ACHIEVEMENTS OF EUROPEAN COLLABORATION IN HIGH-FREQUENCY CAD WITHIN THE EDGE PROGRAMME

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ABSTRACT

The EDGE project represents a two-year collaborative initiative supported by the European Union ESPRIT programme, which concluded in mid-1998. The project addressed a number of important issues in contemporary high-frequency CAD. These included advanced interface development for MMIC design, bi-directional integration of layout with electromagnetic analysis, physics-based yield prediction and optimisation, non-linear device modelling and parameter extraction, non-linear transient simulation, together with a design assistance support tool for power amplifier design. The project created new links between commercial European CAD tools, and with other commercial vendors. It benefited from a strong inter-play between developers, users/designers and component manufacturers. This paper reviews some of the main technical achievements of the EDGE project.

INTRODUCTION

As RF, microwave and millimetre-wave applications continue to expand and new opportunities come into view, serious challenges are emerging in high-frequency analogue circuit design. Commercial products incorporating MMIC's often have critical time-to-market windows, which are unforgiving of delays caused by multiple re-designs to achieve specifications. System specifications are also becoming more critical and demanding, especially in advanced digital wireless communications where technologies such as Wideband-CDMA are being proposed for Third-Generation (UMTS/IMT-2000) systems.

Against this background of the increasing strategic importance of high-frequency CAD in the development of mobile communications (an area in which Europe has achieved real success at the global level), the European Commission decided in 1996 to support a 28 Person-Year project entitled EDGE (**E**nhanced **D**esign for **G**aAs/Si in **E**urope). EDGE was intended to strengthen Europe's technical and commercial position in high-frequency CAD, with a consortium composed as follows:

Co-ordinator:		
University College Dublin	*UCD*	[IRL]
(Talbot Technologies Ltd.	*TTL**	*[IRL])*
Partners:		
Barnard Microsystems Ltd.	*BML*	[UK]
Dassault Electronique	*DE*	[F]
GaAsCode Ltd.	*GC*	[UK]
GEC-Marconi Materials Technology	*GMMT*	[UK]
Jansen Microwave GmbH	*JMG*	[D]

* *new company formed to commercialise UCD's activities, including EDGE outcomes*

Philips Microwave Limeil	*PML*	[F]
Associated Partner (to GC):		
University of Rome 'Tor Vergata'	*UR*	[I]

EDGE was launched as an ESPRIT project, and had a range of specific technical objectives, some of which are described in the following. Besides the technical work, the project also had another level of activity on the business and commercial arena, which aimed to create a stronger business partnership among the European CAD vendors, and which could also act as a focus for commercial exploitation of the many excellent research results which continue to come from European universities and institutes.

PROJECT OBJECTIVES

While the project sought to build on a range of distinctive complementary CAD capabilities in Europe, from the outset EDGE was not intended to be an 'open-ended' research project focusing on fundamental problems primarily of academic interest. The emphasis was instead very much on solving practical problems from a user's perspective. In this way of thinking, an excellent CAD technique or simulation 'engine' will find little support among the user community if is not supported by a professional, easy-to-use interface, good on-line help, support and documentation, while it must also be extensible in the sense of using standardised file formats, and should support design re-use and the availability of design entry information at one point at any other point in the design.

A central issue for EDGE, therefore, was to address the difficulties users had prior to the project in using European commercial CAD software, originating from different vendors with individualistic approaches. Besides improving on the interfaces themselves and offering new tools and models, this involved trying to standardise (as far as practicable) interface formats, and using standard file structures - including a new 'Project File' concept. Figure 1 shows a high-level representation of the so-called 'EDGE Road-Map' showing a longer-term perspective of the process of unification and integration.

The specific aims of the EDGE project may be listed as follows:

Provision of Effective Links Between Existing European Tools
As already stated, at the beginning of EDGE, a variety of independent European commercial high-frequency CAD tools were marketed by several of the companies in the EDGE consortium. From the users point of view this situation was undesirable, as the products appeared disjointed and effort was required on the part of the user to combine them for specific applications. A key achievement of the EDGE project has been to demonstrate effective, working, user-friendly links between these different CAD tools at the conclusion of the project (see Fig. 2);

Provision of Links between European Tools and Established US Vendors
The consortium has been well aware that the products of US CAD vendors are widely used in the industry at present for analogue MMIC design. The EDGE project has allowed users to complement existing investments of this kind with a set of easy-to-use extensions and links to European CAD tools and models;

Support of Advanced User Interface Development and a Common Interface Style
From the point of view of the user, a flexible, powerful yet intuitive interface is of the greatest importance in promoting attractiveness of CAD products and ensuring maximum design productivity. The EDGE project has successfully demonstrated major enhancements to existing CAD interface formats which provide real benefits to MMIC designers, in particular through the

provision of a close co-operation between layout and electromagnetic analysis. New interface developments also provide direct access to foundry library modules, standardised wherever possible, as well as integrated access to a range of powerful EM-oriented simulators. Furthermore, the consortium has made real progress towards a common European style of user interface during the course of the project, demonstrating a similar 'look-and-feel' across various tools, to complement the links at the data exchange level described earlier;

Integration of Time-Domain Tools for MMIC Design and Yield Enhancement
EDGE has sought to address the continuing serious problems of MMIC designers in performing reliable non-linear analysis of MMIC's which are complex, multi-function and operating in strongly non-linear and/or low-power regimes. Furthermore, yield evaluation for self-bias circuits has always presented particular problems. By integrating a series of existing advanced complementary capabilities in Europe, the EDGE project has demonstrated an EDGE Large Signal time-domain simulator, with links via convolution analysis to frequency-domain data. The main emphasis in this work has been on low-cost, PC-oriented software solutions;

Provision of a Standardised, Advanced Non-linear European FET Foundry Model
Foundry users around the world have persistent problems with circuit-level, non-linear models of FET-based devices. The EDGE project has developed an advanced, standardised non-linear FET model for two of the foundry processes represented in the consortium, using a synthesis of the best available research ideas. Among the latter is included a unified, physics-constrained modelling strategy already existing within the consortium. The final model has been designed to be as general-purpose as possible in the sense of being scaleable and usable over a wide range of typical DC operating conditions, with a single set of model parameters. It is also supported by a highly sophisticated parameter extraction tool which has been developed as a commercial product by Talbot Technologies Ltd. within EDGE.

EXAMPLES OF PROJECT ACHIEVEMENTS

The following highlights some of the technical achievements of EDGE. For example, the project has demonstrated:

- an advanced interface from Jansen Microwave GmbH for layout-oriented electromagnetic analysis, allowing integrated access to a range of advanced EM-analysis tools, ranging from multi-layer quasi-static, fast 2.5D, full 3D and diakoptics-based for complete MMIC simulation. The interface also allows direct access to library process modules from several foundries (see Fig. 3);
- a close and bi-directional interaction between layout and electromagnetic analysis, allowing import and export of design information using all the standard formats;
- a physics-based FET modelling capability from GaAs Code Ltd. which allows MMIC performance to be optimised for yield as well as yield forecasting to be performed. This capability is especially useful in identifying critical circuit specifications which may have a drastically adverse effect on yield. Figure 4 shows physics-based simulations for a four-stage test MMIC (proposed for EDGE validation exercises by Dassault Electronique). The simulations are performed using layout/design software from Barnard Microsystems Ltd.
- a new, compact, scaleable general purpose nonlinear model for MESFET's/PHEMT's has been developed by University College Dublin which can be adapted across different processes, and which allows accurate prediction of non-linear effects such as intermodulation distortion over a wide range of DC bias conditions, device sizes and frequencies (see the example in Fig. 5 for a

0.2µm x 120µm PHEMT from Philips Microwave Limeil. This and other widely-used models are supported by a powerful parameter-extraction tool called *COMET*;

- a novel fast synthesis tool for optimum power amplifier design developed by the Universita di Roma 'Tor Vergata' in co-operation with GaAs Code Ltd. The *PANDA* tool (Power Amplifier Numerical Design Assistant) is based on an approximate description of key transistor nonlinearities, enabling optimum matching conditions to be established not only at the fundamental but also at higher harmonics;
- a non-linear transient simulation tool called *OOPS* (Object-Oriented Personal Simulator) has been developed at UCD which incorporates state-of-the-art nonlinear device models together with a convolution-based means for importing frequency-domain S-parameter data directly into the transient analysis.

CONCLUSIONS

The EDGE project provided a valuable structure for the development of high-frequency CAD in Europe, where software and model developers not only worked with, and learned from, each other but also had an opportunity to interact closely with users and designers. As a result of the project, European CAD tools and models have new features and capabilities and can inter-work to a much greater degree than before. These technical achievements have been underpinned by an increasing convergence in business and commercial terms between the commercial CAD developers represented in the consortium.

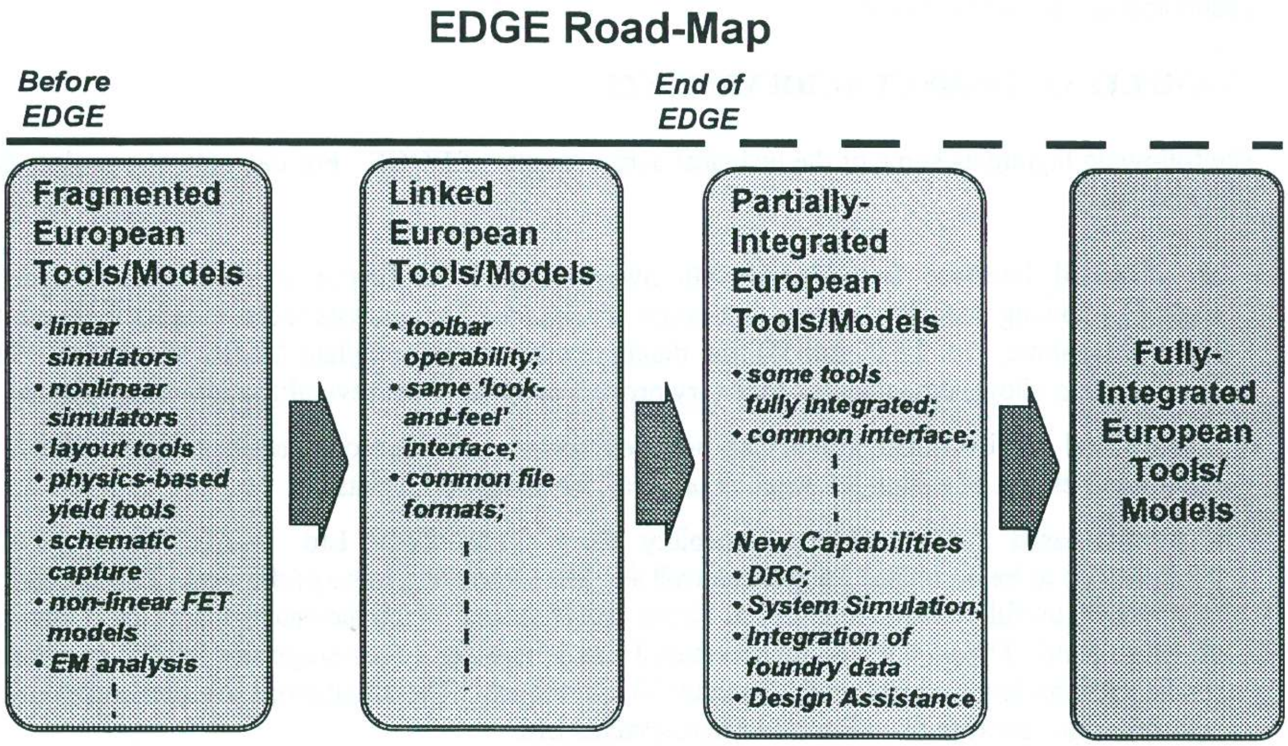

Fig. 1: Evolution of Software Tool/Model Integration

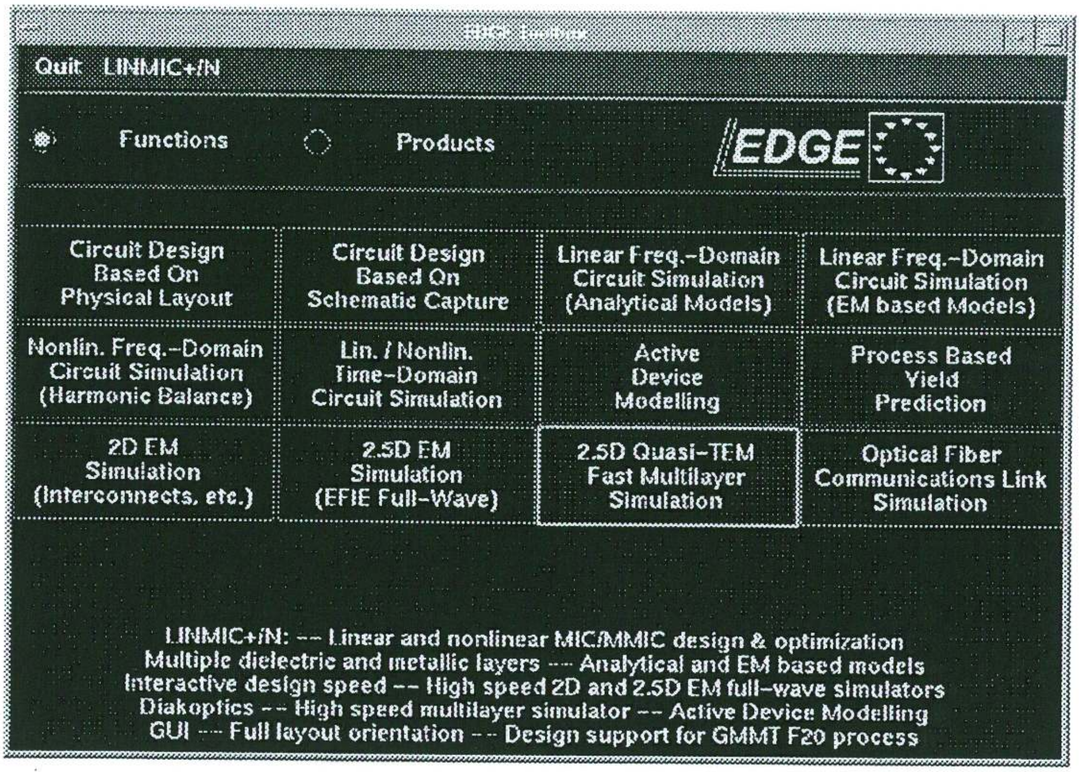

Fig. 2. High-Level Interface Allowing Unified Access to EDGE tools

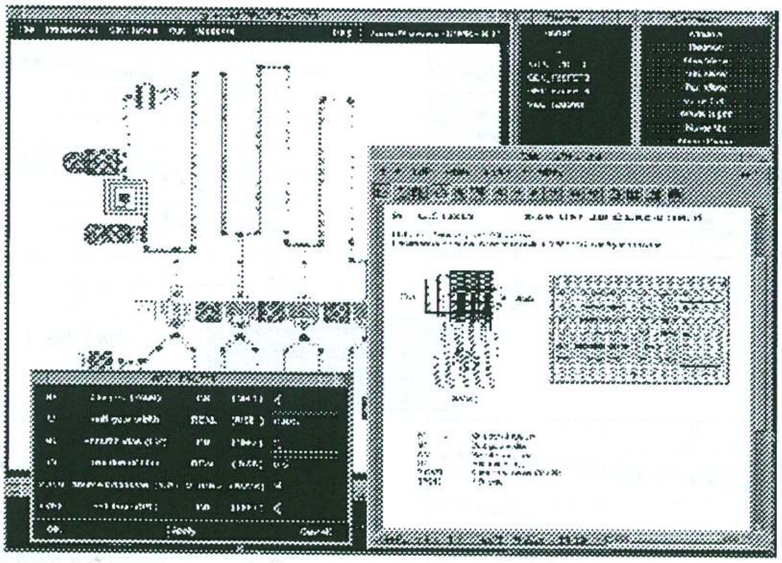

Fig. 3: Advanced Interface for MMIC Design Integrating Foundry Process Library Data with On-Line Help

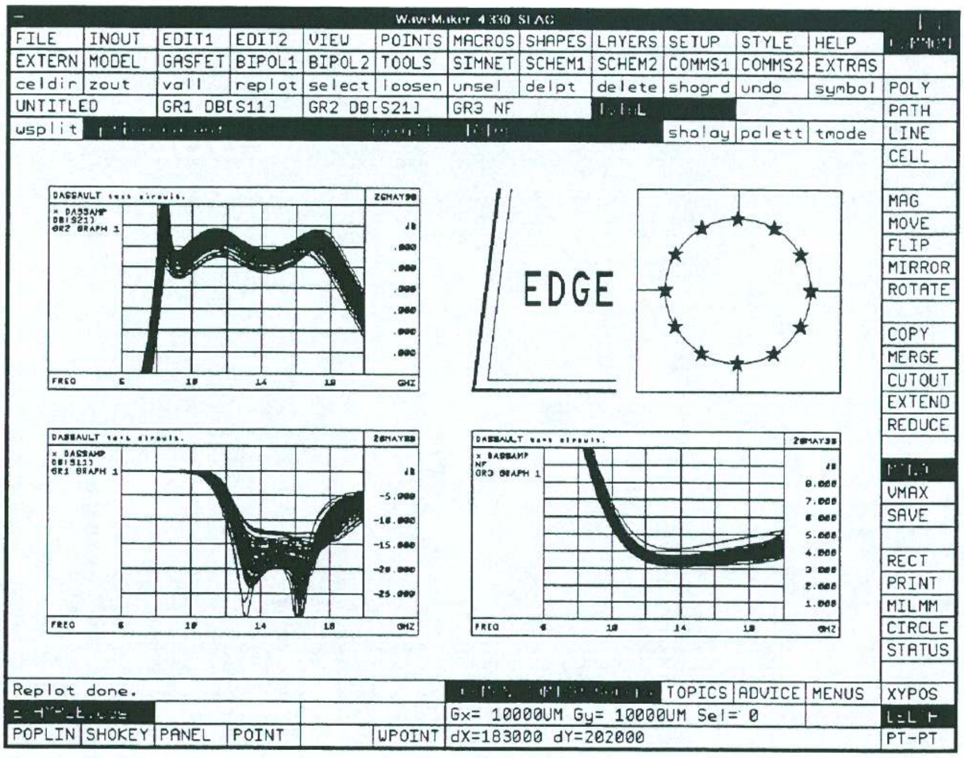

Fig. 4: Simulation of Spreads for Dassault Electronique EDGE Test MMIC using Physics-Based Analysis

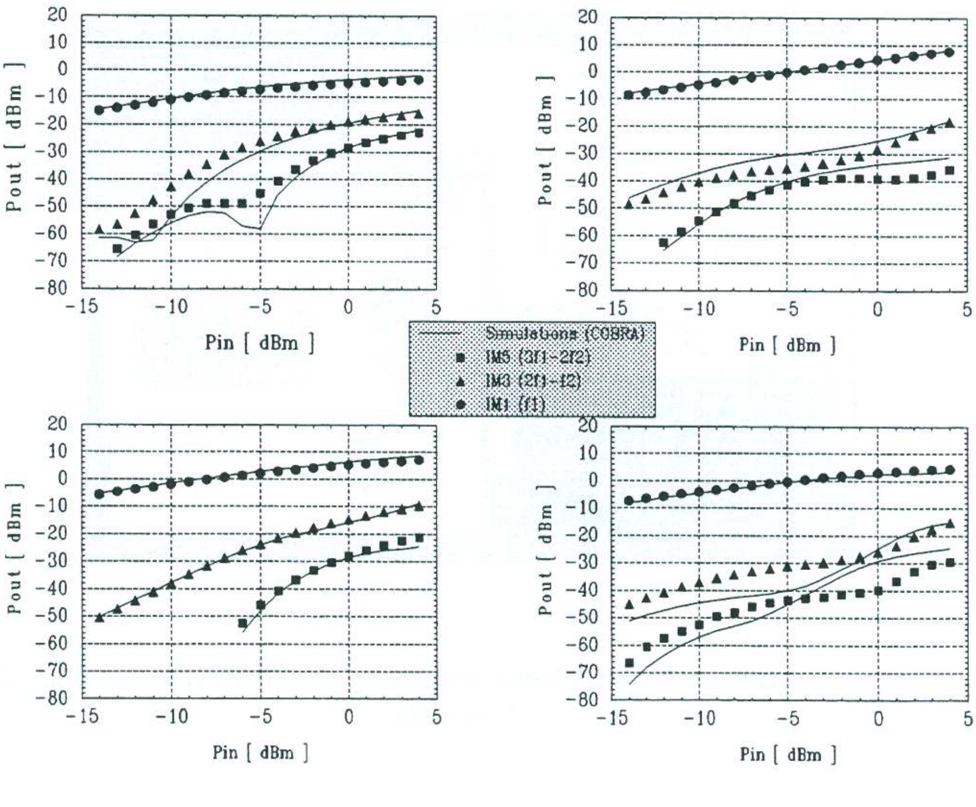

Fig. 5: Two-Tone Intermodulation Tests at Four Bias points 9GHz Using EDGE Scalable Non-Linear Model *COBRA* (0.2µm x 120µm PHEMT from PML)