Intertoll Trunk Net Loss Maintenance under Operator Distance and Direct Distance Dialing

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Nearly all of the components of an intertoll trunk contribute in some degree to its variations in transmission loss. Automatic transmission regulating devices in carrier systems and in many voice-frequency systems control inherent variations in the intertoll trunk plant. These variations in transmission come mainly from unavoidable causes such as temperature changes. The success of these devices depends on how precisely the trunk is lined up and the manner in which the maintenance adjustments are made. When the nationwide dialing plan with automatic alternate routing is in full swing, maintenance requirements will be more severe because of the material increase in switched business and the number of possible links in tandem, and because operator checks will not be obtained on most calls. Therefore, the maintenance forces will have to keep closer watch on intertoll trunk transmission performance and insure that the necessary adjustments are made in the right places. This article discusses some of the maintenance techniques now used and suggests fields for further study.

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INTRODUCTION

Currently there are over 230,000,000 long distance calls made in the Bell System per month. They range from relatively simple connections involving a single intercity trunk to complex connections involving several intercity trunks in tandem, perhaps totaling 4,000 miles in length. In each case there is a toll connecting trunk at each end. Almost half of this traffic involves distances over 30 miles. The transmission engineer's problem is how to provide uniformly good and dependable transmission so that every one of these calls will be satisfactory to the customers involved. To accomplish this requires among other things that:

1. The design loss of every trunk must be the lowest permissible from the standpoint of echo, singing, crosstalk and noise.
2. The actual loss of every trunk must be kept close to the design loss at all times.

Meeting the first requirement is a matter of system design and circuit layout engineering. The factors involved have been covered in a previous article.[1] Meeting the second requirement is an important function of the maintenance forces and is discussed in this article.

THE PROBLEM OF NET LOSS MAINTENANCE

The transition from manual operation under the "general toll switching plan"[2] to dial operation under the "nationwide dialing plan"[3, 4] is requiring material changes in intertoll trunk design and also in techniques for maintaining these trunks. While precise maintenance is becoming increasingly necessary, it is also becoming more difficult to achieve. There are three important reasons for this.

First, the nationwide dialing plan increases both the possible number of trunks used in tandem for a given call and the variety of the connections in which any particular trunk may be used. This increases the chances of impairment due to deviations from assigned loss in individual trunks since these deviations may combine unfavorably in multi-switched connections. To minimize this, the transmission stability of the individual trunk links must be better than under the old plan.

Second, more and more of the trunks are being put on carrier because

[1] H. R. Huntley, Transmission Design of Intertoll Telephone Trunks, B.S.T.J., Sept. 1953.

[2] H. S. Osborne, A General Switching Plan for Telephone Toll Service, B.S.T.J., July, 1930.

[3] A. B. Clark and H. S. Osborne, Automatic Switching for Nationwide Telephone Service, B.S.T.J., Sept., 1952.

[4] J. J. Pilliod, Fundamental Plans for Toll Telephone Plant, B.S.T.J., Sept. 1952.

it is the best solution to the transmission and economic problems. However, carrier involves many more variable elements and requires higher precision of adjustment than voice-frequency systems need. These increase the difficulty of maintaining trunk losses close to design values on a day-by-day basis.

Third, as operator distance and direct distance dialing grow, there is constantly diminishing opportunity for operators to detect and change unsatisfactory connections or to report unsatisfactory transmission conditions to the appropriate testboards for action.

Thus the maintenance problem is in two parts:

1. How can we reduce departures from design standards even in the face of increasing complexity of plant?

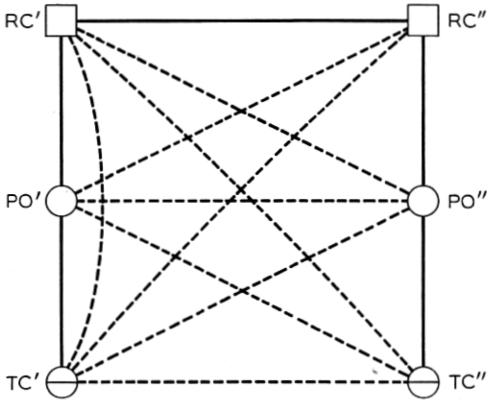
2. What substitute can we find for operator detection of troubles, and can we find even better means of detection?

The ways in which switching plans and the use of carrier reflect upon the problem of trunk net loss maintenance is discussed in more detail in the following sections.

EFFECT OF SWITCHING PLANS

Manual Operation

For many years long distance traffic has been handled on a manual basis under the "general toll switching plan" illustrated in Fig. 1. Between two points indicated by toll centers, TC′ and TC″, it was theoretically possible to get as many as five trunks in tandem. This rarely occurred be-



TC = Toll Center   PO = Primary Outlet   RC = Regional Center

Fig. 1 — General toll switching plan — manual operation.

Thus under dial operation there is a need for better trunk stability. Therefore, a greater burden is placed on the plant forces to locate unsatisfactory trunks so that proper maintenance action can be taken before customers experience difficulty.

EFFECT OF CARRIER OPERATION

Carrier is the principal transmission instrumentality which makes it possible to go ahead with nationwide dialing with assurance that people can talk satisfactorily over the complex connections set up by the switching systems. But it brings with it formidable problems of maintenance. The high attenuation per mile of the line conductors at carrier frequencies increases the number of variable elements as well as the precision with which they must be adjusted. The interrelation between the elements adds to the complication.

Table I illustrates this by giving some figures comparing 100 miles of a voice-frequency cable trunk with 100 miles of a typical trunk on K carrier, which is widely used on cable facilities. The figures apply in both cases to one direction of transmission.

The ten-to-one ratio in the number of electron tubes represents a greater chance of trouble developing in the carrier trunk due to aging or failure of electron tubes. In the carrier trunks there are more automatic adjustable features. For instance, in a typical K2 carrier system there are five flat gain regulators and one twist regulator in one twist section of approximately 100 miles, against a single regulator in a voice-frequency trunk 100 miles long. These regulators are depended upon to keep the loss variations to tolerable amounts. Any malfunction can have a serious effect on trunk loss. Furthermore, they must be adjusted to the desired regulating range and therefore they are points at which maladjustments may be made.

The channels of any one carrier system or of a 12-channel group are commonly routed by the circuit layout engineers to a number of terminal

TABLE I

	V-f Trunk	K2 Carrier Trunk
Total Conductor Loss -db	35	378
Gain Required to Reduce to Via Net Loss -db	31	377.4
Percentage of Line Loss Represented by a 2 db Variation	5.7	0.53
Number of Electron Tubes	3	28
Number of Amplifiers	3	7
Number of Automatic Regulators	1	6

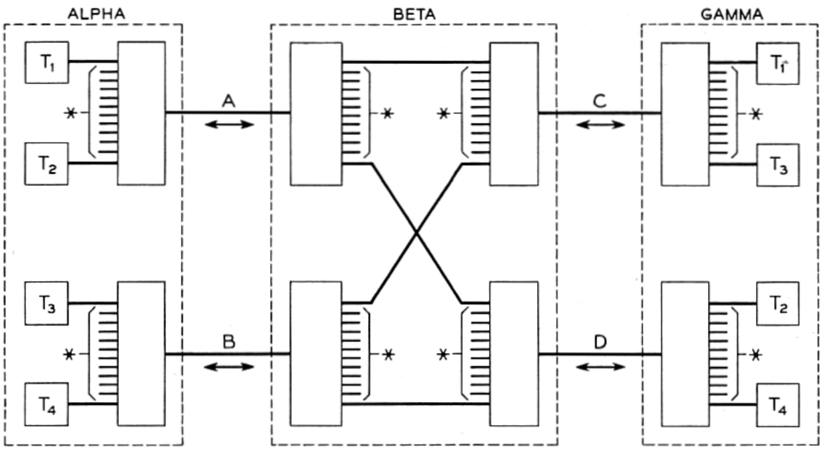


Fig. 3 — Typical carrier channel assignments.

points even though circuit requirements to a given point are sufficient to utilize 12 or more channels. This is done to minimize the chances that all of the trunks between two points will be interrupted by a system failure. A simple case is illustrated by Fig. 3 which shows trunks between Alpha and Gamma connected at an intermediate point, Beta, in such a manner that a failure in any one of the systems A, B, C, or D will affect only half the trunks.

This routing problem, however, complicates the maintenance problem. For example, if trunk T1 were found to have excess loss in the Alpha-Gamma direction it could be corrected by raising the channel gain at Gamma. On the other hand, a correct diagnosis might have disclosed that the trouble was due to a repeater in system A. If this were the case, merely compensating for the excess loss in T1 by changing the channel gain would still leave all other trunks associated with system A in trouble. Later on, if the repeater difficulty were corrected, and no further action were taken, the net loss of T1 would then be too low.

Thus, the flexibility which is so desirable to minimize interruptions of whole circuit groups leads to a difficult problem in the administration of trunk loss adjustment and maintenance. Furthermore, because of the larger numbers and greater dispersion of trunks and terminal points, the situation in the actual telephone plant is much more complex than in the above example. Also, the diagnosis of trouble conditions is made more difficult by the normal variations of channel losses in the carrier systems and consequently of the trunk losses about their design values. This can be better appreciated when some quantitative aspects of the problem are considered.

QUANTITATIVE ASPECTS OF THE PROBLEM

When the nationwide dial switching plan began to take shape some 8 or 10 years ago, intensive study of the transmission maintenance problem was undertaken. The existing situation was examined to determine whether or not the plant would continue to be satisfactory under the changed conditions. This was done by analyzing the results of many thousands of transmission measurements which had been made on a routine basis in toll test rooms all over the Bell System. Both the measured and the assigned losses were available so the differences between them could be derived and analyzed statistically.

Although the distribution of differences expressed in db for an office did not necessarily follow precisely a normal probability law, the distributions were close enough to normal law so that they could be treated as normal. The results were similar throughout the System. The differences within an office were random as also were the means of the differences from office to office. However, the means tended to be biased in the direction of excess loss. The performance of trunks in multi-link connections which would be set up by the switching machines could therefore be estimated with reasonable accuracy. In the statistical analysis of measurements on the group of trunks, the performance was expressed in terms of "distribution grade" and "bias." In telephone transmission maintenance terminology, bias is the algebraic average of the measured transmission departures in db from individual specified net losses for the group of trunks. The distribution grade is the standard deviation of the differences between measured and specified trunk losses about this bias value. The distribution grades found in these studies were about as follows:

For trunks under 500 miles — about 1.8 db.

For longer trunks — about 2.5 db.

Table II illustrates the effects of the distribution grades on connections involving various combinations of these trunk links, assuming that bias can be neglected.

The design loss objective for a 4-link connection, say 1,000 miles long, is about 7 or 8 db (including 2 db of connecting trunk or pad loss at each end). Table II shows that, in an appreciable percentage of the 4-link connections involving the above type of plant, the variations can be expected to exceed the design loss. Variations of this magnitude can result in transmission impairment due to echo, hollowness, singing, crosstalk,

TABLE II

Number of Intertoll Trunks in the Connection	2	4*	6*	8*
Distribution Grade in db	2.5	4.4	5.0	5.6
Per cent of Connections Departing from Average				
±2 db or more	42	65	69	73
±4 db or more	11	36	42	47
±8 db or more	0.2	7	11	15

* Includes two trunks over 500 miles long.

noise or low volume. Furthermore, undesirable contrast may be encountered on successive calls between the same two telephones.

The results of the study as well as experience with the beginning of automatic alternate routing show that the performance of the existing trunk plant must be improved. Three immediate objectives have been set:

1. Reduction of distribution grades to about ½ of the values mentioned above, i.e., about 1.0 db.
2. Maintenance of office bias within ±0.25 db.
3. Removal from service of individual trunks differing widely from their design losses (in the order of 4 or 5 db).

To achieve these objectives requires effort along four lines. First, systems should be designed to have sufficient stability once they are adjusted. This involves the inclusion of stable circuit elements and the provision of automatic regulating devices to compensate for unavoidable transmission variations arising from natural causes. These features have been applied to existing systems within limits imposed by economic considerations and the state of the art. Further extension of these features will be required in the future in order to meet the above objectives.

Second, before a trunk is placed in service, each of its component parts and the over-all trunk should be adjusted to give the correct loss. From the transmission maintenance point of view, it is extremely important for each trunk to start out with all of its adjustments correctly made.

Third, existing and incipient troubles, and deterioration or maladjustment of components, must be detected and corrected by routine maintenance of individual systems used in making up trunks. Such activity must make up for the inability to design systems to have the desired stability.

Fourth, significant departures from trunk design losses must be detected by over-all transmission measurements, and must be corrected before service reactions occur. Such measurements will also be of aid in determining the effectiveness of efforts along the first and third lines.

As discussed earlier, the presence of the operator on every call was of material assistance in the detection of unsatisfactory trunks. On operator or direct distance dailed calls, there will be little or no operator conversation over the intertoll trunk connection. As a substitute, the maintenance forces may need to make more frequent checks of the transmission performance of the trunks unless the stability of individual systems and components of systems can be improved. Manual methods have been used by the maintenance forces in the past to measure trunk losses. Semiautomatic measuring methods have been developed to reduce the time and effort required. In many cases the necessary number of measurements will be economical only when made by automatic devices. One form of such gear is described in a companion paper.[6]

The ability to measure over-all trunk losses simply and frequently is of direct aid in detecting when loss deviations exceed maximum tolerances. Such measurements in themselves, however, are insufficient to detect incipient troubles or to indicate the component part responsible for unsatisfactory transmission. An attempt has been made to achieve these objectives by using statistical analysis of the measured data as an aid to diagnosis. The following sections discuss the application of such analysis.

Use of Transmission Loss Data

It has been shown that considerable variation can be expected in trunk losses even in the absence of trouble conditions. For any given group of trunks selected for analysis, the performance is described by the distribution grade and the bias. If a group of trunks is found to have bias, it is usually an indication of some assignable cause. One such cause might be a change in gain of an amplifier common to the group. Another cause might be improper gain adjustment for channel units of a carrier terminal associated with the group.

If a group of trunks is found to have a greater distribution grade than the distribution grade for all the trunks in the office, this may indicate excessive instability in a component part common to the trunks in the group. If analysis of all the trunks terminating in an office shows a higher distribution grade than is usually found in similar offices, the fault may be due to maintenance routines being inadequately or improperly applied.

[6] H. H. Felder, A. J. Pascarella and H. F. Shoffstall, Automatic Testing of Transmission and Operational Functions of Intertoll Trunks, page 927 of this issue.

Statistical analyses must thus be made of data for small groups as well as for large groups of trunks. Furthermore, the groups which are studied must have elements or factors in common in order for the statistics to have significance. Analyses of periodic measurements of losses for the same trunk or groups of similar trunks can likewise indicate significant changes in performance.

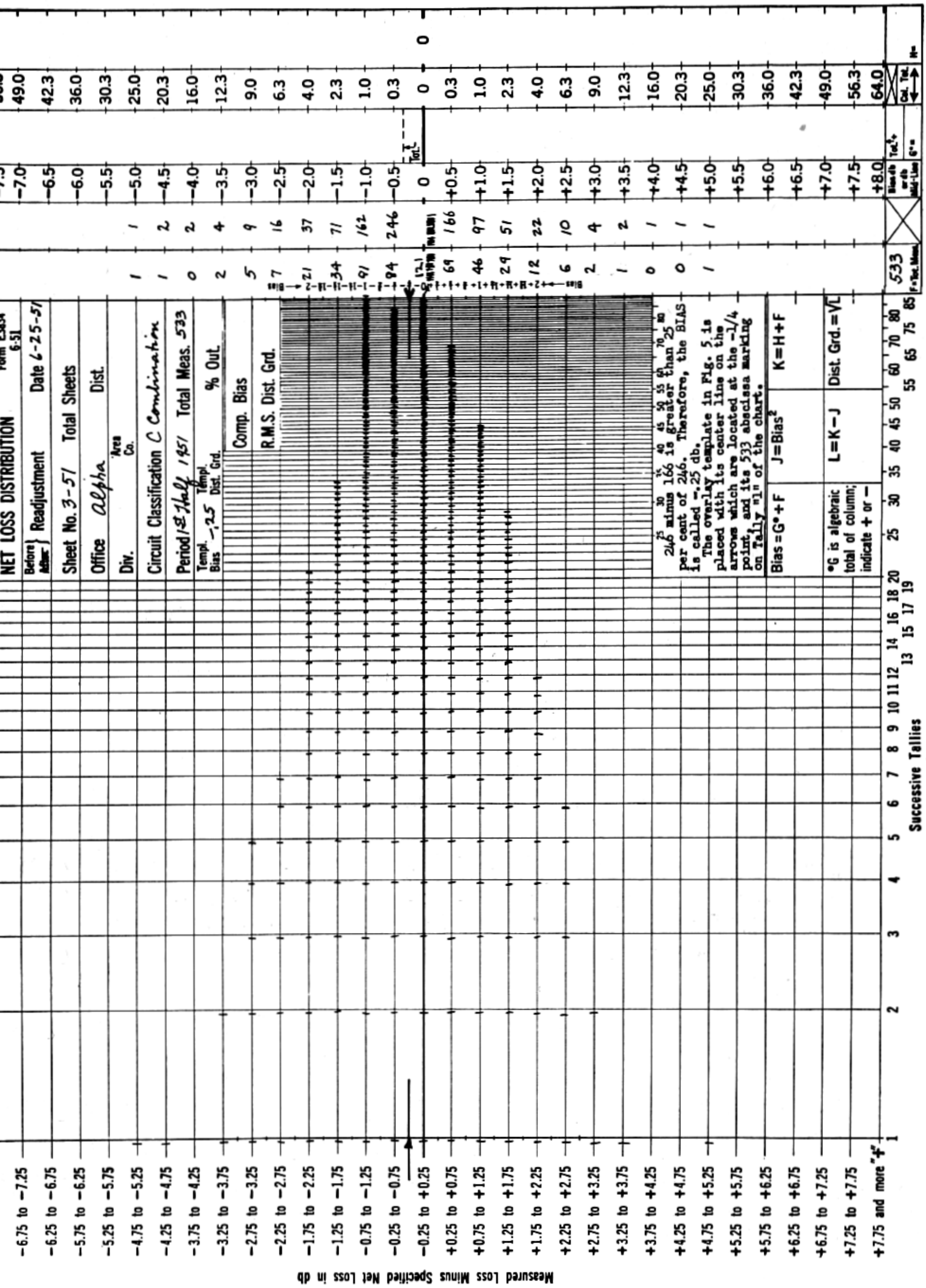
As yet, the problems of properly selecting the trunks to be analyzed and of correlating the results of the analyses with particular system elements needing maintenance attention have been solved only partially. In addition to the need for proper procedures, there is the need for thorough training of maintenance personnel. The complexity of the telephone plant today is increasing the importance of all maintenance personnel having a thorough knowledge of how individual systems function and how the performance of the various system elements reacts upon overall trunk performance.

Procedure for Analyzing Measurements

In an effort to facilitate the application of statistical analysis of trunk performance by plant personnel, a special data sheet and associated templates have been devised. These are shown in Figs. 4, 5, and 6. The method of analysis gives only approximate results but has been found to be sufficiently accurate for reasonably large amounts of data. It is simple, rapid and easily comprehended by the plant personnel. The procedure to be followed consists first of subtracting the specified loss from the measured loss for each of the trunks under study. A stroke is placed on the chart for each of the resulting deviations at the intersection of the appropriate classification and tally lines. For example, the first deviation between -3.25 db and -3.75 db would be stroked on the horizontal line for that band, just to the left of the vertical line for tally 1 (See Fig. 4). The second deviation in that band would be stroked just to the left of the tally 2 line. This is continued until all the deviations have been recorded.

The last stroke in each $\frac{1}{2}$ db band indicates the number of deviations found having values within that band. As shown on Fig. 4, for the analysis by the template method this value is written in the first column, marked "Line Tots. (A)." These values are added and should equal the total number of measurements in the study (533 in the example).

Next, the column "Cum. to $\frac{1}{2}$" is filled out. Beginning at the top line, totals are accumulated to the point where adding the next line total will result in a value exceeding $\frac{1}{2}$ the grand total of measurements (266 in the example). Similarly a value is obtained accumulating the totals from the bottom. In Fig. 4 these values are 246 and 166, respectively.


NET LOSS DISTRIBUTION
Before / After Readjustment
Date 6-25-51
Sheet No. 3-51 Total Sheets
Office Alpha
Div.
Dist.
Area Co.
Circuit Classification C Combination
Period 1st Half 1951
Total Meas. 533
Templ. Bias -.25
Templ. Dist. Grd.
% Out
Comp. Bias
R.M.S. Dist. Grd.
246 minus 166 is greater than 25 per cent of 246. Therefore, the BIAS is called -.25 db.
The overlay template in Fig. 5 is placed with its center line on the arrows which are located at the -1/4 point, and its 533 abscissa marking on Tally "1" of the chart.
Bias = G* + F
J = Bias²
K = H + F
L = K − J
Dist. Grd. = √L
*G is algebraic total of column; indicate + or −
Successive Tallies
Measured Loss Minus Specified Net Loss in db

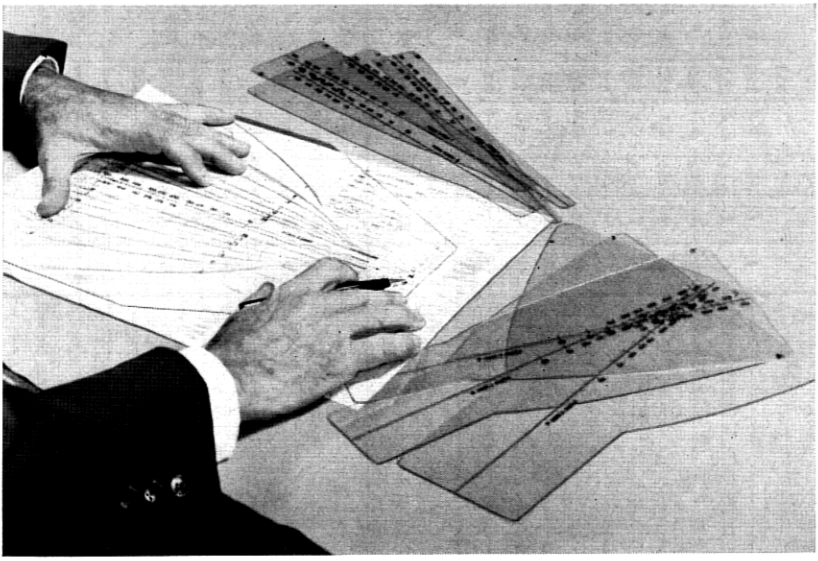
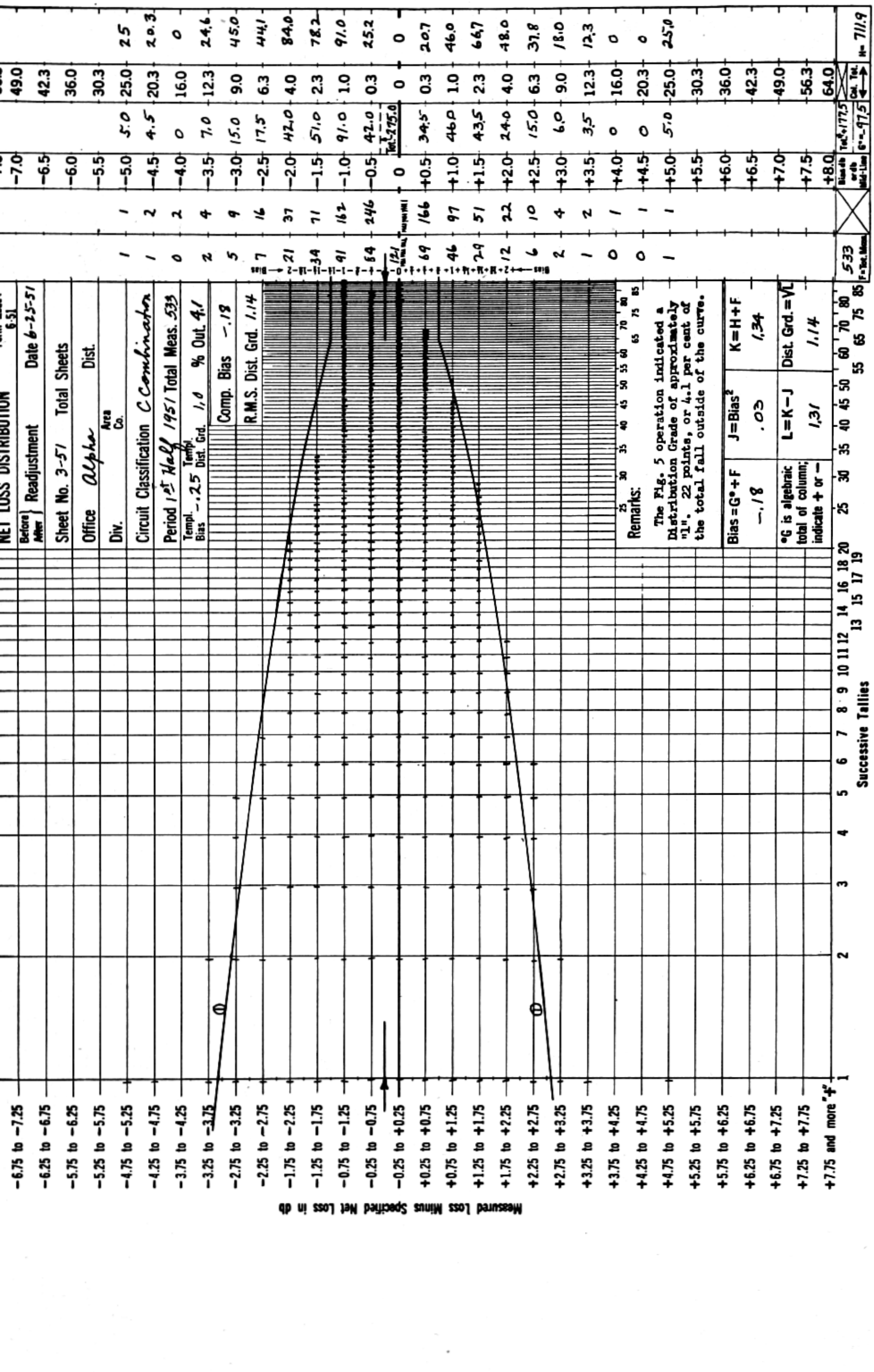


Fig. 5 — Combined template on stroke chart.

By use of this information the approximate bias is determined. The scale of the bias values on the stroke sheet is shown in $\frac{1}{4}$ db steps along the left-hand edge of the "Line Tots. (A)" column, and bias is determined to the nearest $\frac{1}{4}$ db. If the two cumulative totals differ from each other by less than 25 per cent of the larger value, an arrow indicating the bias is placed midway between the two class lines representing these cumulative totals. Its value is read on the bias scale. If the two cumulative totals differ from each other by 25 per cent or more of the larger value, an arrow indicating the bias is placed $\frac{3}{4}$ of the distance between the two class lines representing these cumulative totals and nearer the larger value. In Fig. 4, since 246 minus 166 (80) is greater than 25 per cent of 246 (61.5), the arrow is placed $\frac{3}{4}$ of the way from the line representing 166 toward the line representing 246; i.e., at the $-\frac{1}{4}$ db point on the bias scale. A second arrow is placed at the corresponding point on the tally 1 line.

As shown in Fig. 5, a combined template is then placed over the chart so that the center line of the template coincides with the two arrows. Along the center line of the template there is a scale indicating numbers of measurements from 50 through 700. The template is moved horizontally so that the point on the scale corresponding to the grand total of measurements (533 in the example) is placed on the 1 tally line. Envelope


NET LOSS DISTRIBUTION
Before/After Readjustment Date 6-25-51
Sheet No. 3-51 Total Sheets
Office Alpha Area Co. Dist.
Div.
Circuit Classification C Combination
Period 1st Half 1951 Total Meas. 533
Templ. Bias -.25 Templ. Dist. Grd. 1.0 % Out 4.1
Comp. Bias -.18
R.M.S. Dist. Grd. 1.14
Remarks:
The Fig. 5 operation indicated a Distribution Grade of approximately "1". 22 points, or 4.1 per cent of the total fall outside of the curve.
Bias=G*+F -.18
J=Bias² .03
K=H+F 1.34
L=K−J 1.31
Dist. Grd.=√L 1.14
*G is algebraic total of column; indicate + or −
Successive Tallies
Measured Loss Minus Specified Net Loss in db

curves for distribution grades from 0.38 db to 3 db are shown on the template. The smallest envelope having not over 8 per cent of the grand total of measurements outside of the envelope represents the approximate distribution grade. In the example, this is the 1 db curve, for which 22 points or 4.1 per cent of the total fall outside of the curve. Using a cut-out template corresponding to the distribution grade, a trace is placed on the stroke sheet, as shown on Fig. 6.

In cases where the small number of measurements or the character of the dispersion makes it difficult to fit the data with any of the envelope curves of the template, RMS methods of determining the distribution grade and bias afford a better estimate. In the example on Fig. 6, the bias is thus found to be -0.18 db and the distribution grade is found to be 1.14 db.

When the automatic transmission test and control circuit described in the companion paper is used for measuring net losses, the bias and distribution grade can be determined more quickly and easily. This circuit measures the transmission in terms of deviations from the specified loss and records these by a teletypewriter. In addition, registers indicate the total number of measurements and the number of deviations falling in the ½ db bands shown on the stroke chart. The final strokes for each band can thus be placed on the chart directly without the need for stroking each measurement. From this point on, the analysis and the final tracing of the envelope curve which is selected are the same as in the case illustrated by Fig. 6.

EFFECTIVENESS OF OVER-ALL TRUNK TESTS AND ANALYSES

Simple Layouts

With simple trunk layouts particularly those involving one voice-frequency or carrier link, plant forces have been able to use over-all trunk measurements and analyses as a direct aid in maintenance. Early field trials of the stroke chart method were made at two operating telephone company offices. The testers made up stroke sheets from their routine measurements and interpreted the results to find clues as to what to investigate. Stroke sheets made at successive routine testing periods also showed them what improvements they were obtaining in the operation of the trunks.

Both offices started with distribution grades of about 1.8 db and with biases of about ¾ db. The trunk plant was then given a thorough cleanup and realignment more rigorous than that called for in the maintenance practices at the time. Similar rigorous circuit order tests were followed as circuit order changes were made. Many small troubles were found and cleared. As the result of such rigorous circuit order work and the use of statistical analyses, the distribution grades at the end of the trial were reduced to about 1 db and the biases were brought close to zero.

The maintenance activities were conducted by the regular test forces during normally available maintenance time. Although the initial work involved in cleaning up the trunks necessitated some slippage in the periodic maintenance tests, troubles requiring realignment were eventually reduced to the point where it became possible to carry on the periodic testing work concurrently with the more rigorous circuit order work.

Complex Layouts

During the field trial of the automatic transmission test and control circuit discussed in a companion paper, there was an opportunity for studying transmission data taken on intertoll trunks of greater length and complexity of layout. These trunks were composed of two or more carrier links and connected Washington, D.C. to several outlying points; namely, Atlanta, Georgia; Boston, Massachusetts; Hempstead, New York; New York, New York; Oakland, California; and Richmond, Virginia. A total of 231 trunks were in the groups. When the trial began, without preliminary rigorous circuit order work on the trunks involved, the distribution grade was 2.26 db and the bias was +0.35 db. Maintenance investigation was initiated only when trunks were found to have departed more than a prescribed amount from their specified net losses. Initially this value was 4 db and later it was reduced to 3.5 db.

As many of these wide deviations were investigated and corrected as available manpower permitted. The layouts were so complex, however, that it was found impracticable to give prompt attention to all of them; and in many cases it was impossible to check carrier systems that were suspected of being the source of some of the deviations. At the end of the trial the distribution grade had been reduced from the original 2.26 db to a range of about 1.8 to 2 db. The bias had not been changed significantly from the original +0.35 db.

These results indicated very little improvement from the limited readjustments found practicable during the tests. Analysis of the test results has shown that transmission maintenance methods must be improved in some respects. An example of this was a case where the data indicated several trunks to be affected by excessive variation from some common cause. This was traced to a group pilot being out of limits. If routine maintenance methods had indicated this difficulty earlier, the amount of time in which service could have been affected by these trunks would have been reduced. This is important because of the difficulty of finding evidence of common trouble sources, with complex layouts.

The scope of the trial was then limited to a smaller group of intertoll trunks which could be given close attention. The 42 trunk group between Washington, D.C., and Atlanta, Ga., was selected and these trunks were put through rigorous circuit order tests and adjustments approaching the completeness of initial line-up tests. A test cycle composed of transmission loss measurements made on the 42 trunks in both directions was performed four times daily for a period of about five months. During the period covered by this phase of the trial, adjustments were made only as indicated by carrier pilot variations, by deviations from specified net loss large enough to operate the limit feature of the automatic transmission test and control circuit, or with other trouble clearance.

The tests for each day were analyzed as a group. On the first day the distribution grade of the deviations from specified net loss for the group was 0.8 db and the bias was +0.5 db. On the last day the distribution grade was 1.2 db and the bias was −0.25 db. For the entire group of measurements (584 test cycles), the distribution grade of the deviations was 1.26 db and the bias was −0.08 db. This represented a substantial improvement over the results obtained in the first phase of the trial. It showed that a great deal can be accomplished by improving the circuit order procedures and increasing the thoroughness with which they are carried out.

It was found that combination carrier trunks composed of permanently connected links, thus not having the benefit of control by terminal-to-terminal pilots, have more variability than individual trunks having over-all pilots. Adjustment of such combination trunks requires coordinated action at the various pilot terminals through which the trunk passes, in order that readjustment of the over-all trunk loss can be made at the point in the system responsible for the deviation. In the case of many route junctions, the complexity of the layout makes it difficult to coordinate the necessary measurements at several points so that the proper point for adjustment can be determined.

NEED FOR EDUCATION

The complexity of carrier system layout as indicated above, has imposed a difficult task on the plant transmission maintenance forces. Although our present transmission maintenance practices seem to be adequate for systems in simple layouts, some expansion appears needed for the more complex layouts. This will require further study.

It is important to keep in mind, however, that the provision of good practices and training of personnel in following the detailed steps therein are not in themselves sufficient to assure good transmission maintenance. There is an additional need for *education* of plant personnel in fundamental considerations affecting operation of carrier systems. This must include over-all objectives, inherent capabilities and limitations, and the interrelation of functions of the many basic blocks comprising carrier systems. Personnel so educated can approach the problems of transmission maintenance with understanding and avoid the maladjustments and troubles due to "man-failure" which are potential hazards in any complex systems.

SUMMARY AND CONCLUSIONS

In summary, the problem of maintaining satisfactory transmission over trunks under distance dialing involves, primarily:

1. Improving the over-all trunk net loss stability so that the distribution grade does not exceed 1 db, as an initial objective.
2. Reducing trunk loss bias for individual offices to less than ±0.25 db.
3. Removing from operation those trunks having excessive loss deviations before unfavorable service reactions occur.

To do these things in the face of the increasing complexity of our plant and the absence of operator surveillance will require that:

1. Individual systems have adequate short term stability to keep day-to-day variations small.
2. Routine tests and adjustments be made on individual systems and components to correct for long-term deterioration.
3. Frequent over-all trunk tests be made to locate trunks whose performance is beyond acceptable limits and, as a quality control measure, to monitor the performance of the trunk plant.
4. Trunk trouble-shooting be performed on a well coordinated basis to locate and correct the source of trouble. (Compensating maladjustments must be avoided.)

Although facilities are available and methods are known for doing some of these things, considerable effort is required as follows:

1. Study of performance of individual systems to determine capabilities of present design and major sources contributing to over-all trunk instability.
2. Study of transmission maintenance procedures, both routine and trouble-shooting, to determine the proper test intervals and how best the procedures can be carried out on a coordinated basis.
3. Development of improvements in systems and test facilities as indicated by the above studies. Convenience is an important factor in test arrangements.
4. Thorough education of personnel in the over-all make-up, function and interrelation of systems within the trunk plant, and in the significance of transmission maintenance in providing uniformly good and dependable transmission.