# RF Coupler Design of 352.2 MHz RFQ

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*Abstract*

A 3 MeV, 352.2 MHz Radio Frequency Quadrupole (RFQ) accelerating structure is under design and development stage at RRCAT, Indore. The RFQ is a part of $H^-$ front end linac for the future ISNS project. The RFQ accelerator needs 503 kW peak power with a duty factor of 1.25% for its operation and this power will be delivered through RF coupler. Presently there are two schemes in considerations for the RF coupler, one is using the iris type coupler and another is using the loop antenna. The design of iris type coupler is done using CST Microwave studio. For iris type coupler, the power from the klystron will be coupled to the cavity through a standard waveguide (WR-2300). Iris type coupler consists of WR-2300, ridge loaded tapered waveguide and an iris at the periphery of the RFQ. Here the ridge loaded tapered waveguide section is used to match the impedance and also to lower the cut-off frequency to the required value. For loop type coupler, two loops will be used to deliver the required power. These loops will be positioned at same longitudinal position and at diagonally opposite to each other. In loop type coupler, 3 1/8" coaxial transmission line will be used to feed the power from klystron. The design aspects of these two types of coupler are presented in this paper.

## INTRODUCTION

The microwave coupler is an important component for an accelerator structure. It couples the RF power from the RF source to the RF cavity. The RF power from RF source to the RF cavity can be coupled either through electric field or through magnetic field. In our structure, the RF power is coupled to the RFQ through magnetic field. Here, we study two types of couplers- one is the iris type coupler and another is a coaxial loop type of coupler. Both these coupler have their own advantages and disadvantages. Choosing a specific type of coupler depends on the specific requirements and availability of different components. An accurate prediction of the coupling between a RF cavity and the RF coupler attached to it is the main task in a RF coupler design.

The coupling co-efficient $\beta$ is defined as the ratio of the power reflected when the source is turned off, to the forward power fed to the RF cavity. We need critical coupling when beam is present. For this case, the value of $\beta$ is decided by the following relation

$$\beta = 1 + \frac{P_b}{P_c}, \tag{1}$$

where $P_b$ is the beam power and $P_c$ is the power dissipated at the structure. For our RFQ, beam power and structure power dissipation are 88 kW and 415 kW (by taking 30 % safety margin) respectively. So the value of $\beta$ will be 1.2 for critical coupling when beam is present.

## IRIS TYPE COUPLER

Iris type coupler has the advantage of good power handling capability and at high frequency power loss is less than coaxial loop type coupler. Iris type coupler has a standard waveguide WR-2300, ridge loaded tapered section and iris as shown in Fig.1. The cut-off frequency of the waveguide and the iris should be lower than the resonance frequency of the RFQ. The operating frequency of the RFQ is 352.2 MHz. Here the standard waveguide WR-2300 is chosen because the cut-off frequency of the WR-2300 is 256 MHz. To maintain the cut-off frequency below the operating frequency of the RFQ and to match the impedance, a ridge loaded tapered wave guide section is used from WR-2300 to the iris. Tapered transmission line has characteristic impedance that varies continuously in a smooth fashion from the waveguide to the RFQ cavity.

We simulate the iris type coupler using CST MWS to achieve the required cut off frequency and then connect this to the middle section of the RFQ (RFQ is divided in three sections) and calculate the S parameter in time domain by using CST MWS. The optimization of $S_{11}$ was done by changing the iris dimension, ridge width and also length of the tapered section. The 3D model of the iris type coupler with RFQ is shown in the Fig.1. The optimized dimension of iris obtained from CST simulation is 102 mm × 51 mm. At the iris the ridge has a width of 50 mm and the gap between two ridges is 1 mm. With this dimension the cut off frequency of the iris is 253 MHz. The width of the ridge also varies from the iris to waveguide and it is 100 mm at the waveguide. At the waveguide end the gap between two ridges is simply the width of the WR-2300 waveguide. The length of the tapered section is taken as $\lambda/4$ = 21.28 cm. All these dimension are optimized to maintain the cut-off frequency as well as to minimize the reflection coefficient $\Gamma$, which is related to the $S_{11}$ by the relation $\Gamma = |S_{11}|$. The dependence of $S_{11}$ with frequency as calculated using CST MWS is shown in the Fig.2. From this figure we see that $S_{11}$ has dip at 343 MHz and it has value -24 dB (in linear scale it has value 0.063). The coupling factor ($\beta$) is related to $S_{11}$ by the following relation

$$\beta = \frac{1 + |S_{11}|}{1 - |S_{11}|}, \tag{2}$$

where $S_{11}$ has the value in linear scale. From this calculation $\beta$ comes as 1.13. Further simulations are being done to achieve the required $\beta$ value and the required frequency of 352.2 MHz.

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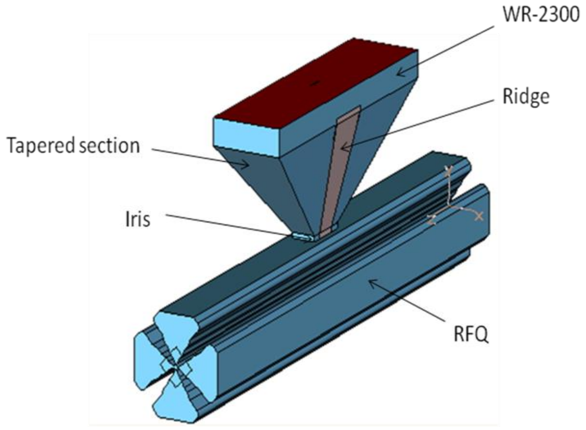


Fig.1. 3D model of the iris type coupler connected to the RFQ .

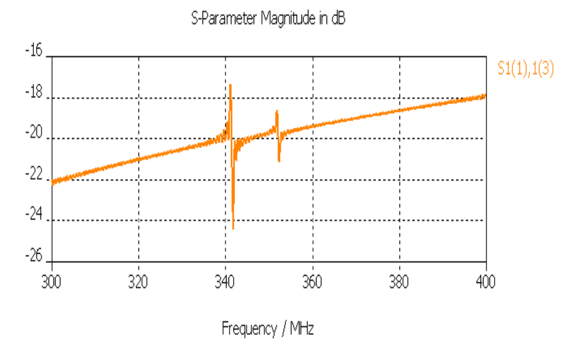


Fig.2. $S_{11}$ vs. frequency.

## LOOP TYPE COUPLER

Another possibility of feeding RF power to an RFQ accelerating structure is through loop coupling using a co-axial transmission line. The main advantages of the loop type coupler are that it can be easily modified and coupling coefficient is also easily adjustable. Here our main task is to calculate the loop area for our specific requirements and also choose a proper coaxial transmission line with suitable power handling capability. A particular coaxial transmission line is chosen on the basis of maximum peak and average power requirement of RFQ. The maximum peak and average power required for our RFQ is 503 kW and 6.3 kW (@ 1.25% duty factors). From literature [4] we get that the average power handling capability of 3 1/8” coaxial transmission line is nearly 27 kW and peak power rating is around 440 kW. On the basis of this, 3 1/8” standard coaxial line with an outer diameter of inner conductor as 33.4 mm and inner diameter of outer conductor as 79.3 mm is chosen as the transmission line from klystron to RFQ. Now to calculate the loop area, let us assume that the co-axial cable has characteristic impedance $Z_0$, the loop area is $S$ and peak magnetic field perpendicular to the loop is $B$ corresponding to dissipated power $P_c$ at the surface of RFQ structure. Note that for a given geometry of RFQ, $B/\sqrt{P_c}$ is independent of $P_c$ and can be obtained using electromagnetic simulation. For the case of perfect coupling, where there is no reflection from RFQ, the peak voltage across the co-axial cable should be $\sqrt{2P_cZ_0}$ . As per Faraday’s law of induction, the induced voltage across the loop should be $\omega B_p S$, where ω is the RF frequency. Equating these two, we get the following expression for the loop area for perfect coupling

$$S = \frac{\sqrt{2P_cZ_0}}{\omega\, B_p}. \tag{3}$$

It can be shown that the coupling factor ($\beta$) for the case of loop coupling is given by the following expression

$$\beta = \frac{\omega^2 B_p^2 S^2}{2P_cZ_0}. \tag{4}$$

It is also possible to feed power from two locations. It can be shown that if equal amount of power is to be fed at two locations where the magnetic field has the same amplitude and phase (like the two opposite quadrants of the RFQ), then for the case of no reflection from the RFQ, we require $\beta=0.5$ at both locations. Including beam loading, for the case of loop coupling at two identical ports, we require $\beta = 0.5 + P_b/2P_c$.

The magnetic field where the loop has to be placed has the value 7.54 mT corresponding to the dissipated power 415 kW on RFQ structure and the surface area for loop calculated from Eq. (4) is 298 $mm^2$, assuming power feeding at two ports and $\beta = 0.6$. Here, the loop is placed perpendicular to the magnetic field.

## CONCLUSION

Here we have studied both the iris as well as the loop type coupler. One option will be selected by considering the requirements and feasibility of the fabrication. Advantages and disadvantages of two types of couplers are considered. The detailed study of both of these options is going on.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] A. R. Mallahzadeh, A. A. Dastranj and H. R. Hassani, Progress In Electromagnetics Research B, Vol. 1, 67-80, 2008.

[2] Robert E. Collin, **“**Foundations for Microwave Engineering” second edition, pp. 205 to 207(2004).

[3] J. Corlett, Derun Li and A. Mitra “A 35 MHz re-buncher RF cavity for ISAC at TRIUMF” 6th European Particle Accelerator Conference, Stockholm, Sweden, 22-26 Jun 1998, e-proc. 1790.

[4] http//www.myat.com.