Space For Microwaves

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THE FORTY-EIGHT technical papers of the 1965 MTT Symposium provide a great fund of detailed information of the state of the microwave art. In a more general sense, the content of the program also shows unmistakable trends which we must not ignore. Before devoting our attention to the specialized presentations to follow, let us pause to consider where we are headed in microwave theory and techniques. This is our eleventh symposium, and the microwave art is now about twenty-five years old. The record of those years is something to be proud of in scientific applications, in engineering, and in business enterprise—except perhaps for some recent microprofits.

I think we can all agree on this past record—it inspires confidence. But are we confident about the next ten years for MTT? Is there space for microwaves among the technologies of the future?

Space for Microwaves—that's the title of this talk—and I propose to you that there is no space for microwaves in the future, either in aerospace or in commercial components. By this, I mean no space for mirowave circuits and components as we have known them: comfortable lengths of line and guide, convenient cross sections for file or tin snips, junctions full of symmetry with reference planes attached. No space for a technology separable from the domains of solid-state circuits, physical optics, and quantum electronics. In the future, it may be difficult to single out a specifically microwave technology of major proportions. But it won't be for lack of functions to be performed in the microwave spectrum. That is the challenge facing us: much to be done, but not in the old way, and not by us alone.

In the past, there have been focal points of effort which have revolutionized key aspects of microwave technology. Ferrites had such an impact on microwave circuit elements and devices, the junction diode played a similar part in parametric amplifier and switching applications. Now, another such focal point has appeared. Namely, the extension of the video region through the development of microcircuits capable of operation throughout the microwave band.

The new microwave circuits will be identifiable by function rather than by spectral region. Computers, data processors, amplifiers, or any combination of circuit functions should ultimately be operable at gigacycle rates with microcircuits.

How about losses? Where we need high Q we can get it from solid-state resonators or from molecular resonanaces. For some purposes, controlled negative resistance may suffice; for others, the absence of appreciable spacing between circuit elements eliminates coupling losses. Microwaves and microcircuits are natural partners from a scaling point of view, except at high power. Waveguide will then be limited to high power and long distance service.

Progress in microwaves is therefore subject to two major forces. The first is the displacement of distributed constant or wave devices by solid-state microcircuits. The second is the normal maturing of the technology, which reduces opportunities for research and invention.

What then is the future for microwave theory and techniques? How can we continue to build on our past achievements? There are three choices. Stick with it, join up, or move on. By stick with it, I mean continue to advance our present technology, particularly by taking advantage of new materials such as single crystal garnets, ferroelectrics, and newly accessible phenomena, such as phonon propagation and superconductivity. Obviously, there is much to be done that is genuinely new. However, there is also a danger of merely pyramiding refinements with diminishing returns for the effort.

The second choice is to join up with the development of microcircuits and to extend their applicability to the microwave spectrum. This is a challenging field, but the problems are largely in solid-state materials and processing, rather than in microwave theory and techniques.

A third alternative is to move on to a spectral region where waves are still waves, even at microcircuit scale. It is true that Fresnel was there first, but that should not deter us. After all, we were able to build well on the foundations of Hertz and Maxwell. Lasers, birefringent modulators, and the like are closely akin to microwave masers and ferrites. Probably more of the contributors to quantum optics have microwave backgrounds than have experience in classical optics.

Given these three choices, what is the best response? We must move in the right direction, and at the right pace. There is a tendency for those deeply involved technically to be overly reluctant to move to a new area. On the other hand, it is easy for program planners and managers to set up a broad effort on meager foundations.

It is for us here to lay sound foundations, and stake out new space for research and advancement. Without detracting from the opportunities remaining in more conventional microwave techniques, I think the two new avenues for progress offer tremendous opportunity. For the joiners, there is the task of making microcircuits and microwaves compatible. Digital operation with nanosecond timing or better is a worthy goal. Application of microwave elements such as circulators or phonon delay lines directly to microcircuits is another.

To those moving on, the dominant region of the entire spectrum, visible light, is now accessible to coherent techniques. The potentials for information storage, processing, transmission, and display are enormous. The present display techniques using sequential scanning with the intermediary of electron beams and phosphors might well be replaced—replaced with optical scanning, or perhaps even a direct parallel image projection. Then there is the possibility of using optical signals directly in computers and other circuit functions.

To me, there is a striking historical precedent for the relationship between microwaves and optics. It is the audio frequency-radio frequency relationship in the twenties and thirties. Then, audio was the basic information channel, as required by the human ear. Radio frequencies were gradually extended to provide increased channel capacity and transmission range. Now, visible light is the basic information channel for the human eye. However, the information capacity of many such channels is adequately served by the frequency bands common to microwave technology. The microwave modulation of optical beams is in this sense a dual to the audio modulation of radio frequency carriers.

The case for moving on to promote the marriage of microwave techniques and coherent optics is a strong one from many points of view. It provides opportunities for science, for the development of a new technology, and also, for the kind of market microwaves have penetrated only indirectly. Almost all of early radio was based on what people could hear directly, through radio broadcast or radio telephone. Visible information is incomparably more important. The sources and modulators for optical displays and data processors of all kinds will surely involve coherent optics. The most efficient broad-band modulation techniques have yet to be developed. The developers must be those who move on to apply microwave techniques to coherent optics, and also those who join in bringing microcircuits to microwaves.

Can we do it? We already have started.

Thus the laser is still sometimes called optical maser, in deference to the general concept of stimulated emission, first conceived and demonstrated in the microwave maser. The coherent optical processing schemes using holograms to produce striking three-dimensional images were first explored for microwave radar data processing. Optical modulation schemes characteristically deal with microwaves as the modulating signal. With the right effort, the revolution in optics can be microwave engineered to a large extent.

For a keynote to this second decade of MTT, I propose a threefold way to maintain our growth in the face of declining space for microwaves.

First, continue to advance conventional microwave technology, but concentrate primarily where new materials present an opportunity.

Second, join enthusiastically with those reducing microwave circuits to microcircuits.

Third, summon our initiative and imagination for a carefully planned attempt to control one micron wavelengths with the same finesse that we now display at one centimeter.

The upcoming program confirms that this threefold way will open new space for microwave engineers and entrepreneurs. Indeed, with only a little imagination, the technical content can be grouped into the three proposed categories.