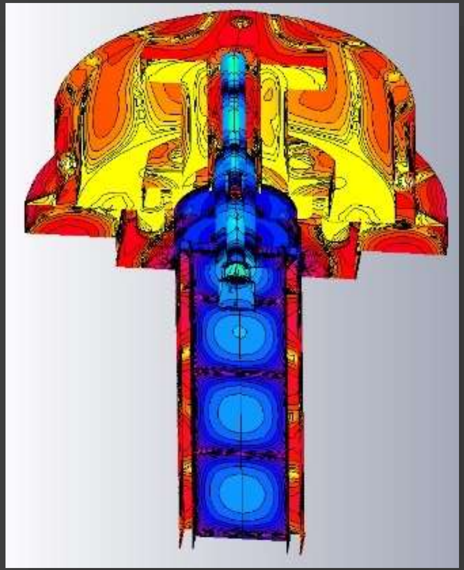

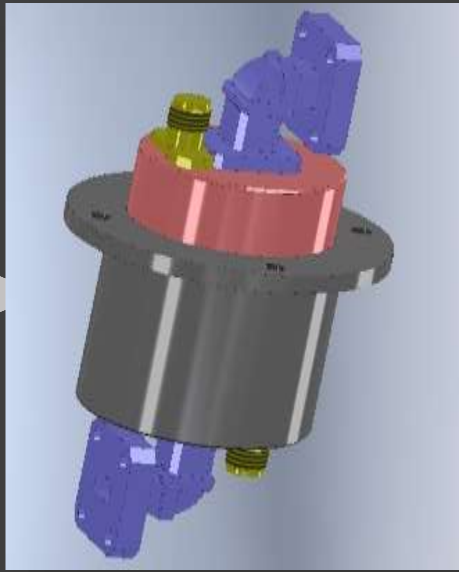

Design & Manufacture of Multi-Channel Microwave Rotary Joint

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ARMMS
RF & Microwave Society

Abstract

Radar and surveillance systems over the last several decades have undergone major changes with much focused on transmitter design, receiver design, antenna modelling and signal processing.

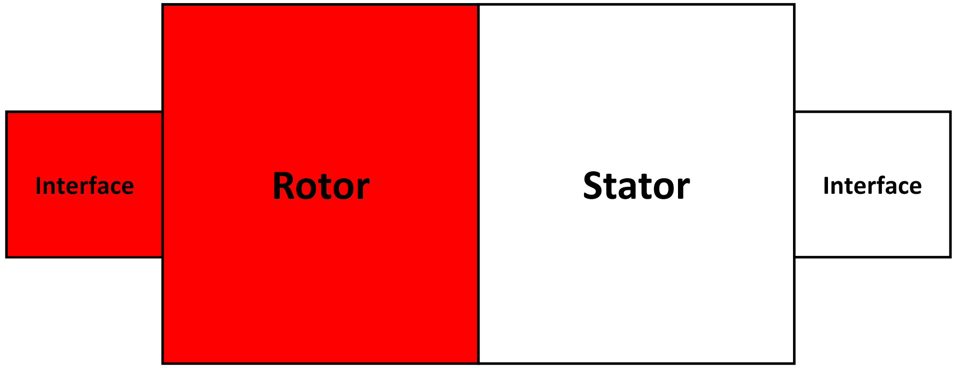
Little though is mentioned about the rotary joints and how these complex assemblies are engineered. As an interfacing medium that permits RF continuity at power or high frequency while allowing controlled motion, the design and manufacturing considerations have direct impact on overall system performance. As the only UK designer and manufacturer of multichannel / complex MW rotary joints, we aim to highlight some of the development challenges, their system impact and approaches that can be taken to address them.

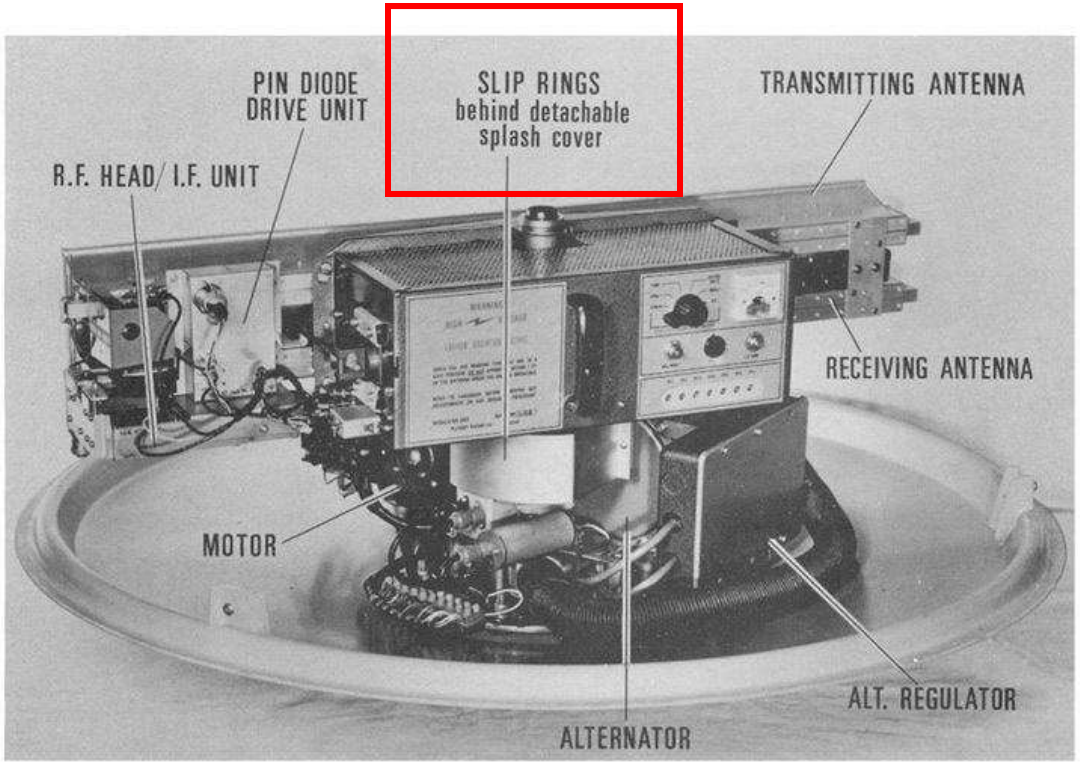
Content

- Concept & History
- Contacting MW rotary joint
- Contactless MW rotary joint
- Mode conversion
- Choke structure
- Multi-channel stacking
- Questions

Concept & History

- Interfacing stationary element of a system to the rotating element while allowing signal continuity
- Optimum transmission throughput, low reflection, broad bandwidth, and power capability
- Heritage extending several decades to early 1940's and development of Type159B by Decca
- MR12 Radar developed in 1966 by Decca engineering (became part of Plessey)

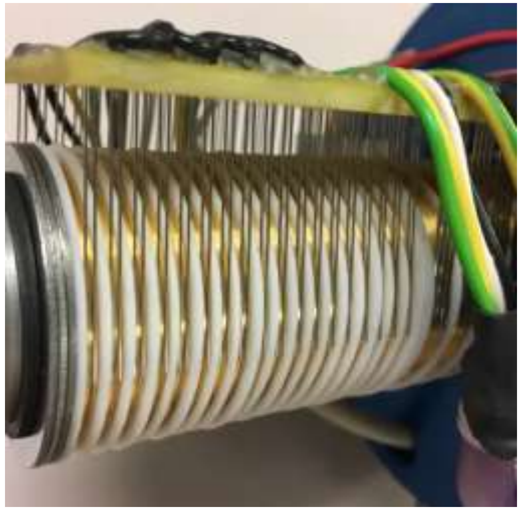


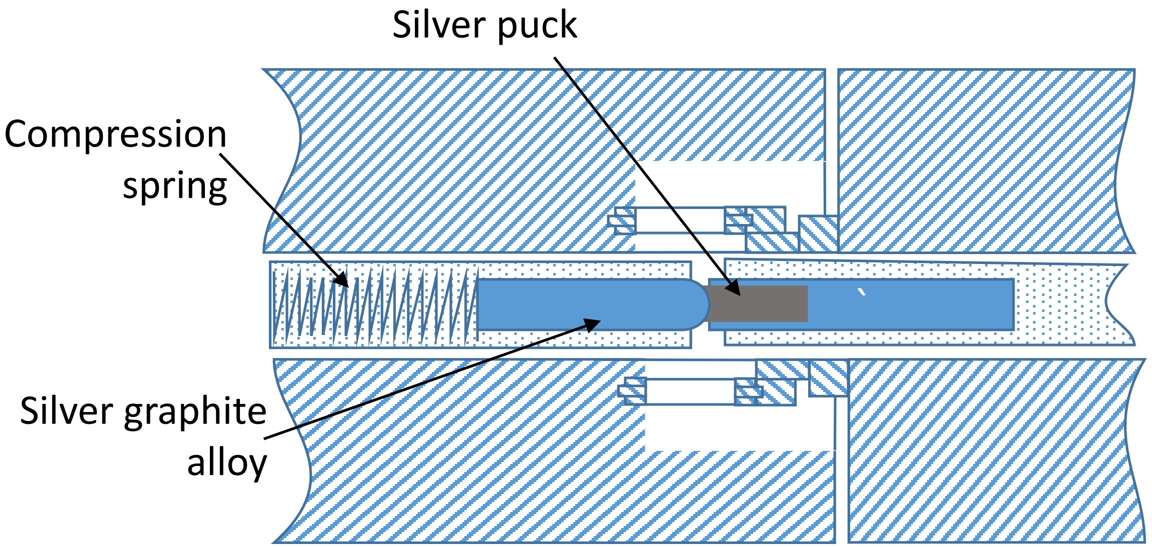


MR12 Antenna Unit with Radome removed

Contacting MW rotary joints

- Physical size have direct impact on performance
- DC up to low VHF (few 100 MHz)
- Metallic contacts are used inside a slip ring track
- Brush technologies: Monofilament, Poly-filament, Composite/Graphite
- Continuous use will lead to abrasion, loss of performance and potentially arcing hence operational life is a key consideration.
- High data (~1Gbps) with multiple brushes but signal integrity will be impacted; High frequency contents are filtered. Splitter and combiner networks adds complexity, size, cost



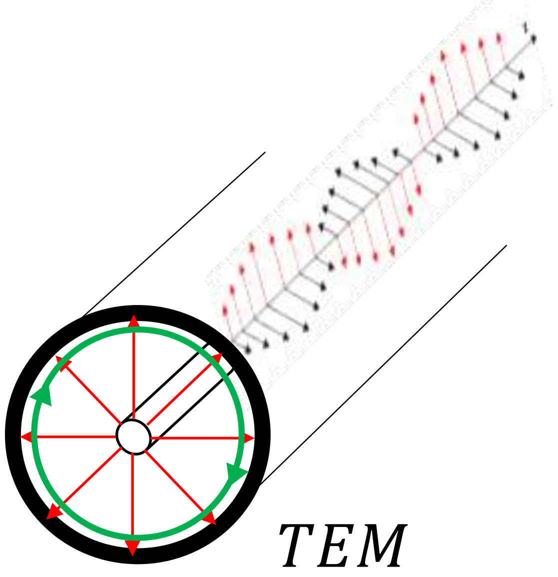


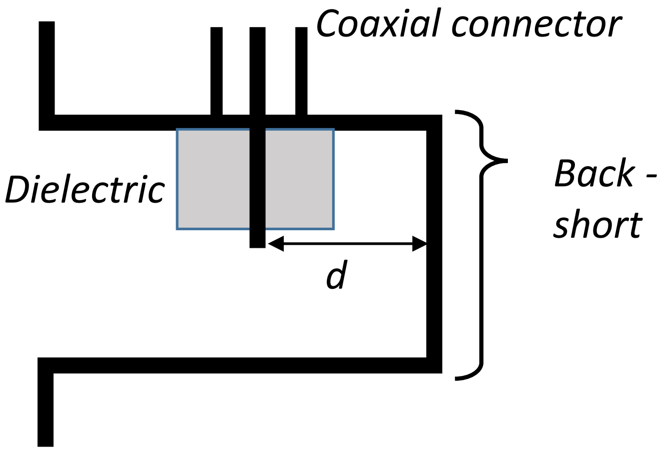
Contactless MW rotary joints

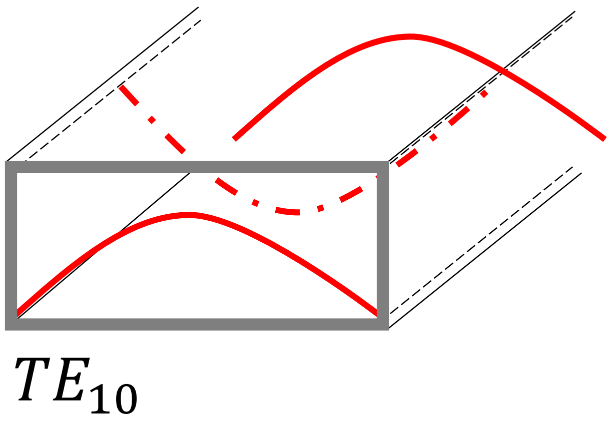
- RF continuity under constant angular motion
- Physical contact between rotor and stator limited to mechanical bearings; operational life up to 15+ years
- Multi-channel design have narrow operational bandwidth with optimised performance
- *Single channel modules are available that can operate multi octave bands*
- Special structures and techniques can be implemented to achieve close coupling without contact between the stator and rotor.
- Regardless of I, L or U configuration, uniform field distribution need to be maintained in a continually rotating assembly
- Specific modes can be utilised, predominantly TEM (coax) or TE11 (Circular WG)

TE10/TEM mode conversation

- For rectangular waveguides, Fundamental TE10 mode is the lowest and most prominent that support EM field propagation
- Peak electric field at the centre of waveguide
- Width of waveguide equal appx. $\lambda/_2$ at the frequency band of operation
- Probe position at distance d nominally $^1/_4\,\lambda$ in relation to back-short to reflect EM energy going the wrong way

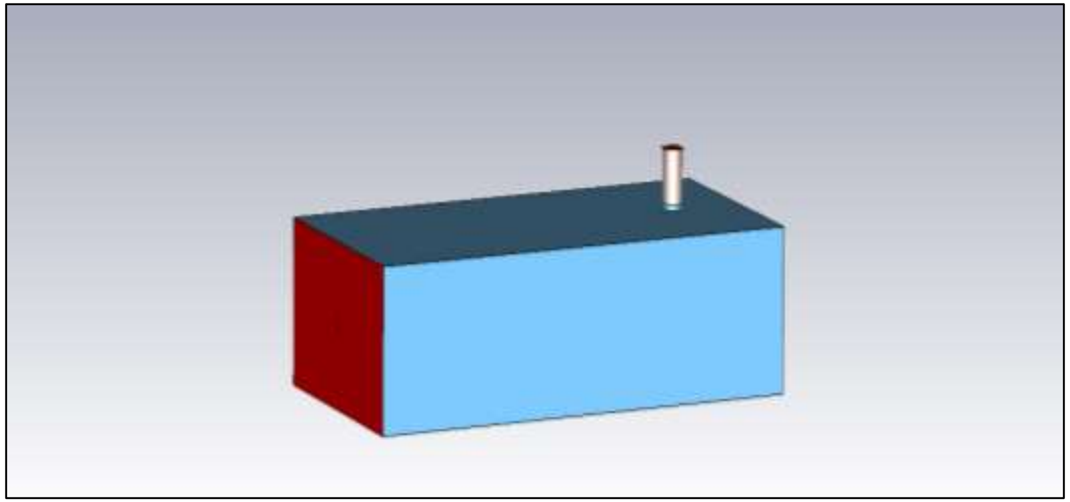


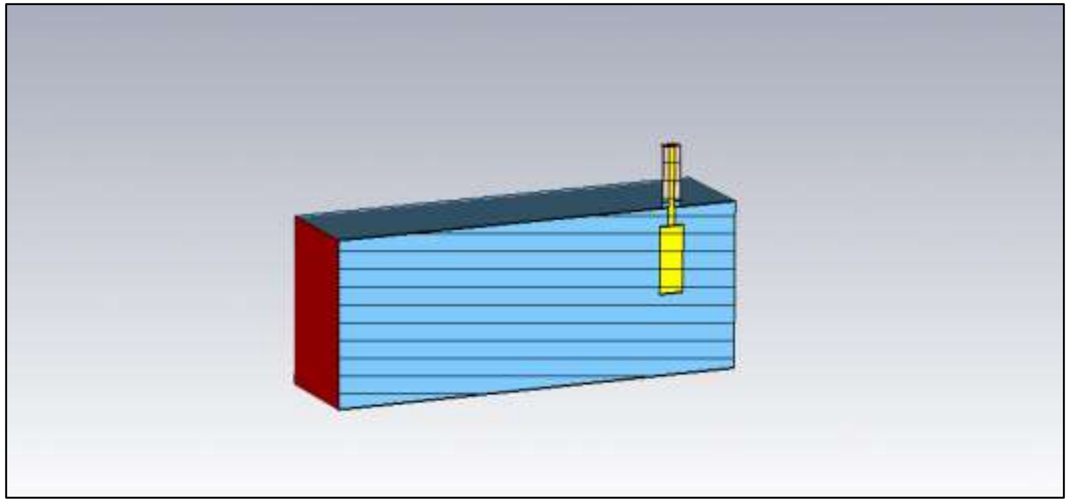




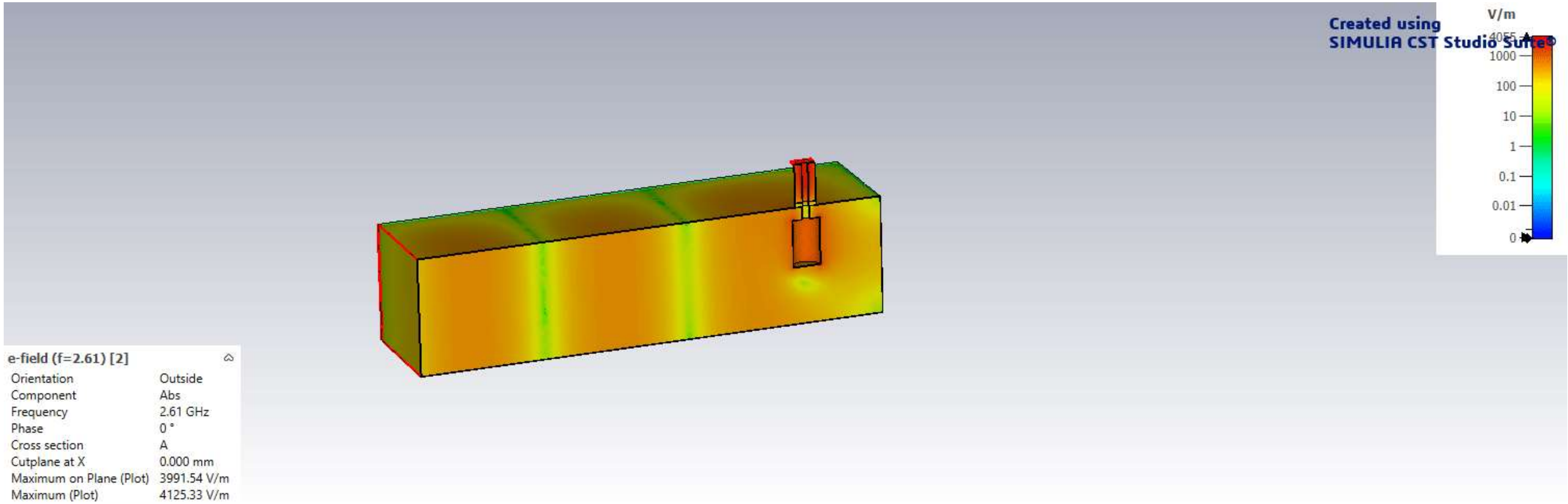
TE10/TEM mode conversion

- Example of an E-plane Transition showing good return loss at circa 2.61 GHz Fc.
- For mechanical fabrication ideally an E-plan cut can be used to allow surface uniformity
- E-plane cut allows easier soldering and mounting of probe and dielectric material
- Precision of 20um can be used to have seamless integration between the two halves

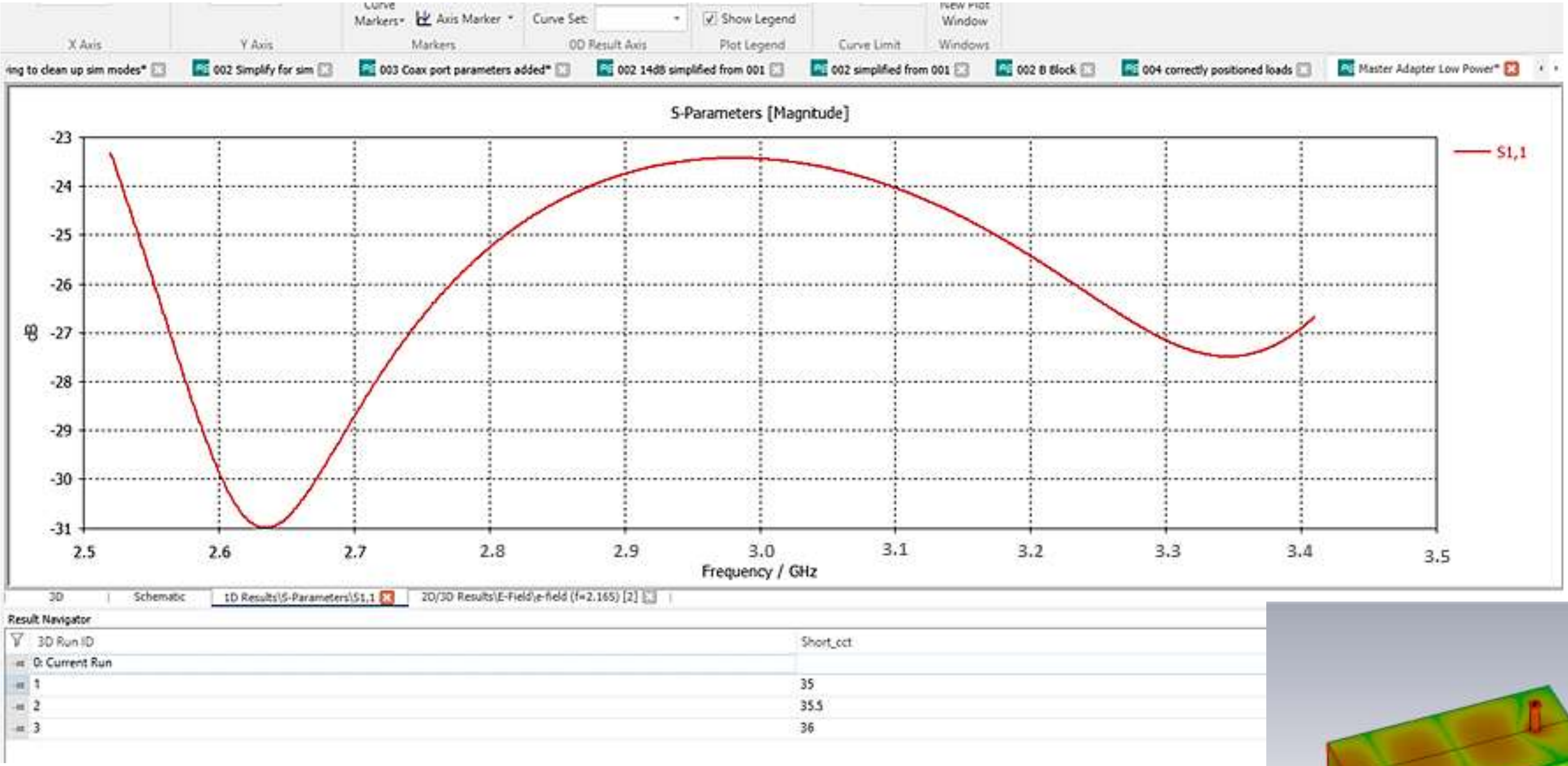


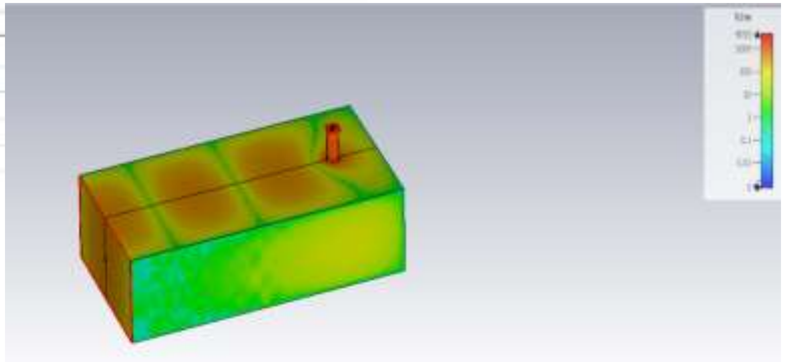


TE10/TEM mode conversion



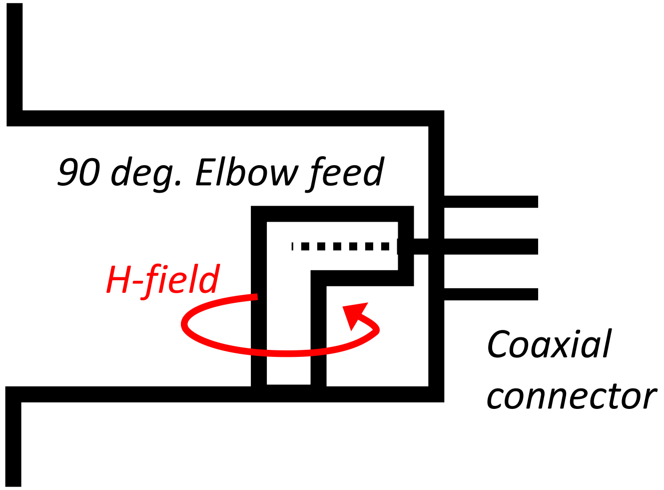
TE10/TEM mode conversion

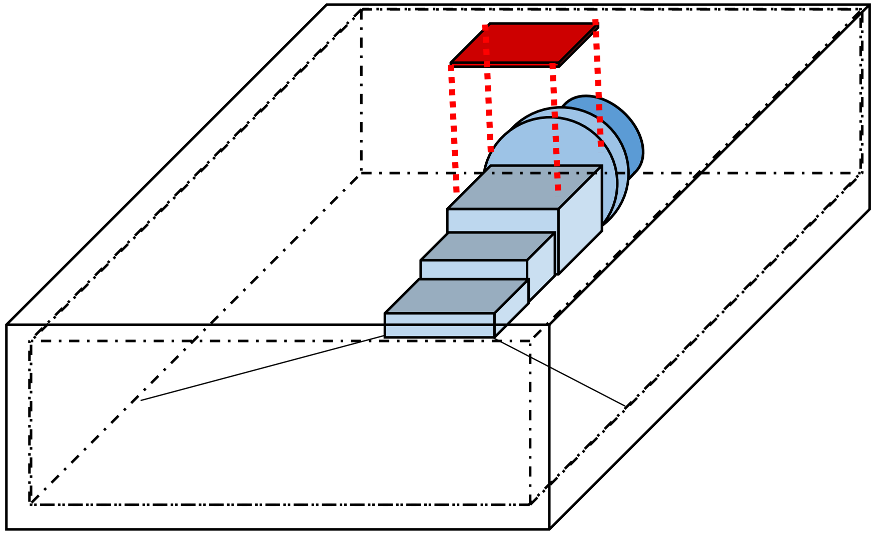




TE10/TEM mode conversion

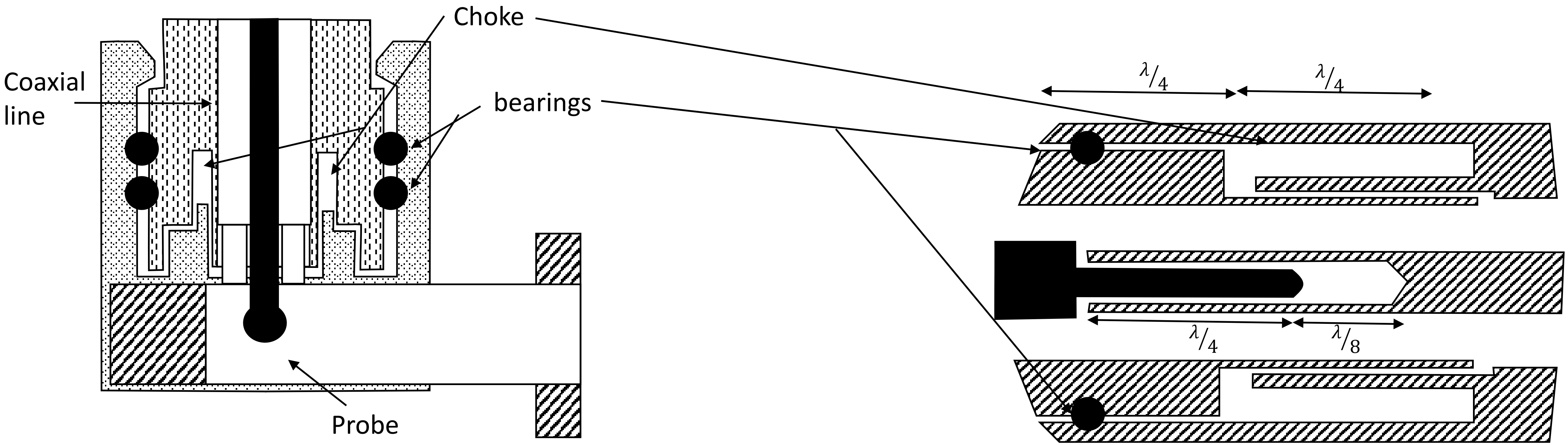
- Design can be more complicated for an I configuration rotary joint design
- To have an Inline TE10 to TEM mode conversion is required
- One approach to having an inline TE10 to TEM mode convertor is to use a shortening elbow
- This will generate a time varying field to have EM propagation.
- Degraded Return loss, Insertion Loss performance but marginally better power handling due to thermal dissipation path. DC short to be taken in to account on this design approach
- A more common approach could be to utilise stepped impedance transformer to match the wave impedance of a Waveguide to that of a 50 ohm coax line.





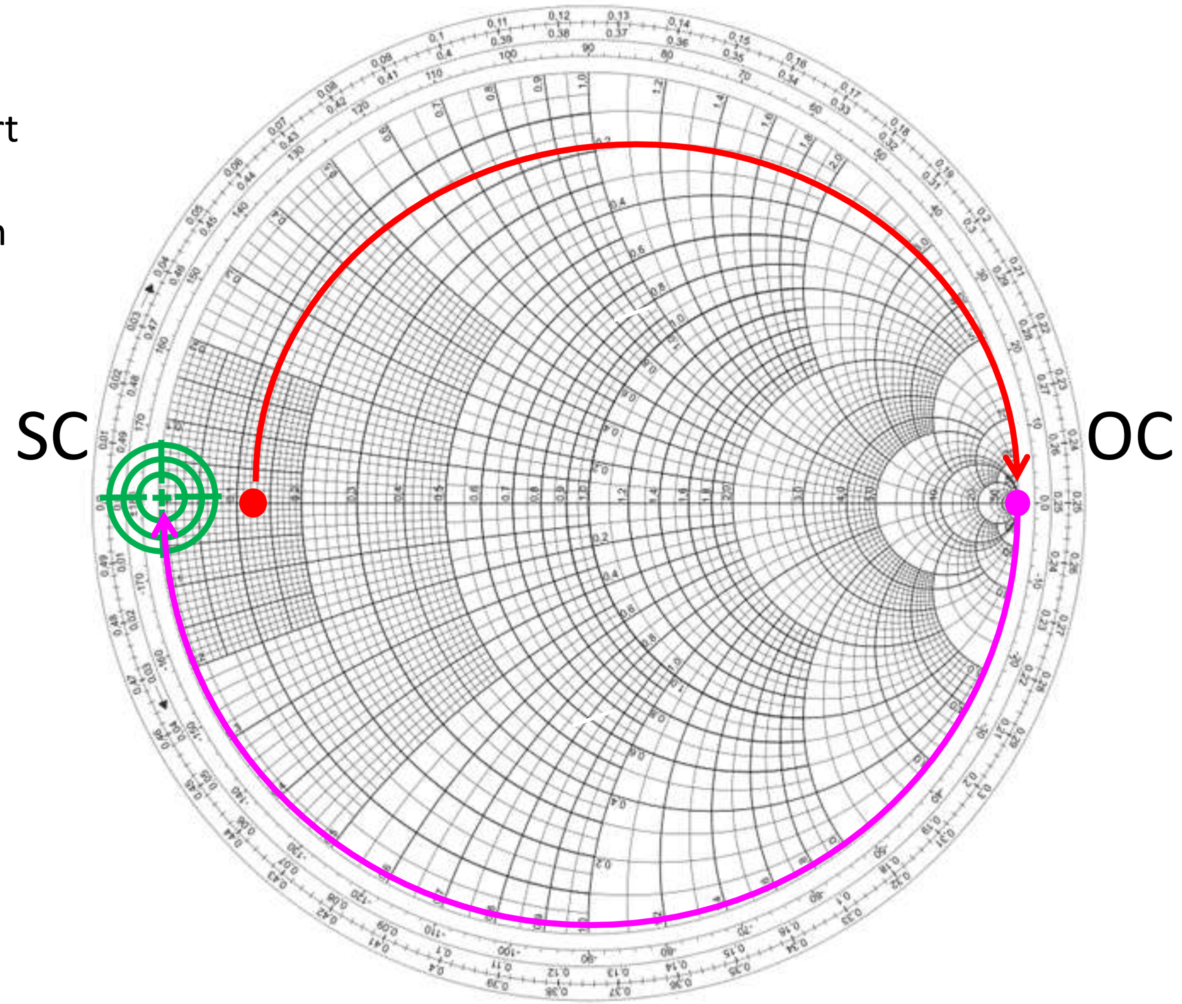
Implementation of choke

- Centre coax machined as male and female mating contacts to allow for optimum Magnetic and Capacitive coupling
- Launch pin simulated and adjusted for best match
- RF continuity is maintained on the outer ring by implementing choke structure



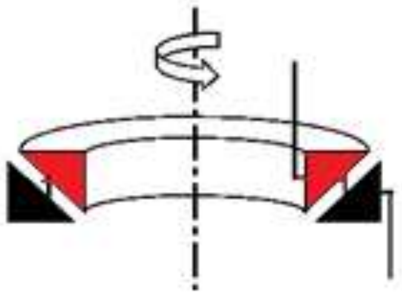
Implementation of choke

- Implement a short circuit in the outer conductor while maintaining physical separation
- A precision gap would allow for a rather average performance short
- $\lambda/_4$ Stubs are implemented to move from a low Impedance to high impedance back to low impedance
- Concentricity play a critical part in maintaining performance.
- Variation in concentricity from machining imperfection to bearing tolerance gives rise to insertion WoW and phase WoW.
- Tighter tolerance bearings can be used but the driving torque would need to be taken in to account particularly on larger low frequency design with higher physical mass

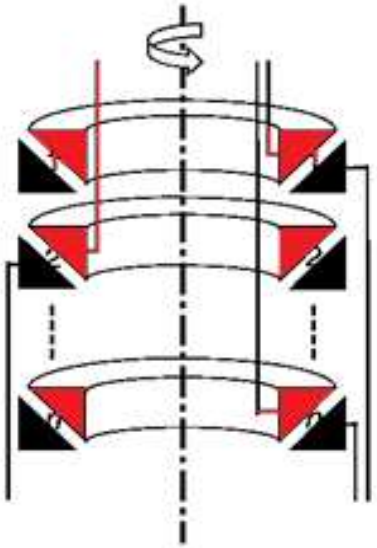


Multi-channel stacking

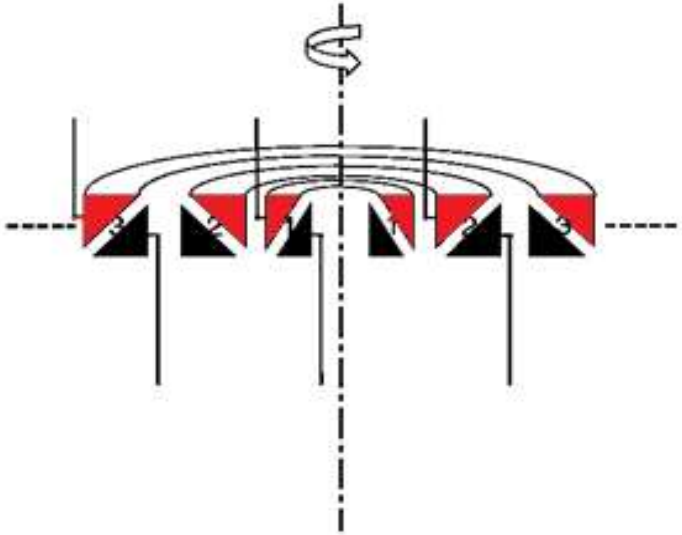
- A multi-channel configuration consist of multiple modular sections each stacked axially or interleaved radially
- Stack configuration would be governed primarily by the system space envelope.
- To allow channel feed, a centre opening is implemented for cables to be fed through
- Each module would have its own stator and rotor bearing



Hollow bore



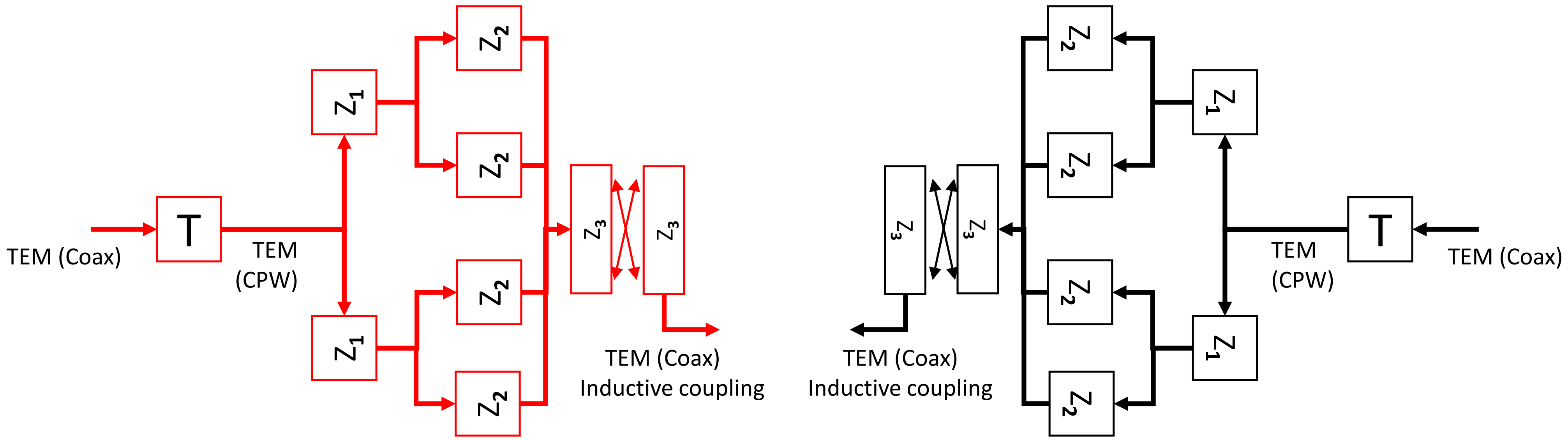
Axial stacking



Radial interleaving

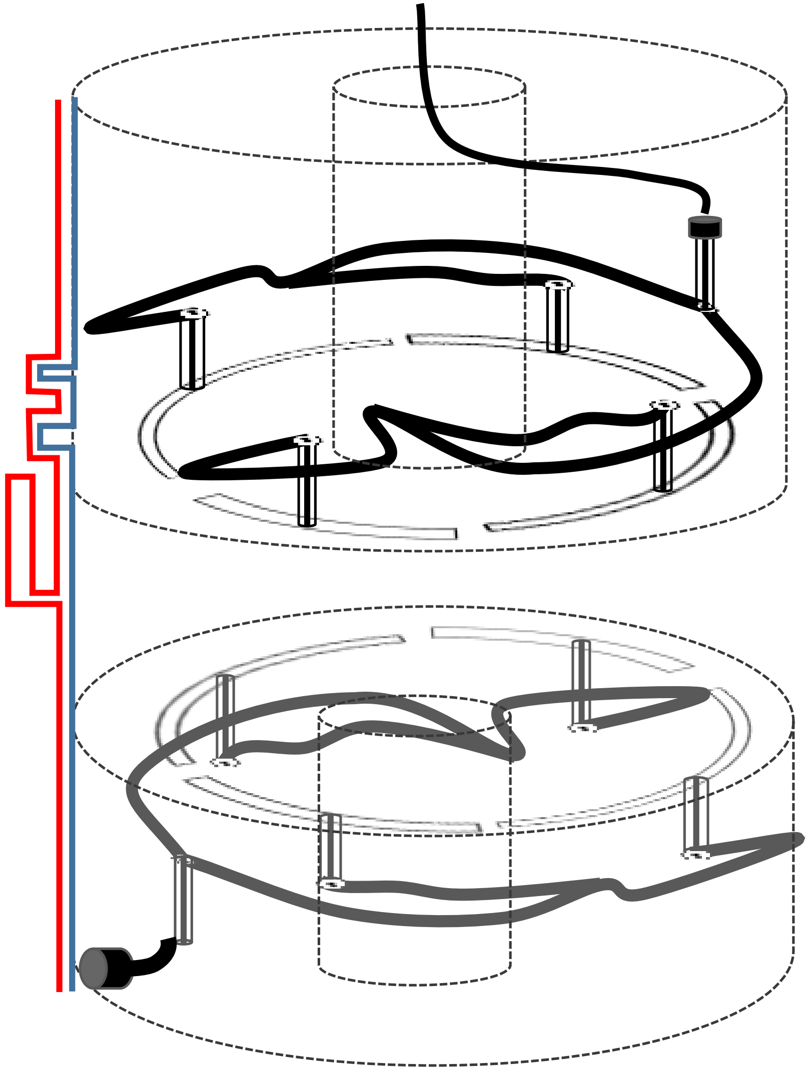
Multi-channel stacking

- To accommodate the internal large central opening, CPW transmission line is used with in the rotor to allow a Quasi-TEM field to be setup
- The splitter network is used to match nominal 50 Ohm input on to the low impedance EM coupled feed tracks (few ohms)
- Feed points are positioned equidistant to create a phase matched and balanced and symmetric TEM excitation and suppress higher order modes



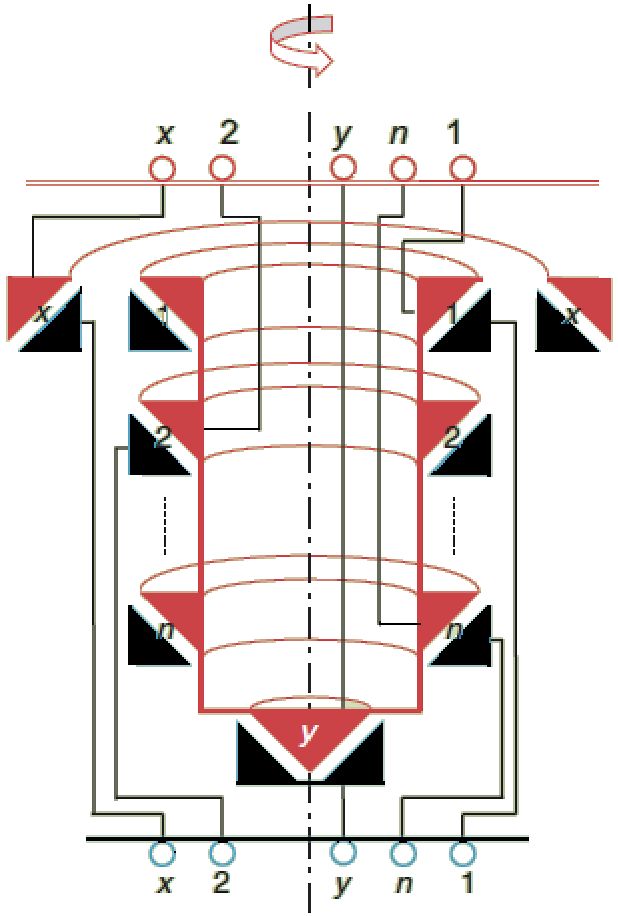
Multi-channel stacking

- Reciprocal configuration is used on the stator.
- EM coupled signal is recombined and impedance matched for interfacing with the coaxial port
- Choke rings on the outer cavity allow for RF continuity



Example of Multi-channel stacking

- 8 channel
- Shipborne L/IFF-band radar
- Continuously rotating assembly
- Phase matched ports
- Encoder for angular position and speed data



Link Microtek in a Glance

Components	EMF Safety	Service & Cal.	Emisens	AZDEC	Engineering	Telecoms	Link-IT
Active and passive RF and Microwave components, modules, assemblies and systems DC-290GHz	EMF instruments and survey equipment DC-100GHz	Service, calibration and repair centre	RF & optical non-invasive liquid integration system	Optical communication system for land, naval and underwater systems	Design and manufacture of Microwave multi-channel rotary joint and waveguide assemblies	Supplier of BTS antennas, PIM testing instruments and DAS components	Cyber security training, data recovery, managed services and IT consultancy

Southampton

- SME in business since 1995
- 38 staff
- 2 sites, Basingstoke and Southampton
- ISO9001:14001
- Cyber Essential Plus

Basingstoke

Thank you

Questions?