The Lenkurt Demodulator

NEWS FROM LENKURT ELECTRIC

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MOBILE TELEPHONY

People now find a ready use for extension telephones throughout their homes and pay stations are available all along our highways. Still, in spite of the ever-increasing amount of time that we spend in our automobiles, very few of us can be reached by telephone there. The telephone industry in the United States has provided a certain amount of mobile telephone service, but only on a limited scale. Recent developments in mobile telephone equipment now make it possible for even the smaller telephone companies to offer mobile telephone service.

A mobile telephone system permits extension of subscriber loop circuits to stations which are not fixed in location. In order to accomplish this, two-way radio is an essential part of the system. However, in addition to straight two-way radio, control facilities are necessary to integrate the mobile system into the central office. For most effective usage, the control facility should make the mobile service comparable with that used for fixed telephone stations; and this service should include such features as: (1) selective signaling, and (2) the control and supervision expected at a switchboard position.

In this article, the fundamentals of mobile telephony are reviewed, and some of the major parts of mobile systems are described.

Mobile communications systems may be used for a number of different types of service. In the most common of these, two-way radio provides the communication path between a moving (mobile) unit and a fixed base station. Familiar examples of these *mobile radio* systems are police radio and taxicab dispatching services. Where the message is for only one unit, some form of identification is stated by the operator at the fixed station. In replying, the mobile unit will be identified by its own spoken code.

For normal personal use, the communication facilities offered by straight two-way radio facilities are too restricted. These restrictions can be overcome by arranging the mobile service

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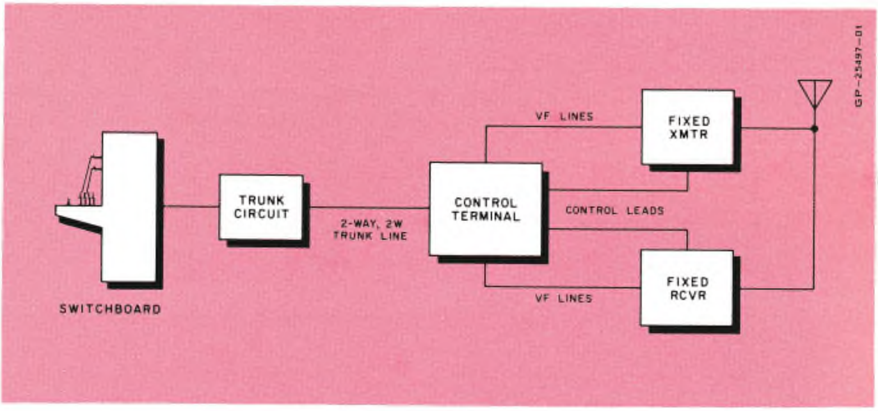


Fig. 1. Block diagram of the base station equipment showing interconnection to central-office switchboard.

to work with and take advantage of the established telephone network. When this is done, *mobile telephony* provides an entirely different and more universal type of service than that used for straight two-way radio systems.

The two basic objectives of a mobile telephone system are: (1) that a mobile subscriber may place and receive a telephone call in much the same manner as a fixed station subscriber; and (2) that mobile telephone calls are handled in the central office in much the same manner as regular fixed station calls.

To accomplish these objectives, refinements of the basic mobile communications equipment are necessary. These refinements consist principally of coordination and control measures. Coordination is required in the overall transmission aspects as well as in detailed level coordination and impedance matching. Control, in the form of signaling and supervisory equipment, is necessary so that mobile telephone service may be readily integrated into the telephone plant.

The manner in which the necessary functions of a mobile telephone system are obtained is best illustrated by an analysis of the operation of the various components that make up a system. A block diagram of the base station terminal equipment for a Lenkurt Type 901A Mobiltel-Manual system is shown in Figure 1. The two-wire, two-way trunk line, trunk circuit and switchboard are also shown.

In addition to a talking path, the trunk line provides the path for the signaling and supervisory functions. For a manual system, these functions appear at the operator's position, and are under control of the operator. The trunk circuit is typical of those found at switchboard positions and is not a part of the mobile system.

Control Terminal

The control terminal shown in block schematic form in Figure 2 is the heart of the mobile telephone system. It includes the two-to-four wire conversion equipment, and the signaling oscillator, signaling supervisory and control relays.

Voice communications from the switchboard reach the radio transmitter through the level-coordinating pads and amplifiers in the transmitting branch of the control terminal. The tone signaling used to selectively call the mobile units is derived in the control terminal from dial pulses originated at the switchboard.

Voice communications from the mobile unit come through the receiving branch of the control terminal to the combining network, where it is split into two parts. Half the received energy goes into the transmitting branch for rebroadcast, with the other half going to the switchboard. The control and keying relay circuits accomplish transmitter control plus incoming supervision.

Figure 3 is a photograph of a control terminal assembly. This assembly shows all of the equipment panels that may be included in a Lenkurt Mobiltel control terminal.

Mobile Equipment

The equipment necessary at the mobile station is shown in block diagram form in Figure 4. This equipment consists essentially of the antenna, radio transmitter and receiver, signaling selector equipment and the dash unit. In the design of the mobile equipment, both power consumption and physical size are prime considerations, and both are kept to a minimum consistent with good engineering practice.

Operation of the mobile station in a manual system is similar to that for a fixed subscriber's station with manual

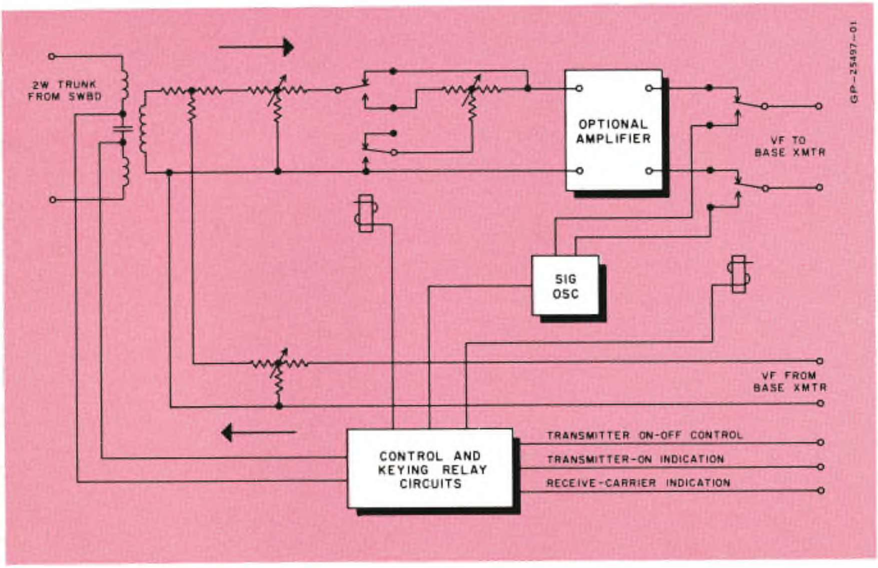


Fig. 2. Simplified schematic diagram of a manual mobile telephone control terminal.

service; and, except for the push-to-talk feature, it is used in much the same way. Push-to-talk is used because the desired isolation between transmitting and receiving circuits can be most effectively achieved in this manner.

Fixed Station to Mobile Station Call

In a manual system, a mobile service operator is required. When someone at a fixed telephone station wants to call a mobile unit, the calling party asks for the mobile service operator and gives her the telephone number of the desired mobile unit.

If the mobile circuit is not busy, the mobile service operator initiates the call by patching to the trunk circuit jack. By this operation, a busy indication is obtained, and the control terminal turns on the transmitter and applies signaling tones. When the transmitter is on the air, the operator is notified visually by means of an ON-AIR lamp located at the switchboard.

The dial pulses, which are transmitted as frequency-shift signals over the radio, actuate the selectors of all mobile units within range. Because of selector coding, only the unit having the proper selector code will operate. In this mobile unit a call bell is sounded for a period of four seconds by a tone from the control terminal and simultaneously a call lamp lights. Following this signaling interval, a short

90101A Control Terminal Panel
The basic signaling and control features necessary to integrate a mobile telephone system into the telephone plant are included in this panel. For the simplest system applications, this panel is the only one required.

90113A Automatic Gain Adjusting Amplifier Panel
This optional amplifier compensates for variations in level which may occur as a result of variations in line length and talker-volumes.

90111A Monitor Speaker and Amplifier Panel
This panel permits loudspeaker monitoring of both directions of transmission for maintenance and supervisory purposes.

90104A Trunk Circuit Panel
This panel allows simplexing of the control and supervisory functions on a four-wire basis and is used when the control terminal is located separately from the radio equipment.

90107A Satellite Receiver Applique Panel
This panel permits satellite receivers to be added to the base station for extension of the nominal coverage area. During operation, only the receiver obtaining the best signal is automatically selected for use, and the remaining of up to four receivers is disabled to avoid interference.

90102A Power Supply Panel
The control terminal operates from an office battery voltage of −48 volts. This power supply is used in locations where the required voltage is not available.

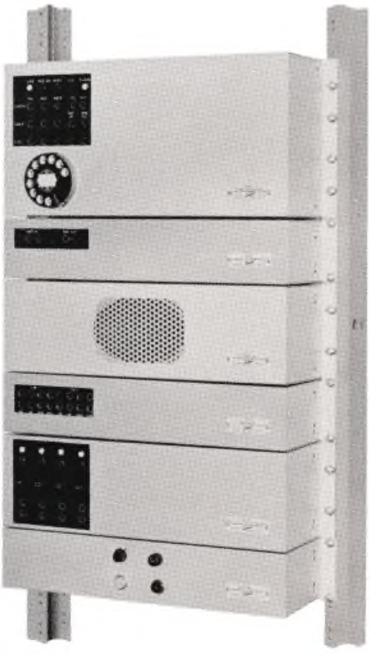


Fig. 3. The above is a photograph of a complete L2 Control Terminal used in the Lenkurt Mobiltel-Manual system.

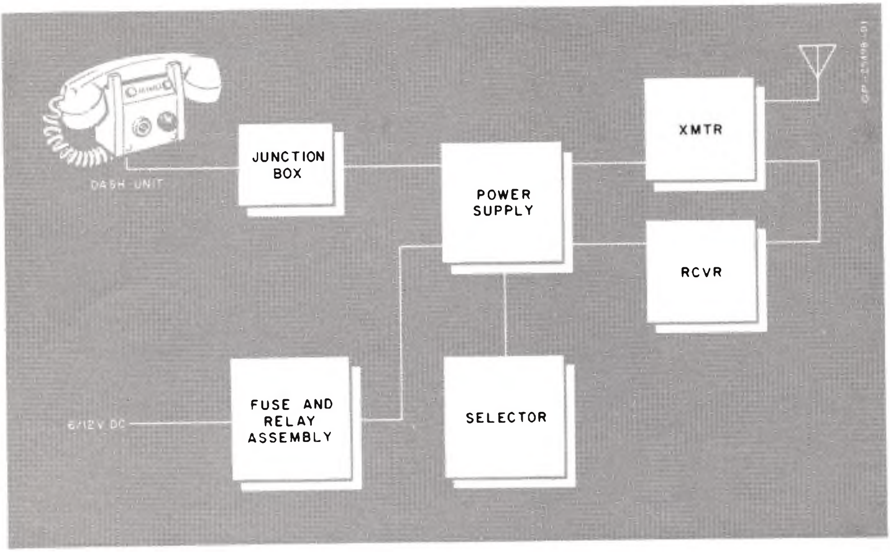


Fig. 4. Block diagram of a typical mobile subscriber station.

pulse is transmitted which returns all selectors to normal, preparing them for the next call.

If the mobile subscriber is out away from his vehicle, he will not answer the call immediately. However, the CALL lamp will remain lighted until the subscriber lifts his handset from its cradle. This feature allows him to recall the operator and complete the call later. Also, the mobile equipment may be arranged so that the automobile horn is sounded for 4 seconds when a call is received.

Mobile Station to Land Station Call

When the mobile subscriber wishes to place a call, he lifts his handset from the cradle and depresses the push-to-talk button. This transmits the carrier frequency from the mobile unit. When the carrier is detected by the receiver, the control terminal operates to light the LINE lamp at the mobile service operator's position.

The mobile service operator answers the mobile subscriber by voice acknowledgement and obtains the details of his call. If a number verification is desired, the operator can request the subscriber to replace his handset on hook while she calls him back. This provides positive identification, since only one mobile unit will respond to the assigned directory code. The operator completes the call via toll or local facilities and makes a ticket as on a normal toll call.

Mobile to Mobile Call

The control terminal is arranged to rebroadcast all transmission from mobile units so that both sides of each conversation are audible to all mobile units. This permits calls between mobiles to be made with the aid of the mobile service operator.

Fixed Mobile Service

A mobile telephone system may include fixed mobile units to provide telephone service in locations inaccessible to wire lines. Such service is permitted under FCC rules on a secondary-shared basis with vehicular service.

Telephone companies have access to additional frequency allocations for fixed mobile use which are not available to them for vehicular use. These frequencies are primarily assigned to miscellaneous common-carrier service. They are not normally available for common carriers which also operate land line service. However, for rural radio telephone service only, they may be used by common carriers on a secondary-shared basis. This use might be attractive in some isolated exchange areas where several subscribers could be served when no other means is economically practical.

Conclusion

Mobile telephony adds a new dimension in convenience to telephone service. The service available to vehicular (automotive) subscribers alone increases the ability of man to communicate in areas where it was either inconvenient or impossible. In addition, the service may be extended to marine and air-to-ground communications as well as to isolated areas on a fixed-service basis.

Equipment cost, physical size and complexity, which have been major deterrents to widescale installations of mobile service, have been greatly reduced by new equipment design. This makes it easier for telephone companies to establish compatible, manual service.

In addition, the availability of fully automatic mobile systems, which permit full two-way dialing, makes mobile telephony practical in areas where manual service could not be advantageously used. The operation of an automatic mobile system will be discussed in a subsequent article.

DIVERSITY ADVANTAGE

of the Type 5055 Combiner

In radio system engineering, one of the more convenient and economical methods of improving system reliability is to use diversity reception. Diversity techniques depend upon the reception of radio signals over two or more paths in which the propagation over each path is independent of the others. Double diversity (use of two paths) is very common in connection with microwave systems operating in the 6000-mc region. Although diversity may be obtained in a number of ways, the two techniques commonly used are: (1) space diversity in which two or more receiving antennas intercept signals from the same transmitter; and, (2) frequency diversity in which the baseband signal is applied to two or more transmitters operating on different frequencies. Frequency diversity offers an economic advantage in that

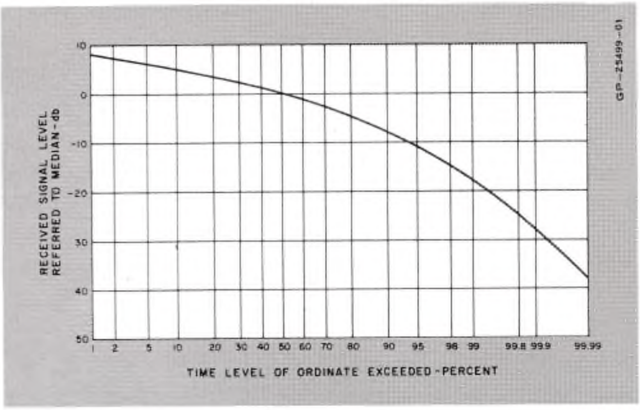


Fig. 1. The Rayleigh distribution shown is used to predict radio signal level variations which may be expected to occur over a well-engineered radio path.

only one transmitting and one receiving antenna are required. In addition, the use of two transmitters and two receivers virtually eliminates outage time due to equipment failure and maintenance. This increases overall *system reliability*.

The reliability of a radio circuit (system reliability) is often defined as the ratio of the total usable circuit time to the total elapsed time. For example, with a system reliability of 0.999, the radio circuit will be out-of-service about 9 hours during a year. It is very likely that many of the individual service outages will be of very short duration. However, outages for periods exceeding about 10 minutes may occur, although these longer outages will be much less frequent.

The factors which cause outages are normally divided into two classes: (1) those due to radio wave propagation; and, (2) those due to equipment failure. For diversity operation, the improvement in reliability (diversity advantage) is achieved by reducing the deteriorating effects of deep fades on the output at the receiving terminal.

An important part of engineering a radio link is determining the free-space path loss. When this loss is known, the median signal level can be found. However, even for a well-engineered path, fading will occur. The depth of fading and the length of time of the fade will vary from path to path. The variation in signal level that may be expected, due to multipath fading during those periods of the year when fading occurs, follows the Rayleigh probability distribution as shown in Figure 1. In this curve, the ordinate is the variation in signal level above or below the median. The abscissa shows the percent of time that the signal level exceeds the ordinate. For example, the received signal level will be −28 db or greater (referred to the median signal level) for 99.9 percent of the time. Neglecting outages due to equipment failure, the reliability of the radio circuit then depends on the ability of the radio receiver to handle the variations in signal level expected for a specified percentage of the time, without introducing excessive noise into the baseband output.

Although signal fading may be expected to follow the Rayleigh probability distributions, it is possible, as in diversity reception, to combine signals from two or more receivers so that an effective improvement in signal-to-noise ratio is obtained. The amount of improvement obtained, and the percentage of time over which it is effective depends upon the combining method. The three basically different methods of combining presently available are: (1) linear; (2) switching; and (3) ratio-squared. Each of these types is illustrated in Figure 2. In addition, combining is possible either before (I-F or Pre-detection) or after (Baseband or Post-detection) detection of the R-F signal. Only baseband combiners are considered in this article.

In a linear combiner, the output signals from each radio receiver are always combined, and no effort is made to adjust the output of the receiver in relation to the noise present. A disadvantage of linear baseband combining is that during deep fading, the noise increases and this noise is introduced directly into the output circuit. For this reason, linear combining shows an improvement for about 96 percent of the time, but deteriorates rapidly and is actually worse than a single receiver during the other 4 percent.

Where combining is done by receiver switching, the output is obtained from only one receiver at a time. The receiver with the lower noise output is always selected. Theoretically, this combining method shows decided improvement over a single receiver, and is only slightly inferior to the improvement obtained with ratio-squared combining. However, a major disadvantage to continuous selection of the best output signal by switching is that transients are introduced each time a switch is made.

In ratio-squared combining, the output of the receivers are added together. But the signal contribution from each receiver is variable and is controlled by the noise present. In this way, deep fading on one receiver does not cause deterioration of the total output signal. Therefore, the resultant signal-to-noise at the output is always much better than that predicted by the Rayleigh distribution. In fact, the theoretical results obtainable by ratio-squared combining are often used as a basis for comparing the capability of various types of combining methods. However, the complexity of the equipment necessary in ratio-squared combining, as well as the use of active circuit elements—such as tubes—which are subject to failure, makes the method unsuitable for some applications.

Linear and switching combining techniques can be used together to obtain a relatively high diversity advantage with a minimum of equipment complexity. This method is used in the Type 5055 Combining and Transfer Panel designed for the Lenkurt Type 74A Microtel system. In operation, the 5055 operates as a linear combiner for a large percentage of the time. However, where the noise power in one receiver exceeds a predetermined value, that receiver is switched out to prevent deterioration of the output signal-to-noise ratio. At the same time, the noise sensitivity of the "good" receiver is decreased, and that of the "bad" receiver increased to prevent hunting during rapid fading periods. In addition, the circuit is designed to effectively nullify switching transients. In Figure 3, the diversity advantage of the

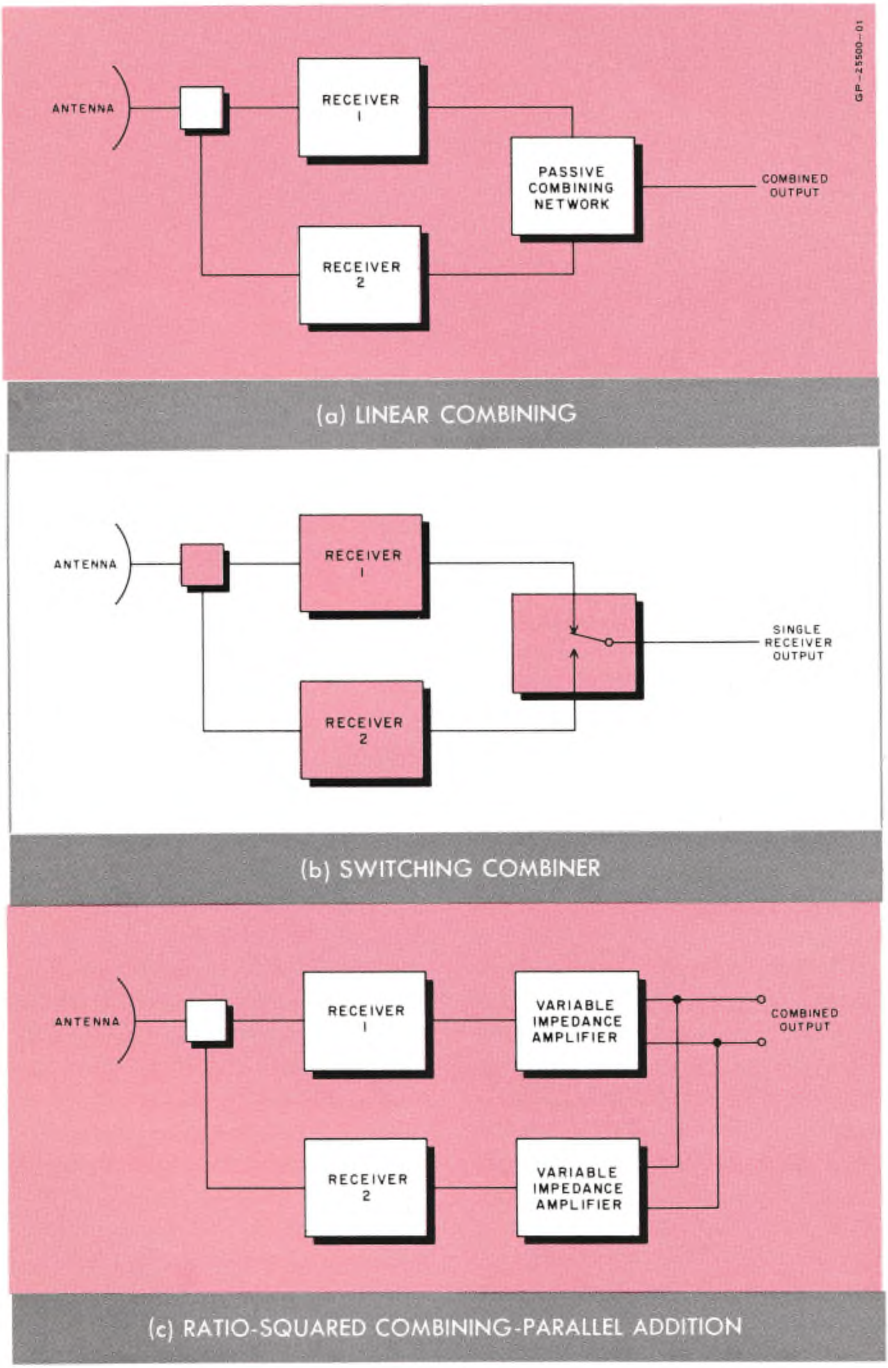


Fig. 2. The three basic combining methods shown in block schematic form.

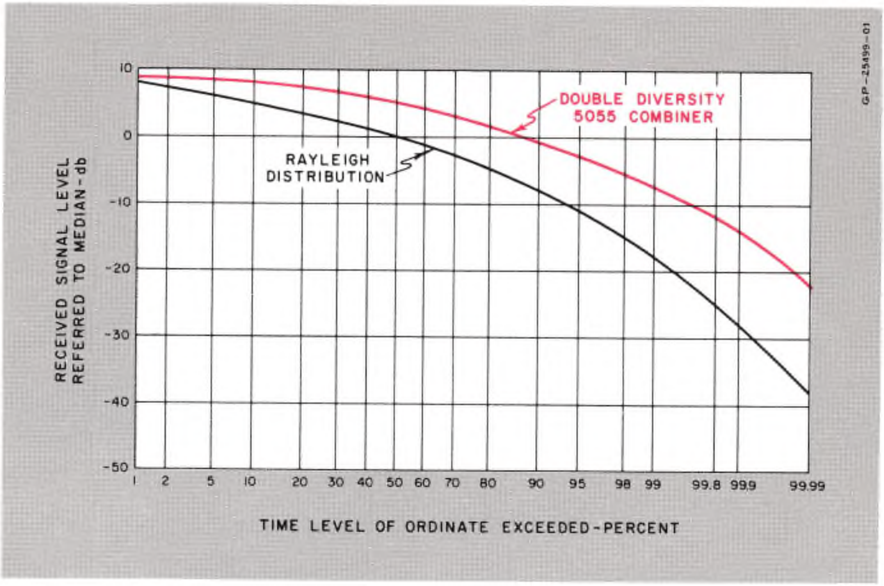


Fig. 3. Radio signal level distribution of the Type 5055 Combining and Transfer Panel is compared to the Rayleigh distribution. The signal level difference between the two curves is the Diversity Advantage.

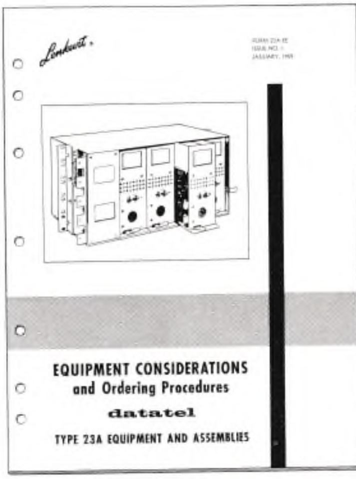
Type 5055 panel is compared with the Rayleigh distribution. The advantage that may be obtained is variable and depends upon the point at which switching occurs.

The diversity advantage available from a combiner can be used for two different purposes. The first is to increase the reliability of a circuit over that which would normally be expected. This is most effectively demonstrated by comparing the operation of a single link without and with diversity. Referring to the Rayleigh distribution (Figure 1), the signal level is more than 28 db below the median for 0.1 percent of the time when a single receiver is used. If frequency diversity is used with the 5055 combiner, the radio signal level would be more than 28 db below the median for less than 0.01 percent of the time, or less than 1 hour per year. Not only is system reliability improved from the standpoint of propagation, but additional reliability is obtained through the use of separate transmitters and receivers.

Rather than to increase system reliability, diversity can be used to advantage on unavoidably long or difficult radio paths. As in the above example, the path loss with diversity could be 15 db longer, and the reliability of the circuit would be effectively unchanged from that of a single receiver. A major disadvantage of using longer than normal path lengths is that the median signal level will be 15 db lower. This may cause undesirable variations in per-channel noise, and may seriously affect the normal signal-to-noise ratio.

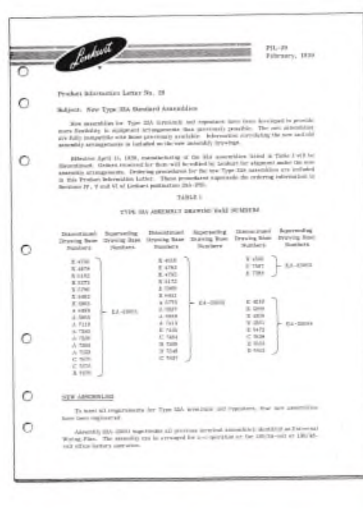
SOME RECENTLY ISSUED PUBLICATIONS

Complete equipment considerations and ordering procedures for the Lenkurt Type 23A datatel system are contained in the new bulletin, Form 23A EE. Each panel, unit and shelf used in Type 23A assemblies is described, and equipment options and their applications are explained. Copies of the bulletin, Form 23A-EE, may be obtained from Lenkurt's offices and distributors.



Bulletin, Form 45A-P4, which describes the Lenkurt Type 45A 12-channel, long-haul carrier telephone system, has recently been revised to include simplified ordering information for standard assembly arrangements. Copies of the bulletin, Form 45A-P4, may be obtained from Lenkurt's offices and distributors.

To provide more flexibility in equipment arrangements, new assemblies have recently been made available for Lenkurt Type 33A terminals and repeaters. These new assembly arrangements are fully compatible with those previously furnished. Simplified as well as detailed ordering information for the new Type 33A terminal and repeater assemblies is included in the new Product Information Letter No. 29. Copies of this publication may be obtained from Lenkurt's offices and distributors.



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Change has its place in the natural order of things. Times change. So do addresses, titles and positions. We don't like to tamper with this process. But we would like to make sure that the **Demodulator** reaches you every month without delay. To do this, we need up-to-date information on your correct address.

If your address needs changing, please let us know. And please include your **old** address along with the new. This helps us to locate your old listing and complete the change quickly.

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