Design and Implementation of a Production Model Bias Tee

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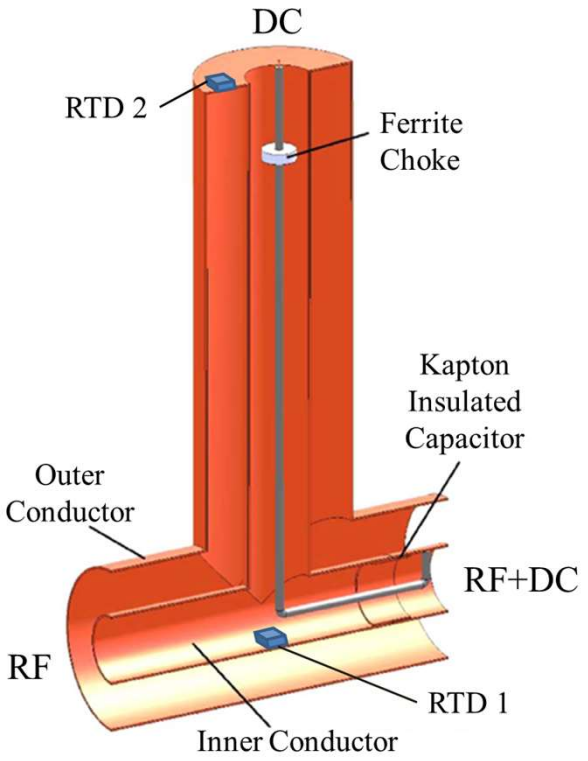
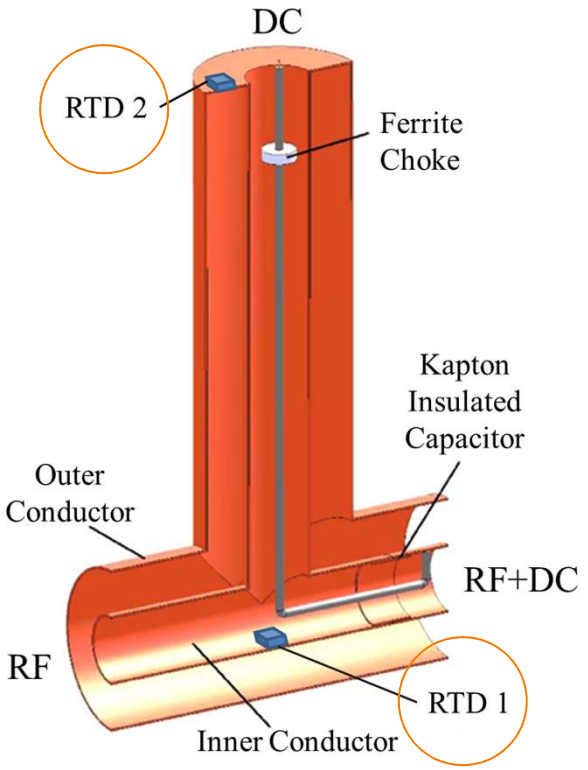
Introduction

- Applying high voltage on a half wave resonator's fundamental power coupler (FPC) antenna has been shown to suppress multipacting
- A bias tee is a three-port device used to provide a DC voltage on the inner conductor of the RF transmission line (between the RF amplifier and the FPC)
- A λ/4-short stub coaxial segment is used to create an entry point for a high voltage wire
- The high voltage wire runs along the inside of the coaxial inner conductor and connects to the RF+DC side of a blocking capacitor
- The wire is insulated from RF via the shielding effect of the inner conductor as well as an in-line resistor
- The cylindrical DC blocking capacitor is created by isolating overlaying inner conductors with dielectric film



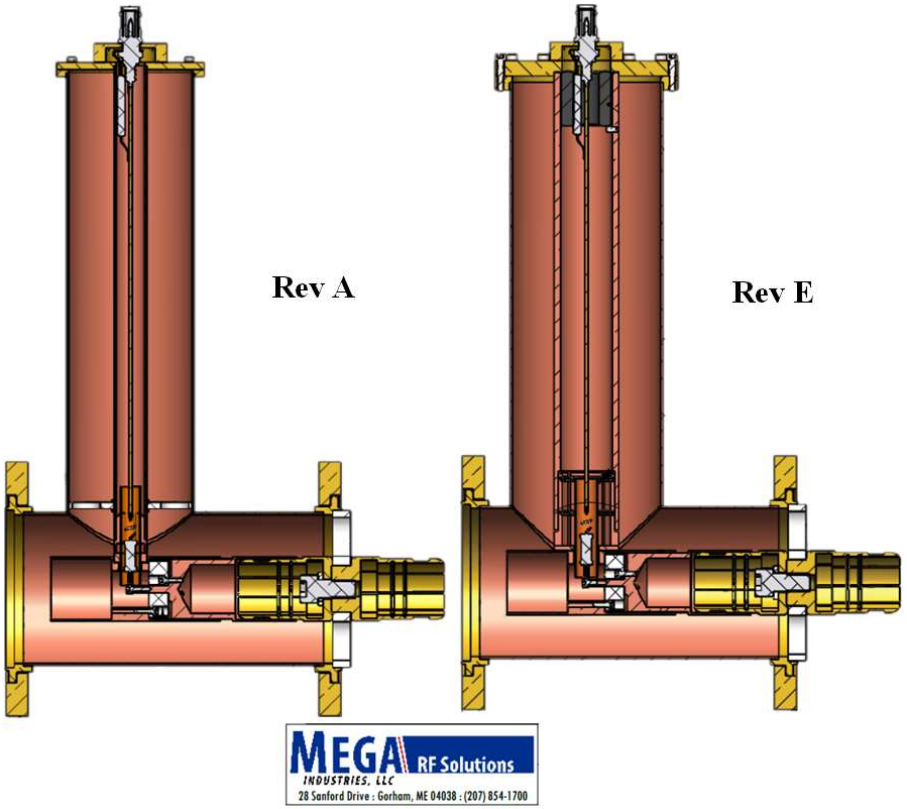
Production Bias Tee Development

- FRIB created two prototypes and then commissioned Microwave Techniques LLC (formerly Mega Industries) to create 220 production model bias tees
- The Mega tee prototypes were tested at FRIB by applying 5 kW continuous wave RF at full reflection and worst-case phase
- RTDs were placed inside the tees to measure temperature:
  - RTD 1: inside the inner conductor junction
  - RTD 2: on the short circuit plate of the stub
- Temperature measurements were taken once the tees were seen to reach thermal equilibrium



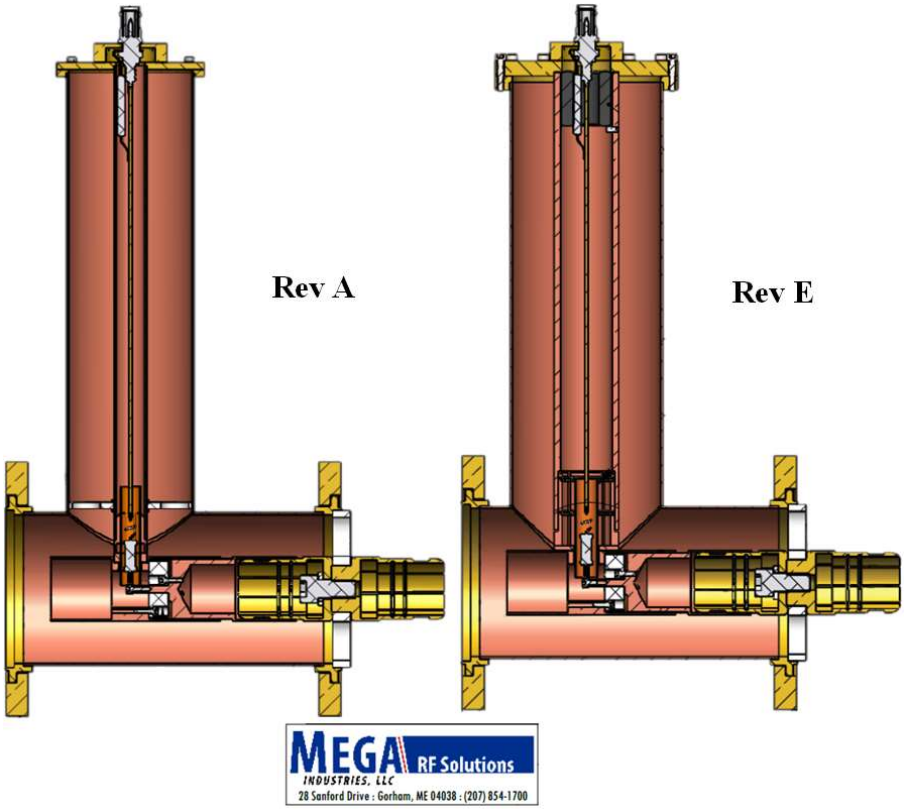
Production Bias Tee Development

- Revision A of the Mega tee showed poor thermal performance
  - 101.68 ºC on its inner conductor junction vs the original 78.56 ºC on the FRIB prototype
  - Short circuit plate was at 42.23 ºC, indicating there was little thermal dissipation across the tee stub
- Attempted several additions that only had small positive effects:
  - Thicker stub short circuit plate
  - Additional heat sink on plate
  - Coat of high-emissivity black paint
  - Different diameters of transmission line for the stub section



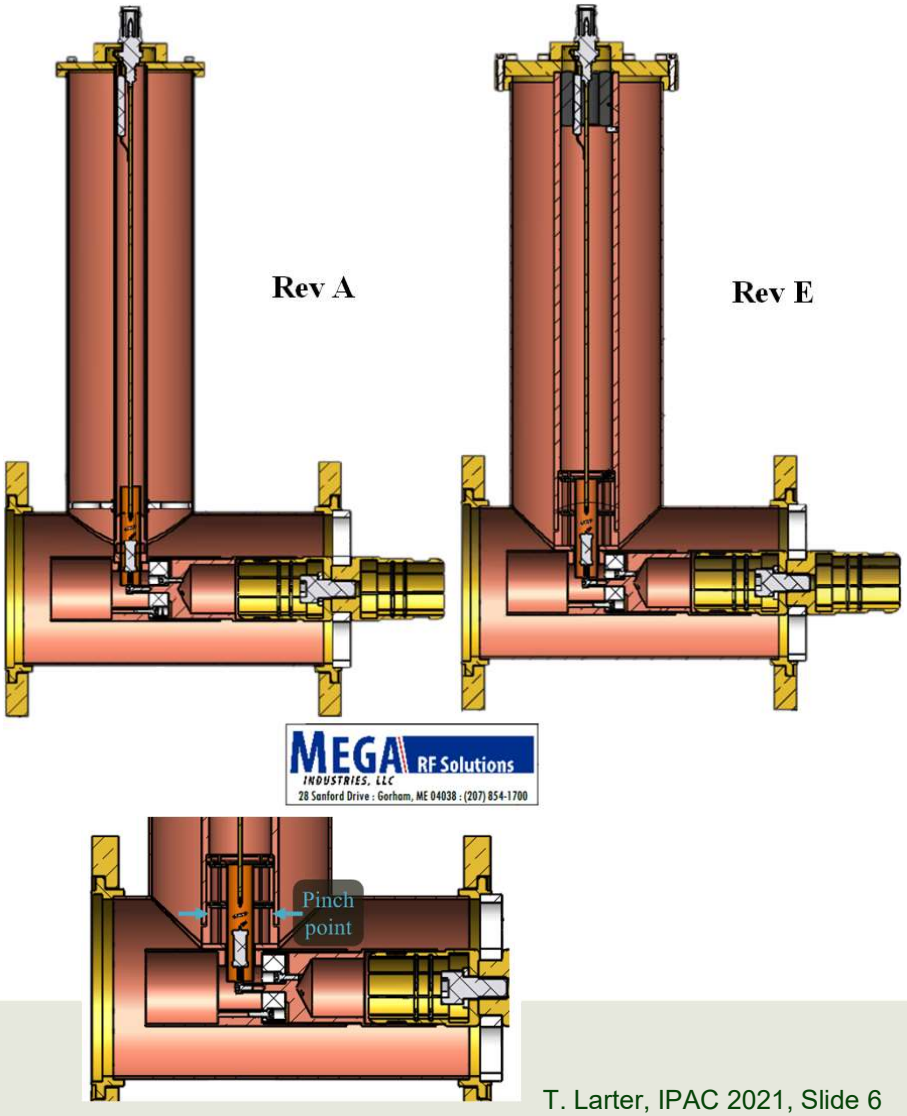
Production Bias Tee Development

- The connector for the stub's inner conductor went through several revisions
  - First version had a small, custom-style connector with shorter fingers
  - Later versions experimented with increasing connector diameter and finger length
  - Connector diameter and finger length made larger to add more material and hopefully improve conduction



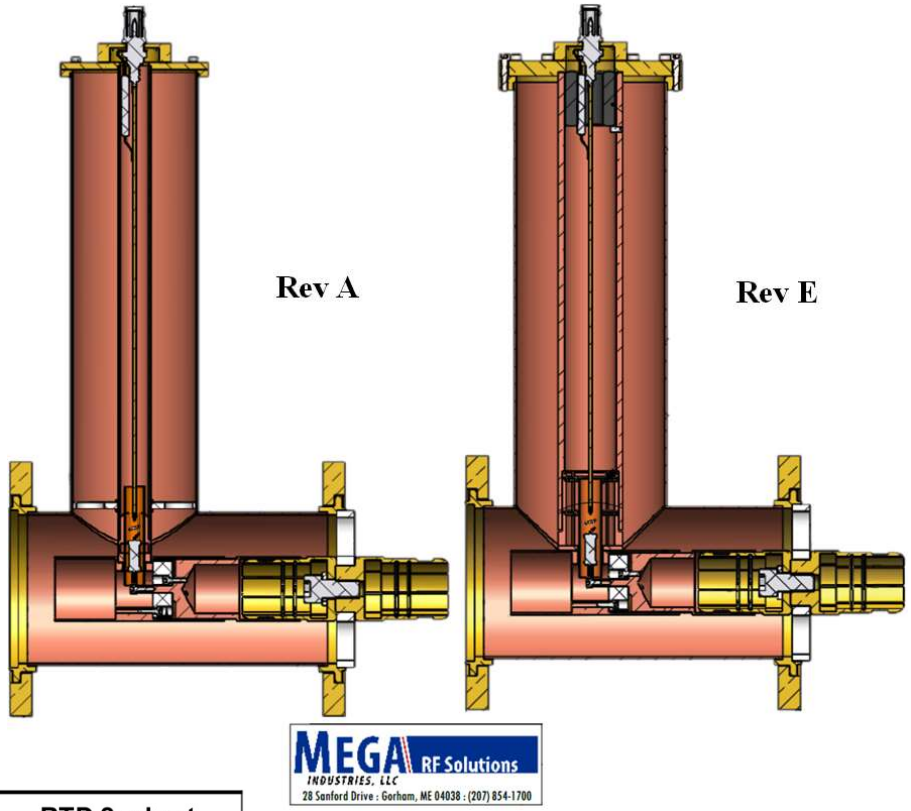
Production Bias Tee Development

- Experimenting with stub connector design revealed it as the source of the high thermal resistance:
  - The stub's inner conductor created a fulcrum where it met the connector
  - This fulcrum acted as a pinch point with the connector fingers and pushed the connector fingers away from the inner conductor walls
  - This caused there to be only a weak thermal connection between the two, raising the temperature at that junction



Production Bias Tee Development

- Final revision used the same design as a typical 3-1/8” EIA-sized connector, having longer fingers but also using two retaining rings inside
  - Junction temperature dropped drastically, from 101.68 ºC in Revision A down to 49.10 ºC in Revision E
  - This was also better than the FRIB prototype, which was at 78.56 ºC
  - Temperature distribution across the tee was now just 3.5 ºC drop from junction to short circuit



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

Installation in FRIB

- 220 final version tees were produced by Mega and delivered to FRIB
- All tees have since been installed in FRIB
- Tees have been in operation since October, 2019