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An Automatic Transmission Measuring System for Telephone Trunks

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An Automatic Transmission Measuring System (ATMS) has been designed to provide means for making rapid and accurate transmission measurements on telephone trunks. The system consists of a control unit (director) in one office and one or more responding units (responders) at distant locations. Trunk selection (not treated in detail in this paper) is accomplished either by a specially designed test frame in electromechanical offices or by special programming in electronic offices.

All measurement sequences are under command of the director which in turn receives its information from a teletypewriter tape or punched cards. New measurement techniques utilized in ATMS which permit rapid and accurate measurements are discussed. System accuracy of ±0.1 dB for loss and ±1 dB for noise is achieved using these techniques. Total measurement time (excluding trunk seizure and printout time) for loss measurements in both directions and noise at both ends is less than five seconds.

Although the ATMS is presently capable of making only loss and noise measurements, additional measurements can be added conveniently because of its modular design and construction.

Where responders are not installed at the distant offices, other kinds of existing Bell System transmission test lines may be utilized by the director to make whatever measurements the test line permits.

Two schemes are described whereby measurements may be made on trunks between two remote central offices and the results sent to a controlling director in a third office.

I. INTRODUCTION

The problem of trunk maintenance in the Bell System is magnified by the number of trunks which must be considered. A typical central office has more than a thousand trunks and there are about 2.7 million trunks in the Bell System. Proper maintenance of these trunks requires routine measurements at monthly or shorter intervals. In addition, at least four different transmission measurements are required to insure proper operation.

In view of the large number of measurements required, fully mechanized testing appears not only economical but necessary. The Automatic Transmission Measuring System (ATMS) discussed in this paper was developed to meet this need.

II. BACKGROUND AND PRIOR ARRANGEMENTS

In order to appreciate some of the intricacies involved in automatically measuring telephone trunks, a brief description of the telephone plant is in order. Fig. 1 is a simplified illustration of the telephone plant. A connection between customers is made up of two customer loops and 0, 1, 2 or more trunks. The loops shown connecting customers to the central offices are generally passive, i.e., without amplifiers. The trunks connecting central offices, on the other hand, frequently have active devices associated with them.

Fig. 2 depicts the make-up of a hypothetical trunk. A particular trunk contains some of the elements shown. They will be discussed only to the extent to which they affect measurements.

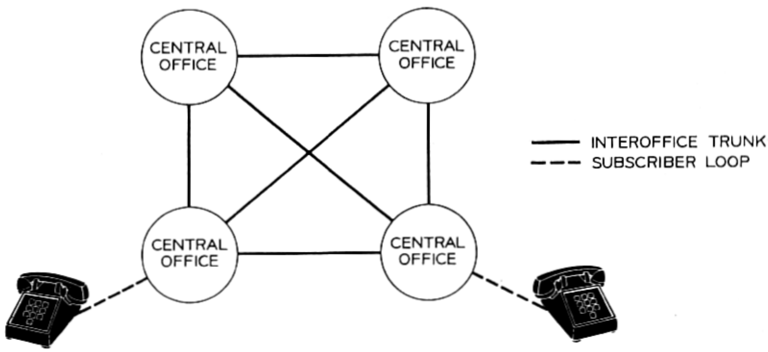

Fig. 1 — Simplified telephone plant.

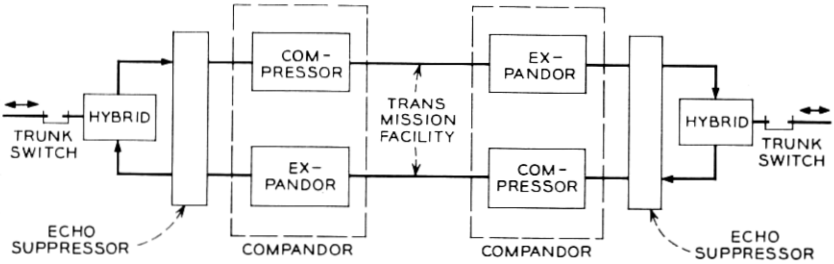

Fig. 2 — Hypothetical trunk.

(*i*) Systems with Amplifiers

Trunks utilizing carrier systems or hybrid-type repeaters complicate transmission measurements since the transmission in the two directions is affected by different elements. Thus, measurements must be made at both ends of the trunk.

(*ii*) Echo Suppressors

Echo suppressors, devices utilized in long haul trunks, affect remote automatic measurements because they prohibit simultaneous transmission in both directions.

(*iii*) Compandors

Compressors and expandors (known collectively as compandors) if functioning perfectly, are of no concern to transmission measurements. However, imperfect compandor action implies that the insertion loss of the trunk at one transmitting level differs from that at another transmitting level.

The use of active devices demands closer surveillance of the trunk to detect changes in their characteristics due to aging, maladjustment, etc. Until a few years ago, an operator using cords made the connection between loops and trunks. Since the operator was required to complete any call, she could perform rudimentary tests to determine the suitability of the connection. By listening to the person placing the call and to the person to whom the call was placed, the operator could note excessive loss or noise if present, and if necessary, establish an alternative connection. With the introduction of Direct Distance Dialing (DDD), even this minimal transmission check has been lost.

Trunks may be classed as incoming, outgoing, or two-way depending upon whether the trunk may be seized only from the distant office, only from the near-end office, or from either office. These terms do not imply the transmission is limited to a single direction. It does mean that (in the case of manual measurements) if a transmission test is to be made on incoming trunks, the distant office must be requested to originate the test call.

When a connection has been established, manual effort is required at each end of the trunk if measurements at both ends are desired. Perhaps the most serious disadvantage of such manual measurements is the time involved in coordinating the efforts at each end and the number of tests involved.

Semiautomatic measurements are defined for the purposes of this paper as two-way measurements which are made manually using automatic far-end equipment. In this case, manual effort is required only at one end to make the measurements in both directions with the automatic far-end equipment. More will be said of this later.

Automatic transmission measuring systems for measuring telephone trunks are not new. At least two other systems have been developed prior to ATMS. One of these, which was developed by the Bell Telephone Laboratories in the early 1950's, is known as the automatic transmission test and control circuit (ATTC).[1] The other system was developed in the early 1960's by the Swedish Company Telefonaktiebolaget L. M. Ericsson.[2, 3] Both systems utilize the measurement technique illustrated in Fig. 3. After amplification and rectification, the resulting voltage is compared with a fixed reference voltage. The attenuator is then adjusted in discrete steps until the output voltage is equal to the reference voltage within the limits of the attenuator's step granularity.

Here the similarity between the two systems ends. The far-end equipment associated with the ATTC adjusts a second set of attenuators to equal the near-to-far loss. The far-end equipment then sends a test tone first without and then with the additional loss stored in the second attenuator. The near-end equipment measures the far-to-near loss under both conditions and then computes the loss of the trunk

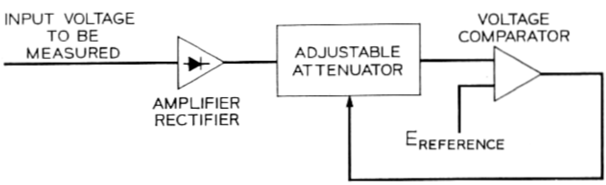

Fig. 3 — A transmission measurement scheme.

in the near-to-far direction as the difference of the levels of the two received tones. The Ericsson system sends the information contained in the state of the relays controlling the adjustable attenuator to the near-end in digital form by means of a multifrequency signaling system.

Each of these systems has its advantages and disadvantages. One of the attractions of the ATTC system is its adaptability to semi-automatic measurements. The results can be decoded by manual measurements. No special equipment is needed. On the other hand, imperfect compandors and other nonlinearities in the trunk being measured can cause appreciable errors. The system used by Ericsson circumvents this problem by coding. Specialized decoding equipment, however, must be used at the near-end for both automatic and semi-automatic measurements.

Both the Ericsson system and the ATTC system are comparatively slow due to the process of adjusting discrete step attenuators. Both also make only noise checks, not noise measurements. In addition, the Ericsson system does not contain some of the self-checking features provided in the ATTC.

III. REQUIREMENTS

The following is a summary of the requirements upon which the ATMS design is based.

3.1 *Operational Requirements*

(*i*) The system must make measurements at both ends of trunks.

(*ii*) Measurements at both ends must be made automatically without manual assistance.

(*iii*) Measurements at the far-end should be controlled by signals sent by the near-end equipment.

(*iv*) Measurements should be made of insertion loss in both directions of transmission and background noise at both ends of trunks. Noise measurement results should indicate the amount of "background" noise present such as thermal noise, crosstalk, steady tone, etc. These are kinds of noise most disturbing to a human listener. Impulse noise, although its effects may be very serious on trunks used for data transmission, should be included only to the extent that it disturbs the human listener.

(*v*) Measurements should be made as rapidly as practical.

(*vi*) All measurement results should be made available at the near-end.

(*vii*) Modular construction should be used to allow for future expansion to include other tests and to facilitate maintenance.

(*viii*) The near-end equipment should be capable of making tests to existing far-end measuring equipment to whatever extent practical.

(*ix*) Measurements should be possible on trunks where echo suppressors prevent simultaneous transmission in both directions.

(*x*) All measurement results of loss and noise should be displayed in logarithmic (decibel) units as deviations from reference values.

3.2 *Accuracy and Range Requirements*

(*i*) Overall system accuracy should be ±0.1 dB for loss measurements and ±1 dB for noise measurements.

(*ii*) Loss measuring circuit should accept +5 to −15 dBm signals.

(*iii*) Noise measurement range should extend from +15 to +50 dBrnC.

IV. GENERAL SYSTEM DESCRIPTION

4.1 *System Functions*

In discussing a system which will automatically test the transmission performance of all outgoing trunks in a telephone office, it is necessary to include associated equipment both in the originating and terminating offices. In addition to the measurement, the functions of gaining access to the desired trunk and of establishing a connection to the far-end test equipment must be considered. The complete measurement process can be broken down into a number of relatively simple steps which can then be related to specific equipment. These steps are:

(*i*) accept priming information on trunks to be tested: i.e., tests to be made, the transmission requirements of the trunks, and so on;

(*ii*) seize the trunk to be tested and dial up the far-end test equipment;

(*iii*) coordinate the operations of the near-end and far-end test equipment;

(*iv*) make transmission measurements at both ends of the trunk;

(*v*) transmit the far-end test results to the near-end;

(*vi*) display both the near-end and far-end results, in appropriate units, at the near-end; and

(*vii*) release the connection.

In addition, to increase the reliability of the system operation, two more steps may be added. These are:

(*viii*) repeat the test on a trunk when a transmission impairment is detected to determine if it is momentary or continual;

(*ix*) periodically make internal system checks of the measuring circuits to insure accuracy.

4.2 *System Equipment*

The overall system is comprised essentially of four units: the director, the responder, an automatic trunk test frame, and a test line (designated the 105-type test line). The director is used in conjunction with the automatic trunk test frame in the office in which the tests (and the trunks) originate (hereafter referred to as the near-end office). The responder, which is accessed through the 105-type test line, is far-end test equipment.

4.2.1 *ATMS Director*

The director was designed primarily to make measurements with the aid of the far-end responder and its associated test line. However, it is also capable of making limited measurements with other far-end arrangements. The director performs the following functions:

(*i*) Receives instructions from the automatic trunk test frame.
(*ii*) Sends commands to the responder.
(*iii*) Send test tones.
(*iv*) Provides a termination for far-end noise measurements.
(*v*) Receives data signals from a responder.
(*vi*) Makes far-to-near trunk loss and near-end noise measurements.
(*vii*) Converts the trunk loss and noise measurements made by the director and data signals from a responder into numerical readings and cues (indications that limits have been exceeded).
(*viii*) Provides these results to the automatic trunk test frame which causes them to be printed on the readout device.
(*ix*) Performs a self-check of its operation and a check on the operation of the responder when commanded to do so.

4.2.2 *ATMS Responder*

In addition to the basic measurement functions, which are similar to those of the director, the responder receives commands from the director over the trunk under test, converts the received level of the test tone or noise into data signals, and transmits the data signals to the director.

4.2.3 *Automatic Trunk Test Frames*

Several different automatic trunk test frames are used in the various types of telephone offices. ESS offices have special programs which provide the equivalent of a test frame. These test frames provide arrangements for seizing the trunks to be measured and for pulsing forward the codes of various test lines at the distant end of the trunk. Information necessary for the director to make appropriate transmission loss and noise measurements and to evaluate the results is also supplied by the test frame. In addition, it provides facilities for printing the measurement results.

Another test frame function is to maintain trunk supervision, which includes the ability to send and/or receive on-hook, off-hook, busy, and reorder signals. In addition, most test frames make operational tests on trunks (indeed, this may be their primary function) in conjunction with an operational test line in the terminating office. These tests check the trunk's ability to pass supervision and signaling and are made independently of the transmission tests.

4.2.4 *105-Type Test Line*

The responder must be accessed through a 105-type test line. This test line provides holding and supervision, connects the responder through the switching system to the trunk being measured, and supplies transmission measuring information to the responder. A group of these test lines provides a parking arrangement which enables incoming calls to wait and be served in turn if the responder is engaged.

4.3 *ATMS Operation*

A typical transmission measurement setup using the ATMS is shown in Fig. 4. A near-end connection to the trunk is made through the office switching equipment or special test connectors. The code of the far-end test line (in this case a 105-type test line) is then pulsed forward, and the distant switching machine makes the connection. The 105-type test line terminates in a responder. The automatic trunk test frame feeds the test conditions and trunk transmission requirements to the director, connects the trunk to the director, and instructs the director to perform certain measurement sequences.

As the director makes the measurements, it provides measurement data to the automatic trunk test frame which records the results on a Teletype printout or other readout device. At the end of the test sequence, the trunk and measuring equipment are released and control

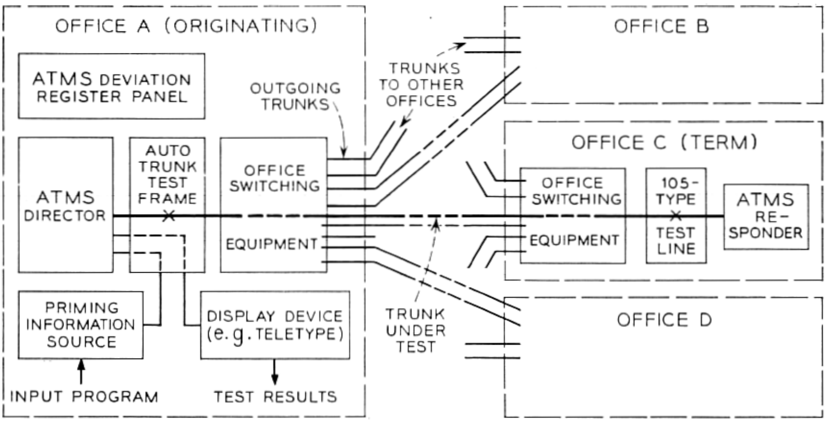

Fig. 4 — Typical ATMS system.

reverts to the automatic trunk test frame or central control (in an electronic office).

The automatic test frame then advances the priming information source to the next trunk to be tested and the sequence is repeated. In the event that successive trunks have the same transmission characteristics and terminate in the same distant office, the priming information, except for individual trunk identity, is stored in the test frame until all trunks of this category have been tested. At this time, the test frame advances the priming source to the next trunk group.

4.4 *Additional Features*

A feature of the director that increases the usefulness of the test results is the ability to make a repeat test whenever a measurement exceeds predetermined (and selectable) limits. For example, suppose the deviation from the expected value of the near-to-far loss exceeds a preselected limit of ± 1.5 dB. The director will complete the initial measurements (loss in both directions and noise at both ends) and then compare all the results against preselected limits. It then tells the test frame either "end of test" or "repeat test." When a "repeat test" is indicated, the test frame holds the connection to the responder and the director and responder repeat all four measurements. If the second measurement is also out of limits, the trouble is probably not momentary, for the time interval between the first try and repeat of any given measurement is about 5 seconds. A "good" second measurement indicates a momentary or varying trouble or a hit on the trunk, either during the measurement or during data transmission of test results from the responder to the director.

It was mentioned earlier that a self-checking feature is desirable to insure system accuracy and reliability. This is true particularly in a system like ATMS, for hundreds, even thousands, of trunks may be tested without manual intervention.

The ATMS makes a self-check of both the director and responder when it advances to a new responder (a self-check command is included in the priming information supplied by the test frame). This self-check includes practically all of the measuring and data transmission circuits.

A loss and noise deviation register panel is available, which accumulates statistical data on the measurements made by the ATMS. This is accomplished by dividing the complete measurement range into intervals and counting, or "scoring," the number of measurements that fall within each interval. This provides information which can be used in compiling measurement results statistics.

Modular construction facilitates both maintenance and addition of new measurements.

4.5 *Other Transmission Test Lines*

Before completing a description of the ATMS, it is worthwhile to mention other transmission test lines that are currently in use. The ATMS director was designed with the capability to test to a number of existing Bell System transmission test lines and make all the measurements that are within the test line's capability. The exact measurements to be performed are dependent upon the capability of the far-end test line and the test requirements. Table I summarizes Bell System Test Lines to which the ATMS will test and the measurement capability they provide.

V. MEASUREMENT TECHNIQUE

In a sense the ATMS may be considered a very specialized digital voltmeter. However, the measurement technique employed by the ATMS must provide a number of features not generally imposed upon a digital voltmeter. Because measurements cannot be performed and the results transmitted simultaneously on the same trunk (a condition precluded by the use of echo suppressors on some trunks) some storage element must be used at least in the far-end equipment. Results of measurements made at the far-end must be in a form suitable for transmission to the near-end by a means essentially inde-

TABLE I—BELL SYSTEM TRANSMISSION TEST LINES

Test line type*	Measurements		Description
	Loss	Noise	
100†	Far-to-near	Near-end	5 seconds of milliwatt followed by quiet termination
102	Far-to-near	No	Milliwatt, interrupted at 10-second intervals
104	Both ways	Near-end	Transmission measurement and noise checking circuit
105	Both ways	Both ends	ATMS responder

* This includes both toll test lines accessed by 10x codes and local and tandem types accessed by other than 10x codes.
† This test line will be available soon.

pendent of the transmission characteristics of the trunk over which the results are sent. Finally, all loss and noise measurement results should be presented to the user in logarithmic units to conform with the universal use of the decibel in the Bell System.

One of the simplest schemes which accomplishes the above is used in the ATMS and takes advantage of the logarithmic character of an RC discharge. After the signal to be measured is amplified, rectified, and filtered, a capacitor is charged to the resulting voltage. The capacitor provides a needed means for temporary storage of the measurement. After the capacitor is charged, relay contacts remove the charging source, leaving the capacitor with a charge proportional to the signal voltage being measured.

The length of time that the capacitor is connected to the amplifier-rectifier is about 0.4 second in a typical case for ATMS. If the trunk being measured has a so-called beating problem (a condition associated with some carrier systems which causes the gain to fluctuate slowly with time) and if the beating period is long, an ATMS measurement will give a result equivalent to the average value of the received voltage during that time.

The capacitor is now removed from the amplifier-rectifier for a brief period during which it will retain its charge. A resistor is then connected across the capacitor and the charge on the capacitor decays in a known exponential manner as illustrated in Fig. 5. A voltage comparator monitors the voltage on the capacitor and generates a pulse from the time the capacitor begins to discharge until the voltage on the capacitor reaches the reference voltage E_R. The duration of the

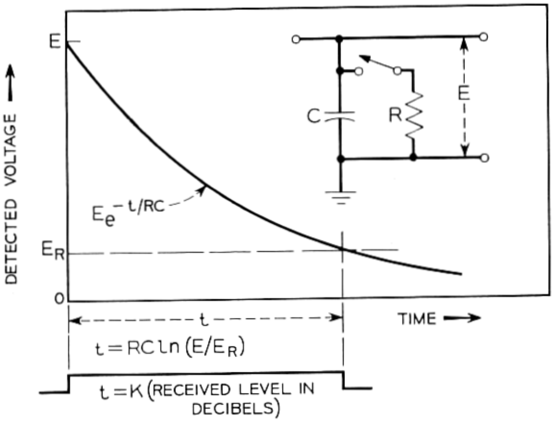

Fig. 5 — Voltage-to-time conversion.

pulse so generated is

$$t = \mathrm{RC} \ln (E/E_R), \tag{1}$$

where E is the initial voltage on the capacitor C and R is the value of the discharging resistor.

This time interval is proportional to the signal voltage (measured in decibels) with the addition of a constant which is composed of known factors. By means of a frequency shift data transmitter and receiver the pulse length information can be sent to the director.

Errors at the director in determining the length of the pulse sent from a responder may occur due to large impulse noise and the finite bandwidth of the trunk over which the information is sent. Impulse noise, if sufficiently large, may produce "holes" or additional error pulses in the received pulse. Either of these conditions will cause errors in determining the length of the pulse. Finite bandwidth implies that the beginning and ending of the received pulse cannot be precisely determined due to the finite rise and fall times of the pulse. Both the effect of impulse noise and the effect of bandwidth limitations can be mitigated by lengthening the RC time constant which in effect increases the period of the pulse transmitted per dB. It is possible then, at the expense of increased time spent in measuring, to achieve any practical degree of error desired.

It remains now to determine the length of the pulse generated in order to ascertain the magnitude of the voltage being measured. Examination of (1) shows that equal intervals of time represent equal decibel increments. Therefore, a gated oscillator and counter circuit such as shown in Fig. 6 may be used to determine how many decibels above the reference voltage the voltage on the capacitor was before discharge. For example, the oscillator's frequency may be set such that one cycle is equivalent to 1 dB. If then the voltage placed on the capacitor is 10 dB above the reference voltage, 10 cycles of the oscillator output will be gated to the counter. This is shown pictorially in Fig. 7. As a practical matter it can be shown that if the oscillator and gate are not synchronized, a one count ambiguity can occur. Since the exact time a pulse arrives cannot be arranged to correlate with the phase of the oscillator and since turning on a precision oscillator and obtaining full accuracy instantaneously is very difficult, synchronization is not feasible. An alternative solution used in ATMS is to employ a free-running oscillator whose frequency is much higher (36:1 in the case of ATMS) than necessary. Then a gated divider is used which divides the oscillator frequency down to the desired frequency and gates the output to the counter. In this way the ambiguity is reduced by the ratio of the oscillator frequency to the gating frequency. In the case of an ATMS loss measurement, for example, where a tenth of a dB is represented by 2 milliseconds the ambiguity is reduced to 2/36 milliseconds which corresponds to 0.0028 dB.

The counter output in Fig. 6 is the difference in dB between the unknown voltage and the reference voltage, provided the counter was set initially to zero. In practice, the quantity of interest is the difference between the measured voltage and the expected voltage. This can be obtained by the use of a presettable reversible counter. Fig. 7 shows its operation. Assume that the readout is in dB's and that the expected voltage is 10 dB above the reference voltage. From this information the counter is preset to 10 and set to count down. Further, assume that the measured voltage is 10 dB above the reference voltage. When the capacitor discharges, 10 cycles of the oscillator output are gated into the counter causing it to count down to 0. The resulting

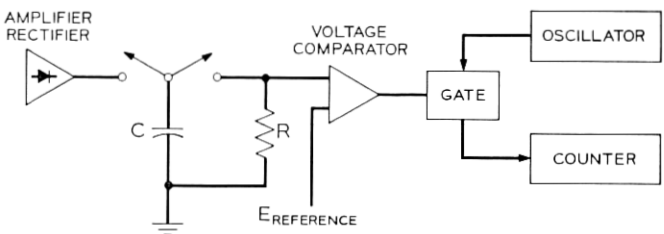

Fig. 6 — Block schematic for measurement of time interval.

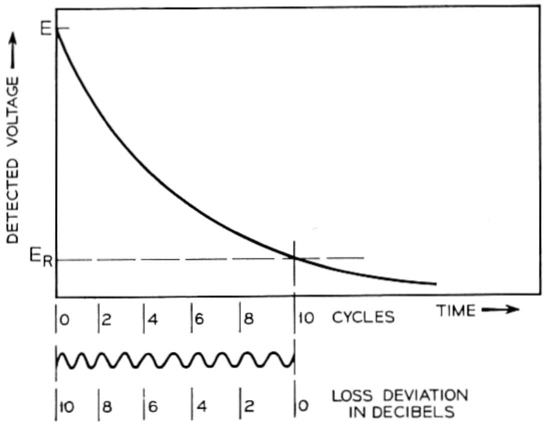

Fig. 7 — Loss deviation computation.

digital display on the counter will therefore be 0, corresponding to the difference between the measured and expected voltages.

If, however, the voltage on the capacitor was 11 dB above the reference voltage, the counter would count down from 10, through 0, reverse and count up to 1. The difference or deviation is then read out as 1 dB; the reversal of the counter indicates that the measured voltage exceeded the reference voltage.

To change the precision to which the results are displayed, it is only necessary to change either the oscillator frequency or the RC discharge time constant. In the ATMS, loss measurements are displayed to the nearest 0.1 dB and noise measurements are displayed to the nearest 1 dB. The change is made by decreasing the RC time constant by a factor of 10 during noise measurements.

VI. NOISE MEASUREMENT

The previous section discussed how a loss measurement was made and the results displayed. The ATMS noise measurement is discussed in more detail because it is the first widespread application in which a noise reading made in a fraction of a second is taken as a measure of the disturbing effect of noise to a telephone customer.

6.1 *General*

The fundamental objective of message circuit noise measurement is to give the same reading on various kinds of noise that are judged to be equally interfering to a telephone customer. The accepted noise measuring set in the Bell System for measuring message circuit noise is the 3A Noise Measuring Set.[4] The ATMS noise measurement circuit will give approximately the same results as a 3A Noise Measuring Set.

6.2 *Frequency Weighting*

The ATMS noise measurement circuit employs the same C-message weighting filter as the 3A set. This characteristic was determined during tests[4] in which listeners were asked to adjust the loudness of 14 different frequencies between 180 and 3500 hertz until the sound of each was judged to be equal in annoyance to a 1000-hertz reference tone. The results of these tests were averaged at each frequency, combined and smoothed to obtain the C-message weighting as shown in Fig. 8.

6.3 *Quasi-rms Detector Circuit*

The ATMS quasi-rms detector employs the same kind of detector as the 3A Noise Measuring Set. The appendix of Ref. 4 explains in detail the principle of operation of this circuit (see Fig. 9).

Briefly, the quasi-rms detector is somewhere between a peak and an average detector. Since the rms value of a positive function lies between the average and peak value, it is instructive to investigate the action of a detector which gives a dc voltage corresponding to something between average and peak.

6.3.1 *3A Quasi-rms Detector Circuit*

Consider the capacitor of Fig. 9 to be large enough such that the circuit time constants are much longer than any associated with the input signal. The diodes conduct only when the input voltage is higher than the voltage across the capacitor. If R_1 is zero ohms, then e_{out} is equal to the peak value of the input signal minus any diode voltage

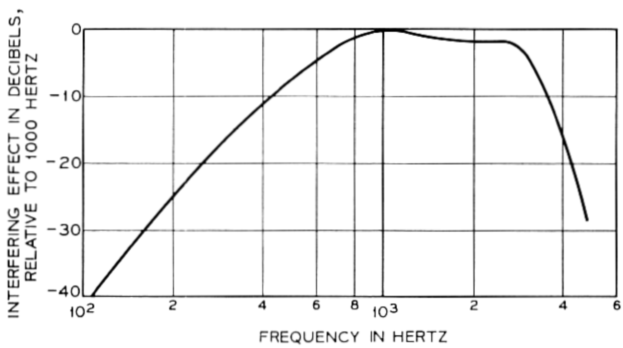

Fig. 8 — Response vs frequency of C-message weighting characteristic.

drop in D_1 or D_2. If R_1 is made very large compared to R_2, then e_{out} is a measure of the average value of the input signal. By selecting the proper ratio of R_1 and R_2, the circuit can be made to produce equal e_{out} for any two input signal waveforms of equal rms value.

Thus, if one wishes that sine waves and white noise of equal powers produce the same e_{out} then a ratio of

$$\frac{R_2}{R_1 + R_2} = 0.796.$$

should be chosen.

6.3.2 *ATMS Quasi-rms Detector Circuit*

The ATMS quasi-rms detector circuit[5] is shown in Fig. 10. The operation of this circuit may best be understood by first considering that diode D_5 is an open circuit. Let the input be a sine wave. The gain of the amplifier from the input to point H will be very large until one pair of diodes D_1, D_2 or D_3, D_4 is broken down. D_1, D_2 will conduct on the positive swing at point H and D_3, D_4 on the negative swing. Resistors R_{1_2} are much higher than the forward resistance of a conducting diode. When the diodes are conducting the gain of the amplifier is determined by the feedback resistors (R_{1_1}, R_{f_1}, and R_{f_2}) and R_s.

Thus, the signal at point H will appear to be a magnified replica of the input signal sliced through at the zero voltage point with a square wave of peak-to-peak amplitude $VD_1 + VD_2 + VD_3 + VD_4$ added. If one were now to look with an oscilloscope at point A, a positive half-sinusoid with an additional dc voltage of VD_1 would be observed when the signal at H swings positive. If the signal at point B were now subtracted from the signal at point A, a full-wave rectified signal riding on an added dc voltage equal to a diode voltage drop would be observed.

It is this added diode voltage drop which now permits compensation for the voltage drop of D_5, which we will now reinsert.

C is the storage capacitor (4.22 μF) mentioned in Section V. If diodes D_1 and D_2 are conducting, then C is charged through the R_{1_2} across

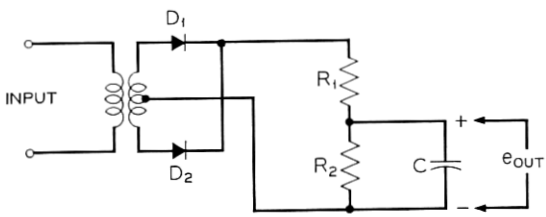

Fig. 9 — Simple quasi-rms detector.

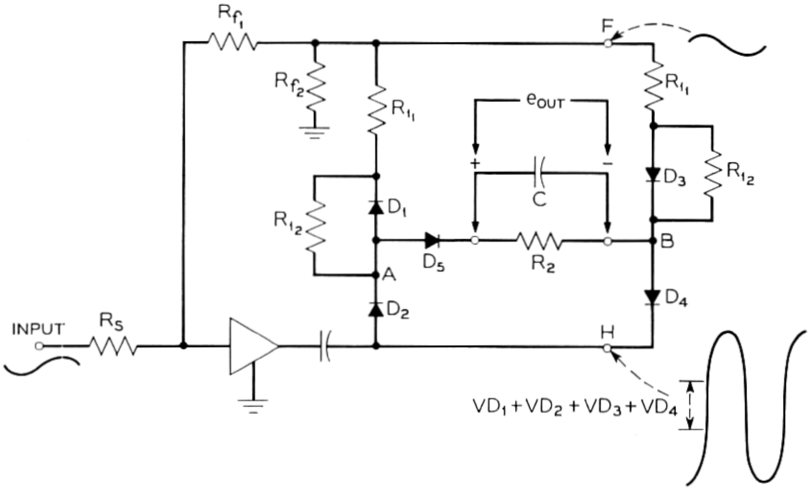

Fig. 10 — ATMS quasi-rms detector.

D_3 and the two R_{1_1}'s in series. The relationship between the resistors is as follows:

$$\frac{R_2}{R_{1_1} + R_{1_1} + R_{1_2} + R_2} = 0.796.$$

When the signal is first applied to this circuit, diode D_5 will be conducting most of the time. As C charges, D_5 will conduct less of the time as determined by the input signal waveform.

Diode D_5 is chosen so that its forward voltage drop is the same as the forward voltage drop across D_1 or D_3, which carry higher currents than D_5. The size of the R_1's, R_2 and C are chosen as described below.

6.4 *Noise Detector Transient Response*

The ATMS quasi-rms measurement circuit, as in the 3A set, is designed to match the transient response of the human ear. This response was determined[6] during tests in which listeners were asked to match the loudness of bursts of 1000-hertz tone to that of a steady 1000-hertz tone.

The response of the ear could not be exactly matched with a quasi-rms charging characteristic so a compromise was made to ensure a close match in the 150 to 250 millisecond range ($R_2 = 42.2\text{k}\Omega$ in Fig. 10).

The selection of a time constant must take into account the fact that the discharge time constant of the quasi-rms circuit is more than four times the initial charging time constant. Thus, for noise which falls off during the measurement interval it is desirable to have R_2 as small as possible.

6.5 *Noise Measuring Interval*

The ATMS was designed to measure background noise rather than impulse noise. The most common types of background noise occurring on trunks are single-frequency tones, combinations of tones or white noise. The single-frequency tones can arise from such sources as power line harmonics and modulation products on carrier systems. The white noise arises from thermal and shot noise effects. The modulation products falling in a carrier channel from a large number of talkers in other channels also behave like white noise.

How long a period is necessary to measure white noise? It has been shown[7] that the error resulting from a noise measurement made over a short interval of time decreases with increasing bandwidth and increasing measurement interval. It was desired that successive ATMS noise readings of a stable white noise source exhibit a standard deviation no larger than 0.25 dB. With the quasi-rms detector time constant as determined previously, a measurement interval of 0.375 second was found to meet this requirement.

Because of the characteristics of the quasi-rms detector, the measurement of a sine wave over this interval produces less than .05 dB error.

6.6 *ATMS vs 3A Noise Measuring Set Observers*

The ATMS noise measuring system performance was checked against 15 observers using a 3A Noise Measuring set on a series of noise tapes selected at random from a survey of 1069 intertoll trunks covering the whole Bell System. Fifteen-second noise samples from 15 different trunks were selected from each of two trunk length ranges: 250 to 500 miles and over 2000 miles.

Each individual noise segment occurred twice at random positions on the tape. The ATMS made three measurements during each 15-second segment for a total of six ATMS readings per segment.

The results of these tests are shown in Table II.

This data shows that the ATMS readings are consistent with the design requirements. Even greater reliability can be obtained by using the various repeat measurement modes. The possibility of rejecting

TABLE II—COMPARISON OF ATMS AND 3A OBSERVERS

		250 to 500 mile trunks	Over 2000 mile trunks
3A observers	δ	0.31–0.33 dB	0.33–0.35 dB
	Mean	31.7 dBrnC	38.8 dBrnC
ATMS	δ	0.82–0.84 dB	0.60–0.61 dB
	Mean	32.0 dBrnC	39.0 dBrnC

a good trunk for high noise readings on two successive measurements is remote.

VII. OVERALL ATMS OPERATION

7.1 *General*

So far, the basic measurement technique employed by ATMS and some special considerations for the measurement of noise have been discussed. In order to operate satisfactorily as a system, a number of other functions must be considered. These relate back to the nine simple steps described in the general description (Section 4.1) and include: accepting priming information, coordinating simultaneous operation of director and responder, making measurements, and displaying all results at the director location. All ATMS operations may be related to specific circuit functions or subsystems as follows:

(*i*) Measurement circuits.
(*ii*) Computational (counting) circuits.
(*iii*) Storage (or registration) circuits.
(*iv*) Signaling system.
(*v*) Data transmission sytem.
(*vi*) Control circuits.
(*vii*) Timing circuits.
(*viii*) Logic circuits.

Before describing how these circuits and subsystems function together, however, it is necessary to say a few more words about the measurement procedure.

7.1.1 *Measurement Procedure*

As described in Section V, the ATMS amplitude-to-pulse-width converter generates a pulse whose length is proportional to the logarithm of the input signal level. A complete measurement requires that this pulse length be converted into a digital output which can be used to drive a Teletype machine or other display device. This is shown in Fig. 11, a block diagram of the ATMS measuring circuits. Thus, the pulse length is converted into a number of pulses which are then fed into a binary-coded decade counting circuit.

The counting circuit, functioning as described in Section V, determines the difference between the measured and expected values. Thus, upon completion of a measurement, the result, regardless of whether the actual measurement was made by the director or the responder, is stored in the director counting circuits.

7.2 *Measurement Sequence*

Using this information on the ATMS measurement procedure, the overall operation of the system may be described by a relatively simple sequence of events. In Fig. 12, a complete functional block diagram of the ATMS is shown. The procedure involved in gaining access to a trunk, making a measurement and advancing to the next trunk, is described in the General System Description, Section 4.3, which also discusses the functions of the automatic trunk test frame and the test line. The circuit blocks within the ATMS director and responder will be discussed as they occur in the description.

Before the measurement sequence begins, the test frame supplies the director with all necessary priming information. This permits the logic and control circuits to preset counters and limit circuits to

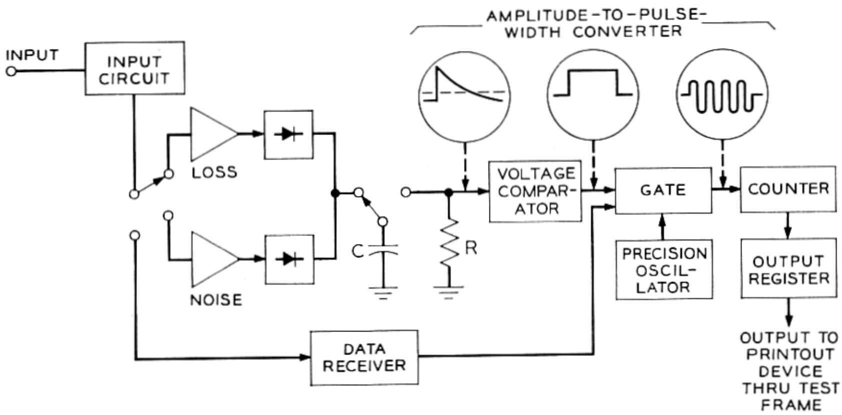

Fig. 11 — Block diagram ATMS measuring circuits.

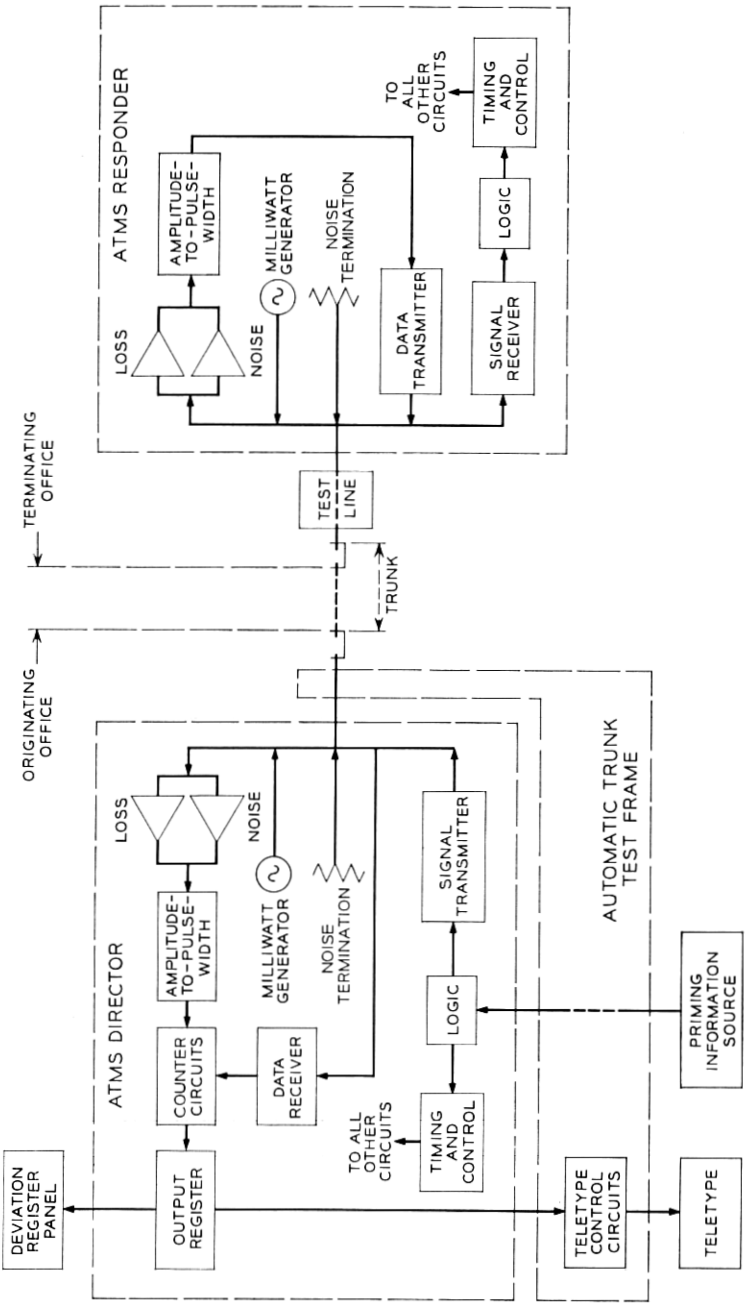

Fig. 12 — ATMS functional block diagram.

their correct values, set up the correct measurement mode (discussed in Section VIII), set the input circuit for the correct impedance and level, set the measuring circuits for self-check or trunk test, and other similar operations. Once the responder has been connected to the trunk, the test frame instructs the director to start the measurement sequence. The measurement sequence can be described using as an illustration a test sequence which includes loss in both directions and noise at both ends.

7.2.1 *Loss Measurements*

The simultaneous activities carried on by the director and the responder during loss measurements and the time allotted for each of these activities are shown in Fig. 13. Loss measurements are initiated when the director sends a 2-out-of-6 (2/6) multi-frequency (MF) signal to the responder commanding it to begin a loss measurement sequence. The timing circuit of the responder is triggered by the receipt of the signal, and the next three steps occur automatically. The responder sends a 1-kHz milliwatt test tone over the trunk to the director. The loss measurement circuit of the director amplifies and

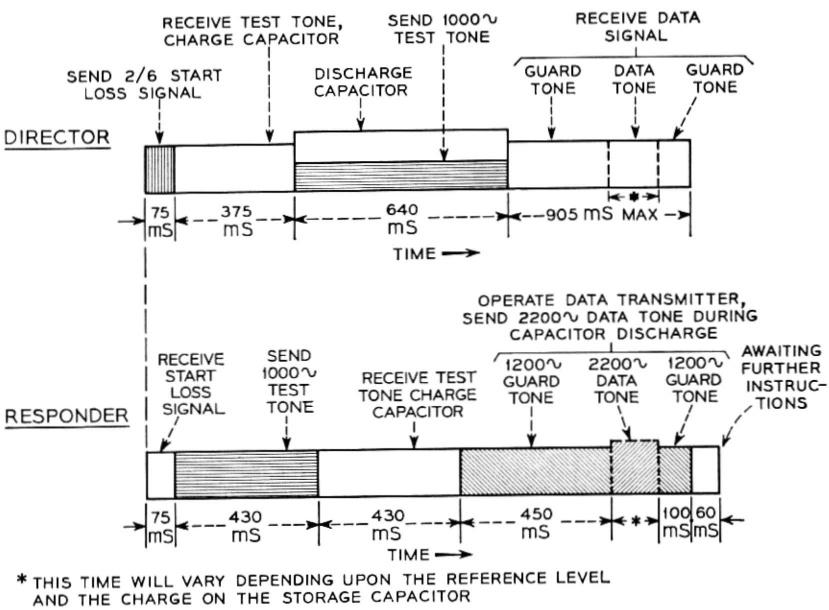

Fig. 13 — Loss measurement timing.

filters the signal. The amplitude-to-pulse-width converter rectifies the signal and uses the resulting dc potential to charge a storage capacitor.

The director then performs two simultaneous activities. It discharges the storage capacitor of the amplitude-to-pulse-width converter. This pulse gates on the precision oscillator, and the decade counting circuits count these pulses to rate the trunk on its far-to-near loss. At the same time, the director transmits a 1-kHz test tone to the responder as the first part of a near-to-far loss measurement. The loss measurement and the amplitude-to-pulse-width converter circuits of the responder are identical to those of the director. These circuits charge the storage capacitor in the responder to a level which is dependent upon the near-to-far loss characteristic of the trunk. The loss measurements are completed as the responder sends data back to the director to indicate the near-to-far loss characteristic. When the storage capacitor of the responder is discharged, the pulse is used to control a data transmitter which starts by sending guard tone (1200 Hz). It then shifts to data tone (2200 Hz) for the duration of the pulse, then returns to guard tone for a short period. The data receiver of the director converts this data signal into the dc pulse which gates on the precision oscillator so that the near-to-far loss deviation may be counted. Two-way loss measurements are accomplished in less than two seconds.

7.2.2 *Noise Measurements*

Noise measurements begin when the director samples the noise present on the trunk under test. The noise is amplified, weighted with C-message weighting and rectified in the noise measuring circuit, then used to charge the storage capacitor. The responder at this time functions only as a quiet termination for the trunk at the far end. Next, the director commands the responder to make a noise measurement. It does this by transmitting a 2/6 MF signal to the signaling receiver of the responder. After sending the "start noise" measurement command, the director provides a near-end termination for the trunk under test. The responder uses its own measuring circuit and amplitude-to-pulse-width converter to charge the responder storage capacitor from noise present at the far-end of the trunk. Simultaneously, the director discharges its storage capacitor which had been charged from the near-end noise. The resulting pulse gates the precision oscillator and the near-end deviation from the reference noise level is counted. Then, the responder discharges its storage capacitor and sends a data signal indicating the results of the far-end noise measurement to the director. The data receiver of the director converts the data signal into a gate pulse for the counting of the far-end noise deviation from reference level.

7.2.3 *Nonmeasurement Functions*

At the appropriate time in the testing sequence, the measurement is transferred from the counter to the output register, a relay circuit which translates the results from a binary to a decimal code and stores them. The automatic test frame "reads" the ATMS output and causes the results to be printed. Once the results of a measurement are stored in the output register, the counting circuits may be preset and the sequence advanced to the next measurement. Note that this provides the director with the capacity for the simultaneous storage of two answers; one in the output register and one in the counter. This feature is used to advantage to decrease the measurement time.

In addition to the functions described above, counters are preset, results are compared with limits to determine cues (indications that a measurement has exceeded a limit), and a determination is made as to whether the trunk should be retested.

VIII. MEASUREMENT MODES

The ATMS provides its users with a choice in the amount of printout information that may be obtained. In all the preceding discussions, the operation of the ATMS was described with all of the measurement results printed out. This would include self-check results and both initial and repeat results when a trunk test is repeated, and is the maximum printout available. There are occasions, however, where such complete results are not necessary (and indeed, may even make it more difficult to utilize the results), and when desired, the ATMS may be instructed to print out the results of only those trunks whose measurement results have exceeded some limit. The advantages of such operation include increased testing speed and a printed record of only those trunks exceeding certain maintenance limit.

8.1 *Measurement Limits and Cues*

The ATMS director may be set for measurement limits that correspond to two different degrees of urgency: maintenance limits and immediate action limits. Any of ten maintenance limits and seven immediate action limits may be selected. During the measurement sequence the director provides special indications called cues, along with the measurement results, whenever one or more measurements exceed one of these limits. A cue of "1" (Q_1) is provided when a maintenance limit is exceeded and a cue of "2" (Q_2) is provided when an immediate action limit is exceeded. In addition, self-check limits are built into the director. A cue of "0" (Q_0) indicates a satisfactory self-check and a cue of "9" (Q_9) indicates a self-check limit has been exceeded (±0.1 dB for loss and ±1 dB for noise).

8.2 *Measurement and Printout Modes*

Four different measurement and printout modes may be set into the director by switch selection at the test frame. These modes are as follows:

(*i*) Full Printout—No Repeat: All measurements are printed out and no repeat tests are made regardless of the cue.

(*ii*) Full Printout—Repeat on Q_2 : All initial measurements are printed out and if Q_2, which is the highest limit, is exceeded, the measurements are repeated and printed out.

(*iii*) Full Printout—Repeat Q_1 or Q_2: All initial measurements are printed out and the measurements are repeated and printed out if either Q_1 or Q_2 is exceeded.

(*iv*) Abbreviated Printout—Repeat on Q_1 or Q_2 : Initial measurements are not printed out. If no limit is exceeded, no record is made. If either Q_1 or Q_2 is exceeded, the measurements are repeated and the results of the repeat test are printed out.

All self-check results are printed out, both initial and repeat test, regardless of the print mode selected.

IX. MECHANICAL FEATURES

ATMS directors and responders each consist of a group of modules called circuit packs which plug into horizontal mounting shelves. The shelves, in turn, are fastened to the framework of 23-inch relay racks. A typical circuit pack is shown in Fig. 14. Each circuit pack is 8-3/8 inches high, 8 inches deep, and either 1 or 2 inches wide. Most electrical parts are mounted on epoxy glass printed wiring boards. A few components, such as keys and jacks, are mounted in the face panel of the cast metal frame. A multiple plug at the rear of the circuit pack provides interconnection to other units through a mating connector and the shelf wiring. On the director, installer wiring termi-

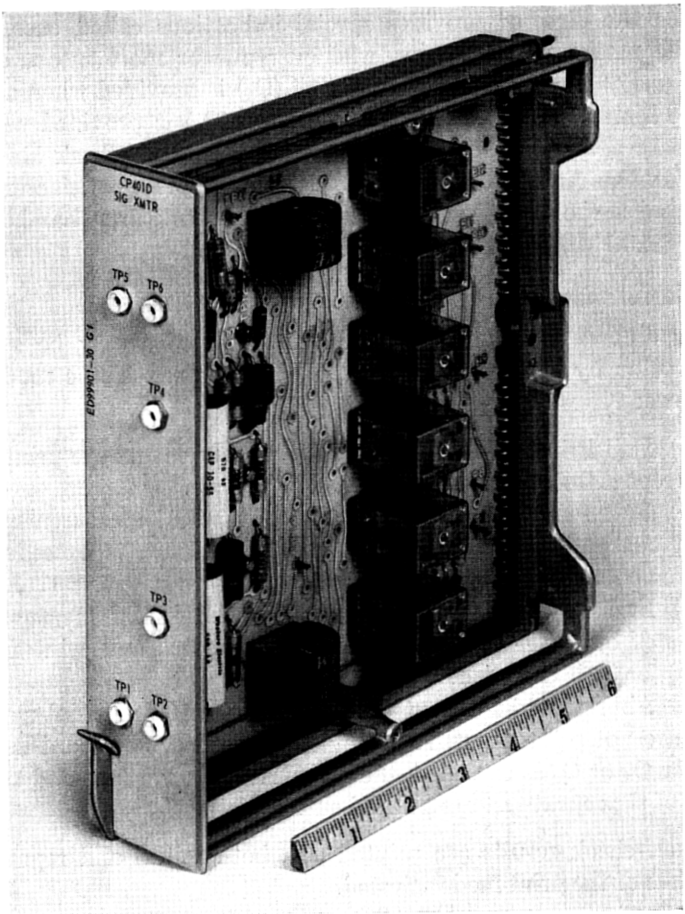

Fig. 14 — ATMS circuit pack.

nates in several multiple plugs which engage mating connectors wired to appropriate circuit pack connectors.

Circuit packs of the director mount in four horizontal shelves. The shelves are each 10 inches high. The overall assembly therefore occupies 40 inches in a 23-inch bay. The director is shown in Fig. 15.

The responder occupies only three horizontal shelves of a bay. The complete assembly, shown in Fig. 16 is 30 inches high and 23 inches wide. As shown in Fig. 15 and 16, both the director and responder contain circuit packs with no designations on the front. These are

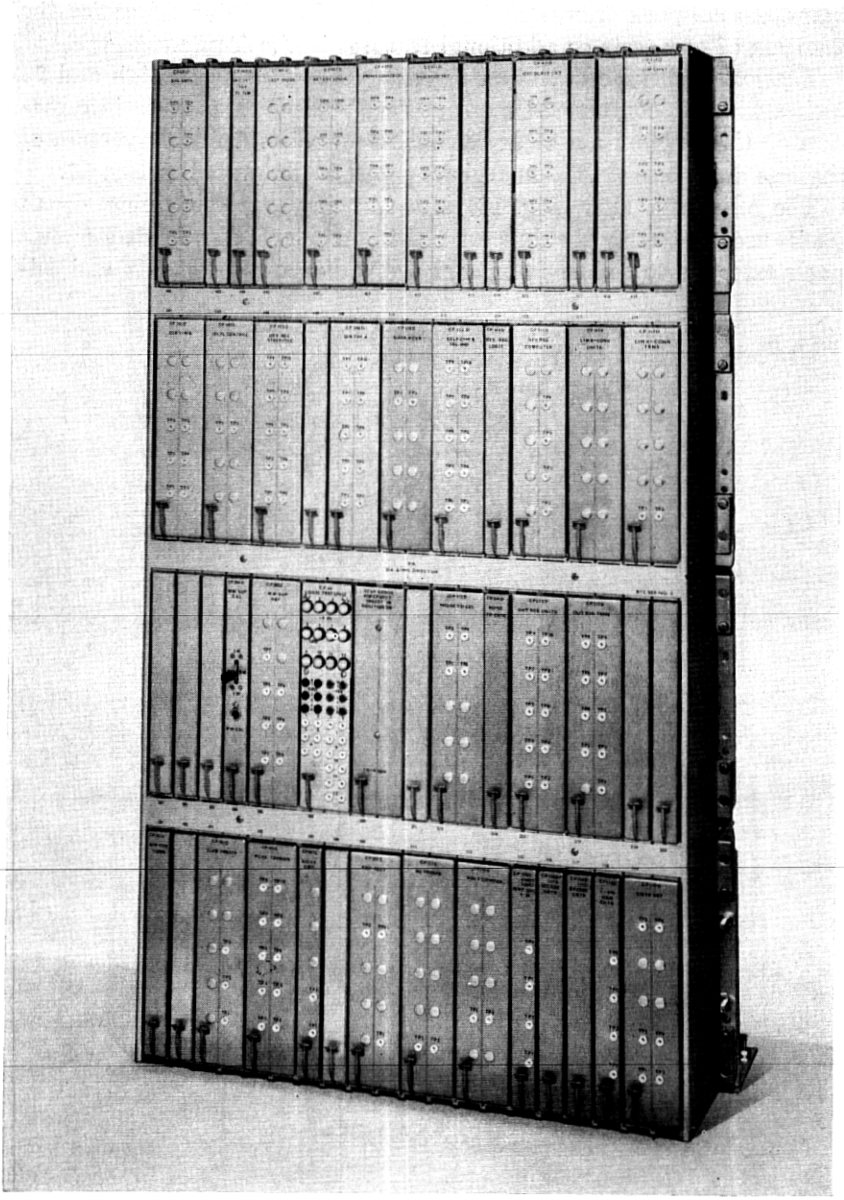

Fig. 15 — ATMS director.

blank circuit pack frames and represent the expansion space for the addition of new tests or additional features in the future.

The loss and noise deviation register panel is 6 inches high and 23 inches wide. It contains 34 message registers which provide information on the distribution of deviations in an office. An early version of the loss and noise deviation register panel is illustrated in Fig. 17.

The alignment unit (Fig. 18) is a carrying case containing circuit packs used in testing the director and responder. It also holds a circuit pack extender to aid in making maintenance measurements and ad-

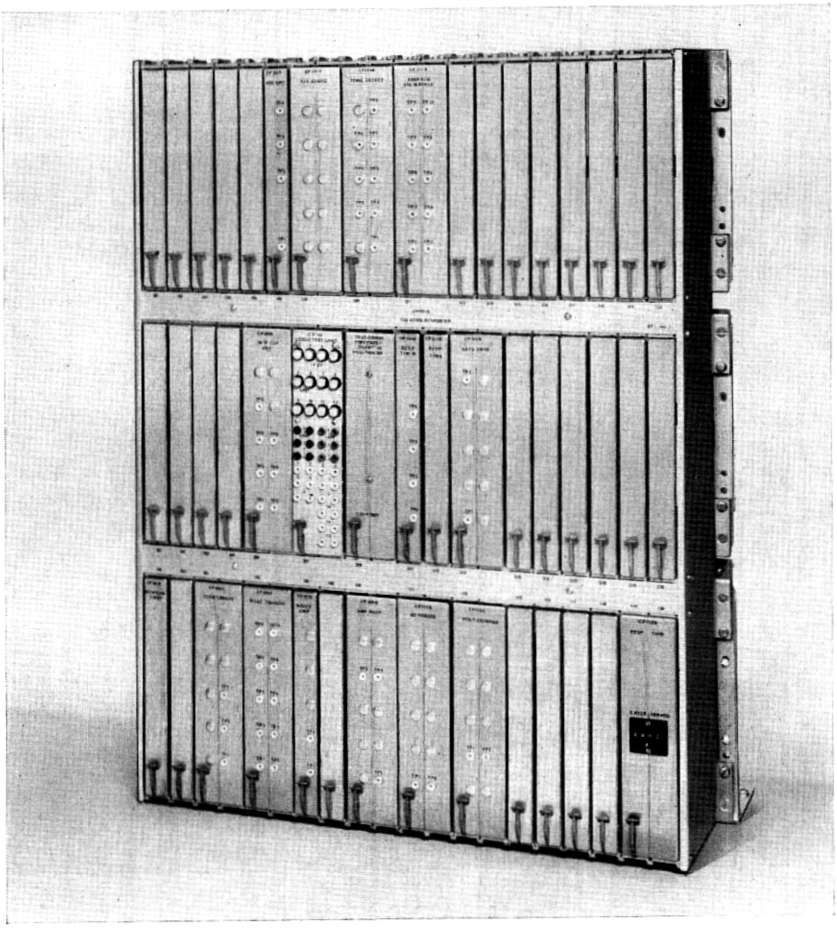

Fig. 16 — ATMS responder.

justments. The unit is 10 inches high, 15 inches wide, and 11 inches deep. It can be mounted by brackets in a 23-inch bay. In this case, the whole assembly is 10 inches high and 23 inches wide.

X. MAINTENANCE

10.1 *Alignment*

Alignment of the director or the responder is accomplished by use of test circuit packs which normally are stored in the alignment unit. Alignment is necessary upon installation, when a critical circuit pack is replaced, and on a routine basis. Routine alignment is not expected to be necessary more often than every six months.

10.2 *Trouble Location*

Maintenance is facilitated by use of test points located on the face panels of the circuit packs. The test points provide access to particularly important points in the circuits. The circuit packs can be placed on an extender (included in the alignment unit) to make internal measurements or adjustments. No maintenance or repair of individual circuit packs is required by the user. Instead, the faulty circuit pack is simply located and replaced. The faulty circuit pack is then sent to a repair center. Special test procedures are provided for rapidly identifying faulty circuit packs.

XI. ATMS FIELD TRIAL

An extensive field trial was undertaken to assure that the ATMS and the associated switching equipment would function properly in the actual telephone offices.

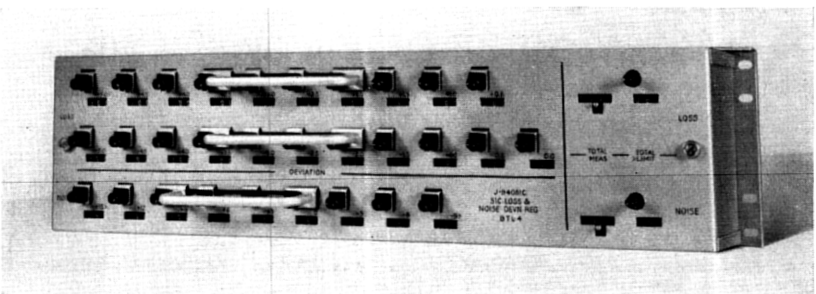

Fig. 17 — ATMS loss and noise deviation register.

11.1 *Equipment Location*

The ATMS was on field trial in the Norristown, Pennsylvania, area between January, 1965 and January 1967. An ATMS director was associated with a No. 5 Crossbar Automatic Progression Trunk Test Frame (APTT) in the Norristown, Pennsylvania, central office. Five responders were located as indicated in Table III. Other far-end offices with 102-type and 104-type test lines were included in the trial.

11.2 *Field Trial Results*

11.2.1 *General*

The ATMS was found to meet all its design requirements. Trunks were tested more frequently and precisely than would have been possible with manual trunk testing by the telephone office personnel.

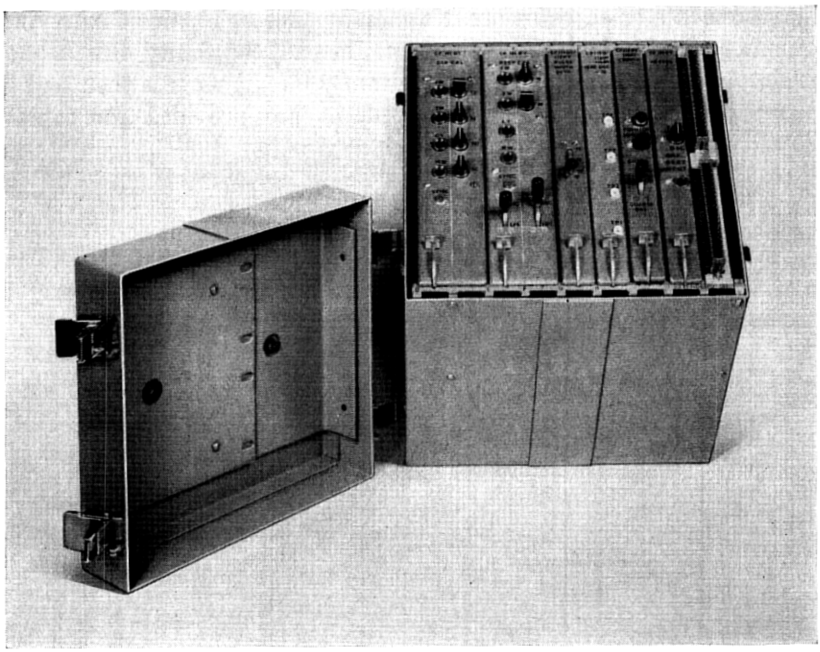

Fig. 18 — ATMS alignment unit.

TABLE III—RESPONDERS FOR ATMS FIELD TRIAL

Location of responder	Airline distance to Norristown, Pa. in miles	Type of access to responder through 105-type test line
Wayne, Pa.	6	4A toll
Lansdale, Pa.	9	SXS toll, SXS local
Philadelphia, Pa.	15	XB tandem, 4M toll IXB local, panel local
Pottstown, Pa.	19	5XB toll, 5XB local
Newark, N. J.	80	4A toll

11.2.2 *Trunk Testing Time*

It is desirable not only to reduce the time per trunk tested, but to reduce the holding time of the trunk so that it will be available to customers. The typical trunk was held for approximately eight seconds on a no-repeat loss and noise measurement to an ATMS responder. About half of this time was measurement time. The remaining time was necessary to complete the printing of the measurement results.

The speed at which trunks can be tested varies considerably depending on any or all of the factors below.

(*i*) Number of trunks in the trunk group.
(*ii*) Number of self-checks requested.
(*iii*) Printout mode—no repeat or repeat.
(*iv*) Number of trunks requiring a repeat measurement.
(*v*) Busy trunks—this is a function of the time of day.
(*vi*) Trunk seizure time.

The trunk noise readings are usually highest during the hours of peak office activity. Unfortunately, busy hour testing implies a maximum number of busy trunks (80 percent during one extended test) as well as competition with the customer for the few available trunks. The "busy hour" in Norristown extends almost all day, necessitating night-time testing.

During the field trial, measurements were made in the Repeat-on-Q_1-or-Q_2 printout mode during the hours from midnight to 8 a.m. Dividing the total time by the number of trunks tested results in an average time of 50 to 60 seconds per trunk tested.

Assuming 10 hours of usage per day, a seven-day week and an average trunk test time of 60 seconds per trunk, one may then test 4,200 trunks per week.

XII. REMOTE-OFFICE TESTING

The classes of ATMS testing previously discussed permitted testing of trunks between an office containing an ATMS director and other offices with 100-, 102-, 104- or 105-Type Test Lines. See Table I.

Trunks between offices too small to justify an ATMS director and its associated test frame could not be tested with the ATMS until the advent of the Remote Office Test Line (ROTL). The ROTL (to be available soon) permits the director at Office A to obtain the results of measurements on trunks between Office B, equipped with a ROTL, and Office C equipped with a Code 100-, 102- or 105-Type Test Line.

12.1 *General*

The office containing the director and its associated test frame will be referred to as the near-end office, the office with the ROTL as the remote office, and the office containing the test line as the far-end office. The trunk between the near-end office and the remote office will be called the access trunk.

Two kinds of remote office testing have been developed.

(*i*) Remote-Office-Responder Testing—full accuracy, measurements made at the remote office using a modified responder—see Fig. 19.

(*ii*) Remote-Office Through Testing—reduced accuracy, no measurements made at the remote office, lower cost—see Fig. 20.

The remote office concept may be used to measure trunks if the far-end office is equipped with a 100-, 102- or 105-Type Test Line.

Under control of the test frame the ROTL can seize an outgoing

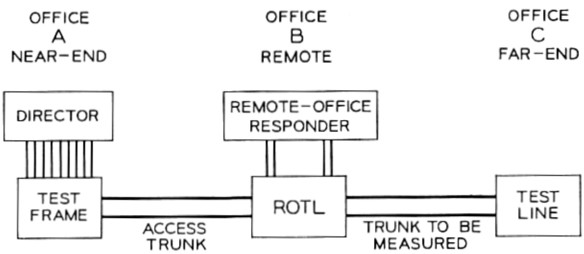

Fig. 19 — Remote-office-responder testing.

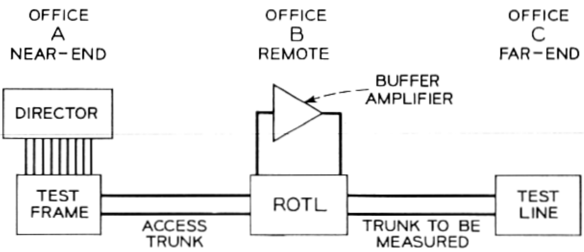

Fig. 20 — Remote-office through testing.

trunk to the far-end office, pulse forward a test line code and assist in making transmission tests on the outgoing trunk.

The responder and test line can be in the same office or building as the director and test frame to permit testing of incoming trunks. An incoming trunk is defined as one which can be seized only at a distant office. An access trunk and ROTL are used to gain access to the originating end of these incoming trunks.

12.2 *Systems with Similarities to Remote-Office Testing*

12.2.1 *L. M. Ericsson Remote-Controlled Measurement*[2]

The Swedish Ericsson system mentioned in Section II can operate in a mode in which the controlling set in office A can control test sets in offices B and C. The results of the measurement of the trunk between B and C is then relayed to A by means of a multifrequency code. This system employs a slower measurement method.

12.2.2 *Loop-Around Test Line*

At the present time manual, one-man, two-way loss measurements are possible without 104-Type Test Line or ATMS equipment if the remote office is equipped for loop-around testing.

All trunks in a group to the remote office are first measured in the far-to-near direction by seizing the Milliwatt Test Line in the remote office. One of these trunks is then selected as the reference trunk and is connected in turn through the loop-around test line to each of the other trunks in succession. Test tone is then sent from the originating office through the trunk to be tested and back through the reference trunk. Subtraction is then necessary to obtain the near-to-far loss of each trunk.

Loop-around testing necessarily requires that a means be available at the test location in the originating office for originating and holding two connections simultaneously. Only outgoing trunks may be tested by this method.

There are many disadvantages to this method in addition to the subtraction required. If the loss of the reference trunk varies with time or level (see Section II), then the computed near-to-far losses for the other trunks will be in error. Mistermination errors may occur when the reference trunk is connected to the trunk to be measured. As with all manual measurements, the procedure is slow.

12.3 *Remote-Office-Responder Testing*

All measurements in this mode are made by either the far-end responder (for the case of a 105-Type Test Line) or a modified responder at the remote office. All measurement results are sent back to the director in the form of frequency-shift data signals. The loss and noise of the access trunk therefore do not degrade the accuracy from that of a director-to-responder measurement.

12.3.1 *Responder Modification*

A responder is modified to a remote-office responder by the addition of three circuit packs. These provide for modification of the timing cycles and independent output circuitry toward the access trunk. The remote-office responder is capable of transmitting different signals simultaneously, one toward the director and another toward the far-end equipment. This responder may still be utilized as a standard responder, if desired.

By using the isolation amplifier contained in the remote-office responder one can pass a signal *through* a remote-office responder in either direction. 2/6 commands may be passed through the remote-office responder to the far-end responder or the data from the far-end responder may be passed through the remote-office responder to the director.

12.3.2 *Remote-Office-Responder Testing Sequence*

Fig. 21 shows a two-way loss and noise measurement between a remote-office responder and a far-end responder. One new 2/6 multi-frequency command is necessary to make the near-end noise measurement. The other 2/6 commands are the same as those required for a normal director-to-responder measurement. It should be noted that a

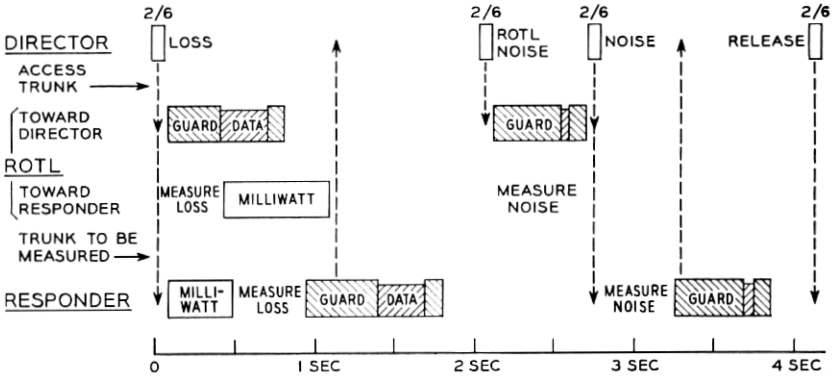

Fig. 21 — Remote-office-responder testing to a far-end responder.

normal responder will not reply to any other 2/6 commands than those mentioned in Section VII.

Both the remote-office responder and the far-end responder will reply to the 2/6 loss signal. The remote-office responder will measure the far-end responder test tone and at the same time transmit the 1200-Hz guard tone to the director. The remote-office responder will now complete the data signal to the director which it is transmitting test tone toward the far-end responder. The director then receives the loss data signal from the far-end responder through the remote-office responded.

The director then commands the remote-office responder to measure noise. After the director has received this data signal it commands the far-end responder to measure noise, and with the same signal, the remote-office responder to pass a data signal through to the director. When this final noise data signal has been completed, both responders return to a state where they can receive 2/6 commands.

Loss and noise self-checks of the remote-office responder and the far-end responder may be completed in a somewhat similar manner.

It is now clear that the loss and noise of the access trunk will have no effect on the accuracy or range of measurements.

12.4 *Remote-Office Through Testing*

This mode of testing necessitates connecting the access trunk to the trunk to be measured. If both of these trunks employed negative impedance repeaters, then a possibility of a singing condition exists due to mistermination. This can be eliminated by the use of a buffer amplifier.

12.4.1 *Buffer Amplifier*

The buffer amplifier eliminates the effect of interaction between the impedances of the two trunks and provides terminations of nominal impedance during measurements. Because of its unilateral transmission, however, the buffer amplifier necessitates more control functions in the ROTL.

Since no measuring equipment is present in the remote-office equipment, the director must make the measurement for noise at the remote-office end of the trunk to be measured. Noise on the access trunk of the same level as that on the trunk to be measured can have a large effect on the measurement accuracy. For this reason a buffer amplifier gain of 20 dB was chosen for the period of this noise measurement. At all other times a buffer amplifier gain of 0 dB has the advantage of preserving signal levels.

In the sequences which follow, the buffer amplifier is used in such a manner that its actual gain is relatively unimportant as long as the amplifier is linear.

12.4.2 *Remote-Office Through Measurement Sequence*

Fig. 22 shows the actual sequence for a measurement to a far-end responder. Fig. 23 is a simplified diagram of the amplifier and the transmission portion of the ROTL. Table IV describes the sequence followed by the circuit shown in Fig. 23.

The far-to-near loss measurement is made by first measuring the loss of the access trunk (interval t_1) from the remote-office to the director and then subtracting this from the loss of the trunk to be measured and the access trunk in tandem (interval t_3). During interval t_4 the far-end responder is measuring the test power from the remote office.

The director makes a measurement of the noise at the ROTL end of the trunk to be measured during interval t_6. During interval t_8 the responder can make a valid noise measurement because the buffer amplifier is pointed toward the director. Not only does it block any noise on the access trunk, but it terminates the trunk to be measured in the correct impedance independent of the impedance of the access trunk.

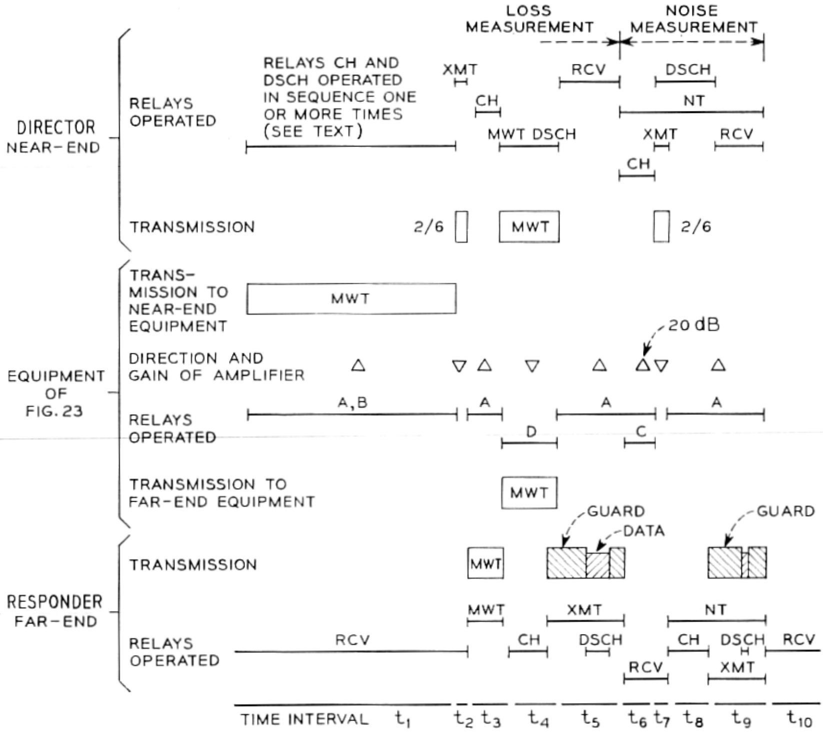

Fig. 22 — Remote-office through testing to a far-end responder.

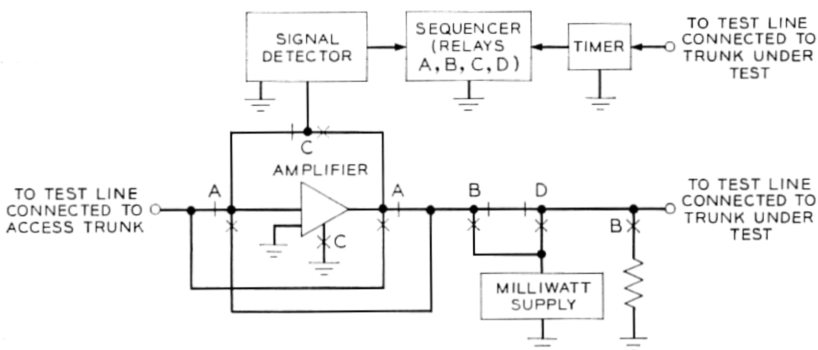

Fig. 23 — Simplified ROTL for remote-office through testing.

TABLE IV—REMOTE-OFFICE THROUGH TESTING SEQUENCE

Time interval from Fig. 22	Approximate time in seconds	Relays operated				Function being performed during the time relays are operated and relaesed as shown
		A	B	C	D	
t_1	3.00	X	X			3 sec. MWT from Fig. 23 to near end
t_2	0.08					2/6 freq. signal from near to far end
t_3	0.43	X				MWT from far end to near end
t_4	0.64				X	MWT from Fig. 23 to far end
t_5	0.65	X				Loss data from far to near end
t_6	0.38	X		X		Near end measuring noise
t_7	0.15					2/6 freq. signal from near to far end
t_8	0.43	X				Far end measures noise
t_9	0.54	X				Noise data from near to far end
t_{10}	0.08					2/6 freq. signal from near to far end

It should be noted that the far-end responder receives commands from the director and acts on these commands in exactly the same manner as it would in a measurement without a ROTL. Thus, a responder does not have to know whether its commands come through a ROTL.

Testing to a 100- or 102-Type Test Line is accomplished by employing parts of the 105-Type Test Line sequence shown in Fig. 22.

12.4.3 *Remote-Office Through Testing Limitation*

In the loss measurement portion of the sequence the director must make a measurement of the access trunk loss which it will subsequently subtract from the loss of the trunk to be measured and the access trunk loss in tandem. The access trunk loss measurement is made during an initial transmission of the remote-office test tone through the remote-office buffer amplifier. Since the director cannot measure a received level below −15 dBm the loss of the two trunks in tandem cannot be greater than 15 dB.

Raising the gain of the buffer amplifier at the remote-office would increase this range but would also imply initial transmission of the remote office milliwatt at the level about 0 dBm. Such a transmission could cause overload and crosstalk problems on an access trunk over a carrier system. The most practical plan, therefore, is to use access trunks with as low a loss as possible.

The subtraction process to obtain the loss of the trunk from the far-end office with the test line to the remote office involves two separate measurements made at different times and at different levels. With some carrier access trunks, beating of pilot frequencies can easily result in time-varying trunk loss variation of 0.2 dB. Compandor tracking errors can add another 0.1 dB or more of error.

If the far-end test (100- or 105-type) line permits noise measurement at the remote-office then the 20 dB buffer amplifier gain mode is employed. The loss of the access trunk now affects the noise measurement accuracy, for the noise level at the director must be reduced by 20 dB minus the loss of the access trunk. This access trunk loss is stored in pads in the noise measurement path in the director. This loss is stored to the nearest 1 dB—thereby introducing a noise error of ±0.5 dB. Compandor tracking errors are greater at noise measurement levels. These errors add to the carrier beating problem already mentioned.

The necessity for the initial test tone transmission from the remote-office limits the printout to one mode—full printout—no repeat.

No remote-office through automatic testing is attempted to a 104-Type Test Line because its automatic mode (as opposed to manual mode) cannot be utilized. The half-minute cycle time for the 104 circuit in its manual mode restricts the number of trunks which could be tested.

XIII. SUMMARY

The Automatic Transmission Measuring System (ATMS) permits accurate and more rapid measurement of telephone trunks than was previously possible. The 1000-Hz loss of a trunk may be measured in both directions to an accuracy of ±0.1 dB. Noise measurements at each end of the trunk are accurate to ±1 dB. The results of these measurements are printed on page copy, or perforated on punched tape or cards.

An ATMS director is in one office and an ATMS responder is in the other office. The responder may be commanded to make any one of several measurements in conjunction with the director.

The ATMS director works in conjunction with one of several automatic test frames or ESS central control which provides an interface for the director to the particular switching system. Interface for the ATMS responder is provided by a 105-Type Test Line. For most switching systems, the total ATMS measurement time for two loss and two noise readings is less than the overall time to read the trunk information from the input tape and seize the trunk.

Personnel are needed only for loading the input, reading and interpreting the output, periodic alignments and occasional maintenance. When an ATMS director and its associated test frame cannot be provided in a particular office, measurements may be made on trunks between central offices by using one of two Remote-Office Test Line (ROTL) concepts.

The ATMS director can make measurements to four different far-end test lines—

(*i*) 100-Type 5 seconds of milliwatt followed by a quiet termination (to be available soon).

(*ii*) 102-Type Milliwatt, interrupted at 10-second intervals.

(*iii*) 104-Type Transmission Measuring and Noise Checking Circuit (TMANC).

(*iv*) 105-Type ATMS responder.

A director may make measurements through a remote-office to a 100-, 102-, or 105-Type far-end test line.

Flexibility and ease of maintenance result from the use of transistor circuits on plug-in circuit packs. The director requires 40 inches of a 23-inch relay rack and the responder requires 30 inches of a 23-inch relay rack.

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