At Bell Laboratories' Indianapolis location, Dennis Burcher of the Telephone Circuits group prepares to make acoustic measurements of the new G36 telephone handset.

This new handset, which features two built-in amplifiers, is one important element in a new "Long Route Design" system that enables Operating Companies to provide rural telephone service on their longest loops more simply and reliably, and at lower cost.

G36 Handset:

Good News for Serving Far-out Customers

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THE LARGE, SPARSELY SETTLED AREAS served by the Bell System are a source of great concern because some of the longest customer loops—commonly twisted wire pairs—may in extreme cases extend as far as 60 miles from a central office. Cost becomes a prime factor in these fast-growing areas because to serve long loops the Operating Companies must use large diameter wire to keep the electrical resistance low enough for good transmission and signaling. If these loops were served by cable alone, they would cost three to ten times more than the average Bell System loop. However, if electronic equipment is also provided on these loops, more economical cables can be used. The need to use this electronic equipment is made urgent by the fact that the growth of the longer loops (over 30,000 feet) accounts for more than five percent of the Bell System's total growth.

To help improve service to rural areas, two basic categories of electronic equipment—carrier and voice frequency—have been under development at Bell Labs. Carrier systems, such as the Subscriber Loop Multiplexer (see *Digital Multiplexer for Expanded Rural Service*, RECORD, *March 1972*) and the Subscriber Loop Carrier System, increase the capacity of existing cables by multiplexing many phone conversations on two pairs of wire. These systems are used when wire pairs needed for new customers are not available in existing cable or when it would be uneconomical to install new cable.

The voice-frequency systems, which are used to satisfy most of the rural growth demands, consist of equipment that extends the signaling and transmission range of the central office, enabling Operating Companies to use smaller diameter wire pairs in cables. These voice frequency systems comprise equipment such as the new G36 handset, the subject of this article, and the Range Extender with Gain, or REG (see *Customer Lines Go Electronic*, RECORD, *February 1972*, and *REG Circuits Extend Central Office Service Areas*, RECORD, *September 1972*).

A System Concept

The G36 handset had its beginnings in 1971 when AT&T adopted engineering guidelines for the kinds of voice frequency equipment to

Built into the G36 handset are two solid-state gain units: one for transmit (left), one for receive (right).

be used in rural areas. These guidelines—called the "Long Route Design"—specified standardized equipment arrangements and an administrative framework to guide their use. Included in this system concept were some of the engineering and design techniques pioneered by various Operating Telephone Companies in coping with longstanding rural service demands.

Long Route Design accomplishes the following improvements:

- Allows loops to be designed to a maximum conductor resistance of 3600 ohms instead of 1300 ohms, the design limit of most central office equipment.
- Divides long routes into resistance zones for easier administration. This feature allows equipment to be prescribed by zone, relieving engineers of the need to design each new customer loop individually.
- Promotes good transmission quality in low density rural areas.

Resistance Zones

The resistance zones (RZ) specified by the Long Route Design are as follows:

- RZ13—loop resistances up to 1300 ohms.
- RZ16—loop resistances ranging from 1301 to 1600 ohms.
- RZ18—loop resistances ranging from 1601 to 2000 ohms (originally 1800 ohms).
- RZ28—loop resistances ranging from 2001 to 2800 ohms.
- RZ36—loop resistances ranging from 2801 to 3600 ohms.

The equipment originally specified for each resistance zone (see illustration, opposite page) consisted of the 2A Range Extender (for service in the 1301 to 1600 ohm range) and combinations of various Dial Long Lines units (DLL) and the E6 repeater, which provided range extension and gain, respectively, for the remaining resistance zones. A major drawback of this original scheme was the need on RZ36 loops to mount the E6 repeater remotely from the central office. The cost of housing, powering, and maintaining these field-mounted repeaters is high.

Introducing the REG Unit

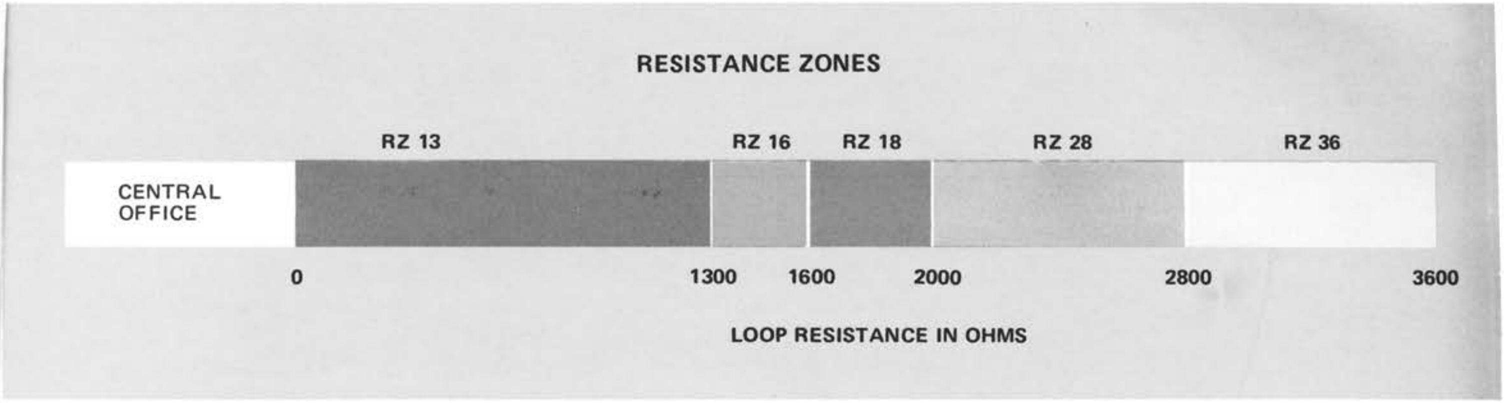
In 1972 Bell Laboratories introduced the Range Extender with Gain (REG) which combines range extension and gain in a single plug-in unit. The REG costs about 40 percent less per line than the DLL and E6 combination and is simpler to adjust than the E6 repeater. It applies universally to all classes of residential service: one-, two-, four-, and eight-party lines; and to any ringing system.

The original REG unit, REG I, was limited to a maximum electrical resistance range of 2800 ohms due to the method used to detect and augment loop current. However, an improved version eliminated this problem. The latest version, REG III, has a range of 3600 ohms.

The improved REG unit made it possible for Operating Companies to serve the remote resistance zones from 1601 ohms to 3600 ohms with a single plug-in unit at the central office. All that remained was to provide a remotely located circuit with 3 dB of gain to augment the 6 dB gain provided by the REG unit (6 dB gain is the maximum gain allowable in a central office under the present crosstalk objectives). Although remote repeaters were again a possibility, their high cost dictated that an alternative method be pursued—that of locating the gain unit on the customer premises.

Gain in the Handset

For ease of design and economy, AT&T and Bell Labs engineers decided to place the gain unit in the telephone handset. One of the first considerations was to minimize the number of telephone set codes required. To accomplish this, the amplifier circuitry was adapted to the G-style handset found on all standard, non-



ZONE	ORIGINAL SPECIFICATIONS: EQUIPMENT	ORIGINAL SPECIFICATIONS: REMARKS	CURRENT SPECIFICATIONS: EQUIPMENT	CURRENT SPECIFICATIONS: REMARKS
	2A RANGE EXTENDER	NO GAIN NOT REQUIRED IN NO. 2 ESS AND SOME NO. 5 CROSSBAR OFFICES	2A RANGE EXTENDER	NO GAIN
	DIAL LONG LINES UNIT (DLL) AND E6 REPEATER	4 dB GAIN DLL AND E6 ARE SEPARATE PLUG-IN UNITS	REG I, II, or III	4 dB GAIN
	DLL AND E6 REPEATER	6 dB GAIN	REG I, II, or III	6 dB GAIN
	DLL AND REMOTE E6	9 dB GAIN E6 IN REMOTE CABINET	REG III + G36 HANDSET	6 dB CENTRAL OFFICE GAIN + 3 dB STATION GAIN

Long routes are divided into resistance zones (top) to make administration easier and to allow engineers to prescribe equipment by zone instead of designing each customer loop individually. Chart at bottom shows equipment originally and currently specified for each zone, including the new G36 handset. RZ13 is served by normal central office equipment.

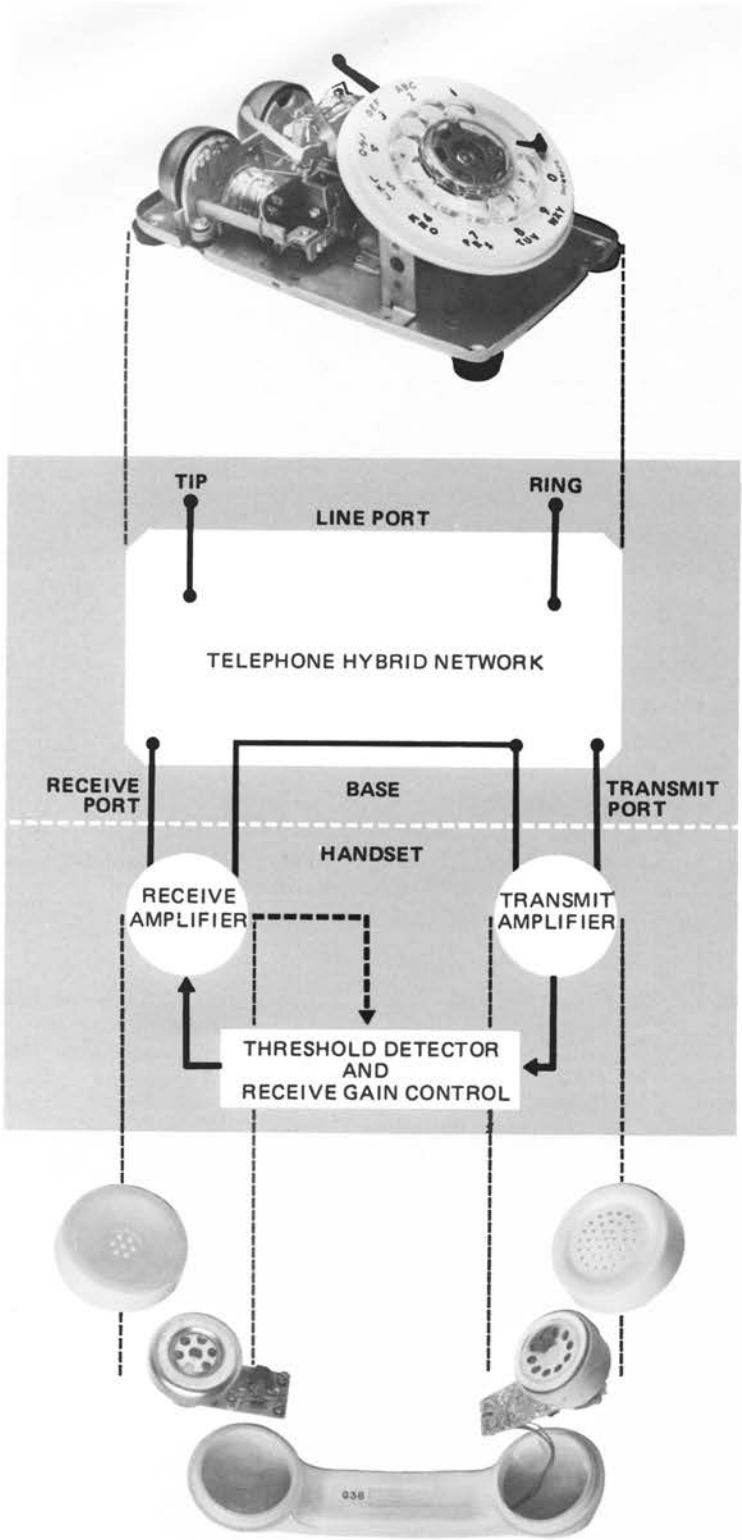
premium telephones as well as the PRINCESS® set. This approach resulted in only two new handset codes (modular and non-modular versions in nine different colors) instead of dozens of new telephone-set codes.

Among a large number of design objectives were the following:

- Provide approximately 3 dB of transmit and receive gain relative to that of the standard telephone set.
- Assure that satisfactory sidetone performance is achieved (sidetone is the signal one hears in the receiver when talking).
- Operate on telephone set currents as low as 3 milliamperes during reverting calls (calls made between parties on the same party line) or when two or more sets are off hook in the same household.

A Linear Microphone

Once the decision was made to place the gain unit in the telephone set, work on the G36 handset began. The handset design recognized the need for Operating Companies to continue offering party line service at the extreme ends of rural routes. The low operating currents



The new G36 handset (at bottom) contains built-in electronic amplifiers to provide talking and receiving gain for customers on loops having resistances from 2801 to 3600 ohms. The G36 is compatible with all general purpose telephone bases.

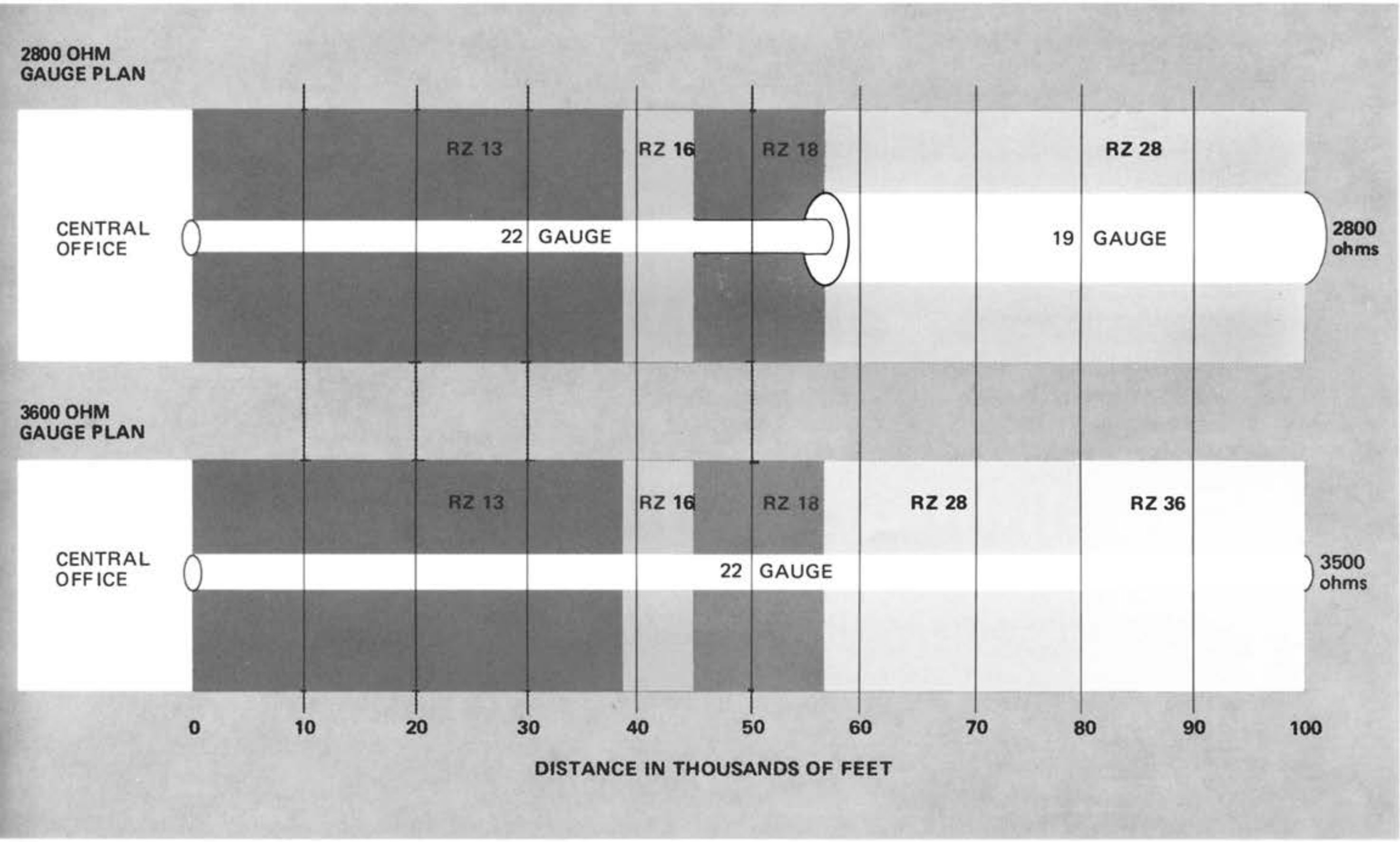
encountered in these situations led Bell Labs engineers to specify a linear microphone, such as an electromagnetic transducer, because its low-current performance is better than that of the conventional carbon transmitter. The electromagnetic transducer is a reciprocal device which can be used as either a transmitter or a receiver. Such a unit, the LB7, was already in production as the receiver for the lineman's handset, and was easily adapted for use as a transmitter for the G36 handset.

Although amplification could be provided in a somewhat conventional manner, there were several problem areas. For example, it was necessary to derive the dc power for both amplifiers (transmit and receive) from the transmit port of the telephone network located in the base of the telephone. The challenge was to keep both amplifiers functioning properly with this dc power, which under some conditions could get as low as 1.5 volts and 2 milliamperes at the transmitter. Moreover, the transmit ac signal (generated by speaking into the phone) is superimposed on this dc, making it necessary for the amplifiers to follow these voice-frequency excursions. To ensure good performance with the small amount of power available, Bell Labs engineers designed both amplifiers using combinations of NPN-PNP transistors which are self biasing and can follow the ac excursions on the amplifiers' power supply without impairing their operation.

Controlling Sidetone and Receive Levels

Another design challenge was how to reduce the increased amount of sidetone present in the receiver resulting from the sum of the transmit and receive gains. Without proper compensation, some users would find the level of sidetone to be unacceptably loud. In this case, Bell Labs engineers provided a small amount of loss switching in the handset circuitry. The loss-switching circuit—by detecting the presence of the transmit signal—reduces the receiver gain by a fixed amount whenever someone is talking into the handset. By keeping the amount of switched loss as small as possible, the switching action is almost undetectable. Although this circuit satisfied the criteria for sidetone level, it was also destined to perform another control function related to the "received" gain level coming from nearby sets.

Receive levels can also get high when party-line customers are talking to other parties on



SAVINGS IN COPPER

The copper saved on long customer loops can be substantial if the newly specified loop equipment—the G36 handset and REG III unit—is used wherever possible. For example, the above illustration shows a route 100,000 feet long as it would be designed with both 2800 ohm and 3600 ohm equipment specifications.

The 2800 ohm design (top) necessitates about 41,000 feet of the larger diameter, expensive 19 gauge cable pairs. (The 19 gauge cable pairs contain twice as much copper as 22 gauge cable pairs.)

With the REG III and the G36 handset, the farthest point on the loop can be designed to a resistance of 3600 ohms (bottom). This eliminates 19 gauge cable entirely in this case. A conservative estimate of the potential worth of the G36 handset to the Bell System is a savings of three million dollars a year in copper.

the same line or from extension sets. Under these conditions, the transmit and receive gains are again additive. Moreover, the transmit efficiency of a linear microphone does not decrease with decreasing current as does a conventional carbon transmitter. The net effect of these two factors would be an increase in receive levels of about 11 decibels over the normal level. Although customers could adapt to these increased levels by talking lower or holding the receiver further away, field trial results showed that eleven percent of the party-line customers considered the receive level to be too loud when talking to other parties on the same line. The loss-switching circuit was then modified in such a way that it could also detect receive levels. When the received level exceeds a threshold value, a fixed amount of loss is switched into the circuit and reduces the receive level. Thus the same loss switching circuit compensates for excessive sidetone and also acts as a quasi-automatic gain control. A bonus of this development was that the added function was attained at no extra cost.

The new handset looks identical to the conventional G-type handset except for the marking "G36" which is embossed on the underside of the handle in a contrasting color. Production lead time and set-up costs were minimal because only one die change was necessary in fabricating the handle.

Administration by Resistance Zone

Past experience with amplifiers built into telephone sets (the 238-type transmitter amplifier, for example) indicated that the new handset must be compatible with Operating Company administrative procedures in addition to providing the required transmission performance. The designation of G36 on the handset is part of the administrative framework called for in the Long Route Design ("G" refers to the G-type handset, while "36" refers to the resistance zone). Under Long Route Design guidelines, customers are identified in the cable records by resistance zone. For example, when a service request is received by an assignment clerk, the clerk identifies the customer's location by the resistance zone: "RZ36" for the resistance zone of 2801 to 3600 ohms, in this case. This code is written in the service order so that the proper central office equipment can be assigned and so the G36 handset can be ordered instead of the conventional G3 handset. This means that when material is delivered to the installer's truck, along with the service orders, the correct handset is included.

RZ36 Equipment

The complete "RZ36" package consists of the following equipment:

- The REG III unit—provides 6 decibels of central office gain and increases the signaling current for use in loops having up to 3600 ohms resistance. This unit is mounted in the central office.
- The G36 handset—provides 3 decibels of transmit and receive gain at the customer's telephone set.
- 11A or 11B ringing extenders—improve ringing range and isolate grounded ringers from power line induction. The range extenders are located on customer premises, usually next to the station protector.
- The 71A2 REG power unit—provides the higher current necessary for TOUCH-TONE® dialing on 3600 ohm loops. This unit is located at the central office and serves up to 165 REGs.

To complete this package, engineering practices are now being revised to supply guidance to outside plant engineers, equipment engineers, plant assigners, and plant installers.

A field trial of an interim version of the RZ36 equipment package was conducted in 1974 in Waynesboro, Mississippi, a territory served by South Central Bell. The trial's objectives were to test the administrative procedures planned for the new equipment arrangement, to elicit customer satisfaction, and to check assumptions concerning the labor costs incurred in converting a route to the new RZ36 system. In this case, the route had been served previously by a remote DLL and E6 repeater installation located about ten miles from the central office.

Trial Results

G36 handsets and 11A ringing extenders were installed in the homes of 74 customers; in all, 99 handsets were installed. To check on transmission quality, each customer was interviewed by telephone before and during the field trial. Aside from the high receive levels experienced during reverting calls (which was corrected by detecting receive levels), customers were pleased with the system. No handset failures occurred, the labor cost assumptions were found to be valid, and valuable insight into telephone company operations was gained, especially with respect to the administrative aspects of the new RZ36 system.

The first production models of the handset were manufactured by Western Electric in February of this year for shipment to South Central Bell, where the handset will undergo an introductory appraisal. The handset—and the rest of the new zone 36 equipment—will be available to Bell System companies this summer.

The successful development of the zone 36 package resulted from a concerted Bell System effort involving four areas of Bell Laboratories, three AT&T departments, three Western Electric manufacturing locations, and two Operating Companies. The outcome of this coordination and cooperation: timely introduction of an economical loop design package that meets all Bell System objectives for service and operations. □