of the cost of the accelerating cavity it is recommended to apply it.

References:

[1] "Coupled Bunch Instabilities and Implications for RHIC rf Cavity Impedances" J. Rose, RHIC/rf-27

[2] Ibidem

[3] "A New Type of Broadband Higher Order Mode Coupler Using Parallel Ridged Waveguide In Comparison with a Coaxial Filter Version" F. Caspers, G. Dome, H. R. Kinderman IEEE PAC, 1987

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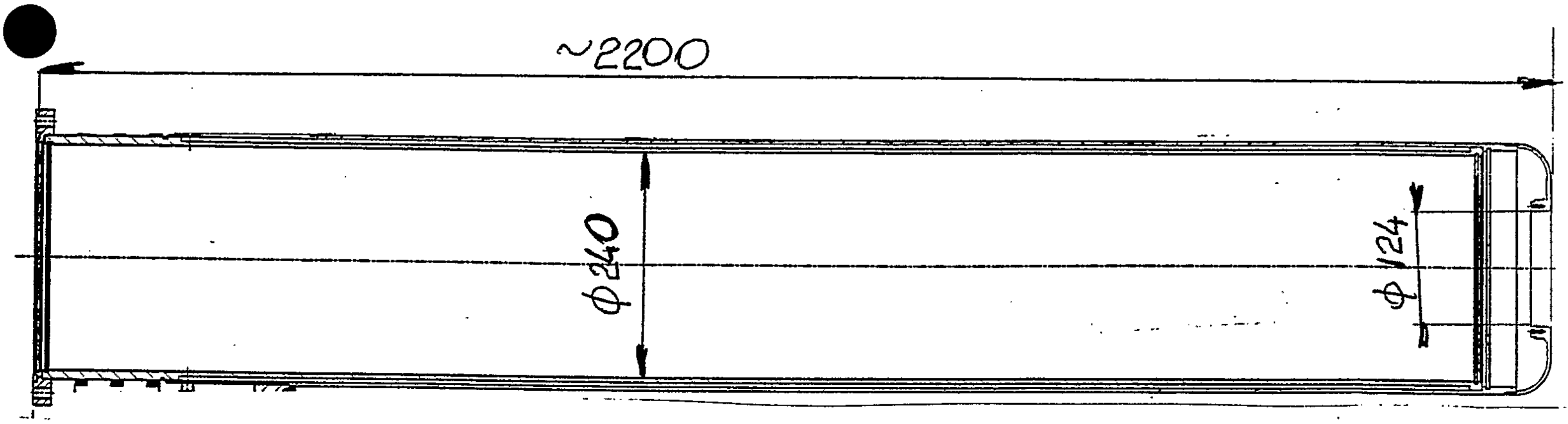

~2200
φ240
φ124

Fig. 1

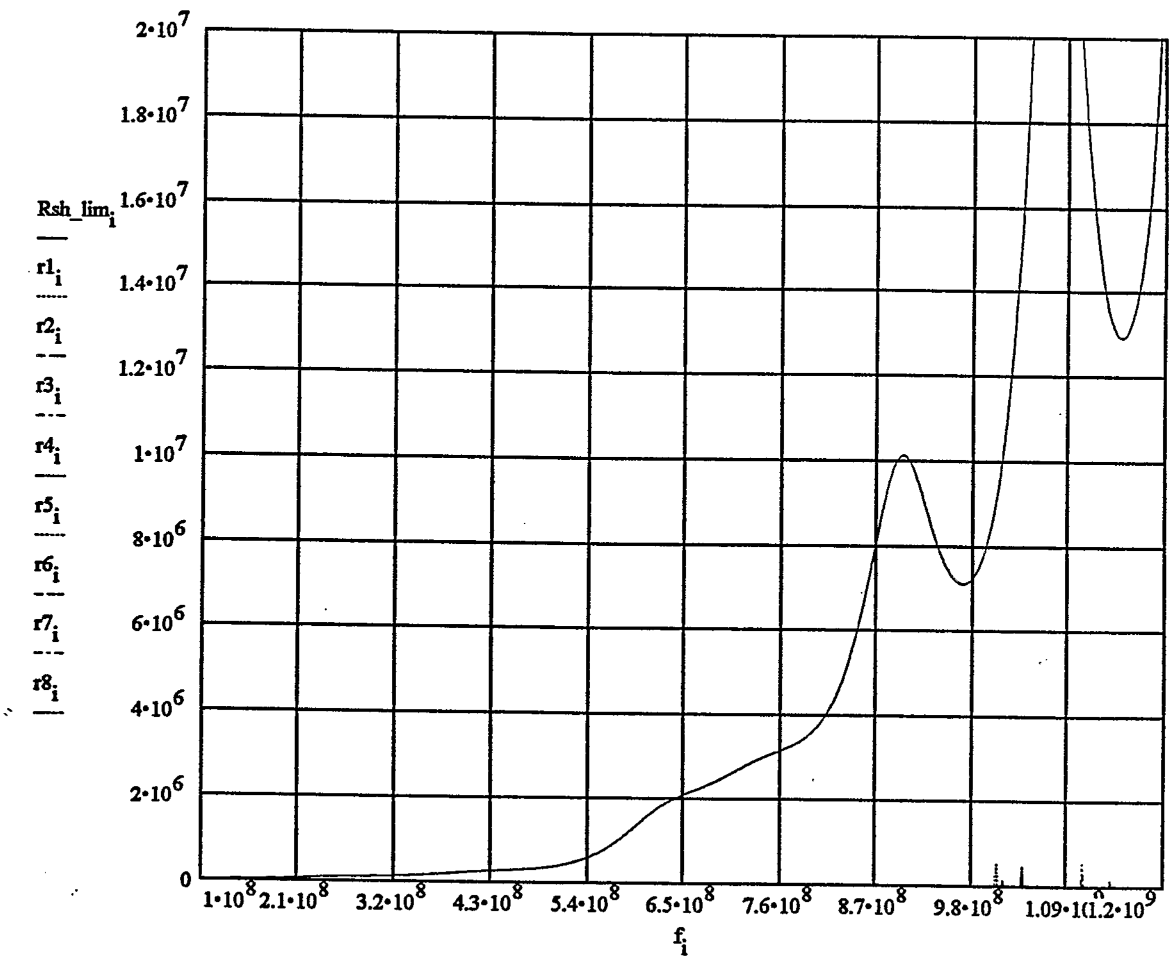
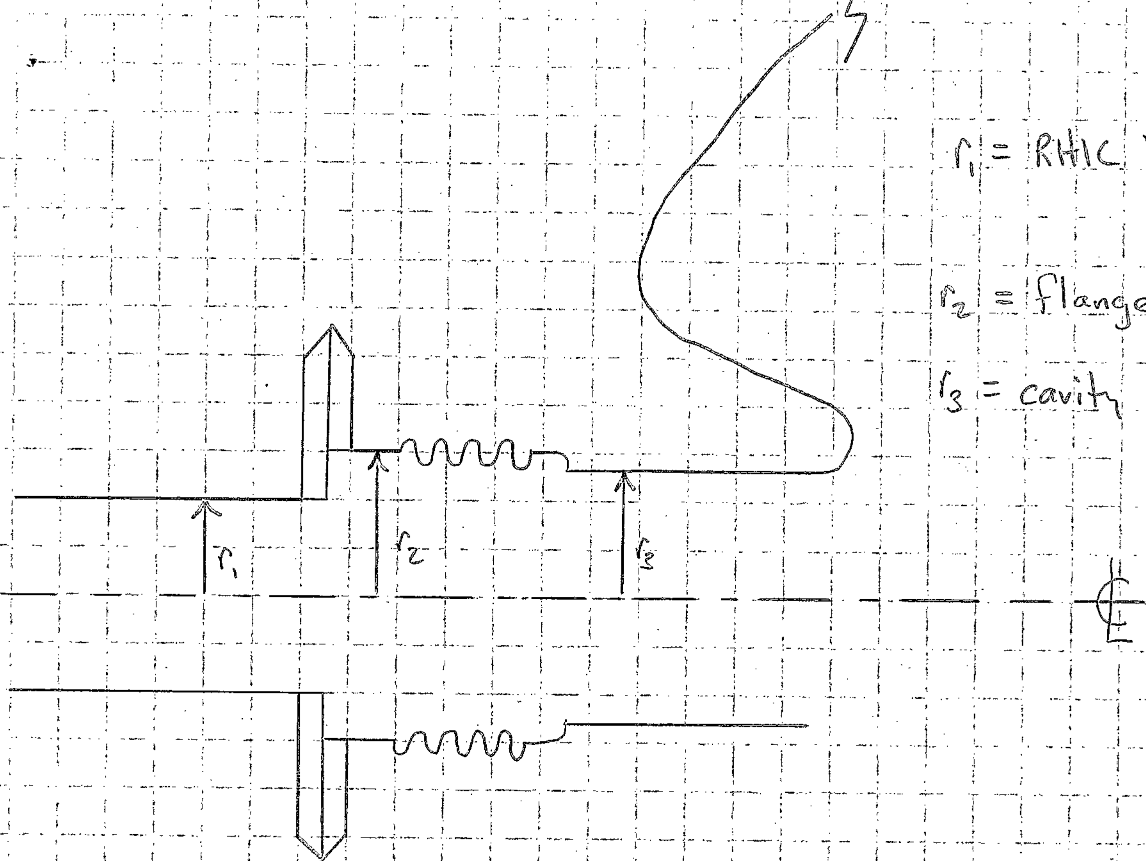

2·10^7
1.8·10^7
1.6·10^7
1.4·10^7
1.2·10^7
1·10^7
8·10^6
6·10^6
4·10^6
2·10^6
0
Rsh_lim_i
r1_i
r2_i
r3_i
r4_i
r5_i
r6_i
r7_i
r8_i
1·10^8
2.1·10^8
3.2·10^8
4.3·10^8
5.4·10^8
6.5·10^8
7.6·10^8
8.7·10^8
9.8·10^8
1.09·10
1.2·10^9
f_i

Fig. 2.



r_1 = RHIC beampipe = 2.44"

r_2 = flange bore = 3.063"

r_3 = cavity beam tube = 2.88"

197 MHz Storage Cavity beampipe geometry

FIGURE 3