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The Lenkurt DEMODULATOR

TRENDS IN MICROWAVE

Microwave radio transmission systems are becoming increasingly important because of their general utility and economy. Continual improvements in design and performance—especially solid-state advances—will greatly increase the popularity of these systems.

The demand for microwave radio service has steadily increased since its introduction to the communications industry during the 1940's. Much of the technology for microwave radio came from rapid developments in radar made during World War II. A few of the microwave devices that were applied to both radar and to radio systems include high gain reflector antennas, waveguides, klystrons, and traveling wave tubes.

Most early microwave radio systems were limited to carrying multiplexed speech signals over public common carrier or military communications networks. Long-haul, wideband systems, such as the Bell System type TD-2, transmitted network television across the nation. At intermediate points, light-route narrowband systems were used to branch off and distribute small groups of telephone channels to local switching offices. These light-route systems could not carry television which required a bandwidth of 4.2 MHz.

Rapid Growth

Since those early days, the use of microwave radio systems has spread into many areas. Railroads, pipelines, and power utilities were given the authority to operate their own microwave radio systems. In September 1960, the FCC extended this authority to private business.

The growth of microwave radio communications since then has been spectacular. The U.S. Government, independent common carriers (non-Bell System companies), and public and private industrial users of communications systems increased their expenditures for microwave and associated equipment by 150 percent between 1960 and 1966. In comparison, cable carrier systems grew only by half this amount during the same period.

The astonishing growth rate of microwave radio communications systems certainly parallels what has been called the "information revolution." In fact, the use of microwave radio has helped to overcome certain economic and technological problems involved in transmitting large amounts of information. The growing complexities of business, commerce, and military operations have had an enormous impact on the development of microwave communications systems. This impact has been felt not only in the greater number of channels needed for the "information revolution", but also in the types of information signals transmitted over electrical communications systems. Message, video (including high-resolution closed-circuit and broadcast), high fidelity music, supervisory signaling and control, telemetry, teletype, digital data and high speed facsimile are types of signals now being processed over microwave radio communications systems.

Advantage

There is at least one special feature that has made microwave radio extremely useful as a multichannel transmission system—its broad bandwidth. By comparison, open-wire carrier systems have a practical limitation of 12 to 16 voice channels, and multipair cable carrier systems have been limited to about 24 channels. There are many high quality microwave radio systems available today that are capable of handling more than 1200 voice channels or a video channel, and the Bell System TH cross-country system can handle up to 1860 voice channels.

Although coaxial cable transmission systems are also capable of handling large numbers of voice channels or TV, they are not as practical as microwave systems in many situations and locations. Also, delay distortion problems encountered in wideband coaxial systems must be overcome by equalization, and repeater spacing is in the order of 2 to 4 miles. Signals processed over microwave radio systems, on the other hand, do not experience delay distortion to the same extent, and repeater spacing—limited generally by terrain—is in the order of 20-30 miles.

Present Trend

With the rapid expansion of microwave radio into many areas of communications, there has been continual pressure to develop systems that are lower in cost, have greater capacity, are more reliable, and have higher quality.

One of the most prominent developments currently underway in microwave radio equipment is total solid-state electronics. Since 1962, most microwave manufacturers have provided communications equipment with all solid-state circuitry except the klystron tube oscillators and traveling wave tube amplifiers. Completely solid-state IF modulators and up-converter multipliers have been used to convert baseband signals to a frequency range suitable for amplification by these electron tube devices. Operating life and reliability of electron tube systems are extremely satisfactory, and the best performing systems in the 6 GHz and higher frequency bands still use klystrons and traveling wave tubes. However, rapidly evolving semiconductor technology promises new compact mechanics and the use of significantly more efficient power sources.

Total solid-state construction involves more than simply adapting semiconductor components and microwave design principles to meet existing industry standards for stability, noise performance, bandwidth and power. More important considerations are cost and reliability. Cost is very important since a microwave system must be reasonably priced to be of practical use in many applications. Reliability is also important and sometimes outweighs cost considerations.

The continual trend towards improved transmission performance has been exemplified by the expanding use of low-noise IF amplifiers and mixer diodes, as well as new designs with parametric and tunnel diode amplifiers. However, parametric and tunnel diode amplifier designs are not particularly attractive because of high cost, low signal capacity, and marginal noise figure improvement.

Another aspect is increased spectrum use through tighter frequency control. This is becoming possible with more efficient transmitter klystron temperature control and with solid-state microwave sources replacing klystrons as receiver local oscillators. Generation with crystal reference not only will increase frequency stability, but will allow the use of low voltage power supplies at the receiver.

The reason for not immediately extending this approach to solid-state transmitters is because present-day solid-state sources are generally limited in power. To maintain the same net path loss as in tube systems, expensive construction techniques, such as increased antenna size, would have to be used. Solid-state transmitter sources also contribute greater than acceptable system noise levels, particularly at frequencies of 6 GHz and higher, and are somewhat limited in modulation bandwidth. But both difficulties are rapidly being overcome.

Semiconductor device manufacturers are providing packaged multiplier chains for use as solid-state local oscillators at 2, 4, 6, and 8 GHz. But communications equipment designers generally must adhere to stringent noise requirements, and usually have to develop their own frequency sources. Ultimately, of course, suitable low-noise frequency sources will be available "off the shelf" from suppliers.

Klystrons and traveling wave tubes require stable high voltages. Solid-state devices, conversely, do not need such stable high voltages and, with proper circuit design, are not susceptible to parameter changes with variations in voltage or operating temperature. However, at higher frequencies—above 6 GHz—the efficiency of solid-state devices decreases. At powers of 1 watt or more, broad bandwidths and low noise figures are difficult to attain.

Solid-State Local Oscillator

One method of generating a frequency at 6 GHz (see Figure 1) is to

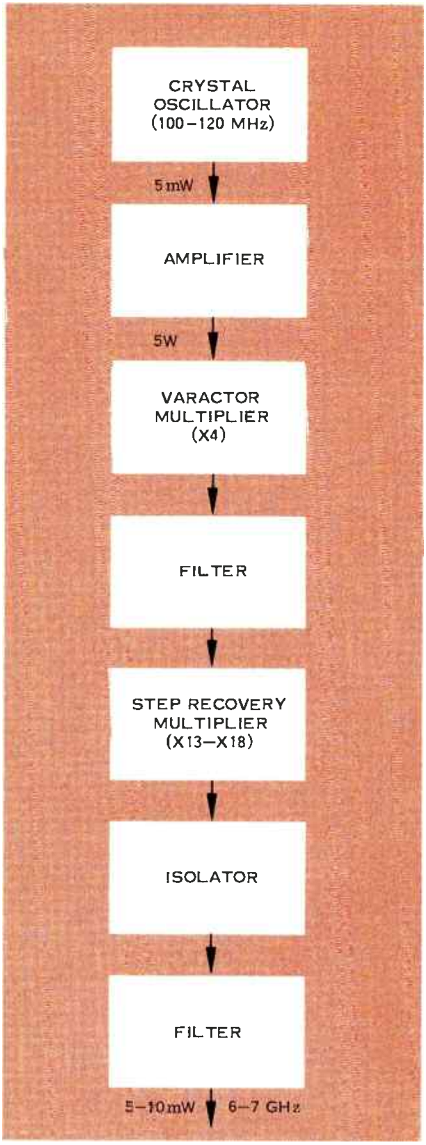

Figure 1. Typical solid-state local oscillator design uses crystal oscillator frequency reference source, varactor diode multiplier for times four multiplication and step recovery diode for times thirteen to times eighteen multiplication. Microwave frequency in the 6 to 7 GHz range, determined by the step recovery multiplication, has from 5 to 10 milliwatts output.

use a very stable crystal reference source operating at 100 MHz. A substantial amount of power can then be provided by amplification. Succeeding varactor and step recovery diode frequency multipliers convert the energy to microwave frequencies in the order of 6 GHz. But efficiency is low. Approximately 5 to 10 watts of power at 100 MHz is reduced to about 10 milliwatts at 6 GHz. Ten milliwatts is adequate power for a local oscillator signal, but much less than needed to drive a solid-state transmitter. However, at lower frequencies, for example 2 GHz, the multiplier efficiency is much higher, and transmitter power outputs of about 2 watts and broad bandwidths for 300 message channels are now available.

Receiver local oscillators, using a crystal reference source, are not generally affected by environment. However, the oscillation frequency of the klystron varies with changes in environment, power supply voltage, the stabililty of the frequency reference cavity, and the AFC loop. The oscillation frequency of a common type of reflex klystron is guaranteed by the manufacturer to have a temperature coefficient of less than 100 kHz per degree change in Centigrade. A temperature change of 10°C could change the klystron frequency as much as 1 MHz.

This is not too important, however, since the conventional klystron local oscillator is normally operated with an AFC loop which makes it not only immune to temperature and power supply variations, but also causes it to track accurately the frequency variations of the transmitter. The microwave discriminator reference cavity has a negligible variation with temperature, and by feeding an error voltage to the power supply, changes are made in repeller voltage to bring the klystron back on frequency. Typically, the repeller modulation coefficient is 500 kHz per volt. Thus, a 12-volt change in repeller voltage will compensate for a shift of about 6 MHz at −30°C. The effects of temperature variations, therefore, can be reduced substantially.

The introduction of a solid-state receiver local oscillator having a fixed and highly stable frequency—without automatic frequency control—requires a corresponding improvement of the transmitter frequency stability. Variations in temperature affect both the power output versus frequency characteristic and the linearity of the frequency modulation characteristic of a transmitter klystron. The klystron must be modulated linearly, and this is especially important with wide baseband signals. Some means must be used to keep the modulation linearity characteristic constant even during ambient temperature changes.

Temperature Control

Conduction heat sinking continues to be highly successful in all microwave systems using klystrons. This method uses a finned aluminum radiator attached to the klystron to dissipate heat —it is economical and requires no maintenance.

Another method of controlling the temperature of a transmitter klystron is called heat value control. Though mechanically more complicated than heat sink dissipators, heat value control devices maintain more stable temperatures and thereby decrease the amount of shift of the modulation linearity curve of a klystron.

Heat value control, also referred to as vapor phase cooling, uses the boiling or vapor point of a liquid to maintain a constant temperature—usually higher than the temperature that would be reached by the surrounding atmosphere. Thus, the name "cooling" could be considered a misnomer when comparing this method with conduction heat sinking.

One technique of heat value control (Figure 2) is to pass water through the bottom of a circular waveguide flange which has an enclosed annular passage surrounding its rectangular opening. The waveguide flange is attached to the output flange of the klystron. At the bottom of the flange water is vaporized and rises through the flange to the top opening where it is passed to a finned radiator heat exchanger. The vapor is cooled to liquid in the radiator and returned to a reservoir for reuse. This process continues indefinitely at atmospheric pressure without any mechanical pumps. Inert chemicals may be used for the "coolant", but distilled water is readily available, more convenient to use, and has a much higher latent heat of vaporization.

The temperature coefficient of a klystron using this device is reduced to about 8 kHz/°C, maintaining modulation linearity for a baseband wide enough for up to 1200 channels.

Benefits

One of the major advantages of completely solid-state transmitter and receiver equipment will be the elimination of high voltage power supplies. Thus, repeaters located at isolated sites can be operated from a 24-volt battery, eliminating the need for engine-driven emergency power genera-

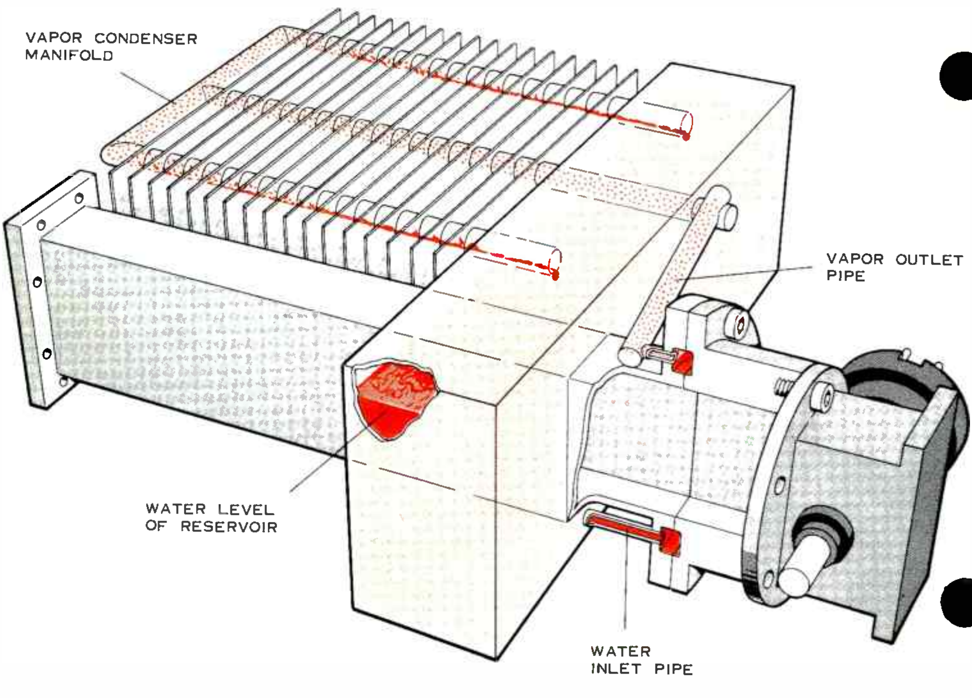

Figure 2. Typical cooling device maintains constant klystron temperature. Water vapor rises through outlet pipe to condenser manifold where it returns to liquid state and drops into water reservoir.

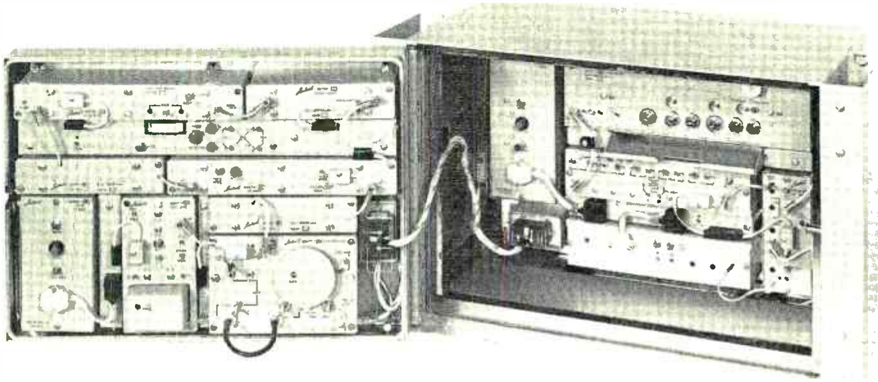

Figure 3. Construction of the Lenkurt 71F 2-GHz Microwave Radio typifies the advanced modular design and high density packaging afforded by total *solid-state construction.*

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tors. Also, the low power requirements of solid-state repeaters will permit the use of previously unsuitable power sources, such as solar cells and thermoelectric generators. These devices require very little attention and generally provide uniform efficiencies over a wide range of power outputs at extremely low operating costs.

The development of suitable solid-state devices will greatly influence the mechanical and maintenance features of modern microwave radio equipment. This will be especially noticeable in high density packaging and modular construction techniques. These techniques will allow equipment to be put together in "building block" fashion so that systems can be specially arranged to better fit the needs of each application. These separate modules will usually be placed on shelves mounted in equipment racks, allowing the modules to be removed and replaced very quickly and easily for maintenance purposes.

For the present time and possibly for a long time to come, klystrons will be used predominately in baseband transmitters. It is expected that improvements in power with tube devices will generally provide lower noise and increased baseband capacity, therefore contributing to the overall efficiency of microwave transmission systems. Heterodyne repeater microwave systems also will probably continue to use traveling wave tubes, with solid-state sources for the transmitter up-converter and receiver local oscillator.

Later developments in microwave will certainly continue to decrease the size of the equipment while providing more efficient performance and greater reliability. In the future, miniaturized microwave radios will probably be mounted directly on top of antenna towers, thus avoiding the cost and technical problems of long waveguide runs.

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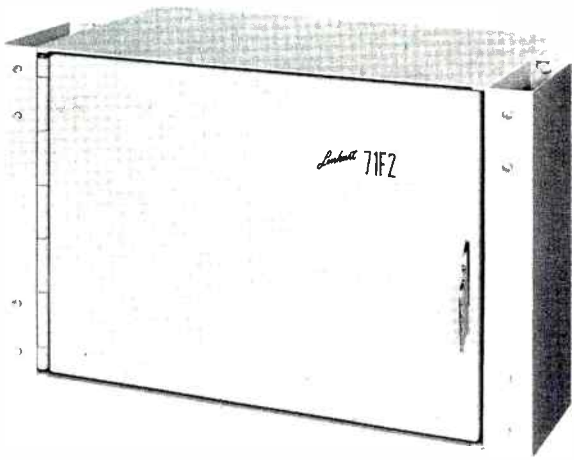

Lenkurt's 71F2 is a 300-channel light-route microwave system ideally suited for industrial, common carrier, and government applications in the 1700 to 2300 MHz frequency range. Compact design and superior performance are achieved using all solid-state construction with 2 watts power output. For information, write Lenkurt, Dept. B720.

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