

MARION LEE EDWARDS

GUEST EDITOR'S INTRODUCTION

Several developments have benefited microwave technology at the Applied Physics Laboratory, as elsewhere, over the last decade. First has been the refinement and availability of high quality III-V semiconductor materials. These materials, whose molecules consist of combinations of atoms from the third and fifth columns of the periodic table, are necessary for microwave solid-state circuits because of their high electron mobility. Gallium arsenide, often referred to as "gas" because of its chemical abbreviation, GaAs, is an example of such a material used to fabricate high-speed electronic devices; GaAs chips permit digital systems to operate at high frequencies.

A second important advance has been the improvement in device and circuit modeling. Implementation of both linear and nonlinear techniques in personal computer- and workstation-based computer-aided-engineering software has facilitated the development of new circuits and reduced the "black art" aspect of microwave design. This has been particularly important for microwave circuits on a chip substrate such as gallium arsenide, where fabrication is expensive and ill suited to a "cut and try" approach to design. Direct numerical field solution to Maxwell's equations is now possible for uncharacterized structures and results in predictions that faithfully agree with subsequent measurements.

Advances in microwave testing have also been important in the development of the technology. Because of their great sensitivity to parasitic effects, accurate microwave measurements have been difficult, tedious, and usually seriously contaminated with spurious effects. Computer-controlled testing and new calibration techniques permit test fixtures to be de-embedded from circuit measurements. Probe stations and network analyzers are now capable of measuring chips well into the millimeter wave range.

This is the first of two issues reporting on accomplishments in microwave technology at APL. Although originally motivated by advanced military applications, the technology developed is also an essential part of future high-performance systems such as personalized satellite communications, automotive navigation and control, wireless medical instrumentation, and aeronautical safety systems, among others.

Monolithic microwave integrated circuits (MMIC'S) have been designed at APL since 1989 and fabricated at several foundry facilities. Integrated software has been customized at APL utilizing personal computers and

workstations. Layout and packaging are integral parts of a microwave design, and their effects can be modeled in the software if the design engineer wishes. As they report in their article in this issue, Moore and Penn have used integrated schematic, layout, and simulation software on personal computers and workstations to produce designs resulting in "first pass" success when fabricated. Such designs include circuits operating at frequencies up to 50 GHz with impressive comparisons of predicted and measured performance. Reinhart has designed and discusses in his article a four-bit Ku-band MMIC phase shifter using the APL design capability and applying it to digitally controlled switching elements.

Sloan, Bokulic, and Sinsky have extended application of the design capability by integrating microwave components into a subsystem requiring consideration of linear and nonlinear methods. Their design of an X-band telecommunication transmitter for the Mid-Course Space Experiment (MSX) had to meet the stringent environmental requirements of space, forcing technology trade-offs and special design considerations. It is noteworthy that this sponsor-funded work was a natural outgrowth of the APL Internal Research and Development initiative.

The MSX satellite beacon receiver systems require an agile source to compensate for variable Doppler shifts. A programmable source where microwave signals are directly converted from a digital stream is referred to as a direct digital synthesizer, in which the frequency can be changed simply by modifying the digital signal. Russo and Clatterbaugh have led the APL development of a space-based, high-speed GaAs direct digital synthesizer (DDS) multichip module. Their multilayer (ten conducting layers) design was fabricated using a low-temperature co-fired ceramic substrate with a low dielectric constant referred to as green tape.

Custom design of monolithic microwave integrated circuits is not always required. Kopp and Barnett have shown that commercially available MMIC elements can facilitate the rapid development of prototype components for complex systems such as active arrays. They used this technique in the development of a C-band receive module for a phased array antenna.

The Applied Physics Laboratory has a rich history in the development of antenna technology, including phased array systems. The patch antenna, which has become the basis for most conformal arrays, was invented and patented by Rupert Collings of the Space Department at APL in the mid 1960s. Frank and O'Haver summarize phase

array work in the Fleet Systems Department on the Aegis System, the Cooperative Engagement Capability, and other MMIC architectures.

Reliability of microwave systems is paramount in weapon systems and space systems. Nhan, Lafferty, Stilwell, and Chao discuss one of the parts most vulnerable to failure in a microwave system: the connection interface between components. The space environment subjects electronics to severe thermal and mechanical stress. Their article uses recent APL experience with S-band hybrid couplers and power dividers to illustrate the problems and preventive methods.

The next issue, *Advanced Microwave Technology—II*, will include additional systems applications of modern microwave technology and will report on microwave integration with fiber-optic and superconductivity technologies.

THE AUTHOR



MARION LEE EDWARDS is supervisor of the Microwave and RF Systems Group in the APL Space Department and chairman of the Electrical Engineering Program in the Whiting School of Engineering. He joined the Applied Physics Laboratory in 1977 and is a member of the Principal Professional Staff. He is a leader in the development of microwave capabilities at The Johns Hopkins University. Dr. Edwards has been a member of the Part-Time Engineering Faculty and was the 1985 J.H. Fitzgerald-Dunning Professor. He received his B.S. and M.S. degrees in electrical engineering from North Carolina State University and Northwestern University, respectively, and earned his Ph.D. degree in mathematics at the University of Maryland. He is a senior member of the IEEE.