Technological Design Centering for a 44GHz Low-Noise Amplifier

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1. Aim

This paper describes the technological design centering methods used in the realisation of a 44GHz low-noise amplifier in the MONOFAST project as partially funded under the European Strategic Programme for Research into Information Technology (ESPRIT).

2. Background

The traditional approach to MMIC manufacture is based around the concept of the "fixed foundry" process, reflected in terminology such as the "20GHz process" or "the half micron process". Here, technology is a constant, serving to reproduce the microwave properties of active and passive devices and circuit elements characterised previously by measurement. At millimetre-wave frequencies, the fixed foundry may lead to circuits with poor yield unless designers are free to alter technology in order to achieve specification and to minimise performance spreads. Such *technological design centering* raises two requirements:

(i) It must be possible to predict the outcome of structural changes on the microwave performance of the device and circuit. Without this capability, the approach would be uneconomic.

(ii) The technology used to fabricate components and circuits must be capable of responding to the demands of the device designer with accuracy and precision, without the need for a long sequence of trials.

MONOFAST set out to demonstrate that software and fabrication tools have evolved or could be developed to the point where high-performance circuits can be designed and fabricated with predictable yields starting from physical descriptions of the components, taking a 44GHz low-noise amplifier for space flight use to the following specification as the demonstrator:

Gain: >15dB Return losses:<-10dB

Noise figure: circa 4dB

Bandwidth: 1GHz Centre frequency: 44GHz

3. Device Design

A device simulator was used to carry out detailed design of the GaAs-AlGaAs FET concurrently with, and iteratively with, initial circuit design and practical development of the FETs.

4. Selection of Circuit Topology and Preliminary Design of Circuit

The selection of a circuit configuration was based on analysis of the sensitivity of trial circuit designs to residual variations in technology affecting the active devices.

5. Sensitivity Analysis of the MMIC

By linking a FET simulator to a circuit simulator as in Figure 1, the sensitivity of the overall circuit to variations in technology affecting the FETs can be forecast. In a mature technology, random variations in MMIC behaviour are due more to process variations affecting the active devices rather than the passive elements.

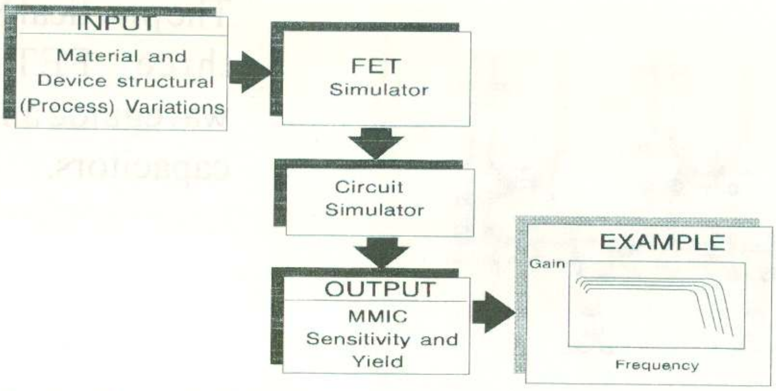

Fig. 1 Basis of MMIC Sensitivity Analysis and Yield Forecasting

6. Yield Forecasting

Using the scheme of Figure 1, the yield of an MMIC may be forecast using the Monte Carlo method to generate random, practically realistic, varying values for the physical parameters of the FET. The technique automatically generates and keeps all the correct correlations which exist between the equivalent circuit element distributions or S-parameter distributions.

7. Results

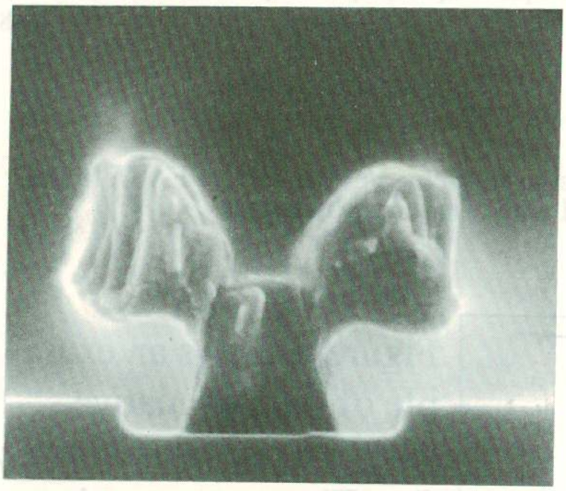

Fig. 2 Practical MONOFAST FET

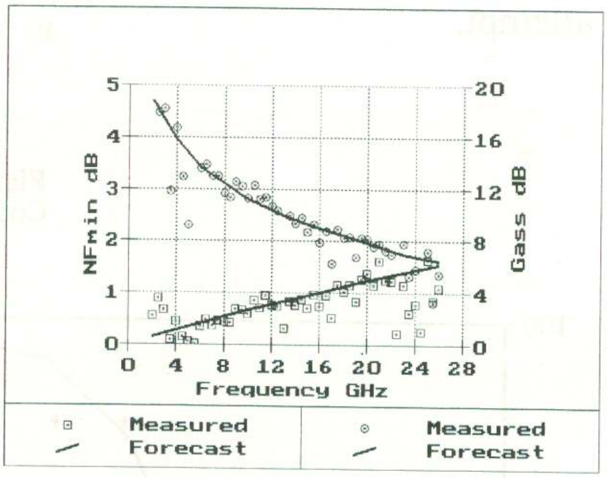

Fig. 3 Measured and Forecast Noise Figure and Associated Gain for the MONOFAST FET

Figure 3 shows the measured and forecast noise figure and associated gain of the FET in Figure 2 biased for minimum noise (the maximum frequency to which on-wafer noise measurements were available was 26GHz.) The lines through the measured points are not best-fit curves, but are the design forecasts from the simulator based on carefully measured technological data. At 12GHz, the FETs have 0.75dB noise figure and 11dB associated gain.

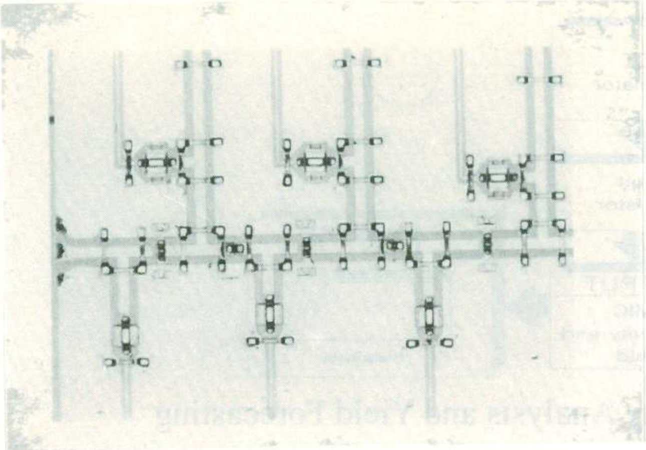

Fig. 4 44 GHz Low-Noise Amplifier

The practical MMIC employs three FETs, co-planar waveguide and metal-nitride capacitors.

Figure 5 shows the design responses (as continuous lines) and the measured responses (as discrete symbols). The amplifier met the design specification at the first full processing attempt.

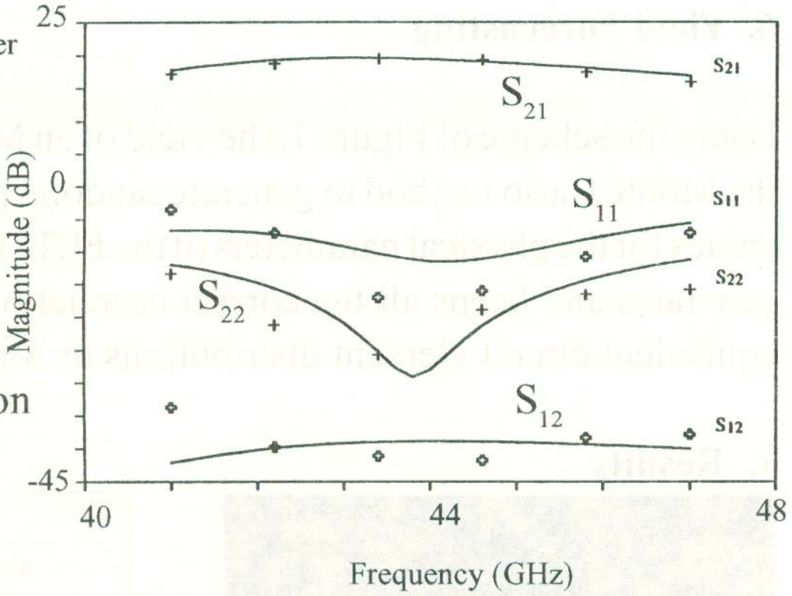

Fig. 5 Design Responses of the MONOFAST MMIC Compared with Measured Responses

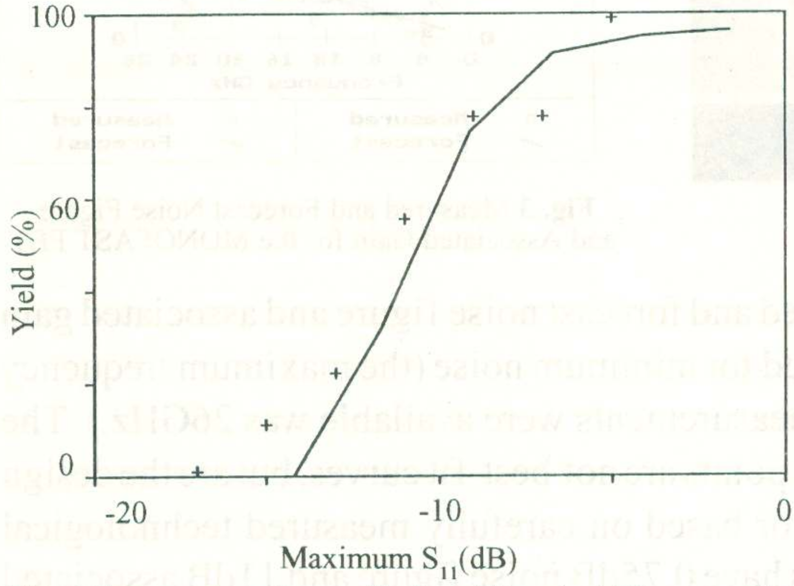

Fig. 6 Forecast (continuous line) and Practical (discrete points) Cumulative Yield on S_{11}.

Figure 6 shows an example of the cumulative yield on one S-parameter, S_{11}. The agreement between the forecast and the practical yield is good enough on all S-parameters for the forecasting method to be judged useful as a design aid for manufacturability.