# Further enhancements on the CAE horizon

Two Canadian suppliers of computer aided design tools for microwave and rf applications have now added major upgrades to their respective programmes. Ingsoft and Optimization Assocoates, both in Ontario Canada, in Willowdale and Dundas respectively, cover quite different areas of modelling and simulation. Ingsoft's RF Designer is an Apple Macintosh-based simulation programme which now has a filter and transmission line synthesis program added, while OSA's HarPE is principally a device modelling, parameter extraction and simulation package that has now added a statistical analysis and yield prediction capability, which does appear to have put in place an appropriate stepping stone to full yield optimization at some point in the future.

## Statistical modelling

The features of statistical modelling and analysis are available as an add-on module for HarPE. The package is released as HarPE Version 1.4+S, available on Apollo, Hewlett-Packard and Sun Workstations.

The new version implements a multi-device optimization and postprocessing approach to statistical modelling. Suitable measurements (large-signal power spectra, small-signal S-parameters, and/or DC IV data) are collected from a sample of devices to build up the statistical database, typically from 100 to 300 devices.

Clearly, such a measurement exercise is time consuming but it is possible to automate the process, possibly by a measurement system such as Cascade Microtech's MicroCAT, which is supported by HarPE. From the measured data, multiple device models are extracted through repeated optimization, using the company's gradient-based $l_1$ optimizer OSA quotes typical run times for 100 devices, with S-parameter measurement at two bias points and five frequencies per bias, that range from 45 minutes on an Apollo DN3500 to 15 minutes on a Sun SPARCstation 1.

The sample of extracted model parameters is postprocessed to generate a consolidated statistical model, which is then back annotated to produce a HarPE circuit file immediately suitable for Monte Carlo analysis. Parameter correlations are automatically estimated and included in the multidimensional normal (Gaussian) distribution model.

## Non Gaussian

For parameters exhibiting substantially non-Gaussian distributions, the user can choose to keep the histograms as discrete approximations of the marginal density functions. This combined discrete/normal approach is claimed to preserve the means, standard deviations, correlations and marginal distributions derived from the sample. It provides enhanced accuracy of the model while retaining the simplicity of the normal distribution.

The statistical postprocessor can also be applied to arbitrary raw data supplied by the user. The statistics (means, standard deviations and correlations) of such data can be analyzed, and histograms and scatter diagrams can be displayed.

The Monte Carlo analysis is intended for use with large-signal, DC and small-signal simulations. The statistical models for Monte Carlo analysis may include uniform, normal, exponential and lognormal distributions with absolute or relative tolerances. Histograms, run charts, and sweep diagrams are displayed, and yield can be computed from specifications on spectra, S-parameters, DC currents and arbitrary user-defined functions.

The statistical features can be used with any of HarPE's built-in or user-created device models. Popular equivalent circuit models are supported, including the Materka model, Curtice model and Raytheon model for FET, bipolar models, and the diode model. It is interesting to note that HarPE Version 1.4+S also provides a physics based FET model together with statistical modelling and analysis capabilities.

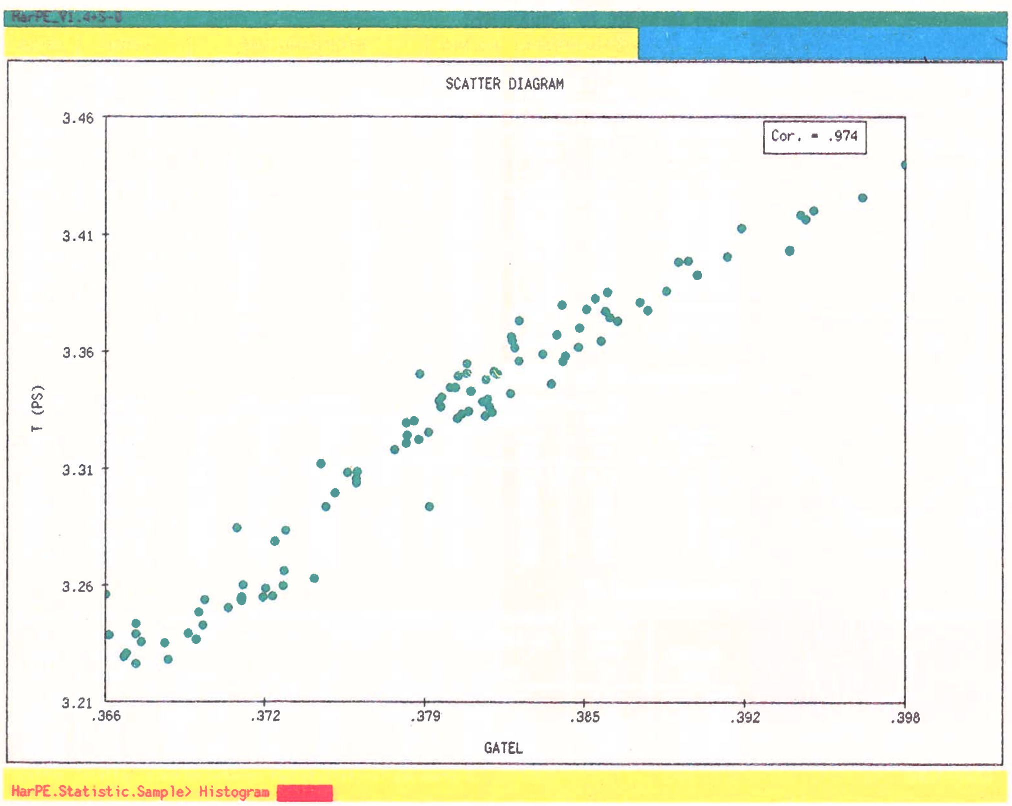


*Figure 1: A scatter diagram from OSA's HarPE, showing the correlation between channel delay time and gate length (GATEL) after statistical modelling.*

## Large signal model

The physics based model in HarPE is a large-signal analytic model based on the work of Khatibzadeh and Trew at the University of North Carolina[1,2]. It describes the conduction and displacement current of the FET as a function of instantaneous terminal voltages and their time derivatives.

Model parameters include gate length, gate width, and channel thickness. Uniform doping and arbitrary doping profiles are accommodated.

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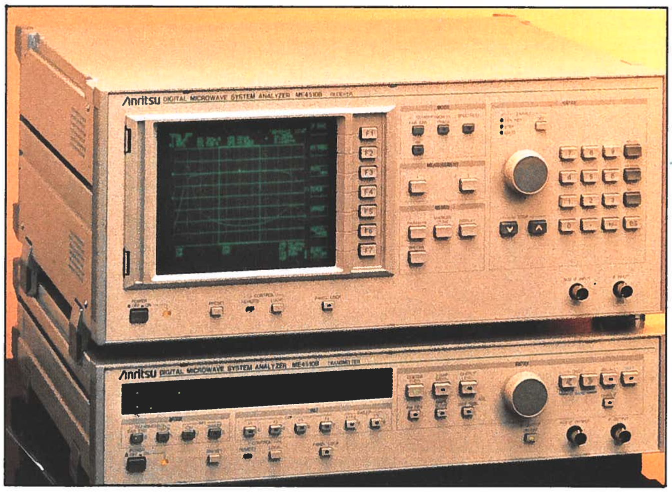
# Instrumentation for digital microwave radios

The test of digital microwave communications links is an area that Anritsu is now intending to cover with its microwave systems analyzer, the ME4510B, an instrument that is effectively an application specific scalar network analyzer with capabilities for spectral maesurement. The instrument is supplied with a separate transmitter and receiver section, which can be split for remote operation over a GPIB, possibly over a telephone link if the two terminals of the communication system are too far apart for a laboratory test.

Since the system is intended for use with operational links as well as those being evaluated in the laboratory, the transmit and receive systems may well be separated by large differences, possibly over a satellite link.

In practice, the more usual mode of operation is expected to be with the transmit and receive instrumentation at both sides of the link. The measurement system aims to provide a single instrument solution to measurement of the principal parameters that affect sytem performance, including the amplitude and time delay characteristics for a single link or as a comparison of two alternative transmission paths. In addition to this, third order intermodulation products and return loss can be measured, and a spectrum analyzer is provided on board.



*Anritsu's analyzer for digital microwave links*

The method of measurement is to use the link IF for both input and output to the instrumentation, and either the 70MHz or 140MHz IF bands can be used for this, according to the capacity of the microwave link. Bandwidths supported at IF are ±25MHz and ±60MHz.

The procedure applied for measurement of the time delay between two different propagation paths is to apply frequency modulation to the transmitted signal and then measure the phase difference between the demodulated signals as a means to assess the difference in the time delays through the paths, rather than undertaking all of the measurements at rf. The delay can be plotted against frequency and consequently the adjustments made to the delay for delay path equalisation.

## Delay range

The measurement range for time delays is 400ns, either 0 to 400ns for a simple through measurement or ±200ns for either the loop back mode or when comparing two different paths, with an internal deviation of better than 1ns. For the amplitude measurements, the system specification includes a 40dB measurement range and an internal deviation of less than 0.3dB, specified at 0dBm input level.

For spectrum measurement, the instrument implements a 10kHz to 300MHz spectrum analyzer, in 4 spans that have resolutions from 1kHz to 1MHz. Display resolution is specified to be 0.1dB and 1/100 of span or 0.1kHz in frequency, whichever is the greater.

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# Further enhancements on the CAE horizon

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The supporters of physics based models, as opposed to equivalent circuit models, claim that they enjoy a distinctive advantage in statistical modelling and analysis. Because such models directly relate to physical, geometrical and process parameters, their statistical distributions can be closer to being normal (Gaussian) and less correlated, an assumption that would be more difficult to justify for the more abstract equivalent circuit models. It is for this reason that OSA believes physics based statistical models should prove to be more accurate and reliable.

Ingsoft's RF Designer is intended to address a broader range of applications and use the Apple Macintosh as the environment for graphically assisted circuit representation and simulation up to 225 components and 90 nodes. In the updated version, 1.2, a number of general enhancements have been made, including the addition of a context sensitive on-line manual, output of S-parameters to 5 significant digits and further graphics facilities for display of more than one plot.

It also adds RFSynthesist to the software, a programme that allows a basic level of synthesis for filters and microstrip lines in addition to the calculation of characteristics for coupled transmission lines and the calculation of transmission line characteristics from the line's physical parameters.

The range of structures for which an equivalent circuit can be created, probably as an input for simulation, includes coplanar waveguide, coax, stripline, coupled microstrip or stripline, printed spiral inductors and several filter types. In filter design, the program is intended to act as an alternative route to the text book for finding equivalent circuits to Butterworth, Chebyshev, Elliptic, coupled resonator, bandpass and band stop filters.

By using other sections of the programme to find appropriate transmission line elements to fit the filter equivalent circuit, a realistic design could then be simulated.

**OSA HarPE**
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**RF Designer**
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### References

[1] M A Khatibzadeh and R J Trew, "A large-signal, analytic model for the GaAs MESFET", IEEE Trans Microwave Theory Tech, vol MTT-36, 1988m pp 231-238.

[2]J W Bandler, Q J Zhang and Q Cai, "Nonlinear circuit optimization with dynamically integrated physical device models", 1990 IEEE MTT-S Int Microwave Symp Digest (Dallas, TX, 1990), pp 303-306.