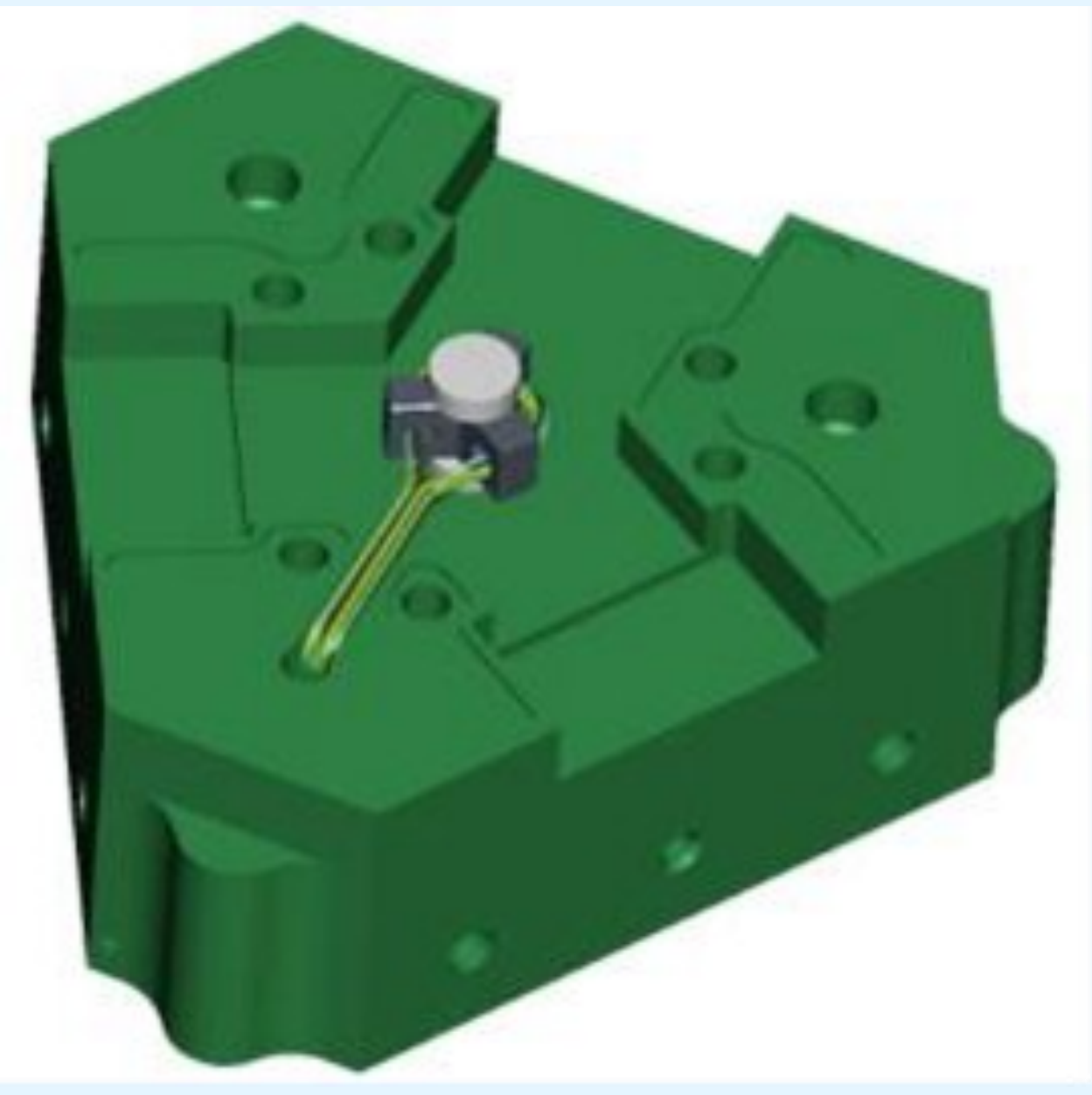
COM DEV®
EUROPE

FERRITE BASED SWITCHES FOR EARTH OBSERVATION PAYLOADS
Applications—Radiometer Calibration and Altimeter/Scatterometer Front Ends

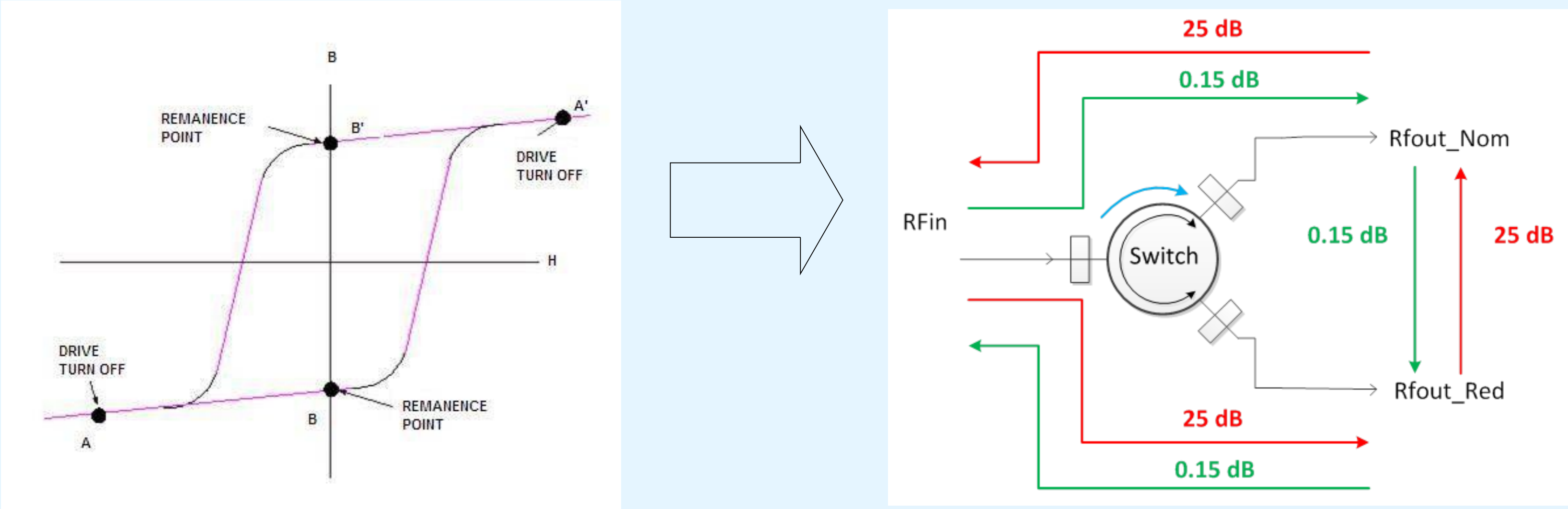
Ferrite Switch Background

Basic Concept

- A ferrite switch is a 3-port waveguide assembly
- WYE ferrite resonator located at the centre
- Dielectric spacers mechanically supports the resonator and provides heat path from ferrite to housing
- Wire loop passing through ferrite arms
- High current switching pulse magnetises the ferrite junction



Theory

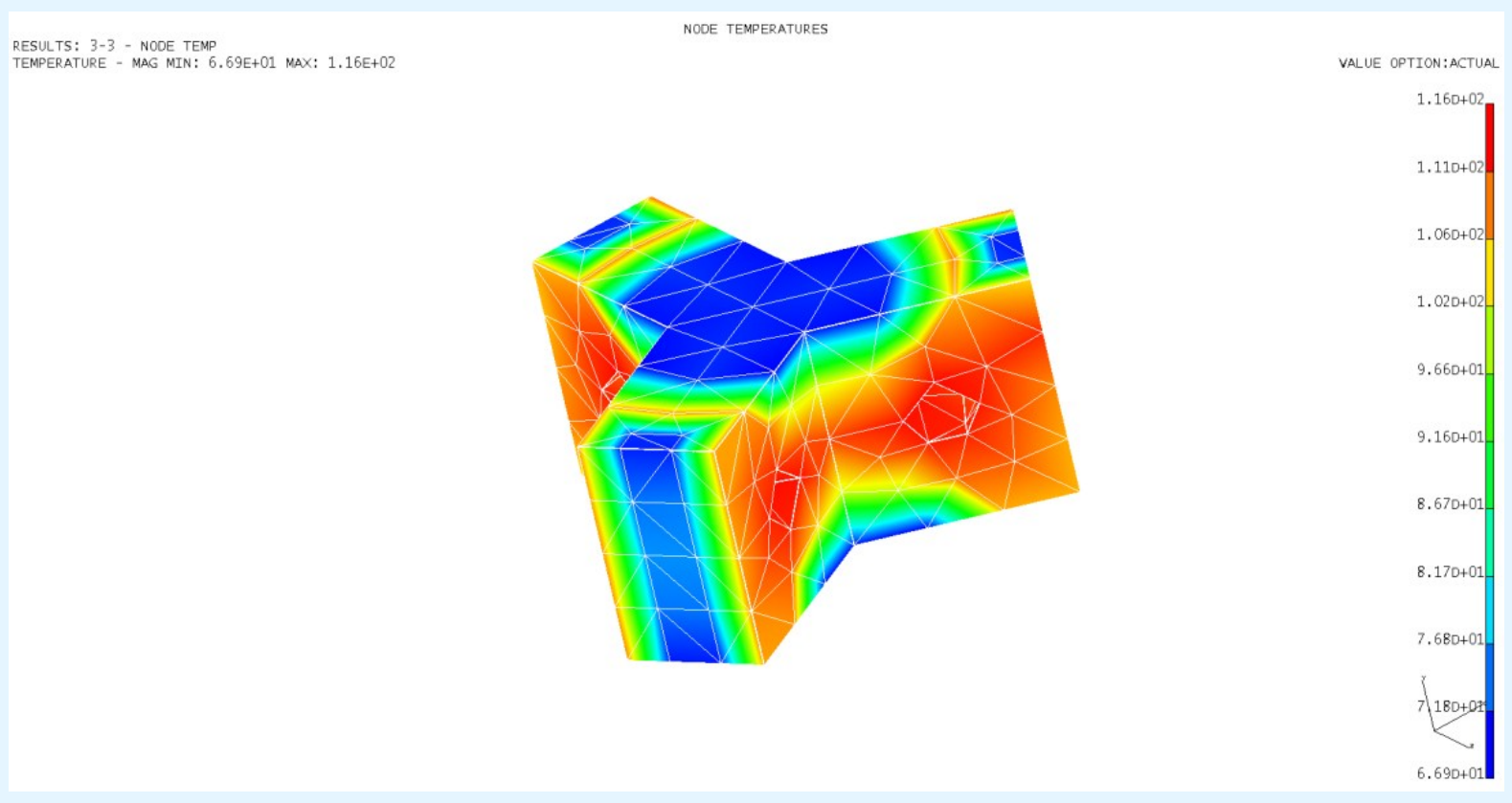


- Forward current applied to latching wire; the resulting magnetic field strength (H) drives ferrite to +ve magnetic saturation (A')
- Current removed, so magnetization now drops to +ve remanence (B')
- Ferrite is now latched to remanence point and the switch acts as a standard circulator
- No current required at this point
- Reverse current applied to latching wire; consequent magnetic field strength (H) drives ferrite to –ve magnetic saturation (A)
- Current removed, magnetization now drops to –ve remanence (B)
- Ferrite is now latched to remanence point and acts as a standard circulator in opposite direction

High Power Handling

- Thermal issues are of primary importance when designing a ferrite switch capable of handling 200W of CW power
- With an insertion loss of 0.15 dB, a ferrite switch subject to incident power of 200W will have to dissipate 7W of continuous thermal power
- Below are the techniques employed to ensure that the RF performance is maintained and the switch continues to operate reliably over the mission lifetime

Thermal Management



Temperature Profile 20GHz at 170W

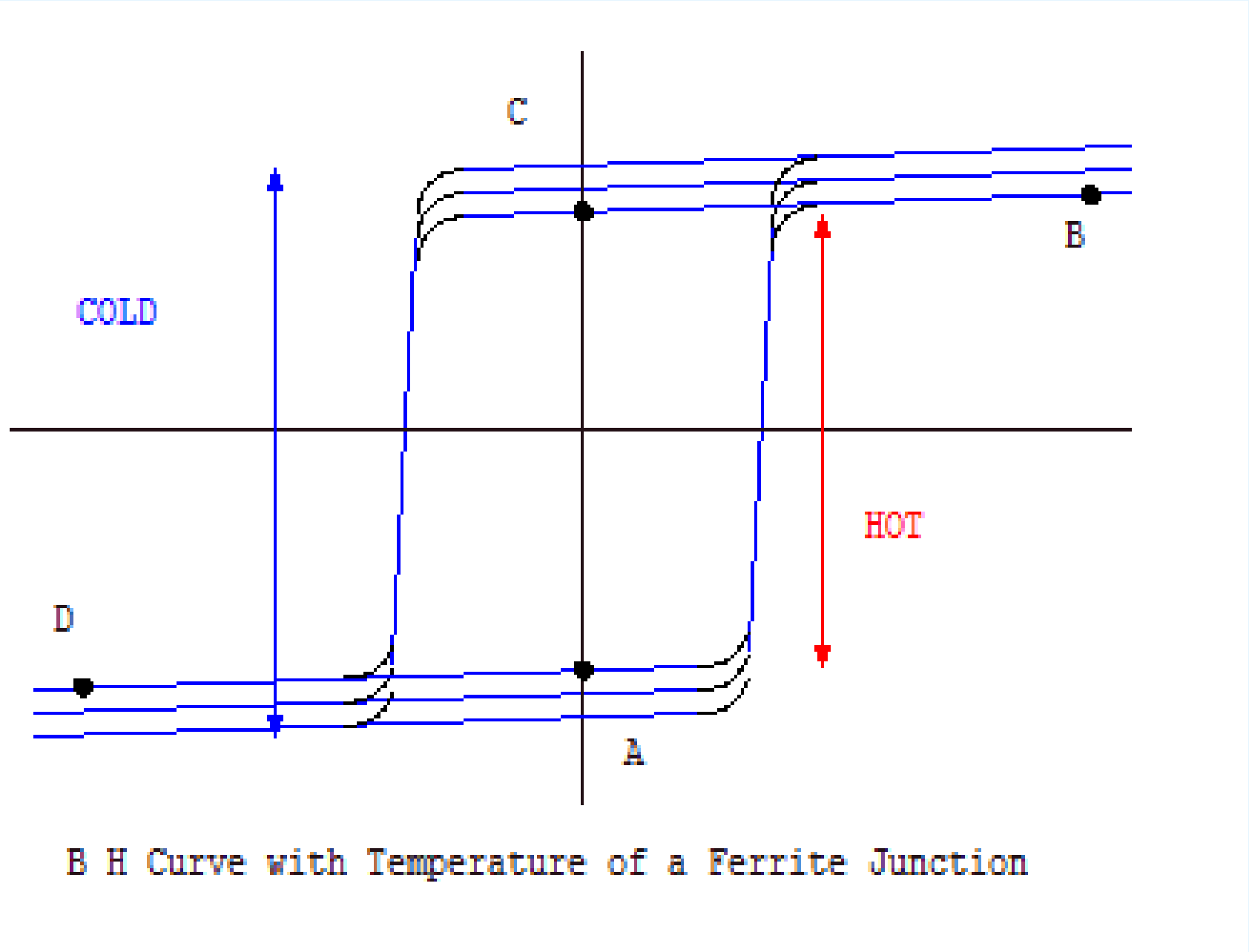
The switch design is optimised to ensure that the thermal power is dissipated effectively to the surrounding assembly, and that the ferrite junction does not heat up excessively. The heat paths within the junction are optimised, thus allowing the heat to be dissipated efficiently and so preventing the ferrite temperature from rising to unsustainable levels. High temperatures lead to a reduction in the RF performance of the switch. Excessive temperature gradients must also be avoided since these can cause damage or destruction of the ferrite junction.

Commercially available ferrite material for the junction is carefully selected and screened, thus enabling good stable performance with temperature and power. The dielectric spacers material is also vital for the thermal management of the switch. The key characteristics are low loss, good thermal conductivity and low dielectric constant.

The predicted temperature profile within the ferrite is shown in the diagram above. This basic switch junction design, operating at 20 GHz, has been successfully tested with a CW power of 175 W.

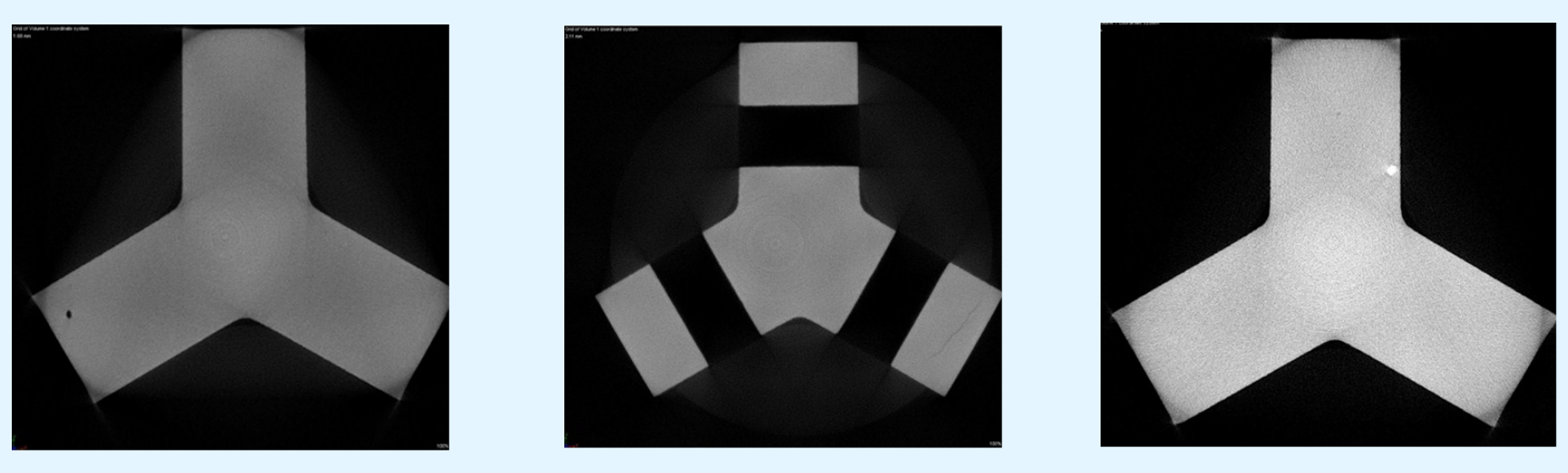
Temperature Compensation

As can be seen in figure below, the B-H curve will change as a function of temperature. Switch driver electronics has been developed which compensates for the temperature variations and therefore guarantees repeatability of insertion loss and isolation over temperatures ranging from ambient to 56 deg C above the maximum rated temperature at full power. Measured values have shown the repeatability of insertion loss (< 0.15 dB) and isolation (> 25 dB) over a wide temperature range.



Ferrite B-H Curve Variation with Temperature

High Power Screening



Void **Crack** **Occlusion**

When operating at high average powers, it is essential that the ferrite material in the switch junction is of the highest quality. Any faults, for example cracks, holes, voids or occlusions, will lead to catastrophic failure when subject to high CW power. In order to guard against this, a systematic testing and screening regime has been developed to ensure that the delivered switches will not fail under any circumstances. The process consists of ferrite inspection using Computed Tomography (CT) scanning and high power testing at all stages of manufacture and integration.

Multiple X-ray images are taken while slowly rotating the assembly over a period of around one hour. A 3D X-ray image of the ferrite is then built up. Once the 3D image has been created, 2D "slice by slice" frontal and axial sections of the 3D image can be viewed. The images are run in video format in order to fast sweep through the 3D image thus giving very good realisation. By using this technique any internal anomalies (e.g. voids and inclusions) within the materials can be identified.

The images above show typical faults: voids, cracks, and occlusions.

Higher Order Mode Operation

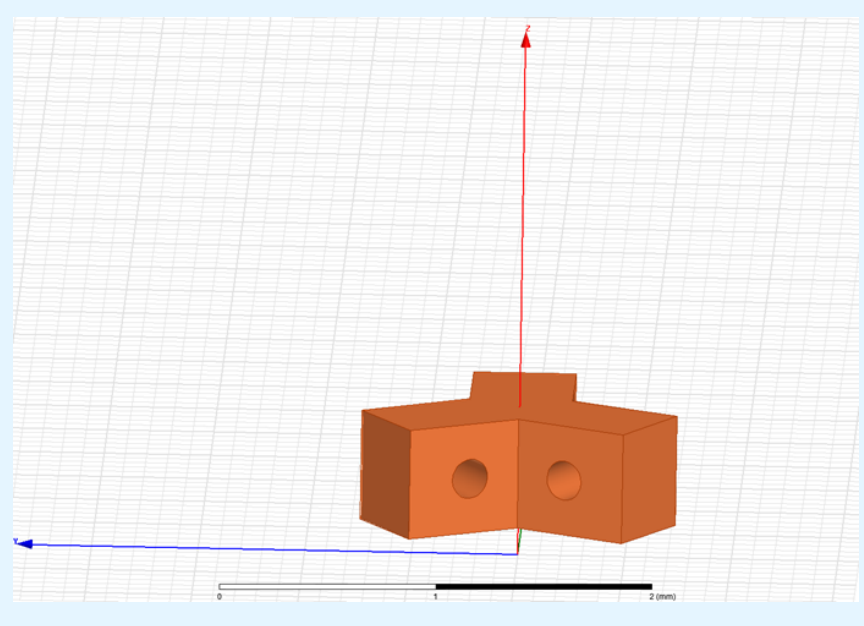
Concept

Ferrite switches are waveguide based. Therefore as the operating frequency increases the dimensions of the various components reduce accordingly. This can be a great advantage for Space applications where envelope and mass are at a premium. However, at frequencies above 50 GHz the components reduce in size to such an extent that it can become increasingly difficult for them to be manufactured. This is of particular relevance to the actual ferrite resonator, which is only 3mm across at 35 GHz. At these dimensions, the machining technology required to drill the holes which are required for the coil wires which carry the drive current is starting to reach its limits.

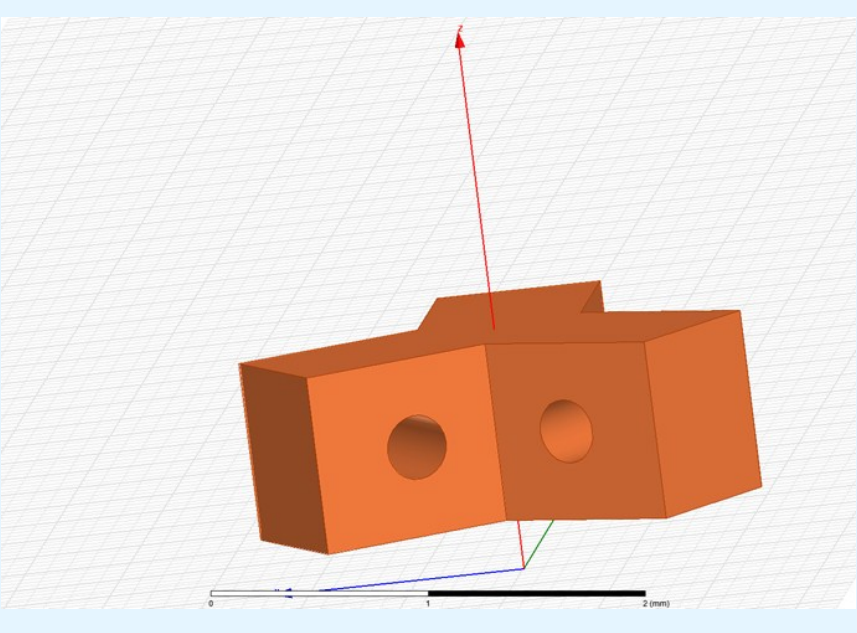
Using this type of design to handle 90-110 GHz would mean a resonator 1mm across, and the required machining and handling would be extremely difficult if not impossible. In addition, a very small ferrite resonator has very severe restrictions on the amount of power it can handle.

An alternative is to drive the ferrite in one of its higher resonant modes. In this way the dimensions of the resonator will remain manageable (comparable to 35 GHz case), but the switch will be suitable for 90-110 GHz signals.

Dimension Comparison



94 GHz Ferrite Switch Junction Implemented at Fundamental TM Mode



94 GHz Ferrite Switch Junction Implemented at Higher Order TM Mode

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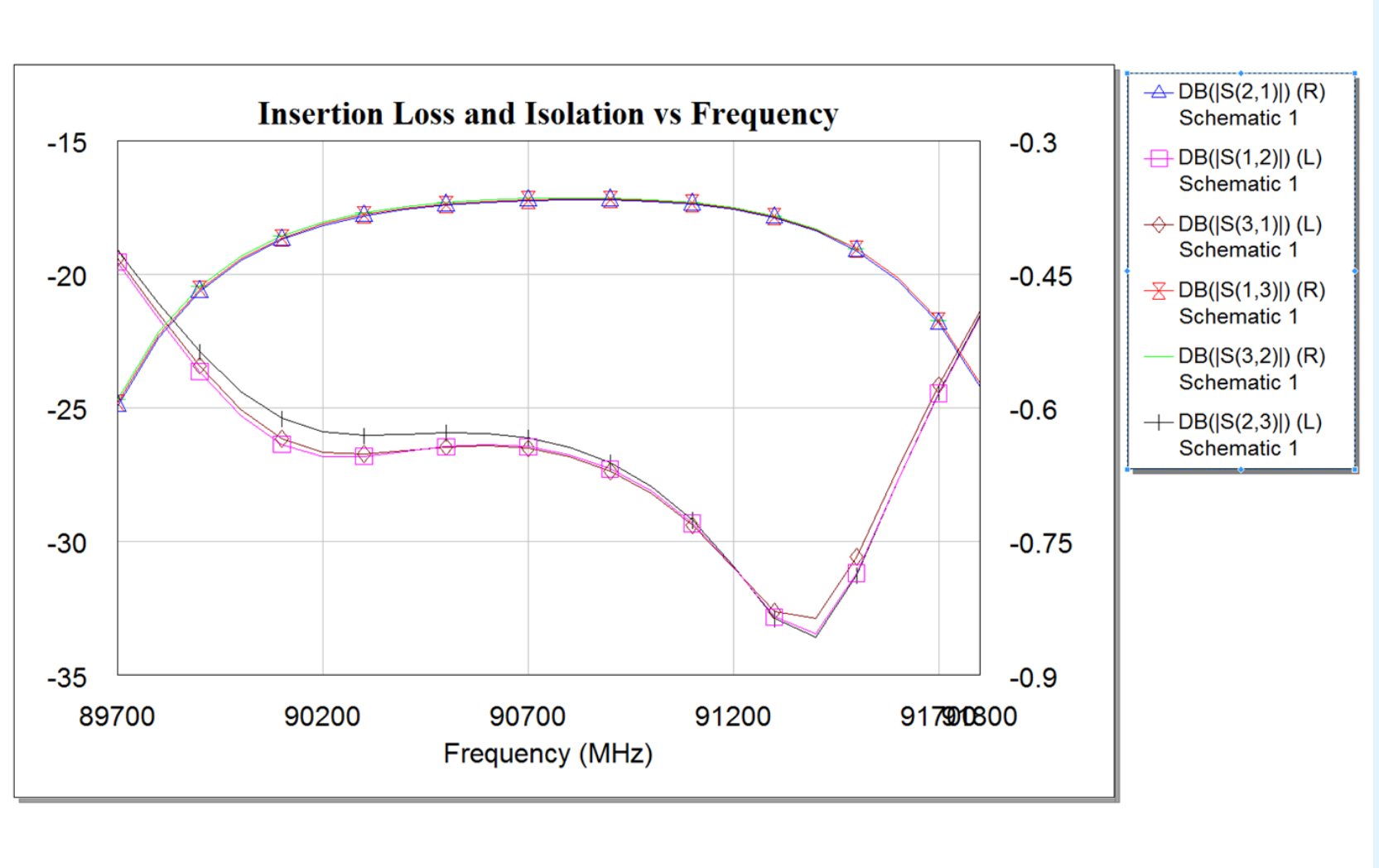
Implementation

A 94 GHz higher order TM mode switch is being developed with funding from the NSTP Pathfinder programme. One intended application is on radiometer calibration systems at operating frequencies up to 120 GHz.

94 GHz (WR10) Ferrite Switch



Simulated Insertion Loss and Isolation Response