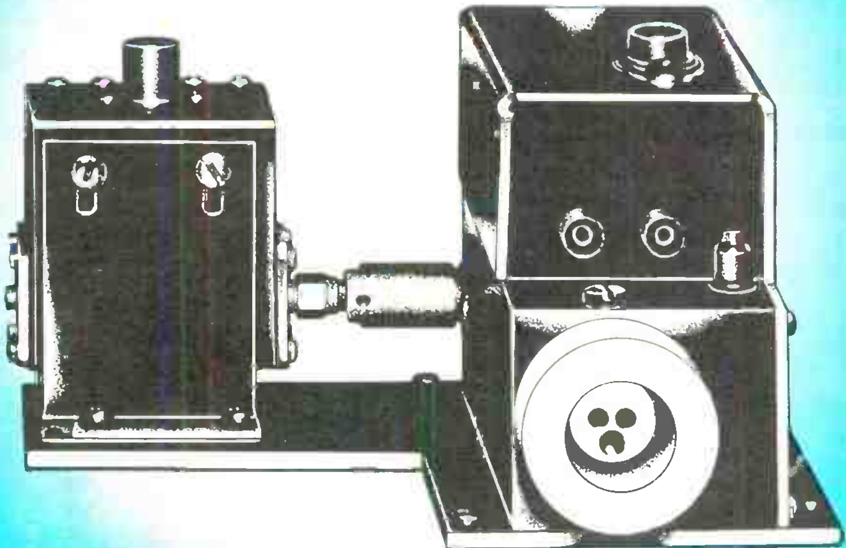
GTE LENKURT

DEMODULATOR

JANUARY 1973



innovations in microwave transmission

Recent developments in solid state devices and transmission control have had a profound effect on microwave radio equipment, with especially pronounced results in baseband radio.

In the telecommunications industry, microwave radio systems are used to transmit wideband, baseband signals. Such baseband signals, which may consist of multichannel telephony, video, or wideband data, are transmitted between microwave terminals. Where the distance between terminals is such that line-of-sight transmission is not feasible, microwave repeaters are used at intermediate points between the terminals.

Generally, the types of radio equipment used both at microwave terminals and microwave repeaters can be divided into two categories – baseband (directly modulated) and IF (intermediate frequency) heterodyne. Each provides a different way of modulating the microwave carrier to convey information from one location to another, and each is designed for a specific type of application. IF heterodyne systems are usually used in long-haul networks where the information conveyed does not need to be dropped off at repeater points along the way. Baseband systems are generally utilized in short- and medium-haul applications, where access to the baseband is necessary along the microwave route. In the past, however, an IF system has sometimes been chosen – because of its better noise performance – to do a job which might otherwise be accomplished by a less expensive baseband system. Today, with modern technological improvements, baseband systems have been enhanced in performance to closely approximate IF heterodyne performance, in short- and medium-haul routes.

In IF as well as baseband systems, the receiving equipment performs essentially the same function; the great difference between the two systems is manifested in the nature of the transmitting equipment. And, it is in the baseband transmission equipment that significant changes have occurred. One major change has come as a result of the incorporation of solid state microwave sources into baseband radio equipment; but other changes, such as improvements in transmission control,

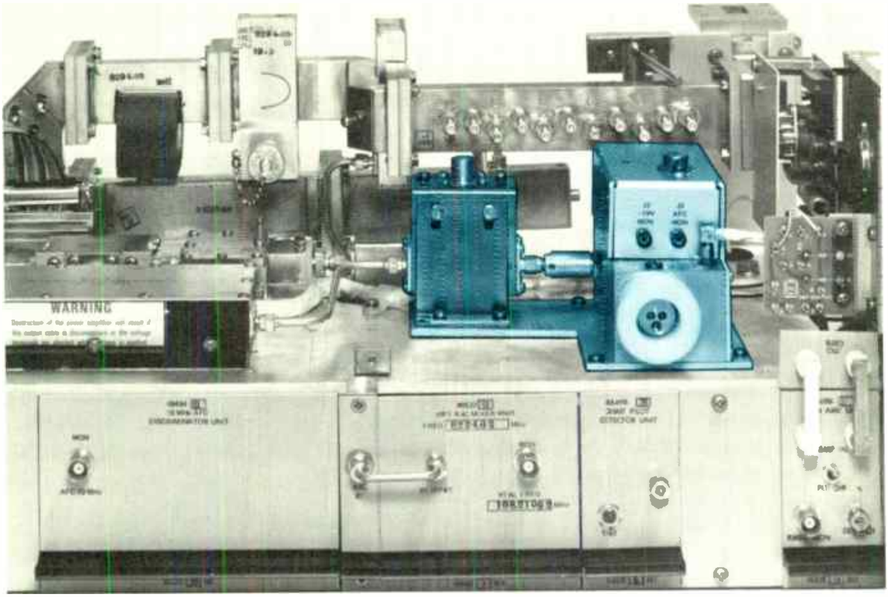


Figure 1. The replacement of the klystron with a solid state microwave source is one of the major changes in GTE Lenkurt microwave radios.

delay networks, and linearity, and the use of more stable components throughout, have been instrumental in improving the performance and reliability of baseband equipment. The advances in solid state technology have been beneficially applied to both baseband and IF systems, but the most dramatic changes have occurred in baseband radio, where there was the greatest margin for improvement.

Microwave Sources

The microwave source is the device which determines the frequency of transmission and reception. (See Figure 1.) In baseband transmitters, where it is directly modulated by the baseband signals it is known as the FMO (frequency modulated oscillator). In heterodyne transmitters, where the microwave source output is mixed (heterodyned) with the baseband modulated output of the MODEM (modulator-demodulator), it is generally known as the *up converter*.

In all commonly used microwave receivers (for either IF or baseband systems), the microwave-source output is mixed with the received microwave signals to produce an intermediate frequency. Here the microwave source is also known as the *down converter, or local oscillator*. In this case it determines the frequency of reception by having the IF frequency (usually 70 MHz) either added to, or subtracted from its own frequency. Previous to the introduction of solid state microwave sources, the klystron tube, which required extremely high voltage power supplies, was used as the frequency generator for both baseband and IF heterodyne systems.

Historically, baseband microwave transmitters were developed to take advantage of the reflex klystron (developed for use in radar equipment during World War II), the characteristics of which made it ideally suitable for direct modulation, since the modulating signal (baseband) could be directly applied to the klystron reflector. This process produced a relatively uncomplicated transmitter in that the klystron, with its frequency-controlling cavity, was, in fact, the entire transmitter. The disadvantages of this arrangement were primarily the problems of frequency stability, the necessity of providing the stable, high-voltage power supplies required to operate the klystron, and the problems associated with producing modulating amplifiers with a high degree of linearity while, at the same time, delivering a relatively high modulating voltage output.

The frequency stability problem was, to a degree, solved by using stable reference cavities with automatic frequency control (AFC) to the klystron. Later, the inherent stability of the klystron itself was further improved by stabilizing the temperature of its frequency-controlling cavity, the physical dimensions of which determined the operating frequency. Still, the linearity requirements for the modulating amplifiers, and the high voltage power-supply requirements remained a source of concern to telecommunications equipment manufacturers.

Further Advances

The next step in the development of microwave transmitters resulted from the development of efficient solid state, frequency-multiplying devices. With the advent of these, it became possible to have the baseband signals phase modulate, amplify, and multiply the output from stable, crystal-controlled oscillators operating in the 100-MHz region. The problems associated with this arrangement were those of (a) producing a relatively high-power output at the crystal-controlled frequency to offset the power loss associated with each frequency multiplication and (b) noise introduced into the modulated RF output by the many multiplication stages. The high-voltage power supply, the high-voltage swing of the modulating amplifier, and the frequency stability problems associated with the klystron transmitter were, however, largely solved. The noise performance of the transmitters remained essentially unchanged.

The more recent development of the AFC controlled, solid state microwave source has dramatically reduced the number of frequency multiplying stages required (from about 60:1 to 4:1 in the 6- to 8-GHz bands), thus

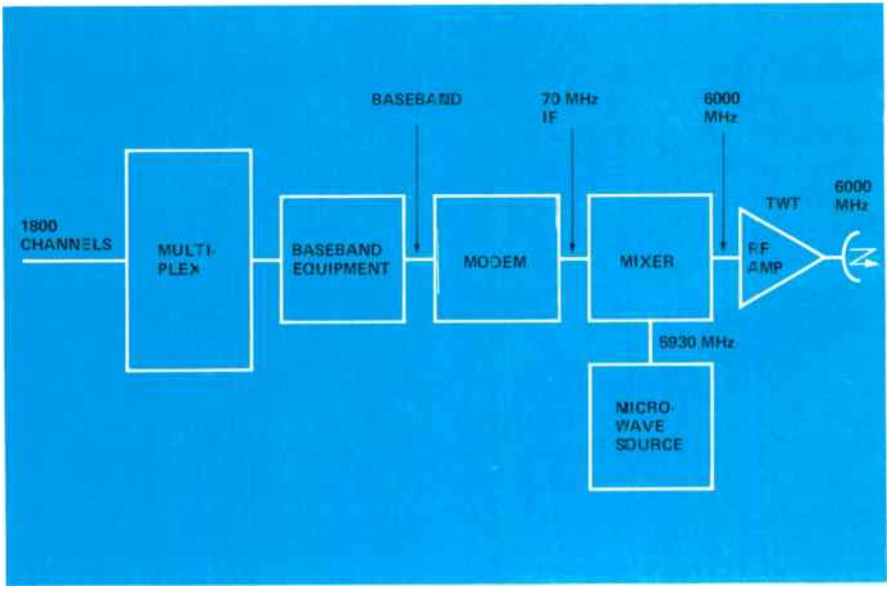


Figure 2. The transmit section of an IF heterodyne microwave radio terminal connected to telephone multiplex equipment.

reducing the total noise from these devices.

Amplification at Repeater Stations

One of the major problems in microwave transmission is that of amplification at microwave frequencies. The simplest non-remodulating repeater is the RF type in which the incoming modulated RF signal is only amplified and translated to the outgoing radio frequency. The difficulties associated with the stable amplification of microwave frequencies with existing devices, have, however, so far prevented extensive use of RF repeaters.

To better appreciate the problem of microwave amplification, it should be recalled that a typical receive-signal level on a microwave system is of the order of −30 dBm, and a transmitter output is typically around +30 dBm. Working systems must also take the effects of fading of the receive signal into consideration. Typically, fades of 40 dB may be expected so that received signals as low as −70 dBm must be considered.

The difference between these two power levels (−70 dBm and +30 dBm) represents the gain necessary at a repeater. This is 100 dB, or a power amplification of 10,000,000,000. While stable solid state devices needing these high gain requirements are readily available for amplifying frequencies of the order of 70 MHz, they are not yet generally available for microwave frequencies. So, it becomes necessary to reduce the microwave signal frequency (from 6 GHz, for example) to around 70 MHz (the intermediate frequency), by mixing it with the output from a microwave source. At 70 MHz, the required amplification can be achieved with readily available and well proven devices which operate from low-voltage dc supplies. The output from this IF amplifier carries all the baseband information from the received microwave signal at a greatly increased power level but at a much lower frequency. It is still, however, a frequency modulated signal and it is the manner in which this signal is treated before onward transmission where the basic difference between IF and baseband repeaters lies. In the heterodyne repeater, the IF signal is mixed with the output from a second microwave source, and the resulting RF signal is usually amplified and fed to the transmitting antenna. In a baseband repeater, the modulated IF signal is demodulated and used to remodulate the microwave source (FMO) of a baseband transmitter.

IF Systems

Baseband and IF heterodyne microwave radio systems differ in the way they process the baseband; baseband meaning the entire volume of information to be transmitted by the microwave system. This might, for example, be 1800 voice channels coming from the multiplex equipment of a telephone company. Microwave terminals provide the facilities for modulating and demodulating the RF carrier to permit the insertion and retrieval of the baseband signals.

At an IF transmitter terminal (shown in Figure 2), the baseband coming from the multiplex equipment is first adjusted to the correct signal level by the baseband equipment. It then modulates (deviates) a 70-MHz oscillator contained in the modulator section of the modem to produce the frequency-modulated IF signal. The modulated intermediate frequency is then heterodyned (mixed) with the output from a fixed-frequency, solid state microwave source. The desired product of the mixing process (either the sum or difference of the 70 MHz and the microwave source frequency) is filtered out and usually amplified by a TWT (traveling wave tube) before being applied to the transmit-antenna system. The function of the microwave source in this process was once performed by a klystron tube.

At through IF repeaters (see Figure 3), the received RF signal coming from the terminal, is heterodyned with a microwave source and filtered to produce the IF frequency, which is amplified, heterodyned with a microwave source, and filtered to produce an output at the repeater transmit frequency. This is usually amplified again before being fed to the forward direction antenna. The 100-MHz difference between the input to the repeater and the output, is typical of the frequency necessary to avoid interference between the two. This also applies to baseband repeaters. From this description, it can be seen that microwave sources play a major role in microwave transmission systems. The important

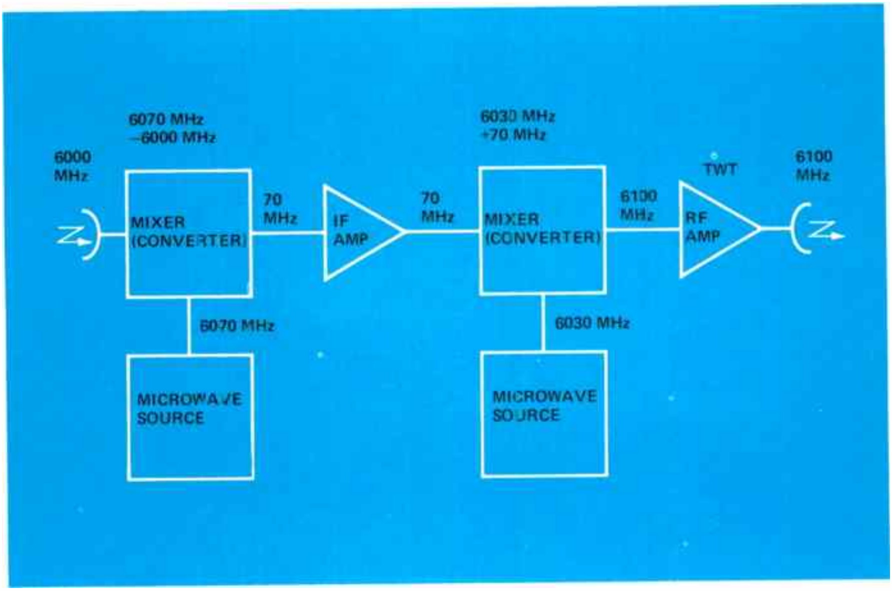


Figure 3. An IF repeater does not require extraction of the baseband from the RF carrier during amplification.

thing to remember about IF systems is that their great effectiveness lies in that, ideally, the RF carrier is not demodulated down to baseband at any point along the route. If it becomes necessary to access the baseband at any repeater, noise caused by the demodulation-remodulation process is introduced, and the system begins to lose its effectiveness.

Baseband Systems

The "baseband" microwave system is so termed because at each repeater stage, the incoming modulated carrier wave is demodulated down to the baseband frequency.

In a baseband terminal, such as GTE Lenkurt's 78A2 (see Figure 4), a single solid state microwave frequency source is used. At this terminal, the baseband signal from the multiplex equipment is first adjusted to the correct level and then fed directly to the FMO (a frequency-modulated microwave source). In a 6-GHz system, for example, the modulated signal usually emerges from the FMO in the region of 1500 MHz, which is then amplified and fed into two multiplier stages. The first stage doubles the frequency and emits a 3000-MHz signal into the second multiplier. The second multiplier again doubles the frequency and sends a 6000-MHz (6-GHz) signal to the antenna. Each time the frequency is multiplied, power is lost. Also, each time a modulated

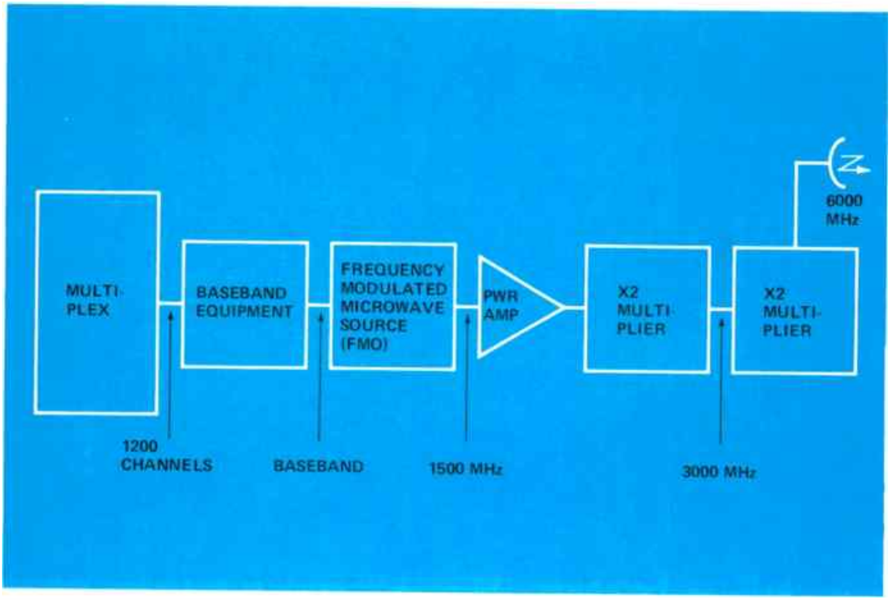


Figure 4. The transmit section of a baseband microwave radio terminal working with telephone multiplex equipment.

signal is multiplied, noise is introduced into the baseband. This is random noise which is inherent in the baseband and which is emphasized during the multiplication process – it is not caused by the multiplier itself.

The great advantage of modern microwave sources and their effect on baseband systems is evidenced in the dramatically few multiplication steps necessary to attain the transmit frequency – two doublers in the case of a 6-GHz system. A previously used microwave source might be capable of modulating at only 150 MHz, instead of the 1500 MHz made possible by solid state sources. *This would mean a 40:1 multiplication ratio would be required compared to the 4:1 ratio for modern microwave sources.* The use of a solid state microwave source results in greater bandwidth, lower noise, better stability, and lower cost.

The Baseband Repeater

Baseband (or remodulating) repeaters are essentially terminal receivers and terminal transmitters connected back-to-back. The function of the baseband repeater is to amplify the incoming signal and relay it to the next repeater or terminal. If, for example, the signal received is 6000 MHz as shown in Figure 5 (6000 MHz referring to the center frequency), it is mixed with a constant 6070-MHz frequency from the microwave source. The difference between these two fre-

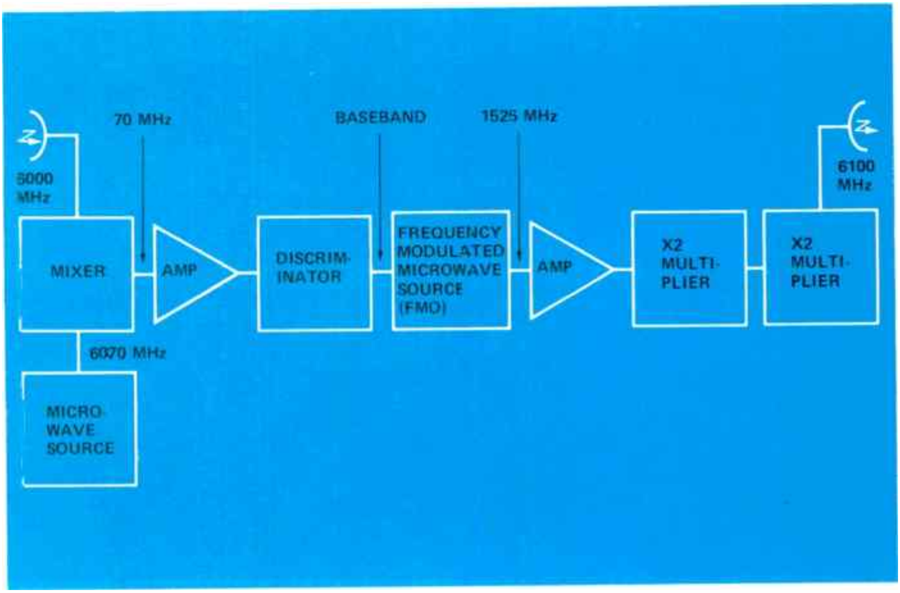


Figure 5. In a baseband repeater, the baseband must be extracted from the RF carrier during the amplification process.

quencies (70 MHz) is then amplified and sent to the discriminator, where the signal is demodulated down to baseband. The baseband now remodulates an FMO, and the output is amplified, and multiplied to the desired 6100 MHz.

The great advantage of a baseband system is that full access to the baseband is available at each repeater point. This availability facilitates the inserting and dropping of baseband information. Furthermore, combining and switching from a working to standby system on a per hop basis is facilitated – affording additional reliability of operation. This, coupled with the high performance of modern baseband systems, provides an ideal arrangement for telephone communications or video networks, for example, which require access to baseband at intermediate repeaters along the route. The improvement in baseband systems can be seen in Figure 6, which shows the typical overall noise performance for a six-hop system (2 terminals and 5 repeaters) of GTE Lenkurt type 78A2 baseband radio. This system is loaded with 1200 channels of SSBSC (single-sideband suppressed carrier) multiplex with a nominal deviation of 141 kHz (rms) per channel, and with –30-dBm RF input to each receiver.

Also, order wire and alarm facilities, for maintenance and trouble locating are almost mandatory at re-

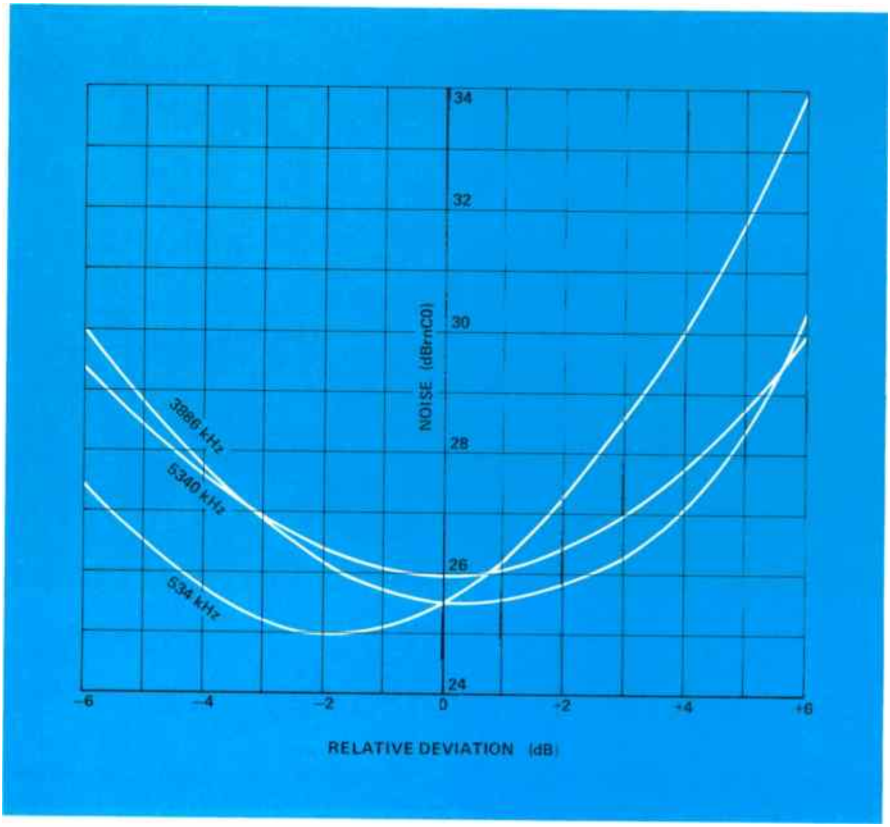


Figure 6. Typical overall noise performance for a GTE Lenkurt type 78A2, 1200-channel baseband radio, in a 6-hop system.

peater stations, and baseband access is required to provide these facilities. This problem is automatically solved with baseband systems.

Receiver Terminals

The process involved in the microwave receiver terminals for either baseband or IF heterodyne operation is the same. The modulated microwave signal from the antenna system, is mixed with a signal from a microwave signal source to produce a "difference" signal at an IF frequency (commonly 70 MHz), as shown in Figure 7. The 70-MHz signal is then amplified and demodulated (by a discriminator) to extract the baseband signal. The baseband equipment adjusts the baseband level and feeds the baseband into the multiplex equipment. The multiplex equipment separates the voice channels contained in the baseband and makes them available for distribution.

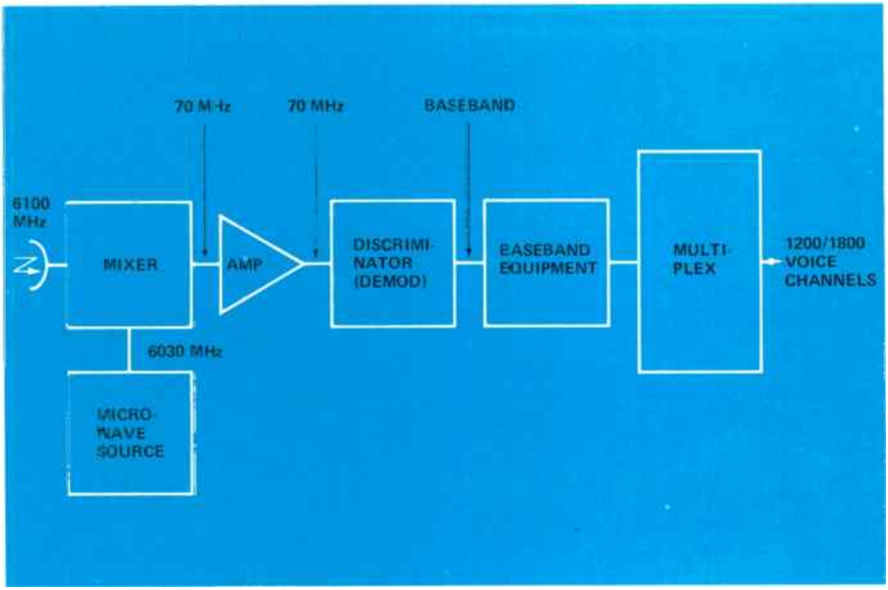


Figure 7. The receiver-terminal function is the same for both baseband and IF heterodyne microwave systems.

It should be remembered that for telephone conversation in the opposite direction, another complement of microwave radio equipment, usually operating through the same antenna system, is necessary.

Baseband microwave systems have undergone many changes since their inception. But the most recent – those connected with new microwave sources and transmission control techniques – have had the most significant impact. This reflects not only a savings to user and customer alike, but also shows continual technological progress in the telecommunications field.

GTE LENKURT
1105 COUNTY ROAD
SAN CARLOS, CALIFORNIA 94070

ADDRESS CORRECTION REQUESTED

Bulk Rat
U. S. Post
PAID
San Carlos
Permit No

The GTE Lenkurt Demodulator is circulated monthly to selected technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions. Permission to reprint granted on request.