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DESIGN AND IMPLEMENTATION OF A PRODUCTION MODEL BIAS TEE*

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Abstract

The Facility for Rare Isotope Beams (FRIB) includes two types of half wave SC resonators (HWR) operating at 322 MHz. The fundamental power couplers used to transmit RF power into the HWRs commonly suffer from multipacting which can result in long conditioning times. A bias tee can be used to apply a high voltage to the couplers to help alleviate multipacting. A production version of the bias tee was commissioned for use at FRIB. The bias tee went through several design revisions to diagnose and correct thermal dissipation issues. This paper will discuss details of design and challenges faced during production validation of the bias tee.

INTRODUCTION

The Facility for Rare Isotope Beams (FRIB) particle accelerator uses fundamental power couplers (FPC) to transmit RF field to its superconducting cavities. These FPCs often suffer from multipacting during operation, hindering RF power transmission to the cavity [1]. Multipacting can be suppressed by applying a high voltage DC bias to the FPC with a bias tee. A prototype tee was designed and multipacting suppression verified with halfwave resonator cavities [2]. This paper will investigate the design and refining of a production-version bias tee and outline the challenges faced in doing so.

INITIAL DESIGN ISSUES

Bias tee designs generally consists of a LC network that allows a DC bias to be applied to a part of an RF transmission line [3, 4]. In FRIB, a bias tee prototype was implemented using a quarter-wave stub and an in-line capacitor (Fig. 1). The stub allows a high voltage wire to travel inside the inner conductor to the FPC-side of a DC blocking capacitor. This creates a port that has both RF and DC voltages available. A series resistor and ferrite choke were put in-line with the high voltage wire to prevent RF from leaking through the blocking capacitor and back to the high voltage supply. A shunt resistance was also added to the high voltage wire as a safety measure to keep the blocking capacitor discharged when not in use. Once initial tee-prototyping was completed at FRIB, a production model was commissioned from Microwave Techniques LLC (formerly Mega Industries) (Fig. 2)

The Mega tees were tested using 8 kW RF power amplifiers. This was done to mimic the worst-case conditions the tees would see while connected to a FPC. To test the tees, a short circuit plate was attached at the end of a length of transmission line. Line extensions of various sizes were used to achieve worst case phase at the tee. 5 kW CW RF power was then run through the tees until a steady-state temperature was achieved. RTDs inside the tee measured temperature distribution across the stub section; one RTD was mounted inside the tee's inner conductor junction and another on the tee stub's short circuit plate. This would allow measurement of the thermal dissipation across the stub.

During high power RF testing of the Revision A Mega prototype tees, it was found that the steady-state temperatures of the tee were much different than the temperatures seen in the original FRIB prototype tests (refer to Table 1). The Mega inner conductor junction measured 101.68 ºC while its stub short circuit plate measured 42.23 ºC, a difference of 59.45 ºC. This indicated a high thermal resistance existed somewhere in the inner conductor junction. The Mega inner conductor junction was also 23.12 ºC hotter than the original FRIB prototype, further indicating thermal issues. These differences in temperature led to an extensive revision process of the Mega tee to try and identify the source of the temperature issue and improve thermal distribution.

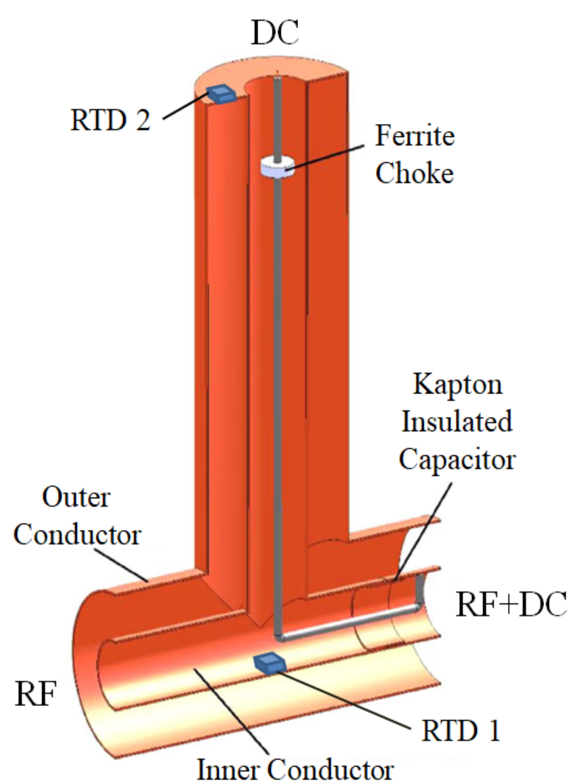

Figure 1: Bias tee concept model.

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Table 1: Comparison of Steady-State Tee Temperatures at Worst Case Phase and 5 kW Output Power

5 kW Testing	**RTD 1: Inner Junction**	**RTD 2: Short Circuit Plate**
FRIB prototype	78.56 ºC	39.00 ºC
Mega, Rev. A	101.68 ºC	42.23 ºC
Mega, Rev. E	49.10 ºC	45.60 ºC

BIAS TEE DEVELOPMENT

Numerous factors were found to contribute to poor thermal distribution in the Mega prototype tees. The first few revisions of the Mega tees experimented with various custom diameters of transmission line for their short circuit stub sections. Eventually it was found that a larger diameter stub with more material maintained better thermal conduction. This led to using standard 3-1/8” EIA diameters for the stub section.

Several other changes were made in the revision process to try and aid thermal dissipation. The tees were coated in a high-emissivity black paint to increase thermal radiation. The stub’s short circuit plate thickness was increased to increase thermal conductivity. These changes contributed minor temperature improvements but did not solve the problem of poor internal thermal conduction.

The connector between the inner conductor junction and stub inner conductor also went through several design changes. Initially the connector was comprised of short fingers with no internal retaining rings. Upon inspection it was found that the stub’s inner conductor was pinching the fingers inward at the contact point, leading to a very poor thermal connection (Fig. 3). This prompted lengthening of the connector fingers and installation of internal retaining rings in the connector. These changes moved the fulcrum between the connector and inner conductor more towards the stub’s short circuit plate and increased the contact force and surface area between them.

The bias tee steady state temperatures were much improved after the last modifications to the connector were made. As shown in Table 1, the temperature of the inner conductor tee-junction dropped dramatically from 101.68 ºC to 49.1 ºC in the Revision E tee. The temperature distribution between the two measurement points was much improved in the Mega tee, with now only a 3.5 ºC difference between inner conductor junction and short circuit plate. The main source of these improvements was found to be the increased contact force at the tee-junction connector. Contributions from other additions (such as high-emissivity paint) were not individually measured but deemed acceptable for inclusion in the final design.

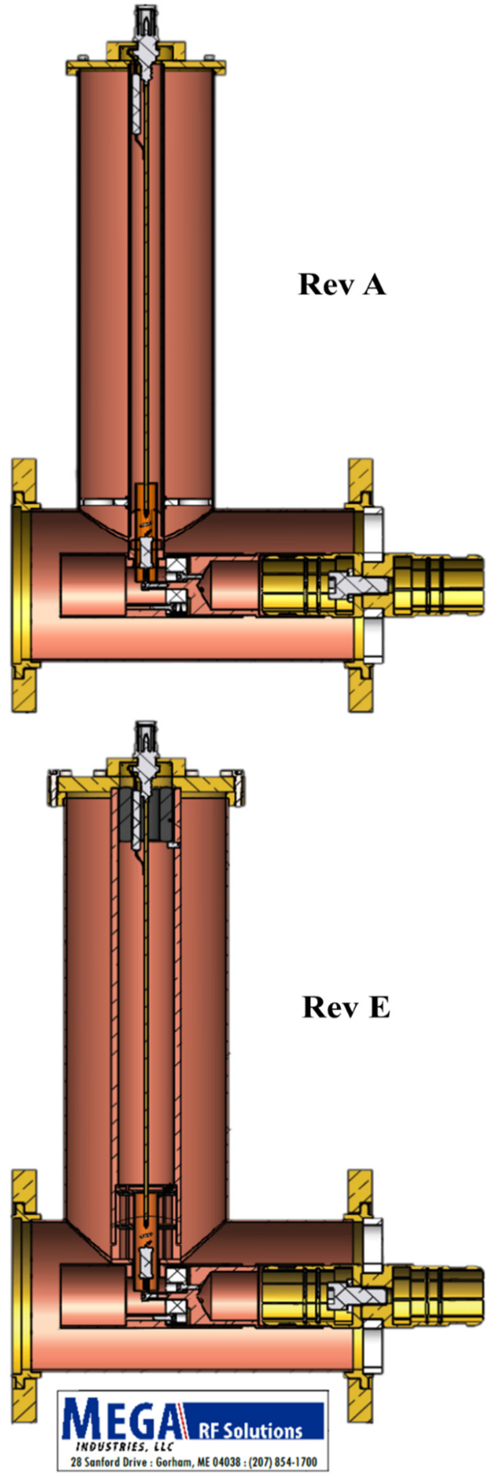

Figure 2: Comparison of cross-sections for Mega Revision A and Revision E tees.

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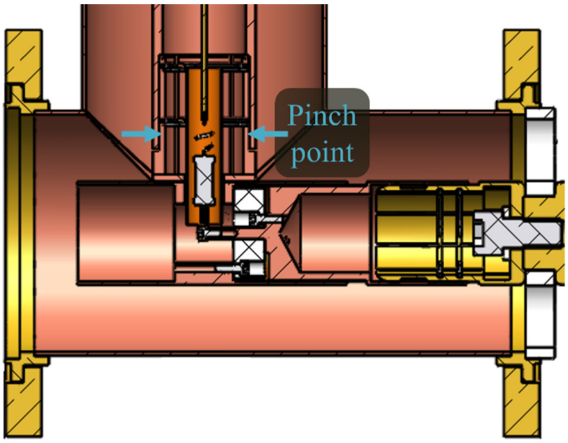

Figure 3: Pinch point on bias tee stub connector.

CONCLUSION

A production version of a bias tee was commissioned from Mega Industries for use in the FRIB. The initial version of the Mega tee had some issues with thermal dissipation, but these were corrected after several revisions. It was found that the main source of the early tee versions' poor heat dissipation was insufficient surface area and contact force at the interface of the stub inner conductor and its connector. It is assumed that the other revision alterations (addition of high-emissivity paint, larger stub diameters, etc.) together attributed to the large improvement over the FRIB prototype steady-state temperatures. Since then, 220 bias tees have been produced by Mega Industries and put into operation at FRIB (Fig. 4).

Figure 4: Mega bias tees installed in FRIB.

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