**ARMMS Meeting UK November 2000**

**Farran Technology Ltd**
**Speaker : D R Vizard   Director, Technical Sales**

## 'Challenges in MMIC Multi-Chip Modules'

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**Abstract**
The design and manufacture of mm-wave MMIC multichip modules in low to medium volume manufacturing is considered. Some current design tools, manufacturing processes and requirements for testing and ensuring reliability are described. Future directions for improving yields and delivering lower manufacturing costs are suggested in the light of this SME's experience.

**Design Issues**

The successful low cost design of mm-wave multi-chip modules requires the use of many different transmission media, substrate materials and modeling tools. Some of the key areas addressed by successful designs are summarized below :

- the external interfaces, involving a transition from either a waveguide or coaxial connector to a planar circuit environment. The simulation of this transition involves extensive 3-D simulation which can be very time consuming as optimization is generally not feasible. An example of a low loss broadband transition developed by Farran Technology Limited in the mm-wave band 26-40 GHz is described in Figures 1 and 2.

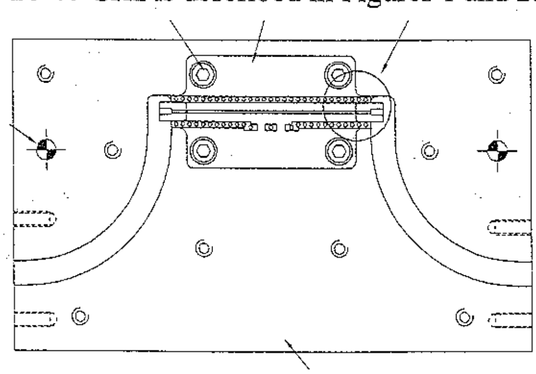


Figure 1   26-40 GHz Waveguide to Microstrip  Transition Test Jig

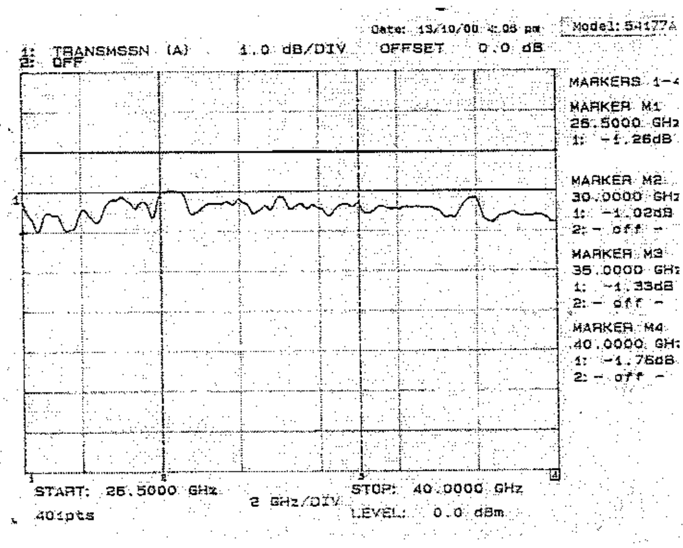



Figure 2  :  Waveguide to Microstrip Insertion Loss Performance

**Design Issues : Filters and Interconnects**

The provision of filters and low loss interconnects between MMIC stages are critical to the performance of the modules and often involve interfaces between the microstrip circuit, MMIC , and possibly drop in ceramic filters and other elements. The accurate modeling of mm-wave board based filters and transmission line is often an issue with currently available software. Figures 3 and 4 detail a typical microstrip filter with modeled and actual test data.

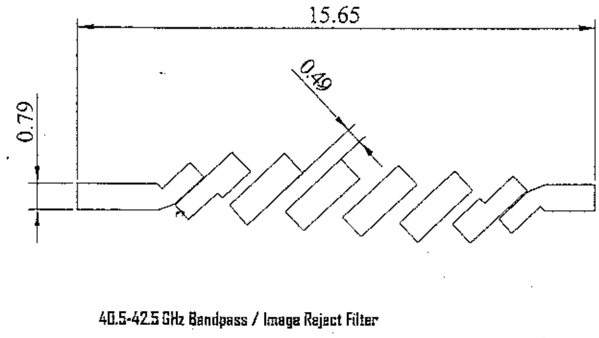
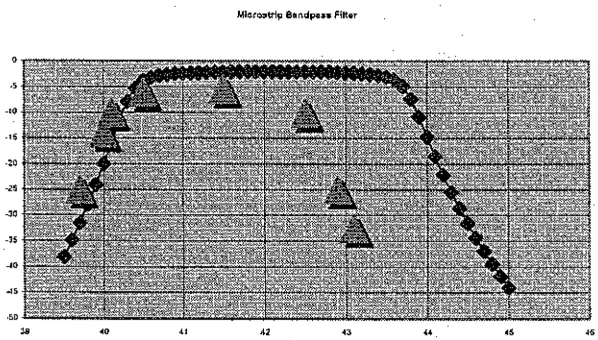



Figure 3 Microstrip Edge Coupled Bandpass Filter 40-42 GHz

Design Issues : Filters and Interconnects
contd

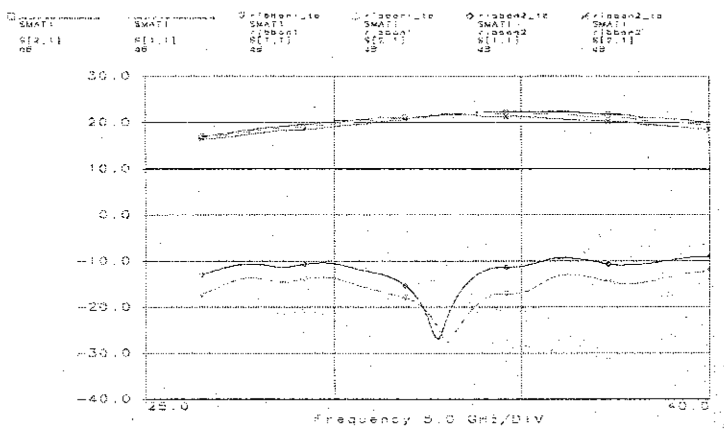
Figure 4 Actual versus Modeled Performance

Parasitics Effects
-the parasitics associated with the assembly process must also be factored in to the design e.g. wire bonding tolerance,




mechanical tolerances in chip placement. The use of bond wires needs to be accounted for and where possible built into the MMIC designs [where customized devices can be used]. Figure 5 shows the modeled effects on device performance for a single stage broadband LNA including bond wire effects.

Figure 5 Bond wire effects on S11 and S21 performances for a broadband mm-wave LNA



**Design Issuues : Simulators and software inter-compatibility.**
The simulation an entire multi-chip mm-wave module is not currently possible : -
-Whereas many MMIC manufacturers will provide small-signal S-parameters for their MMICs, virtually none provide large signal modeling data. Therefore, when using MMICs which are either not in their linear region (e.g. saturated power amplifiers) or using MMIC components

which depend on non-linearity to function (e.g. MMIC frequency multipliers), simulation is generally not feasible.

**Linear and Non Linear Simulation**

-A circuit level simulator is used to perform simulations of devices with linear characteristics, however this simulator cannot fully take into account details such as the bondwire connections to the MMIC mentioned above or the external interfaces. The method currently employed by Farran is that linear components that may not be simulated correctly by the circuit simulator (e.g. bondwire parasitics or unwanted coupling between close proximity transmission lines) are simulated with a 3-D EM simulator and then the S-parameter data file is inserted in the circuit simulator (3-D EM simulators cannot model non-linear components). In this way, small-signal simulation of a chain of components may be carried out using manufacturers S-parameter data. The big drawback of this method becomes apparent when the simulator is required to optimize the circuit or a portion of it.

**3D optimizations**

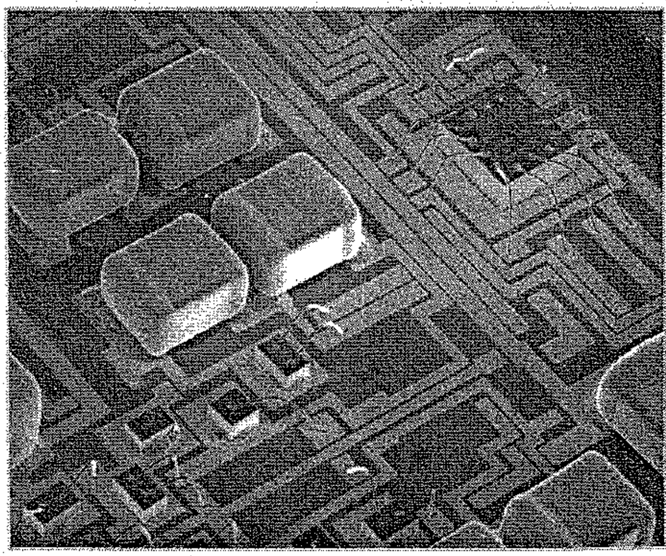
- Whereas optimization in a circuit simulator is mature and extremely fast, optimization with 3-D EM simulators is relatively new and time consuming. The optimization of both type of components (circuit simulation and 3-D EM simulation) and non-linear effects is not feasible. In general, these software packages are not compatible with each other and so an iterative design process is employed .

1) **Manufacture**

Multi-chip modules contain many different types of components, from plastic SMT devices and chip capacitors/resistors which are designed for automatic "pick-and-place" techniques, to bare chip GaAs MMICs , which because if their size and fragility are more difficult to place and interconnect automatically.

However a wide range of specialist equipment is available for the automatic assembly of chip and wire designs albeit at high cost. The use of such equipment has the advantage of higher yields and reliability due to the superior accuracy and repeatability of chip placement and wire bonding compared to manual approaches. The justification for the use of automated equipment depends on the nature and volume of the product to be assembled. As a custom designer of MMIC's and MMIC modules we anticipate using such equipment to support the breadboarding and [medium volume] pre-production manufacturing requirements of our designs prior to volume production.

Figure 6 Hybrid Module With Wire Bonded MMIC



**MMIC Interconnection and Die Attach Schemes**
Depending on the frequency range of interest and the packaging to be employed , a choice can be made from bare die interconnected with wire bonds [so called 'chip and wire '] or 'flip-chip' devices where the MMIC has connection pads pre-soldered and arranged such that the inverted device can be flow soldered during production. It is beyond the scope of this paper to go into more detail; suffice to say that either technique has its merits and disadvantages. However the lack of significant interconnection lengths make flip chip devices very attractive from a performance point of view especially at higher mm-wave frequencies.

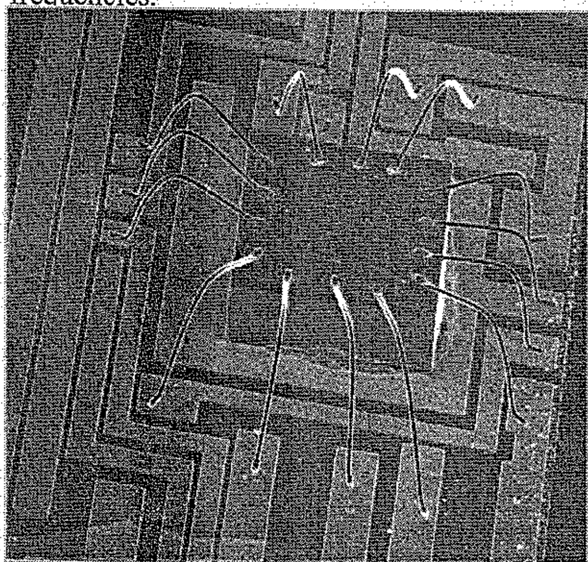


Figure 7 Manually Wire Bonded MMIC

**Epoxy or Solder.**
An associated issue is the choice of epoxy or solder for MMIC die attachment. Epoxy is regarded as the more flexible since re-work tends to be easier. It is the least expensive method but may not provide the necessary dissipation for power MMIC 's. However if the module designer pays particular attention to the thermal environment, eg. by mounting the MMIC's directly to the module metalwork, satisfactory conditions can often be provided. Eutectic soldering provides excellent reliability and thermal management, and is generally suited to high power products and or those with very high volume throughputs.

**Testing & Testability**
As the functionality and therefore complexity of mm-wave products increases, so do the number of parameters that require validation during or following the manufacturing process. Testing is one of the major cost drivers for MMIC modules with estimates of > 40 % of the cost incurred in test. As a consequence, if the product volume warrants, investment in automated test equipment is mandatory. As far as is possible the test arrangements are designed to be software re-configurable and the equipment re-useable for a range of product lines. An example of a high speed automated test applied at wafer level is shown below. Similar approaches can be taken at the module level.

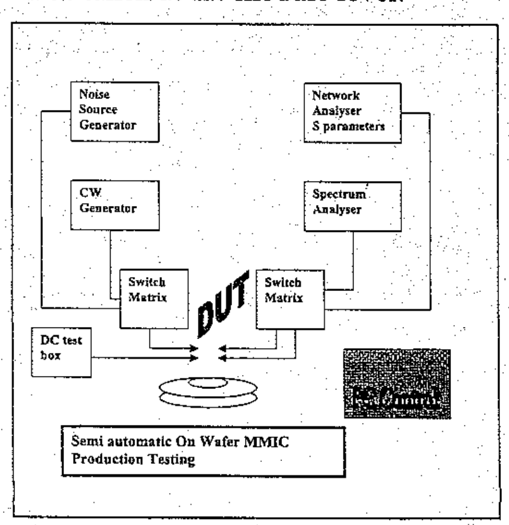



Figure 8 High Speed Wafer Testing

**Design for Test contd**
The other key factor for successful low cost manufacture is the amount of provision made within the design for testing. Because of the high frequencies used in mm-wave assemblies it is often difficult to arrange appropriate test points. One approach which we have explored is to introduce inter-stage test structures which allow on line probing a complex assembly. We show an example of a possible test structure designed to use customized probe tips interfaced with conventional spectrum or network analyzers.

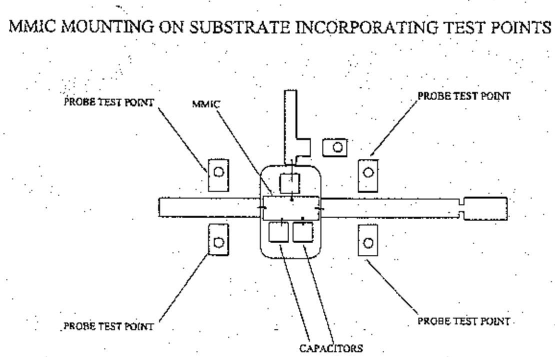
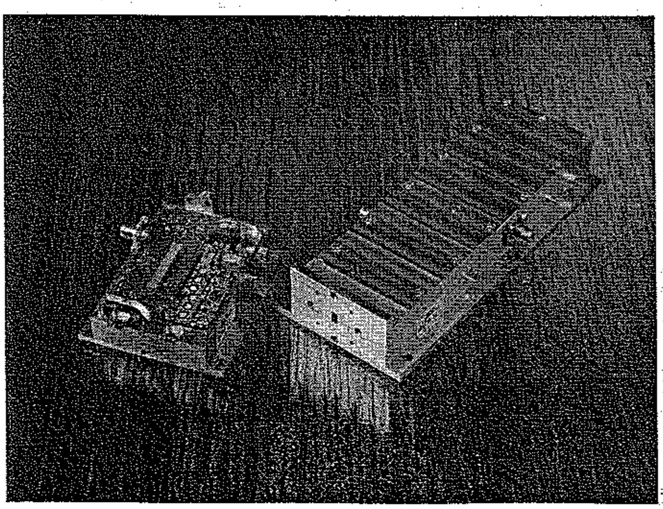



Figure 8 Example of Test Probe Pattern Integrated on Substrate

**Designed and Manufactured Products**
Examples of MMIC Based Mm-Wave Modules Produced by Farran Technology Ltd

**Figure 9 40-42 GHz Up/Down Convertors for BWA**



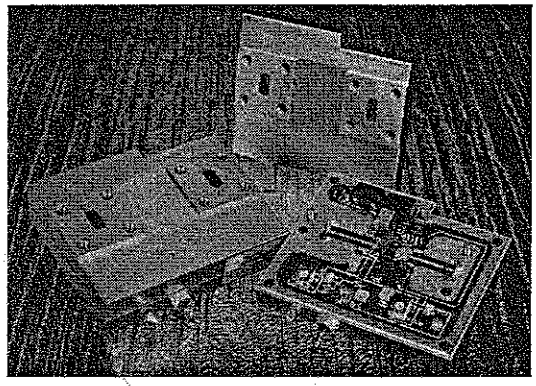


**Figure 10 35 GHz MMIC Power Amplifer Module**

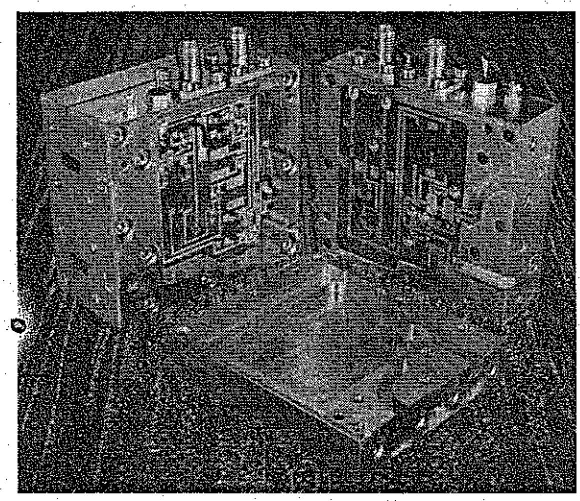


**Figure 11 35 GHz MMIC Image Reject Mixer Preamp Module**

## Conclusions

The use of mm-wave systems in commercial applications is growing rapidly. To accommodate the need for low cost integrated modules a variety of design and manufacturing expertise is required. Historically the focus has been on the MMIC itself but as the need for higher volumes increases more attention is being focused on design for manufacture, packaging, test and related areas. There is a need for better integrated circuit design tools with accurate models for mm-wave use, and for the MMIC manufacturers to provide more extensive wafer test data. The trends to higher frequencies and increased volumes will increase the use of automated assembly and flip chip technologies. Custom MMIC chip sets designed with the appropriate packaging constraints in mind have the potential to lower costs and improve circuit performance.

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1. Laurie Roth at Kulicke and Soffa Inc , USA, regarding automation equipment.
2. Microwaves and RF, Aug 99 pg 98 , 'Production Testing of Millimeter Wave MMIC's', Alpha Industries, USA

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