Mr S. H. Towner
3321

ELECTRICAL COMMUNICATION

1958
VOLUME 35
NUMBER 3

THE TECHNICAL JOURNAL OF ITT

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

ELECTRICAL COMMUNICATION

Technical Journal Published Quarterly by

INTERNATIONAL TELEPHONE and TELEGRAPH CORPORATION

67 Broad Street, New York 4, New York

President: Edmond H. Leavey

Secretary: C. Douglas Webb

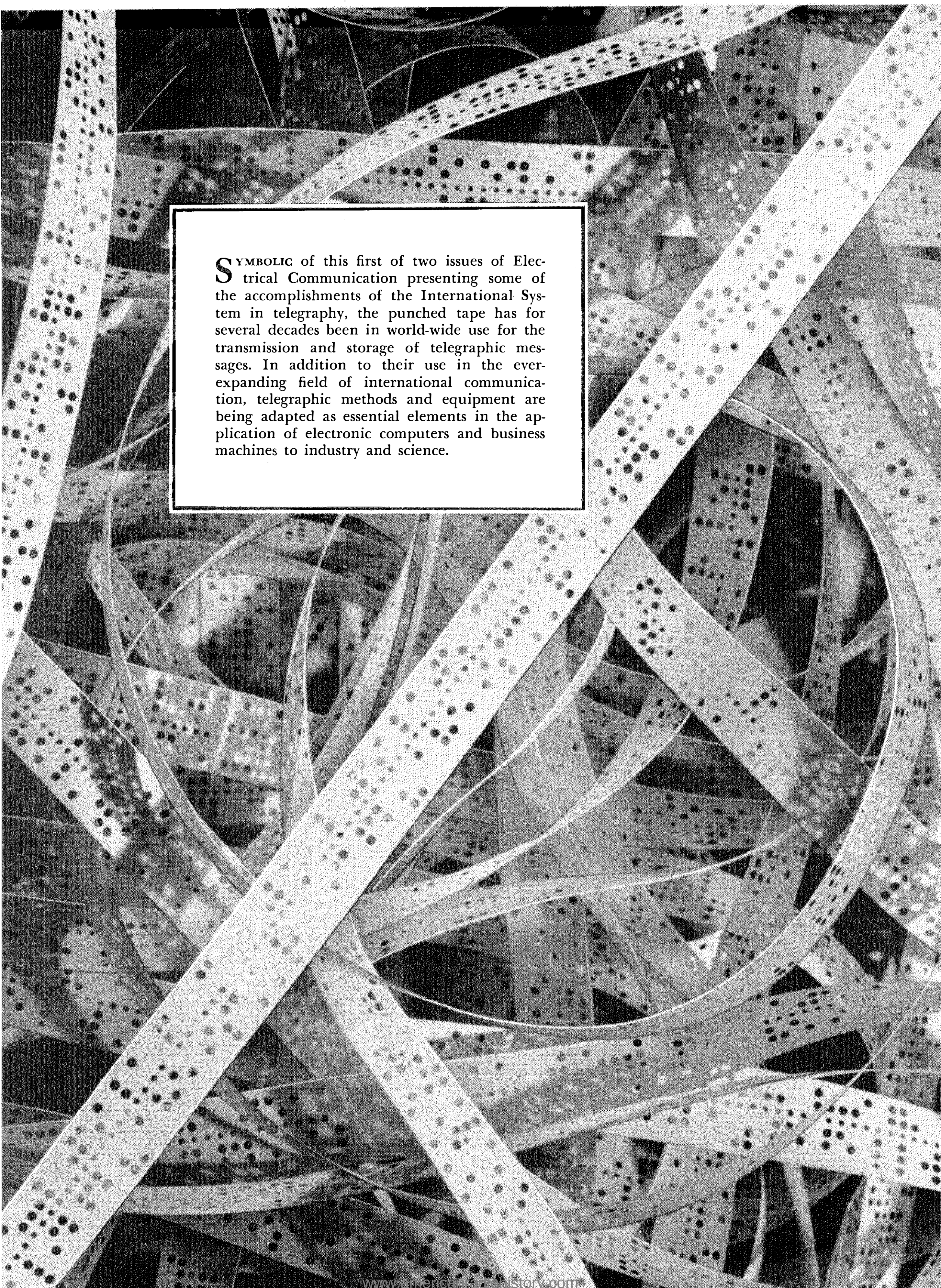
Subscription: $2.00 per year; 50¢ per single copy

ELECTRICAL COMMUNICATION

The Technical Journal of
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION AND ASSOCIATE COMPANIES

CONTENTS

VOLUME 35 **1958** **NUMBER 3**



Symbolic of this first of two issues of Electrical Communication presenting some of the accomplishments of the International System in telegraphy, the punched tape has for several decades been in world-wide use for the transmission and storage of telegraphic messages. In addition to their use in the ever-expanding field of international communication, telegraphic methods and equipment are being adapted as essential elements in the application of electronic computers and business machines to industry and science.

STRAD—New Concept for Signal Transmission Reception, and Distribution

By E. P. G. WRIGHT

Standard Telecommunication Laboratories Limited; London, England

SUFFICIENT difference exists between electromechanical and electronic switching systems to provide ample material for a technical paper. However, few readers will have the time to study intricate details—they will probably be more concerned to consider what advantages an electronic system such as STRAD has over earlier systems—and as a consequence the paper commences with the basic advantage of the rapid processing that is now possible and the manner in which this speed can be employed to provide an economical arrangement of the various operations that need to be carried out.

It is explained that different requirements may need different arrangements; this state of affairs is similar to that experienced with electromechanical systems.

For readers who are familiar with the principles of electronic digital computers it will be evident that no new technique is essential.

Special procedures have been adopted to achieve a system reliability vastly greater than that existing in present computer systems for which a high degree of accuracy is necessary but for which a predetermined "down time" can be accepted. For communication systems, continuous service is necessary although a very small percentage of errors may be tolerable.

1. *Electronic Data Processing*

STRAD is an electronic version of a torn-tape system capable of receiving, storing, and retransmitting different forms of coded information. Arrangements can be made for push-button operator control, for automatic operation, or for a combination of these two methods. No electromechanical switches are employed, and the electronic devices introduce a reduction in annual charges both on the operating staff and on the maintenance staff required for the upkeep of telegraph instruments.

The speed of data processing possible with electronic components is so high in comparison with the customary telegraph line speeds that it is possible with time division to employ common high-speed cross-office circuits serving most, if not all, of the lines. This rapid processing of the data introduces economy and simplicity in a number of ways, one example being the handling of multi-address messages. In a torn-tape system it is customary to employ a tape factory to produce a separate tape for each direction of retransmission required. A single electronic record of the message is sufficient for any number of retransmissions. No delays are introduced before retransmissions can commence, and there is complete flexibility to proceed with the retransmissions as the outgoing circuits become available without any necessity for the retransmissions to be in phase with one another. The simplicity of the arrangement is emphasized by saying that the processing of each retransmission of a multi-address message is identical to that of a single-address message. In Figure 1 a message B is decoded at B_d and thereafter retransmitted B_r over a number of outgoing lines. Outgoing line 5

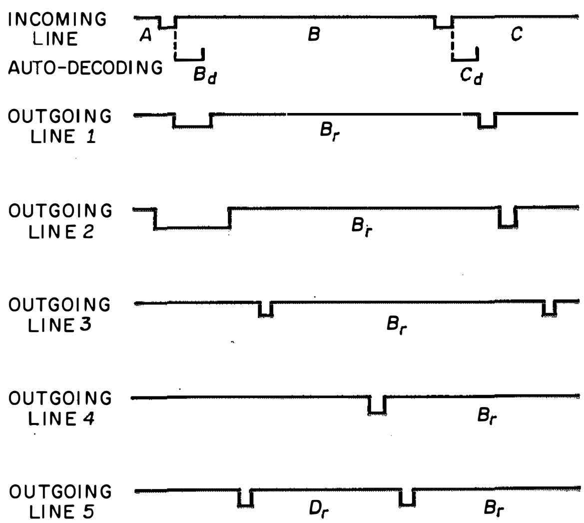


Figure 1—Retransmission of multi-address message using precedence control.

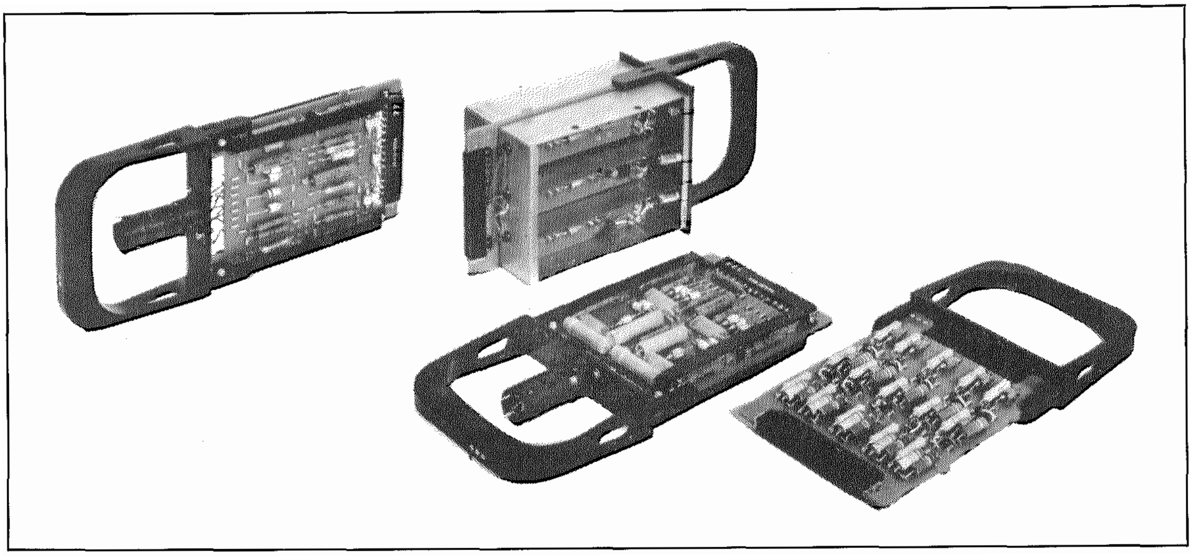


Figure 2—Typical plug-in units.

has to retransmit a message of higher precedence D_r before sending B_r.

Another striking example of the benefit obtained by rapid processing concerns the sorting of waiting messages of different precedence and chronological order. When an outgoing circuit becomes free at the completion of a retransmission, an examination is made of all the messages in storage to choose the next message in precedence and chronological order. It may happen that several outgoing lines are free at once, and in this case the message of highest precedence for all these lines is chosen first and then a similar message selection is made for the other waiting lines. The searching process involves only a few milliseconds because of the high speed.

There are many other ways in which the high processing speed is used to introduce economies. These will be described in detail later in the paper so that some consideration may first be given to reliability, faultfinding, and other aspects of maintenance.

2. *Reliability*

Some apprehension may arise on account of the extensive dislocation to the service that could result from a fault in one of the common circuits using time division, and this situation is catered for by a complete duplication of the common circuits with comprehensive cross-checking to isolate, disconnect, and alarm the section of the circuit that has developed a fault. The majority of the circuit units are of the plug-in type, so that a faulty unit can be identified, replaced, and tested *in situ* without interruption of the service. The importance of high-grade components and ample circuit margins needs no special emphasis.

It is a feature of STRAD that a relatively small number of different circuit units is employed to produce the various logical functions that need to be undertaken, and this arrangement goes a long way towards removing the necessity for the maintenance staff having to learn the operation of a variety of different circuits. The basic switching and processing operations are undertaken by triggers and gates, while the writing and reading of data into or out of the stores is undertaken by standardized amplifiers. It is not intended that any circuit-unit testing should be carried out on the racks, but only on the bench in conjunction with the appropriate testing devices. As a consequence the testing and repair of units can be undertaken under ideal conditions. Figure 2 shows examples of typical plug-in units.

It is appreciated that in such an electronic system, using pulses at a 50-kilocycle-per-second repetition rate, a serious fault liability can arise through the presence of dry joints due to imperfect soldering or due to wire fractures caused by excessive heat. To overcome this fault liability, secondary solderless wrapped connections are employed, and the experience gained with this type of joint over a number of years has been entirely satisfactory. Special emphasis has been directed to this subject because the tracing of an intermittent failure of a pulse lasting only a few microseconds is necessarily elusive. Figure 3 shows secondary wrapped joints on a plug-in unit.

Mention has been made of the ability of a single link or highway circuit with time division to carry the traffic of a number of lines, and it is necessary to describe briefly what safeguards are employed to ensure that a serious interruption of the traffic is not caused by a component failure within the link.

The first step taken is to duplicate the link, then to make arrangements that both circuits operate in parallel, and then to check that they provide the same output. If the outputs should fail to check, an alarm is given, and it is then desirable that the failure should be analyzed and identified so that the faulty unit can be prevented from interfering with the output being supplied by the correct circuit. Figure 4 shows schematically this form of highway duplication. With such an arrangement the chance of disturbance is substantially reduced and the information provided to the maintenance staff enables a rapid replacement of the faulty unit to be made.

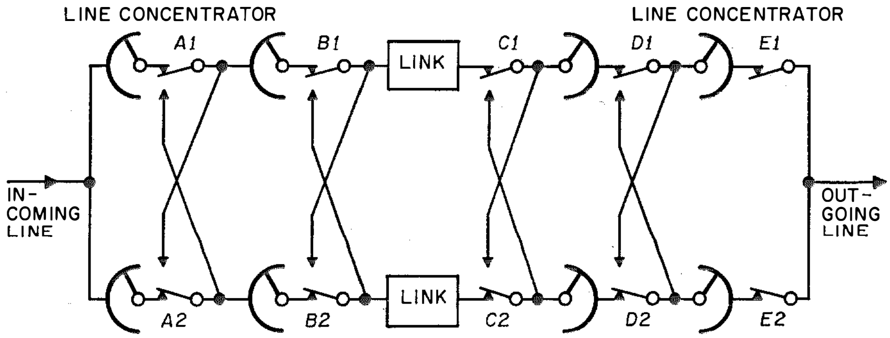


Figure 4—Highway duplication.

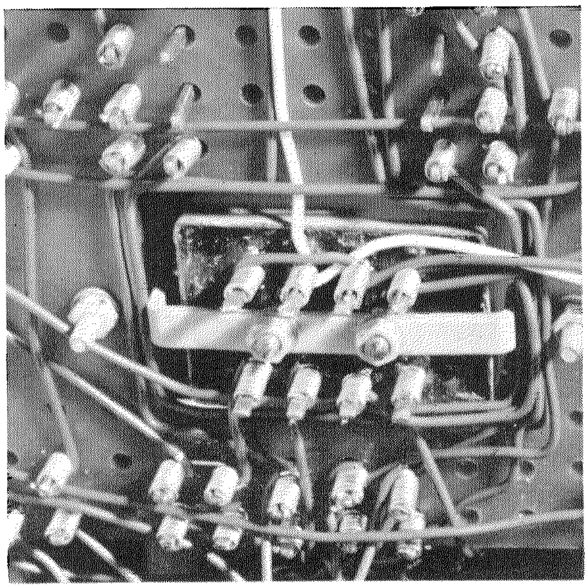


Figure 3—Secondary wrapped joints of a plug-in unit.

It is worth noting that complete equipment duplication is not restored at the time that the faulty unit is replaced because the link is associated with storage equipment in which information may have been stored incorrectly as a result of the fault and, therefore, when the link is returned to service there will be a possibility that the alarm will again be given as a consequence of the original fault. However, the difficulty is one that tends to be self-clearing because the contents of the stores are normally quickly refilled and at the end of a few seconds the links will pull into line if they are operating correctly. The faulty unit can be checked on the test bench with the appropriate testing equipment, but this check and repair of a faulty component is not a matter of any urgency; it is a much more urgent matter to replace in service the unit on which the failure occurred.

A simple example can be taken from the case of a group of incoming lines served by a highway with time division applied to allow the various lines to be sampled in sequence by a common timing circuit. A concentrator designed for this function causes the incoming signals to be reshaped and interleaved in sequence as output signals on the highway. The majority of component faults will appear as if the component is either short-circuited or disconnected. The consequence on a time scale will be either that counting ceases or that it proceeds at double speed due to one trigger stage sticking in the operated condition. During the period between characters each circuit can be examined to see that there is no sticking, and, should any be found, the link concerned can be alarmed and steps taken to disconnect the multiplex output provided from the faulty concentrator. On the other hand, if the counting ceases, the concentrator automatically fails to give any output and it is therefore only necessary to give an alarm that there is a failure to check. In this case the

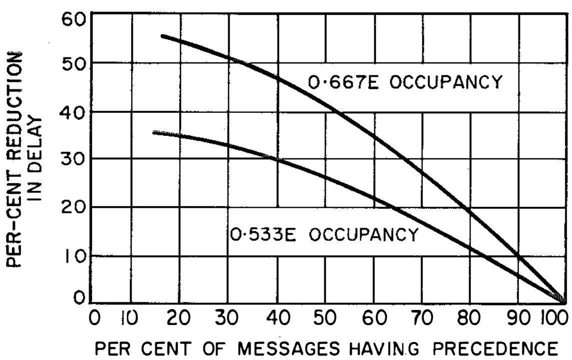


Figure 5—Effect of precedence on delay.

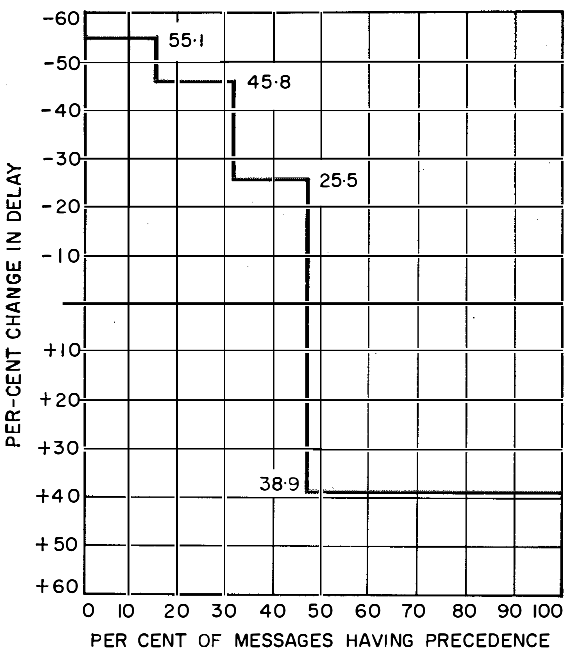


Figure 6—Relative effect on delay when using 4 precedence states.

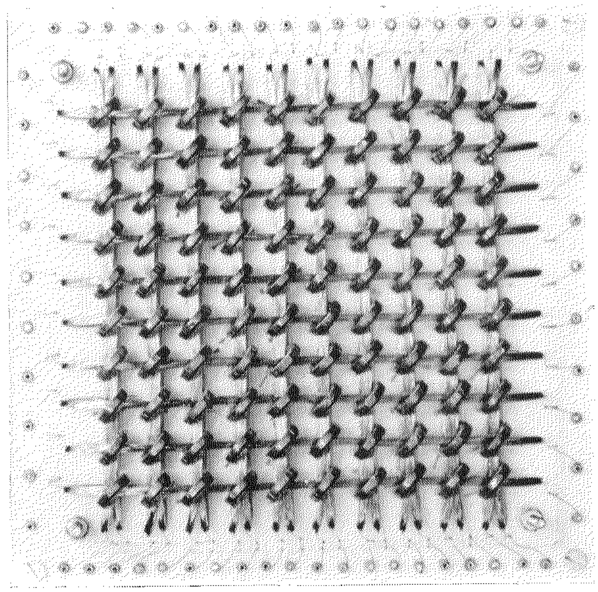


Figure 7—Ferrite access selector.

whole contents of the store are replaced in the period needed for the reception of two characters (say one-fifth of a second) so that the maintenance staff can determine without delay whether the faulty unit has been identified, replaced, and brought into synchronism with the other circuit.

3. Storage

A torn-tape system is normally employed to allow the incoming and outgoing circuits to be much more heavily loaded than would be possible with a direct switching system without storage in which the number of busy connections must be limited to avoid the additional operating that would otherwise be involved. Torn-tape systems are not usually expected to pass messages as quickly as direct switching systems. However, an electronic system with storage does not suffer from this disadvantage because the retransmission of a message can start a few seconds after the message commences to arrive. Heavy loading of the outgoing lines will inevitably introduce delays, but the use of different precedence categories will ensure that the urgent messages will be handled with a minimum of delay. With lightly loaded outgoing lines, the speed of handling precedence messages may be faster than with a direct switching system. Figure 5 shows the effect of precedence on delay, and Figure 6 shows the

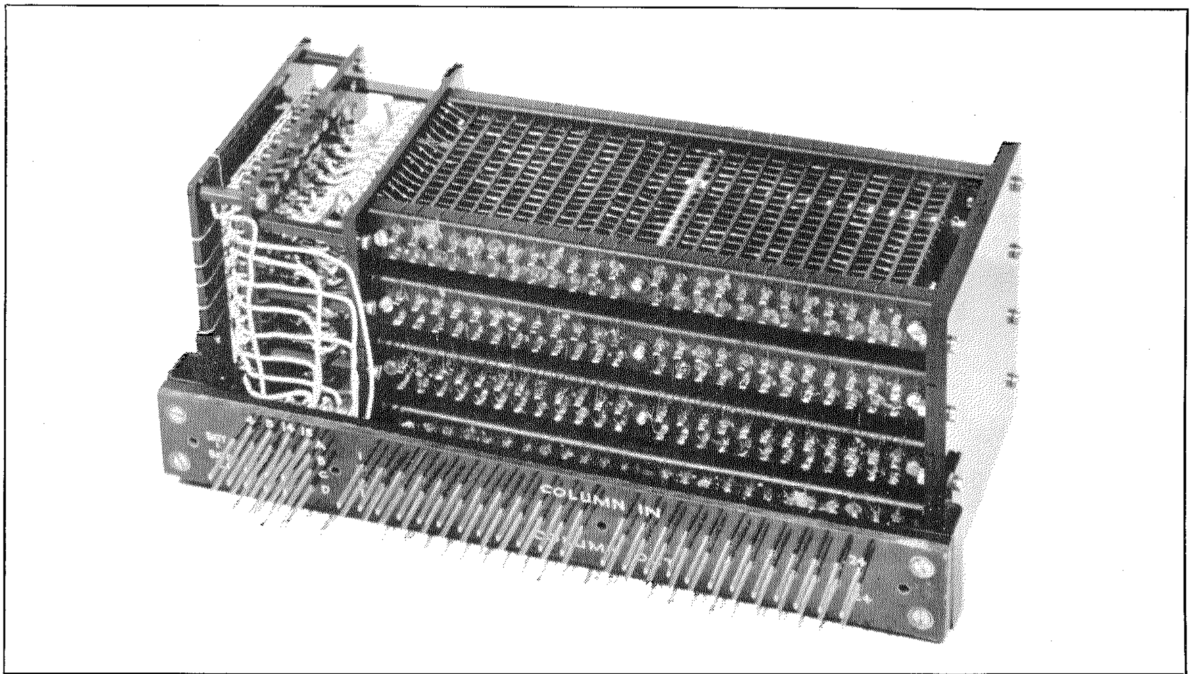


Figure 8—Ferrite store.

relative effect on delay when using four precedence states.

There are several interesting features in electronic switching systems, and for telegraph application perhaps the most important is the message store. There is a variety of different electronic devices available for the storage of telegraph characters, that is, shift registers, ferrite cores, magnetic drums, and magnetic tape. Figures 7 and 8 show a ferrite access selector and store,

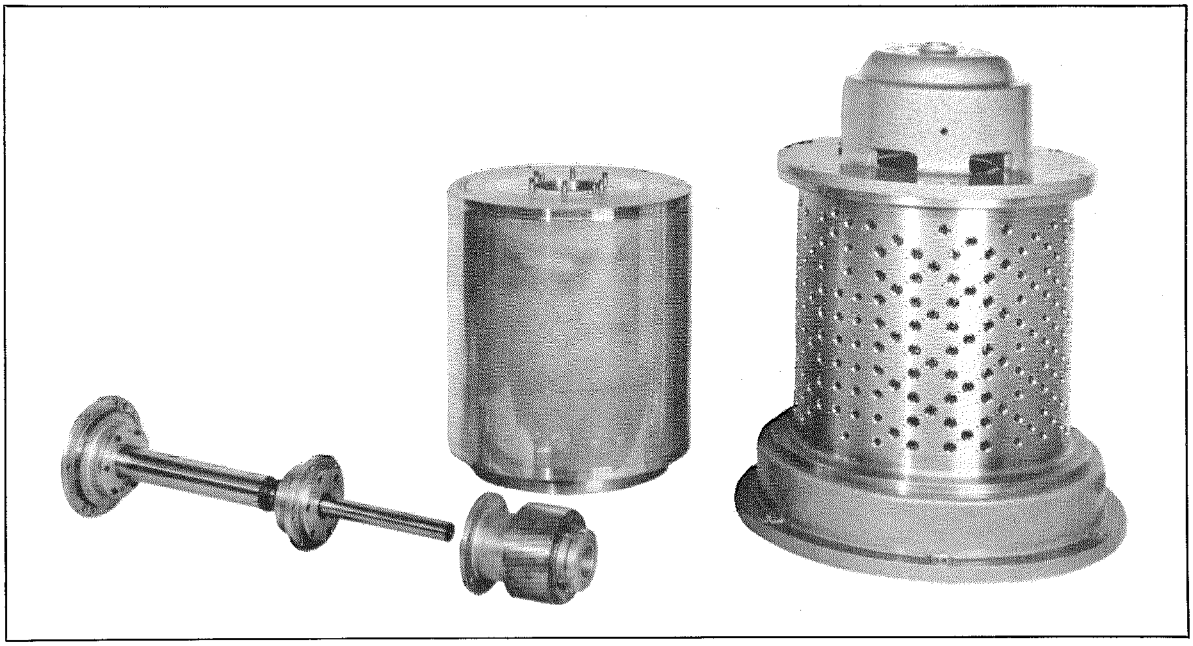


Figure 9—View of magnetic-drum components.

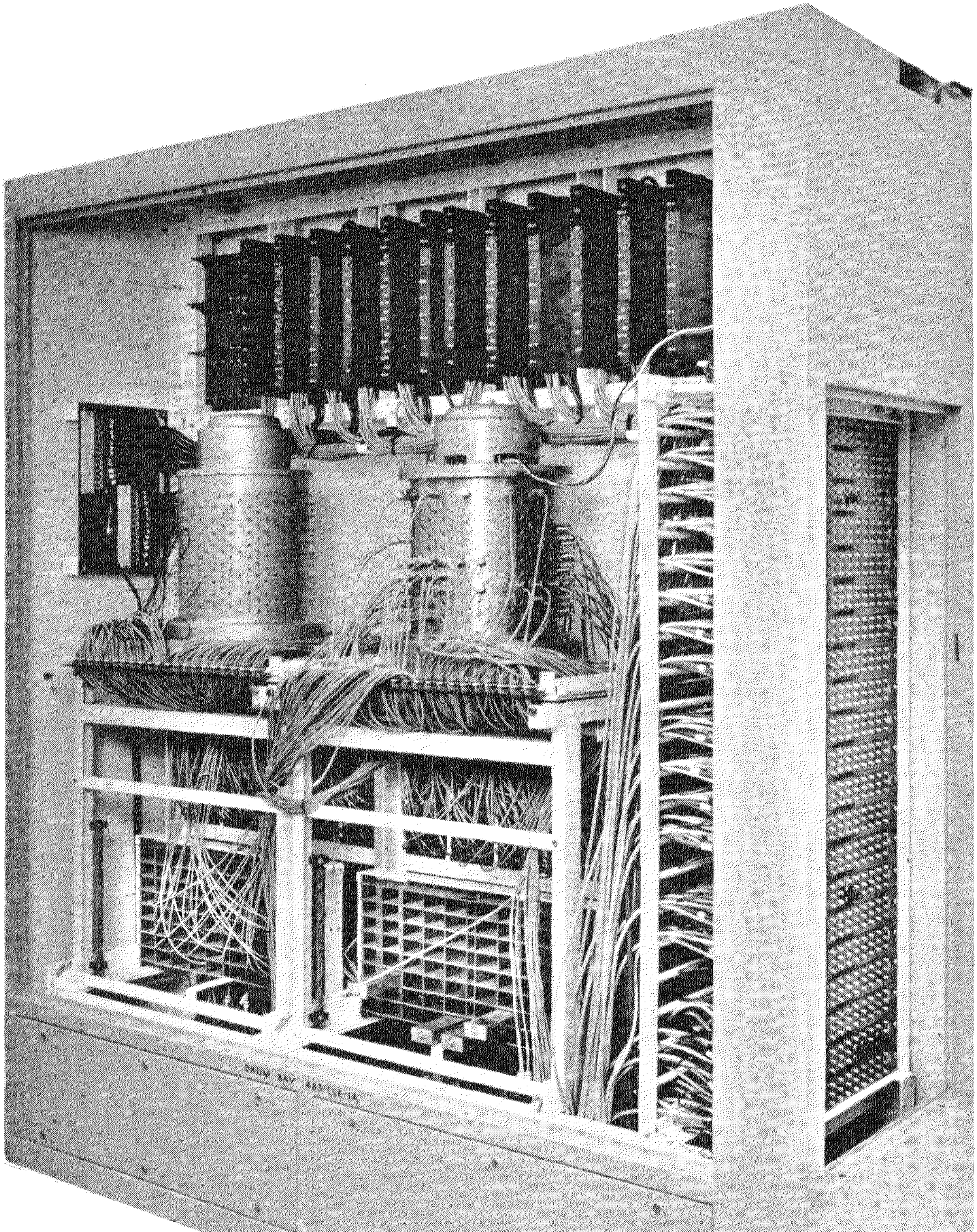


Figure 10—View of magnetic-drum console.

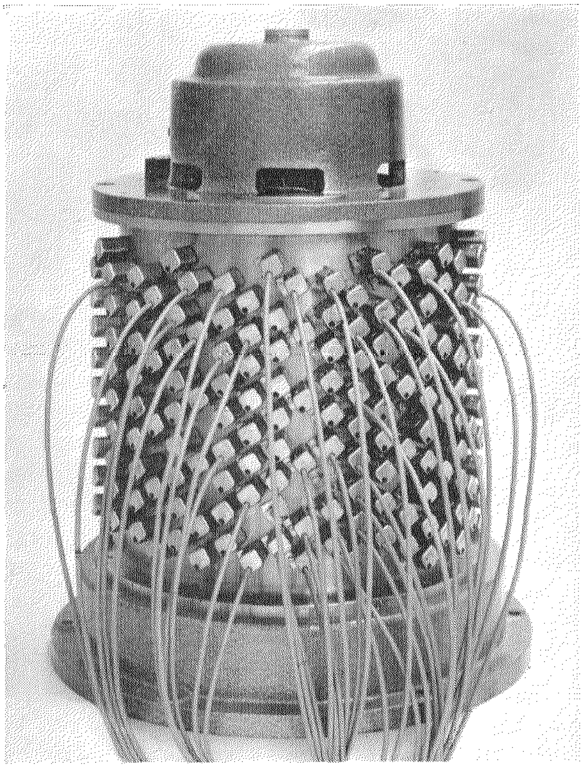


Figure 11—View of magnetic drum.

Figures 9, 10, and 11 show views of magnetic drums, and Figure 12 shows a large-capacity magnetic-tape machine. The suitability of these different devices depends on cost and access time. In the examples given above, the stores are arranged in order of decreasing cost and increasing access time. For applications in which a large amount of storage is needed it is advisable to use tape, while on the other hand, if the storage capacity needed is small, there are economies to be realized by employing ferrites because of the quick access that is available with them for writing or reading. Shift registers are too bulky and expensive to be used for the main store, but they are valuable for temporary storage for the following applications.

The shift register can be used as a time buffer to enable characters to be read at one speed and retransmitted at another speed. Such buffers can be used to record characters and transfer them onto the track of a magnetic drum or to withdraw the characters from the drum track and retransmit them to lines. The drum is rotating continuously, and it is necessary to employ a distributor to control the writing of successive characters in correct sequence on the track; this distributor can take the form of a shift register with an associated carrier (revolver) track.

It is necessary to scan messages for various service indicators, and it is convenient to employ a shift register to scan each character in turn throughout a message.

The most efficient storage arrangement is that employing a single common store for all incoming and outgoing lines (Figure 13), but as all the lines may be in the process of receiving or transmitting at the same time there is clearly a necessity for quick access to the appropriate section of the common store to

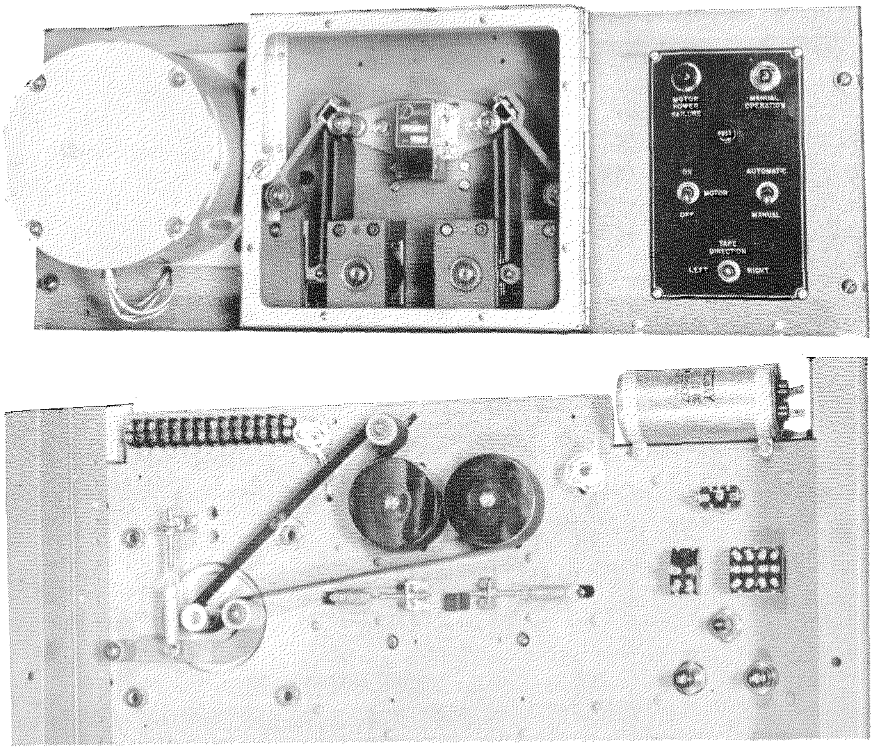


Figure 12—Large-capacity magnetic-tape machine; front view at top and rear below.

ensure that each of the lines may be serviced sufficiently rapidly so that there is no danger of information being lost or delayed. The number of operations for the access selector can be materially reduced by writing and reading a whole character at a time as opposed to element by element.

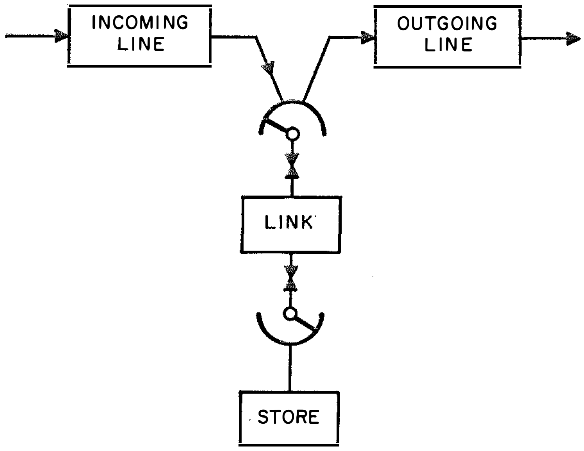


Figure 13—Block diagram for STRAD with common store.

Common storage is not only valuable because of its general availability but also because it allows retransmission to commence with negligible delay. Overall requirements for quick retransmission of messages may therefore demand a common store, and in general it seems likely that in such systems there will not be any need for a large store because the loading of the outgoing circuits cannot be allowed to be very high, otherwise delays will be introduced.

In other applications, usually with longer lines, there may be a need for higher line loadings to economize on line charges even though this may involve messages being delayed for a minute or two. This naturally necessitates more storage and, as a consequence, a cheaper form of storage such as a magnetic drum. However, the access time for a magnetic drum is necessarily greater and the use of common storage is more difficult to arrange. A compromise is obtained by assigning a drum track for each line and by transferring track loads of characters to the common store one track load at a time. As several hundred characters can be assembled on the line tracks, the number of transfers to the common store is greatly reduced and, furthermore, a complete track load can be transferred during a single revolution of the drum.

There are applications also in which it is necessary to allow for serious congestion when storage capacity is needed for several hours of continuous message reception. In such cases it is advantageous to employ the cheaper form of storage available with tape machines (Figure 14).

In addition, a tape machine can be employed as a buffer to absorb the incoming traffic at any time if it is desired to service the switching equipment. Although it might be expected that an interruption of this kind would result in a serious disruption in the traffic flow, this is by no means inevitable as the tape boxes associated with the outgoing lines will normally be holding a number of messages whose retransmission will continue until all the waiting messages have been sent. Furthermore, the cross-office speed through the switching equipment is many hundred times the line speed, so that, when the switching equipment is restored to service, the backlog will be taken up relatively quickly.

It is evident that the overall system requirements have a basic influence on the storage arrangements and that there is considerable flexibility for meeting widely differing traffic conditions.

4. *Traffic Calculations*

In an electronic switching system such as STRAD, in which one connecting link can usually carry all the traffic, the only circuits for which quantities have to be calculated are the stores. However, the stores may represent a considerable percentage of the initial cost of the equipment

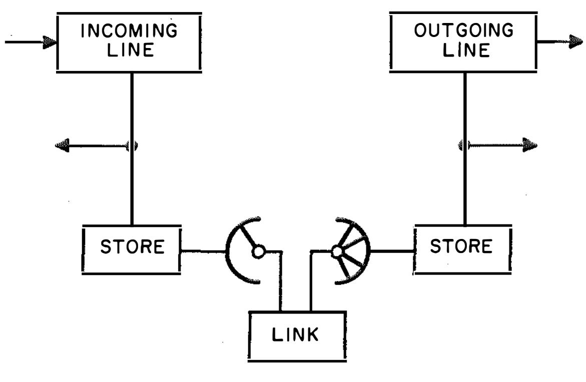


Figure 14—Block diagram for STRAD with line stores.

and as a consequence the quantity calculations merit careful examination.

If the storage is provided on a line basis rather than on a common storage basis, there is no need for calculation because the capacity required can be stated directly.

The conditions are different in the cases for which common storage is provided. If, for example, drum tracks are used, and if the average message length is shorter than the drum track, then the traffic in erlangs can be taken as the product of the number of messages multiplied by the holding time of the store expressed in hours. Normally this holding time will be the delay before the message is retransmitted, and Figure 15 shows this delay in relation to the message

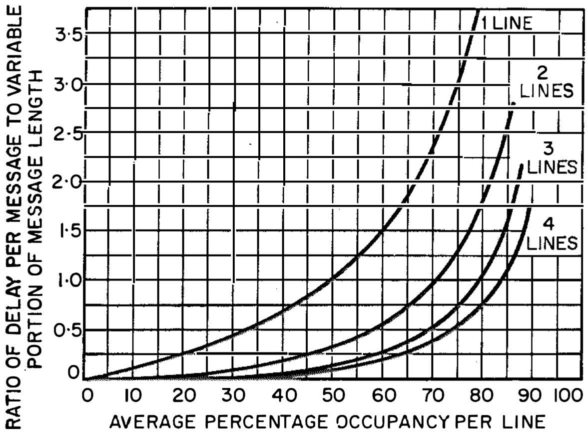


Figure 15—Average delay per message as a multiple of average message length in respect to occupancy for different line groups.

length and the line occupancy. The number of stores needed for this traffic at any specified loss can then be calculated from available probability curves.

Similarly, if the average message length necessitates 2 drum tracks, the traffic will be approximately 2 multiplied by the number of messages, multiplied by the holding time of each track. It is necessary to point out that, if the average message length is exactly twice the capacity of a drum track, it is not reasonable to assume that the average number of tracks required will be 2; there will be many messages of less than average length that still require 2 tracks and many messages of more than average length that require at least 3 tracks. The correct quantity is, therefore, likely to be nearer $2\frac{1}{2}$ tracks per message than 2. An exact answer can be obtained only by examining the distribution of holding times during the busy hour.

When common storage is provided by ferrite cores the calculation is more involved because

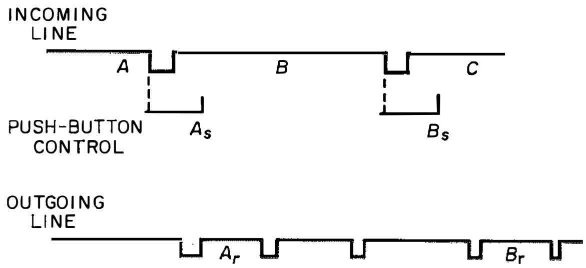


Figure 16—Message retransmission with push-button control of incoming messages.

the size of the store section is not controlled mechanically and its optimum value has to be calculated. The store traffic will approximate to the average message length (in words) divided by the store section capacity (in words), plus a half, and multiplied by the holding time of the store section. In the earlier example the holding time is substantially the average delay before retransmission commences. In the case of the ferrite store the holding time is the average delay plus the time taken to empty the store. If the cadence speed for filling the store is lower than the autocadence speed for emptying the store, then the holding time for each store section used for the average message will be different and a separate calculation will be necessary for each. Figure 16 shows a message B received at low cadence speed, directed by push-button control at B_s and retransmitted at B_r at autocadence speed.

Having calculated the traffic on the lines indicated above, the number of stores can be determined for any appropriate loss probability. However, it will sometimes happen that no free store is available when needed, and there is no simple way of indicating to the sender that his message has not been wholly recorded. This state of affairs cannot be satisfactorily overcome by reducing the loss probability to 1 in 100 000 or 1 in 1 000 000 because the congestion may be introduced by abnormal delays that are much more severe than the average traffic flow on which the loss calculations are based. Relief can be obtained, however, because the percentage occupancy of the whole common store can be continuously monitored by automatic means, and, as soon as some predetermined value is reached, overflow circuits can be introduced to transfer some of the waiting messages to tape storage. Figure 17 shows a small-capacity low-speed magnetic-tape machine. These messages can be returned to the store as soon as the occupancy falls to some second predetermined value. The messages temporarily withdrawn in this way may be subjected to some extra delay, and in consequence it is clearly desirable that the messages selected should be of low precedence.

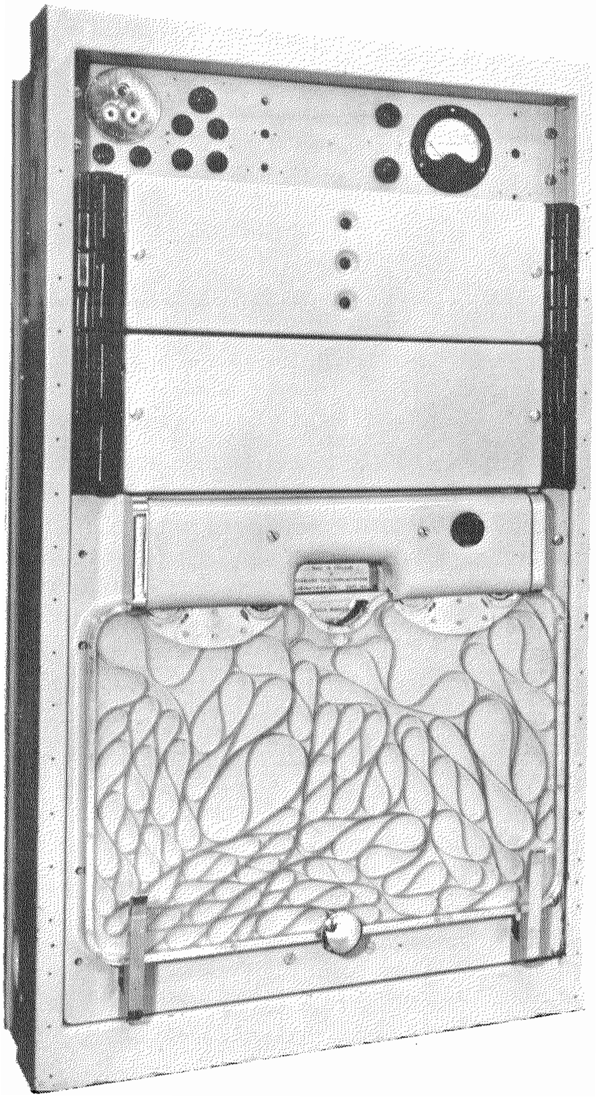


Figure 17—Small-capacity magnetic-tape machine.

In the foregoing description the average delay before retransmission commences has been mentioned. This average delay has to be determined from data providing the occupancy of the outgoing lines and the average holding time of the messages (see Figure 15). In the case of multiaddress messages, only one message needs to be counted, but the holding time will be influenced by the number of retransmissions that have to be made. The delay times in all cases increase steeply as the outgoing line occupancy approaches 100 per cent, and, if the traffic offered to a line exceeds 100 per cent during a busy hour, there will inevitably be some overflow to the following hour. This fact emphasizes that from the point of view of the store the busy hour is not necessarily the hour in which most messages occur but the hour in which most messages are awaiting retransmission. The busy-hour traffic will vary from the mean each day, and it is unfortunately necessary to collect reliable statistics of these variations if an accurate estimate is to be made of the storage requirements. The advantage of common storage is striking in this connection because, instead of having to collect statistics about each line, it may be sufficient to take the overall traffic and to estimate the average message delay while awaiting retransmission for all lines because it is of little importance which line has the greatest delay if the distribution pattern is known.

5. *Electronic Switching*

The electronic switching equipment employed is basically the connecting link between the lines and store. In the cases in which a common store is provided, a switch on one side of the connecting link gives access to the different parts of the store, while on the other side of the link there is another switch giving access to the different incoming and outgoing lines (see Figure 13). If magnetic drums are employed, then the link provides a connection for a period of about 100 milliseconds for the transfer of a track load of data and for the various control operations that are carried out at the same time. It may be calculated that it takes approximately 40 seconds at line speed to fill or empty a track, and it is, therefore, evident that even with heavy line loading a single link will be able to cater for a number of lines.

With the use of ferrite storage the arrangements are rather different because the link is provided with a character store, and it is, therefore, possible to draw a distinction between the use of the connecting link to transfer element information from the lines to the link store or vice versa and its use for transferring complete characters from the link store to the common store and vice versa. The link is set up several times per millisecond for the transfer of element information, and approximately one operation in seven includes the transfer of a complete character to or from the common store. As before, a single link circuit can handle the traffic for a considerable number of lines.

The link arrangement is different for the case in which larger stores are provided per line because it is then necessary to connect one side of the link to the incoming lines and the other side to the outgoing lines. As, however, the message may have several addresses, it is arranged that the switch on the outgoing side can make connection simutaneously to any combination of these lines.

The provision of supervisory and control facilities in the link circuit to recognize indicators and check serial numbers represents an economic arrangement because a single circuit is serving so many lines. In the cases in which a common store is used, the link is also an economic arrangement to examine and compare data because here again a single circuit is serving a number of lines (see Figure 18).

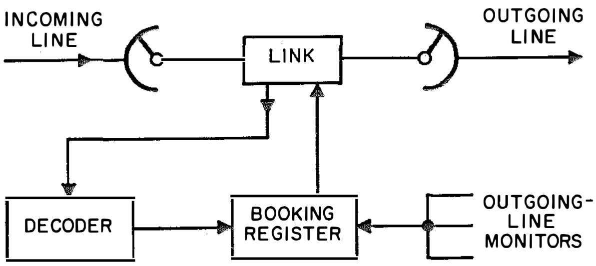


Figure 18—Block diagram of message booking and retransmission.

The means by which the connecting link makes access to the different lines is interesting to examine in some detail because there is a variation between the different cases. When there is a store associated with each line, the link switch gives access directly to these stores and in consequence there is one position for each line. On the other hand, in the case of the ferrite stores it is possible to employ space-to-time conversion in the form of a concentrator, and as a consequence the link switch only needs to give access to these concentrator outlets or inlets and not to the lines. In the case of the incoming circuits some 16 or 20 lines are grouped on a single concentrator which has an outlet providing in multiplex form the mark/space condition of these lines that the link circuit receives and distributes to the different character stores that it contains. Somewhat similarly on the outgoing side the multiplex lead is informed of the mark/space-element conditions to be transmitted by each of the lines in the group, and it is one function of the outgoing concentrator to distribute these signals to the different lines in the group.

The use of these concentrators, therefore, serves to simplify and reduce the size of the switches associated with the link and also to reduce the wiring involved in making connection to each individual line. In addition, the concentrators are used to make an economy in the hardware, that is, by providing time scales both for the examination of the lines to read the incoming data and for the corresponding process involved in retransmitting the data. To achieve this purpose the incoming-line concentrator employs a small matrix in which each row corresponds to a different incoming line. These rows are read continuously in a fixed sequence, and a number of column circuits together act as a binary counter, so that when required a unit can be added to the number read and the new value can be rewritten in the matrix. This counting operation is controlled by data also inserted in the row information as a consequence of the start element being received for each character in turn. Once this counting process is commenced by the start element it is continued automatically until the link circuit signals that it has received the complete character. The use of an electronic time scale to provide the necessary examination pulses calls for no description, but it may be explained that as a consequence of the examination the condition of the line is also recorded in a storage element in the row associated with the line examined; this information is held available until the link circuit is in a position to ask for it. The introduction of this element storage in the matrix associated with the line concentrator allows the latter to operate at a repetition rate that is sufficiently high to reduce the ratchet error (introduced by the sequential examination of the lines) to a small fraction of a millisecond, which is of minor consequence. On the other hand, the effective repetition rate of the link can be reduced to that necessary for collecting and distributing the elements of the different characters received from the incoming lines. The repetition rate used for the link may be increased with the number of concentrators connected, but for centers having fewer than 120 lines this repetition rate is still much lower than that of the concentrators. This lower rate provides an advantage in allowing more time for the entry and withdrawal of characters to and from the common store.

The concentrator principle is also of interest for the control of a number of way stations on an omnibus line. One way of operating such an arrangement includes interrogating the stations in turn to ascertain whether they have a message waiting for transmission. The storage matrix can be used in conjunction with a set of column circuits to act as a distributor so that each station is signalled in turn. It will be appreciated that it is also necessary to design this distribution arrangement so that each new interrogation commences at the point at which the previous one ceased. It is a simple and economical arrangement to maintain the data in a row of a ferrite matrix and to employ common column circuits for processing this information at the proper times.

6. *Message Length*

There is no fundamental restriction on the length of message that can be accepted, but there are practical reasons for fixing a limit. For example, a long message of low precedence may hold up the retransmission of a more urgent message unless facilities are provided for interrupting messages in process of retransmission.

Furthermore, in the event of a failure to recognize the end-of-message indicator, due to distortion, an alarm can be introduced when reception exceeds the maximum length; for accounting and statistical purposes, facilities can also be provided for measuring the number of words in a message.

7. *Flexibility*

There is no restriction on the character combinations that may be chosen for the start-of-message, the end-of-message, or the end-of-routing indicators and similarly there is no restriction on the number of letters or on the combination of letters and figures used for the routing indicators. A booking register is used to record particulars of messages received and to provide translation facilities for relating the routing indicators with the lines or trunks with which they are associated. The booking register is connected to a link via a decoder, as shown in Figure 18, and is used for initiating the retransmission of messages under the control of the available outgoing lines.

The translator circuit in the booking register is designed in such a way that the routing indicator combinations and their line associations can be changed from time to time without any equipment or wiring rearrangment. This is not intended as a saving in material but rather as a means of avoiding any instability in service that could result from making physical modfications in the field. It will be appreciated that certain advantages can be obtained by choosing routing indicators that are abbreviations of the names of the organizations concerned because this will lead to simpler and shorter messages. On the other hand, there is some advantage in choosing routing indicators so that the first few characters identify the switching centers, and thus the translator has a much simpler function to perform. If codes are being selected to suit the switching system, it is advisable to choose a series that permits error indication by parity checking.

Arrangements can be made for STRAD to remove from message retransmissions the routing indicators corresponding to stations for which retransmission has been provided elsewhere. This is a rather-more-complex arrangement than causing the translators to obey a program that orders that certain predetermined indicators are disregarded on messages from other switching centers. In both cases facilities are provided for changing the program to admit alternative routes introduced as a consequence of congestion.

Arrangements can also be made for the automatic "erasure" of surplus incoming-channel identification and message numbers from the retransmitted message. The facility might be useful in large networks employing a number of interconnected switching centers to eliminate the cumulative build-up of the original message preamble.

For networks employing several precedence categories, a "break-in" facility can be provided to ensure that a message in course of retransmission can be interrupted to allow one of higher precedence to be cleared. This facility is probably only worth consideration for networks handling long messages, and it is evident that a message of the highest precedence should not interrupt a message of equal importance.

These different facilities are made economically practicable because they can be applied to the messages as they traverse the link at a speed of 50 kilobauds (approximately 83 000 words per minute with the 5-unit teleprinter code).

The line terminal conditions for STRAD are unrestricted. The system is designed for duplex channelling, both lines and trunks having independent send and receive channels. The line terminations may employ either manual keyboard transmission or autotransmission. The lines can be associated with one or a number of stations. The trunks can terminate in torn-tape, push-button, or automatic switching systems. For radio channels it is likely that the problems of propagation, frequency changing, and interference will make it desirable to employ reperforators and autotransmission.

8. Monitoring and Supervision

On a push-button system the operator can either book the direction for a message when it appears in the text or she can wait until she has checked that the message is correctly terminated before booking. With automatic switching it is arranged that any message with an unidentified precedence or routing indicator is passed to the supervisor who can reinsert it into the system with push-button indications of the action to be taken.

In addition a record is made of the essential parts of the preamble of all incoming messages; a separate record of outgoing messages provides a cross reference of channel-identification serial numbers. A record can also be produced on request of all waiting messages.

Facilities can be provided for periodic line testing so that in the absence of a message for some predetermined period a signal is generated asking for a test message. A copy of this request is sent to the supervisor. If no response is forthcoming within a reasonable period, an alarm is given so that the line can be tested.

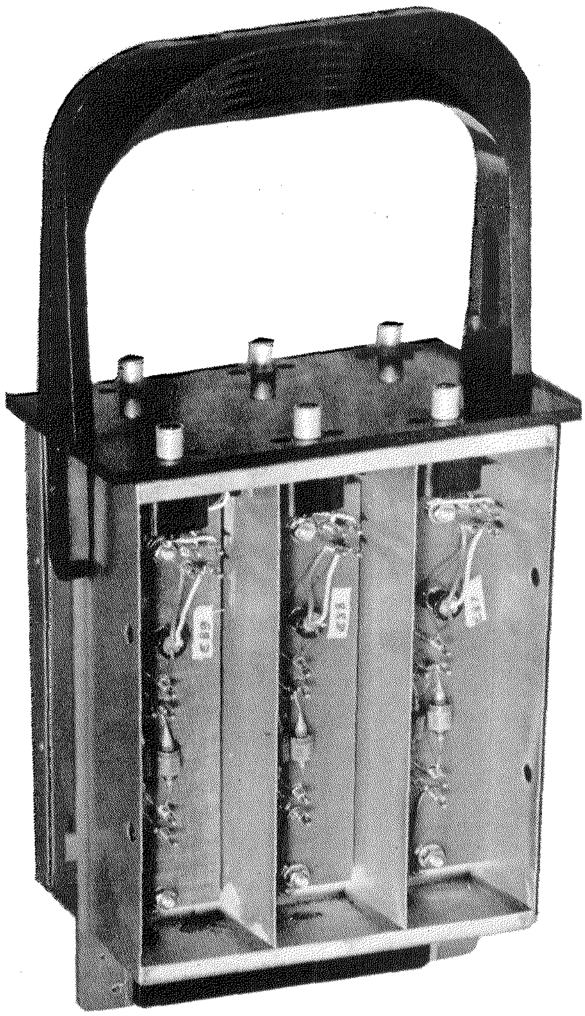


Figure 19—Typical switching unit.

9. Hardware

It would have been possible to present this paper with the main emphasis applied to the components. It is true that the components are of extreme importance in respect to performance, but STRAD does not depend on a particular range of components and the system could employ hard tubes, gas tubes, or transistors for the logical functions. It has been mentioned elsewhere that different types of storage devices may be used. It is of interest to state that in all cases symmetrical transistors are employed for switching purposes, and Figure 19 shows a typical switching unit.

10. Conclusions

It may well be argued that no worthwhile conclusions can be reached about a new switching system until field experience has demonstrated practical results. Nevertheless it is pertinent to observe that most of the electronic technique used in STRAD has already been used elsewhere and that this part of the development is not therefore new but in line with progress on digital computers and other data-processing systems.

A major question that arises with any new system employing entirely different components is whether it represents merely a stepping-stone in a long-term development or whether it constitutes a significant advance justifying immediate adoption. In this connection it should be pointed out that contemporary component development is very likely to provide either better or cheaper components that can be incorporated as they become available. It is difficult to forecast whether entirely new components will render the design of the system obsolete within a few years, but it will be difficult to justify any higher cost for components capable of operating at a higher speed because in most respects the speed of existing components is adequate.

11. Acknowledgments

The author acknowledges the assistance of many colleagues in Standard Telecommunication Laboratories Limited and Standard Telephones and Cables Limited, and in particular that of Mrs. E. Loverseed.

12. References

12.1 E. P. G. Wright and J. Rice," Probability Studies Applied to Telecommunication Systems with Storage," Proceedings of the First International Congress on the Application of the Theory of Probability in Telephone Engineering and Administration, Copenhagen, Denmark; June, 1955: also, *Electrical Communication*, volume 33, pages 308–321; December, 1956.

12.2 R. M. Kalb, "Electronic Processing of Air-Traffic-Control Information," *Electrical Engineering*, volume 74, pages 374–377; May, 1955: also *Communication and Electronics*, number 18, pages 152–155; May, 1955.

Basic Considerations in Calculating Storage for an Electronic Telegraph Switching Center*

By E. P. G. WRIGHT

Standard Telecommunication Laboratories Limited; London, England

OUTSTANDING among the features of an electronic switching center employing time sharing is that there is little necessity to calculate switch quantities to satisfy traffic requirements. A single highway can be used for a number of channels, and the determination of how many channels is partly influenced by traffic considerations but predominantly by the maximum pulse repetition frequency that is acceptable. However, the amount of storage to be provided for messages awaiting retransmission does constitute a calculation that is comparable with the switch quantity calculations undertaken to determine the number of registers necessary for a telephone exchange. Accurate storage calculations are a matter of basic importance both in relation to the initial cost and to the annual charges. For a system in which the storage requirements are modest, because the delays before retransmission are short, the cost of the store may represent less than half that of the whole center; but if the delays are long and there is a requirement to store hundreds or thousands of messages, then the majority of the cost of the center will lie with the storage equipment. Extra operating expenses will be involved in relieving the store manually if and when the store capacity proves to be inadequate.

1. Switch Calculations for Electronic Systems

To derive the amount of traffic to be stored, design curves[1] have been established from the number and occupancy of the outlets from the center, and from the time distribution of the message lengths. It is of interest to observe that the average message delay is a function of the variable part of the message length, and that the average delay can be appreciably reduced if there is an effective maximum message length of approximately 20 minutes.

Most design curves imply that with a circuit loading of 100 per cent the average delay will reach infinity, and before examining the calculations of storage capacity it is desirable to pay some attention to the question of outlets that are offered messages totalling 60 minutes in an hour.

2. Busy-Hour Traffic

2.1 Message Accumulation

It is evident that, if 60 minutes of messages to be retransmitted are presented during the busy hour, the number of message minutes awaiting retransmission at the end of this busy-hour period (MMAXE) cannot be less, but may be greater, than the number of message minutes awaiting retransmission at the initiation of this period (MMAXI). If there is a succession of such busy-hour periods following one another, the final MMAXE will be determined by the busy hour in which the distribution of messages is most irregular and none of the other hours will have any effect on this final MMAXE.

The irregularity of the incidence of messages has an unfavourable influence if at any time during the hour there remain no messages available for retransmission and as a consequence line time is wasted. As the number of hours is increased, the greater is likely to be the irregularity in any one hour. Conversely, the greater MMAXI becomes, then the greater is the likelihood of the traffic in an hour maintaining continuous retransmission. In fact, if MMAXI reaches 60 (minutes), it is no longer possible to experience a break in retransmission however irregularly the messages appear.

* Presented at the International Teletraffic Congress (Second International Congress on the Application of the Theory of Probability in Telephone Engineering), The Hague, Netherlands; July, 1958.

[1] E. P. G. Wright and J. Rice, "Probability Studies Applied to Telecommunication Systems with Storage," Proceedings of the First International Congress on the Application of the Theory of Probability in Telephone Engineering and Administration, Copenhagen, Denmark; June, 1955: also, *Electrical Communication*, volume 33, pages 308–321; December, 1956.

2.2 100-Per-Cent Busy-Hour Occupancy

It is necessary to consider what is meant by 100-per-cent busy-hour occupancy. It must certainly include the case in which 60 minutes of retransmission are offered during the busy hour, but should it not also include the case in which 24×60 minutes of retransmission are offered during the day? This broader conception is again capable of further analysis:

A. A smooth intensity of 100-per-cent occupancy.

B. A random condition in which peaks occur at certain specified periods of the day.

C. A random condition in which peaks occur at random periods of the day.

A smooth intensity over a number of successive hours must be accepted under the term 100-per-cent occupancy.

If peaks occur at certain specified periods of the day, only these periods should be considered in calculating the busy-hour traffic, and the traffic offered during these periods must exceed 100-per-cent occupancy.

If the peaks occur at random times, there are two precedents to consider:

A. The recommendations made by the Comité Consultatif International Télégraphique et Téléphonique for semi-automatic traffic; in principle these recommendations would accept the condition as 100-per-cent occupancy.

B. The procedure followed by certain administrations according to which only the busiest hour in each of a succession of days is considered. With this interpretation the traffic condition would exceed 100-per-cent occupancy.

TABLE 1
Throwdown Calculations

MMAXI	MMAXE			Message Delay in Minutes (Average over hour)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
0	0	12·19	21·74	5·02	8·94	13·89
3	3	12·44	21·74	5·02	9·04	13·89
6	6	12·86	21·74	5·03	9·77	15·70
9	9	13·22	21·74	5·23	11·09	18·71
12	12	15·59	21·74	5·43	12·70	21·71
15	15	16·76	21·74	6·77	14·51	24·71
18	18	18·67	21·74	8·57	17·26	27·71
21	21	21·06	21·74	10·37	19·94	30·71
24	24	24·00	24·00	13·17	22·89	33·71

Average message length = 4 minutes
Maximum message length = 20 minutes
Minimum message length = 48 seconds
Message length distribution = exponential
Number of hours observed = 12
Messages per hour = invariably 15

TABLE 2
Percentage Distribution of Individual Message Delays in Throwdown Described in Table 1

Delay in Minutes	Per Cent	Delay in Minutes	Per Cent
0	17·75	13–14	2·5
0–1	2	14–15	2
1–2	5·5	15–16	3·25
2–3	7	16–17	3·75
3–4	9·5	17–18	3·25
4–5	3·25	18–19	6·5
5–6	5·5	19–20	2
6–7	2	20–21	2
7–8	1·75	21–22	1·75
8–9	7	22–23	2
9–10	1	23–24	0·5
10–11	2	24–25	0
11–12	2	25–26	1
12–13	3·25		

For the purpose of determining the store capacity, it is impractical to take the average traffic over a period but essential to consider the peak conditions within this period. These peak conditions are not caused solely by the messages offered during the most intense 60-minute period because the storage requirements are likely to be influenced to an important extent by the MMAXI value, as will be seen from Tables 1 and 3.

The MMAXI value is dependent on the intensity and irregularity of the traffic during one or a number of preceding hours, and as a consequence storage requirements should not be based on the estimated delay for the traffic in any single busy hour but rather on the maximum number of message minutes likely to accumulate in a sequence of hours.

The most general case arises when the average of the busiest hour of a number of consecutive working days in the busy season equals 100-per-cent occupancy. In such a case there will be many hours above (and below) the average. There is likely to be a small chance, say 2 per cent, of the load reaching 150 per cent in one hour. It is evident that with 150-per-cent loading the MMAXE cannot be less than 30; the likelihood that there will occur pauses, during which there are no messages to transmit, must be less than with 100-per-cent loading, and it therefore seems unlikely that the MMAXE will often exceed 40 or 45. If two such hours follow one another, the MMAXE is likely to reach approximately 75.

3. *Throwdown*

It is a tedious undertaking to make a throwdown under the above conditions because the maximum MMAXE and delays will arise only in a small percentage of the hours examined, and yet all must be calculated to find the overall average. The results quoted in Tables 1 and 3 relate to throwdowns with an invariable loading of 100 per cent and may be considered as typical examples of excessive traffic hours from a group whose average is only approximately 75-per-cent loading. A number of throwdowns with 100-per-cent loading have been made, and from these throwdowns two sets of results are used to illustrate the typical accumulation of message minutes awaiting retransmission as a consequence of 100-per-cent loading during one or more busy hours.

3.1 4-Minute Messages

It should be stated for Table 1 that the busy hour that gave the maximum MMAXE figures also provided the minimum message-delay figures, while the hour responsible for the minimum MMAXE figures corresponded to the hour providing the maximum message-delay figures above the MMAXI figure of 3. In the first case the bulk of the messages occurred late in the hour, whereas in the second case the bulk occurred early in the hour.

TABLE 3

THROWDOWN CALCULATIONS

MMAXI	MMAXE			Message Delay in Minutes (Average over hour)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
0	3·76	5·36	9·18	2·80	3·72	4·37
3	3·76	5·36	9·18	3·17	4·41	6·10
6	6·00	6·53	9·18	3·54	5·67	8·75
9	9·00	9·02	9·18	6·54	8·67	11·75
12	12·00	12·00	12·00	9·54	11·67	14·75

Average message length = 40 seconds
Maximum message length = 20 minutes
Minimum message length = 5 seconds

Message length distribution = exponential
Number of hours observed = 6
Messages per hour = invariably 90

TABLE 4

PERCENTAGE DISTRIBUTION OF INDIVIDUAL MESSAGE DELAYS IN THROWDOWN DESCRIBED IN TABLE 3

Delay in Minutes	Per Cent	Delay in Minutes	Per Cent
0	3	7–8	9
0–1	8	8–9	10·5
1–2	11·5	9–10	3·5
2–3	15	10–11	0·2
3–4	12	11–12	0·2
4–5	9	12–13	0·4
5–6	10	13–14	0·2
6–7	7·5		

In Table 2 it is to be noted that with 60 minutes of message retransmission offered in each hour (100-per-cent loading) 17.75 per cent of the messages were retransmitted without delay. The increased delay apparent around 15–19 minutes is a consequence of the longest message present in each of the hours having affected several messages immediately following. This distribution is made assuming an MMAXI figure of 3; it can be seen from Table 1 that the delays would not have been seriously altered if a figure of 0 or 6 had been taken.

If the storage requirements are associated with the MMAXE figures, it would seem that for a single hour it would be sensible to assume a figure of about 16 minutes, for two successive hours perhaps 19 minutes, and for more successive hours perhaps 21 minutes. It is evident that a 12-hour throwdown is insufficient to indicate the worst irregularity that can occur, but it is probably unnecessary to cater for an irregularity that rarely manifests itself. A further point for consideration concerns the probability of similar peaks occurring on the different outlet groups simultaneously; this factor is of interest, particularly if the store is common to many outlet groups.

3.2 40-Second Messages

For Table 3 it should be stated that the busy hour that gave the maximum MMAXE figures also produced the minimum message-delay figures.

The delays shown in Table 4 are consequent on an MMAXI figure of 3.

4. *Influence of Message Length and Number of Traffic Sources on Delay*

4.1 Message Length

It can be seen from examination of Tables 1 through 4 that in general the shorter average message length will result in shorter message delays; this is apparent with all values of MMAXI for the maximum delays but only with the low values of MMAXI for the minimum and average delays. For the MMAXE figures there is a 2:1 ratio for the maximum but little difference for the minimum. It is perhaps surprising that the percentage of messages not delayed is much greater with the longer holding time. As the ratio of the holding times is 6:1, it is evident that no linear relation exists. If the average message holding time is increased to an impractical figure, such as 30 minutes, it is difficult to imagine the MMAXE going beyond 30.

4.2 Number of Traffic Sources

It is logical to assume that the greater the number of potential sources the less will be the chance of several messages coming from the same source within a busy hour. The examination of the subject is complex because, even if it can be established that, say, 25 or more sources are involved, it is unlikely that they will each offer the same percentage of the traffic. If several messages are habitually offered from the same source, then the chance that these messages will delay one another is eliminated because any such delay will occur at the source and not at the switching center. If there is only one source there will be no delay. This condition is likely to be somewhat artificial and one that will have little influence on the provision of storage equipment. Also it must mean that 100-per-cent loading from one source is not the average of several hours but the loading of either one hour or each of a number of hours.

4.3 Throwdown for 20, 10, and 5 Sources

The throwdown described in Table 1 has been repeated with 20, 10, and 5 sources, and the results appear in Table 5. It should be added that the number of sources had no influence on the minimum, average, and maximum MMAXE values.

The change in message-length distribution is of interest; with only 5 sources, about 25 per cent of the delays exceeding 19 seconds are reduced below this duration while another 20 per cent are reduced but not sufficiently to fall below 19 seconds. Furthermore, the percentage of messages with no delay increases to 20 per cent by virtue of certain follow-on messages that occur as the outgoing circuit becomes free.

It may be observed that the reductions in average delay are not varied by the MMAXI values. If the average delay with infinite sources is taken from Table 1 as 9 minutes and a curve is drawn of the average delays from Table 5 to terminate in no delay with one source, it will be found that the curve approximates to:

$$d_n = d_\infty - \frac{d_\infty}{n}$$

where d_n is the delay from n sources when the delay with infinite sources is d_∞.

This equation appears logical for examples in which most of the delayed messages have to wait for only one previous message to be completed. In such examples, with messages derived from many sources, the messages may be assigned to one or other of two empirical sources, and it will be seen that half of the message delays will then occur at the source rather than at the switching center. For the cases in which a message has to await the completion of more than one previous message, it will still be found that, when there are only two sources, half of the delayed messages will be delayed at the source.

It may well be found from traffic examination that a particular outlet receives 50 per cent of its busy-hour messages from one source whereas the remainder may be contributed from many other sources. The reduction due to the 50 per cent from one source would be equivalent to an outlet supplied from 4 sources because 25 per cent of the delay is eliminated. If the percentage of the traffic from one source rises to 80 per cent, then 64 per cent of the delay is removed. If the remaining 20 per cent of the messages all come from a second source, it will result in only 68 per cent of the delay being removed.

TABLE 5

COMPARISON OF DELAYS WITH DIFFERENT NUMBERS OF MESSAGE SOURCES

MMAXI	Message Delay in Minutes								
	20 Sources			10 Sources			5 Sources		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
0	Table 1	Table 1	13·61	Table 1	Table 1	13·61	Table 1	Table 1	13·32
3	Values	Values	13·61	Values	Values	13·61	Values	Values	13·32
6	Minus	Minus	15·40	Minus	Minus	15·40	Minus	Minus	15·40
9	0·26	0·24	18·40	0·26	0·75	18·40	0·26	1·38	18·40
12			21·40			21·40			21·40

5. *Abnormal Overload*

A condition for which storage equipment may have to be designed is that in which for one or more outlets there may be consistent overloading on possibly only one day of the week. It is evident that the MMAXE value will mount hour by hour so long as the overload persists. This increase will be largely determined by the extent to which the messages offered for retransmission exceed 100-per-cent loading, but there will also be a contribution due to the irregularity of the traffic flow at the time when the traffic intensity exceeds the 100-per-cent level. A reasonable idea of this increase can be estimated from Tables 1 and 3. It is evident that the overload may be accommodated by storage until the traffic slackens or by withdrawing the messages from the store for retransmission by courier or other means.

6. *Optimum Size of Store Sections*

6.1 Use of Store Sections

Torn-tape telegraph switching systems involve the storage of messages, but the very nature of the record made on punched paper tape ensures that the tape can be used only for a single message and as a consequence the provisioning of tape becomes a question of how many rolls will be required per week or month rather than how much simultaneous storage capacity is necessary.

Electronic stores have the inherent advantage that they can be used over and over again, and in consequence there arises the question of how much capacity will be required for the peak traffic condition.

It is quite unrealistic to make an electronic store with a number of sections each of sufficient capacity to accept a message of maximum length. A reasonable compromise is obtained by determining the optimum store-section size and making arrangements for each message to use as many store sections as may prove to be necessary.

6.2 Holding Time of Store Sections

The effective holding time h of a store section for a message should include allowances for the time needed for the identification of the addressee t_1, for the period d that elapses until the outgoing circuit is free, and for the time needed for retransmission t_2. The holding time may therefore be written as:

$$h = t_1 + d + t_2. \quad (1)$$

If the input speed is higher than the output speed, (1) remains correct, but if the input speed is lower than the output speed it may be desired to await the end of the message before allowing retransmission to commence. In this case the holding time will be:

$$h = t_3 + d + t_2 \quad (2)$$

where t_3 is the time taken to receive the message.

If on the other hand retransmission is permitted to commence at once, then the holding time will be whichever is the greater of $(t_1 + d + t_2)$ or (t_3).

6.3 Factors Influencing Store-Section Size

It is inevitable that if a message uses a number of store sections the last of these store sections will on the average be only half filled. The percentage of the storage capacity that may be wasted in this way will tend to decrease as the size of the section is reduced.

Furthermore, the time t_2 will be influenced by the store-section size, and, unless the value of d is much greater than t_2, it is likely that the total store capacity can be substantially reduced by keeping t_2 reasonably small. It will be appreciated that neither t_1, d, nor t_3 is affected by the size of the store section.

These arguments would appear to favour a very-small store section, but there are two reasons for not making the section too small. In the first place, for every store section filled it will be necessary to record where the message is continued; and in the second place it will be necessary to choose free store sections for continuation and to indicate that they are engaged until they become available for reuse. Both these functions involve an amount of hardware proportional to the number of store sections.

6.4 Comparison of Store-Section Sizes

6.4.1 *Ferrite Matrix*

It is easy to make a size comparison when apparatus such as a ferrite matrix is used for storage. Assuming that each row of the matrix

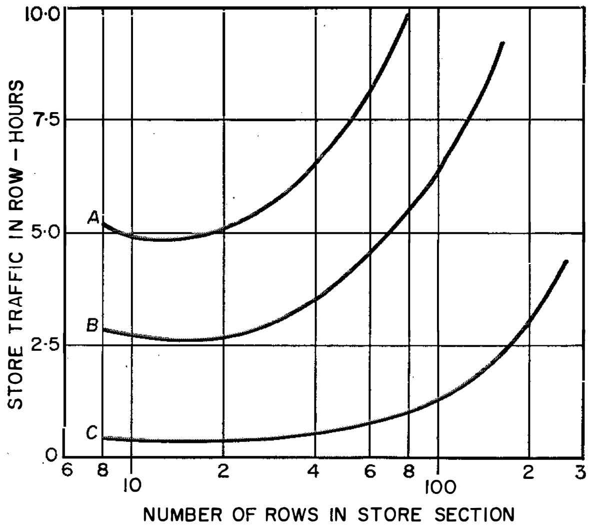


Figure 1—Determination of optimum store-section size, with a delay of 22·5 seconds between receiving and retransmitting. $A = 1950$, $B = 1050$, and $C = 150$ characters in each message. There are 5 characters per matrix row.

contains 5 characters and that the cost of continuation and supervision is equivalent to 4 rows of storage equipment, then, using the following equation, it is possible to compare different store-section sizes with the respective "row-hour" store quantities for particular lengths of message and delay:

$$S = \frac{n(R+4)(d+t_1) + (R+4)(t_2)}{3600} \quad (3)$$

where

S = store traffic in row-hours
n = number of store sections taken into use
R = number of rows in store section
$d + t_1$ = delay in seconds before retransmission commences, and
t_2 = time in seconds taken to retransmit the message.

Figure 1 shows a family of curves for messages with average lengths of 1950, 1050, and 150 characters, all with a delay of 22.5 seconds between receiving and retransmitting. As an example, if each store section includes 40 rows, each of 5 characters, then 200 characters can be accommodated, and for a message of 1050 characters 6 sections are needed. If each section has capacity for only 100 characters, then 11 sections are needed. However, if each section has capacity for 150 characters it is not sufficient to provide 7 sections, but 8, because it must be assumed that on the average the last section is only half filled.

The curves in Figure 1 show, for varying store-section sizes, the product of the amount of storage and the duration for which it is occupied for the 3 particular message lengths, and hence it is possible to determine the smallest load on the store for these message lengths. The optimum section size indicated by the minima of the curves in Figure 1 is expressed in numbers of rows, each containing 5 characters. The product of these two values gives the section capacity in characters and will apply also to cases in which the row is designed for more (or fewer) characters. It is evident that the longer messages need more capacity. In all cases a section of approximately 16 rows is economic and a larger section can become very wasteful.

Figure 2 shows corresponding curves for store sections with a negligible delay between receiving and retransmitting, and in this case the optimum section size decreases to about 5 rows.

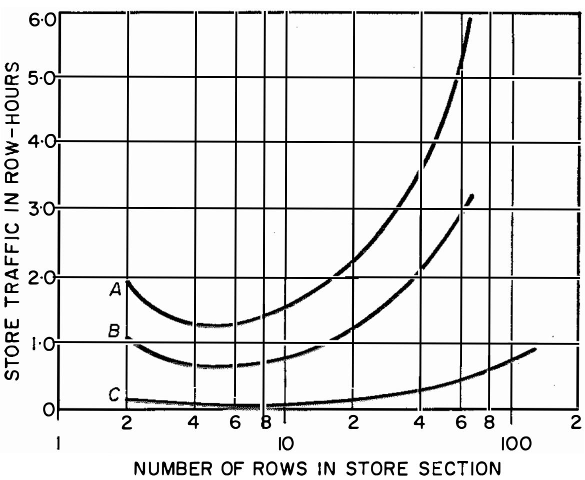


Figure 2—Determination of optimum store-section size with a delay of 2·25 seconds between receiving and retransmitting. $A = 1950$, $B = 1050$, and $C = 150$ characters in each message. There are 5 characters per matrix row.

Figure 3 shows corresponding curves for store sections in which the delay between receiving and retransmitting is 225 seconds; this increase tends to swamp t_2, and in consequence the optimum section size increases to about 32 rows.

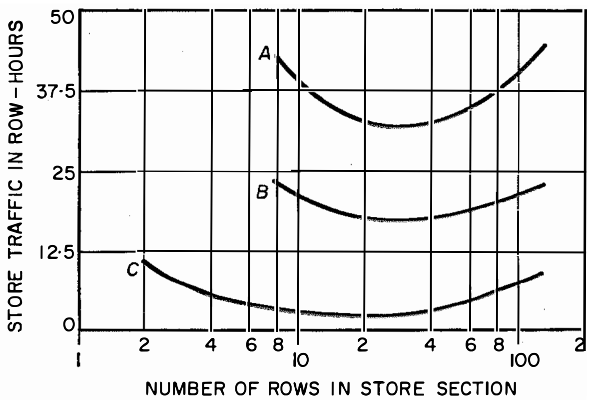


Figure 3—Determination of optimum store-section size, with a delay of 225 seconds between receiving and retransmitting. $A = 1950$, $B = 1050$, and $C = 150$ characters in each message. There are 5 characters per matrix row.

Figure 4 shows the optimum size of the store sections for a message of 1050 characters with varying delay between receiving and retransmitting. For the other message lengths the optimum number of rows does not vary by more than ± 6.

Figure 5 illustrates 4 store sections being taken into use successively during a message. After the delay period $(d + t_1)$ the message retransmission period (t_2) commences and the store sections are released in turn. It will be seen that store section 1 could be reused for the third or fourth parts of the message. It will also be seen that the last section is used for a shorter time than the others because the message did not fill this section.

6.4.2 Other Forms of Store

It is a feature of a ferrite matrix that it is possible to assume a cost per row and subsequently to make a cost comparison on the basis of the row-hour traffic that is needed as a consequence of store sections of different size.

For other forms of store, such as a magnetic drum, the division of a track into a number of different sections introduces supplementary expenses that are more difficult to assess. These extra expenses will all tend to favour rather larger store-section sizes than those shown for the ferrite matrix.

Both in the case of a magnetic drum and of magnetic tapes there are timing matters also to be taken into consideration. As an example, a message may need to be assembled in a buffer before being transferred to a magnetic-drum store; as the store section becomes smaller and smaller, the number of transfers will increase, and it is unlikely that the duration of the transfer operation can be reduced sufficiently to prevent the larger number of transfers from causing an increase in the traffic that has to be handled by the link.

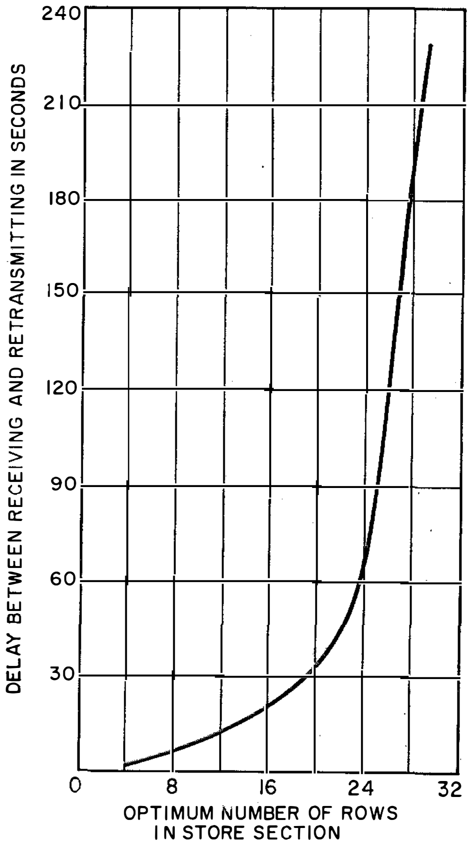


Figure 4—Optimum store-section size, with varying delay between receiving and retransmitting (1050 characters in message).

7. *Size of Common Store*

It will be appreciated that a considerable amount of data is needed to make an accurate estimate of the busy-hour traffic. The optimum size of store section does not require a precise measurement of the message length, but this length has an important influence on the average message delay. Adequate information can usually be obtained by measuring tape lengths for a number of messages. Message analysis will also provide the necessary information on the average number of characters that have to be received before the addressee can be recognised. The same analysis may also be employed to divide the average message length into the invariable pro-forma portion and the variable text portion, and also to provide an estimate of the relative number of messages addressed to one, two, three, or more addressees. This information is not likely to vary appreciably during the course of the day, but it is evident that a close scrutiny of the traffic must be made to ascertain the busy-hour period during which the store will be expected to hold most messages. Such an examination involves an hour-by-hour summary of the messages awaiting retransmission on each outlet group, and the summary will need to be taken on a succession of busy days.

After the estimate of the present-day traffic has been made it will be necessary to decide what traffic growth ought to be catered for and whether changes such as alterations in line speed

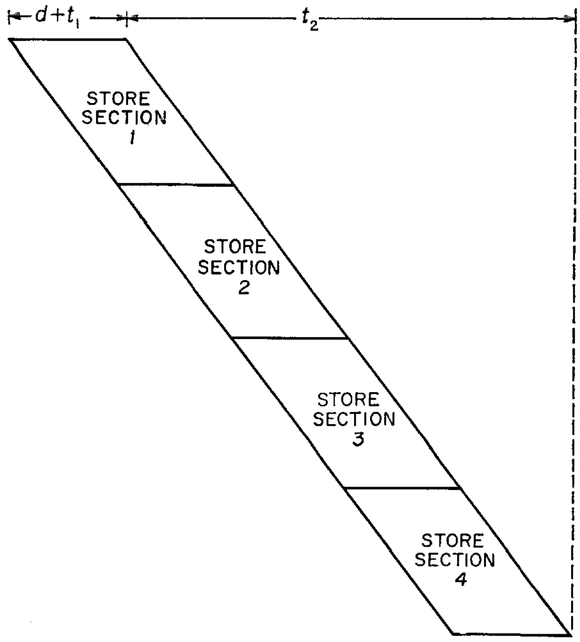


Figure 5—Relative engagement and release times of store sections during a message.

need to be taken into account. Over and above these allowances it will be necessary to make some reserve for day-to-day cases of congestion that may occur as a consequence of a failure in the line or terminal equipment.

An accurate traffic summary is difficult to produce. No two days' records are likely to be similar, and, although averages can be calculated, there is also a necessity to estimate the heaviest load likely to be experienced. This information is needed because it would be uneconomical either to cater for very-exceptional overloads or to admit frequent cases of store congestion. It is too complicated to consider giving an engaged tone when no store sections are available—a condition that may be experienced perhaps half way through a message—and it is much more convenient to make arrangements to provide an alarm when a certain degree of congestion has accumulated. To obtain relief, this alarm may be used either to restrict the incoming traffic or to initiate transfers from the common store to overflow storage machines. Such overflow machines may have a large capacity and employ magnetic or paper tape, and it is evident that the relief can be more quickly obtained if the transfer speed from the common store to the overflow store is higher than the normal line speed.

It has been explained that the common-store traffic can be calculated by (3) in terms of store-section-hours. These traffic units correspond to the call-hours in a telephone exchange and are, in effect, erlangs. By the use of well-known formulas the traffic load and a predetermined loss value will enable the quantity of store sections to be determined. In the telephone exchange example each call is considered to occupy a selector for the average holding time, whereas in the telegraph case each message is likely to occupy several store sections for a duration that may be greater or less than the message length, depending on the average delay before retransmission.

With telephone exchange traffic, message commencements and terminations are substantially unrelated occurrences, which provide something approaching a random distribution of traffic load. The use of a series of store sections for a single message introduces some interrelation, but it is not evident that the probability of instantaneous peaks will be much more pronounced as a consequence.

8. *Traffic Analysis in Electronic Switching Centers*

It is interesting to observe that the rapid processing possible with electronic equipment enables an automatic analysis to be made of messages awaiting retransmission for any particular direction. Furthermore, arrangements can be made to record various degrees of storage congestion so that data can be collected as to the periods and extent of the higher storage loads. Such methods are likely to prove of value in the future, on account of both accuracy and economy of effort.

9. *Acknowledgments*

The author acknowledges the assistance of many colleagues, in particular that of Mrs. E. Loverseed and Mr. A. D. Marr.

Shared-Channel Voice-Frequency Telegraph Equipment, UT-57/1*

By WOLFGANG A. KAISER

Standard Elektrik Lorenz A.G.; Stuttgart, Germany

TELEPRINTERS are often operated over telephone channels and a voice-frequency telegraph equipment, *UT-57/1*, has been developed for such use. Transmission may be over wire and cable lines as well as by radio.

Transistors are used exclusively. The parts are mounted on both sides of a relay panel and include the voice-frequency telegraph equipment, power supply, and a converter for direct connection to the teleprinter. The channel equipment uses 6 transistors. Level variations of ± 0.7 neper (± 6 decibels) are compensated by a fast-acting level corrector. The measured distortion during operation is $\leqslant 5$ percent and, hence, is in accordance with the recommendations of the Comité Consultatif International Télégraphique et Téléphonique for standard telegraph channels.

1. *Mode of Operation*

1.1 Combining of Teleprinter and Telephone Channels

The frequency of 2820 cycles per second, which is channel *21* of a 24-channel voice-frequency telegraph system, was selected for the carrier because some telephone channels, for instance those in radio equipment, often show a substantial increase in attenuation at 3000 cycles. To provide for the telegraph band, the high-frequency limit of the speech band was reduced to 2400 cycles. The resulting loss of syllable articulation is negligible and hardly affects the understandability of speech transmitted over the system.

The frequency scheme employed is shown in Figure 1. At both the transmitting and receiving ends, band-elimination and band-pass filters are used rather than the conventional low-pass and high-pass filters. The band-elimination filter for the suppression of speech frequencies is simpler than a comparable low-pass network and the band-pass filter can be utilized as a transmitting and receiving filter for the telegraph channel. Unlike a low-pass filter, however, the band-elimination filter does not suppress frequencies above 3300 cycles. A highly resistive attenuator decouples the band-pass from the band-elimination filter. The telegraph transmitting level must be adjusted with respect to the speech level to keep interference between the two channels as low as possible. The direct leakage from one system into the other must be kept small by providing adequate attenuation in both the band-elimination and band-pass filters. If this attenuation is insufficient, speech frequencies appearing in the telegraph channel cause irregular telegraph distortion. On the other hand, the keying spectrum generated by the modulation of the telegraph carrier will reduce the signal-to-noise ratio in the telephone channel if the band-pass filter does not properly attenuate the frequencies outside of its pass band. Both effects can be minimized by suitable dimensioning of the filters.

The disturbances caused by nonlinearity of the transmission system are of a more-serious nature. The third harmonics of all speech-frequency components lying near 940 cycles generate interference in the telegraph channel. This is true also for the second harmonics of frequencies around 1410 cycles. Harmonics generated in the common transmission path are not affected by the filters and the only remedy is to make the telegraph transmitting level high compared with the speech level, for a given distortion coefficient of the transmission system. Nonlinearity of the transmission system will also reduce the clarity of speech through the generation of spurious frequencies resulting from the beating of telegraph frequencies with various voice frequencies during simultaneous transmissions. Also, a high telegraph level re-

* Originally published in German under the title, "Das Einkanal-Überlagerungstelegraphiegerät UT-57/1," in *SEG-Nachrichten;* volume 6, number 3, pages 146–149; 1958.

duces the damaging effects of line noise on the telegraph distortion. On the other hand, to assure a good signal-to-noise ratio in the speech path, the telegraph level must not predominate. The optimum telegraph level was found to be 0.2 neper (1.7 decibels) below the reference level of the speech path. Since this zero level is rarely reached in normal speech, the telegraph level is relatively high. These signal levels permit the use of transmission paths subjected to substantial distortion and strong interference as might be encountered in radio links. The band-pass filter was so dimensioned that a signal-to-noise ratio of 6 nepers (52 decibels) is safely maintained despite the relatively high telegraph level.

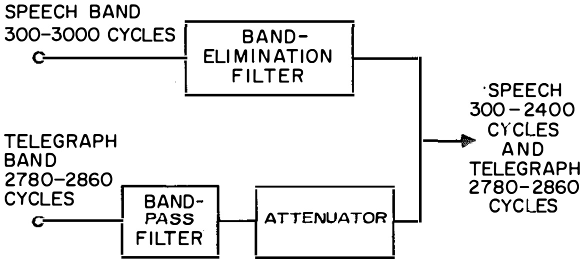


Figure 1—Arrangement of telephone and telegraph frequency bands in a telephone channel.

The sum of the telegraph and speech levels must not exceed the point of overload of the transmission system; otherwise, inadmissibly high distortion would result. To eliminate this danger, a limiter was provided at the input of the band-elimination filter to prevent any speech peak from exceeding the reference zero level by more than 0.2 neper (1.7 decibels).

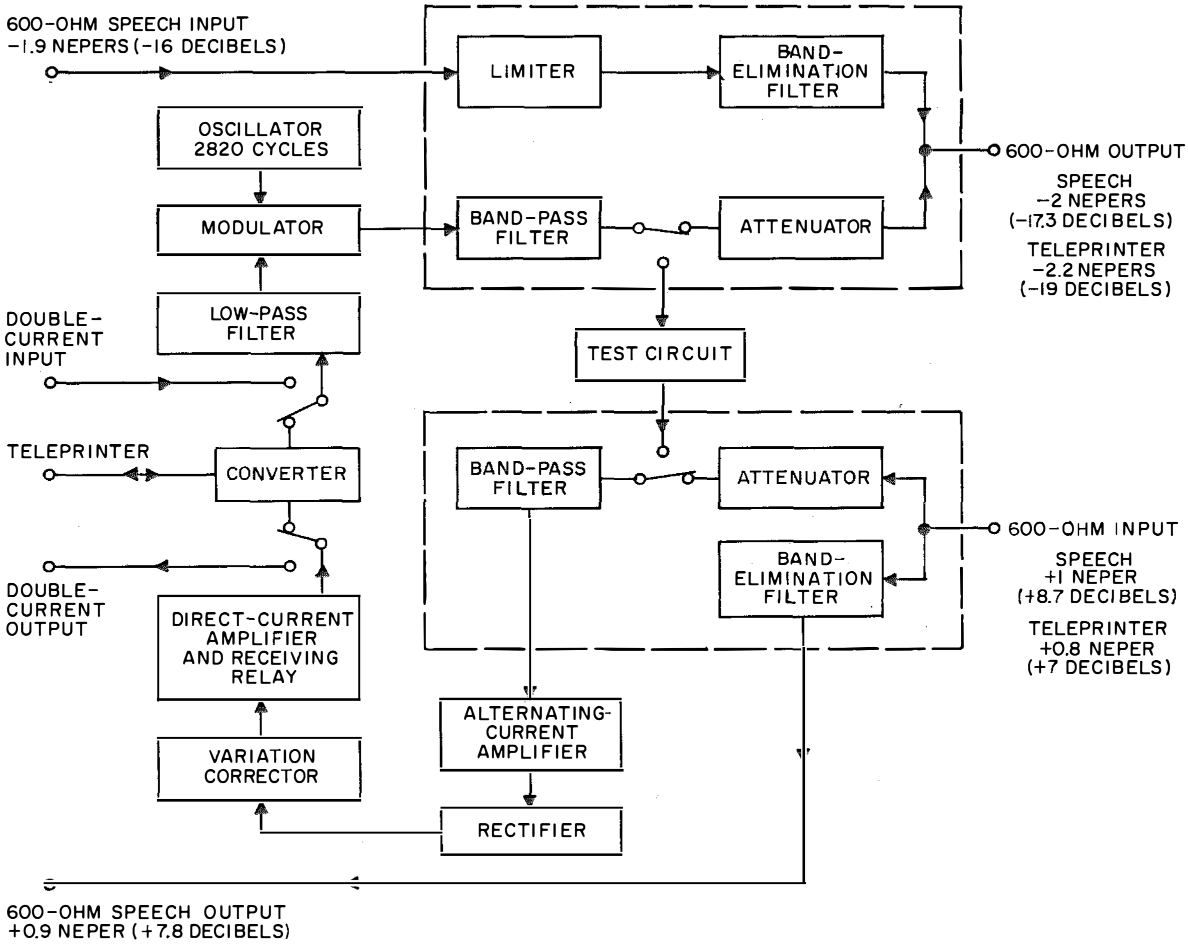


Figure 2—Block diagram of *UT-57/1*.

1.2 Transmitting Equipment

A block diagram of the telephone and telegraph combining equipment, *UT-57/1*, is shown in Figure 2. An oscillator employing a junction transistor in a bridge circuit generates the carrier. The frequency-determining resonant circuit is temperature compensated. The oscillator output voltage is stabilized so as to be independent of power-supply fluctuations. Its output can be adjusted over a range of ±0.2 neper (±1.7 decibels). The oscillator is connected to the modulator for keying the amplitude of the carrier.

The double-current or polar signals coming from the converter pass through a low-pass filter that removes the short interruptions caused by contact chatter of the transmitter relay or by the armature reversal. This ensures a steady transition between spacing and marking currents. The output signals thus formed control a push-pull combination of four diodes in the modulator so that the modulator conducts for one polarity of voltage and attenuates by at least 6 nepers (52 decibels) for the other polarity. This results in full carrier suppression. Another two diodes are responsible for the so-called interruption attenuation by means of which the carrier is completely blocked if one or both conductors of the local circuit are opened. The modulator is wired for open-circuit operation; that is, a tone goes to the line only when actual writing takes place. However, the equipment is easily converted for closed-circuit operation.

The intrinsic distortion of the modulator is low. If the current in the local circuit is reduced from its rated value of ±20 milliamperes to ±10 milliamperes, the resulting additional telegraph distortion is negligible. The diodes are so arranged in the modulator that its output impedance has the same value both in the conducting and in the nonconducting state. As a result, the band-pass filter connected to the output is terminated with the correct source impedance at all times. This is a triple-tuned filter that has a bandwidth of about 75 cycles between the half-power points and is dimensioned so that the signal-to-noise ratio in the speech channel complies with the requirements. The signal spectrum appears at the output of the equipment after having passed through an attenuator serving as a decoupler.

1.3 Receiving Equipment

In the receiving branch, the telegraph signal passes through a decoupling attenuator and a band-pass filter, which is an exact duplicate of the band-pass filter in the transmitting branch. It then goes to a three-stage transistor alternating-voltage amplifier. The amplifier input contains a continuously adjustable level control by which the receiver sensitivity is adjusted to the center of the range over which the automatic level corrector operates. A jack permits this center level to be checked with a voltmeter. A push-button switch in the negative-feedback branch decreases the level by 0.5 neper (4 decibels) to facilitate adjustment of the polarized receiving relay to its neutral position.

The amplified telegraph signal is then demodulated in a full-wave rectifier and applied to a level-correcting unit. The originally square amplitude-modulated telegraph signal is distorted into pulses with almost sinusoidal leading edges as a result of the frequency limitation imposed by the two band-pass filters. The proper pulse duration remains at only half the pulse amplitude. To prevent telegraph signal distortion, the armature of the polarized receiving relay must reverse just when the signal pulse has reached half its amplitude after a change in polarity. However, the signal amplitude will vary somewhat, which requires that this feature of the operation of the relay be under control of the received-signal level. Conventional control circuits employ components that produce integration and they cannot therefore compensate instantaneously for sudden level fluctuations. For this reason, an instantaneously responding level corrector was provided. A network derives a correcting voltage with the required amplitude by differentiating the received signal voltage. This voltage is applied via a direct-current amplifier to a separate opposing winding of the receiving relay and immediately corrects the level for each individual signal-pulse edge. By alternately operating two controls, the corrector circuit can be adjusted so that the telegraph distortion practically disappears over a level range of ±0.7 neper (6 decibels).

The correcting unit is followed by a direct-voltage amplifier having two transistors. This difference amplifier has two inputs one for the signal and one for the correction voltage. Its output is connected to the receiving relay.

1.4 Power Supply

The equipment consumes 25 watts and can be operated by batteries providing +60 volts and −60 volts to ground. For convenience, the built-in power supply develops these voltages from the alternating-current power line of either 110 or 220 volts with a tolerance of ±10 percent and at frequencies between 48 and 65 cycles.

1.5 Operating Features

The quality of a telegraph transmission system is judged primarily by the magnitude of telegraph signal distortion. Before measuring, the channel should be adjusted to neutral. For this purpose, a switchable test path has been provided connecting the transmitting band-pass filter via an attenuator to the receiving band-pass filter input; an alternating-polarity test voltage having equal amplitude and duration for each polarity is applied to the near-end input of the modulator, and the double-current pulses appearing at the output of the receiving relay go to an instrument or distortion-measuring set to produce an optical display. Then the controls of the level corrector are so adjusted for levels of 0 and −0.5 neper (0 or −4.3 decibels), respectively, that the receiver is in its neutral position.

After system adjustment to the neutral state, tests of the overall distortion with the Comité Consultatif International Télégraphique et Téléphonique test text at 50 bauds showed values of less than 3 percent in the level range ±0.7 neper (±6 decibels). This distortion did not exceed 5 percent even when the operating voltage fluctuated by ±10 percent and the carrier frequency was detuned by ±7 cycles. The receiver responds to a level of about −1.55 nepers (−13.5 decibels) referred to the level range center. Interfering voltage having peaks of less than this value cannot cause faulty operation even in the keying intervals.

1.6 Teleprinter Connections

To facilitate directly connecting the teleprinter to the equipment, a simple converter from two-wire single-current teleprinter operation to four-wire double-current equipment and line operation has been provided. The circuit is shown in Figure 3. A battery provides a steady-state current of 40 milliamperes to the teleprinter.

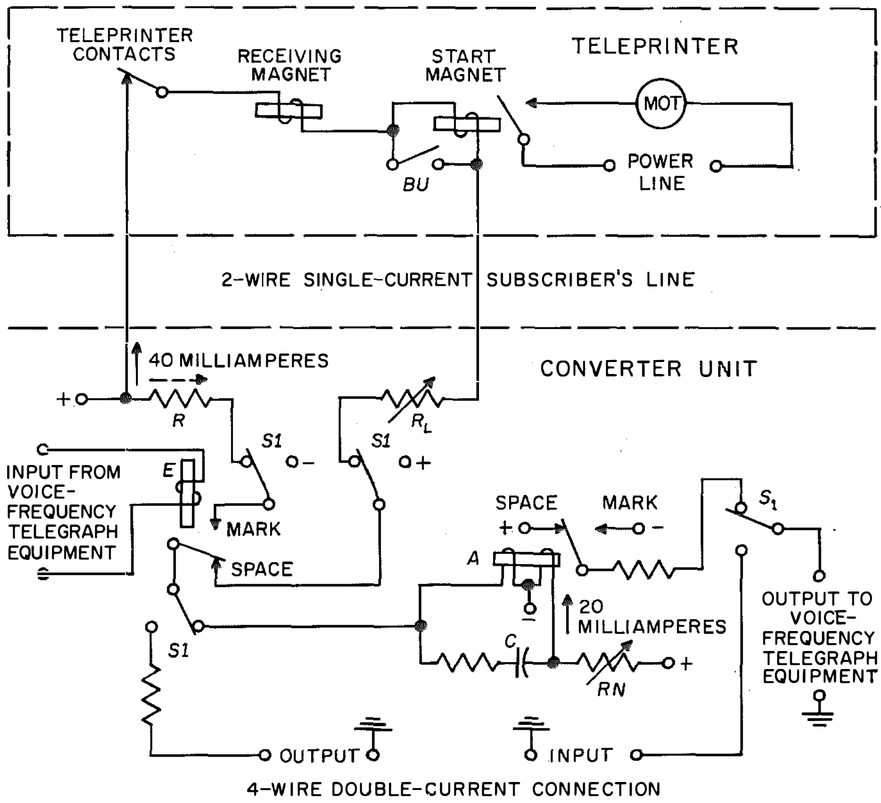


Figure 3—Converter permitting teleprinter operation from either a two-wire single-current or a four-wire double-current system.

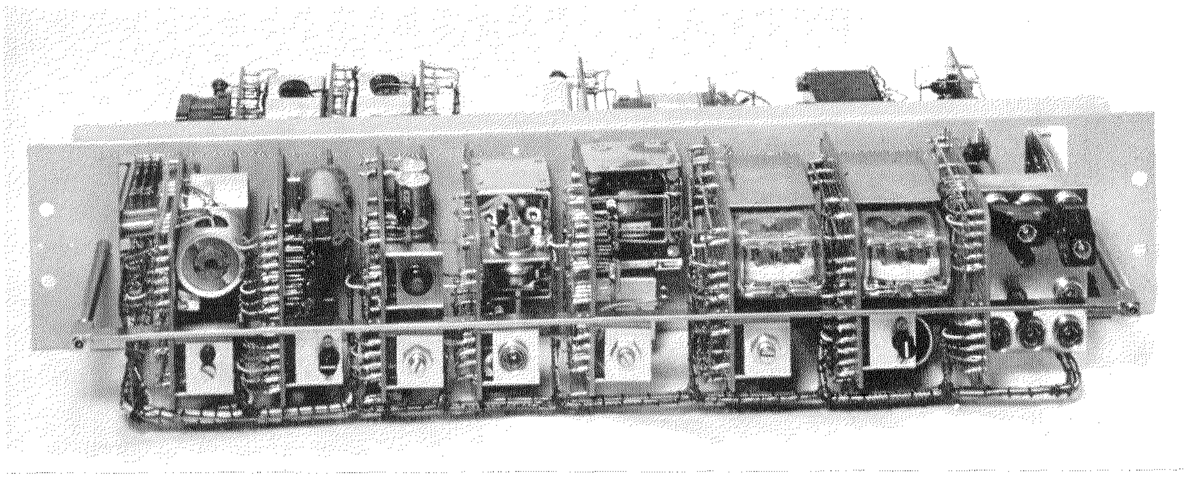


Figure 4—Front view of the *UT-57/1* equipment with covers removed.

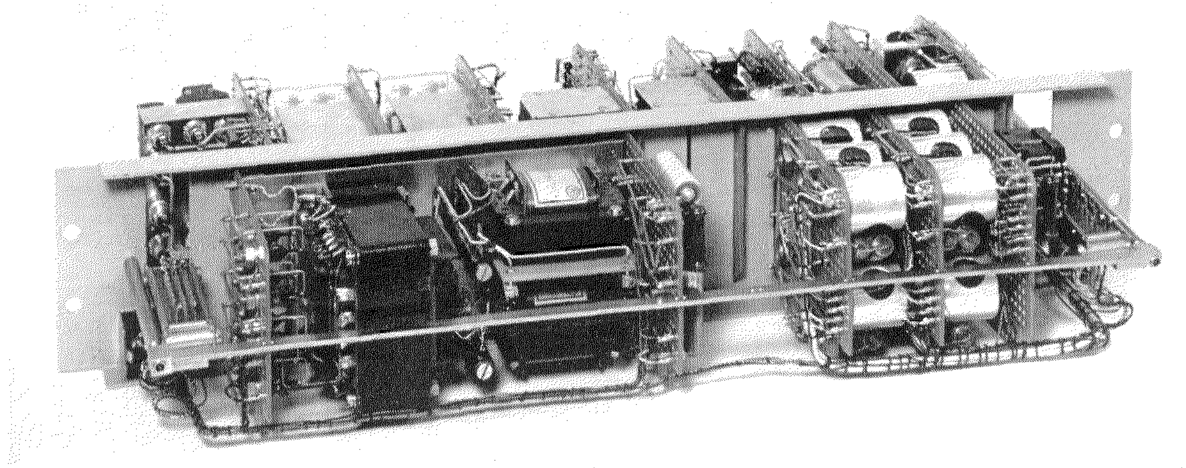


Figure 5—Rear view with covers removed.

To obtain this rated current, the effects of the line losses can be compensated for by R_L.

By depressing the teleprinter key BU, the solenoid of the motor switch is short-circuited and its contacts close and start the motor. During typing, the teleprinter transmitting contacts open and close the subscriber loop according to the code of the telegraph signals. When the subscriber loop is closed, the flow of current through the left-hand winding of relay A in the converter actuates contacts that put $(+)$ on the modulator of the voice-frequency telegraph equipment through the low-pass filter. In the other winding of this telegraph relay, an opposing current of 20 milliamperes flows so that when the subscriber loop is open and no current flows in the first winding, the relay operates to the other side to send $(-)$ to the modulator, which releases the 2820-cycle signal to the outgoing line.

At the far-end station, the corresponding receiving relay E is reversed in polarity and its contact is switched to the marking position. The relay A in that station is not affected because, in marking position, a current of 40 milliamperes flows through resistor R and the moment of reversal is filled by the energy stored in capacitor C. Through the reversal of the contacts of E, the current through the teleprinter receiving magnet is interrupted in the rhythm of the telegraph signals. The first current interruption causes the teleprinter motor to be started. This motor continues to operate until a writing interval exceeding 30 seconds occurs. The resistor *RN* serves to adjust the opposing current in relay *A* and, hence, establish the neutral position of the latter. Switch *S1* changes the circuit to permit either two- or four-wire operation.

An additional toll subscriber relay terminal strip is provided for operation through manual or automatic exchanges. It is designed so that, apart from the actual message, those signals necessary for establishing a connection in toll traffic are converted into a form suitable for voice-frequency telegraphy. The subscriber station can be connected for either four-wire single-current duplex or two-wire single-current simplex operation. The operating voltages required for this additional strip are derived from the power supply incorporated in the *UT-57/1* equipment.

2. Constructional Details

System constructional design was aimed particularly at simplicity. On both sides of a conventional relay panel 520 millimeters (20.5 inches) wide and 100 millimeters (4 inches) high, pertinax boards are fixed to which the individual units are mounted. The boards are first completely wired and then fastened into slots in the panel. They are then interconnected by preformed cable harnesses whose terminals are soldered to the boards. This construction combines simplicity of assembly with easy accessibility and facilitates replacement of parts. Individual boards can be exchanged for others meeting special requirements. The wiring can be altered readily since all boards have a standard raster of holes providing for the simple insertion of soldering lugs in any desired arrangement. The weight of the completely equipped *UT-57/1* panel is about 10 kilograms (22 pounds).

Figure 4 is the front view of the panel. From left to right, are the oscillator with transmitting level control, modulator and test path, input stages of the alternating-voltage amplifier with control and 0.5-neper push-button key, power stage of the alternating-voltage amplifier with toll jack, rectifier and level corrector with the second neutral control, direct-voltage amplifier with receiving relay *E* and the first neutral control, converter with relay *A* and reversing switch, and jacks for the subscriber station. The rear side of the panel as shown in Figure 5 mounts the power supply, the transmitting and receiving directional filters, and the limiter. The components are protected by removable covers, which will be seen in Figure 6. Below the panel in this illustration will be seen the relay terminal strip required for exchange operation.

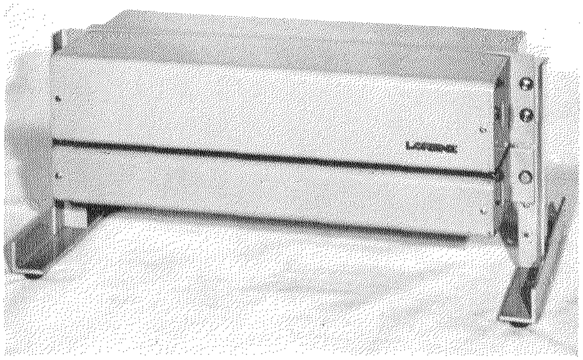


Figure 6—The main equipment is housed in the upper covers and the exchange-operation strip is below it.

3. Compatibility with Radio Equipment

The voice-frequency telegraph equipment was tested with an *SEF-7* very-high-frequency radio equipment[1] built by Lorenz. The setup is shown in Figure 7. This radio equipment employs frequency modulation. To prevent interference to adjacent radio services, a limiter prevents excessive frequency shift. At the design level the shift is ±10.5 kilocycles. Through the action of the limiter, the maximum swing is ±15 kilocycles at +0.4 neper (+3.5 decibels). The telegraphy signal in the speech channel causes an increased level to appear at the input of the radio-frequency modulator; therefore the frequency shift for the reference level must be reduced to about 7 kilocycles by a series input attenuator of about 0.4 neper (3.5 decibels). This gives a sufficient margin between the summed message (speech and telegraphy) and the overload level. Measurements have shown that this reduced swing does not essentially reduce the range of the radio equipment. A signal-to-noise ratio of about 3 nepers (26 decibels) in the speech path at the

[1] G. Sidow, "UKW Funkgerate für bewegliche Funkdienste," *SEG Nachrichten*, volume 5, number 2, pages 79–87; 1957.

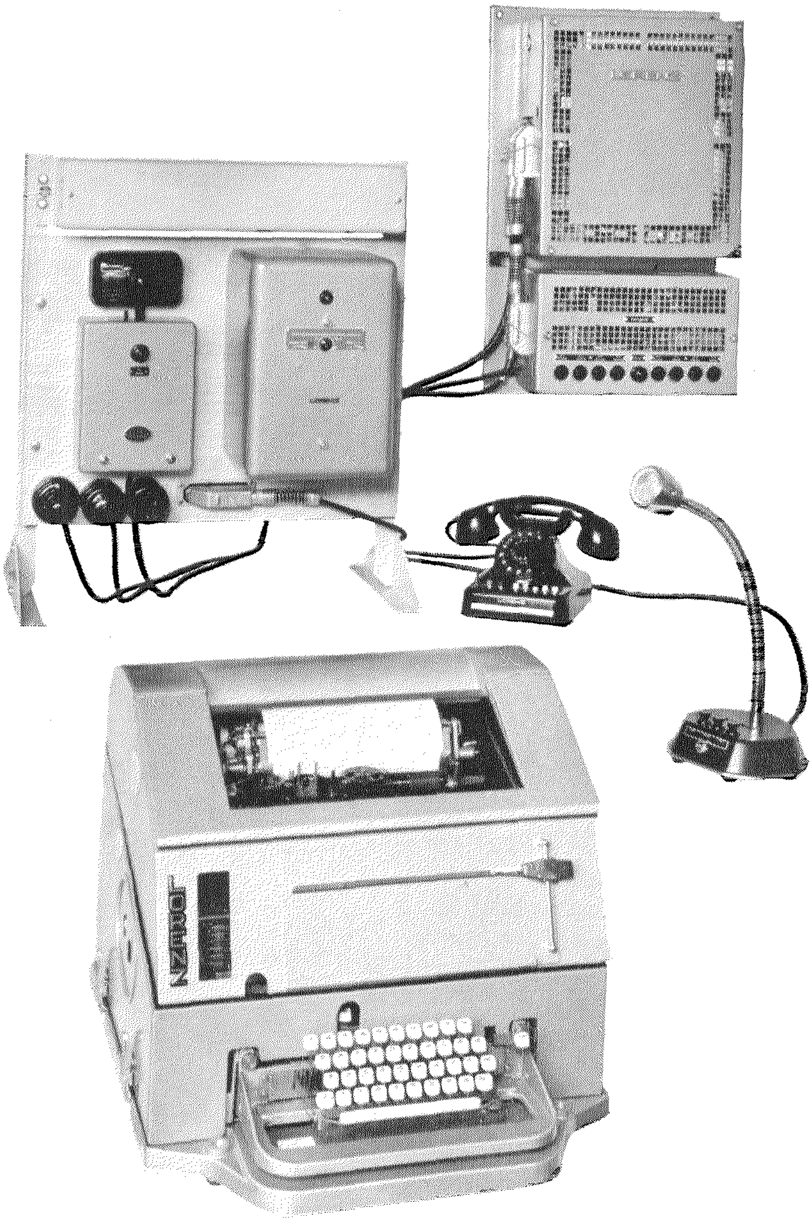


Figure 7—Test setup with the *SEF-7* very-high-frequency radio equipment. The *UT-57/1* strip is mounted on the transfer-equipment frame just back of the teleprinter.

receiving branch is still sufficient for practically undisturbed teleprinter operation. In the *SEF-7* receiver, this corresponds to a receiving field strength of about 1 microvolt per meter. White noise was used as interference in these measurements. The noise suppressor built into the radio equipment must not be switched off in voice-frequency telegraphy operation because absence of the transmitting carrier will increase the sensitivity of the radio receiver and the interference noise present will be powerful enough to start the teleprinter.

Development of Creed Telegraph Apparatus

By BRUCE BROOKE-WAVELL

Creed & Company, Limited; Croydon, England

MOLIÈRE'S character, M. Jourdain, awoke one day to the realization that he had been speaking prose all his life without knowing it. Similarly, telegraph engineers have recently discovered, thanks to Claude Shannon and others, that they have been processing digital information for the last hundred years without being aware of that fact. Fortunately for telegraph manufacturers, many other people have discovered this fact too, even if in some cases they have required a little prompting.

The result has been, during the past five years, that a wide range of telegraph apparatus that was originally developed for purely conventional telegraph applications has been used for quite different purposes. The punched-tape technique, for example, that was originally introduced to save line time is now employed for providing input and output facilities for digital computers, for data recording and processing, and for the automatic control of machine tools.

Back in 1948, however, at the beginning of the ten-year period being reviewed, telegraph engineers were too fully occupied with the pressing post-war requirements of conventional telegraphy to give much attention to other matters. This was certainly true at Creed where, during the war, production was for strategic reasons concentrated on a small range of telegraph machines and in particular on the model-*7* page teleprinter, which accounted for over half of the total number of machines turned out. There was, therefore, the urgent problem of pushing ahead with a variety of new developments to meet the needs of both British and overseas telegraph administrations.

1. Early Post-War Development

The first such development was for the British Post Office which started to reorganize its public telegraph service. To replace the pre-war model-*3* tape teleprinter, which since its introduction in 1929 had been in general use for the transmission and reception of telegrams, the model-*47* tape teleprinter was produced. This machine was similar in principle of operation to the model *7* page teleprinter but embodied improvements resulting from experience with that model and from Post Office experience with the earlier tape machine. Perhaps the most important difference between the models *47* and *7* teleprinters, apart from the obvious one that the page unit on the latter machine had been replaced by a tape unit on the former, was that the model *47* had a 4-row, typewriter-pattern-layout, saw-tooth-comb bar keyboard in place of the earlier 3-row motorized keyboard.

There next followed a series of developments concerned with the provision of automatic tape transmission facilities for the full utilization of line time. This was to meet the increasing interest being shown in simple tape preparation and automatic transmission sets for use both in individual installations and in the more-ambitious manual-transfer push-button semi-automatic tape relay systems.

Equipment for automatic tape transmission sets had been in production since before the war, including a keyboard perforator, a nonprinting reperforator, and an automatic tape transmitter, but a further range of machines was now introduced mainly for use in tape relay systems. The model-*85* printing reperforator was developed for recording messages on printed chadless tape, that is, perforated tape with the chads remaining attached and with the printing superimposed on them. The printing was provided to eliminate the need for operators to read the 5-unit code and the chadless method of perforating to retain the use of standard-width tape. A variant of this machine—the model-*86* printing reperforator—recorded messages on fully perforated wide tape with the printing underneath the perforations.

An essential requirement in tape relay stations is the use of ganged automatic tape transmitters. To meet this requirement, models *71*, *72*, and *74* multiple-tape transmitters were produced. The standard single-head transmitter, model *6S*, was

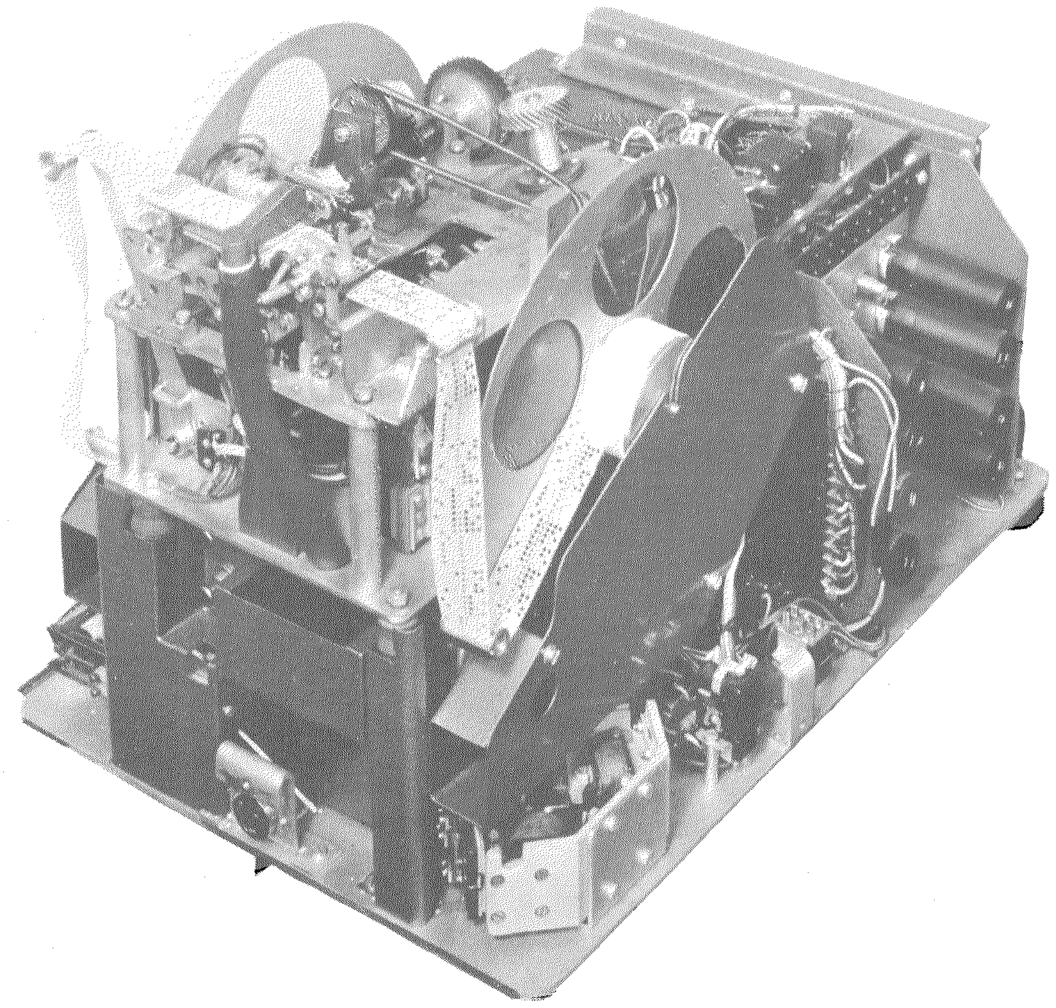


Figure 1—A special variation of the model-25 reperforator. It provides a punched-tape record of the routine operations of equipment such as cash registers and accounting machines for computer input.

redesigned, a transmitting mechanism of the striker pattern being fitted to it to ensure high-quality signals.

Meanwhile, the increasing use of teleprinters by business concerns renting circuits from the British Post Office, as well as the changing needs of telegraph administrations, made it necessary to add to the model-7 page teleprinter, which was still in great demand, a variety of new facilities.

This machine had been introduced in 1931 as a simple, sturdy teleprinter in which the design emphasis had been on simplicity of manufacture and maintenance rather than on a large number of facilities. These characteristics were, undoubtedly, of great value to the armed services and the British Defence Teleprinter Network in which the bulk of the war-time production was used. The changed circumstances after the war, however, created new needs.

The machine was designed originally for double-current (polar) operation: it was now modified to make it equally suitable for single-current (neutral) operation. A new cam unit was fitted to it having an orientation device, that is, a means for centralizing the margin and for measuring the receiver tolerance in the absence of a separate margin-testing set. Later, a further alternative cam unit was made available to provide for immediate printing and to increase the receiver tolerance to over 86 per cent. A reperforating attachment was fitted that could be used to prepare perforated tape with a local record or provide a perforated record of incoming messages as required. Two-colour printing, a period-of-operation counter, improved visibility of the printing point, better sound-proofing arrangements, and many other changes were introduced, transforming the teleprinter into what superficially appeared to be quite a different machine. As the original simple teleprinter continued to sell to customers who did not need these new facilities, the modified machine was distinguished as being the new model *54*.

2. *New Applications*

About five years ago, as already mentioned, a series of entirely new markets with requirements quite unknown to the telegraph art began to appear. Digital-computer manufacturers turned to punched tape as a way of solving their input and output problems. The development of the techniques of data recording and processing, as well as of automation, created a demand for further kinds of punched-tape equipment.

To meet the need of the computer manufacturers, a comprehensive range of *tape-editing* equipment in the form of selfcontained comparator, verifier, and reproducer sets were developed. These consisted of standard teleprinter equipments to which new facilities had been added, together with specially designed relay units and control panels. A series of interpreter sets was also produced to provide computer print-out facilities.

It was early realised that while normal telegraph speeds would be more-or-less adequate for tape-editing equipment, much higher speeds were required for the input and output devices. The computer manufacturers found a satisfactory method of reading input tapes by using photoelectric means for registering the holes. Creed did not, therefore, develop a high-speed tape reader.

The output problem, however, was a more-difficult one that was approached initially by introducing the model-*7P/5W* reperforator. This was derived by modifying a keyboard perforator to reperforate from a 5-wire input. It operated at 15 characters per second, thereby permitting recording at slightly over twice the speed formerly possible with standard teleprinter equipment.

The next step was the introduction of a tape punch that was specifically designed for output recording. This model-*25* reperforator records data in 5-, 6-, or 7-track tapes—either in single tapes or in two tapes at a time—at a speed of 33 characters per second, which is 5 times the normal teleprinter speed. The model-*25* reperforator is at present the standard output punch for the majority of British electronic digital computers. Over 1000 of them have been produced to date for this and other applications, which include the automatic logging of telephone calls on punched tape and the provision of a punched-tape record of the automatic routine operations of a range of modern business equipment such as cash registers and accounting machines. Figure 1 shows the mechanism of one of these models.

The speed of the model-*25* reperforator is still not high enough, however, to make it a completely adequate computer output recorder. Two further machines have, therefore, been developed for this purpose. The first, the model-*3000* reperforator, is the world's fastest output punch, operating at a speed of 300 characters per second. It may be seen in Figure 2. The other is a hydraulically operated character-by-character printer with a speed of 100 characters per second. This operates from a 5-wire input, the characters being built up on the mosaic principle with a 5 by 5 grid. As it has 3 times the speed of the model-*25* reperforator, it is advantageous to use it as a direct-output printer. Alternatively, it may be used in conjunction with the model-*3000* reperforator if a higher output speed is required. The speeds obtainable with these machines are adequate for most purposes. Since they are much-less expensive than the higher-speed line printers on the market, they will undoubtedly satisfy an important need in the computer field. Figure 3 is an example of the use of teleprinter equipment adapted to computer requirements.

A range of machines is also under development in the data processing and automation fields. These are, in most cases but not all, modified versions of standard teleprinter equipment and include a machine for recording 5-unit combinations on the edges of cards and tickets, a tape transmitter for process control by punched tape, which has been modified to feed forwards or backwards under the control of external signals, and a teleprinter that operates directly from a 5-wire input.

All these are individual instruments that have been produced for use in conjunction with other manufacturers' equipment. Creed is also investigating the problem of providing complete integrated data-processing systems using punched tape throughout, for use where the total quantity of information to be processed is not sufficient to justify the employment of electronic equipment.

The next step will almost certainly be the extension of both the computer and data-processing fields to include telegraph communication facilities. When this occurs, the demand for higher speeds of operation, codes with a greater information-carrying capacity, and new standards of transmission accuracy will radically affect present telegraph practice.

Figure 2—Model-*3000* tape punch. It was designed for use as the output equipment for electronic computers. It can punch 5-, 6-, 7-, or 8-track tape at the high speed of 300 characters per second or 3000 words per minute.

3. Fresh Start in Teleprinter Design

The history of the models *7* and *54* teleprinters and the rapid growth of nontelegraphic applications of telegraph apparatus both played an important part in determining the design of the new model-Seventy-five teleprinter.

Some four years ago, it was realised that the model-*54* teleprinter, while still adequate for normal communication needs, could not be modified to meet the new requirements that were arising in the communication and data processing fields without undue complication and increase of weight.

To take the communication field first, it was becoming evident that with the accelerating expansion of the telex and private-wire services, the teleprinter was becoming an indispensable piece of office furniture on the same basis as, although complementary to, the telephone. There was reason to believe that the large telegraph organisations, both public and private, would tend in the future to provide the interconnection facilities such as switching and channel equipment, but leave the operating and servicing responsibilities to the user.

From this the conclusion was drawn that teleprinters would have to meet, in the near future, the following requirements:–

A. *Reduced Maintenance.* The dispersal of telegraph equipment in business offices instead of their previous concentration in telegraph offices would put a premium on low maintenance.

B. *Dual-Speed Operation.* For economic reasons, there would be a strong demand for automatic tape transmission sets. An improvement on present practice could be made if a dual-speed teleprinter with a manual speed-change control were used that could prepare tape "off line" at a high speed and provide message transmission facilities "on line" at the normal telegraph speed.

C. *Modern Appearance and Small Size.* If teleprinters were to become standard office furniture, their appearance and size would play a more-important role than in the past.

These requirements were seen to hold also for the data-processing field, but there were additional requirements. It was apparent that an increasing demand would exist for communication channels between business offices and centrally placed computers serving them. Many of these business offices would not want full-time channels but would prefer channels that could be used partly for transmitting data and partly for normal communication traffic. There would, therefore, be an advantage in using dual-purpose terminal equipment that would be suitable for the transmission and reception of messages and also for the local processing of data. As these two kinds of use ideally require sequential and simultaneous (5-wire) modes of signalling respectively, a satisfactory dual-purpose machine would have to be readily convertible from one mode of signalling to the other.

All these requirements have been met in the design of the model-Seventy-five teleprinter, which needs less-frequent maintenance than previous Creed teleprinters, operates at both 66 and

Figure 3—Application of teleprinter equipment to record output data from an electronic digital computer in punched-tape and printed-page form.

100 words per minute, is the smallest teleprinter in the world in production, has a smoothly styled modern appearance, and is easily convertible to either 5-wire or sequential operation.

This machine is shown in Figure 4. It has been in production for some months and is the basic unit of an integrated range of telegraph machines that are now in various stages of development. A reperforating attachment for the model-Seventy-five teleprinter is already in production, whilst a new automatic tape transmitter attachment, a printing reperforator, and a tape teleprinter are on the way.

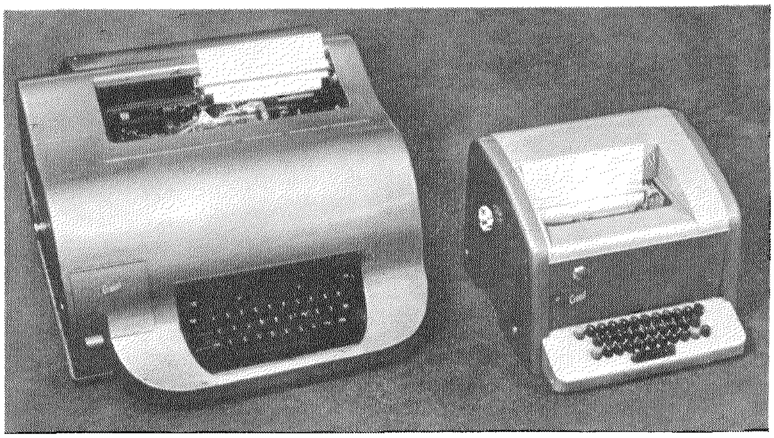


Figure 4—The model-Seventy-five teleprinter at the right is only about half the size and a third of the weight of former models. It is capable of operation at 100 words per minute with greatly extended servicing intervals.

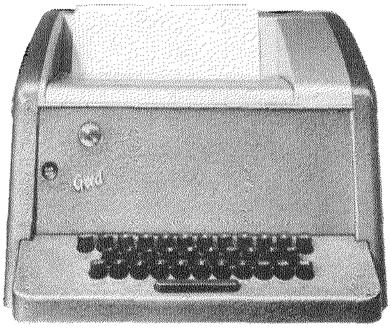
Mention of the model-Seventy-five teleprinter brings us to the present phase of Creed development. As this is, naturally, of greater interest than the largely historical material in this article, a full, separate article has been devoted to it.

Creed Model-Seventy-Five Teleprinter

By BRUCE BROOKE-WAVELL

Creed & Company, Limited; Croydon, England

EARLY IN 1958, the first production units of a new teleprinter left the Creed factory. This model Seventy-five machine (Figure 1) is the smallest teleprinter in production in the world, and its weight of 35 pounds (16 kilograms) for the receiver-only version is well under half that of most other teleprinters.



Considerable interest in these features was shown by aircraft operating companies well before the production stage was reached. In March, 1956, a pre-production version of the machine was fitted as an airborne teleprinter in a British Overseas Airways Corporation Stratocruiser on regular service from London to New York and continuously recorded weather data and other essential flight information broadcast from radio stations in Galdenoch, Scotland, and Halifax, Nova Scotia. This trial was very successful, the operation of the machine being unaffected by either vibration or tilting.

All this might suggest, on the principle that one cannot get something for nothing, that small size and light weight have been obtained at the expense of robustness, range of facilities, standards of performance, or other features. This, however, is not so. It is the first and basic unit of a new integrated range of teleprinter equipment to supersede existing machines, both in conventional telegraph communication services and in the growing number of special applications in data processing and automation. The surprising reductions in size and weight are byproducts of new design methods.

The basic design of the model-Seventy-five teleprinter is quite different from that of present machines. Existing Creed teleprinters were developed by modifying and adapting the model 7, which was originally introduced in 1931, to provide the greater variety of facilities and higher standards of performance called for by progress in telegraphy since that time. Although these machines are adequate for most present needs, it is becoming increasingly difficult to add new facilities to them without also adding disproportionately to their size and weight. By making a completely fresh start, it has been possible to provide the full range of present-day facilities in a much-simpler and more-direct manner while, at the same time, making full allowance for foreseeable future requirements.

1. General Features

The teleprinter has been designed to operate reliably at 100 words per minute to cater for an increasingly widespread requirement, especially in data processing and computer output applications. At the more-commonly used communication speeds of 66 and 60 words per minute, to which the teleprinter can be adapted by a simple gear change, this reserve speed provides a large additional safety factor.

Single- and double-current operation are both catered for, the minimum receiver operating current being 40 and 20 milliamperes, respectively. The same transmitter contact assembly, without requiring any relay, is used for both modes of operation. The 5 code elements are first set up simultaneously on 5 changeover contacts and then transmitted sequentially by 5 make-break contacts. This use of separate transmitter contacts for each code element gives optimum transmission characteristics on single-current circuits.

The basic operating facility provided is simplex plus local record, the local record being obtained by a direct mechanical connection between the keyboard and receiver and not, as on previous machines, electrically through a leak resistor. The transmitter changeover contacts read off the transmitted combinations from the selecting pins on the receiver and the make–break contacts are

Figure 1—Smaller, lighter, and simpler than any other teleprinter in production in the world, the model Seventy-five is capable of sustained operation at 100 words per minute with high standards of attention-free performance.

operated by cams on the receive cam sleeve. The need for a separate keyboard transmitter is thereby avoided. This feature is responsible for a substantial reduction in the number of parts in the teleprinter. A further advantage is that the local record is printed immediately after the depression of a key, without any perceptible time lag.

The keyboard can be of the 3- or 4-row type, and the several hundred keyboard layouts catered for on previous Creed teleprinters are all available on the new machine.

The teleprinter is constructed on the unit principle, which has been proved by experience to result in simpler maintenance and manufacture. All units are interchangeable with equivalent units on other machines provided they are adjusted.

Special care has been taken to reduce the maintenance required; the lubrication intervals, for example, being extended to approximately 1000 hours of operation, compared with 300 hours for previous machines. This has been achieved by improved machine movements and by the more extensive use of self-lubricating bearings and felt washers.

Attention has been given to making the cover of the machine both functionally efficient and pleasing in appearance. It is aluminium with smoothly styled lines and a distinctive two-tone grey-silver hammer finish. As part of the sound-reducing arrangements, the cover is made to enclose the machine completely and is lined with an acoustic material, easy access to the paper and ink ribbon being provided by hinged rear and window sections.

2. *Design Principles*

The teleprinter receiver is fitted with a single driving shaft, powered by a lightweight 4200-revolution-per-minute, fractional-horsepower motor. This shaft drives the selector and translator cam shafts through friction clutches. The use of a single driving shaft has the advantage of keeping distortion due to gears to a minimum, whilst the use of friction clutches ensures a constant pick-up time, which contributes to the receiver margin.

The selector cam shaft controls the selector mechanism, which converts the signal combination registered by the receiving electromagnet into a code setting on one or other of two sets of 5 pins on the translator unit. The method of selection employed secures an operating margin of ± 40 per cent at a telegraph speed of 50 bauds and ± 35 per cent at 75 bauds. An orientation adjustment is provided by a simple device that enables the selecting actions to be made earlier or later with respect to the start pulses of incoming signals by any percentage of the length of a signal element up to ± 70 per cent. This provides a simple means of checking the margin of the receiver and enables the selector mechanism to be set in the centre of the tolerance range.

The translator cam shaft controls the translator mechanism. Its main function is to convert the selecting-pin code setting into the appropriate machine action, that is into printing a character or performing a function. It has been mentioned that there are actually two sets of 5 pins. This duplication enables a combination to be set up by the selector mechanism on one set of pins at the same time that the previous combination, which has already been set up on the other set of pins, is being read by the translator. The box holding the two sets of pins is made to move forwards and backwards by the translator unit so that each set of pins engages alternately with the selector and translator mechanism. This mode of operation permits the teleprinter to print each combination immediately after selection without storing it until the receipt of the following combination.

The translator unit effects the printing of the selected characters by moving a typewheel through a simple link-type aggregate-motion mechanism (Figure 2). The typewheel is much smaller and lighter than previous Creed typewheels (see Figure 3 for a comparison between the new typewheel and that on the model-*54* teleprinter). It is mounted vertically and has 4 layers of type on it, one under the other, each layer containing 16 types. It has four degrees of movement:—

A. *Lateral movement* by a rack-and-pawl mechanism actuated by a cam in the translator unit. The typewheel traverses the length of the platen, a character at a time, except when a functional combination is received. If this combination is the carriage-return signal, the typewheel returns sharply to the beginning of the line, where it is smoothly brought to rest by a small piston-type dashpot under the main base.

B. *Vertical movement* under dual control of the letters–figures-shift mechanism and element *2* of the received code combination. In the rest position, to which the typewheel returns after each character has been printed, the top of the typewheel is below the level of the printing point (see Figure 4), thereby ensuring immediate and complete visibility. When the translator camshaft rotates, the typewheel is raised by an amount depending on whether the selected character is in the letters or figures case and whether element *2* is a mark or space. One of 4 layers of types is thus raised level with the printing point. (The mechanical details are illustrated in Figure 2.)

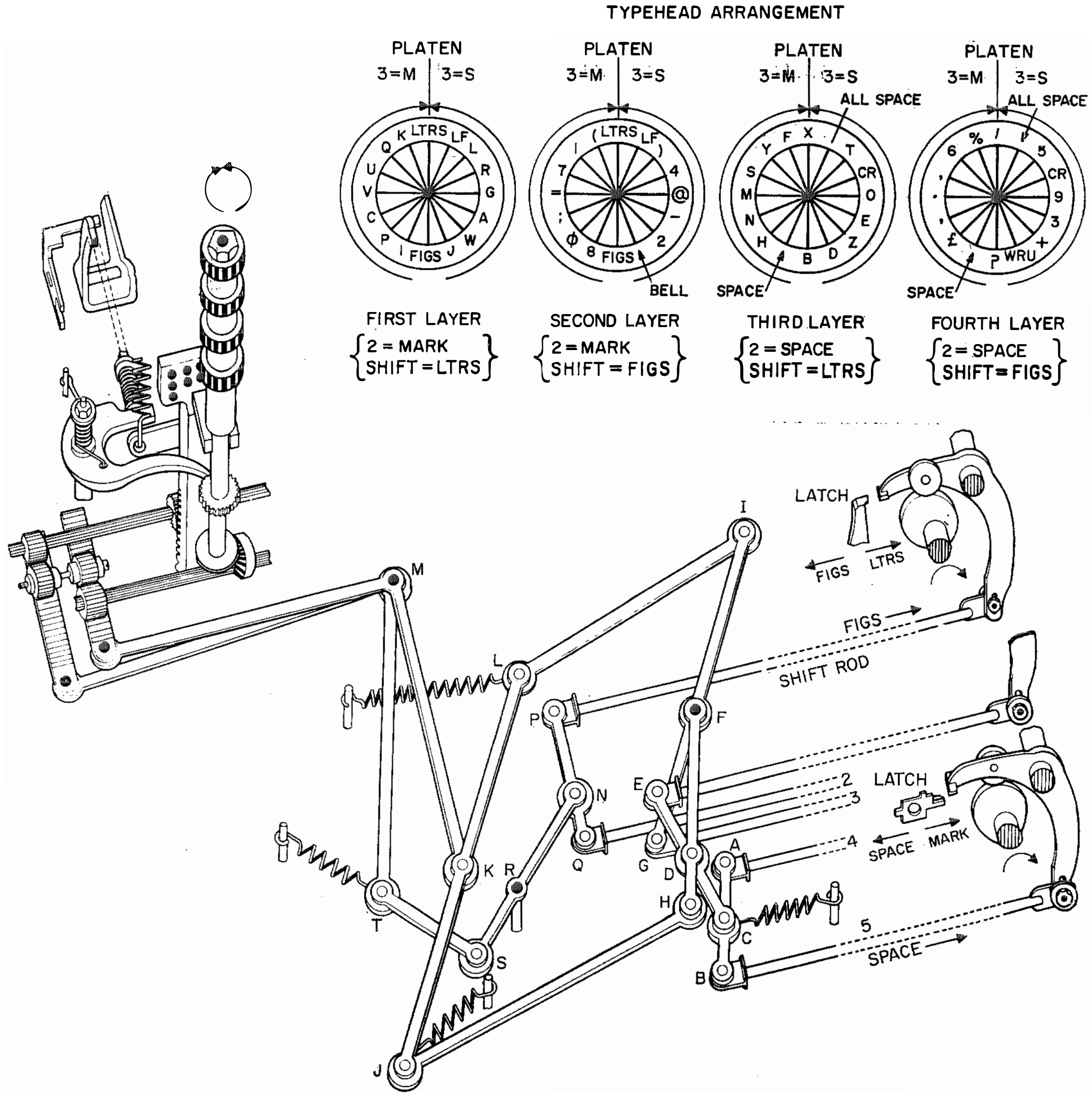


Figure 2—Aggregate-motion-mechanism diagram. Pivots *M*, *R*, and *F* are fixed. Rod movements for shift and elements *1*, *2*, *3*, and *4* are 0·5 inch (127 millimetres) and for element *5* is 0·25 inch (64 millimetres). Proportions of levers are: $AC/CB = 1/1$, $ED/DC = 1/1$, $FD/DH = 3/1$, $IF/FG = 4/3$, $LK/KJ = 1/1$, and $PN/NQ = 2/1$.

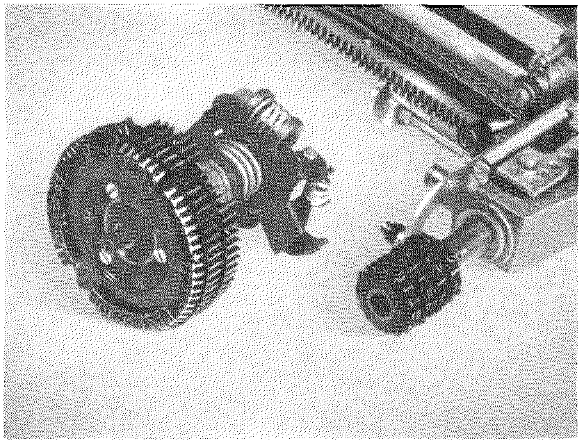


Figure 3A—Comparison of typehead units on the model Seventy-five (right) and model-*54* (left) teleprinters.

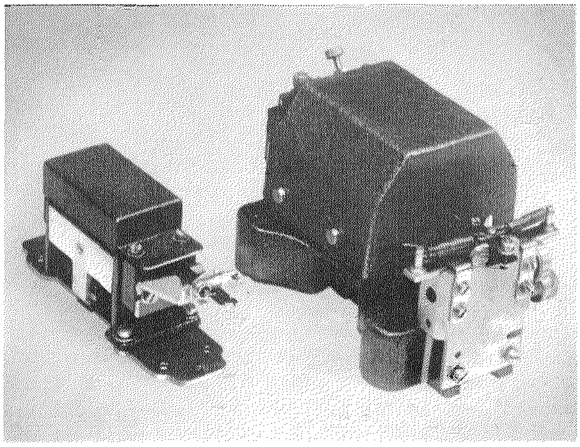


Figure 3C—Comparison of electromagnet units for the model Seventy-five (right) and model *54* (left).

C. *Rotary movement* under control of elements *1*, *3*, *4*, and *5*, of the received code combination. The positions of the selecting pins for these elements determine which of the corresponding control rods on the aggregate-motion mechanism should move to the right (see Figure 2). This determines both the direction and degree of rotation of the typewheel, the direction of rotation being controlled by element *3* and the angle of rotation, which never exceeds half a revolution, being controlled by the combined action of elements *1*, *4*, and *5*. The proportions of the levers in the aggregate-motion mechanism are so arranged that for each combination of marks and spaces for the elements *1*, *3*, *4*, and *5*, one of the

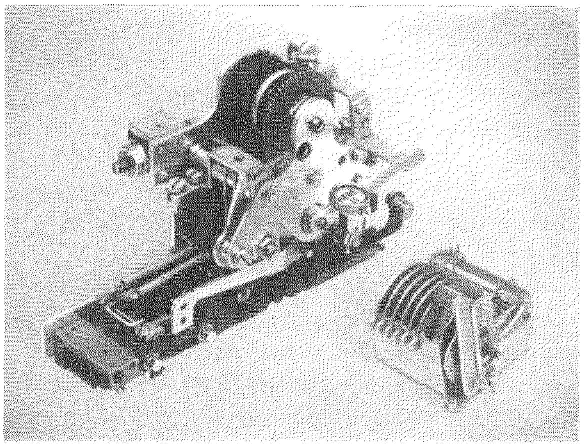
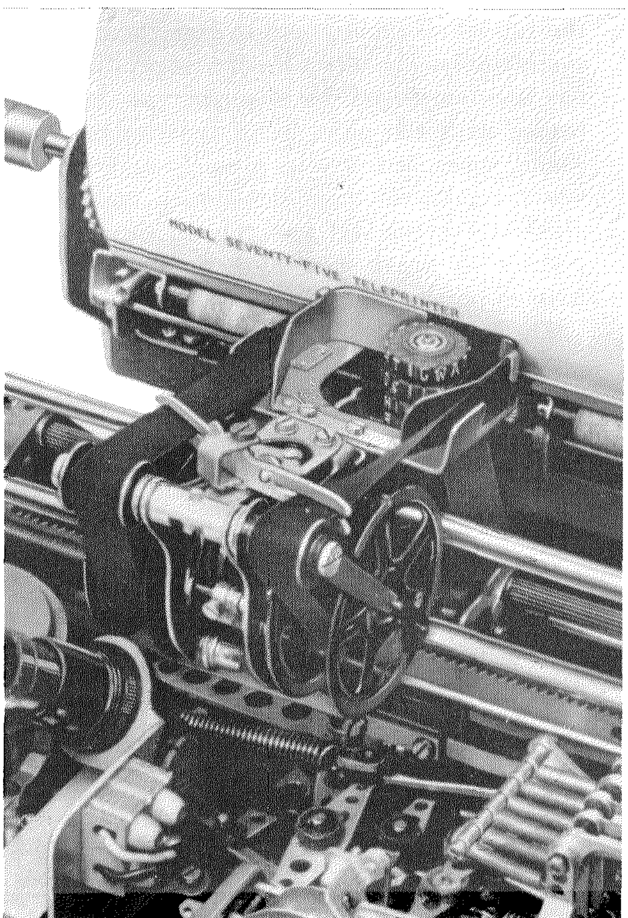


Figure 3B—Comparison of answer-back units on the model Seventy-five (right) and model *54* (left).

16 types on the selected layer is brought opposite the printing point.

D. *Forward movement* by the printing mechanism that is also energised by a cam on the translator unit. After the selected character is positioned

Figure 4—Close-up of printing point showing stationary platen and moving typehead. The typehead returns instantly at all speeds, operation being unaffected by shock, tilting, or vibration. Every character is printed immediately and is visible as soon as printed.



opposite the printing point by the aggregate-motion mechanism, the frame supporting the typewheel is swung forward. This raises the ribbon into line with the selected type and causes the typewheel to strike forward at the platen. At the end of the printing operation, the typewheel returns to its rest position and the ribbon is lowered.

The basic design feature of the translating and printing mechanisms is the use of a stationary carriage and a moving typewheel (see Figure 4). This arrangement is superior to previous Creed teleprinters (moving carriage and fixed typewheel) as it enables the width of the machine, and hence also its weight, to be substantially reduced. It also eliminates the problem of moving and smoothly arresting the mass of the paper carriage, makes the printed copy easy to read, and allows for varying the paper storing and feeding arrangements, particularly where external pre-printed sprocket-feed business stationery manifolds are employed.

The aggregate-motion mechanism and the typewheel embody a number of important design features that combine to reduce to a minimum the energy that has to be dissipated in bringing the typewheel to rest. Consequently, it has been possible to make the components associated with the typewheel smaller and to increase their life considerably. The direct method of printing that has been employed, for example, not only dispenses with the need for a typehammer and sliding types, but permits a much-smaller typewheel. Again, the aggregate-motion mechanism moves the typewheel smoothly to the printing position by the shortest route and more slowly than on previous machines.

The keyboard is of the motorized kind; that is, the power to move the combination bars is provided by the machine itself and not by the key-depressions. In this respect, the keyboard is similar to an existing Creed model used on telex teleprinters, but the touch has been improved by making it possible to depress any key well before the end of the cycle of operations initiated by depression of the preceding key. This allows the operator to type at an irregular speed about the cadence speed of the machine.

The most-novel feature of the keyboard, which makes it much simpler than other teleprinter keyboards, is the absence of a separate keyboard transmitter. When a key is depressed, the code for the key is set up on 5 combination bars. These mechanically select the code on the pins in the translator unit. The transmitter contacts, which are also mounted on the translator unit,

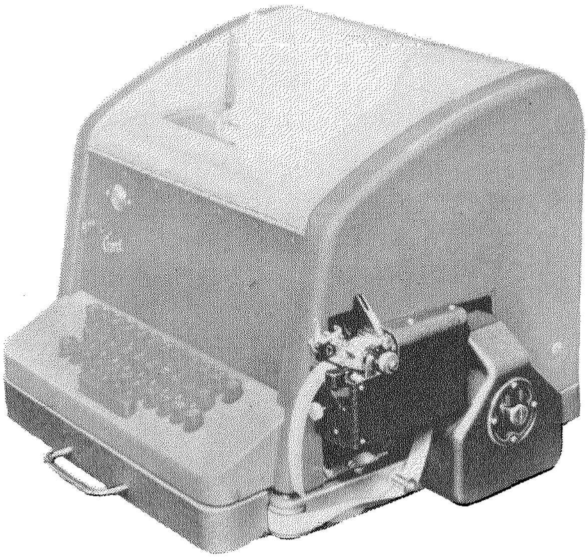


Figure 5—Close-up of reperforating attachment that fits on the right-hand side of the machine and records incoming messages in standard five-channel tape simultaneously with normal page printing. It also enables the machine to be used as a normal keyboard perforator for the origination of punched tape with coincident printed-page copy.

read off the combination from the selected pins and transmit it to line. This mode of operation avoids the need for a separate keyboard camshaft, clutch, and gears, thereby achieving simplification in design and reduction in number of parts. Also, since the combination is read off by the aggregate-motion mechanism and printed at the same time as it is transmitted to line and not, as on previous machines, after a time delay, the response of the machine to the operator's touch approximates that of a typewriter.

A consequence of using the translator camshaft for controlling keyboard transmission is that the transmission is basically $6\frac{1}{2}$ units in length; 130 milliseconds at 50 bauds. It is, therefore, necessary to insert the missing unit, and this is done by employing a spring-controlled time-delay mechanism that extends the stop signal from ½ unit to 1½ units in length.

3. *Further Developments*

As previously mentioned, the model-Seventy-five teleprinter, while being a complete and self-contained machine, is also the basic unit of an integrated line of equipment that is being developed by the addition of special attachments or by modifying the teleprinter in various ways.

In designing the teleprinter, a great deal of attention was given to ensuring that this projected range of auxiliary machines could be developed from the parent machine with a minimum number of modifications. Such integrated design methods result in considerable advantages to customer and manufacturer alike. Smaller stocks of spare parts can be held by customers having more than one of the related types of machine, while overall development time is reduced and manufacturing economies are made possible.

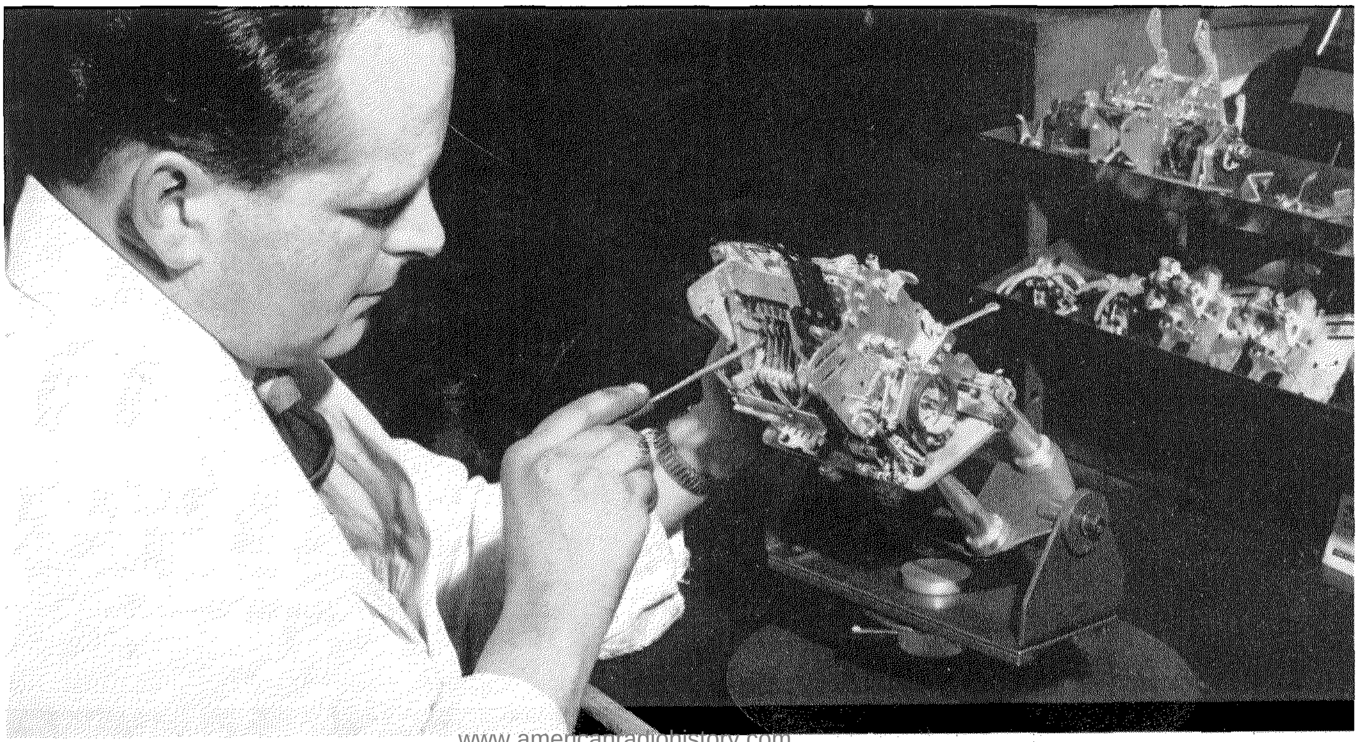
The first of the special attachments—a reperforating unit—which has recently gone into production, is illustrated in Figure 5. This fits on the right-hand side of the teleprinter, its code bars being set by the same operating levers that control the aggregate-motion-mechanism control rods. The attachment provides a perforated record of both transmitted and received signals. The punched tape, which is supplied from a drawer under the main base, issues from the attachment towards the front of the machine. Its compactness may be judged from the fact that it adds less than 3 inches (7·6 centimetres) to the width of the machine and about 1 inch (2·5 centimetres) to its height.

The other special attachments and derivative machines will include an automatic tape transmitter, a printing reperforator, and a tape teleprinter. These are, at present, being actively developed.

The mechanical local-record feature of the teleprinter enables it to be adapted easily to a variety of applications in the field of integrated data processing. One such application, which is now under development, is a teleprinter operating from 5-wire parallel input. This has been derived from the standard machine by replacing the keyboard with five electromagnets, which mechanically set the selecting pins through existing mechanisms in response to the parallel input signals.

The model Seventy-five teleprinter itself is now in full-scale production (Figure 6). Prior to this, preproduction models of the machine were given extensive trials by a number of telegraph administrations and other large organisations. These trials were most successful—how successful can be judged from the fact that orders for several thousand machines have already been received.

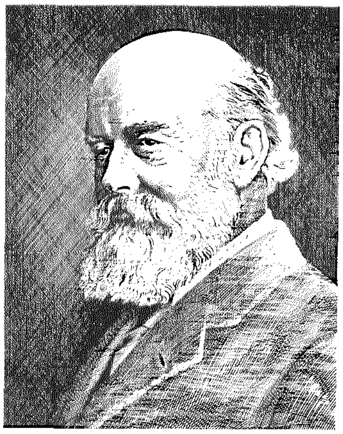
Figure 6—Assembling translator units for the model Seventy-five teleprinter.



Etching of Oliver Joseph Lodge

Oliver Joseph Lodge (1851–1940), British scientist, is depicted in the latest of the series of etchings published by the International Telecommunications Union.

Although originally planning on a business career, Lodge's interest in science led him to enter University College, London, in 1872. Starting his work as a teacher three years later, he succeeded in 1881 to the chair of physics at University College, Liverpool. In 1900, he was appointed the first principal of Birmingham University, where he continued until his retirement from academic life in 1919.



He did original work on lightning, the source of electromotive force in voltaic cells, electrolysis, ionic velocity, electromagnetic waves and wireless telegraphy, motion of the ether, and the use of electricity to disperse smoke and fog. His experiments at Liverpool with the coherer and the phenomenon of tuning, which he fully described in a patent of 1897, were important advances in radio communication. By his writings, Lodge did much to familiarize the lay public with the scientific views of his time. He also published extensively on psychical research.

Lodge was elected a Fellow of the Royal Society in 1887 and received knighthood in 1902. He was a president of the Physical Society, the British Association, the Radio Society, and the Röntgen Society The Institution of Electrical Engineers conferred on him successively its vice-presidency, honorary membership, and Faraday Medal.

The etching of Lodge is the 24th in the series that was started in 1935. On a good grade of paper measuring 9 by $6\frac{5}{8}$ inches (23 by 17 centimeters) including margins, these etchings are available at 3 Swiss francs each from Secrétariat général de l'Union internationale des Télécommunications, Palais Wilson, 52, rue des Pâquis, Genève, Suisse. The entire series is comprised of etchings of Ampère, Armstrong, Baudot, Bell, Erlang, Faraday, Ferrié, Fresnel, Gauss and Weber, Heaviside, Hertz, Hughes, Kelvin, Kirchhoff, Lodge, Lorentz, Marconi, Maxwell, Morse, Popov, Pupin, Rayleigh, Siemens, and Tesla.

High-Frequency Radio Receiver RX.5C

By L. J. HEATON-ARMSTRONG and J. D. HOLLAND

Standard Telephones and Cables Limited; London, England

DESIGNED primarily for the reception of frequency-shift telegraphy in the band from 2 to 30 megacycles per second, the *RX.5C* radio receiver incorporates a number of important features to improve operation under difficult receiving conditions.

The reception of telegraph signals in the high-frequency band is adversely affected by noise, interference, and fading, and it is usual to employ high-gain directive antennae, frequency-shift telegraphy, and dual space diversity to combat these effects.

It has been pointed out[1] that if selective fading is present, the use of the conventional limiter and discriminator for frequency-shift reception does not utilize all of the available information in the signal; some of this is destroyed in the limiter. If, for instance, selective fading is causing strong mark and very-weak space signals to be produced at the receiver input, the signal from the discriminator will consist of good mark signals followed by bursts of noise or the absence of signals, depending on the receiver gain adjustment. If, however, the signals could be observed on an oscillograph it would be immediately apparent that the noisy or missing elements should be space signals.

[1] J. W. Allnatt, E. D. J. Jones, and H. B. Law, "Frequency Diversity in the Reception of Selectively Fading Binary Frequency-Modulated Signals," *Journal of the Institution of Electrical Engineers*, Part B, volume 104, pages 98–110; March, 1957.

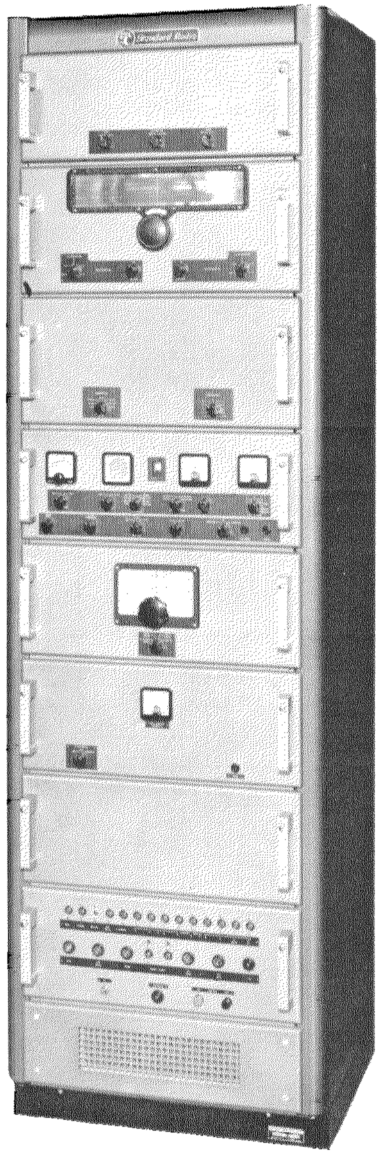


Figure 1—*RX.5C* equipment for frequency-shift telegraphy reception on the high-frequency radio band.

The receiver described here uses a technique that gives satisfactory reception provided a good mark or a good space signal alone is being received. This is equivalent to adding dual frequency diversity, and gives a decisive improvement when selective fading is present.

Another feature is the use of ratio squaring[2] for combining the dual space-diversity signals. Compared to the more-usual method of switching to the strongest signal, ratio squaring gives a worthwhile improvement in signal-to-noise ratio and eliminates trouble due to switching transients.

Another useful feature is the derivation of the voltage for automatic frequency control from both mark and space signals, so that good automatic frequency control is obtained as long as either signal is present. This mode of operation gives less residual mistuning than the use of one signal alone.

1. Equipment

Figure 1 is a photograph of the *RX.5C* receiver, which is housed in a cabinet 78 inches (198 centimetres) high, 23 inches (58 centimetres) wide, and 21 inches (53 centimetres) deep. The equipment is mounted on eight withdrawable trays and is split into small chassis units for ease of servicing and maintenance.

[2] L. R. Kahn, "Ratio Squarer," *Proceedings of the IRE*, volume 42, page 1704 (Correspondence); November, 1954.

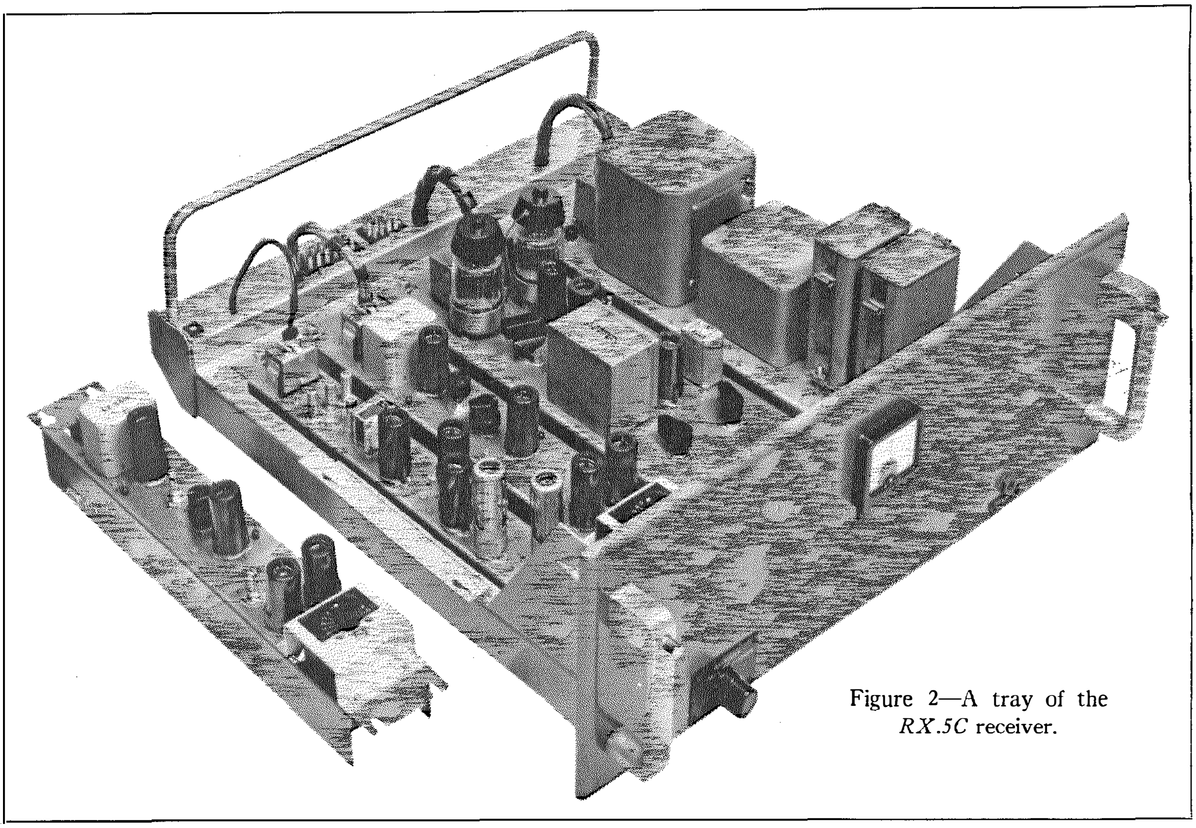
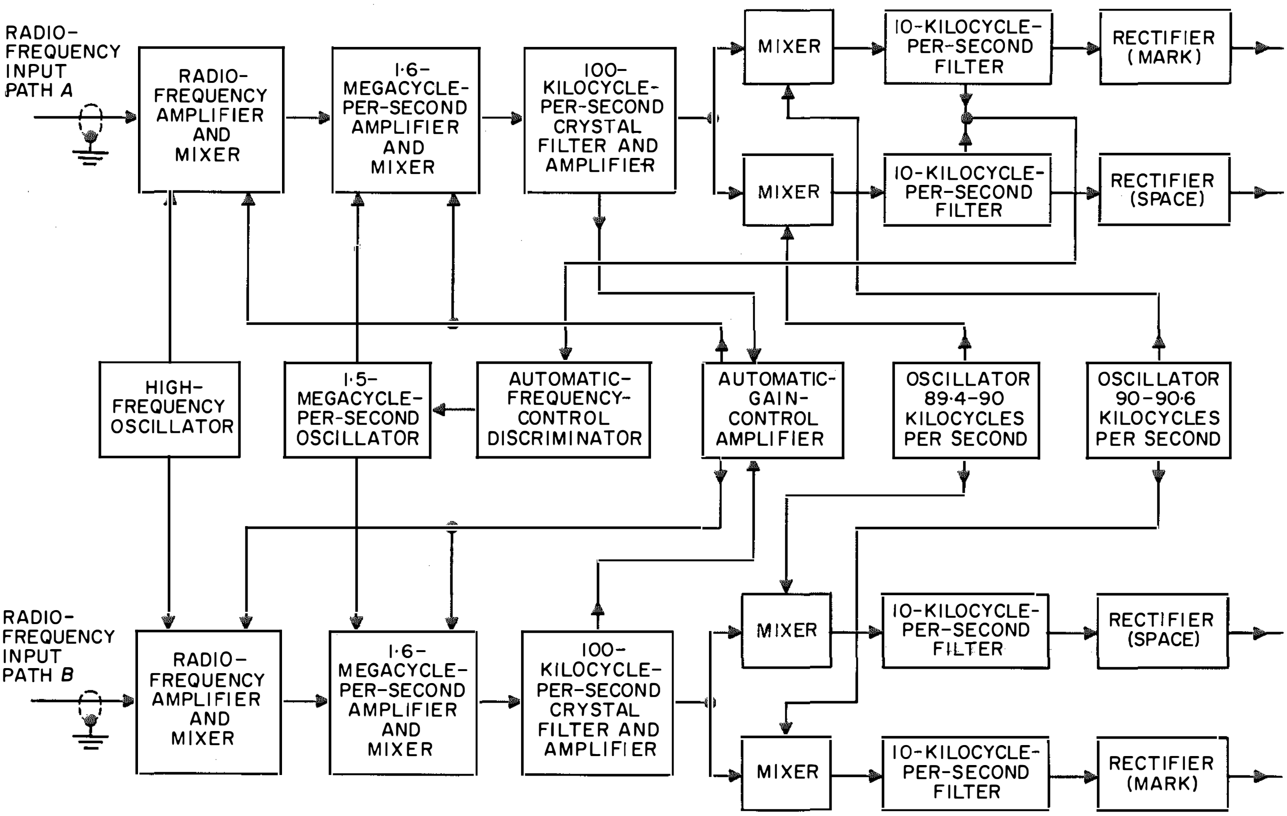


Figure 2—A tray of the *RX.5C* receiver.



A typical tray is shown in Figure 2. Front access only is required.

The equipment is suitable for operation in ambient temperatures from -20 to $+45$ degrees centigrade, a small blower and air filter being provided for cooling.

Silicon rectifiers and encapsulated transformers are used in the power units.

The equipment is suitable for reception of *A1*, *A2*, *A3*, *F1*, and *F6* (4-frequency diplex) signals. If all facilities are not required initially, the appropriate units can be omitted in the first instance and added later, as the cabinet is wired for them.

Only international type valves are used.

2. *Principles of Operation*

2.1 Reception of Frequency–Shift Telegraphy

Figure 3 shows a block schematic of the units used for frequency-shift telegraphy.

The receiver is of the dual space-diversity type employing triple detection. A two-stage radio-frequency amplifier covers the band from 2 to 30 megacycles per second. The amplifiers for each diversity path are ganged to a single control for ease of tuning. A high-frequency beating oscillator, the frequency of which can be either crystal controlled or adjustable, is used to convert the high-frequency signals to an intermediate frequency of 1·6 megacycles per second. After passing through a two-stage amplifier, the signals are then converted to a second intermediate frequency of 100 kilocycles per second and go through a crystal filter that provides the major part of the selectivity.

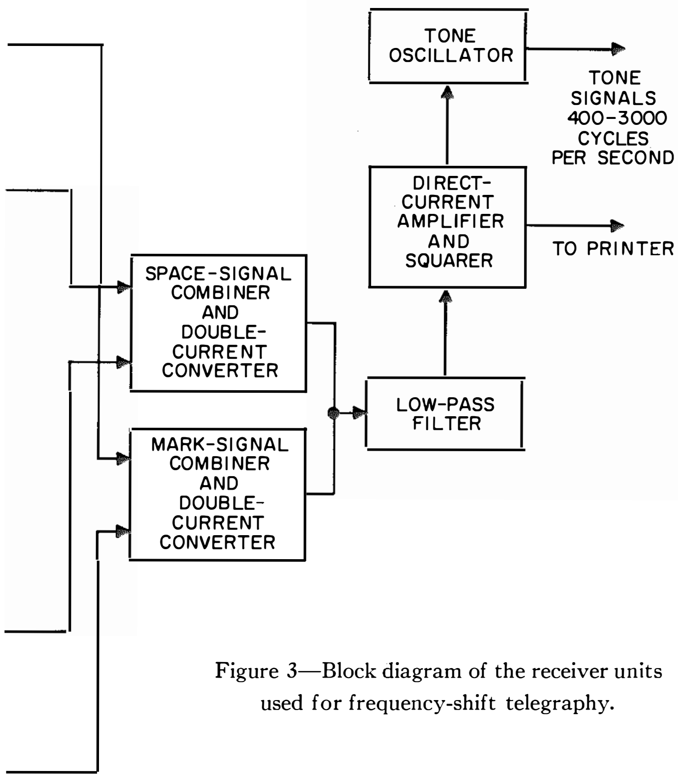


Figure 3—Block diagram of the receiver units used for frequency-shift telegraphy.

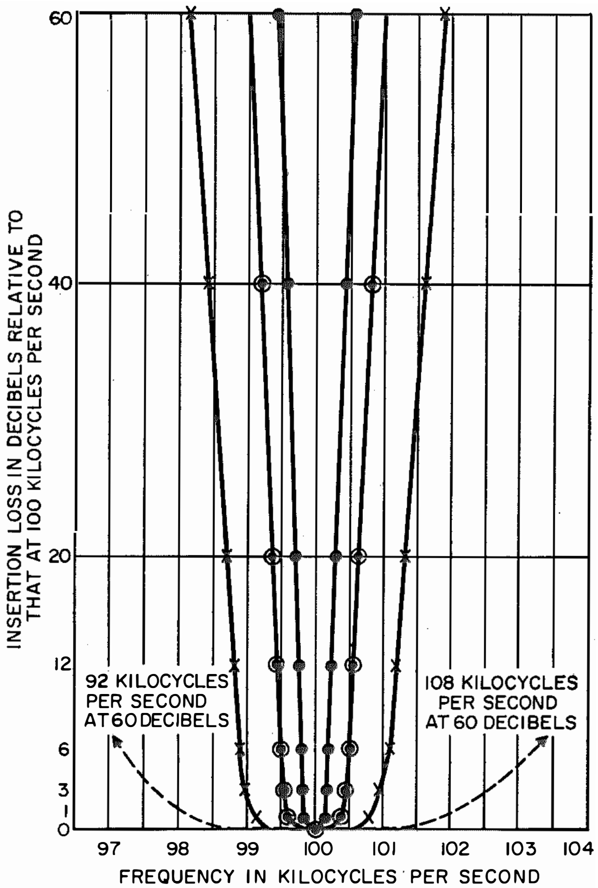


Figure 4—Response–frequency curves for crystal filters used in the 100-kilocycle-per-second section of the receiver. The nominal bandwidths are 500, 1000, 2000, and 6000 cycles per second, the latter being used for telephony.

Filters are available with bandwidths of 500, 1000, and 2000 cycles per second, for the various signalling speeds and services.

Figure 4 shows the filter response–frequency curves. Care has been taken to obtain a good transient response to avoid ringing, which can cause faulty operation under certain conditions of propagation.

The 100-kilocycle-per-second signals contain both mark and space frequencies, which are now separated into individual channels by applying the signals to two mixers. In one mixer, the signal is combined with a 90-kilocycle-per-second wave to convert the mark frequency to 10 kilocycles per second for selection by a filter operating at that frequency.

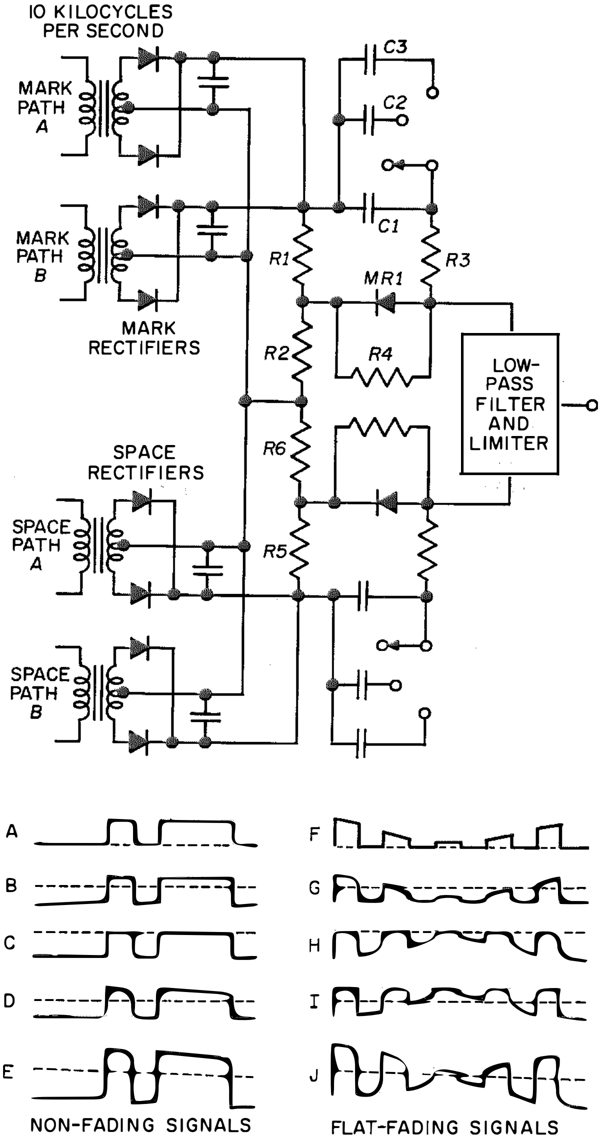


Figure 5—Details of combiner and double-current converter.

A and *F* = mark rectifier output across *R1* and *R2*.
B and *G* = mark signal at input of low-pass filter.
C and *H* = space rectifier output across *R5* and *R6*.
D and *I* = space signal at input to low-pass filter.
E and *J* = combined mark and space signals at input to low-pass filter.

Similarly, an oscillation of appropriate frequency is applied to the other mixer to convert the space frequency to 10 kilocycles per second for subsequent selection by a filter. There are two 10-kilocycle-per-second outputs for the mark frequency (one from each diversity path), and these are now combined in a circuit that adds them in proportion to the square of the signal-to-noise ratios. The mark signals are then converted to double-current signals and applied to a low-pass filter. The space signals are similarly combined and converted to double-current form and applied to the low-pass filter. The signals from the low-pass filter are then applied to shaping circuits to square them before passing to the printer.

2.2. Combiner and Double–Current Converter

It has been shown by Kahn[2] that for optimum results the signals from the two diversity paths should be combined in proportion to the square of their signal-to-noise ratios. A close approximation to ratio squaring can be obtained very simply[3] by connecting the two signals to a common resistance and choosing the source impedance equal to $R(2^{1/2}\text{-}1)$, where R is the common resistance.

Figure 5 shows the circuit for the combiner and double-current converter. The mark signals from the dual paths are rectified and combined in a common load, the value of which is mainly determined by the two equal resistances *R1* and *R2*, which are smaller than *R3* and *R4*. Half the voltage produced by the mark signal appears across *R2* and is applied to the filter input. The other half appears across *R1* and charges *C1*. When the mark signal ceases, *C1* discharges through *R1*, *R3*, and *R4*, but *R4* is large compared to *R1* and *R3*, so that nearly all the voltage from *C1* appears across *R4* and is applied to the filter as a negative voltage. The mark signal has thus been converted to a double-current signal shown at 5B. The space signals are similarly

[3] R. T. Adams, British Patent 801 165.

treated (5C and 5D) and added in series with the mark signals to give a combined signal output shown in 5E.

The time constants for charge and discharge of *C1* are chosen so that *C1* charges in the time of the shortest signal element and discharges in a somewhat longer time than that of the longest signal element.

absent due to selective fading. This condition will very rarely occur in practice and, if present, can be avoided by decreasing the time constant. The circuit will then behave like a normal discriminator and will operate satisfactorily provided there is a sufficiently good signal-to-noise ratio on both mark and space signals.

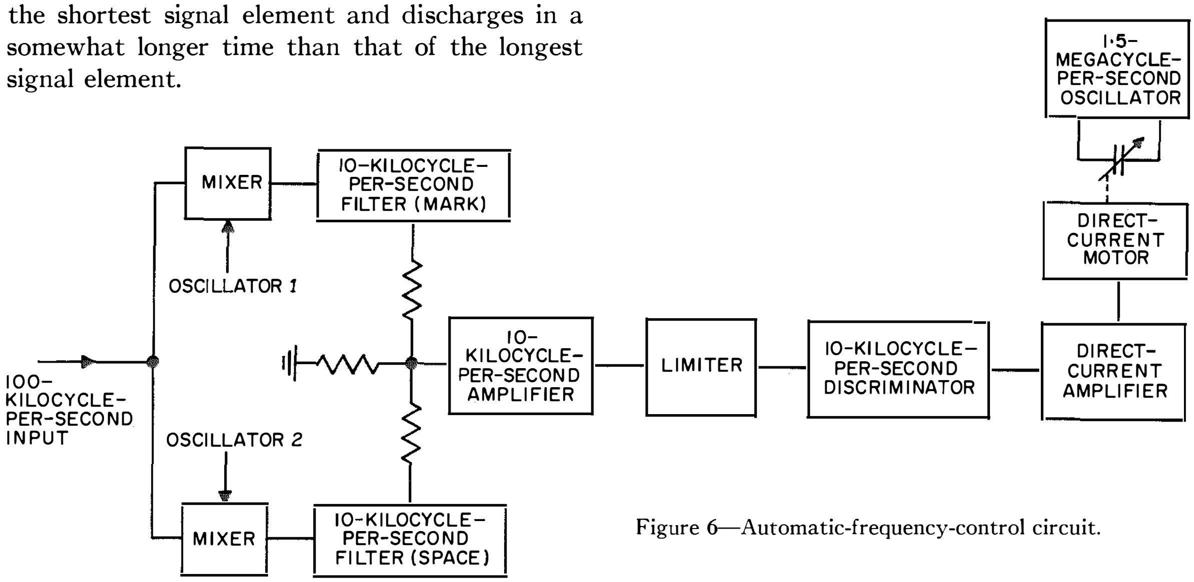


Figure 6—Automatic-frequency-control circuit.

If either signal is present the printer will operate; there is thus a great advantage over the conventional limiter–discriminator, which is almost certain to give errors if the mark or space signal only is present.

It should also be noted that a continuous mark or space signal will be transmitted through the combiner. This is important for teleprinter operation.

The effect of fading will now be considered. If fading is slower than the time constant of $C1 \times R4$, the system will operate as described above. If the fading period is less than the time constant of $C1 \times R4$ but is of the nonselective type, that is, both mark and space frequencies are present, the waveform will remain symmetrical as shown in Figure 5E, and will merely vary in amplitude as shown in Figure 5J. No errors will be produced provided the signal-to-noise ratio is high enough.

Under conditions of fast selective fading that has a period appreciably less than the time constant $C1 \times R4$, the waveform will become unsymmetrical and errors will be produced. This condition is shown in Figure 5G, which shows mark signals only, the space signals being presumed

2.3. Automatic Frequency Control

Figure 6 shows the automatic-frequency-control circuit. The 10-kilocycle-per-second mark and space signals from one path are combined, amplified, and limited, and then applied to a discriminator. The direct-current output of the discriminator is amplified and used to drive a direct-current motor that is coupled to a small trimmer capacitor connected across the 1·5-megacycle-per-second oscillator. When used on twinplex the automatic-frequency-control system operates from the four signalling frequencies, thus giving a control voltage at all times.

2.4 Twinplex, Four–Frequency Diplex

Twinplex[4] is a system by which two communication channels can be maintained simultaneously using a transmitter that need not be of the

[4] C. Buff, "Twinplex and Twinmode Radiotelegraph Systems," *Electrical Communication*, volume 29, pages 20–33; March, 1952.

linear amplifier type. Frequency-shift keying is employed using four frequencies, only one of which is present at any instant. A typical code combination is shown in Table 1. The frequency shift is normally 600 or 1200 cycles per second. *F1*, *F2*, *F3*, and *F4* are the four signalling frequencies.

Figure 7 shows the receiver circuits for one diversity path. The signals at 100 kilocycles per second go to four mixers that are also supplied by oscillators *1* through *4* having frequencies that will convert each of the four signalling frequencies to 10 kilocycles per second. The four frequencies are thus separated and then rectified and applied to the load to produce a positive or negative voltage as required. Several code combinations are in use; a switch is therefore provided in the receiver to connect the rectifier outputs to either side of the load, and thus make up any combination.

The second diversity path is identical with that just described. Combining is done by paralleling the rectifiers. By a correct choice of the value of load resistance and rectifier source resistance, a ratio-squaring characteristic is obtained.

2.5 *A1*, *A2*, AND *A3* SIGNALS

Outputs taken from the crystal filters at 100 kilocycles per second are impressed on the combining circuit shown in Figure 8. For all modes of working the signal envelopes go to the combiner valves *V1* and *V2*. On telephony the combined audio-frequency components are developed across *R4*, and on telegraphy the keyed components appear across *R3*.

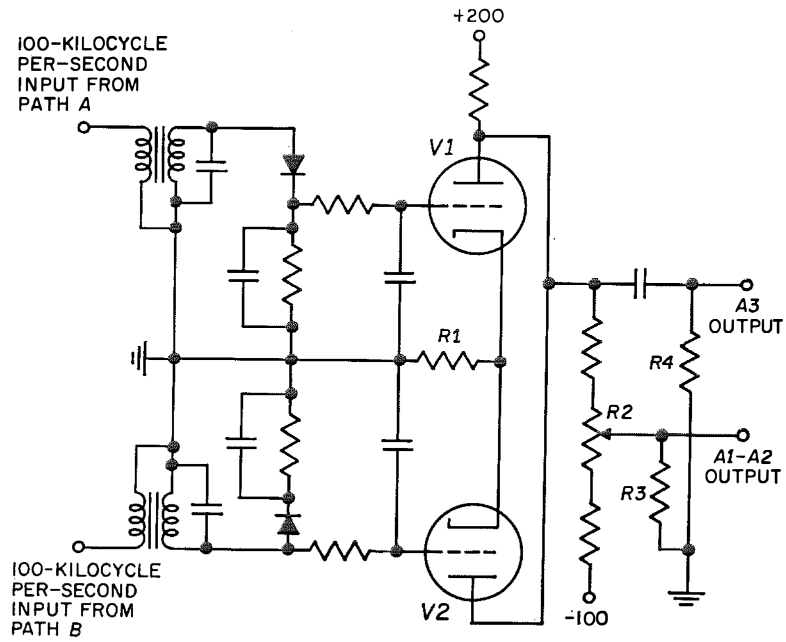


Figure 7—Combiner for four-frequency diplex.

TABLE 1

TWINPLEX SIGNALLING FREQUENCIES

Condition of		Designated Frequency	Deviation from Carrier Frequency in Cycles per Second
Channel *1*	Channel *2*		
Mark	Mark	*F4*	+600
Mark	Space	*F3*	+200
Space	Mark	*F2*	−200
Space	Space	*F1*	−600

The method of combining provides for attenuation of the weaker signal due to the common cathode resistance *R1* and can be described as a linear attenuating and adding system; it is approximately 0·5-decibel inferior to the ratio-squaring system.[2]

On telegraphy, the combiner provides a double-current output from single-current inputs, and this allows the direct-current amplifier and squaring circuits shown in Figure 3 to be keyed effectively as on *F1* working.

This conversion process is obtained by the setting of the threshold bias control *R2*, which is adjusted to give a positive-going output across *R3* on space (no-signal condition) and a negative-going output on mark. The setting of *R2* provides a means for controlling systematic distortion.

3. *Monitoring Circuits*

Facilities are provided for monitoring the following:

A. Direct- and alternating-current levels.

B. Signal and output levels.

C. Frequency.

The first item is covered by monitoring the cathode currents of all valves in conjunction with a wander lead and built-in monitor meter. Each tray carries a socket that is wired to a tray tap switch and meter, and insertion of the wander plug into lead-through pins situated at each valve provides a measurement of valve performance. This method is relatively inexpensive and less complex than one in which each valve is wired to a tap switch. The meter is also, in conjunction with rectifiers, calibrated to indicate the tone output to line.

Item *B* is covered by a monitor meter that indicates the field strengths of paths *A* and *B* in terms of level at the receiver input. The instantaneous signal levels at the 10-kilocycle-per-second branched outputs can be observed on electronic tuning indicators. Separate centre-zero meters are included in the channel-*1* and -*2* telegraph outputs. These meters can be switched to indicate the currents through locally connected teleprinters or a remote load.

The output telegraph level must be free from systematic distortion, and this is obtained by injecting a level at 50 cycles per second into the input terminals of the bistable circuits used on *A1* and *F1* working and adjusting the line output currents for zero indication in centre-zero meters. This procedure checks all the circuits after the demodulating process.

Circuits between the antenna and the various demodulators can be checked, with no input signal, by measurement of input thermal noise in the field-strength meters.

The last item, frequency determination, is accomplished by the use of three crystal-controlled oscillators at 250, 100, and 90 kilocycles per second arranged in various circuit configurations for monitoring purposes as follows:—

A. The 250- and 100-kilocycle-per-second oscillators serve as reference check points for the adjustable-frequency first beating oscillator.

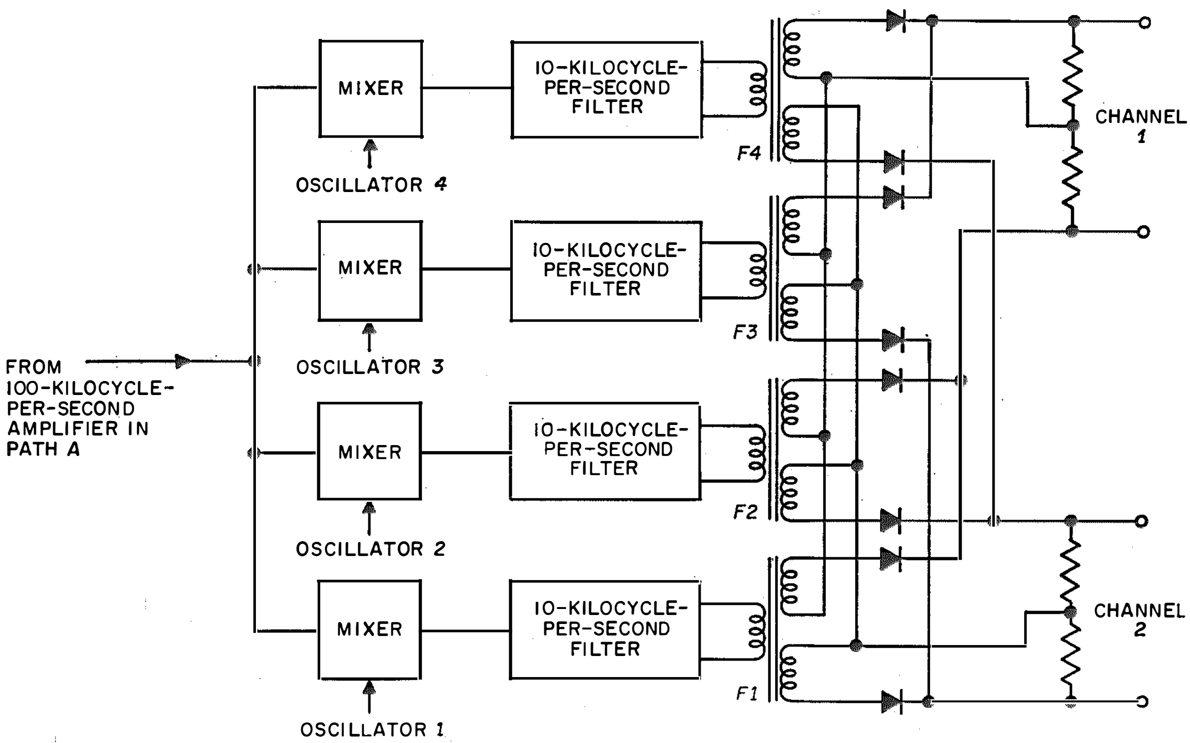


Figure 8—Combiners for telegraphy (*A1* and *A2*) and telephony (*A3*).

B. The 100-kilocycle-per-second oscillator is used to check the 100-kilocycle-per-second discriminator and, by beating with the 90-kilocycle-per-second crystal, yields a 10-kilocycle-per-second output for checking the automatic-frequency-control discriminator and amplifier circuits that operate at 10 kilocycles per second.

C. The 90-kilocycle-per-second crystal oscillator, by substitution, checks the high-stability frequency-shift oscillators shown in Figure 3, which operate at 89·4 to 90 and at 90 to 90·6 kilocycles per second. The shift oscillators are ganged together and are calibrated in shift up to 1200 kilocycles per second. These oscillators, after checking, can be switched into the circuit in turn for a functional check of the motor circuits of the automatic frequency control.

All the main supply circuits are protected by miniature circuit breakers instead of fuses. These are mounted on the front panel of the power unit and provide rapid visual monitoring of breakdown due to overload. These breakers are designed in such a manner that the circuits cannot be re-established until the fault is cleared.

4. Typical Performance

Frequency Range	2 to 30 megacycles per second in 7 bands
Input Impedance	75 ohms, coaxial transmission line
Noise Factor	6 decibels at 28 megacycles per second 4 decibels at 4 megacycles per second
Sensitivity	0·15 microvolt in series with 75 ohms required at 28 megacycles per second on frequency-shift operation using 1000-cycle-per-second pass-band and 400-cycle-per-second shift for 1 error per 1000 characters.
Image Suppression	Greater than 80 decibels
Intermediate-Frequency Breakthrough at 2 Megacycles per Second	Greater than 70 decibels
Selectivity at First Intermediate Frequency	12 kilocycles per second at 3-decibel attenuation 34 kilocycles per second at 20-decibel attenuation
Selectivity at Second Intermediate Frequency	
With 0·5-Kilocycle-per-Second Filter	0·4 kilocycle per second wide at 3 decibels of attenuation 1·1 kilocycles per second wide at 60 decibels of attenuation
With 1-Kilocycle-per-Second Filter	0·9 kilocycle per second wide at 3 decibels of attenuation 2 kilocycles per second wide at 60 decibels of attenuation
With 2-Kilocycle-per-Second Filter	2 kilocycles per second wide at 3 decibels of attenuation 3·8 kilocycles per second wide at 60 decibels of attenuation
With 5-Kilocycle-per-Second Filter	5 kilocycles per second wide at 3 decibels of attenuation 16 kilocycles per second wide at 60 decibels of attenuation
Distortion	Less than 5 per cent at 50 bauds for failure of mark or space signal on frequency-shift operation
Frequency Stability	
First Beating Oscillator (Crystal Controlled)	± 50 parts per million for variation of ± 20 degrees centigrade about a mean ambient of 25 degrees centigrade and ± 5-percent variation in supply voltage.
Adjustable-Frequency Oscillator	±200 parts per million for temperature and supply variations specified above
Second Beating Oscillator	±200 parts per million for temperature and supply variations specified above

Frequency-Shift Oscillator (90 Kilocycles per Second)	±40 parts per million for variation in temperature and supply voltages specified above
Blocking	The unwanted signal must be at least 45 decibels above the wanted signal if it is 5 kilocycles per second off tune
Automatic Gain Control	Less than 6 decibels rise in output level for input variation from −12 to +80 decibels relative to 1 microvolt
Automatic-Frequency-Control Residual Mistune	Will follow drifts up to ±3 kilocycles per second with residual error of less than 5 cycles per second at 50 bauds or 20 cycles per second at 200 bauds
Capture Level	Synchronism with the wanted signal is not lost if the unwanted signal is at the same frequency and the level is not greater than −6 decibels relative to the wanted signal
Keying Speeds	Up to 200 bauds
Output Levels	
Telegraphy	50–0–50 milliamperes direct current. Tone output +10 decibels relative to 1 millwatt in 600 ohms
Telephony	+10 decibels relative to 1 millwatt in 600 ohms
Power Consumption	Not exceeding 600 volt–amperes with all units operating

Recent Telecommunication Development

Electronic Avigation Engineering

INTERNATIONAL Telephone and Telegraph Corporation is the publisher of a recently released book entitled Electronic Avigation Engineering, which was written by P. C. Sandretto, vice president and technical director of ITT Laboratories.

The book is divided into 4 parts and 17 chapters. A short introduction is given for each part. The part and chapter titles are as follows.

Part A—En-Route Long-Distance Zone

Chapter 1—Airborne Direction Finders and Radiophares
Chapter 2—Four-Course Low-Frequency Radio Range and Markers
Chapter 3—Consol
Chapter 4—Some Low-Frequency Developments
Chapter 5—High-Frequency Direction Finding from Ground Stations
Chapter 6—Loran
Chapter 7—Electronic Pilotage
Chapter 8—Electronic Aids to Dead Reckoning

Part B—En-Route Short-Distance Zone

Chapter 9—Very-High-Frequency Phase-Comparison Omnidirectional Radio Range
Chapter 10—Distance-Measuring Equipment
Chapter 11—Some Avigational Aids for the Short-Distance En-Route Zone
Chapter 12—Tacan

Part C—Approach and Landing Zone

Chapter 13—Airport Surveillance Radar
Chapter 14—Fixed-Beam Low-Approach Systems
Chapter 15—Radar Low-Approach Systems
Chapter 16—Landing Altimetry

Part D—Airport Zone

Chapter 17—Airport Surface Detection Equipment.

The book is 6 inches (15 centimeters) by 9 inches (23 centimeters) and contains 775 pages of text, 16 pages of index, 527 figures, 667 equations, and 380 references in selected bibliographies. It is available postpaid at $9.50 per copy or at $7.60 per book in lots of 12 or more to a single address from International Telephone and Telegraph Corporation, Technical Publications Section, 67 Broad Street, New York 4, New York.

Direct-Printing Receiving Systems at Low Radio Frequencies

By L. J. HEATON–ARMSTRONG and J. D. HOLLAND

Standard Telephones and Cables, Limited; London, England

BEFORE 1954 little information was published on the use of direct-printing facsimile and telegraph operation with transmission in the low radio-frequency band. In that year Doutre made a preliminary study of some of the factors that affected the reliability, cost, and complexity of a ground-to-air broadcast service intended for direct printing of weather information in aircraft flying over the North Atlantic.

Doutre estimated that, on a frequency of approximately 100 kilocycles per second, 10 kilowatts of power radiated from each of two stations located in coastal areas on both sides of the Atlantic would provide adequate coverage over the entire route with a measure of overlap. His figure appears to be a realistic estimate from an analysis of the flight tests that have been made.

Increasing interest in these frequencies has been shown by other users, mainly for newscast services and for the reception of meteorological information by weather ships. This has led to the development of narrow-band frequency-shift receivers designed for unattended operation in the band from 90 to 130 kilocycles per second.

For ground-to-air service the receiver is coded *SR.24*. It uses 11 valves and has a built-in rotary transformer operating from a 24-volt direct-current supply. This model will shortly be replaced by a design employing transistors and powered from a 115-volt 400-cycle-per-second supply. The power consumption of this model is less than one-tenth that of the *SR.24*. This receiver becomes an integral part of the model Seventy-five teleprinter supplied by Creed & Company.

For use at sea or for press work a receiver coded *RV.14* has been developed. This is similar to the *SR.24* but operates from alternating-current mains. All these receivers give a choice of 4 crystal-controlled frequencies.

1. Choice of Bandwidth and Shift

The bandwidth occupied by the transmission should be as narrow as possible to avoid interference with other services and also to enable the receiver bandwidth to be a minimum, thus giving the best possible signal-to-noise ratio at the detector.

The modulation index is $m = 2D/B$ where $2D$ is the frequency shift in cycles per second and B is the keying speed in bauds. The relative amplitudes of the carrier and significant sidebands are shown in Table 1 for various values of m. The figures apply to square-wave keying with the higher-frequency components removed.

TABLE 1

RELATIVE AMPLITUDES OF CARRIER AND SIDEBANDS

m	Amplitude of Carrier	Amplitude of Sidebands			
		1st	2nd	3rd	4th
0·5	0·87	0·28	0·75	0·03	0·015
1·0	0·68	0·49	0·2	0	0·03
1·3	0·425	0·53	0·3	0·05	0·03
1·5	0·28	0·53	0·37	0·1	0·03
2·0	0	0·4	0·52	0·22	0·01
2·4	0·15	0·25	0·34	0·53	0·1

The receiver bandwidth must be sufficient to include all significant components, and an allowance for transmitter and receiver frequency instabilities must also be made. The transmitter instability will be approximately ±2 cycles per second. The receiver oscillator instability will be ±2 cycles per second and the intermediate-frequency-discriminator instability will be ±5 cycles per second making a total of ±7 cycles per second for the receiver or ±9 cycles per second for the system. Adding this to the bandwidth required

TABLE 2

BANDWIDTH FOR LOSS OF 1 DECIBEL AT KEYING RATE OF 45·5 BAUDS

m	Bandwith in Cycles per Second	To Include Sideband
0–0·5	63·5	1
0·5–1·5	109	2
1·5–2·4	154·5	3

to take in the significant sidebands, when $B = 45 \cdot 5$ bauds, gives the values shown in Table 2.

Values of m below $0 \cdot 5$ will give poor efficiency because nearly all the power will be in the carrier.

The best value of m is about $1 \cdot 3$ to $1 \cdot 5$ as the bandwidth is then the narrowest possible consistent with a small carrier power. The best value of shift is therefore 59 to 68 cycles per second for a $45 \cdot 5$-baud signalling speed.

2. *Antennas*

The receivers have to accommodate a wide range of open-wire capacitive antennas, and provision is also made for the use of omnidirectional loops.

The balanced double-loop type of antenna has two main advantages in aircraft; namely, reduction in drag and good anti-static properties. This applies particularly to the flush-mounting type since the surface is protected by the boundary layer on the surface of the aircraft. The electrostatic charges will be small, and can be conducted away by graphite impregnation of the loop housing.

deteriorated by a factor depending on the ratio of tuning capacitance to antenna capacitance, and only becomes equal to the loop antenna when the antenna capacitance alone forms the total tuning capacitance; assuming equal values of Q for the loop and the inductance forming part of the tuned circuit associated with the open antenna. For this reason, with open antennas, the stray capacitance must be kept as low as possible, and any impedance-matching device must be mounted as close to the antenna as possible: this condition is not easy to obtain on some installations.

An omnidirectional pattern within ± 2 decibels can be obtained from two crossed loops providing the coils are coupled with a reactive mutual impedance to obtain a 90-degree phase shift between the contributions of the loops before combination. The optimum coupling impedance is that which produces critical coupling, and this can give rise to circuit complexity if the frequency band to be covered is greater than about $1 \cdot 3$ to 1; necessitating adjustment of the reactive elements in discrete steps.

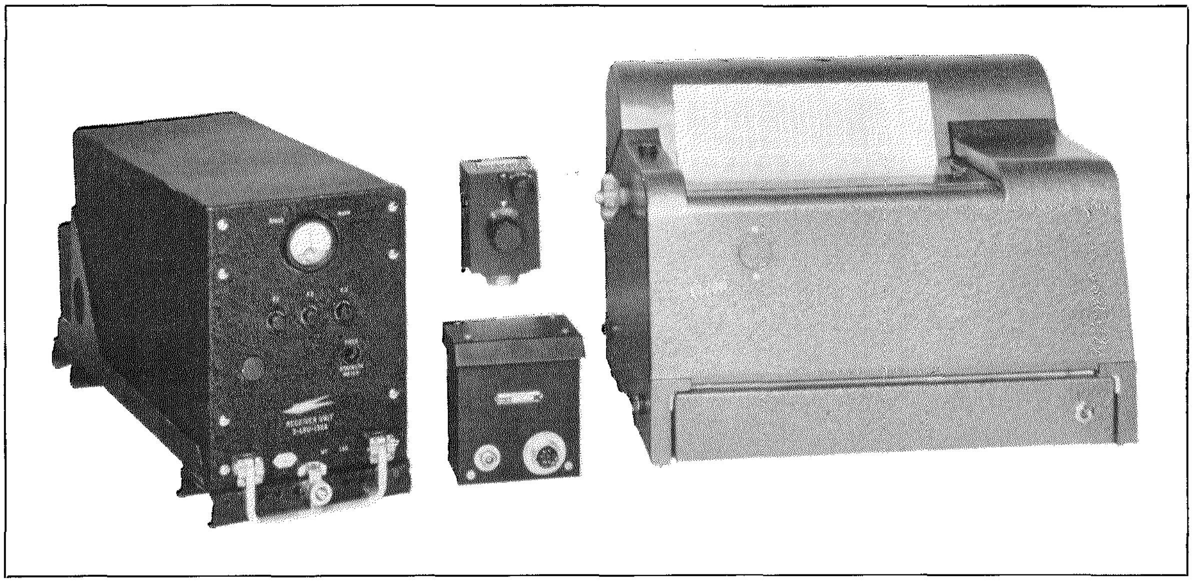


Figure 1—Equipment for a receiving installation.

Comparison of the pick-up factor between given dimensions of the open-wire antenna and the loop antenna are misleading if based on consideration of effective height alone. The signal-to-noise performance of the open antenna is

Recent promising experiments with suppressed antennas may provide an alternative solution to the use of balanced loops or open-wire antennas for aircraft use. For example, a plate having an area of $2 \cdot 5$ square feet ($0 \cdot 23$ square metre)

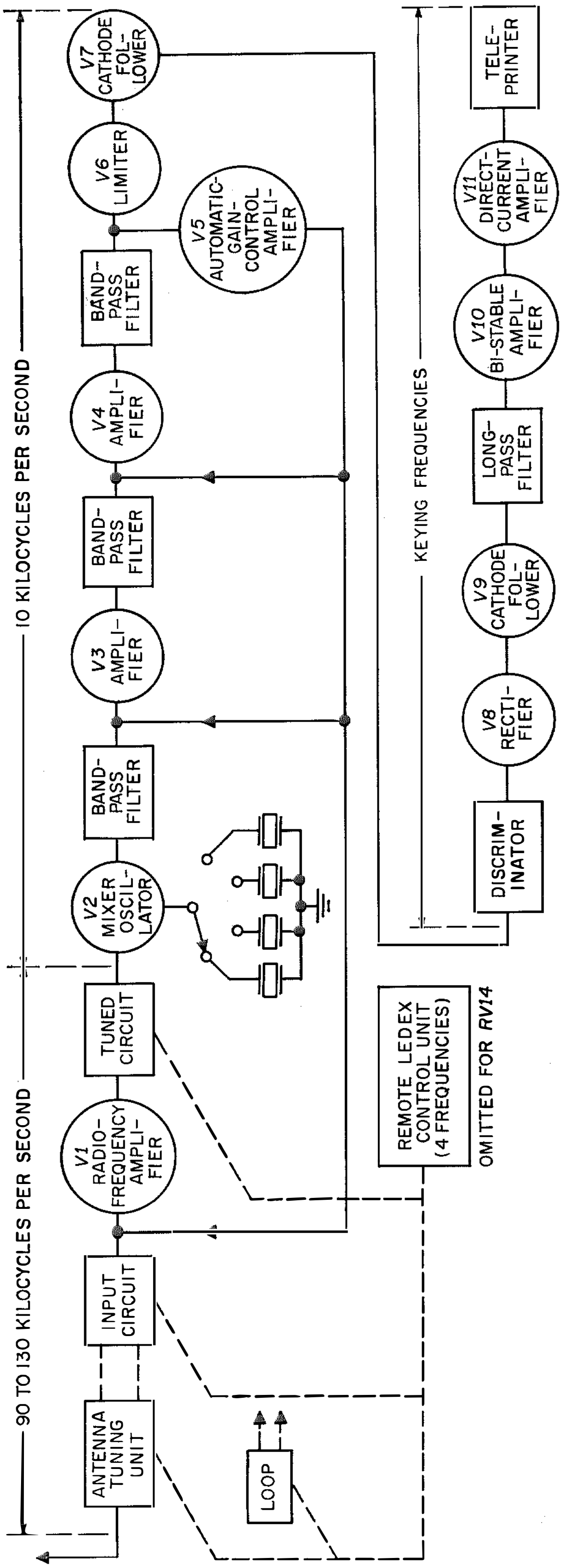


Figure 2—Block diagram of the *SR.24* and *RV.14* receivers. Power for the *SR.24* is obtained from a rotary transformer and for the *RV.14* from the alternating-current mains.

mounted 2 inches (5 centimetres) off the aircraft chassis has the same pick-up factor as an open-wire antenna some 6 feet (1·8 metres) in length and mounted 8 inches (20 centimetres) away from the fuselage. The capacitance of the open type is about 25 picofarads and that of the plate about 80 picofarads.

A plate mounted under and to the rear of the aircraft should have good immunity from rain static.

For electrically resonated antennas using ferrite rods, the best type of rod is one in which the product of effective permeability and the Q of the coil has a maximum value.

An improved pickup factor can be obtained by use of a number of rods with the windings suitably connected and with minimum magnetic coupling among them.

3. *SR.24* Receiver

The *SR.24* receiver was designed for ground-to-air use. A photograph of the equipment for an installation is shown in Figure 1. A block diagram is given in Figure 2.

A band-pass filter is provided before the first amplifier to minimize the effects of strong unwanted signals in coastal areas.

The tuning and crystal circuits are remotely controlled by a Ledex mechanism to provide choice of four frequencies. The crystals have been specially developed for this application. Their dimensions are approximately $1\frac{1}{4}$ by $1\frac{1}{16}$ by $\frac{3}{8}$ inch (32 by 27 by 9·5 millimetres). The maximum frequency variation between −20 and +55 degrees centigrade does not exceed ±42 parts per million. The crystals can be set to the nominal frequency by circuit adjustment.

A total of three critically coupled resonators are used at an intermediate frequency of 10 kilocycles per second. The circuits are temperature compensated, and the bandwidth at 3 decibels down varies between 115 and 135 cycles per second and between 415 and 450 cycles per second at 60 decibels down for a change of 55 degrees centigrade.

The circuits following the discriminator are direct-current coupled and the bi-stable amplifier is keyed at the half-amplitude of the demodulated wave. This represents a compromise between coincident noise voltages occurring at the signal transitions and noise arising during the steady-state condition of the wave. For a shift of 40 cycles per second the maximum degree of frequency error that can be tolerated is therefore ±10 cycles per second.

The discriminator inductances are temperature compensated and encapsulated. The frequency drift of the discriminator due to the combined effects of temperature variation of 55

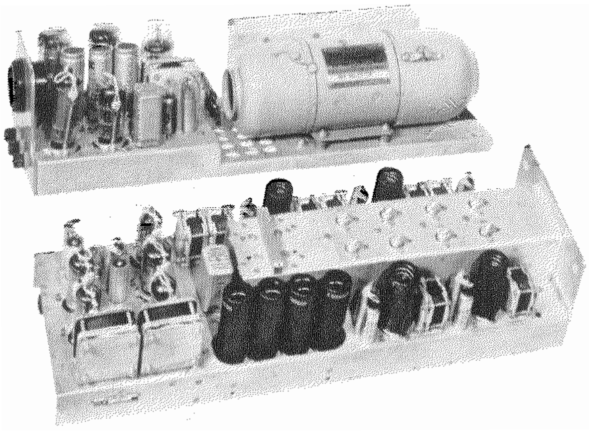


Figure 3—The *SR.24* receiver and its power supply are mounted on two chassis.

degrees centigrade and humidity variations up to 75 percent relative humidity does not exceed 8 cycles per second.

The signal-to-noise ratio is approximately 30 decibels for an input of 1 microvolt into an artificial antenna of 50 picofarads in series with 10 ohms for a bandwidth of 100 cycles per second.

Single-current open-circuit working is used for the model Seventy-five teleprinter, that is, zero magnet current on mark and about 40 milliamperes on space. The performance of the receiver is maintained for variations in the input direct-current supply of ±2 volts of a nominal supply of 28 volts.

The complete installation comprises five units, which are described below. Their dimensions, including allowances for all projections, are given in Table 3.

3.1 Receiver and Power Unit

The units that make up the receiver are shown in Figure 3. One unit contains all the circuits from the antenna to the low-pass filter, and the other unit contains a rotary transformer, stabilizing valves for the high-tension and bias supplies, and the keying circuits. Provision is made for monitoring the field strength via a jack on the front panel.

3.2 Antenna Coupling Unit

The antenna coupling unit contains one circuit coupled via a twin coaxial cable to the receiver input circuit and forms a band-pass filter covering the range from 90 to 130 kilocycles per second. The four pre-set trimmers, corresponding to a choice of four frequencies in the band, are switched by a Ledex mechanism operated from the control box.

3.3 Control Unit

A power-supply switch, four-position switch for frequency control, and an indicator lamp are included in the control unit.

3.4 Backplate Junction Box

The junction box is mounted in the tray immediately behind the receiver and power unit.

3.5 Teleprinter

The model Seventy-five teleprinter is described in full in another paper in this issue and will not be treated here.

TABLE 3

Dimensions of Receiving Units

Unit	Height in Inches (Millimetres)	Width in Inches (Millimetres)	Depth in Inches (Millimetres)	Weight in Pounds (Kilograms)
Receiver–Power	7·875 (200·0)	5·875 (149·2)	17·375 (441·3)	17 (7·71)
Antenna Coupling	5·518 (140·2)	4·986 (126·6)	2·749 (69·8)	1·56 (0·71)
Control	3·687 (93·7)	2·280 (57·9)	3·062 (77·8)	0·75 (0·34)
Junction Box	4·5 (114·3)	5·796 (147·2)	3·312 (84·1)	1·5 (0·68)
Teleprinter	14·625 (371·5)	15·875 (403·2)	14·0 (355·6)	35 (15·88)

4. *RV.14 Receiver*

A photograph of the *RV.14* receiver is shown in Figure 4. This receiver uses the same circuits as the *SR.24* receiver except for the following modifications:—

A. Double-current output at 30–0–30 milliamperes.

B. Power is supplied from the 50-cycle-per-second mains at 110 or 240 volts.

C. Systematic bias distortion can be reduced to a negligible degree by a control brought out to the front panel. This control is coupled to one of the discriminator tuning capacitors and can be operated with reference to a centre-reading meter on the panel.

D. A meter is provided for monitoring field strength.

E. Provision is made to include muting circuits to prevent the printing of random symbols during conditions of high noise or interference.

The *RV.14* receiver is 12⅛ inches (308 millimetres) high, 22½ inches (572 millimetres) wide, and 14½ inches (362 millimetres) deep.

5. *Transistor Receiver*

A receiver using transistors has been developed to replace the *SR.24*. A photograph of it is shown in Figure 5 and a block diagram in Figure 6.

Figure 4—The *RV.14* receiver.

The receiver is mounted in a cast plinth 2 inches (51 millimetres) deep that follows the contours of the model Seventy-five machine. Normally, this space is reserved for a tape reel box for versions of the machine requiring a tape-perforating attachment. This is not required for the airborne service. Installation is completed by connection to an antenna and a 400-cycle-per-second single-phase power supply at 115 volts.

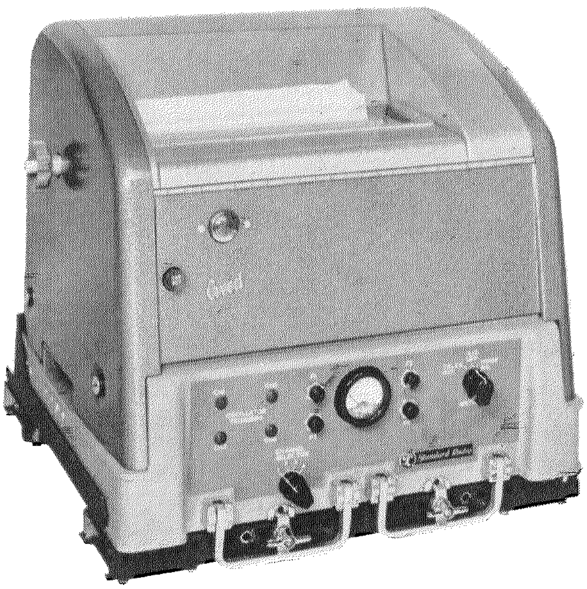


Figure 5—A receiver using transistors is mounted in the case of the model Seventy-five teleprinter. It utilizes the space in which a tape reel box would normally be accommodated.

Two critically coupled encapsulated band-pass filters are used in the radio-frequency stage, and provision is made for a loop antenna.

The inherent internal feedback of the transistor radio-frequency amplifier is neutralised by external feedback between the collector and base of the transistor. The degree of neutralisation required depends on the individual transitor, and provision has been made for this by the use of a small adjustable capacitor. With proper adjustment of the feedback capacitor, the radio-frequency stage is stable over the range from 90 to 130 kilocycles per second.

The crystal oscillator uses the same crystals as the *SR.24* receiver, but in the series-mode condition, and provision is made for adjusting each crystal to its nominal frequency.

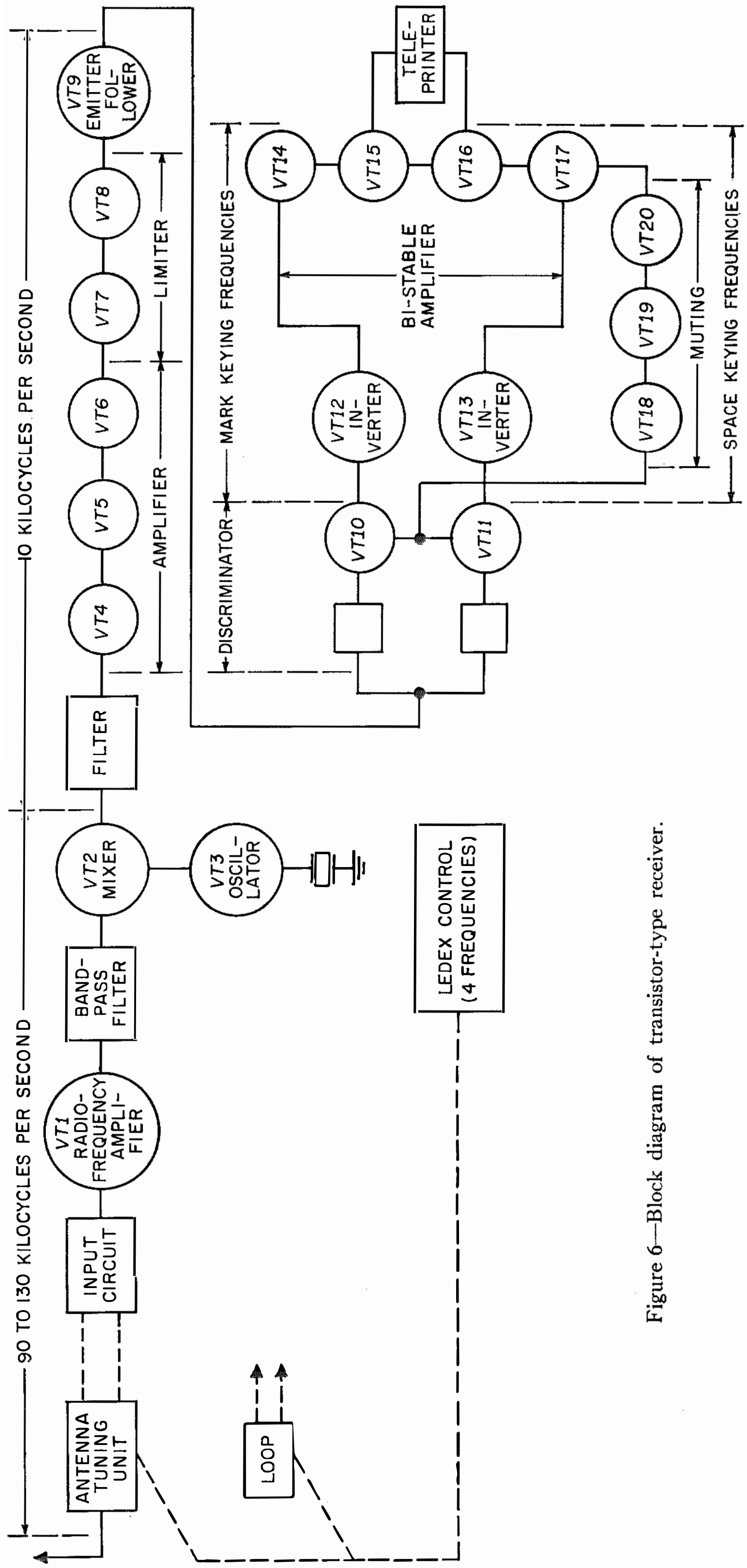


Figure 6—Block diagram of transistor-type receiver.

The mixer stage is coupled into a 5-element hermetically-sealed filter having a bandwidth of approximately 100 cycles per second at the 3-decibel-down points and 400 cycles per second at 60 decibels down with a mid-band frequency of 10 kilocycles.

All frequency-determining components of the discriminator are mounted in a hermetically sealed box. Output keying levels at the mark and space frequencies go to bi-stable amplifiers.

To prevent the printing of random symbols during adverse conditions, one of the output transistors is blocked by a voltage derived from the discriminator, via a threshold control. The all-up weight of the receiver unit is approximately 9 pounds (4 kilograms).

6. *Field Trials*

6.1 Ground-to-Air Over the North Atlantic

Field trials of the system were carried out over the North Atlantic route under the sponsorship of the International Air Transport Association and in co-operation with the British and Canadian Governments and the British Overseas Airways Corporation. One ground station was located at Galdenoch in Scotland and radiated 1·5 kilowatts on 121·6 kilocycles per second. This power was later increased to approximately 2·5 kilowatts. The other ground station was located in Canada, at Chatham, some 400 miles (644 kilometres) inland and radiated approximately 5 kilowatts on a frequency of 118·8 kilocycles per second. A frequency shift of 40 cycles per second was used for the tests reported below.

The limit of range was determined by the point at which the copy had deteriorated to 90 per cent. This point is quite sharply defined; as a further small decrease in signal-to-noise ratio leads to complete failure.

The normal test procedure calls for reception from the nearer station with the change being made at 30 degrees west longitude.

As the tests proceeded, some improvements were made to the receivers and to the antenna system at Galdenoch. The copy obtained at 30 degrees west longitude for later flights was considerably better than 90 per cent. In fact, 99·8-per-cent copy was obtained from both the British and Canadian stations at 30 degrees longitude. When the equipment was left on the frequency of the British station, 98-per-cent copy was obtained at 35 degrees, and 90-per-cent copy at 40 degrees. These figures refer to night ranges.

When operating in daylight the performance is somewhat reduced, but better than 90-per-cent copy is obtainable at 30 degrees. This corresponds to a field strength of 15 microvolts per metre, assuming an effective height of 15 centimetres for the open-wire antenna system.

It should be remembered that the receivers used in these tests were very carefully tuned, and some deterioration should be allowed for in practical service. On the other hand, the Canadian station was located some 400 miles (644 kilometres) inland, and the power of both stations was below the 10 kilowatts recommended by Doutre, which seems to be a realistic figure.

The main causes of mutilation are as follows:—

A. Flying through clouds charged with static. In general, the time lost does not exceed 10 minutes, although this figure depends on the height of the aircraft relative to the height at the top of the cloud.

B. Fading at points where the sky and ground waves are in antiphase and equal in amplitude. This effect does not usually last for more than a few minutes.

C. Intense noise interference from thunder storms. This generally lasts for a period not exceeding fifteen minutes, although the governing factors in *A* will apply. Static crashes from distant storms may cause an occasional mutilation.

On occasions, aircraft noise has been found to be a limiting factor if the installation is defective. With adequate radio-noise suppression applied to the electrical apparatus and with meticulous care in the bonding of interconnecting cables, particularly those connected to the antenna coupling unit, aircraft noise effects are eliminated.

6.2 Shore-to-Ship Trials

In February 1957, an *SR.24* receiver was installed aboard R.M.S. *Queen Elizabeth.* A vertical aerial about 80 feet (24 metres) in length was used, but the tests were somewhat impaired by the length of the cable connection between the antenna and the antenna coupling unit.

The transmitter at Galdenoch was received and 100-per-cent copy obtained at a range of 900 miles (1667 kilometres). This fell to about 90 per cent at 1500 miles (2778 kilometres).

The trials were confined to an outward and homeward passage, and periods of severe weather conditions were encountered. No interference was experienced from any of the transmitters aboard the ship except when using hand-keyed transmission on 143 kilocycles per second at the limiting range.

An *RV.14* has been installed in a weather ship by the Ministry of Civil Aviation and at approximately 20 degrees west longitude, satisfactory copy obtained when receiving Galdenoch.

An *SR.24* was operated successfully from transmissions at Galdenoch at the recent Brussels Universal and International Exhibition.

7. *Acknowledgments*

The authors express their thanks to Messrs. T. Brunt and N. G. V. Anslow of the British Overseas Airways Corporation for an analysis of the ground-to-air flight tests and to Mr. Milton Dishal of ITT Laboratories for helpful correspondence.

Cryptographic Telegraph Equipment Mi544*

By G. GRIMSEN

Standard Elektrik Lorenz AG; Stuttgart, Germany

METHODS of converting ordinary-language or numerical text to enciphered messages or cryptograms are generally grouped into two classes. In the first class, the elements of the original message are jumbled beyond recognition; however, the security of messages so enciphered is low and none of the methods in this class is compatible with teleprinter operation. The other class comprises the various methods of substitution. Some methods of substitution offer limitless security; moreover, the sequential operation of most methods in this class is consistent with the sequential operations of teleprinting and of typewriting or writing in general. The *Mi544*, an enciphering and deciphering equipment for teleprinters, provides the ultimate degree of security. No additional time is lost as a result of the use of ciphers and the *Mi544* can be included in any teleprinter circuit using the 5-unit code.

Enciphering by substitution requires that the original message (plain-language text, numbers, abbreviations, commercial codes, et cetera) be converted to a code determined by the carefully guarded key or cipher. The result is the enciphered message. At the receiving end, the same cipher converts the enciphered message back into the original message.

For processing by machines, each element of both the original message and the cipher must have a numerical value of some kind. This condition is readily met by the teleprinter code where each element of a 5-unit character combination has the value of either 0 or 1. The fact that the binary system of numbers is employed greatly facilitates enciphering and deciphering and does not in the least affect the security of a ciphering system. Security depends solely on the fact that the cipher consists of a practically endless sequence of coded characters statistically distributed and appearing at irregular intervals.

* Originally published under the title, "Das Mischgerät Mi544," in *SEG-Nachrichten*, volume 4, number 4, pages 181–185; 1956.

The preparation of the cipher is an important detail of this ciphering method. There are ciphering equipments that produce the cipher simultaneously with ordinary telegraph operation. They are rather complicated and require operation and maintenance by highly skilled personnel.

1. *Philosophy of Design*

A few historical notes will show that the modern trend is to prepare the cipher separately and to use it, whenever required, in equipment like the *Mi544*.

During 1915 to 1925, methods and devices became known by which, apparently for the first time, ciphers were stored in the simplest form; that is, by perforations in a paper tape. This cipher was used simultaneously with the taped original message to transmit an enciphered version of the latter. Since a cipher of exactly the same form had to be available at the receiving end, the problem arose of producing duplicate perforated tapes. A collateral problem was the physical transfer of the duplicate tapes to the terminal stations without disclosing the ciphers to unauthorized persons.

Events of the years 1915 to 1918 favored the development in the United States of an equipment in which existing units of printing telegraph apparatus were used as building blocks. The result was a device operating on the start–stop principle with the 5-unit code. The original message was manually punched in a tape. The cipher was also punched in a tape. Both tapes were sensed, each by its own transmitting distributor, the 5 contacts of the one being connected with the 5 contacts of the other. This connection employed relay circuits ensuring that two current pulses from the two machines or two no-current intervals resulted in state A $(+)$, state B $(-)$ being established whenever the two tape elements sensed were of differing polarity. The principles of this operation (see Figure 1) are simple for both enciphering and deciphering;

the circuits built into the *Mi544* are based on the same method.

Table 1 shows this scheme in the enciphering and deciphering of the 5-unit code.

Views on the cipher composition to prevent unauthorized deciphering have often changed. Originally, the cipher was relatively short; this involved repeated use of the same cipher at the expense of the inviolability of the method and the ciphered messages. The next step was to use two or more ciphers whose elements were combined by several automatic transmitting distributors. The process of combination was governed by partly regular, partly irregular movements; this and the arbitrary selection of starting points along the cipher tape greatly aggravated matters for the unauthorized intercepting decipherer. The problems of counting the steps along the cipher tape and of marking them by printed numbers were solved satisfactorily. However, expert cryptographers worked out more-and-more-stringent specifications, one of them being that a cipher should be destroyed immediately after use. Another is the purely random statistical distribution of cipher elements. A modern electronic cipher generator has been described.[1]

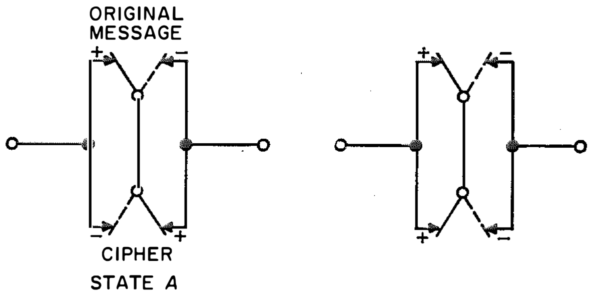


Figure 1—Basic enciphering–deciphering circuit.

TABLE 1

CIPHER PROCESS USING 5-UNIT CODE

Enciphering		Ciphered Message	Deciphering	
Original Message	Cipher		Cipher	Original Message
+	+	+	+	+
+	−	−	−	+
−	+	−	+	−
−	−	+	−	−

The above method of processing the cipher found wide application in the years 1930 to 1950. Several types of devices[2–10] operate on the indicated principles. These are generally receivers and transmitters combined with electric enciphering–deciphering features. Depending on application, the original message is prepared manually with tape transmitters or page printers or even with one or more manual perforators. The enciphered message can be directly transmitted to line or stored in the perforated tape for shipment to the recipient. The receiver can be switched to direct deciphering, producing the original message while receiving the enciphered message; or it may operate as a receiver, perforating a tape containing the enciphered message for deciphering later. These modes of operation are sketched in Figure 2.

Lately, consideration has again been given to the feasibility of combining all these functions in a ciphering teleprinter. In practice, the commercial teleprinter would then incorporate quite a few additional units, of which the most important are:

(A) A tape scanner for the original message.

(B) A tape scanner for the enciphered message.

(C) A storage register for the ciphering process.

(D) A tape transmitter.

(E) A reperforator.

(F) A built-in power supply for all functions.

[1] "Gerät zur Erzeugung von zufallsmässigverteilten Impulskombinationen für die Verschlüsselung von Fernschreibnachrichten ("Würfel-Locher")," *SEG-Nachrichten*, volume 4, number 4, pages 188–190; 1956.
[2] Austrian Patent 91 059; July 15, 1922.
[3] Austrian Patent 92 163; September 16, 1922.
[4] German Patent 355 393; June 6, 1920.
[5] German Patent 364 184; June 6, 1920.
[6] German Patent 452 194; March 21, 1926.
[7] United States Patent 1 516 880; November 18, 1924.
[8] United States Patent 1 522 775; January 13, 1925.
[9] G. E. Vernam, "Cipher Printing Telegraph System," *Electrical Engineering*, volume 45, pages 109–115; February, 1926.
[10] F. L. Rhodes and J. J. Carty, "50 Jahre Fernsprecher in den USA im Frieden und im Kriege," Verlag für Wissenschaft und Leben, Georg Heidecker, Berlin, Germany; 1934: see pages 145–146.

(G) Switches and monitors for the various modes of operation.

The assembly would be of substantial size requiring particular skill for operation and maintenance. An occasional trouble would affect the whole equipment, including the teleprinter functions. Many page printers now in the market would be useless as replacement units. Numerous special units now in use as, for instance, automatic transmitters, receiving perforators, manual perforators, et cetera, would be of no practical value in such a mode of operation.

Things look quite different, however, if the encipherer–decipherer is constructed as a separate, selfcontained equipment. By electrically connecting this equipment to the existing input–output equipment, all the functions described and more can readily be exercised. Such a system is adaptable to varying operating conditions and to varying degrees of mobility; units that are not required for a certain period need not be moved, operated, or maintained.

From the viewpoint of civilian application, it seems a technically and financially sound policy to retain existing teleprinters and to provide attachments for secret communication. For all these reasons, the *Mi544* was developed as an independent attachment. It operates on electromechanical principles using subassemblies and units that have for many years proved their value.

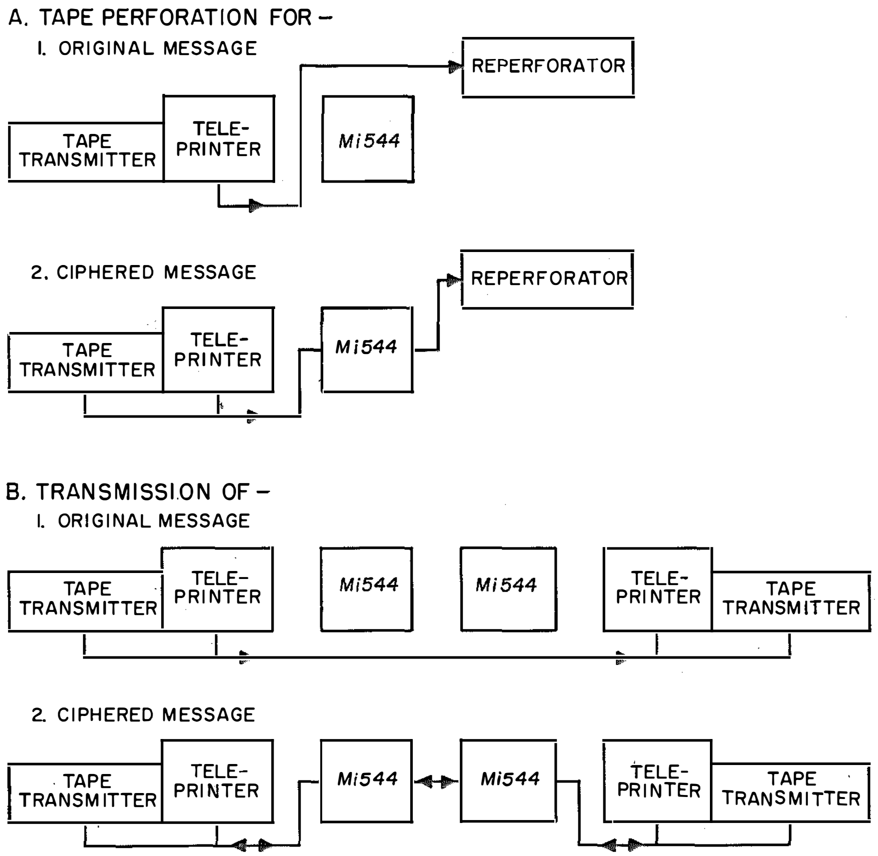


Figure 2—Teleprinter transmission of original and ciphered messages.

2. *Equipment Description*

Figure 3 shows the *Mi544*. Below the control panel with its two switches and two indicator lamps, the unit sensing the cipher is mounted. The top has a recess in which the cipher tape roll is inserted. A metallic magazine encloses this roll and can be locked to prevent unauthorized removal of the roll. Special blocking means preclude the possibility of rewinding the roll and using it a second time.

Figure 4 shows the equipment with roll and hood removed. The two receiving systems are immediately behind the indicator lamps and toward the rear, under the covers, are the driving motor and control relay group. Several receptacles for the connecting local teleprinters and an ammeter monitoring the telegraph circuits are mounted on the left-hand and front apron of the chassis.

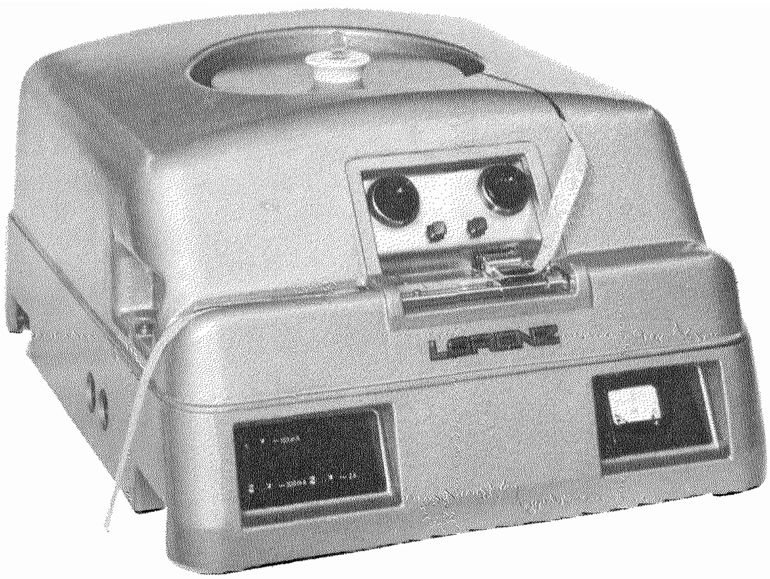


Figure 3—The *Mi544* equipment.

The *Mi544* connects to 220-volt 50-cycle-per-second mains supply. The receptacles in the chassis permit connection of the local teleprinter, the transmitting distributor, and, if necessary, the receiving perforator. Plugs are used for connection to the transmission line or to the subscriber box (in the case of subscriber dialing) respectively.

2.1 Operational Sequence

When a connection is established, the red indica-

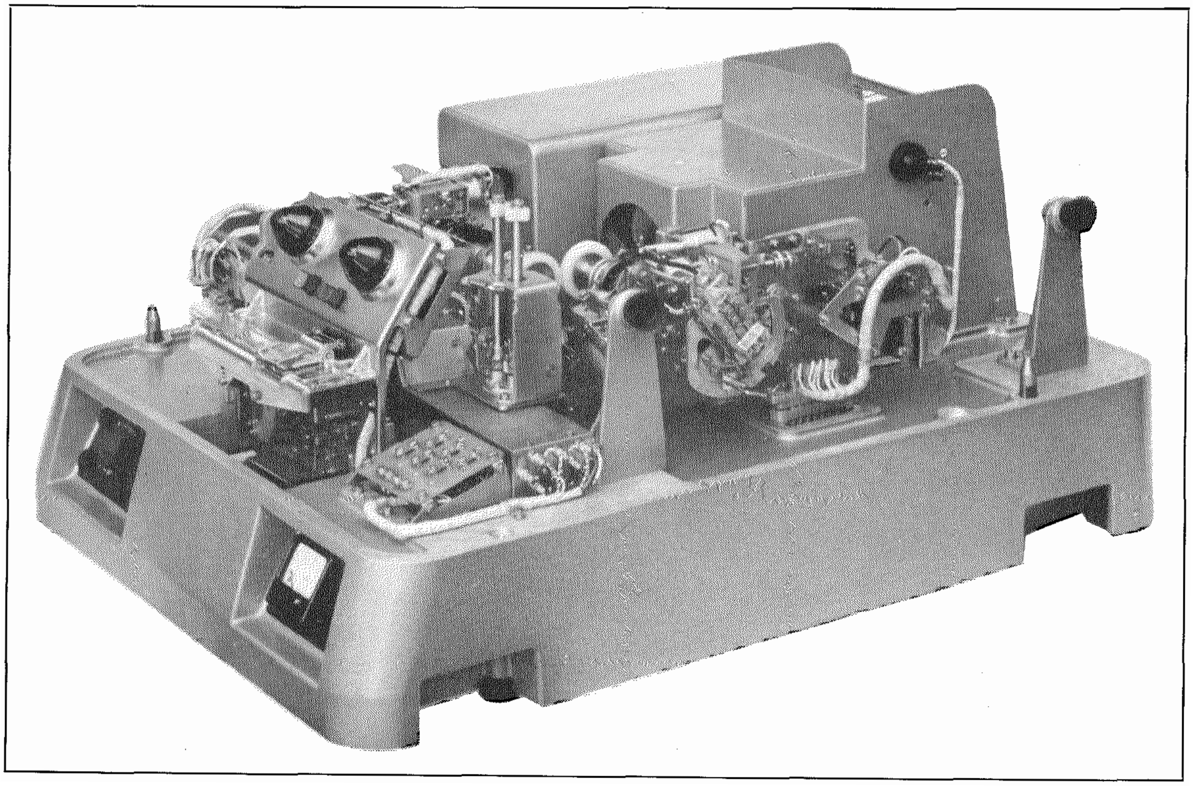


Figure 4—The *Mi544* machine with hood removed.

tor lamp signals and the teleprinter is started. The line is then connected to the teleprinter and the tape transmitter; the subscribers may now communicate in ordinary-language typewriting. When both subscribers have inserted their ciphers at the agreed-upon starting point, the ciphering devices of the *Mi544's* are switched on. The red lamps go out and the green lamps light; at the same time, the *Mi544* motors are started. If the first message character is now keyed on the teleprinter keyboard, the first character of the cipher is also sensed, combined with the teleprinter character of the original message, and transmitted as the enciphered character. At the end of the first character, the cipher tape is advanced to the next character, which is combined with the second character of the original message, and so on. At the receiving end, the cipher is sensed in the same way and used to decipher the incoming enciphered message. The original message character thus recovered is passed to the teleprinter for printing and the cipher tape is fed to the next character position.

2.2 Circuit

Figure 5 shows the basic mode of operation for deciphering. All collateral functions are neglected in this presentation.

For transmitting plain text, see dashed lines, the local equipments (page printer and tape transmitter) are directly connected to the toll line or to the reperforator.

For cryptographic transmission, solid lines, the *Mi544* is divided into two separate circuits.

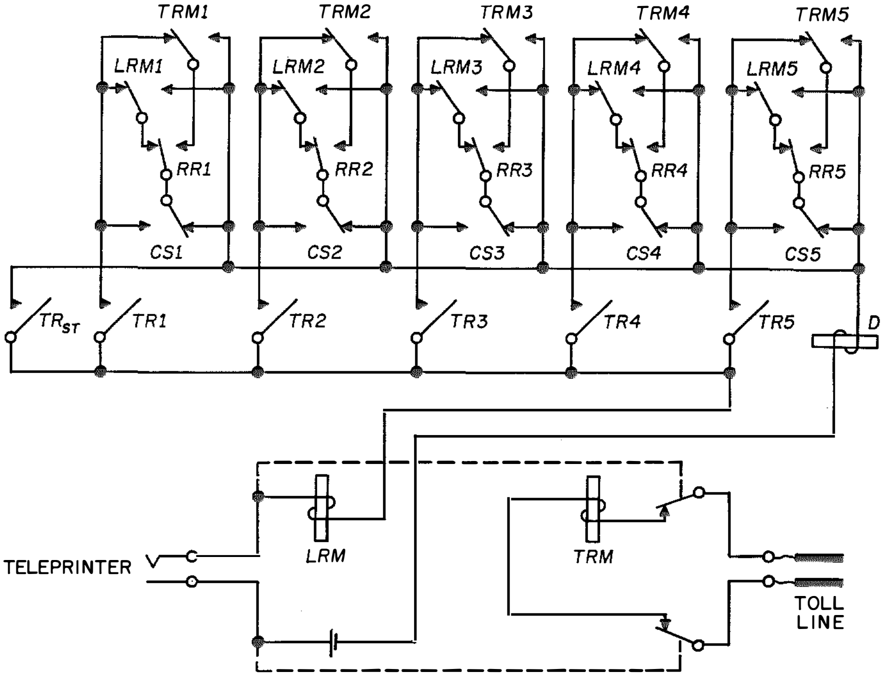


Figure 5—Basic circuit of *Mi544* connected for deciphering. *LRM1* to *LRM5* = storage contacts of the local reception magnet *LRM*. *TRM1* to *TRM5* = storage contacts of the toll reception magnet *TRM*. *CS1* to *CS5* = cipher-tape-sensing contacts. *TR1* to *TR5* = contacts of the built-in cam-controlled sender. TR_{st} = start–stop contact of the sender.

The local teleprinter units are connected to the local-reception magnet *LRM* of the *Mi544* by a two-wire nonpolar circuit also supplying power.

The toll-reception magnet *TRM* of the *Mi544* is connected to the toll line, again a two-wire nonpolar powered line from the next exchange or the telegraph translator. Both reception magnets have additional monitoring contacts that determine whether the first (start) pulse is received from the near end or from the far end. In the first case, requiring enciphering, the contacts *LRM1* through *LRM5* are connected to the cipher-sensing contacts *CS1* through *CS5* in accordance with the operation previously outlined in Figure 1. The resulting enciphered message is applied through the transmitter contacts *TR1* through *TR5* to the toll line.

For deciphering in the incoming direction, the toll reception magnet *TRM* operates and contacts *TRM1* to *TRM5* store the pulses of the received enciphered message. Contacts *CS1* to *CS5* decipher the message by the above method.

The pulses of the original message thus recovered are sequentially sent from the *Mi544* to the local or near-end teleprinter for printing. In this operation, contacts *LRM1* to *LRM5* are disconnected by the reversing-relay contacts *RR1* to *RR5*. The blocking and switching relays for proper timing of these operations are not shown in Figure 5.

Relay *D* is provided so that the operator at the receiving teleprinter can stop the transmission whenever his equipment is not ready for reception or the message received is faulty. He does this by depressing any one key of his teleprinter keyboard (for instance, SPACE). As a result, relay *D* in the transmitting station will release and stop the transmission by the following process.

At the transmitter, the armature of relay *D* is mechanically pressed against the core in the intervals between the stop pulses. In undisturbed operation, the stop signal is always represented by a current pulse. If, however, signals arrive from the receiving end (utilizing the usual half-duplex circuit), there is a very-high probability that the stop pulse will be interrupted or suppressed after a few characters have been transmitted. This causes relay *D* to release. The transmission can only be resumed by the conventional manipulations. This interruption of transmission ensures that the original message is not, by some error, transmitted in plain writing.

Another means of preventing unintentional transmission of the original message is a paper-control lever that, together with the tape-sensing pins, is periodically applied to the perforated cipher tape. This lever remains inoperative as long as the tape moves properly. If the cipher tape runs out or the web between the perforations is damaged, however, this lever actuates relay *D* described above. The *Mi544* is thus switched off and the local circuit is opened so that no transmission is possible.

3. Characteristics

The technical data of the *Mi544* can be summarized as follows:

Dimensions = 400 by 540 by 260 millimeters ($15\frac{3}{4}$ by $21\frac{1}{4}$ by $10\frac{1}{4}$ inches).

Weight = 30 kilograms (66 pounds).

Mains input = 220 volts, 50 cycles per second, 250 watts.

Motor = universal collector type.

Built-in power supplies = 60 volts at 0.5 ampere for switching circuits and 120 volts at 0.15 ampere for teleprinter circuits.

Telegraph current (local and far-end) = 0.04 ampere.

Telegraph speed = 400 characters per minute (50 bauds) or 368 characters per minute (45.5 bauds).

Maximum permissible receiving distortion = 40 percent.

It is possible to build in a device[11] for character-by-character operation as well as for synchronous operation.

---

[11] W. Schiebeler, "Synchronzusatz zum Michgerät Mi544," *SEG-Nachrichten*, volume 4, number 4, pages 185–188; 1956.

United States Patents Issued to International Telephone and Telegraph System; February 1—April 30, 1958

BETWEEN February 1 and April 30, 1958, the United States Patent Office issued 57 patents to the International System. The names of the inventors, company affiliations, subjects, and patent numbers are listed below.

P. R. R. Aigrain, Laboratoire Central de Télécommunications (Paris), Impulse Multiplying Arrangements for Electronic Computing Machines, 2 822 131.

M. Arditi, Federal Telecommunication Laboratories, Radio-Frequency Transducer, 2 825 875.

A. J. Baracket, Federal Telecommunication Laboratories, Montage Amplifier, 2 825 755.

A. J. Baracket and S. A. De Mars, Federal Telecommunication Laboratories, Light-Energy-to-Video-Signal Transducing System, 2 829 199.

A. H. W. Beck, Standard Telephones and Cables, Limited (London), Electron Discharge Devices, 2 829 299.

A. H. W. Beck, A. B. Cutting, and J. W. Rayner, Standard Telephones and Cables, Limited (London), Grids for Electric Discharge Devices, 2 825 839.

A. E. Brewster, Standard Telecommunication Laboratories, Limited (London), Electric Trigger Circuits, 2 832 899.

J. H. Bryant, Federal Telecommunication Laboratories, Traveling-Wave Electron Discharge Devices, 2 822 500.

J. H. Bryant, Federal Telecommunication Laboratories, Traveling-Wave-Tube Oscillators, 2 829 252.

P. F. C. Burke, Standard Telephones and Cables, Limited (London), Electron Discharge Devices, 2 822 492.

V. D. Carver and M. Liao, Farnsworth Electronics Company, Cabinet for Electronic Equipment, 2 823 973.

A. M. Casabona, Federal Telecommunication Laboratories, High-Frequency Hybrid Circuit, 2 822 525.

K. W. Cattermole, Standard Telephones and Cables, Limited (London), Electric Pulse-Time Modulators, 2 822 520.

R. F. Chapman, Federal Telecommunication Laboratories, Display Arrangement for Direction Finders, 2 825 901.

A. R. Denz, Kellogg Switchboard and Supply Company, Temperature-Compensated Direct-Current Transistor Amplifier, 2 830 257.

P. T. Farnsworth, Farnsworth Electronics Company, Storage-Type Electron-Tube System, 2 820 111.

G. C. Florio, Federal Telephone and Radio Company, Mold for Semiconductor Ingots, 2 825 549.

S. G. Fong and H. W. G. Salinger, Capehart–Farnsworth Company, Electron Multiplier, 2 824 253.

H. Grayson, R. A. G. Dunkley, and T. H. Walker, Standard Telecommunication Laboratories, Limited (London), Saturable-Core Transformer, 2 831 157.

S. J. Harris, Capehart–Farnsworth Company, Light-Distribution Measuring System, 2 831 054.

C. Heck, Süddeutsche Apparatefabrik (Nürnberg), Method of Producing Highly Permeable Dust Cores, 2 825 095.

A. Hemel, Kellogg Switchboard and Supply Company, Relayless Line Circuit, 2 828 365.

R. W. Hughes and R. L. Plouffe, Jr., Federal Telecommunication Laboratories, Pulse Generator, 2 829 346.

R. W. Hughes, R. L. Plouffe, Jr., and H. T. Peretko, Federal Telecommunication Laboratories, Pulse Generator, 2 829 282.

H. P. Iskenderian, Federal Telecommunication Laboratories, Traveling-Wave Electron Discharge Devices, 2 825 840.

J. Kalish, Federal Telecommunication Laboratories, Oscillator, 2 829 256.

A. G. Kandoian, Federal Telecommunication Laboratories, Artificial Load for Broad Frequency Band, 2 825 874.

W. Klein and W. Friz, C. Lorenz A. G. (Stuttgart), Electron-Beam Focussing Device, 2 828 434.

J. A. Kostriza and P. Terranova, Federal Telecommunication Laboratories, Line-Above-Ground to Hollow-Waveguide Coupling, 2 829 348.

J. Kruithof, L. J. G. Nys, and J. L. J. Donceel, Bell Telephone Manufacturing Company (Antwerp), Electric Switch, 2 822 431.

A. Lauterer, C. Lorenz A. G. (Stuttgart), Interlocking Electromagnetic Relay Structures, 2 825 239.

E. J. Leonard, Kellogg Switchboard and Supply Company, Intermittent-Flow Condenser-Storage Timer, 2 830 235.

D. J. LeVine and R. J. Merke, Federal Telecommunication Laboratories, Radio-Frequency Transducers, 2 825 876.

W. Lewanda, Federal Telephone and Radio Company, High-Voltage Rectifier, 2 832 923.

M. Lilienstein and A. W. Murphy, Federal Telephone and Radio Company, Regulated Power-Supply System Using Transistors, 2 832 034.

F. T. Littell, Federal Telephone and Radio Company, Grid Network for Pulsed Oscillator, 2 822 521.

S. Metzger, Federal Telecommunication Laboratories, Signal Level Coder, 2 832 827.

A. J. Montachausse and D. Dautry, Compagnie Générale de Constructions Téléphoniques and Le Matériel Téléphonique (Paris), Electromagnetic Relay, 2 824 923.

R. K. Orthuber, Capehart–Farnsworth Company, Automatic Focus Adjuster, 2 831 057.

E. F. Poppe, Bell Telephone Manufacturing Company (Antwerp), Thermoconductive Screening Can for Electronic Tube, 2 829 870.

J. C. Price, Standard Telephones and Cables, Limited (London), Electric Pulse Modulators, 2 822 522.

A. J. Radcliffe, Jr. and A. R. Denz, Kellogg Switchboard and Supply Company, Condenser-Timed Delayed-Signal Repeater, 2 830 128.

D. S. Ridler, Standard Telecommunication Laboratories, Limited (London), Multiple Telegraph Signal Regenerators, 2 828 358.

D. S. Ridler, R. Grimmond, Standard Telecommunication Laboratories, Limited (London), Electrical Information Storage Equipment, 2 825 890.

D. C. Rogers and P. F. C. Burke, Standard Telephones and Cables, Limited (London), Traveling-Wave Tubes, 2 824 996.

G. T. Royden, American Cable & Radio Corporation, Half-Duplex Telegraph Repeater, 2 829 200.

R. D. Salmon and L. B. Salmon, Creed & Company, Limited (Croydon), Printing Telegraph Apparatus, 2 827 511.

P. C. Sandretto, Federal Telecommunication Laboratories, Meteorological Radar, 2 822 536.

K. Sass, Mix & Genest (Stuttgart), Telephone Exchange Circuit, 2 830 126.

W. Schallerer and R. Mosch, C. Lorenz A. G. (Stuttgart), Modulator for Voice-Frequency Telegraph Systems, 2 822 421.

F. Schmidt, Mix & Genest (Stuttgart), Circuit Arrangement for Transmitting Signal over Telephone Lines, 2 831 061.

W. Sichak and E. P. Westbrook, Federal Telecommunication Laboratories, Lens Antenna System, 2 822 541.

V. J. Terry, D. A. Weir, and N. F. Fossey, Standard Telecommunication Laboratories, Limited (London), Start–Stop Telegraph Regenerators, 2 822 422.

C. G. Treadwell, Standard Telephones and Cables, Limited (London), Electric Pulse Coding Arrangements, 2 825 873.

M. W. Wallace, Federal Telecommunication Laboratories, Cavity Magnetron, 2 828 444.

E. P. G. Wright, D. A. Weir, and J. Rice, Standard Telephones and Cables, Limited (London), Information-Handling Equipment, 2 831 179.

E. P. G. Wright, J. Rice, and R. C. Orford, Standard Telecommunication Laboratories, Limited (London), Electrical Information-Storage Circuits, 2 831 150.

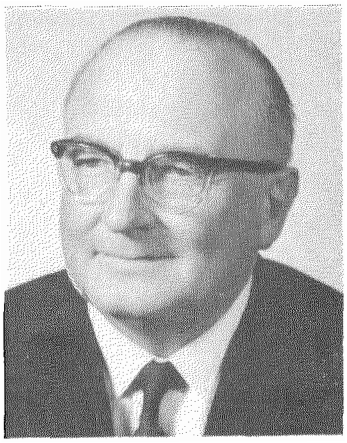
Contributors in This Issue

Bruce Brooke-Wavell

Bruce Brooke-Wavell was born in Hove, England, on June 28, 1916. He studied mathematics and physics at Christ's College, Cambridge, and at London University where he obtained the degree of Bachelor of Science.

After three years teaching mathematics at the Reigate Grammar School he joined the Royal Corps of Signals, spending the last two years of his war service as senior instructor in telecommunications at the British Army Signal School in Cairo.

On leaving the army in 1946, he joined the engineering division of Creed & Company where he is at present in charge of the technical literature section.



Gerhard Grimsen

Mr. Brooke-Wavell contributes two papers to this issue—one describing the new model Seventy-five teleprinter, the other outlining the development of Creed telegraph apparatus during the past ten years.

• • •

Gerhard Grimsen was born in Braunschweig, Germany, on December 2, 1899. He studied at the technical college and university in Braunschweig and at the university in Berlin, from which he received a doctorate in 1922.

For four years, he worked in the Berlin central laboratories of the German Post administration.

Since 1926, Dr. Grimsen has been a member of the staff of Standard Elektrik Lorenz. He has worked on long-haul telephony and the construction of repeater offices, telegraphy, public telex networks, and ciphering systems. After the second world war, he was concerned with the reconstruction of the telex network and with special problems such as punched-tape engineering, enciphering and deciphering systems, and Comité Consultatif International Télégraphique et Téléphonique matters. He is author of the article on cryptographic equipment.

• • •

L. J. Heaton-Armstrong was born in 1905 in Limerick, Eire. He received the diploma and a bachelor of science degree from Imperial College of London University in 1927.

On graduation, he joined Standard Telephones and Cables and worked on the original high-frequency transatlantic radiotelephone system. From 1929 to 1933, he was assigned to the Paris laboratories, where he was concerned with the Madrid–Buenos Aires high-frequency radiotelephone link.

He returned to Standard Telephones and Cables in 1933 and is now in charge of the design and development of point-to-point radio communication equipment.

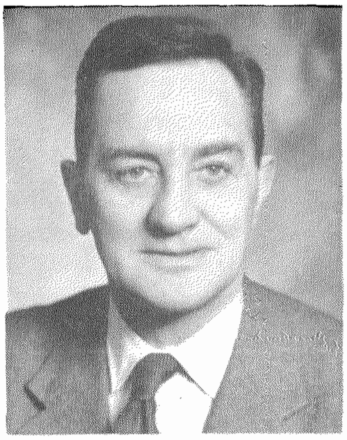
Mr. Heaton-Armstrong is a Member of the Institution of Electrical Engineers, an Associate of the City and Guilds Institute of London, and a Senior Member of the Institute of Radio Engineers.

L. J. Heaton-Armstrong

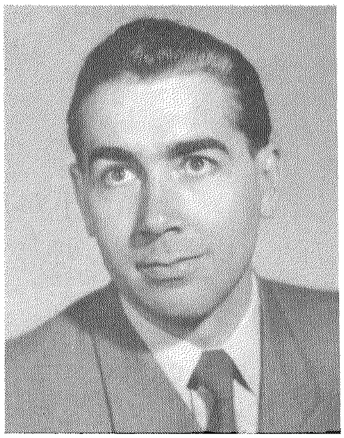
• • •

John D. Holland was born in London in 1902. He was educated at the Salesian School at Battersea and then completed an apprenticeship at the Park Royal Engineering Works in 1922. He was awarded a National Certificate and a first-class pass in the final examination in radio communication of the City and Guilds Institute of London in 1939.

From 1922 to 1928, he served with the Royal Signals.



John D. Holland



WOLFGANG A. KAISER

He joined Standard Telephones and Cables in 1929 as an instrument maker and was transferred to development work in 1935. As a leader of a development group, he has been concerned with the design of receiving systems. Some of his recent work on receiving systems for amplitude- and frequency-modulated telegraph signals is treated in this issue.

Mr. Holland is an Associate Member of the Institution of Electrical Engineers.

• • •

WOLFGANG A. KAISER was born on February 22, 1923 in Schoental, Baden-Württemberg, Germany. He studied communication engineering at the technical college of Stuttgart, where he received his diploma in 1952 and his doctorate in 1955.

Dr. Kaiser joined the laboratories of Standard Elektrik Lorenz in Stuttgart in 1954. He has first been associated with communication systems for television and radar and is now head of a laboratory for the development of voice telegraphy and signal transmission systems.

Dr. Kaiser is the author of the paper on the single-channel carrier telegraph equipment.

• • •

E. P. G. WRIGHT joined the equipment engineering branch of the Western Electric Company in London in 1920, and in 1926 he took charge of project engineering when the company became associated with the International System. In 1928, Mr. Wright was transferred to the laboratories to work on switching problems.

He was in charge of switching system development for Standard Telephones and Cables Limited from 1932 until 1939. He was then appointed to the newly formed Standard Telecommunication Laboratories and has since been working on information-processing systems.

E. P. G. WRIGHT

Mr. Wright is a Member of the Institution of Electrical Engineers and has three times been awarded the Fahie Premium by the Institution. He has been a delegate of the Comité Consultatif International Téléphonique for many years.

Mr. Wright is the author of two papers in this issue. One is on STRAD and the other on the calculation of storage requirements for electronic telegraph switching centers.

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

Principal U. S. Divisions and Subsidiaries

DIVISIONS
Components Division, Clifton, N. J.
Kuthe Laboratories, Inc., Newark, N. J.
Industrial Products Division, San Fernando, Calif.
ITT Federal Division, Clifton, N. J., and Fort Wayne, Ind.
ITT Laboratories, Nutley, N. J.
Kellogg Switchboard and Supply Company, Chicago, Ill.

SUBSIDIARIES
American Cable & Radio Corporation, New York, N. Y.
All America Cables and Radio, Inc., New York, N. Y.
Commercial Cable Company, The, New York, N. Y.
Mackay Radio and Telegraph Company, New York, N. Y.
Federal Electric Corporation, Paramus, N. J.
Intelex Systems Incorporated, New York, N. Y.
Airmatic Systems Corporation, Rochelle Park, N. J.
International Electric Corporation, Paramus, N. J.
ITT Communication Systems, Inc., Paramus, N. J.
Kellogg Credit Corporation, New York, N. Y.
Royal Electric Corporation, Pawtucket, R. I.

and ... International Standard Electric Corporation, New York, N. Y. whose principal research, manufacturing, and sales affiliates are:

ARGENTINA Capehart Argentina S.A.I.C. (50% owned), Buenos Aires
Compañía Standard Electric Argentina, S.A.I.C., Buenos Aires

AUSTRALIA Standard Telephones and Cables Pty. Limited, Sydney
Austral Standard Cables Pty. Limited (50% owned), Melbourne

AUSTRIA Standard Telephon und Telegraphen Aktiengesellschaft, Czeija, Nissl & Co., Vienna

BELGIUM Bell Telephone Manufacturing Company, Antwerp

BRAZIL Standard Eléctrica, S.A., Rio de Janeiro

CANADA Standard Telephones & Cables Mfg. Co. (Canada), Ltd., Montreal

CHILE Compañía Standard Electric, S.A.C., Santiago

CUBA Equipos Telefónicos Standard de Cuba, Havana

DENMARK Standard Electric Aktieselskab, Copenhagen

FINLAND Oy Suomen Standard Electric AB, Helsinki

FRANCE Compagnie Générale de Constructions Téléphoniques, Paris
Les Téléimprimeurs, Paris
Laboratoire Central de Télécommunications, Paris
Le Matériel Téléphonique, Paris

GERMANY Standard Elektrik Lorenz Aktiengesellschaft, Stuttgart
Bauelemente Werk S.A.F. (division), Nuremberg
Informatikwerk (division), Stuttgart
Kabelwerk (division), Stuttgart
Lorenz Werke (division), Stuttgart
Mix & Genest Werke (division), Stuttgart
Schaub Werk (division), Pforzheim

IRAN Standard Electric Iran A.G., Teheran

ITALY Fabbrica Apparecchiature per Comunicazioni Elettriche Standard S.p.A., Milan

MEXICO Industria de Telecomunicación, S.A. de C.V. (50% owned), Mexico City
Standard Eléctrica de México, S.A., Mexico City

NETHERLANDS Nederlandsche Standard Electric Maatschappij N.V., The Hague

NEW ZEALAND New Zealand Electric Totalisators Limited. Wellington

NORWAY Standard Telefon og Kabelfabrik A/S, Oslo

PORTUGAL Standard Eléctrica, S.A.R.L., Lisbon

SPAIN Standard Eléctrica, S.A., Madrid

SWEDEN Standard Radio & Telefon AB, Stockholm

SWITZERLAND Standard Téléphone et Radio S.A., Zurich

TURKEY Standard Elektrik Ve Telekomunikasyon Limited Şirketi, Ankara

UNITED KINGDOM Creed & Company, Limited, Croydon
Standard Telephones and Cables Limited, London
Kolster-Brandes Limited, Sidcup
Standard Telecommunication Laboratories Limited, London

VENEZUELA Standard Telecommunications C.A., Caracas

OVERSEAS TELECOMMUNICATION COMPANIES

ARGENTINA Compañia Internacional de Radio, S.A., Buenos Aires
Sociedad Anónima Radio Argentina (subsidiary of American Cable & Radio Corporation), Buenos Aires

BOLIVIA Compañía Internacional de Radio Boliviana, La Paz

BRAZIL Companhia Rádio Internacional do Brasil, Rio de Janeiro
Companhia Telefônica Nacional, Curitiba and Pôrto Alegre

CHILE Compañía de Teléfonos de Chile, Santiago
Compañía Internacional de Radio, S.A., Santiago

CUBA Cuban American Telephone and Telegraph Company (50% owned), Havana
Cuban Telephone Company, Havana
Radio Corporation of Cuba, Havana

PERU Compañía Peruana de Teléfonos Limitada, Lima

PUERTO RICO Puerto Rico Telephone Company, San Juan
Radio Corporation of Puerto Rico, San Juan

SPAIN Compañia Radio Aérea Maritima Española, S.A., Madrid

UNITED KINGDOM International Marine Radio Company Limited, Croydon

ASSOCIATE LICENSEES FOR MANUFACTURE AND SALES

FRANCE Lignes Télégraphiques et Téléphoniques, Paris

ITALY Società Italiana Reti Telefoniche Interurbane, Milan

JAPAN Nippon Electric Company, Limited, Tokyo
Sumitomo Electric Industries, Limited, Osaka

SPAIN Marconi Española, S.A., Madrid

IN THIS ISSUE

VOLUME 35 1958 NUMBER 3

ITT ELECTRICAL COMMUNICATION

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

Printed in the
United States of America
LANCASTER PRESS, INCORPORATED
LANCASTER, PENNSYLVANIA