Physical and Transmission Characteristics of Customer Loop Plant

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This report covers the principal physical and transmission characteristics of the Bell System customer loop plant. Items covered include a statistical characterization of physical composition, measured and calculated transmission characteristics, and measured noise and crosstalk performance. A survey conducted in 1964 provided the data base for this report and comparisons of data obtained from a similar survey in 1960 illustrate that, in many respects the composition of loop plant changes only slowly with time. Consequently, the 1964 survey results are believed to be representative of today's plant.

The types of analyses presented in this paper are of increasing interest to certain Bell System customers because of the increasing number and types of services provided over local telephone facilities.

I. INTRODUCTION

This report covers the principal results of the 1964 Bell System customer loop survey. This survey provides a statistical characterization of physical composition, measured and calculated transmission characteristics, and measured noise and crosstalk performance of customer loop plant. Comparisons of data obtained from the 1964 survey and a similar survey made in 1960 are also presented.

Several of the principal transmission characteristics of Bell System customer loop plant as defined by the 1960 loop survey were published in 1962 by R. G. Hinderliter.[1] Additional published data on the transmission characteristics of Bell System toll connections is available in a BSTJ article by I. Nåsell.[2]

The 1964 Bell System survey was comprised of two separate surveys which were merged for analysis and presentation purposes. The basic survey was the general loop survey which consisted of a simple random sample of 1,100 main stations selected from the population of all main stations (45, 300, 000) as of January 1, 1964. However, since only 3.25 percent of all main stations are served by loops longer than 30 kilofeet, only 35 samples would have been obtained to define the characteristics of the longer loops. Consequently, a long loop survey consisting of a random sample of 955 main stations served by loops longer than 30 kilofeet was obtained. The data obtained from the long loop survey has been used in those instances where characteristics are being expressed as a function of length to permit better resolution of the characteristics for the longer loops. In both of these sub-surveys, official telephones, foreign exchange lines, dial teletypewriter exchange (TWX) lines and special service lines were omitted as it was felt that their design would not be representative of customer loop plant.

II. SUMMARY OF RESULTS

Analyses of data obtained in the 1964 loop surveys lead to six general results.

(*i*) The average customer loop length is 10.6 kilofeet with only 10 percent of the main stations located beyond 21 kilofeet from their serving office. The length distributions show a slight trend toward longer loops between 1960 and 1964, with the average loop length increasing by 300 feet.

(*ii*) The average 1 kHz insertion loss of Bell System loop plant is 3.8 dB and 95 percent of all main stations are served by loops having a 1 kHz loss of less than 8 dB. At 3 kHz, the average loss is 7.8 dB and 95 percent of the main stations have less than 17 dB insertion loss.

(*iii*) The average noise balance of party-line loops is 56 dB, while the balance for individual line loops is 69 dB. Only 5 percent of the individual line loops have a noise balance of less than 50 dB while nearly 20 percent of party-line customers are served by loops with less than 50 dB of balance. The substantially lower balance for party lines is largely due to the inherent circuit unbalancing effect caused by the use of grounded ringers for party-line service.

(*iv*) The average metallic circuit noise (C-message weighted) at a customer's station set is approximately 5.5 dBrnc including the noise contribution of the central office wiring as well the noise contribution of the outside plant facilities. Only 8 percent of the individual lines have noise in excess of the Bell System objective of 20 dBrnc. However, 18 percent of the party-line customers have circuits which have noise in excess of 20 dBrnc because of the generally poorer circuit balance of party-line circuits.

(*v*) Comparison of measured and calculated transmission characteristics of Bell System loop plant has demonstrated that the outside plant cable records are sufficiently accurate to permit characterizing the loop plant transmission performance by theoretical calculations based on the physical composition of the loops as described in the outside plant records.

(*vi*) Main stations served by loops in excess of 30 kilofeet in length were found to be exponentially distributed as a function of working length, with the population of main stations reduced by 50 percent with every 11-kilofoot increase in loop length (see Fig. 6). It is estimated that 1.5 million Bell System customers (3.25 percent of all customers) are presently served by loops in excess of 30 kilofeet in length. Due to the party-line character of longer loops, the 3.25 percent of all Bell System main stations included in the long loop segment of plant used only 1.7 percent of the working Bell System exchange lines.

III. DESIGN OF THE SURVEY

The first steps in the survey were to define the population to be sampled and to obtain a complete list of the sampling units. In these two surveys (that is general loop and long loop), main stations were selected as the sampling units and all Bell System main stations as of January 1, 1964, were taken as the population to be sampled. A simple random sample was chosen as the sampling plan.

The sample size of the general loop survey was selected to provide data of equal precision to that obtained in the 1960 survey. The design parameter chosen was the average distance to the sampled main stations, and the precision was measured in terms of the width of the confidence interval bounding this average distance. The desired confidence interval (at 90 percent confidence level) of ± 450 feet on the average cable distance to the sampled main stations dictated a sample size of 1,100 randomly selected main stations. The actual confidence interval obtained was ± 476 feet.

In the long loop survey, lack of previous knowledge concerning the composition of long loops made it difficult to accurately determine the minimum sample size which would provide sufficient precision. The design parameter selected for the long loop survey was the average noise metallic (C-message weighting) measured at the telephone sets of the sampled main stations to a dialed-up termination. The precision aimed for was a ± 1.0 dB confidence interval (at 90 percent confidence level). A sample size of 955 main stations was collected, and the confidence interval obtained was ± 0.73 dB.

The two surveys had satisfactorily wide geographical dispersion, with every associated company (except Canada) contributing to the survey. Reference to Fig. 1 will illustrate that the large companies and the metropolitan areas contributed heavily to the general loop survey and the rural areas contributed heavily to the long loop survey.

IV. LOOP SURVEY RESULTS—PHYSICAL COMPOSITION

Data obtained in the loop survey included detailed loop schematics indicating the loop composition of each of the loops sampled in the survey. All distributions of physical quantities discussed herein were derived by analysis of these loop schematics. Since similar data were obtained in the 1960 loop survey, comparison of the physical distributions obtained in the two surveys has also been made.

Table I gives a summary of the statistics for the principal physical properties of loop plant. Data are included for both the 1960 and 1964 surveys and significance levels for differences of mean values are presented when meaningful. Cumulative distributions of these factors are shown in Figs. 2 through 5. The distribution of working bridged tap is not given since 82 percent of the sampled main stations were served by loops having zero working bridged tap and consequently the distribution is not particularly enlightening.

As indicated in Table I, the estimated average route distance from serving central office to main station in the Bell System is 10.6 kilofeet with 90 percent confidence that the true mean value lies within ±476 feet of this estimate. Note that although the estimated mean working length in 1964 is over 300 feet longer than that estimated in 1960, it is not statistically possible to claim that the observed increase is indeed

TABLE I — 1964 CUSTOMER LOOP SURVEY SUMMARY OF MAIN STATION CHARACTERISTICS

Main Station Quantity	Mean (ft)		90% Confidence Limits on Mean (± ft)		Sign. Level for Difference of Means in Percent
	1960	1964	1960	1964	
Working length	10,288	10,613	450	476	*
Total bridged tap	2,619	2,478	169	172	*
Working bridged tap	381	228	107	74	95
Airline distance	7,604	7,758	353	386	*
Working length/ airline distance	1.45	1.50	0.02	0.03	98

Drop wire excluded except when individual lengths exceed 400 feet.
* Levels of significance less than 80 percent indicated by asterisk.

an increase. Reference to the cumulative distribution of working length depicted in Fig. 3 will, however, show that shifts in the distribution have occurred since 1960. Note that the percentage of longer loops increased from 1960 to 1964.

Analysis of the long loop survey data has shown that the Bell System main stations served by loops in excess of 30 kilofeet are exponentially distributed as a function of working length as depicted in Fig. 6, with the main station population diminishing by 50 percent with each 11 kilofeet increase in loop length. Survey analysis indicates that about 1.5 million or 3.25 percent (with 90 percent confidence interval of ± 0.2 percent) of all Bell System main stations were located 30 kilofeet or more from their serving central offices as of the end of 1964. Due to the party-line character of the longer loops, the 3.25 percent of all Bell System main stations included in the long loop segment of plant used only 1.7 percent of the 39,300,000 Bell System lines working in 1964.

Analysis of the survey data has also provided valuable insight into the type-of-service distribution of Bell System customers and the physical composition of the plant provided to meet this distribution as shown in Figs. 7 to 10. The type-of-service distribution was derived as a function of length to the sampled main station and took advantage of the pooling of data from the two surveys. To evaluate the physical composition (type of facility, gauge, and pair size) of the loop plant as a function of distance, the sampled loops from the general loop survey were inspected at intervals of 1,000 feet starting at the central office. Both the general loop survey and the long loop survey were similarly inspected to define these distributions beyond 30 kilofeet.

The extent of party-line development as a function of loop length is shown in Fig. 7. Note the rapid increase in eight-party development for loop lengths greater than 30 kilofeet. Examination of the pair size distribution as a function of distance from the central office (Fig. 8) shows rapidly decreasing pair size with distance (at the 50-kilofoot point 50 percent of the sampled loops are contained in cables with fewer than 16 pairs). Similarly, the distribution of gauge shown in Fig. 9 illustrates a rapid transition to coarse gauge with increasing distance from the central office. For example, at 30 kilofeet 60 percent of the sampled loops are composed of gauges coarser than 22 gauge. Note also (Fig. 10) that the longer loops are primarily developed with aerial facilities. For example, 78 percent of all plant is aerial at the 30-kilofoot point from the central office. For the longer loops where small pair sizes are used, the pole line costs become a significant portion of the total loop costs and this factor is one of the reasons for the present trend towards the use of buried plant. Since the sampled loops were randomly selected from all existing plant, buried plant is not as prominent as it would be in a sample of new construction. Note, however, that beyond 30 kilofeet, buried facilities in 1964 accounted for approximately 20 percent of the loops.

V. 1964 LOOP SURVEY RESULTS—TRANSMISSION PERFORMANCE

Data obtained in the 1964 loop survey have provided considerably more comprehensive knowledge of the transmission performance of customer loop plant than heretofore available. In the 1960 loop survey all transmission performance data were developed by deriving equivalent "T" networks from the information supplied on the loop sketches and analyzing these networks for transmission performance at nine frequencies in the voice band. Similar analysis has been performed for each of the sampled loops in the 1964 loop surveys, and in addition transmission measurements were made. The measurements covered noise, crosstalk, insertion loss at 1, 2 and 3 kHz, and dc resistance. The combination of these two sets of transmission performance data (one calculated and one measured) permits three types of analysis:

(*i*) changes in transmission performance since 1960 by comparison of calculated 1960 data with calculated 1964 data,

(*ii*) comparison of measured versus calculated data for the 1964 survey, and

(*iii*) provision of heretofore unavailable data on the noise and crosstalk performance of customer loop plant.

Since measured insertion loss data was not obtained in the 1960 survey, comparison of 1960 and 1964 data must be based on calculated values. Figure 11 depicts the 1 kHz calculated distributions for both surveys. It can be seen that insertion loss performance has remained virtually unchanged since 1960.

For those transmission characteristics where measured data are available in addition to the analytically derived data, minor differences in performance are exhibited by the two distributions of data (Fig. 12). In this regard it is important to realize that the measured data should provide a more accurate estimate of performance. There are several reasons for greater confidence in the measured data. First, possible inaccuracies in cable records or errors in transferring data from the records to the loop sketches can introduce errors in the calculated data. Second, errors in construction, such as omission or improper connection of loading coils, cannot be detected from the records. Third, use of calculated data assumes that all cables exhibit nominal characteristics and consequently do not reflect manufacturing tolerances and environmental factors.

The cumulative distributions of insertion loss at 1, 2, and 3 kHz for customer loop plant as derived from both measured and calculated data are presented in Fig. 12. These insertion loss measurements and calculations were made with a 900 ohm source and load as depicted in Fig. 13. Measured loss was found to be consistently higher than calculated loss across the entire voice frequency band. The absolute differences between measured and calculated losses are small however, as indicated by the differences in mean losses. For example, at 1 kHz the measured loss was 3.8 dB and the calculated loss was 3.5 dB. This comparison of measured and calculated insertion losses demonstrates the feasibility of characterizing the loop plant transmission performance by theoretical calculations based on the physical composition of the loops as described by outside plant records. Still referring to Fig. 12, note that approximately 95 percent of all Bell System main stations are served by loops having a 1 kHz insertion loss of less than 8 dB with a mean loss of 3.8 dB. Similarly, at 3 kHz the 95 percent point is 16 dB and the mean loss is 7.8 dB. A scatter diagram of the 1 kHz measured insertion loss as a function of loop length is shown in Fig. 14. This diagram was obtained by merging the data from both the general loop survey and the long loop survey and indicates that the high loss loops are not limited to the long loop category. The high losses observed on some of the short loops generally reflect excessive bridged tap.

An insertion loss measurement of particular interest to designers of data equipment is the slope of loss versus frequency from 1000 to 2750 Hz. Cumulative distributions of the 2750 − 1000 Hz insertion loss (insertion loss measured with 900 ohm source and load) have been provided for all Bell System loop plant and for those loops serving business customers in Figs. 15 and 16 respectively.

Another important transmission characteristic is return loss, significant from echo and singing considerations. Return loss performance was not available from the measured data; consequently, it was calculated. Table II provides 1964 loop survey return loss results for nine frequencies and Fig. 17 presents the cumulative distributions and histograms for the 3 kHz singing return loss and echo return loss (equal weighting of the 500 to 2,500 Hz band). These data are all developed on the basis of looking into the customer loop at the central office end of the loop. The return loss is obtained by matching against a 900 ohm, 2.16 μF termination at the central office, with the customer end of the

TABLE II — CALCULATED RETURN LOSS FROM OFFICE TOWARD STATION*

	1964	
Frequency (Hz)	Mean (dB)	90% Confidence Interval (± dB)
200	8.0	0.11
300	10.2	0.12
500	13.4	0.17
1,000	15.4	0.30
1,500	13.1	0.27
2,000	10.9	0.25
2,500	9.1	0.20
3,000	7.7	0.16
3,200	7.1	0.15
Echo	11.2	0.15

* Station end of loop terminated in impedance of "off-hook" station set.

loop terminated in the impedance of the "off-hook" station set. Similar data on return loss are presented later from the station end of the loop.

The comparison of measured versus calculated loop resistance shown in Fig. 18 indicates that for general loop plant there is no significant difference between measured and calculated data but calculated loop resistance is slightly higher than measured resistance (574 ohms calculated, 567 ohms measured). Measured values may have been influenced by the fact that measurements were made during the winter. Calculated resistances were based on an average temperature of 68°F.

Theoretical calculations cannot be made of all transmission performance characteristics. Two such examples are noise and crosstalk. Since these characteristics are dependent upon external influences (induction from adjacent power lines, cable pair balance and the particular pair assignment), field measurements were made on each of the sampled loops using a Western Electric Company model 3A noise measuring set. The noise and crosstalk measurements were made as depicted in Figs. 19 and 20.

It is convenient to analyze loop noise in terms of the two factors which contribute to the resultant interference. The first of these is the magnitude of open circuit longitudinal voltage induced from power lines and the second is the circuit balance of the cable pairs and central office equipment. The cumulative distribution of the open circuit longitudinal voltage for general loop plant is shown in Fig. 21 for 3 kHz flat weighting. This voltage is induced in a longitudinal mode, and consequently only that portion of it which is converted to the metallic circuit will create an interference problem. The circuit balance reflects the extent to which the longitudinal voltage is converted to metallic voltage and is, therefore, a measure of the susceptibility of the telephone plant to inductive interference such as power-line hum.*

As seen in Fig. 22 party lines are much more susceptible to power-line hum than individual lines because of the unbalance introduced by the grounded ringers associated with party-line station sets. On the average, individual lines have approximately 12 dB better balance than party lines. Part of this is a result of the shorter length distribution of individual lines which offers less opportunity for cable pair unbalances to accumulate; but it is reasonable to expect a balance improvement of 10 dB with ringers isolated from ground.

The combination of the induced longitudinal voltage and the circuit unbalance produces the metallic noise distribution at customers' station sets (in off-hook state) as shown in Figs. 23 and 24. For comparison purposes, the C-message weighted noise to ground (longitudinal noise) is also shown on these figures. Figure 23 depicts the noise contribution of the loop plant only, while Fig. 24 includes the noise contribution of the central office wiring. In both cases the station end of the loop was terminated in an off-hook 500-type station set with the transmitter and receiver replaced by equivalent resistors. The metallic noise has been measured with C-message weighting to reflect the relative interfering effects of the noise on voice transmission. The important limits to consider are the Bell System long-term noise performance objective of 20 dBrnc and the immediate remedial action limit of 30 dBrnc. As seen in Fig. 24, only 8 percent of the individual lines had total metallic noise in excess of 20 dBrnc. However, 18 percent of the party-line customers have noise in excess of 20 dBrnc.

The near-end crosstalk coupling loss characteristics of customer loop plant as derived from measured data from the general loop survey are shown on Fig. 25. Along with the overall distribution of crosstalk coupling loss is shown the distribution for nonloaded loops only (84 percent of all sampled main stations). The nonloaded loop distribution

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* Loop circuit noise balance is defined here as

$$20 \log_{10} \frac{\text{open circuit longitudinal voltage}}{\text{metallic voltage}}$$

where both voltages are measured with C-message weighting. The validity of this definition depends on the assumption that the longitudinal voltage induced from adjacent power lines is the only source of metallic noise. This is generally not true when the noise to ground measures less than 20 dBrnc, and consequently loop balance for such loops cannot be computed from the measurements.

can be approximated by a normal distribution with a mean crosstalk coupling loss of 115 dB and a standard deviation of 12 dB. A comparison of these two curves indicates that the poorer crosstalk performance of longer loaded loops dominates the low loss tail of the general loop survey distribution.

The final transmission characteristic to be discussed is the loop input impedance as calculated both at the central office and at the station set. Figure 26 presents the plot of loop input impedance as seen at the central office as a function of frequency (not including central office wiring or equipment). For these calculations the station end of the loop was terminated in an off-hook 500-type station subset with the transmitter and receiver replaced by equivalent resistors. Curves have been provided separately for loaded and nonloaded loops because of the large difference in their characteristic impedance. Also shown is the characteristic impedance of the central office matching network as a function of frequency. The function of this network is to provide high return loss performance across the voice frequency band by matching as close as possible the impedance of the various loops. It is apparent that both the nonloaded loops and loaded loops should have their highest return losses around 1 kilohertz and that the loaded loops should perform more poorly than nonloaded loops at the lower frequencies.

Plots of mean input impedances, such as in Fig. 26, are useful for indicating the general input impedance behavior as a function of frequency. Variations that occur at each frequency, and their effects on return loss, are best shown as scatter diagrams. Figures 27 and 28 present the loop input impedance at 1 kHz for nonloaded and loaded loops. Superimposed on all scatter diagrams are return loss circles referenced to the 900 ohm and 2.16 μF matching network. Any loop having an impedance lying within a particular circle will have a return loss, when measured against the specified matching network impedance, which exceeds the given return loss value. Visual examination of the scatter pattern as it relates to the return loss circles provides a ready means of evaluating the return loss performance of various segments of the loop plant (assuming, of course, that the input impedances of loops in that segment are known).

The range and shape of the input impedance scatter pattern at each frequency are of interest because they point up the difficulty of designing a simple matching network which, at even a single frequency, will provide very high return losses for nearly all loops. Considering the characteristics of the nonloaded loops shown in Figure 27 it is evident that many of the loops tend to follow a smooth curve, while the others are scattered about this curve. The smooth curve results from the variation in loop length, while the scatter is due to the effects of bridged tap, overgauging, and variations in types of subsets.

Perhaps of particular interest to Bell System customers are the input impedance characteristics of Bell System loop plant as seen from the station end of the customer loop. The input impedance of a customer loop as measured at the station set can vary considerably based on the type of facility connected to the loop at the central office. Various circuit connections may involve use of four-wire trunks, two-wire trunks or intraoffice circuits. In the following analysis a 900 ohm and 2.16 μF central office termination has been used to represent a four-wire trunk termination, and the midsection input impedance of 22 gauge H88 loaded cable has been used to represent a two-wire trunk. For the simulation of intraoffice calls, a Monte Carlo technique was used to select a random sample of 500 pairs of loops from the 1,100 loops in the general loop survey. A loop was randomly selected as the sample loop, and then the input impedance (from the central office) of another randomly selected loop was chosen for the central office termination.

The 1,100 loops of the 1964 general loop survey were segregated into two groups (loaded and nonloaded loops) for all but the simulated intraoffice calls because of the great differences in impedance range of the two populations. Presentation of scatter diagrams of input impedance from the station set has been limited to 1 and 3 kHz. These return loss circles were generated assuming the use of a 500-type station set and it was further assumed that the 500 set was operating on a current equal to the average loop current of 45.5 mA.

Figures 29 through 32 are the input impedance scatter diagrams for loops with a simulated two-wire trunk (22 gauge H88 loaded cable) termination at the central office. The scatter is primarily a result of overgauging, open wire, and bridged tap or varied end section length. Smoothed curves of the mean input impedances of loaded and nonloaded loops with a 22 gauge H88 cable termination are presented in Fig. 33. Scatter diagrams for the loops with a central office termination of 900 ohms and 2.16 μF (simulated four-wire trunk) are presented in Figs. 34 through 37. The general input impedance behavior of these loops as a function of frequency is indicated in Fig. 38 by the plot of the mean input impedances at nine voiceband frequencies.

The scatter diagrams and the mean input impedance curve for the simulated intraoffice calls are shown in Figs. 39 and 40. The effect of connecting together two loops, one of which is terminated by a station set, and the other whose input impedance is calculated at its station set, is shown by the mean input impedance curve for simulated intra-office connections in Fig. 41. This curve has a shape characteristic of longer nonloaded loops. The mean input impedance curves for non-loaded loops with simulated two- and four-wire trunk terminations at the central office are also shown in Fig. 41. The major differences in the characteristics of these curves are at the low frequencies where the shunt capacitance of the cable masks the termination less than it does at high frequencies.

VI. ACKNOWLEDGMENTS

The author wishes to acknowledge the collaboration of Mr. F. L. Schwartz in the design and execution of this Bell System customer loop survey and his analysis of noise and crosstalk characteristics of loop plant. I also want to thank Mrs. A. F. Rogers for the substantial programming assistance required in the analysis of the data obtained in this study and Mr. D. B. Menist and Mrs. B. J. Hymanson for their contributions on the input impedance characteristics of loop plant.

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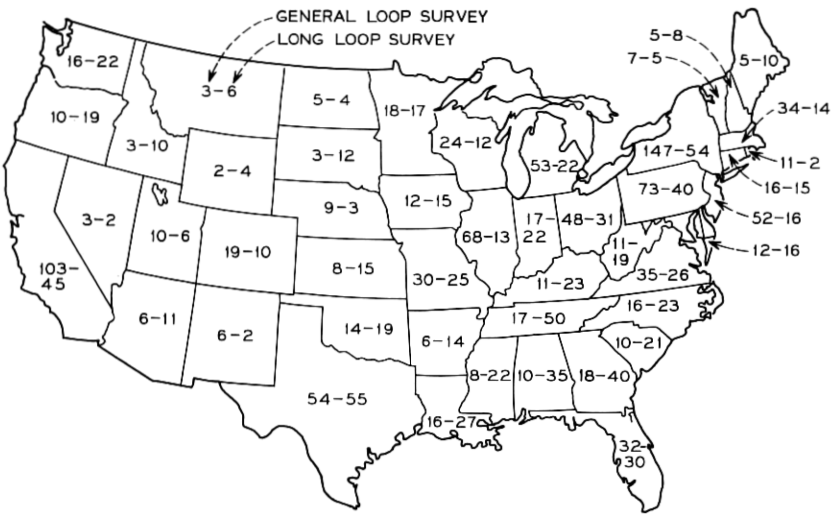

Fig. 1 — Geographic distribution of sampled loops for the 1964 customer loop survey. Eleven hundred loops were sampled for the general loop survey and 955 loops were sampled for the long loop survey.

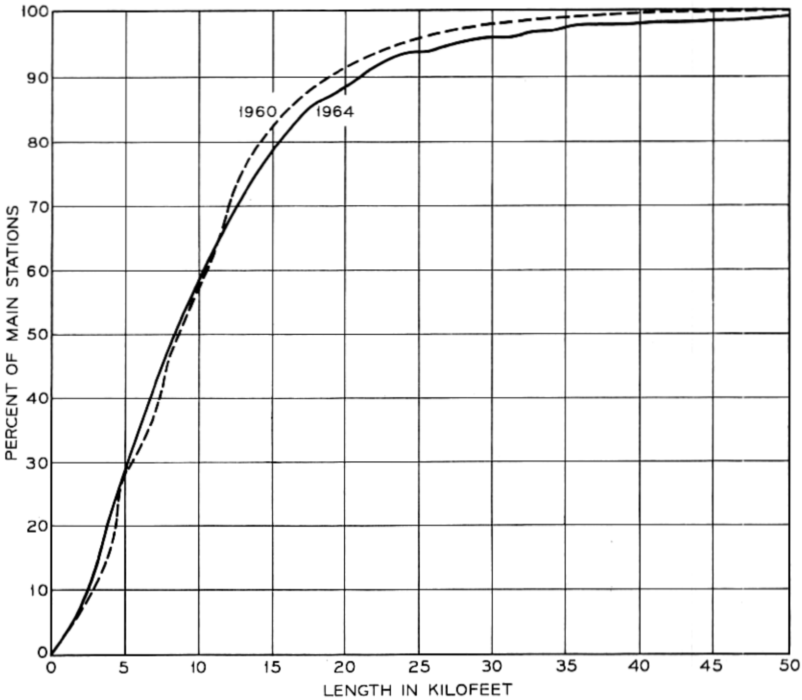

Fig. 2 — Working length to the main station.

	1960	1964
Mean (feet)	10,288	10,613
90 percent confidence limits on mean (feet)	±450	±476

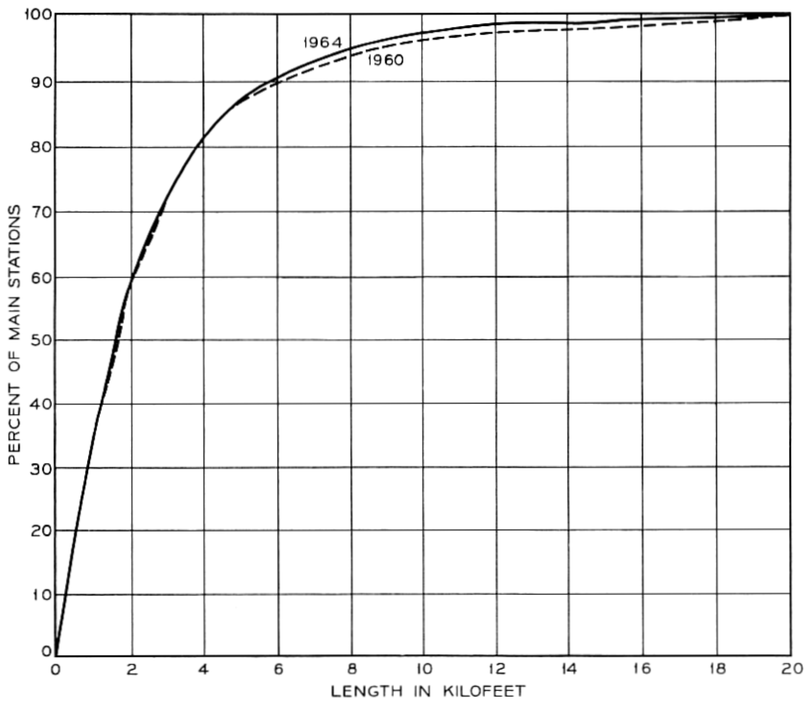

Fig. 3 — Total bridged tap.

	1960	1964
Mean (feet)	2,619	2,478
90 percent confidence limits on mean (feet)	±169	±172

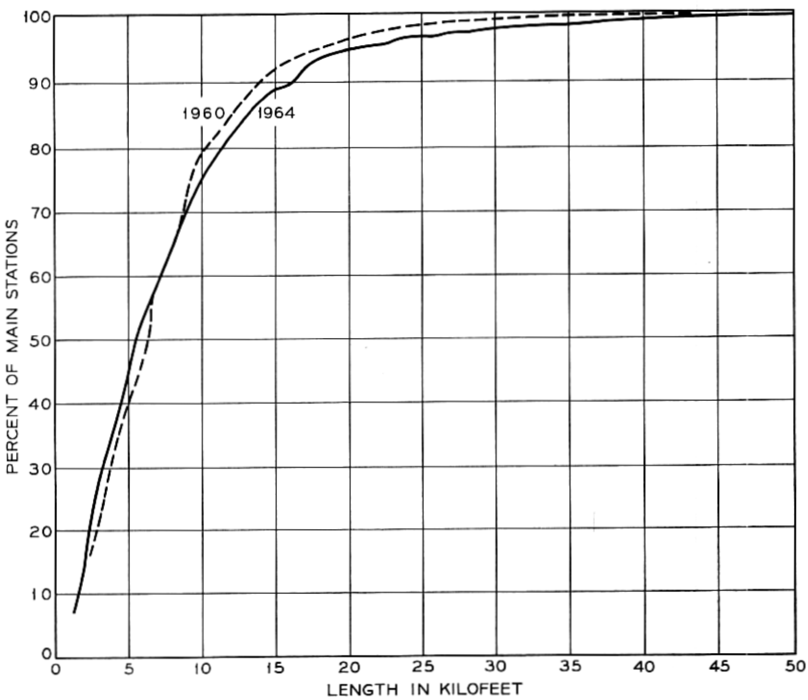

Fig. 4 — Airline distance to main station.

	1960	1964
Mean (feet)	7,604	7,758
90 percent confidence limits on mean (feet)	±353	±386

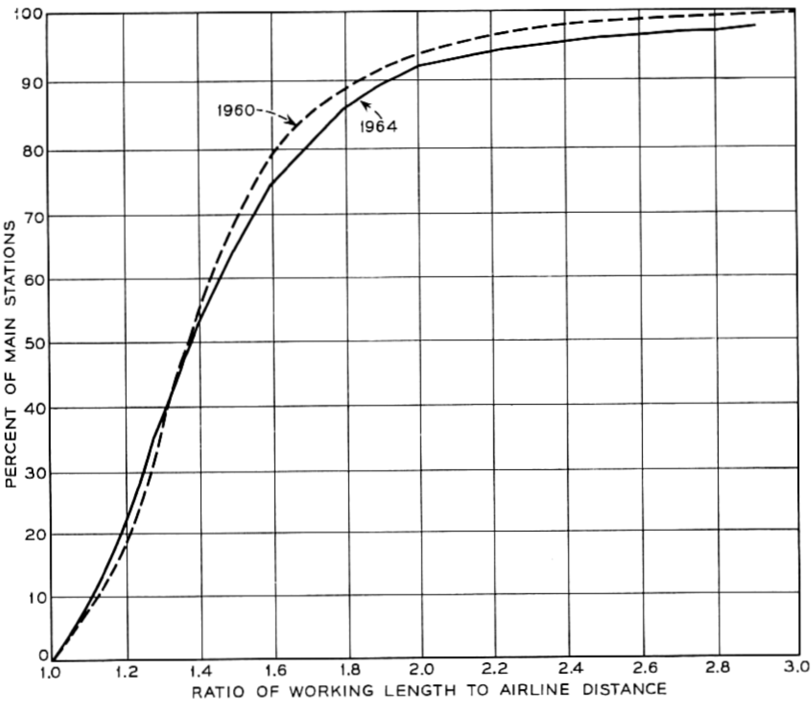

Fig. 5 — Ratio of working length-airline distance to main station.

	1960	1964
Mean	1.45	1.50
90 percent confidence limits on mean	±0.02	±0.03

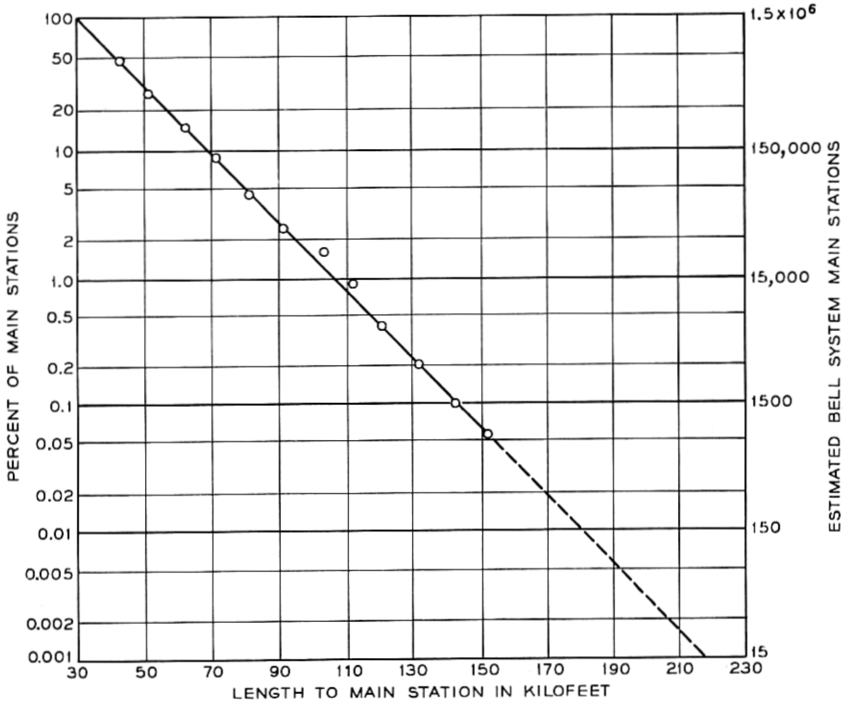

Fig. 6 — Distribution of long loops (1964 long loop survey). The mean was 45,938 feet; 90 percent confidence limits on the mean was ±870 feet.

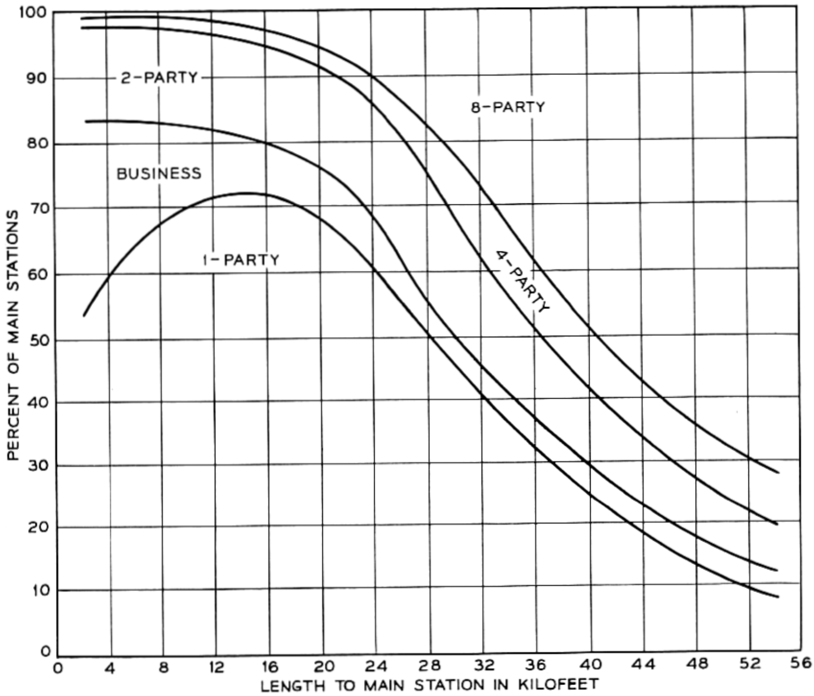

Fig. 7 — Type of service distribution versus loop length (1964 combined loop surveys). One-, two-, four-, and eight-party plots include residence service only; business includes PBX, centrex, and coin.

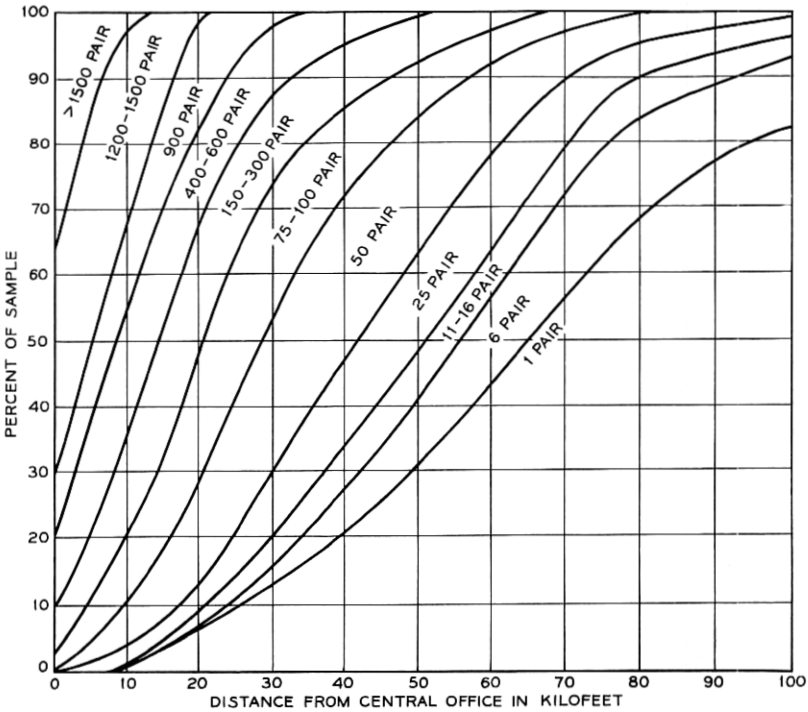

Fig. 8 — Pair size distribution (1964 combined loop surveys—general loop and long loop surveys).

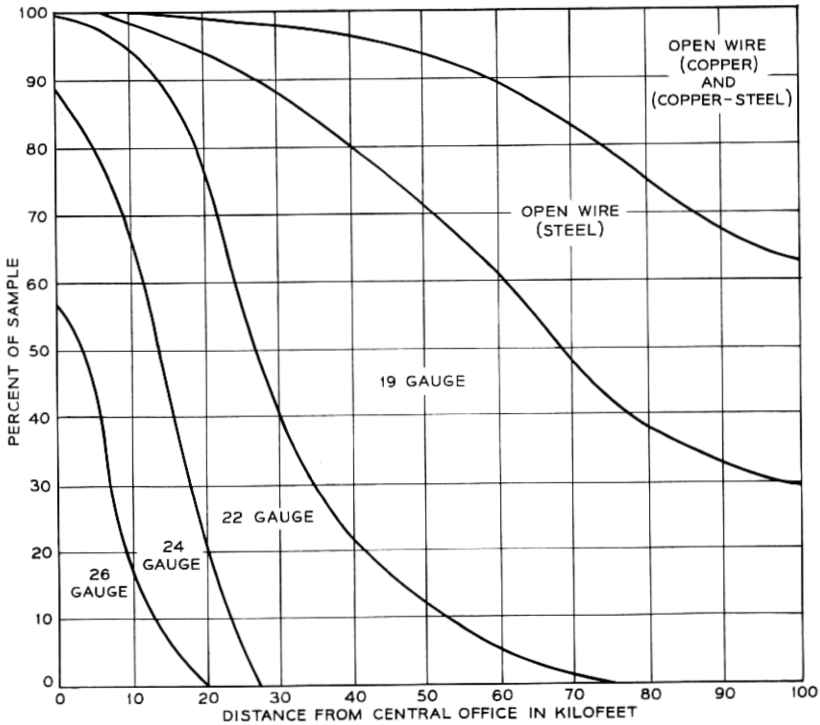

Fig. 9. — Gauge distribution (1964 combined loop surveys—general loop and long loop surveys).

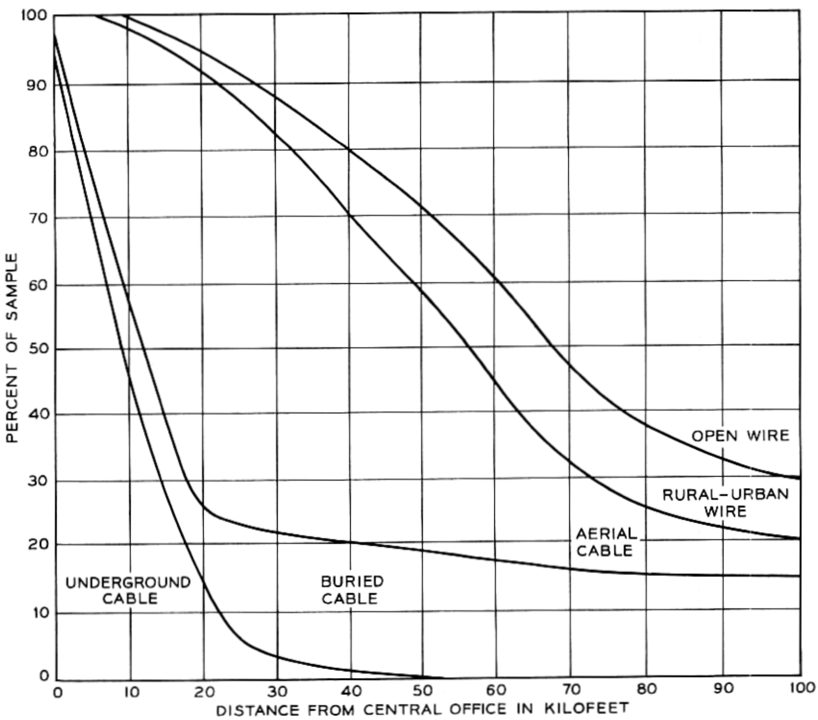

Fig. 10 — Type of construction distribution (1964 combined loop surveys—general loop and long loop surveys).

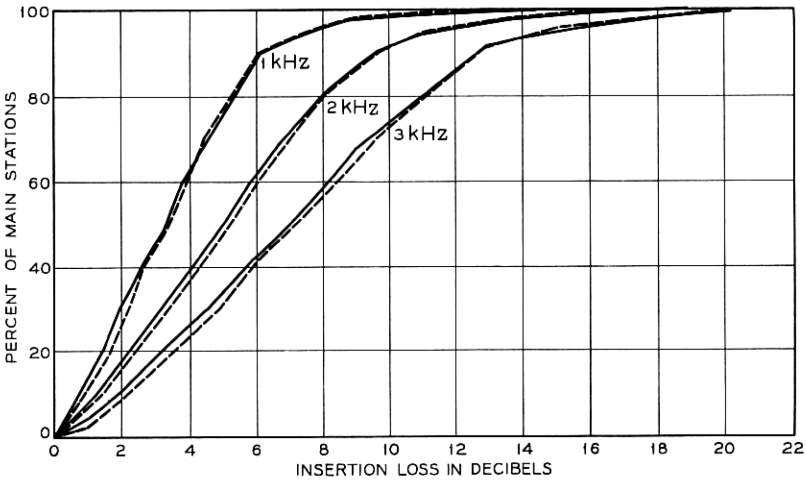

Fig. 11 — Distribution of calculated insertion losses at 1, 2, and 3 kHz (- - - 1960; ——— 1964).

	1 kHz		2 kHz		3 kHz	
	1960	1964	1960	1964	1960	1964
Mean (dB)	3.4	3.5	5.4	5.3	7.4	7.3
90 percent confidence limit on mean (dB)	±0.11	±0.10	±0.18	±0.16	±0.24	±0.21

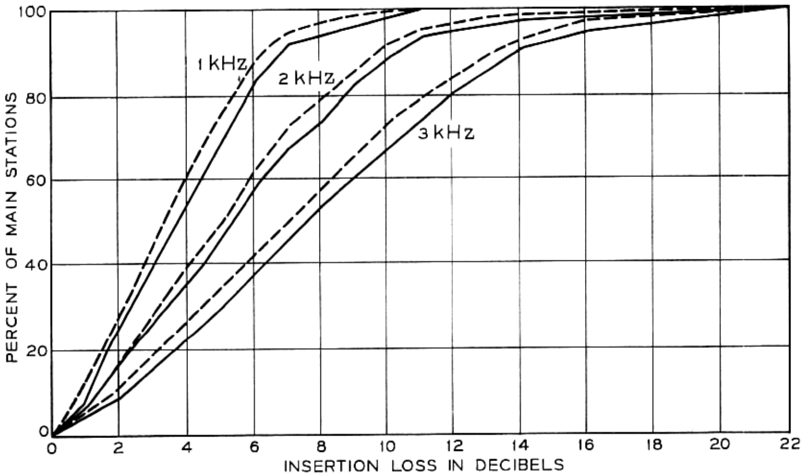

Fig. 12 — Distribution of measured and calculated insertion losses at 1, 2, and 3 kHz (– – – – calculated; ——— measured).

	1 kHz		2 kHz		3 kHz	
	Measured	Calculated	Measured	Calculated	Measured	Calculated
Mean (dB)	3.8	3.5	5.6	5.3	7.8	7.3
90 percent confidence limit on mean (dB)	±0.12	±0.10	±0.17	±0.16	±0.22	±0.21

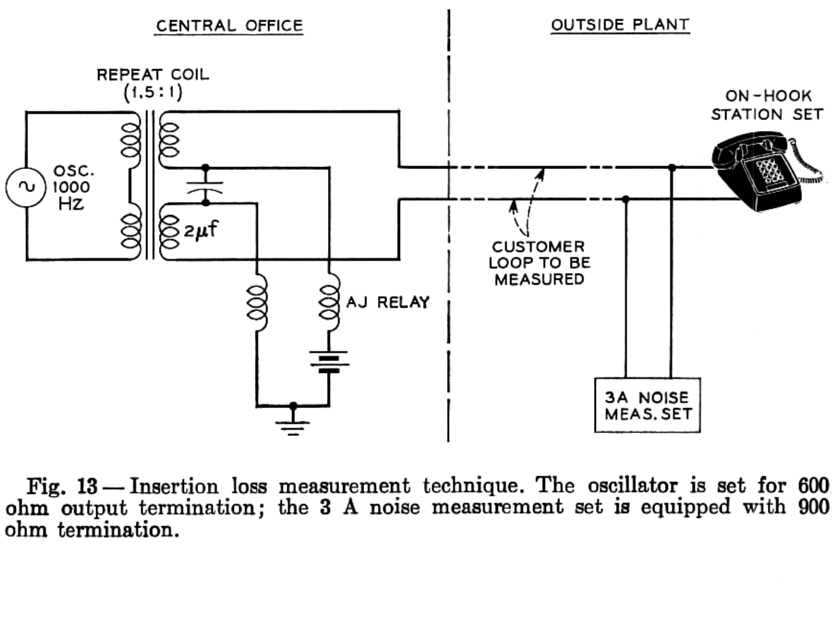

Fig. 13 — Insertion loss measurement technique. The oscillator is set for 600 ohm output termination; the 3 A noise measurement set is equipped with 900 ohm termination.

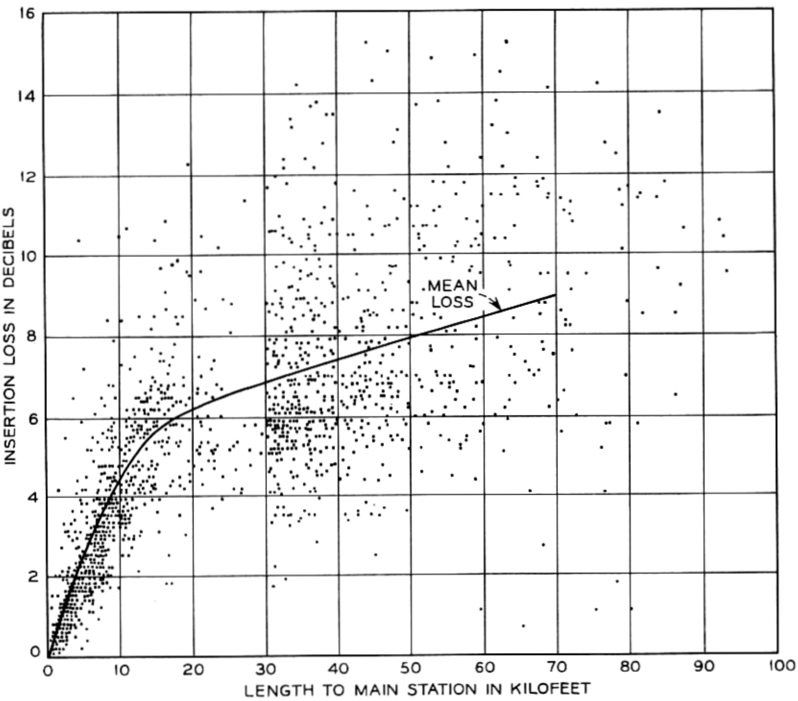

Fig. 14 — Measured 1 kHz insertion loss scatter diagram (1964 combined loop surveys—general loop and long loop surveys).

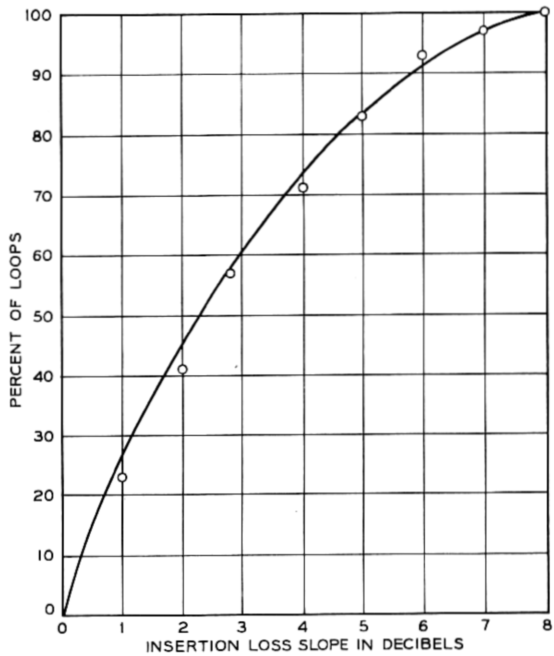

Fig. 15 — Distribution of insertion loss slope between 2750 and 1000 Hz for residential plus business loops.

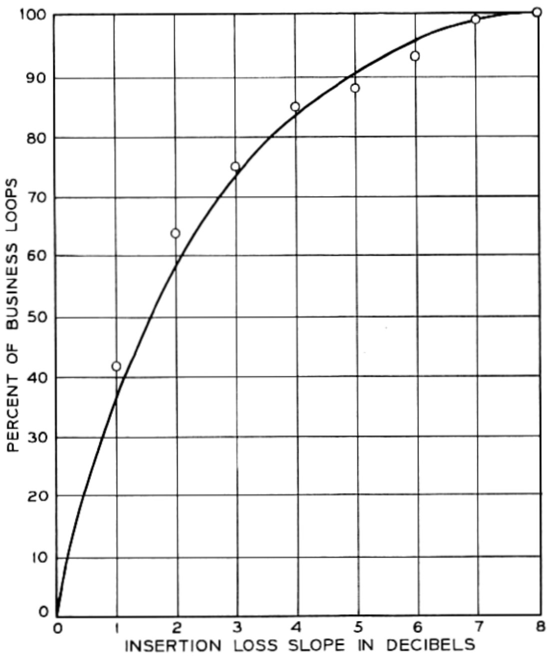

Fig. 16 — Distribution of insertion loss slope between 2750 and 1000 Hz for business loops only.

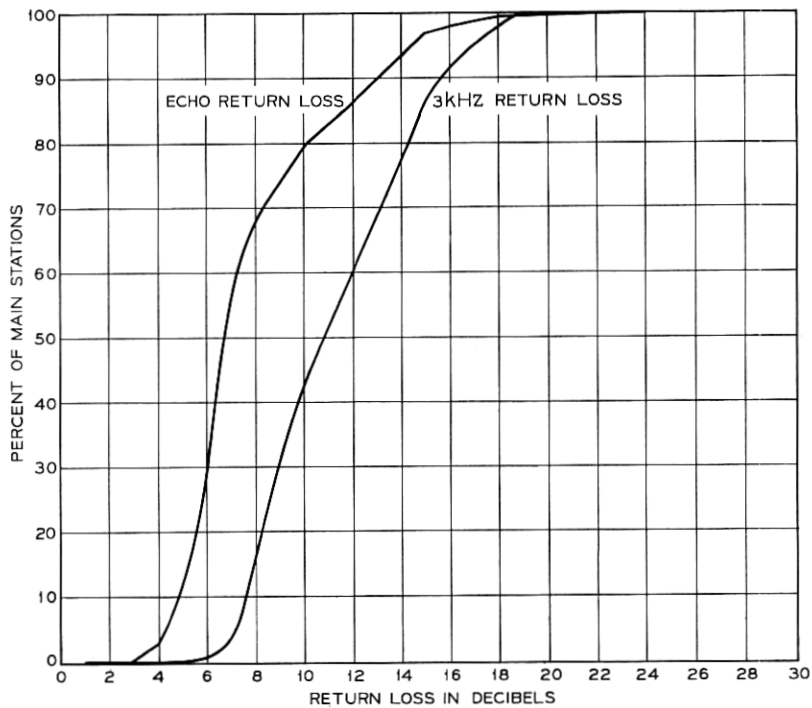

Fig. 17 — Distribution of 3 kHz and echo return losses at central office. Echo return loss distribution assumes flat weighting of 500–2500 Hz band.

	Echo	3 kHz
Mean (dB)	7.7	11.2
90 percent confidence limits on mean (dB)	±0.16	±0.15

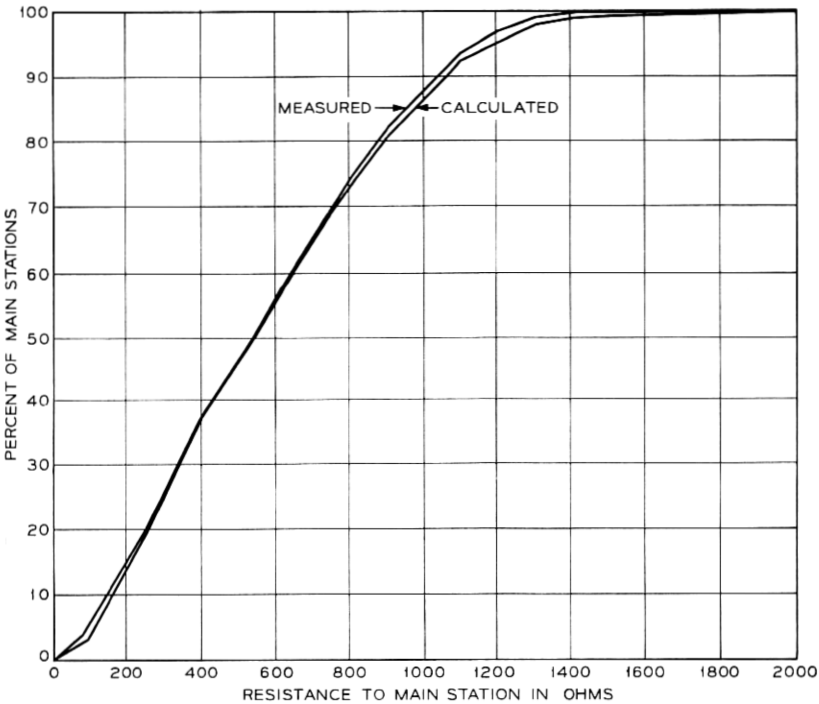

Fig. 18 — Measured and calculated distribution of resistance to main station.

	Measured	Calculated
Mean (ohms)	567	574
90 percent confidence limits on mean	±15.8	±17.0

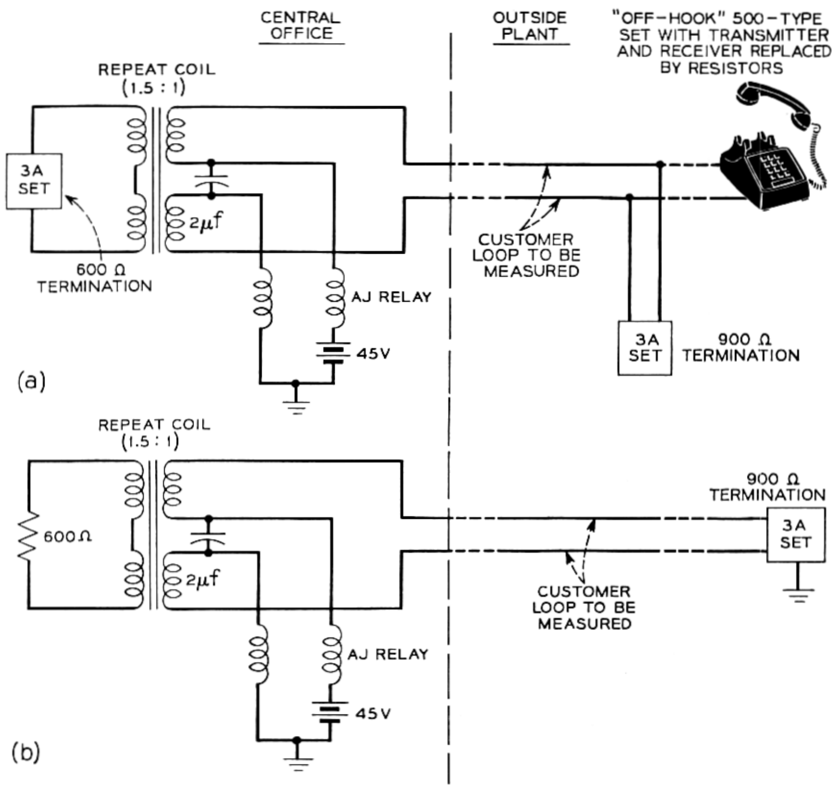

Fig. 19 — Noise measurement technique for (a) noise metallic—loop only and (b) noise longitudinal—loop only.

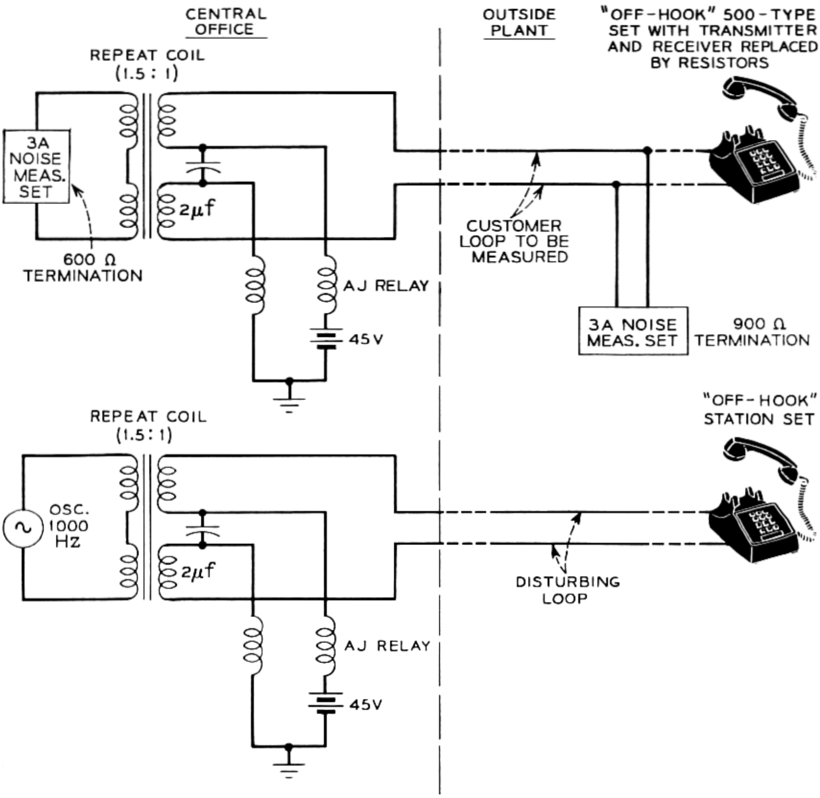

Fig. 20 — Crosstalk measurement technique. Disturbing loop—randomly selected pair in the same 100-pair group as the sample loop on which the measurements are being made. The oscillator on disturbing loop is set for 600-ohm output termination.

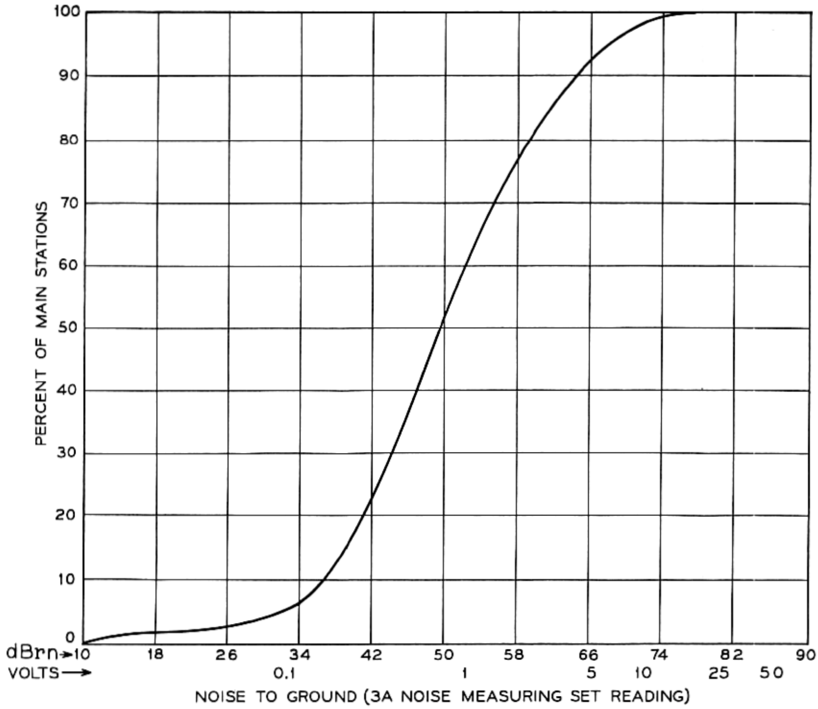

Fig. 21 — Noise to ground at main station for 3 kHz flat weighting. The mean was 49.2 dBrn; the 90 percent confidence limits on the mean was ±0.56 dBrn.

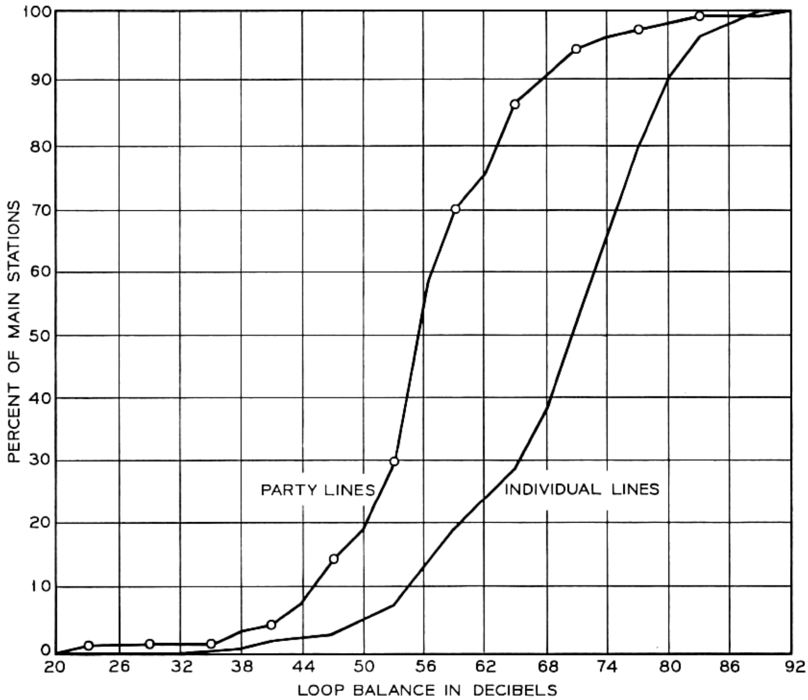

Fig. 22 — Loop circuit noise balance. These distributions are based on the 476 loops where measurements permitted an accurate estimate of loop balance to be made. These are for loops having noise to ground greater than 20 dBrnc.

	Party	Individual
Mean (dB)	56.1	68.7
90 percent confidence limits on mean (dB)	±1.55	±0.87

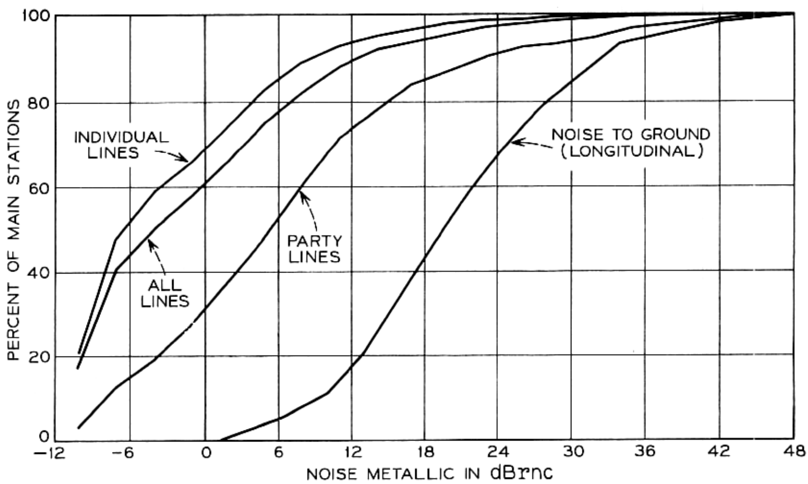

Fig. 23 — Noise metallic at main station with C-message weighting for loop plant only.

	Noise to Ground	Noise Metallic		
		All	Individual	Party
Mean (dBrnc)	19.1	−1.1	−3.1	6.7
90 percent confidence limits on mean (Bdrnc)	±0.5	±0.5	±0.5	±1.3

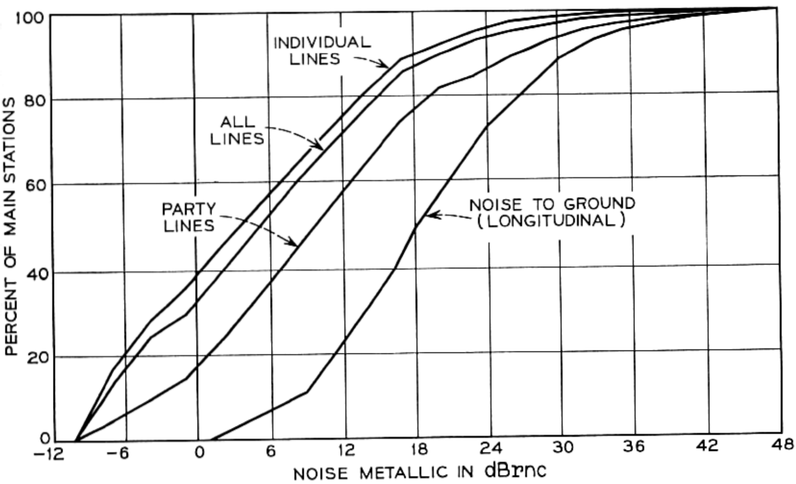

Fig. 24 — Noise metallic at main station with C-message weighting for loop plant plus central office.

	Noise to Ground	Noise Metallic		
		All	Individual	Party
Mean (dBrnc)	19.1	5.6	4.3	10.6
90 percent confidence limits on mean (dBrnc)	±0.5	±0.5	±0.6	±1.2

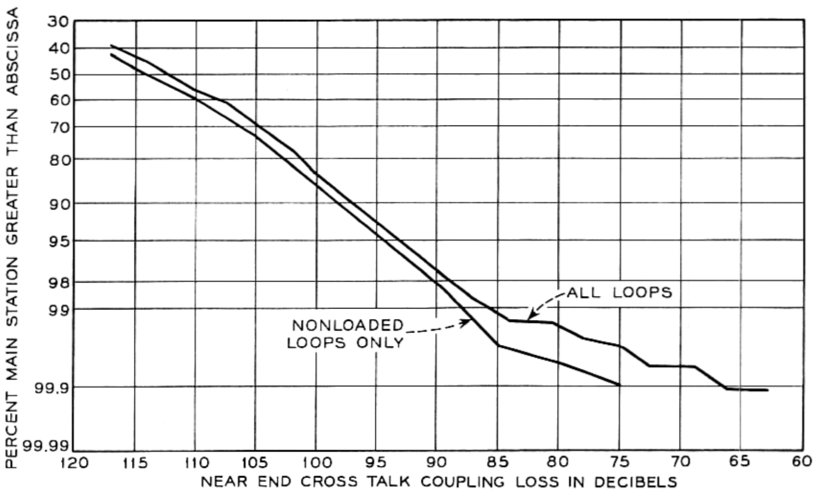

Fig. 25 — 1 kHz near end crosstalk coupling loss at central office. Central office terminated in 900 ohms; customer end terminated in receiver off hook station set.

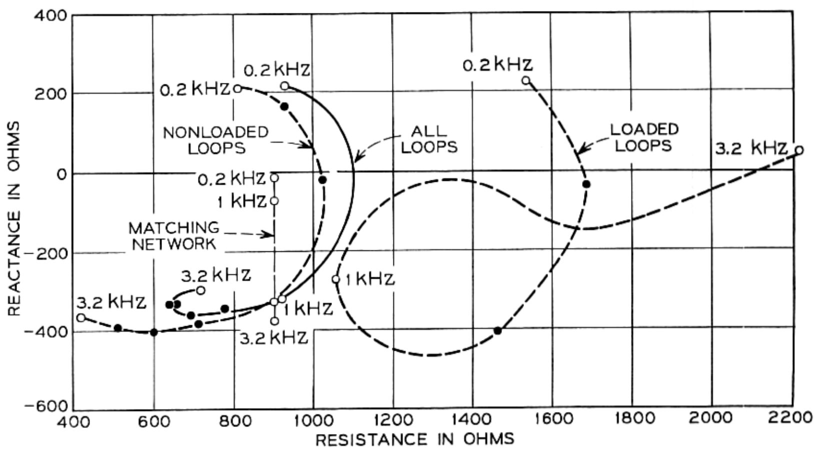

Fig. 26 — Loop impedance at central office.

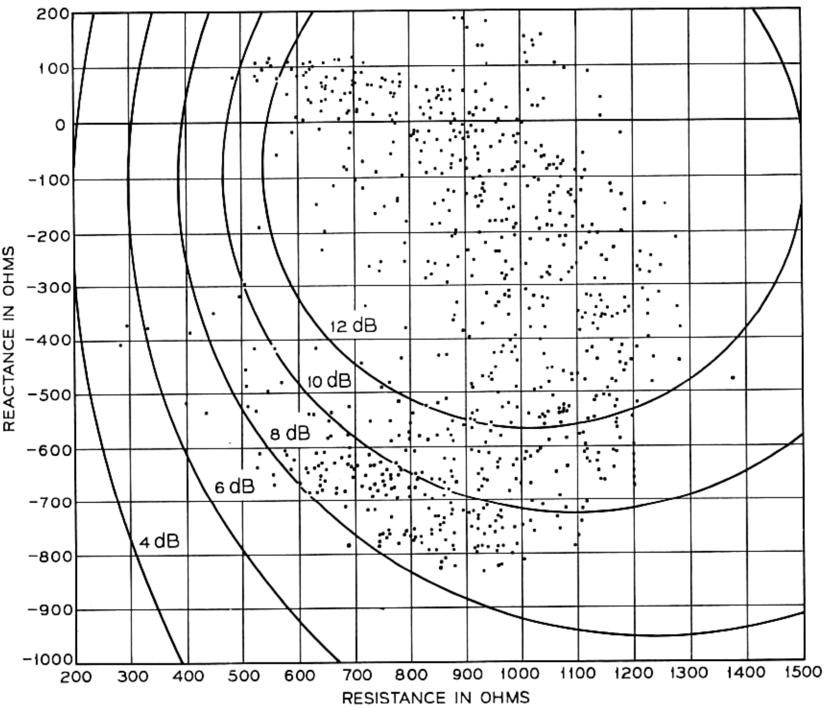

Fig. 27 — Nonloaded loop input impedances at 1 kHz measured from the central office. Return loss circles based on 900 ohm + 2 μF network.

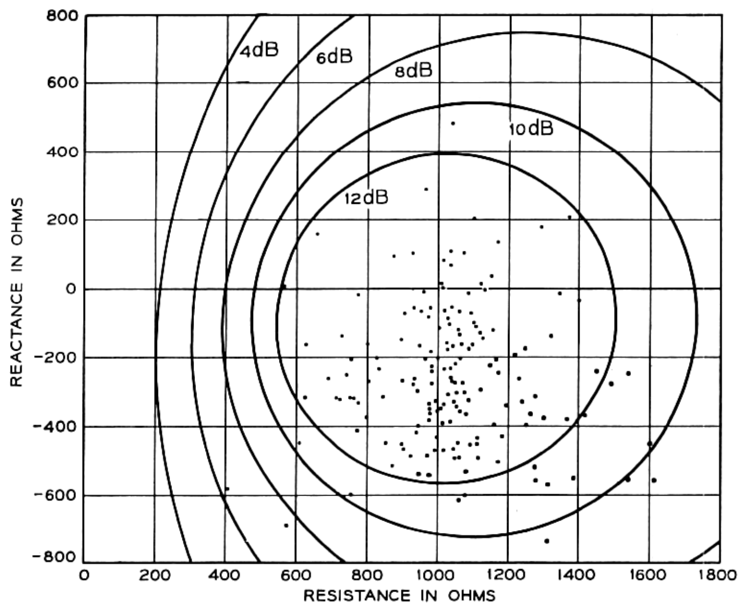

Fig. 28 — Loaded loop input impedances at 1 kHz as measured from the central office. Return loss circles based on 900 ohms + 2 μF network.

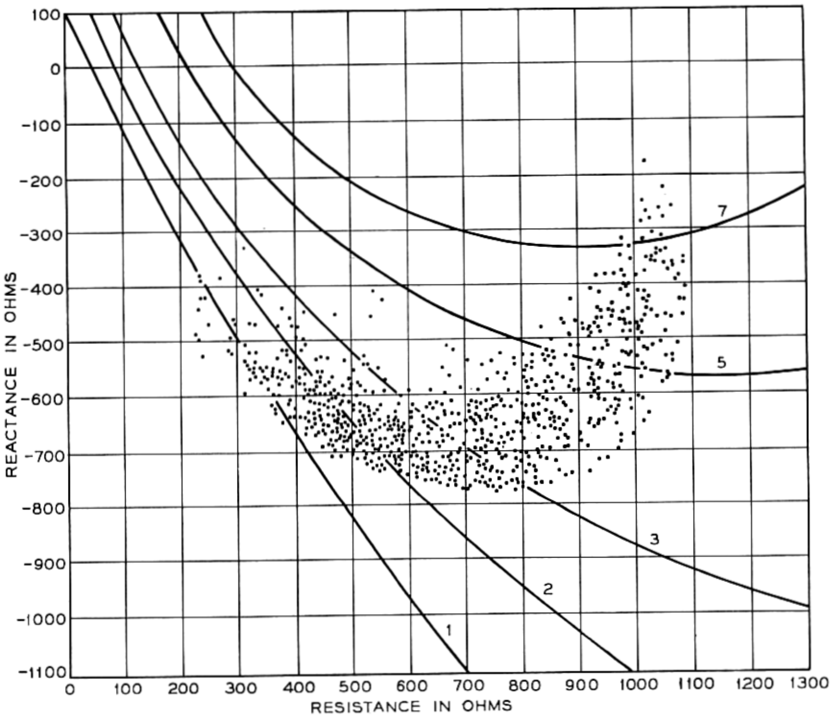

Fig. 29 — Nonloaded loop input impedances at 1 kHz measured from station set with a simulated two-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

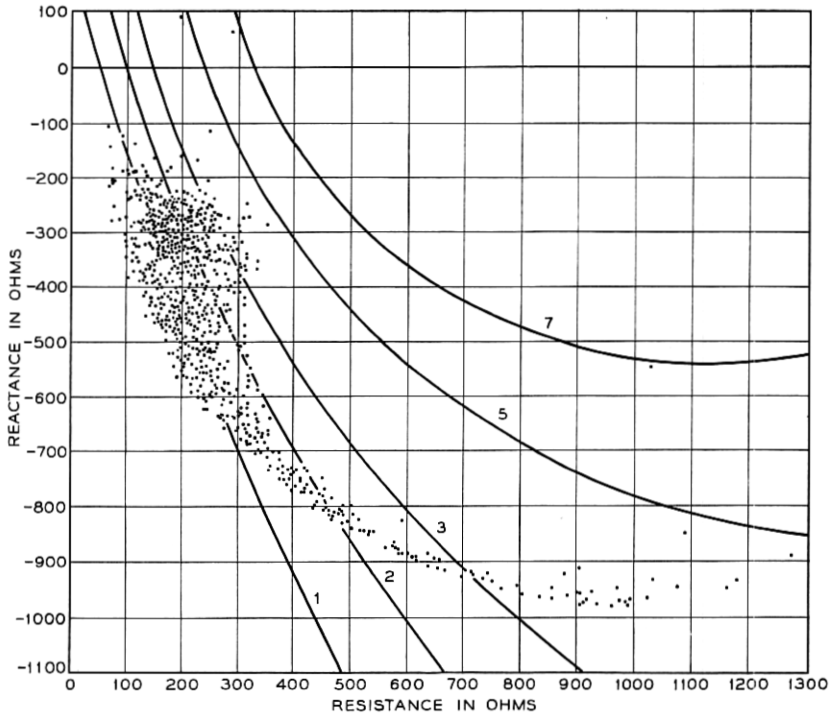

Fig. 30 — Nonloaded loop input impedances at 3 kHz measured from station set with a simulated two-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

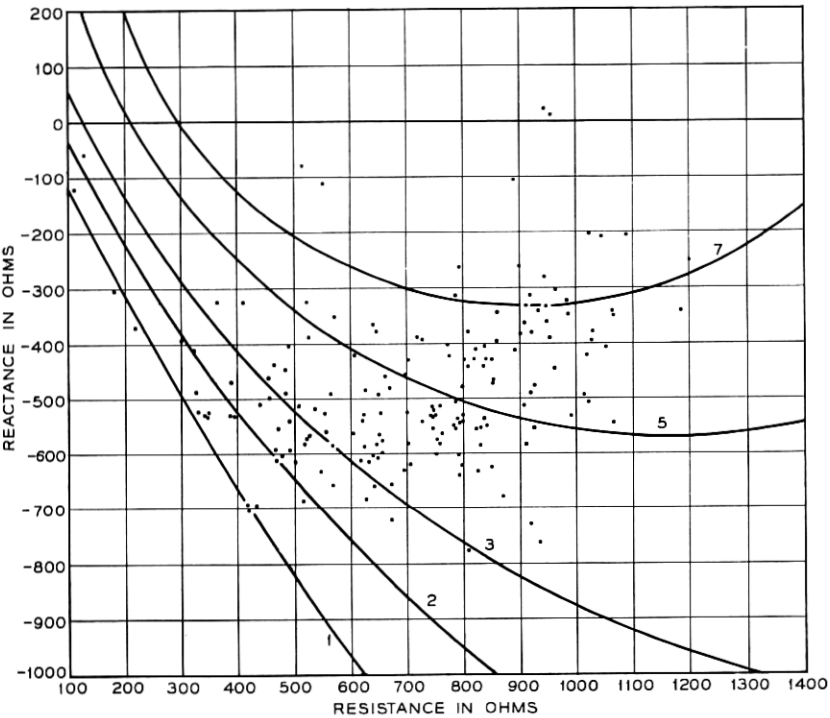

Fig. 31 — Loaded loop input impedances at 1 kHz measured from station set with a simulated two-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

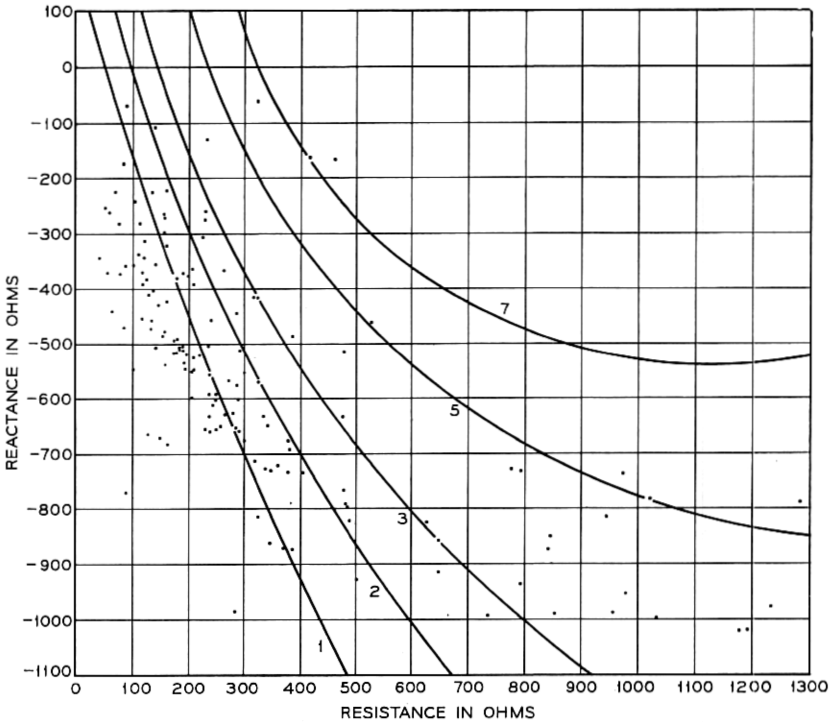

Fig. 32 — Loaded loop input impedance at 3 kHz measured from station set with a simulated two-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

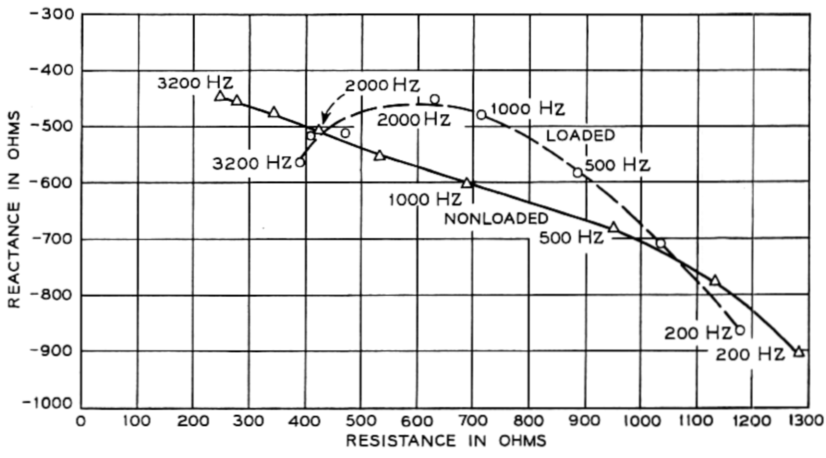

Fig. 33 — Mean value of loop input impedance from station set with simulated two-wire trunk termination at the central office.

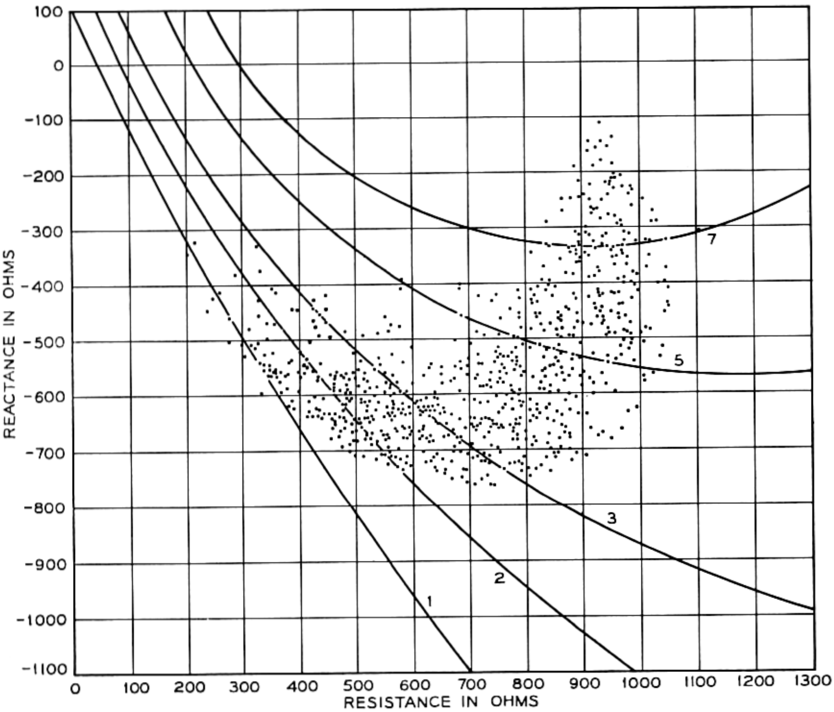

Fig. 34 — Nonloaded loop input impedances at 1 kHz measured from station set with simulated four-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

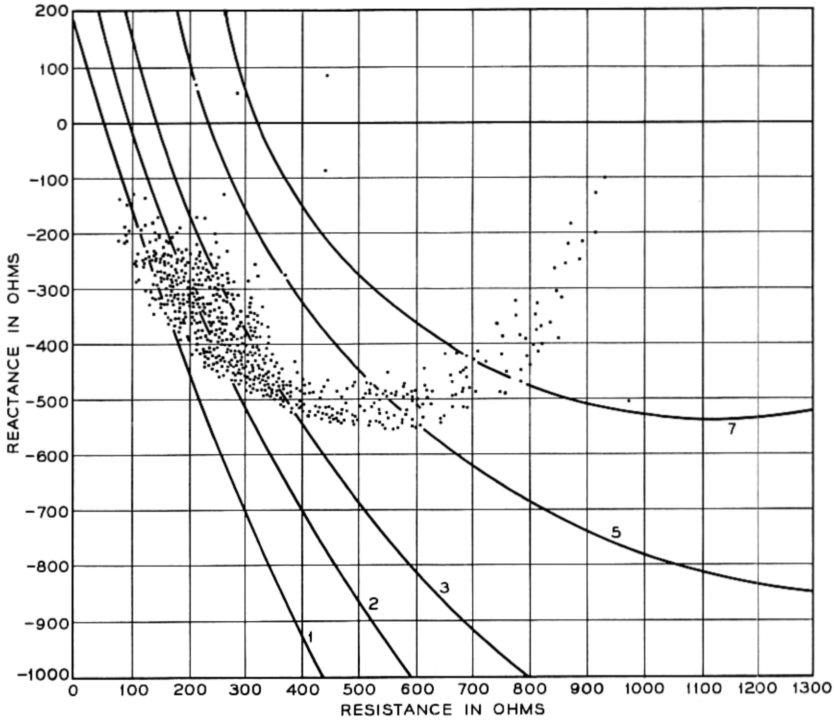

Fig. 35 — Nonloaded loop input impedance at 3 kHz measured from station set with simulated four-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

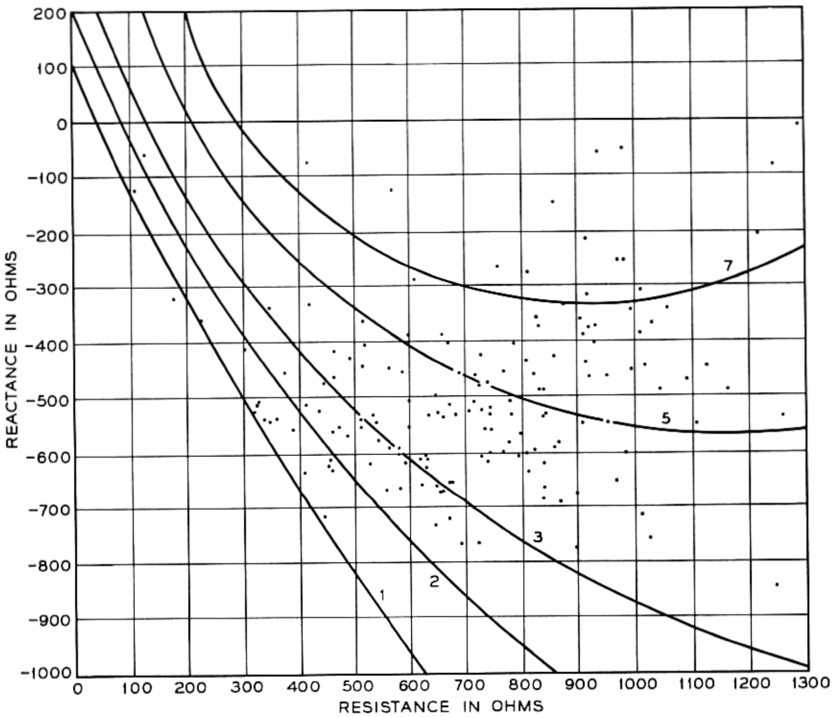

Fig. 36 — Loaded loop input impedances at 1 kHz measured from station set with simulated four-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

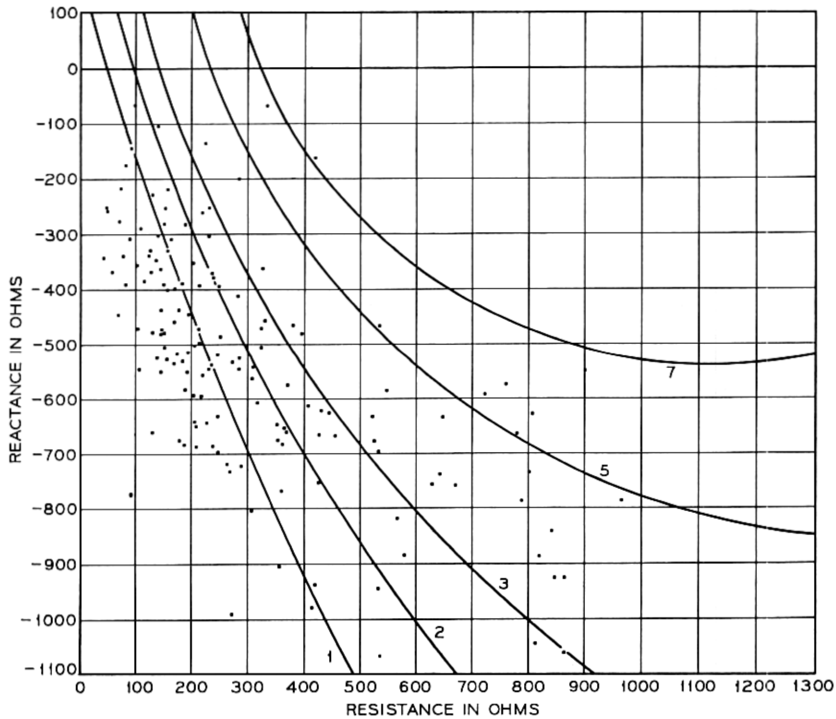

Fig. 37 — Loaded loop input impedances at 3 kHz measured from station set with simulated four-wire trunk termination at the central office. Return loss circles based on 500-type subset impedance.

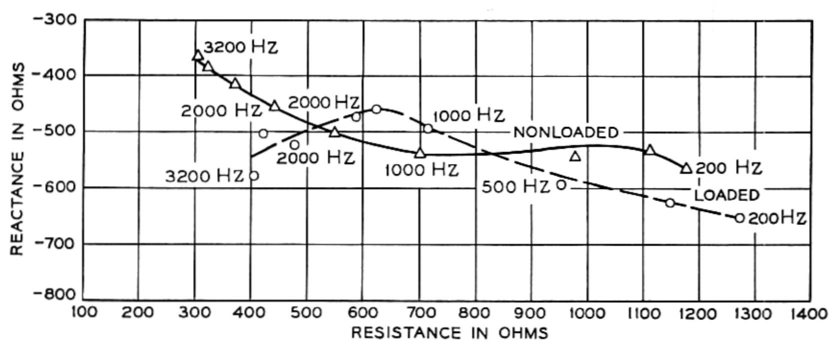

Fig. 38 — Mean value of loop input impedance from station set with simulated four-wire trunk termination at the central office.

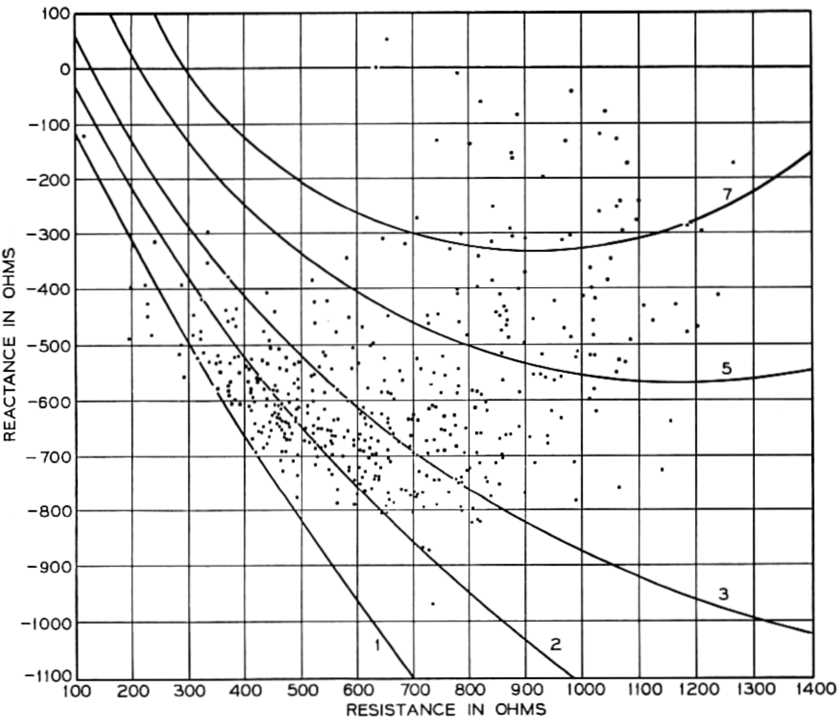

Fig. 39 — Input impedance of all loops at 1 kHz measured from station set with a simulated intraoffice circuit termination at the central office. Return loss circles based on 500-type subset impedance.

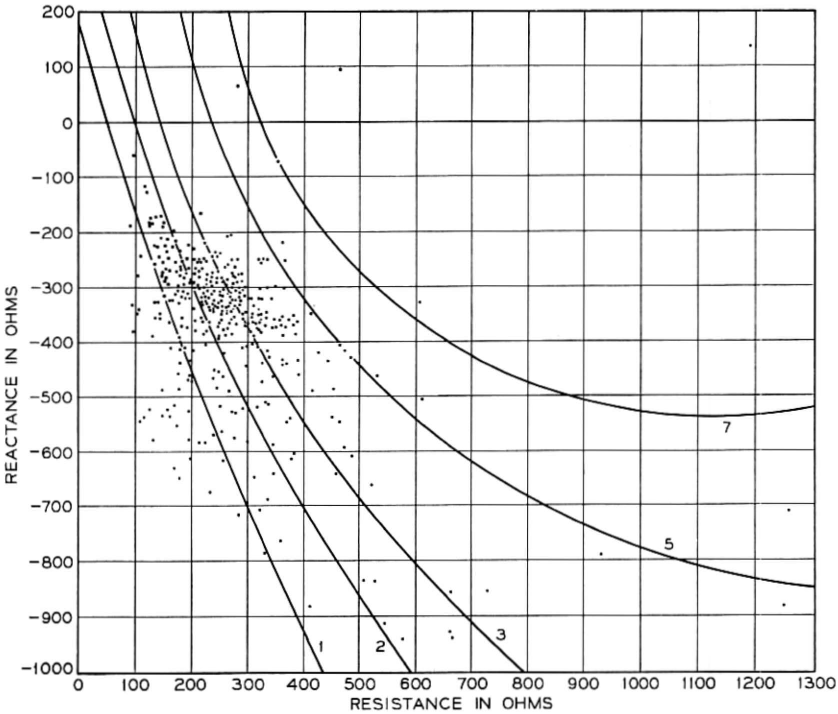

Fig. 40 — Input impedance of all loops at 3 kHz measured from station set with a simulated intraoffice circuit termination at the central office. Return loss circles based on 500-type subset impedance.

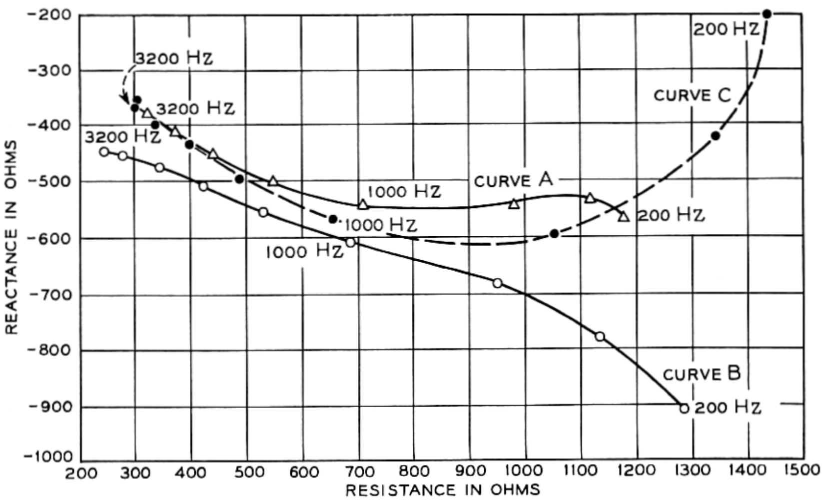

Fig. 41 — Mean input impedance of nonloaded loops measured from station set with: Curve A—simulated four-wire trunk 900 ohms + 2 μF central office termination; Curve B—simulated two-wire trunk 22-gauge H-88 cable central office termination; and Curve C—simulated intraoffice calls condition.