CAD-to-FAB: an introduction to the recent and ongoing investment in the capability to produce, at scale a variety of planar RF passive structures.

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INTRODUCTION

Traditional RF components, produced using automation, are ill-suited to a high-mix/ low volume environment, tending to result in prolonged developments, high prototyping costs, large MOQs, and extended production lead-times.
In contrast, direct, computer-controlled manufacturing techniques, additive (e.g., 3D printing) or subtractive (computer-controlled machining or patterning) have flat cost vs. volume curves essentially proportional to the time on the machine and irrespective of the exact nature of the parts being fabricated.

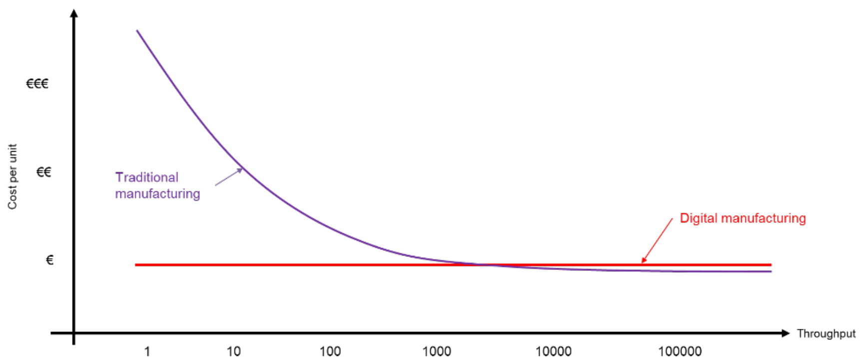


Fig. 1. Cost vs Volume curve

CAD-to-FAB INVESTMENT MOTIVATION

SWaP-C (size, weight, power, and cost) is driving the need for the integration of passive functions including ferrite isolators/circulators, RF filters and couplers into multi-function assemblies.
Smiths Interconnect reports initial results of a novel digital manufacturing process combining both substrative and additive computer-controlled fabrication of planar passive RF devices. We refer to this process capability as CAD-to-FAB.
The prototype CAD-to-FAB system is up and running. The full-scale system is on schedule to be commissioned in Smiths Interconnect, Dundee by Q1 CY2025.

This new manufacturing capability will be used to realise high-performance passive RF components operating in S to K-Bands but is currently being focused on developing SMT components operating from C to Ka-bands enabling the economies of scale required for BFN and radar arrays.

The breadth of product we are aiming to produce using this new process is illustrated below.

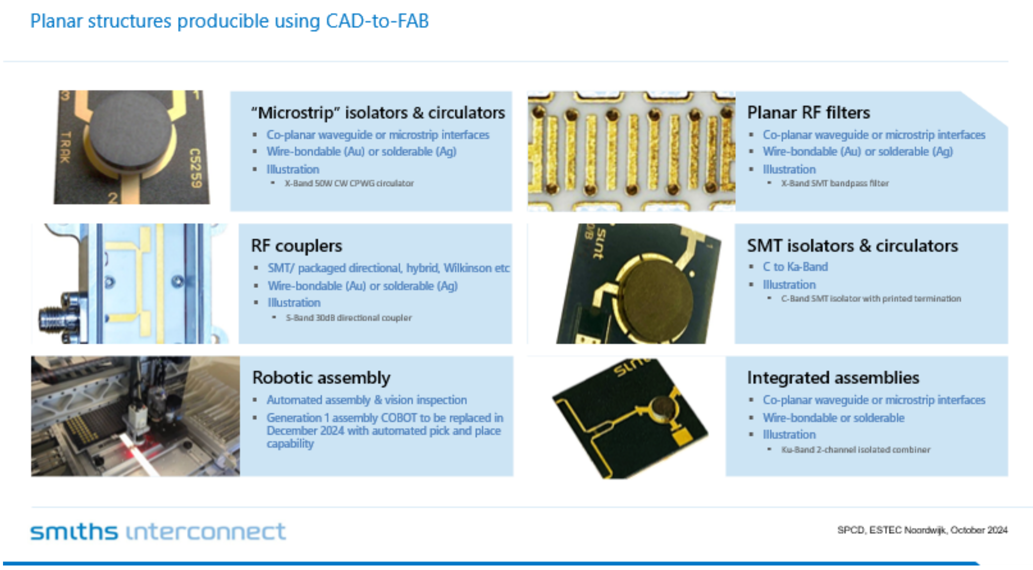


Fig. 2. Planar structures producible CAD-to-FAB

CAD-TO-FAB EXAMPLE OF CAPABILITY ON C-BAND SMT HIGH POWER ISOLATOR

Raw ferrite is procured in wafer form. The "Holes" and "slots", which will later become ground vias or SMT RF signal interfaces, are created then metallisation, dependent on whether wire-bondable or SMT interfaces are required, is applied to the wafer.

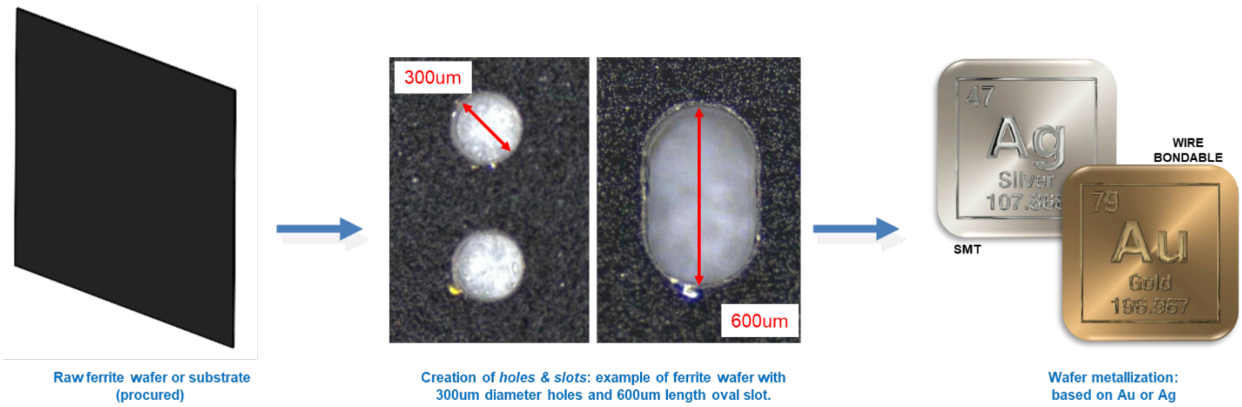


Fig. 3. Raw Wafer to wafer metallization

Resistive elements: where required, terminations or resistors are applied before the wafer is *singulated (*CAD-to-FAB v1.0 singulates at this stage). The *full-scale production system* will singulate at the final stages of assembly.

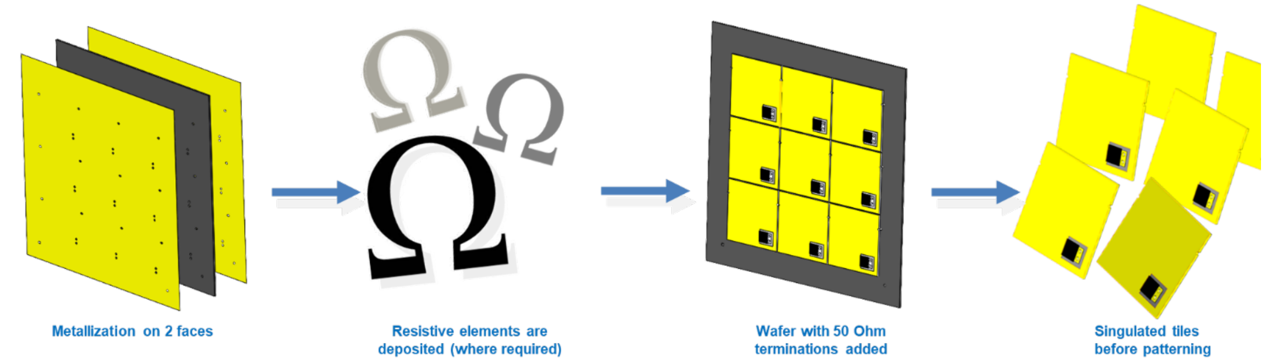


Fig. 4. Metallization & patterning

Metallisation is removed to create the RF “pattern”. Remaining features are “written” to an accuracy of +/- 5 um. In this case assembly is fully automated (including epoxy dispensing) with pick and place components positioned to +/-5um accuracy while automated machine vision inspection is employed during assembly and on the final assembled product. Such is the consistency RF testing need only be undertaken on a sample basis.

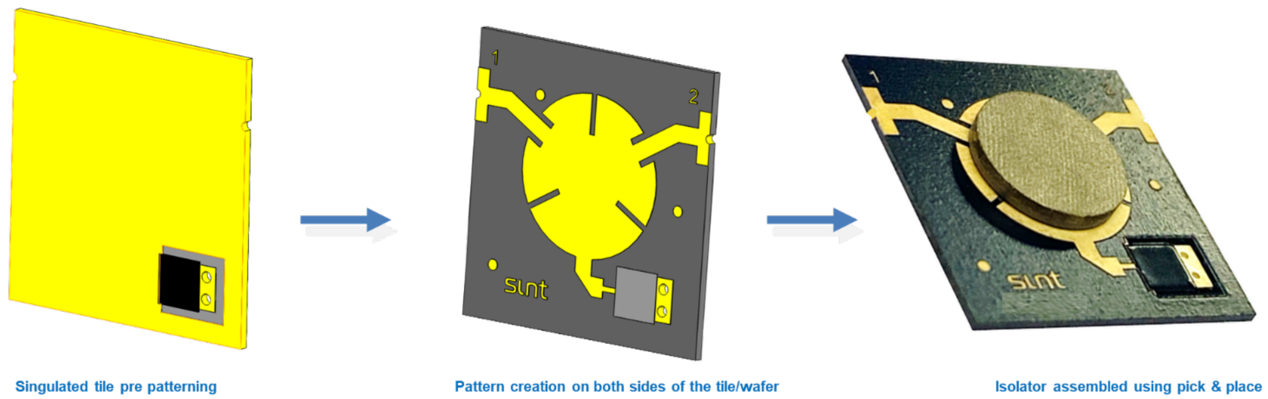


Fig. 5. Patterning to automatic assembly

The first product, a C-Band high power isolator is entering production. This device is compact (13 x 13 x1.5mm) and has a mass of 0.6g. It is simple having only 3-piece parts (excluding epoxy) and is designed to be produced at scale.
The device was designed for SMT reflow technology (note the fiducial marks) and will be supplied on tape & reel. Based on the LOTs produced thus far the devices are incredibly consistent, in part due to the printed resistor (providing a 50Ohm bleed path and is tuneless and are also very broadband.

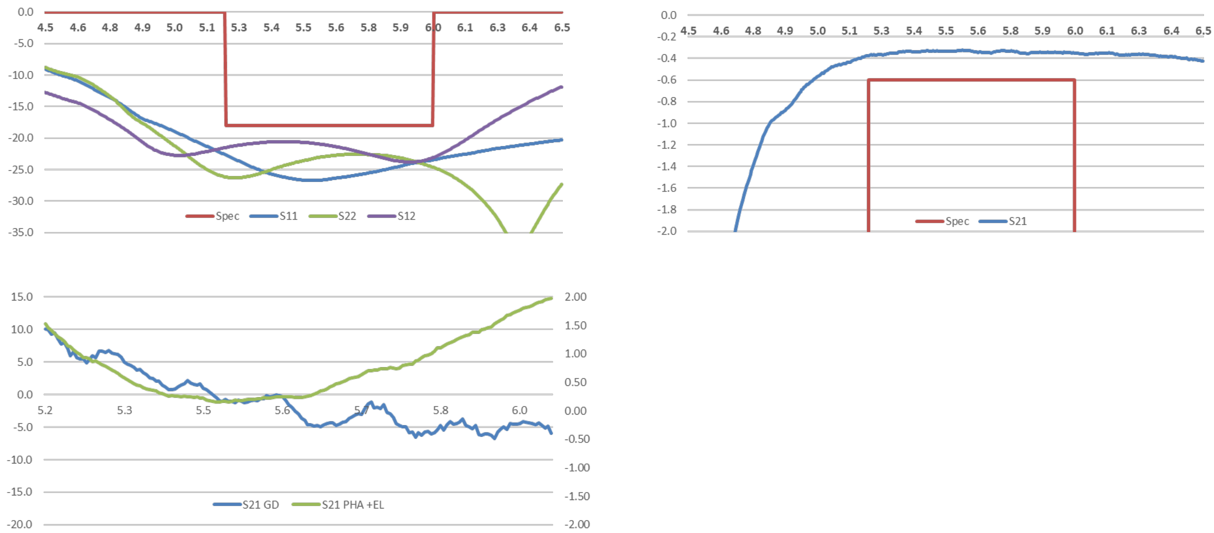
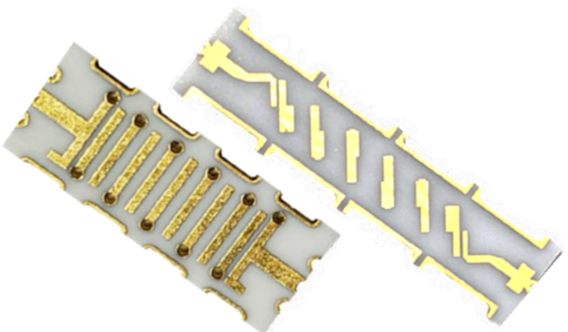
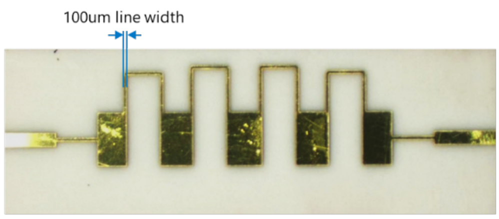


Fig. 6. Typical test results at VNA power and at +22C

The future of this capability is not limited to ferrite devices and in addition to isolators and, of course circulators, we are engaged developing RF directional, hybrid and Wilkinson couplers as microstrip or SMT devices and Planar RF filters (interdigital, coupled line) where measurements demonstrate that RF filters produced using CAD-to-FAB result in similar RF performances to devices produced using traditional photolithography and wet etching but at a substantially lower production cost.



CAD-to-FAB: coupled line and interdigital SMT filters



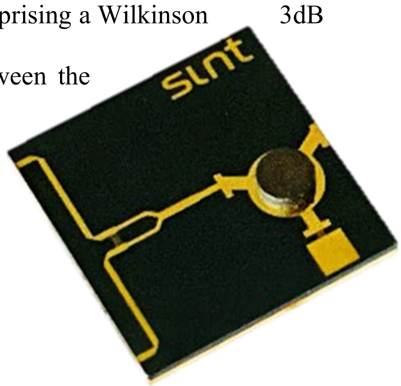
CAD-to-FAB: illustration of line width capability

Fig. 7. CAD-to-FAB open opportunities

Being able to produce these types of component lead naturally to looking at combining products into multi-function assemblies.

As an example, we have created a Ku-Band 2 channel isolated power combiner comprising a Wilkinson 3dB combiner and microstrip isolator using printed termination and 100Ohm resistor.

Physically the device was realised as illustrated opposite noting the spacing between the Wilkinson ports was determined by the space of the SMA test fixture.



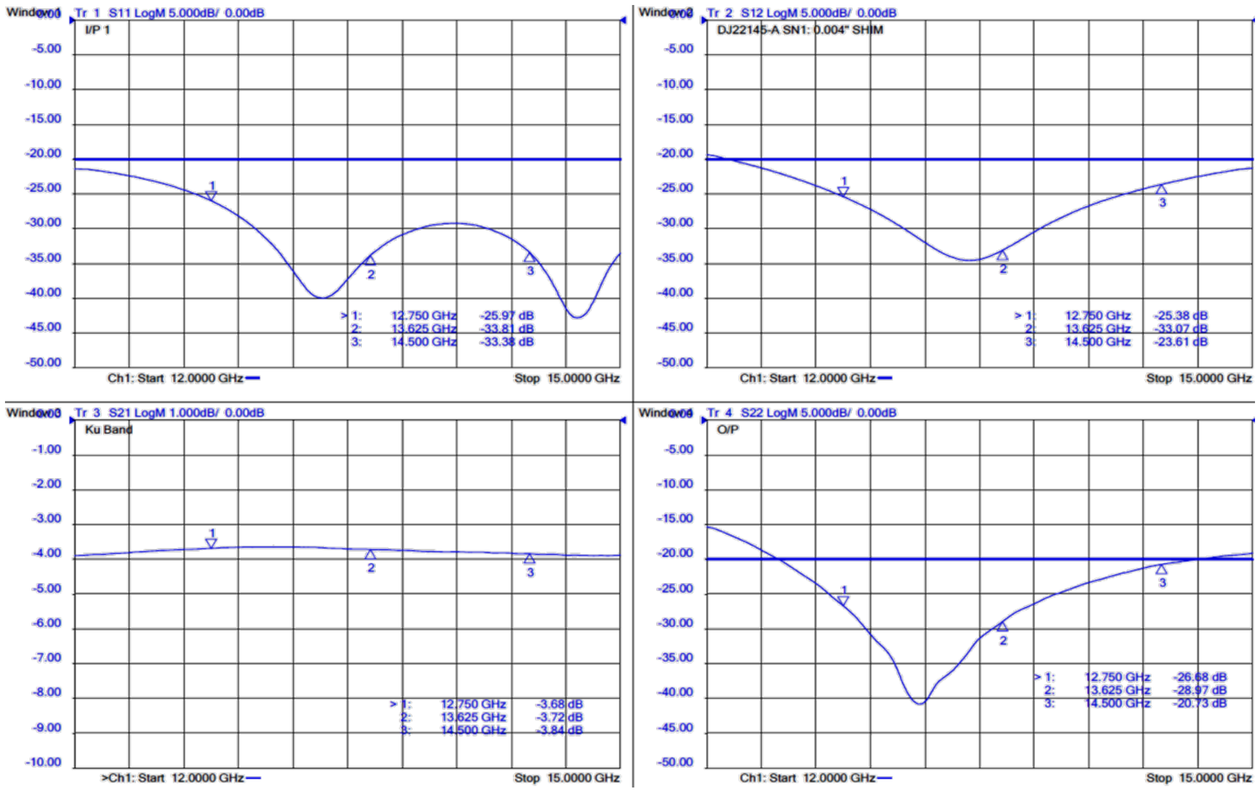
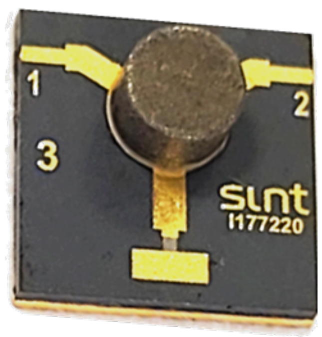


Fig. 8. The results of the prototype exceeded expectations.

In terms of where CAD-to-FAB takes us next.
We expect the process is suitable to Ka-band (and perhaps above) and know it is good to K-Band. The current roadmap focus is at X-Band and K-Band where we are working to realize SMT circulators and isolators respectively. Based on current commitments our non-reciprocal device near term roadmap is bulleted below noting there are no current plans to attempt a classic space qualification approach until the equipment commissioned in the Dundee, Scotland plant and the process “bedded down”.

- C-Band isolator & circulator complete
- X-band circulator _Q3 CY2024
- K-Band isolator _Q4 CY2024
- Ka-Band isolator _Q1 CY2025

It should be noted that all the materials are already space qualified and that the process of mounting an SMT part is part of the qualification challenge and cannot be replicated by SINT Dundee.
Of particular interest to this community is a development we are focused on in K-Band. The device illustrated in the image opposite is a precursor microstrip isolator with “floating termination”. Our standard design approach starts with a microstrip solution, partially optimised before evolving to the SMT solution where the effects of the intended integration are well understood (substrate material, circuit details etc which have a bearing on the device performance). The device opposite is a 17.7-22.0GHz 2W isolator.



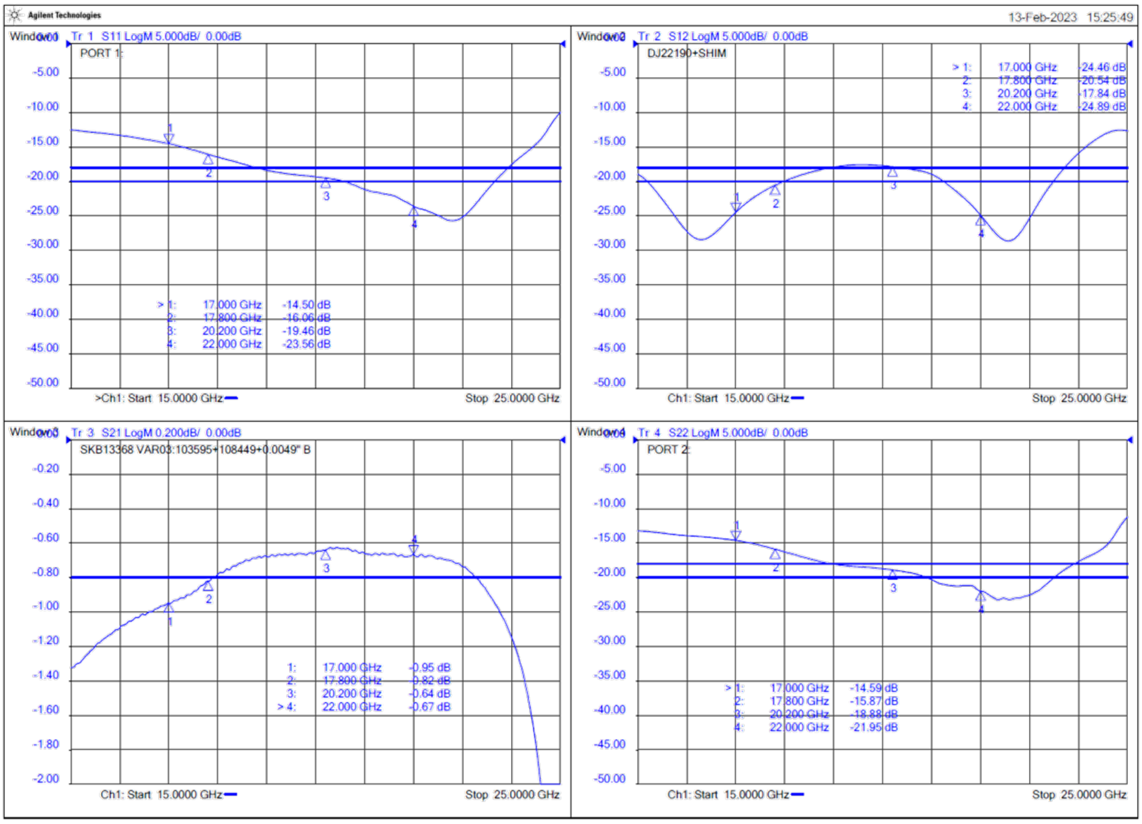


Fig. 9. The performance to date points to an ultimately successful transition to SMT.

CAD-TO-FAB SUMMARY

The CAD-to-FAB capability is the result of a multi-million GBP investment in the SINT, Dundee facility and is scheduled to be fully commissioned in early CY 2025. It is aimed at creating a cost-effective, automated production capability to produce planar, passive products including

- *Microstrip* & **SMT** non-reciprocal single & dual-junction devices.
- "Printed" and suspended substrate stripline RF filters.
- Couplers and power combiners/ splitters.
- **M**ulti-**F**unction **A**ssemblies (MFAs) combining the above.

Driving this investment program is the desire to take advantage the digital manufacturing paradigm which provides, economies of scale and faster time-to-market, the ability to develop new classes of highly customised products, to create substantial and scaleable production capacity and to de-sensitize the business to potential supply chain "*insecurity*" **by** "*on-shoring*" critical production processes.

Finally, on behalf of Smiths Interconnect, I would like to acknowledge the support of the United Kingdom Space Agency (UKSA) through its Space Cluster Infrastructure Funding (SCIF) program contributed £1.9M, matched with a similar amount from Smiths Group, enabling the creation of the CAD-to-FAB facility and the expansion of the Smiths Interconnect, Dundee Space Qualification Laboratory.

AUTHORS

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