Digital manufacturing of passive RF components

Achieving economies of scale in a mass customized environment

Thomas Ducellier, Grant Robertson*, Ally Gorman

Smiths Interconnect, Fiber Optics and RF Components Business Unit

*grant.robertson@smithsinterconnect.com Block 29, Dunsinane Avenue, Dundee, Scotland, DD2 3QF

Abstract

Satellite communication or Telemetry, Tracking and Command (TT&C) rely on a host of active and passive highly customized RF components and sub-systems to perform. With volumes as low as a few units ranging to a few tens of thousands for mega constellations, realizing manufacturing economies of scale in the context of mass customization is challenging.

Here we are reporting results of a novel digital manufacturing process combining both substrative and additive computer-controlled fabrication of thin-film passive RF devices like filters, duplexers and isolators and circulators.

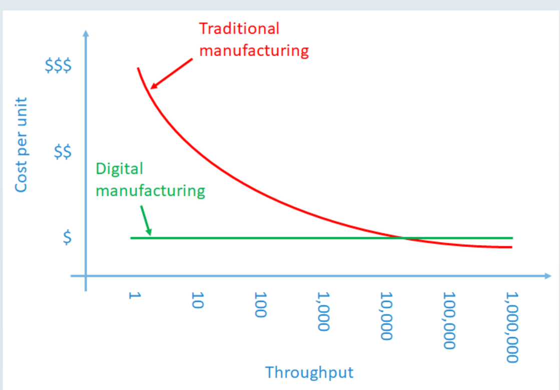
To further improve efficiency and SWaP-C (Size, Weight, Power and Cost) of devices, we will also demonstrate how this new digital manufacturing technology enables the integration of heterogeneous functions onto a common platform.

This new technique is amenable to the realization of high-performance passive RF components from the S-band all the way to Ka-band and beyond and enables economies of scale starting from a few units to a few tens of thousands of units, hence suiting the needs of the smallsat market particularly well.

Motivation for the work

Traditional manufacturing techniques including automation are ill-suited to a high-mix/low volume environment like RF components fabrication, leading to high prototyping costs, large Minimum Order Quantities, and long lead times.

On the other hand, direct computer-controlled manufacturing techniques, either additive (e.g. 3D printing) or subtractive (computer-controlled machining or patterning), have a flat cost vs. volume curve – essentially proportional to the time on the machine – irrespective of the exact design of the parts being fabricated.



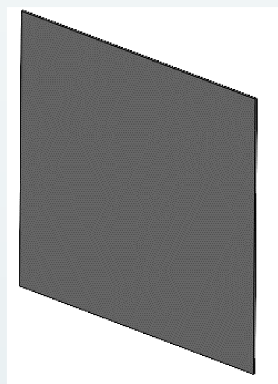
This enables manufacturing of highly customized parts with series as small as one unit up to 10,000+ units at a cost lower than traditional manufacturing, leveraging economies of scale of using a common set of tools over and over again.

Digital manufacturing technique

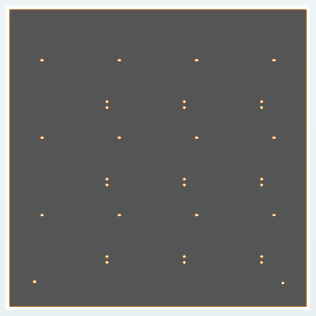
Smiths Interconnect has developed a suite of CAD-to-FAB tools to digitally manufacture a variety of thin film RF components on different substrates, cutting development time from 26 weeks down to 2 weeks, and lowering costs of prototyping by 80%.

An example walk-through of the process for an RF isolator on Ferrite wafer is given below.

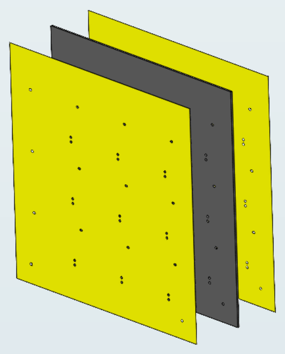
Raw dielectric wafer



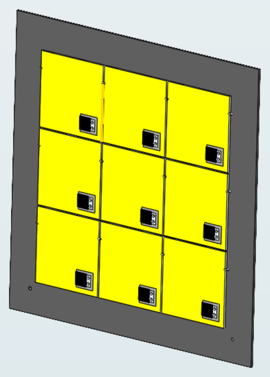
Step 1: wafer drilling (through vias)



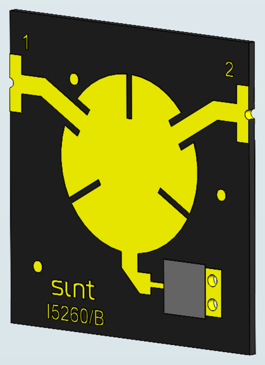
Step 2: wafer uniform metallization (conductors - both sides – and vias filling)



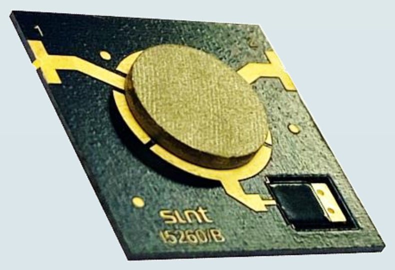
Step 3: additive deposition of Resistors (printing)



Step 4: computer-controlled subtractive patterning

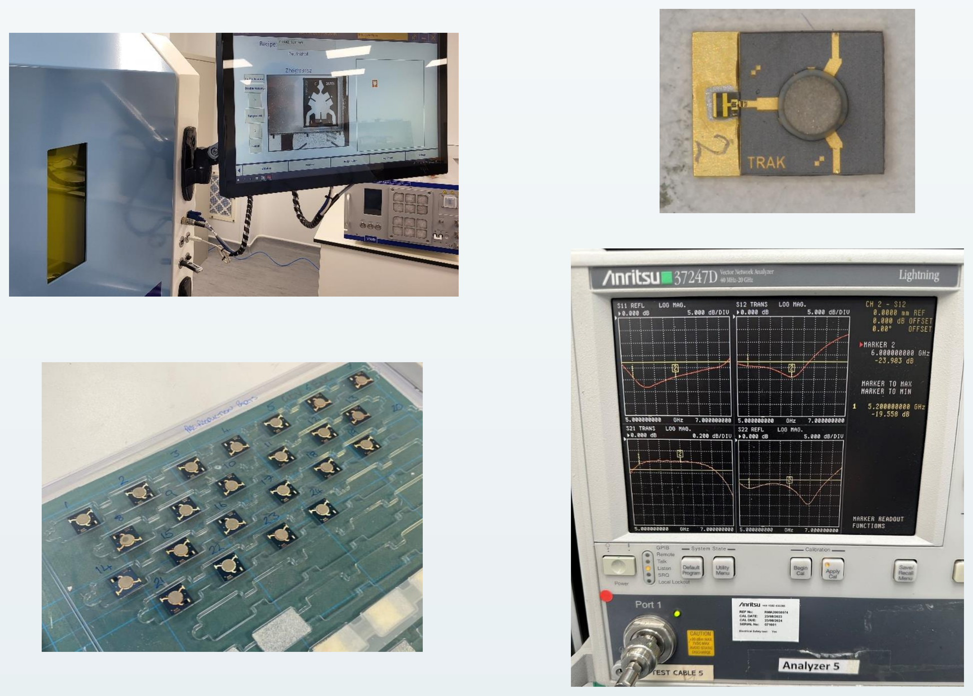


Step 5: singulation and final pick-and-place assembly



Results – RF isolators

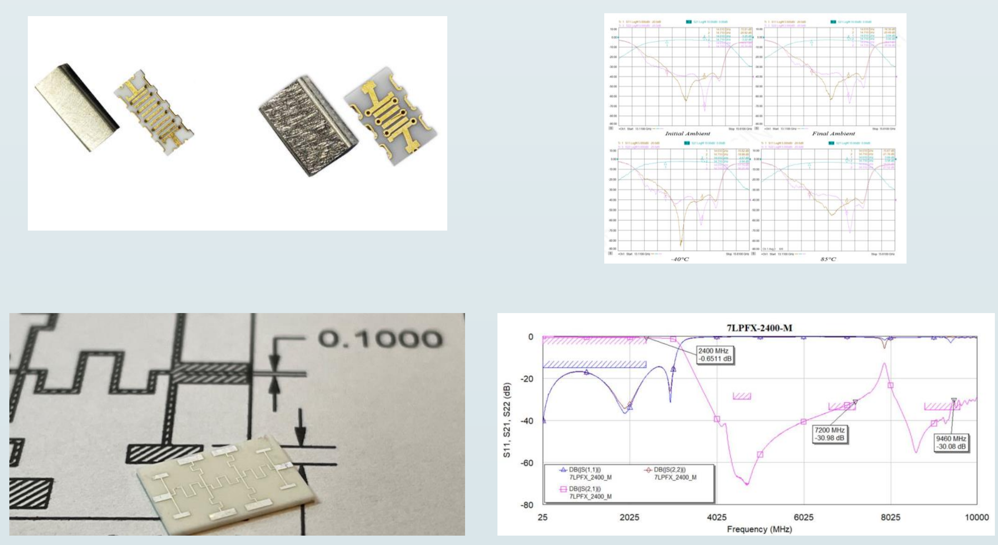
Isolators and circulators on Ferrite wafers have been made (in 1-100 series, with the process capable of delivering up to 5,000 units per month). Devices in C-, X- and Ka-bands have been designed. Measured RF performance is undistinguishable from traditional fabrication techniques.



Results – RF filters

The digital CAD2FAB process was used to fabricate printed filters on Alumina substrate.

Several designs (pass band, low / high pass) at various frequency bands have been realized, with similar RF performance to devices manufactured through traditional thin film vacuum processes with photolithography.

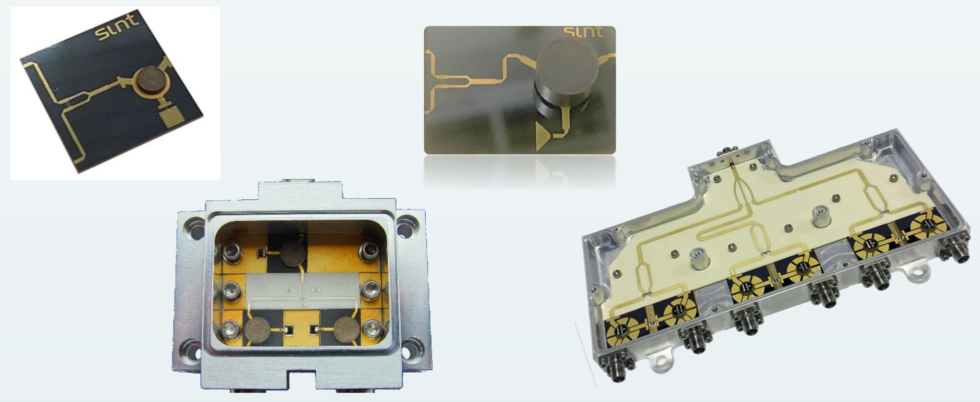


Results – RF multi-functional assemblies

One of the main advantage of the digital CAD-to-FAB process is rapid prototyping and iteration of designs to arrive at final optimized designs quickly. This is particularly useful when combining multiple functions onto a common substrate to achieve higher system-level performance.

For example, it is straightforward to integrated couplers/combiners, isolators/circulators and filters into RF Multi-Functional Assemblies (MFAs) to realize significant Size, Weight and Cost benefits. Optimized RF performances, including lower losses, also translates into higher Power tolerance.

The technique is also well suited for heterogenous integration of planar RF functions onto dissimilar substrates for chip-and-wire assembly.



Conclusion

Highly customized RF components for satcom and TT&C can be manufactured cost-effectively at low- to medium-volume, leveraging a new digital manufacturing paradigm providing economies of scale and faster time-to-market from single unit to 10,000+ units series.

The technique is applicable to a range of RF components at frequencies up to Ka-band and enables multi-functional integration on common substrate or heterogeneous substrates for low SWAP-C integrated RF sub-systems.

Acknowledgement

The authors would like to acknowledge the support of the United Kingdom's Space Agency through its Space Cluster Infrastructure Funding program. Smiths Interconnect received £1.9M from UKSA, matched with a similar amount from Smiths Interconnect to bolster its Space Qualification Laboratory and deploy a digital "CAD-to-FAB" manufacturing line as described in this poster.

UK SPACE AGENCY

Funded by UK Government