EuMC07 Special Session

20th Anniversary of the European Microwave Week

"The Future becomes the Present"

(a Look at Developments in Enabling Technologies and Systems over the Last 20 Years)

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48TH EUROPEAN MICROWAVE CONFERENCE 2018

The 48th European Microwave Conference

EuMIC 2018

The 13th European Microwave Integrated Circuits Conference

EuRAD 2018

The 15th European Radar Conference

Trends

- Restrictions due to ITAR in the US has meant many technologies previously sourced from the US are now being or have been developed in Europe, eg, GaN
- Increasing involvement and competition from China
- Systems companies now doing less or no component or subsystem design. More components being 'bought in'
- Component and subsystem manufacturing companies now doing more of the design to a 'black box' specification
- Difficulty in some countries in recruiting, training and keeping quality RF and microwave engineers

Computer Hardware

- Advances in computer hardware, particularly PCs, which enable more thorough analyses to be undertaken in the design process
- 20 years ago PCs did not have the power to tackle complex circuit simulations, eg, 2.5/3D EM analyses and many other system problems
- More complex problems would be handled on a 'workstation' such as a Sun Sparc
- Today, virtually all design problems can be handled on a high performance PC
- One leading 2.5D EM simulation company stated that computer power has increased over 500 million times over 22 years
- A conservative estimate based on a) the improvements in PC hardware over the last 20 years and b) a 2.5/3D EM analysis scaling with N^3 (N = matrix size), shows a speed increase of over 1,000
- This means that, 20 years ago, a given 2.5/3D EM analysis problem, that would have taken 5 days non-stop to solve, can now be completed in just over 7 minutes. Hence multi-parameter optimisation of a 3D circuit is quite practicable

Circuit CAD & 2.5/3D EM Analysis

- Generally, one uses one or more approximate methods to design a circuit or antenna and then refines the design by using a 2.5/3D EM simulator
- An example in circuit design is to use the decomposition method where the circuit is decomposed into individual, generally isolated components or devices
- The development in high speed PCs and the advances in 2.5/3D EM analyses now enables circuit structures to be analysed ‘exactly’ from a much earlier stage in the design process
- Multiphysics design software and integrated design environments enable the circuit and EM analysis, mechanical and thermal design to be done with one package or within one design environment

Circuit CAD & 2.5/3D EM Analysis

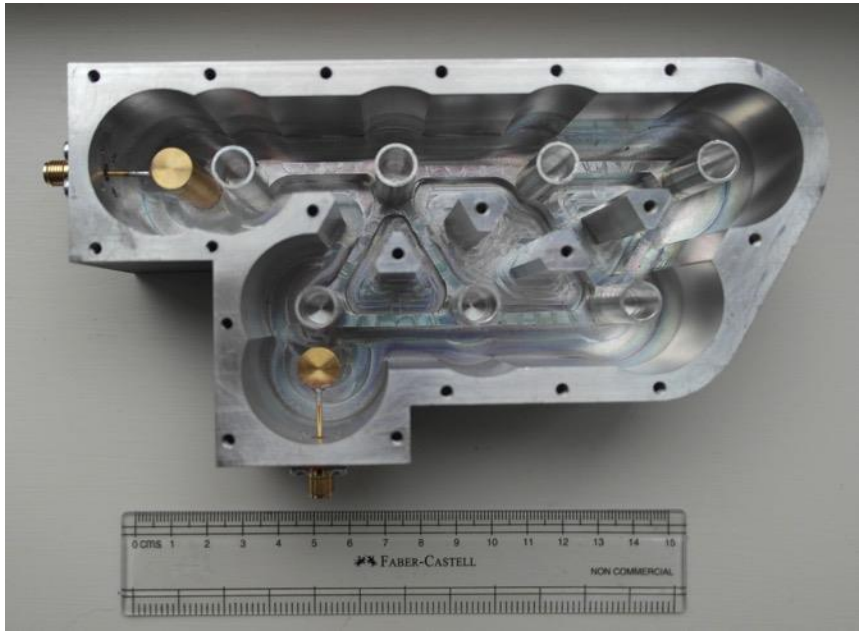
Dual-band Prototype Filter

Specifications:

Passband 1: 1000 MHz – 1010 MHz Stopband 1: 1020 MHz – 1030 MHz

Passband 2: 1040 MHz – 1050 MHz Stopband 2: 1060 MHz – 1070 MHz

Passband Return Loss > 20 dB Stopband Rejection > 30 dB



CST Microwave Studio 3D EM simulation

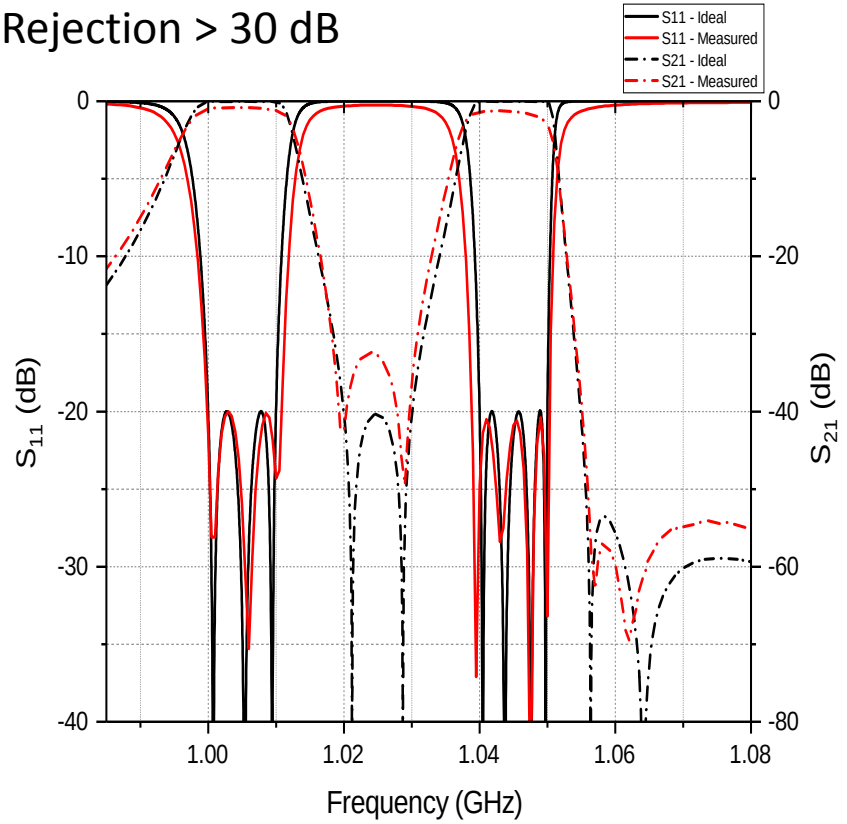
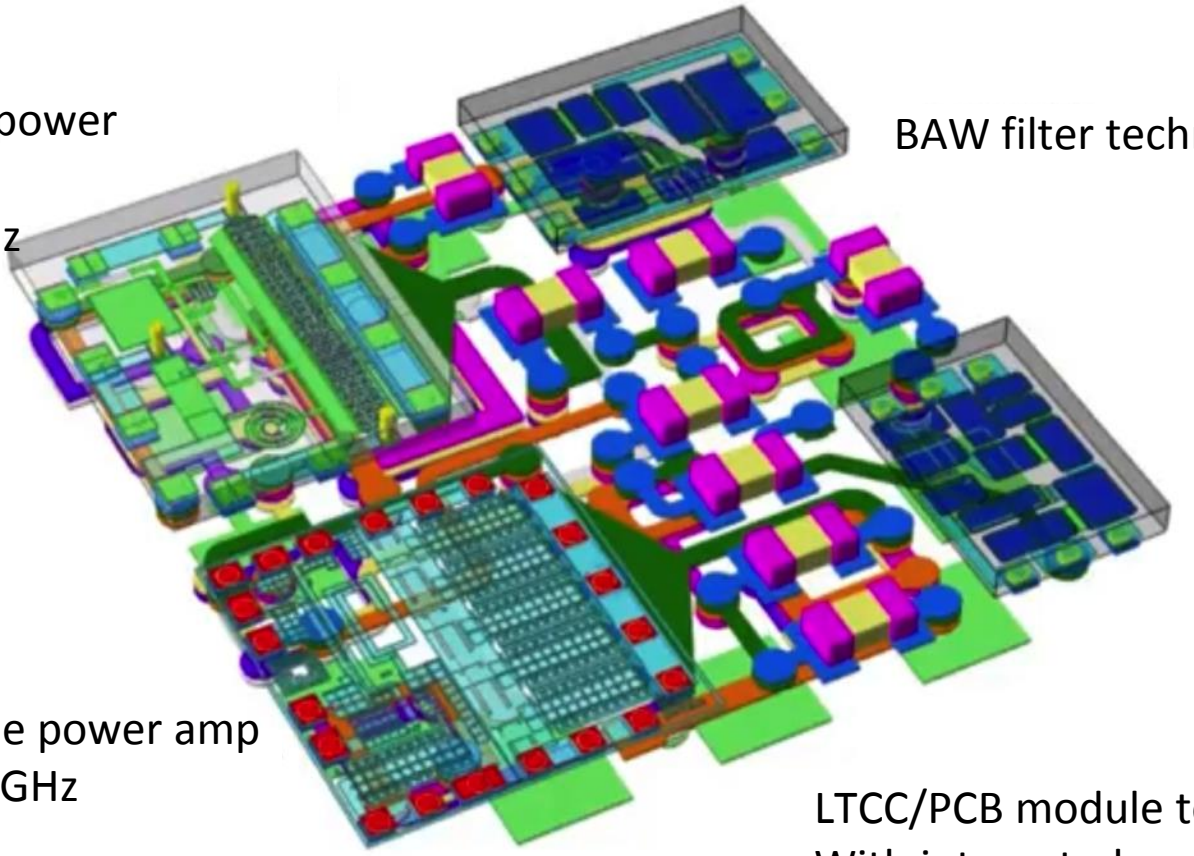


Photo and image courtesy of Ian Hunter and Rucha Parandkar Leeds University

Circuit CAD & 2.5/3D EM Analysis

GaAs power amp 1.9GHz

BAW filter technology



Surface-mount components

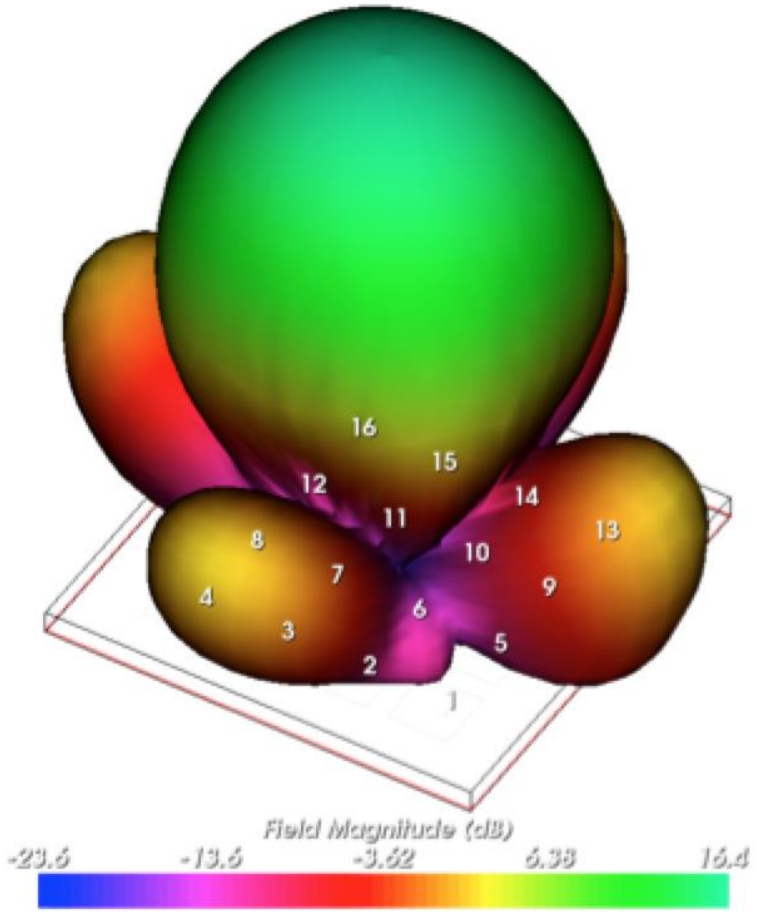
SiGe power amp 2.5GHz

LTCC/PCB module technology
With integrated passives

AXIEM 2.5D EM simulation

Image Courtesy of NI/AWR

Antenna CAD & 3D EM Analysis



4 x 4 microstrip patch antenna

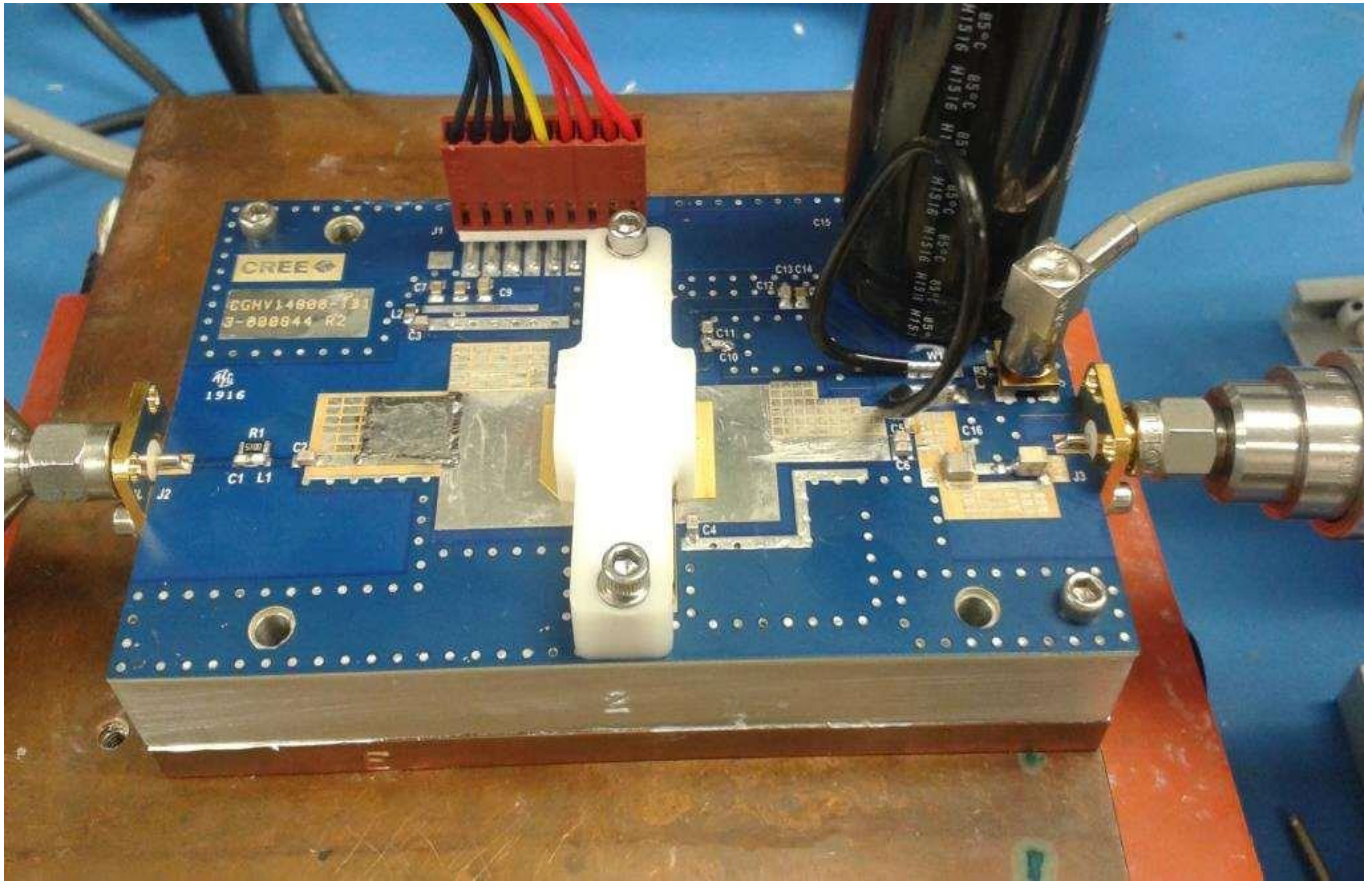
ANALYST 3D EM simulation

Image Courtesy of Majid Naeem NI/AWR

Large Signal Power Amplifier Design

- The arrival of GaN technology using HEMT devices for high power
- The development of accurate nonlinear device models for use in harmonic balance simulations, eg from CREE and Qorvo and the Cardiff model. These device models can include effects due to process variation and temperature
- The improved understanding of harmonic termination for the different classes of operation – waveform engineering
- The development of 2.5D EM simulation tools to enable the desired harmonic terminations to be realised

Large Signal Power Amplifier Design



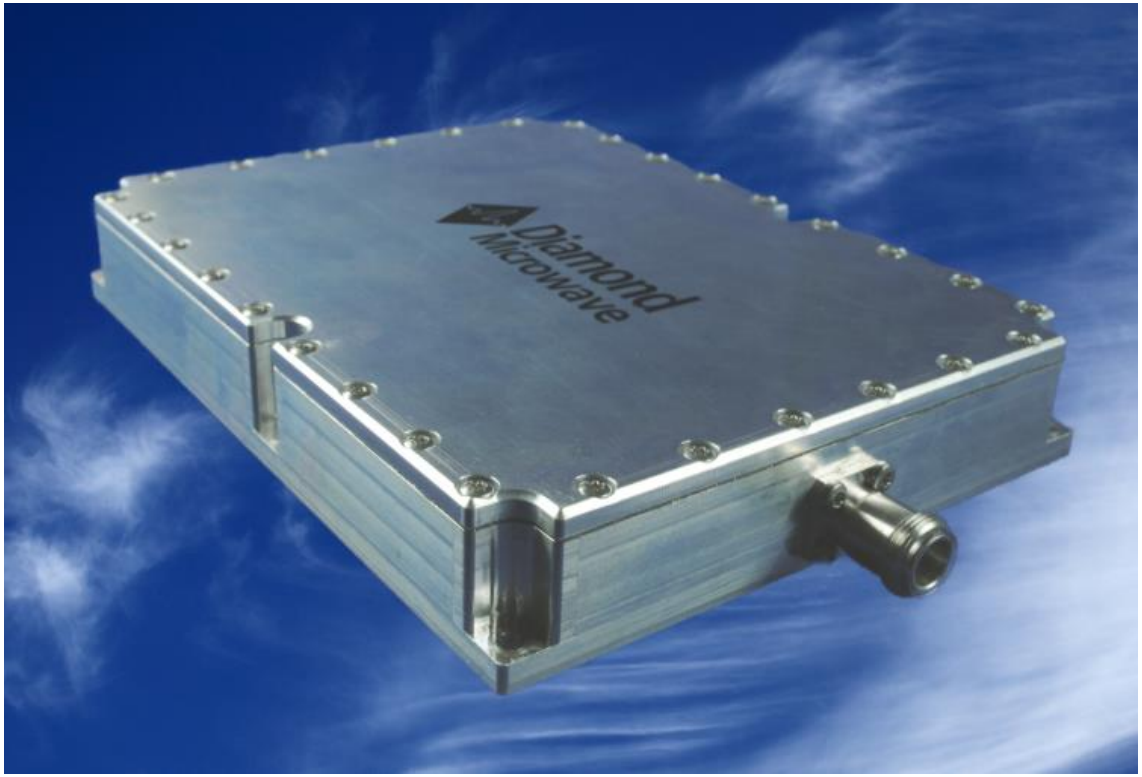
PAE = 73%, 100us pulse width, 10% duty cycle

1GHz 800W GaN Power Amplifier

Photo Courtesy of Dominic FitzPatrick Powerful Microwave

The Future becomes the Present – Large Signal Power Amplifier Design

- Compact and efficient power combining of high power GaN devices to realise 1kW at C- and X-band – Commercially Available Products



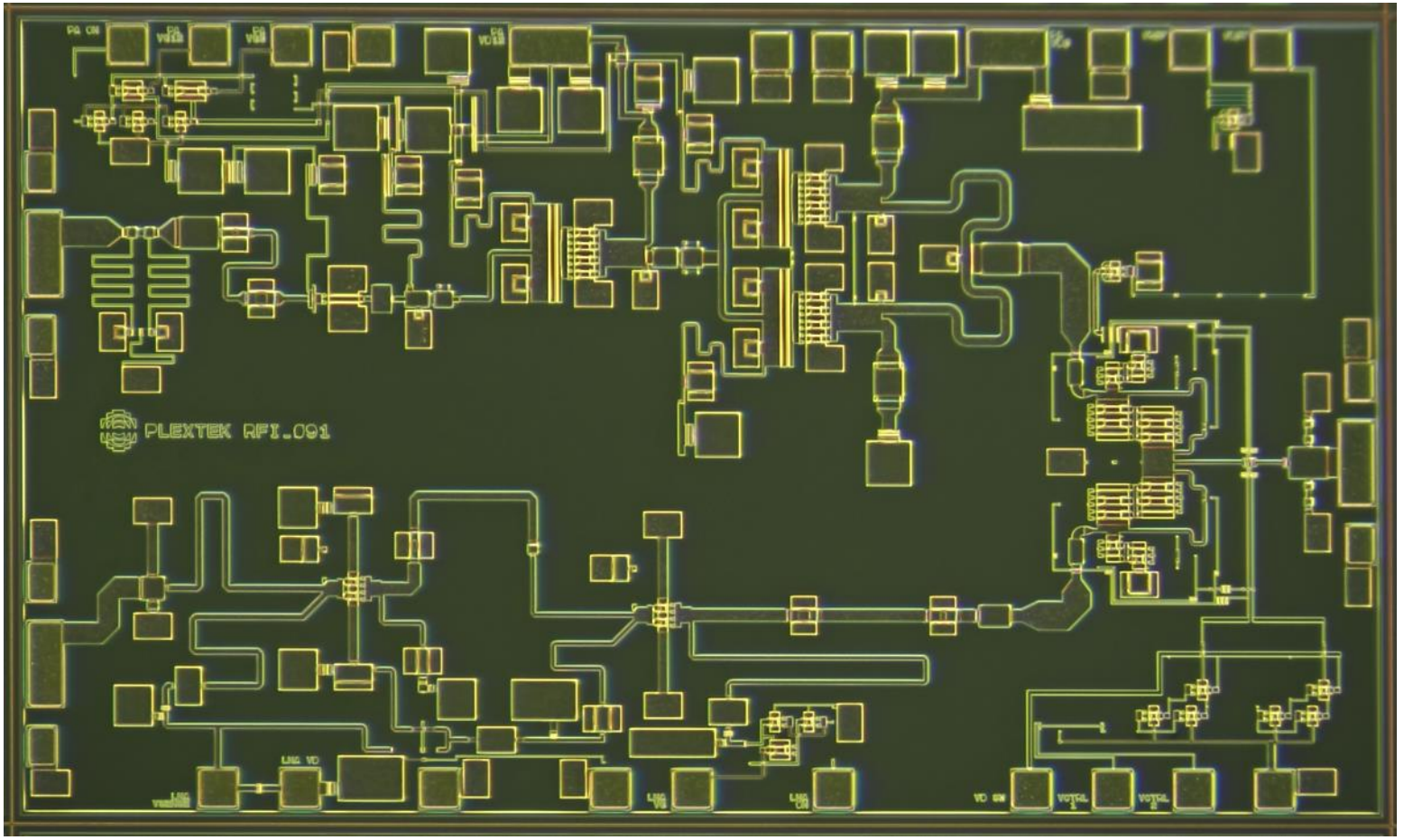
Slimline 400W X-band GaN Power Amplifier

Photo courtesy of Richard Lang Diamond Microwave

MMIC Technology

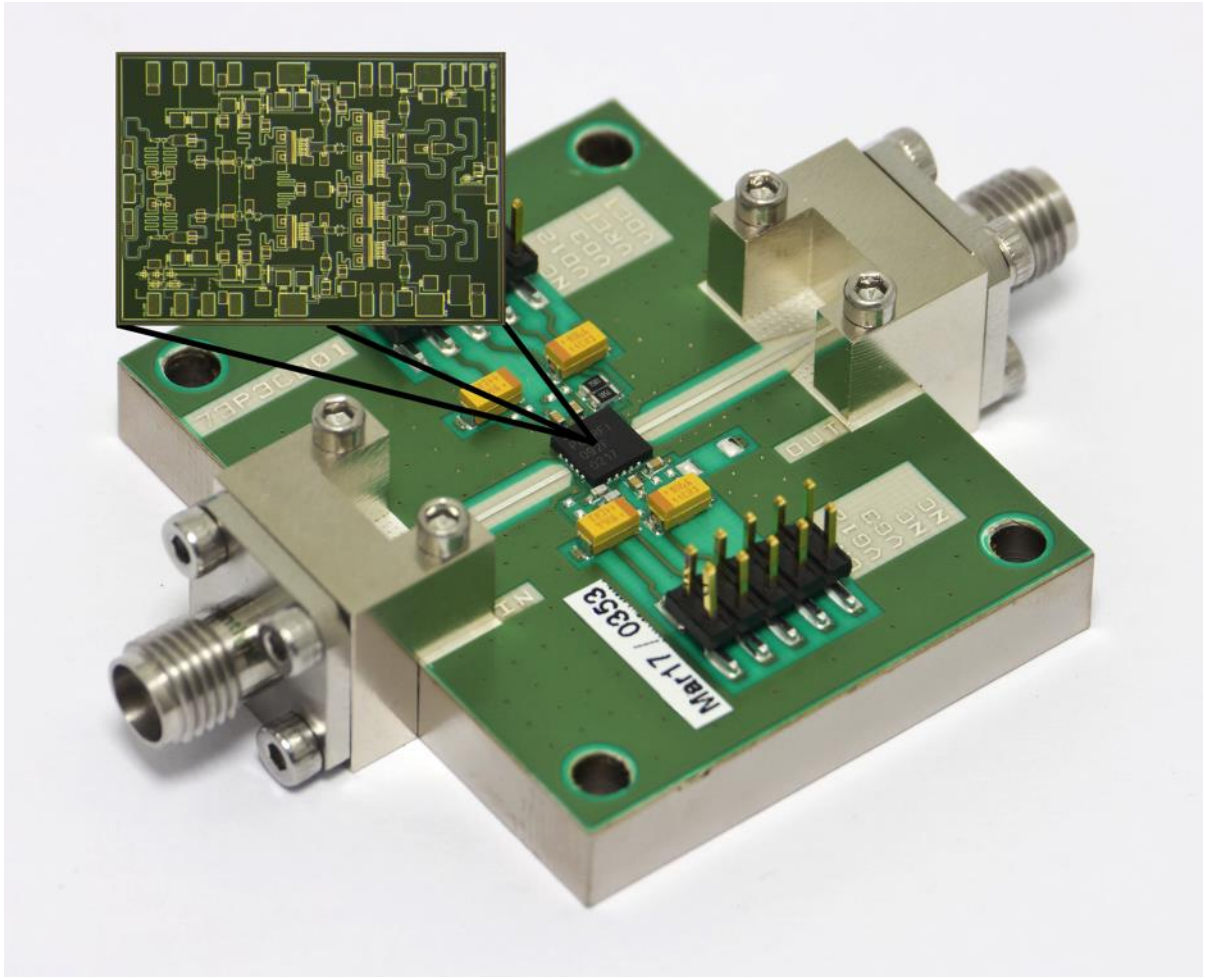
- Process Design Kits (PDKs) supplied by foundries are more capable, often incorporating the ability to simulate over temperature and process spread
- The levels of integration have increased due to better simulation tools, eg, complete tranceiver front end
- Considerably increased capability for complex millimeter-wave designs
- Processes are becoming more complex. E-mode and D-mode transistors are now available on the same MMIC. Work is underway to incorporate PIN devices
- The advent of GaN technology has produced a step change in the level of RF power that can be generated by a MMIC
- Some circuits previously made in GaAs are now being developed in GaN because of the higher level of robustness – no limiter required
- SiGe technology has been developed particularly for low cost, volume millimetre wave applications
- Packaging: SMT packaging is now routinely used at mm-wave

MMIC Design



Front End Module for 28GHz 5G comprising LNA, PA, RF Power detector and Switch

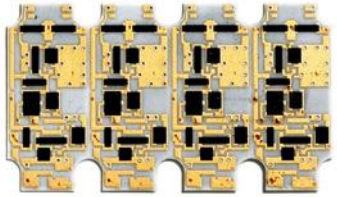
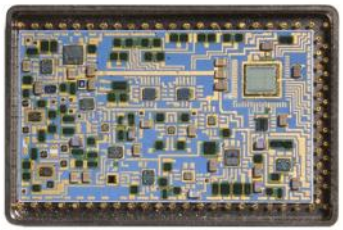
MMIC Design

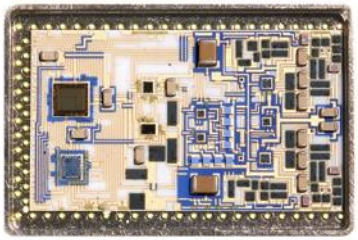


MMIC Power Amplifier for 28GHz 5G

Hybrid Circuit Manufacturing Technology

- The development and improvement of manufacturing techniques, eg thick film printing, LTCC and HTCC
- Increased use of PCB materials instead of ceramic substrates

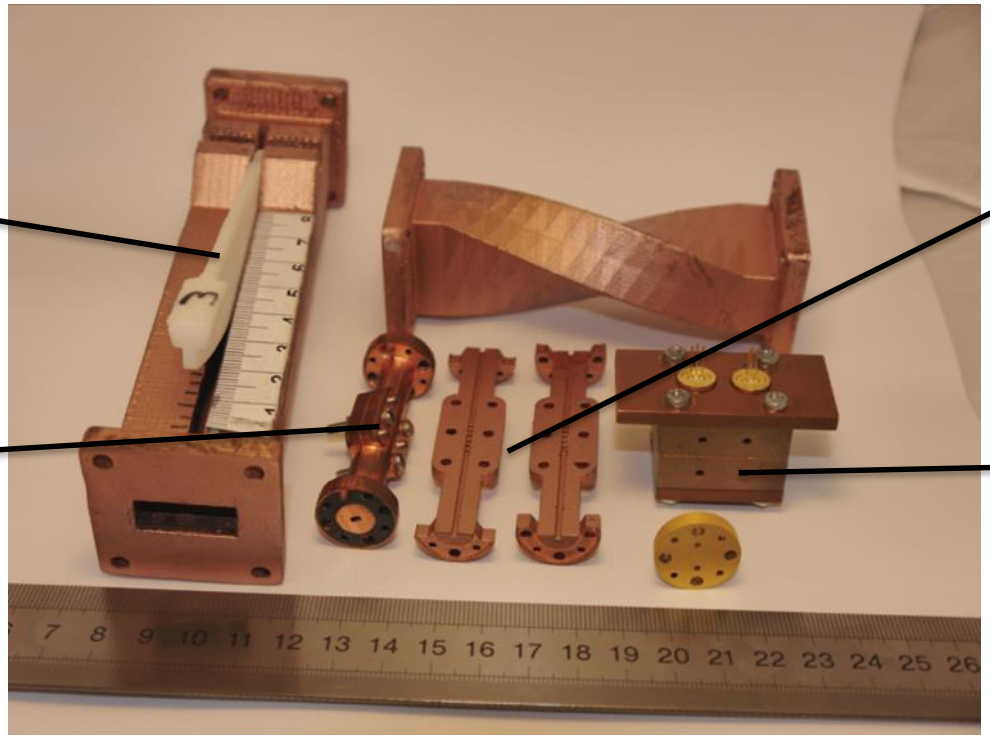





3D Manufacturing Technology

- Aerospace companies are now investing a great deal of time, money and other resources for future commercial exploitation of polymer-based 3D printing of RF products

- Emerging 3D printing technology may well overtake existing machined technologies in the not too distant future for general aerospace applications



Microwave and Millimetre Wave Components made using 3D Printing

3D Manufacturing Technology

2 Inch Waveguide

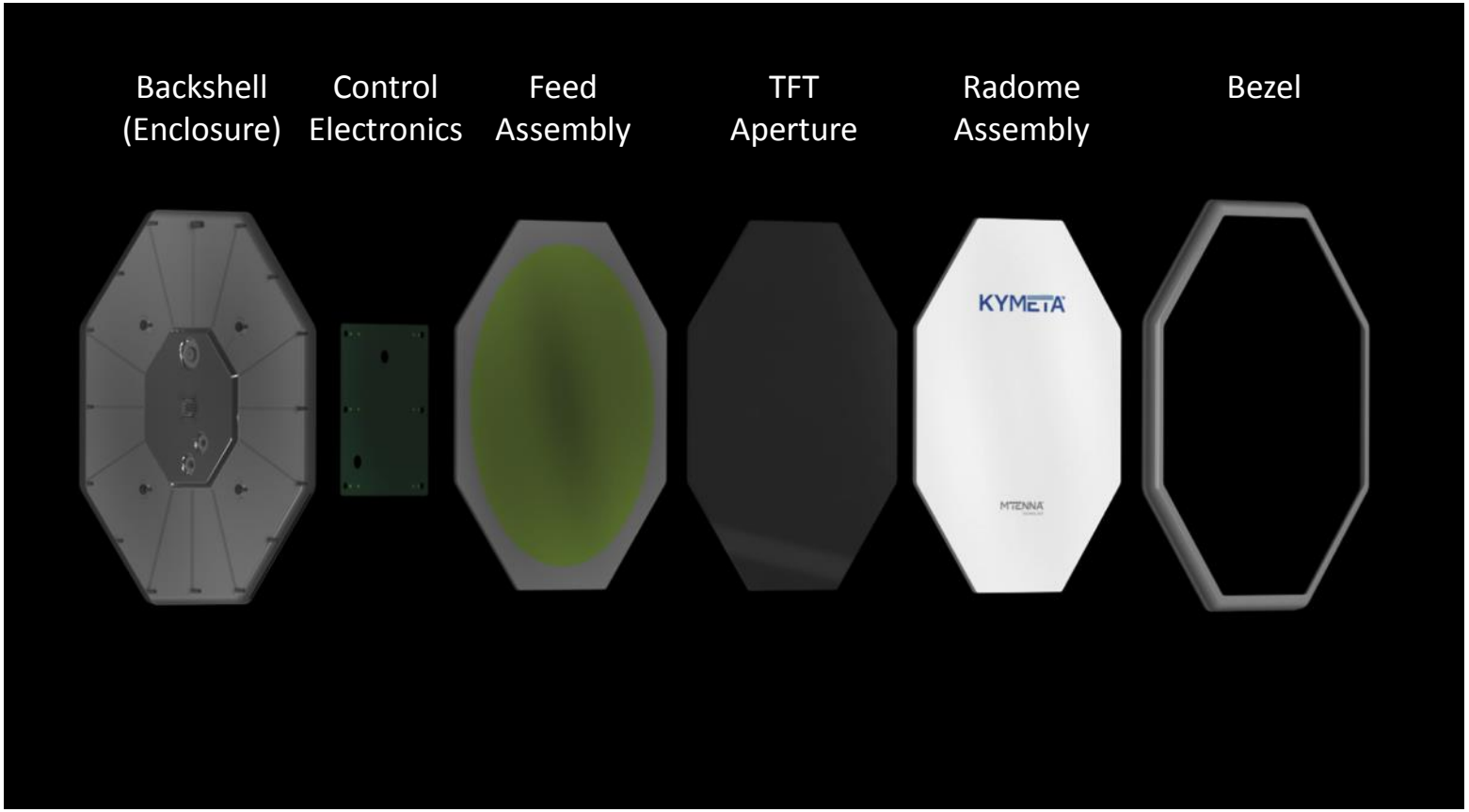
Rectangular Horn Antenna

Parabolic Mirrors

3D Printed Components operating over 145 – 220GHz

Photos Courtesy of Stepan Lucyszyn Imperial College

Low Cost Phased Array Antennas



70cm Aperture, 10:1 reduction in size compared with mechanical alternative, designed for 'SATCOM on the Move'

Photo Courtesy of Kymeta Corp

A Glimpse into the Future

- The development of MMIC devices and circuit fabrication processes to enable more complex circuits to be made operating at higher frequencies, eg 94GHz and above
- Development of processes such as Global Foundries' CMOS – circuits made with 22nm FD-SOI process consume 100 times less power, 10nm process in development
- Tuneable filters with variable pass and stopbands based on photonic principles using stimulated Brillouin scattering – Ben Eggleton, University of Sydney Nano Institute. Filter with a centre frequency of 30GHz can tune over > a decade BW with BWs of 10s -100s of MHz
- 3D multi-layer technologies such as Nuvotronics Polystrata for millimetre wave systems enabling 10 – 100 times reduction in SWaP
- 2 revolutions coming:
  - 5G needs large numbers of steerable antennas
  - Next generation automotive radar

Acknowledgements

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