Microwave Engineering—Is It Specialization or Diversification?

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When a college graduate is considering employment in the field of microwaves, he often asks us, "Wouldn't it be a mistake to specialize so early in my career?"

Before World War I, when I was a boy, I decided to "specialize" in "wireless." I don't know why. No one conceived that wireless would blossom out into the tremendous field that today is embraced in the Institute of Radio Engineers. By the time I graduated from engineering school in 1925, radio broadcasting had already got out of hand and was being brought under control. But all frequencies above 1.5 megacycles were relegated to the amateurs because "they had no practical value."

The field of microwaves today probably occupies the attention of more engineers than did radio broadcasting in its period of most active growth. The microwave professional group has 2,000 members, which places it among the top 6 of the 24 "specialized" groups now active (the top one is that of electronic computers, with 4,000 members). The microwave group has as many members and as diversified activities as the entire IRE had 30 years ago. We have only the faintest conception of the future of microwaves.

The engineering graduate, embarking on his career, is going to do his first useful work on a specific problem. In proportion to his abilities and opportunities, he will become more productive and more versatile. His tools are his method of thinking and the principles he will come to appreciate. He will try to apply his talents where the results will be most satisfying.

He will do his best in a stimulating environment, working on a fascinating subject. Microwaves is a fascinating subject that has brought together many talented workers to form the stimulating environment. They have just enough specialization to be recognized as a fraternity with a common denominator.

The field of microwaves may be identified with either of two physical principles, both effective in about the same frequency range. One is the utilization of wave propagation through hollow waveguides. The other is the utilization of transit time in electron streams.

The present frequency range of microwaves is roughly 500 to 100,000 megacycles, which does not sound very "specialized." Waveguide sizes range from 15 inches to 0.1 inch in width. The largest are formed of sheet aluminum, the smallest are drawn of solid silver. The most concentrated activity has been in the so-called "X-band" around 10,000 megacycles. In this band, electron-tube voltages range from 300 volts for low power of .03 watt, up to 100,000 volts for pulse power of one megawatt. A few further examples will give some idea of the diversified knowledge and experience that is acquired and utilized in this field.

We borrow from the techniques of sound waves in air, and we go much deeper in refinement. In size, they are comparable with microwaves. Sound waves and microwaves are carried through pipes and are radiated from horns. They are resonated in hollow cavities. However, microwaves are propagated in the medium of free space, which is perfectly stable. Their velocity is a million times as great, so their frequencies are a million times as great.

Also we borrow from the techniques of light waves, which are much smaller waves in the same medium, free space. Optical focusing by reflectors and lenses is approximated in microwave beam antennas. The best reflector in optics is a polished silver surface; the reflection of microwaves by the same surface is even closer to perfection.

While microwaves are finding a wide variety of applications, the most spectacular are in the many kinds of radar for war and peace. The military radar was first intended to perform functions previously allocated to sound detectors and searchlights.

But microwaves in radar have succeeded where both sound and light failed, in the all-weather detection of enemy aircraft. Radar operates over ranges of hundreds of miles. It accomplishes not only detection, but instantaneous display in distance and direction, and finally automatic tracking. This last especially is needed for guiding a missile to a target. The same principles are applied to friendly craft in air navigation and blind flying for all-weather transportation. The smaller microwaves are reflected in some degree by clouds and rainfall, so they are put to work scanning the weather for miles around.

The most remarkable generator of microwaves is the magnetron developed during World War II. It is analogous to a power alternator. A typical magnetron for X-band has a "stator" or anode with 16 poles that resonate with the intervening slots. The "shaft" is a hot cathode making available many amperes of electrons. An external permanent magnet provides a stationary field parallel to the cathode. When a high-voltage pulse is applied between cathode and anode, the electrons are

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pulled into cycloidal orbits which quickly assume an orderly form like an 8-pole "rotor," turning about the shaft at a billion revolutions per second. After a thousand turns, the applied pulse is over, and the rotor collapses. This entire operation lasts only one microsecond, and may be repeated a thousand times a second. During the pulse, the power output is $\frac{1}{4}$ megawatt.

For detection of microwaves, the obsolete crystal rectifier was reborn in a stable form. The crystal diode now has become a common tool; the research in its materials and behavior led the way to the "transistor," which is one of the wonders of this generation.

An iron surface has no particular use in microwaves. But powdered iron, developed for reducing eddy-current losses at lower frequencies, finds application as a material used for absorbing microwaves. The latest form of iron, ferrites, exhibits a most remarkable property toward microwaves: when subjected to a superimposed constant magnetic field, it has a gyromagnetic behavior that causes a phase shift of waves passing through. This has enabled the design of a waveguide that passes microwaves in one direction only.

Air and other gases determine the insulation strength in microwave components. Increasing the air pressure increases the pulse power capacity. Conversely, gases at reduced pressure are used in some components to provide an automatic switch that closes at the instant when sparking or arcing is caused by the transmitter pulse.

In propagation through the air, molecular resonance causes absorption of the shorter microwaves. This same principle enables gas analysis in waveguides by observing the absorption at certain frequencies. Also it has been used in the molecular clock based on the resonance of the ammonia molecule.

The high frequencies of microwaves make available many wide-band channels, each useful for the communication of one television signal or hundreds of voice signals. Low-power focused beams of microwaves are now relaying such channels all over the United States, especially for television networks. Much progress has been made toward enclosing these microwave paths in metal pipes, protected from the weather and interfering waves.

In radio astronomy, the largest light telescope (Palomar, 200-inch) has been dwarfed by the 600-inch radio telescope at the Naval Research Laboratory, and much larger ones are under construction. In the past few years, microwave telescopes have observed large regions of space which are obscured to light waves by intervening clouds; also they have discovered "radio stars" which radiate microwaves but no visible light.

In nuclear science, microwaves perform many functions. One of the most spectacular is the motive force for the linear accelerator at Stanford University, which ejects electrons having nearly a billion electron-volts of energy.

The future of microwaves will see techniques and applications which are beyond today's imagination. Like many other branches of science and engineering, the field of microwaves offers endless opportunity.

To the college graduate, we of the microwave group offer one field of activity with a great variety of problems to be solved and a great need for imagination in perceiving and attacking the problems. If he is fascinated with the field, as we are, he is welcome to join us. He is welcome to call it specalization or diversification, whichever he prefers, and to pursue either as his objective.