A Review of the Panel Discussion on Advances in Millimeter-Wave Subsystems

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I. Introduction

THE MILLIMETER-WAVE Subsystems panel was formed to provide an overall picture of the status of millimeter-wave subsystems as seen by a group of panelists from six of the major international companies. The principal features were to be the application of current technologies to systems requiring large quantities of millimeter-wave subsystems. Members of the panel were selected to represent a cross section of technologies and applications as well as to provide an overview of the current technologies throughout the industry. It was recognized early that a diversified group of experts would bring about a varied number of technologies for construction. Emphasis was placed on current and in-place construction techniques, and how these techniques are used to produce practical multifunction subsystems. Almost as an afterthought, panelists were asked to discuss techniques that are applicable to low-volume as well as high-volume production. This last minute change of format seemed appropriate since the current state of the art for many of the techniques is in the prototype stages, that is, still not in the high-volume stage. During the panel discussion, this factor was brought out even more.

Panel members were selected from Europe, Japan, and the USA. Where possible, each panelist covered the state-of-the-art within his company, within his specific country, and speciality area, that is, communications, radar, sensors, etc. The panel, organized by T. H. Oxley and J. B. Horton, was composed of:

Moderator: T. H. Oxley (England, Marconi Research Centre)

Panelists: C. Carbonne (France, Thomson-CSF)
T. T. Fong (USA, TRW)
Y. Konishi (Japan, Uniden Satellite Technology)
H. J. Kuno (USA, Hughes Aircraft Company)
H. Meinel (Germany, AEG-Telefunken)
D. A. Williams (England, Marconi Electronic Devices)

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During the panel session, each member presented a 10–15 minute overview of the techniques and subsystems currently being developed in his own area. After these presentations, a general discussion was held with audience participation in a general question/answer format. There is no doubt that the greatest exchange of information took place during the panelists' presentations, and unfortunately, in some cases, the panelists had to shorten their presentations to meet the time allocation. Additional information is provided in this issue by three of the speakers: Konishi, Meinel, and Williams.

II. Overview

Fabrication techniques clearly were the major topic throughout the panel discussion. In his opening talk, Carbonne presented a list of transmission types that included standard waveguide, oversize waveguide, *H*-guide, groove guide, fence guide, microstrip line, suspended line, finline, slotline, and dielectric waveguide. This turned out to be a fairly representative list of transmission techniques currently used by the panelists, although the particular applications varied. Hybrid construction techniques are being used by all of the panelists for current subsystems. For most of the low-power components (such as mixers and switches), microstrip, suspended microstrip, and finline with beam-lead devices are favored. For high-*Q* and transmitter circuits, standard waveguide is used and usually these circuits are fabricated as separate modules and attached to the integrated subsystems through waveguide to stripline adapters. Circulators and dielectric resonators are usually handled in some sort of hybrid waveguide construction technique. The panelists generally agreed that this hybrid construction technique is needed to reduce losses, particularly for frequencies of 60 GHz and above.

Monolithic millimeter-wave integrated circuits were certainly a favorite topic during the 1985 MTT-S Symposium [1]–[5], but the panelists all agreed that this technique is not currently mature enough for millimeter-wave subsystems. Kuno presented the most optimistic outlook for GaAs monolithic circuits in his discussion of a 27.5–30-GHz monolithic low-noise amplifier. During the question/answer session, Kuno predicted that a practical 30-GHz monolithic subsystem, using hybrid interconnections, could be achieved in the laboratory in 1–2 years, and chips could be ready for production in 3–5 years. It was clear, how-

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ever, that the panel considered monolithic subsystems to be quite some distance in the future.

Devices described by the panelists for millimeter-wave subsystems varied according to the applications. However, the beam-lead device is the favorite for mixers, upconverters, switches, and detectors. This device is compatible with slotline, finline, and most IC construction. IMPATT diodes are used for transmitters, and Gunn diodes for most local oscillator applications. FET's are a favorite for low-noise amplifiers; Konishi showed one application where a GaAs FET is used with a dielectric resonator for a local oscillator (see Fig. 1 of Konishi's paper). All panelists generally agreed that circulators and isolators continue to be a mainstay for subsystem integration and optimization.

Subsystem applications presented varied considerably as can be seen by the summary presented below.

Speaker	Application
Carbonne (Thomson-CSF)	• *W*-band FM–CW transceiver with leveling loop • *W*-band four-channel monopulse receiver (*W*-band is 75–110 GHz)
Fong (TRW)	• 60-GHz modulator/exciter • 94-GHz FM–CW transceiver
Konishi (Uniden Satellite Technology)	• Communications/broadcasting (22–50 GHz) • 60-GHz automobile control system • Automobile collision avoidance (50 GHz) • MMW radio telescope (22 and 115 GHz)
Kuno (Hughes Aircraft)	• *Ka*-band integrated front end • Monolithic LNA chip
Meinel (AEG-Telefunken)	• 61-GHz Doppler-sensor for piston location • 94-GHz dual polarization front end • 66-GHz front end for helicopter obstacle warning radar
Williams (Marconi Electronic Devices)	• Balanced mixer-IF subsystem with BITE (50–75 GHz) • SSB down and up-converters (50–75 GHz) and 75–110 GHz) • FM–CW receiver (94 GHz)

End users for the subsystems included munitions guidance systems, secure communications, satellite communications, helicopter obstacle warning, and a number of unique applications such as oil pollution detection, automobile collision avoidance, and a piston location system for engine test. The end use for each application was not discussed in detail by the panelists. However, some fabrication and packaging requirements appeared to be common to all subsystems. The needs to protect the subsystem from hostile environments and to test the subsystem were discussed by several of the panelists. Williams stressed the need for built-in test equipment (BITE). All panelists mentioned at some time during their presentations that the size and weight advantages of millimeter-wave subsystems were contributing factors to the application. The panelists stressed that integration and packaging, particularly for space-limited applications such as munitions, are a major part of subsystem development, and will continue to be a factor in high subsystem costs using current techniques.

Throughout the presentations, the moderator, Terry Oxley, allowed several questions after each presentation. For the most part, these questions brought out additional technical details about the subsystems. During the question and answer period, however, questions from the audience were concentrated on costs, and generally centered around cost reduction that could be achieved through introduction of monolithic circuits. Fong responded that the 94-GHz FM/CM transceiver that he discussed earlier could be produced for about $80K now, but could be as low as $2K per unit using monolithic circuits. He stated that sufficient volume must be produced to achieve these costs, and at this time the market is not there. Konishi predicted that the 50-GHz automobile collision radar he presented earlier could eventually be manufactured for $100 per unit. Jim Wiltse (from the audience) noted that TRW currently sells a 24-GHz radar sensor for about $200. At this point, Kuno stated that testing and performance specifications are a key factor in price and producibility. Many of the applications he is currently evaluating have testing costs that will dominate the unit costs. Kuno was then questioned more about the monolithic circuits he had presented earlier, and he predicted that monolithic chips could be in production in 3–5 years. He cautioned, however, that integration will have to be done using hybrid techniques. He also predicted that 100-mW monolithic chip transmitters will be available in about 2 years (although it was not specifically stated during the discussions, most of us assumed that the frequency would be around 30 GHz).

One final topic was brought up by Kuno. Is there any prospect of a monolithic circulator in the future? Are the present ferrite materials adequate? This question was left unanswered for the most part, although it was generally agreed that current circulator designs meet subsystem requirements.

III. Conclusions

When Terry Oxley adjourned the panel at 10:00 PM, there was only a brief lull in activity before the panelists were engaged in private discussions. In retrospect, the purpose of the panel was to highlight millimeter-wave subsystems and present the current state of art with applications. We were hoping to project what the state of the art will be in the next 5–10 years. To these ends, the panel discussion was successful. The hybrid construction techniques employed currently offer viable applications ranging from military applications in munitions to a varied number of industrial and civilian applications that include helicopter radar, automobile collision avoidance, and radio astronomy. The potentially large market for volume production (50 000 to 100 000 units) and low-cost production appear to be as elusive as ever. Millimeter-wave monolithic integrated circuits are certainly making great progress, but the impact they will have on millimeter-wave subsystems is still unknown. The millimeter-wave technology that we have followed for many years now appears to be emerging and is being applied. This is the ultimate measure of success in the microwave business. The question of success in the high-volume, low-cost business was not answered during the panel discussion, and it still remains for future applications. Maybe our next millimeter-wave subsystems panel, to be held in 1990 (?), will provide us with the answer.

Acknowledgment

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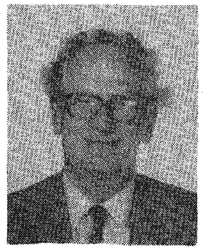

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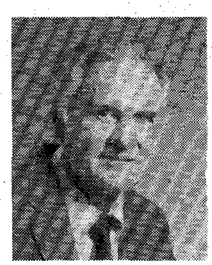
Mr. Oxley has published many papers and is currently involved in technical committees of the IEEE Microwave Theory and Techniques Society (MTT-S) and the Institution of Electronic Engineers (IEE). He received the Queen's Silver Jubilee Medal in 1978 for his outstanding contributions in the field of microwave components.



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