PUB 41803

Bell System TECHNICAL REFERENCE

ACOUSTIC AND INDUCTIVE COUPLING FOR DATA AND VOICE TRANSMISSION

OCTOBER 1972

Bell System Data Communications

TECHNICAL REFERENCE

Acoustic and Inductive Coupling for Data and Voice Transmission

October 1972

ENGINEERING DIRECTOR - TRANSMISSION SERVICES

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If further information is required, please contact:
Engineering Director — Transmission Services
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

This Technical Reference supersedes the following Preliminary Technical Reference (PUB 41803):

"Acoustical Coupling for Data Transmission" — November, 1968

PREFACE

The material in this Technical Reference is an updating of the Preliminary Technical Reference, "Acoustical Coupling for Data Transmission," issued November, 1968. It is intended for use by designers and manufacturers of terminal devices which will acoustically or inductively couple signals into the handsets of Telephone Company stations which are connected to the Bell System switched message network.

Two previously issued Technical References were intended to aid customers and equipment manufacturers in understanding the capabilities and limitations of the Switched Telecommunications Network. These References are entitled:

"Data Communications Using the Switched Telecommunications Network" — May, 1971

"Analog Parameters Affecting Voiceband Data Transmissions — . . ." — October, 1971

This Technical Reference describes the characteristics of the telephone handset affecting the design of customer-provided acoustically or inductively coupled devices. In addition, this Reference is intended to augment the Tariff requirement for interconnection by specifying the criteria for acceptable customer-provided acoustically coupled equipment and describes a test set to be used in determining compliance.

In furnishing this material, the Bell System makes no claims or representations and assumes no responsibility beyond that set forth in the Tariff regulations for the suitability of the transmission path or the performance of services using acoustically or inductively coupled signals. In addition, the Bell System is in no way responsible for the design, performance, installation, operation, or maintenance of terminal devices manufactured by others which are intended to be acoustically or inductively coupled to the telephone network and does not endorse or approve any such terminal devices. The material in this Technical Reference is intended to be helpful to designers in the interest of preventing interference to other Telephone Company services and users and is not intended to provide complete design specifications or parameters for acoustically or inductively coupled devices.

In general, the transmission performance of communications services using acoustically or inductively coupled terminal devices will be limited by electrical characteristics of the telephone handset and the acoustical or inductive interface between the device and handset. Although acoustically or inductively coupled devices may be used for slow speed data communication, customers desiring optimum performance of data communications services should consider DATA-PHONE ® service or Data Access Arrangements.

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1. INTRODUCTION

Customers have expressed a desire for a communications capability over the telephone network facilities from portable terminal devices. To meet these specialized needs, the Bell System tariffs provide for customers to couple data or voice signals, acoustically or inductively, into the switched message network through Telephone Company handsets subject to certain Network Protection Criteria which limit the spectral content of energy to be injected into telephone lines and require that such coupling be done external to the Telephone Company Network Control Signaling Unit.

When modulating and demodulating (modem) functions are performed by the customer's equipment, the Bell System retains responsibility for network control signaling. The signal format (analog or digital, serial or parallel, binary or multilevel) and type of modulation (FM, AM, etc.), is at the option of the modem manufacturer. Customer-provided equipment may input voice as well as data signals acoustically or inductively.

2. SYSTEM DESIGN CONSIDERATIONS

Acoustically coupled terminal devices should be designed to be used with ordinary telephone instruments and dialed-up telephone connections. Only the G-type (without additional amplification in the handset) and TRIMLINE handsets and their associated telephone sets will be characterized in this document (see Fig. 1). Older handsets and future developments, as well as interconnected customer-provided telephones, telephones of the independent telephone companies and decorator set telephones, cannot be assured to be compatible with the information contained herein.

At the point of origin, the telephone connection is first established in the normal way. Then the handset is placed in a special holder provided by the customer, and the transmitted data or voice signals are coupled acoustically or inductively into the telephone handset. The telephone receiver may be used to receive signals. Signals coupled into the telephone transmitter will also appear across the telephone receiver, attenuated by the sidetone path of the telephone instrument.

2.1 Handset Dimensions and Orientation

Figs. 2 and 3 show the nominal dimensions and tolerances for the G-type and TRIMLINE handsets.

In designing the acoustical chamber, it is recommended that the chamber size be minimized and a good acoustical seal attained, and that the plane of the handset transmitter be vertical (see Fig. 4). This is the most sensitive position; that is, it provides the maximum electrical signal on the telephone line for a fixed input acoustical pressure. The vertical is also generally the best orientation from the standpoint of minimizing nonlinear (harmonic) distortion. This is further explained in Section 3.1.

2.2 Modulation and Data Transmission Rates

The type of modulation and data rates to be used should be decided by considering the handset and network characteristics and their effects on specific modulation schemes. Further information on characteristics is presented later in this document and in References a, d, e, h, and k listed in Section 7.

2.3 Communications Between Customer-Provided Modems and DATA-PHONE Data Sets

Data communications may be between two DATA-PHONE data sets, between a customer-provided modem and a DATA-PHONE data set, or between two customer-provided modems. The Bell System ensures compatible operation only in the case where both ends are DATA-PHONE data sets. In addition, it should be recognized that some added degradation is to be expected in the acoustically coupled case as compared to electrically coupled services.

Technical References describing the interface characteristics of DATA-PHONE data sets can be obtained by contacting:

American Telephone and Telegraph Co.
Supervisor — Information Distri. Center
195 Broadway — Room 208
New York, New York 10007

A catalog, numbered PUB 40000, describing all Technical References, is available from the same address.

2.4 Echo Suppressor Considerations

Customer-provided data modems may have the capability to transmit and receive signals simultaneously. For the purpose of this Technical Reference, "duplex" operation will be taken to mean that signals are on the line simultaneously both to and from the data modem. "Half duplex" operation will describe the case where a modem is either transmitting or receiving a signal at any given time, but not both simultaneously. It should be noted that sidetone may become a consideration when simultaneous transmission in both directions (duplex operation) is required.

Within the switched message network, there may be separate paths for the two directions of transmission. In voice communications, at least one of the paths is usually idle at any given time. In order to protect the person who is talking from hearing a disturbing "echo" of his voice on long distance calls, the idle receive path is attenuated by a device called an "echo suppressor." As a result, voice or data signals may be transmitted in only one direction at a time under normal conditions. If "duplex" operation is desired, the echo suppressors must be disabled and held disabled for the duration of the call.

Echo suppressors may be temporarily disabled by applying a single-frequency tone at a level which is in the range of 0 to 5 dB below the maximum signal level (see Section 5.1) somewhere in the 2010-2240 Hz band for at least 400 milliseconds. The subsequent data signal will keep the echo suppressor disabled as long as interruptions in the signals are less than 100 milliseconds in duration.

The "turnaround" time of echo suppressors is a characteristic which concerns the half duplex operation of data modems. A modem receiving half duplex signals from a distant modem should not begin transmitting at the instant the distant modem ends transmission. This restriction is caused by the delay in the removal of the attenuation placed in the distant modem receive path by the echo suppressor. This delay, called "turnaround" time, is usually less than 100 milliseconds.

Additional information concerning echo suppressors and disabling may be found in Section 7 Reference (b).

2.5 Service and Maintenance Considerations

In DATA-PHONE service, the Bell System assumes maintenance responsibility for the service up to the baseband digital interface of the DATA-PHONE data set. Similarly, in voice service the Bell System assumes maintenance responsibility for the service up to and including the telephone set. Where connecting arrangements are involved, the Bell System's maintenance responsibility ends at the interface between the connecting arrangement and the customer-provided equipment (CPE). With acoustically or inductively coupled CPE, the Bell System has maintenance responsibility for ordinary telephone service, i.e., up to the acoustical or inductive interface. Since the CPE can be moved from place to place, transmission characteristics of the loop and handset will vary. Thus, without some form of reference, sectionalization of troubles between the CPE and the Telephone Company equipment would be difficult. Therefore, as part of the maintenance plan for acoustically and inductively coupled services, the Bell System plans to use a test set which will provide a standard of reference. The test set, which converts acoustic or inductive energy into electrical signals, incorporates the characteristics of an average telephone set. It will be used as a standard of reference to ascertain if the CPE is transmitting an acceptable signal power. Normal maintenance procedures will be used to determine if the telephone set and loop meet Bell System requirements for voice transmission.

Since telephone sets are electroacoustical and not inductive devices, the Bell System cannot be responsible for the inductive properties of present or future telephone sets. The newer telephone receivers tend to make inductive coupling less and less attractive. Test arrangements are discussed in more detail in Section 6.

3. TELEPHONE HANDSET CHARACTERISTICS — ACOUSTIC COUPLING

A signal acoustically coupled to the telecommunications network is influenced by the electrical and acoustic characteristics of the telephone handset in addition to the electrical characteristics of the network. Some statistical information on G-3 handset characteristics is given below for the consideration of coupler designers. The data presented are expected or typical values and are not Bell System design specifications.

The information and testing procedures given in this Technical Reference have been derived for the G-type handset, utilizing the T1 carbon transmitter. This handset is used with most present Western Electric Company 500-type, PRINCESS®, and TRIMLINE telephone sets. The relevance of this material to the older Western Electric Company 300-type telephone sets, other telephone sets or its applicability to future telephone set designs cannot be assured.

3.1 Nonlinearity

Nonlinearities in the handset are introduced primarily by the carbon transmitter. One typical example of nonlinearity takes an input of the form $I_i(t)$ and translates it into an output of the form:

$$I_o(t) = a_1 I_i(t) + a_2 I_i{}^2(t) + a_3 I_i{}^3(t) + \ldots$$

Generally, the second order (square) and third order (cube) are the dominating nonlinear terms. When the input is represented by a summation of sinusoids, unwanted energy is generated at multiples and at combinations of sums and differences of the original frequencies. These signals, along with the desired signal, are transmitted onto the telephone line. They are also coupled into the receiver of the telephone through the hybrid network in the telephone. This effect, known as "sidetone," is considered in Section 3.2.

A test of typical telephone sets shows that distortion is mostly second harmonic, increases with increasing input level, and is minimized with the plane of the telephone transmitter in a vertical orientation. For this sample of telephone sets, distortion ranged from 24 to 8.5 dB below the fundamental for the horizontal and from 27 to 12 dB below the fundamental for the vertical for input pressures between +20 and +35 dB above 1 dyne/cm^2. These results indicate that 2000 $\pm$2.5 Hz tones should be avoided in order to comply with the 3995 through 4005 Hz criteria (Section 5.4) if the input level can be increased over the nominal setting on longer-than-average loops or if the handset is placed in other than the vertical position. The Technical Reference, "Data Communications Using the Switched Telecommunications Network" PUB 41005, provides further reasons for avoiding 2 kHz tones (distortion on T1 carrier).

3.2 Sidetone

The telephone is designed with a hybrid network to couple signals from the carbon transmitter to the telephone line and signals from the line to the receiver. In a perfectly matched network, no energy would couple from the transmitter directly to the receiver. However, the hybrid is arranged for voice communication so that a talker hears his own voice in his receiver at a level comparable with that at which he would hear the far-end talker. This signal, coupled to the receiver from the transmitter through the hybrid, is known as "sidetone." The acoustical sidetone signal from the receiver is normally about 8 to 10 dB below the acoustical signal into the transmitter; however, it can be equal to the transmitted signal for some frequencies on short loops. Therefore, serious consideration must be given to sidetone and nonlinearity effects if full duplex operation is utilized. The desired received signal must be separated not only from the transmitted signal appearing through the sidetone path, but also from the nonlinear products of the transmitted signal coupled in via the sidetone mechanism.

3.3 Packing

The telephone transmitter contains carbon granules, whose contact resistance is changed by acoustic pressure variations on a diaphragm. In practice, the granules tend to settle (or "pack") to various degrees. The result

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is a decrease in efficiency. A typical set might show a line signal decrease of up to 10 dB per hour with the transmitter plane horizontal, and up to 2-1/2 dB with the plane vertical. As can be seen, the recommended vertical orientation is best from a packing standpoint. The tendency is for the level to decrease with time. The amount of packing is dependent on input signal frequency and level, loop current, and the previous condition of the carbon granules. To reduce the effects of packing, a handset may be "conditioned" by rotating it several times after going off-hook and receiving dial tone.

3.4 Handset Position

As discussed in previous sections, the telephone transmitter functions best from a standpoint of sensitivity, nonlinearities, and packing if it is placed with the plane of the transmitter in a vertical position. It is assumed in the test set design that this will be the normal operating position.

3.5 Vibration

Acoustically coupled devices may be associated with business machines that may tend to vibrate mechanically. Mechanical coupling between the business machine and the coupler can result in a noise signal in the telephone transmitter by vibrating the carbon granules. The user, therefore, should minimize the mechanical coupling between his terminal and the coupler and should attempt to ensure that he has the best possible acoustic seal to prevent acoustic noise from interfering with the transmitted signal.

3.6 Acoustic to Electrical Translation

The curve shown in Fig. 5 gives the acoustic pressure in a closed coupler which will produce a -9 dBm signal at the telephone set line terminals on an average loop. Variations in gain can be expected from handset to handset. Some tests have shown that, for a given input acoustic pressure at a given frequency and on a given loop, the power at the telephone line can vary by as much as ± 3 dB due to packing, aging, etc. These variations, combined with variations in loop loss, give an idea of the expected range of powers at the serving central office.

3.7 Received Signal Characteristics

The telephone receiver converts an electrical signal to acoustic energy. A curve of the typical response to a telephone line signal of -17.5 dBm (-18 dBv terminated in 900 Ω) at the receiving central office with an average local loop is shown in Fig. 6. The acoustical pressure out of the receiver is a linear function of the signal level into the telephone up to about 39 dB above 1 dyne/cm^2. At this point, the receiver varistor tends to limit the power. As the end-to-end response is a function of the telephone transmitter, receiver performance, telephone set response, loop insertion loss at each end, and the end-to-end office loss, expected received levels can be calculated from this data.

Some preliminary estimations of end-to-end acoustic loss distributions have been made. If an acoustically coupled device is likely to be used on calls covering short, medium, and long distances, a 1000 Hz tone, transmitted at the maximum allowable level derived from Fig. 5, will be received at a mean level of about 13 dB above 1 dyne/cm^2. The distribution of received volumes will have a standard deviation of about 6 dB.

Infrequently, high losses may be encountered on the switched message network, as can be seen in Section 7 (h) and (k). The received acoustic pressure at 1000 Hz will seldom be lower than 10 dB below 1 dyne/cm^2. A typical station-to-station toll call is shown in Fig. 7.

4. TELEPHONE HANDSET CHARACTERISTICS — INDUCTIVE COUPLING

The telephone set is designed for voice communication. Therefore, acoustic coupling of voice and data into the telecommunications network, discussed in this Technical Reference, provides a viable means of connection in many cases where portability is desired. In some cases it is possible to make use of noncontrolled parameters, such as stray magnetic fields in telephone receivers, to inductively transmit or receive signals through telephone sets. Inductive coupling is not recommended, however, since the magnetic parameters of a telephone set are not controlled. In addition, telephone sets with improved receivers are far more difficult to inductively couple to and may render such coupling equipment obsolete. However, for those who recognize these limitations and still wish to use inductive coupling, a test arrangement for measuring Tariff compliance on one form of inductive transmitting is discussed.

4.1 Coupling to the U-Type Receiver

Since a telephone set contains many elements with stray magnetic fields associated with them (coils, wires, etc.), there are many ways to inductively couple energy into a telephone. However, most coupling modes are impractical because of the inefficiencies of energy transfer. Further, none can be well characterized for the long term because the inductive properties of telephone sets are not controlled. In practice, the U-type receiver found in most 500-type telephone sets up to the present time has exhibited an inductive characteristic making inductive coupling possible. For this reason, and because some manufacturers have expressed interest in inductive transmitting or receiving, the test set will measure inductive transmission to a U-3 type receiver. However, it must be stressed that TRIMLINE and some present 500-type set receivers (LA- or LB-type) have magnetic structures that produce a very small stray magnetic field, making inductive coupling impractical.

4.2 Inductive Receiving With U-Type Receivers

Since receiving by inductive (or acoustic) coupling places no signals on the telephone lines, no criteria are placed on it. The information is presented for the general interest of the designer of inductive receivers. Fig. 8 shows the frequency response of the magnetic radiated field of typical U and L type receivers. Measurements made on a sample of LA and LB receivers for inductive reception show about a 30 dB drop in radiated signal with the new receivers compared to the U-type. Optimum coil position is not very critical for the U-type receiver; however, it is for the LA or the LB receiver. An optimum placed pickup coil for the LA or the LB receiver can increase the pickup 20dB, but this positioning is so critical that it is impractical for normal use. Additional difficulties can be encountered, since these are typical values and not design specifications.

4.3 Inductive Transmission With U-Type Receivers

Compliance for inductive transmission calls for inband signal power not to exceed -9 dBm at the telephone set line terminals over a 3-second average on an average loop. The telephone receiver contains click suppressor diodes (varistors) which generally limit the input signal by peak clipping. Some typical values of signals on the line (input to the telephone set) at which receivers with different click suppressor limits are as follows: U-1, -7 dBm; U-3, -11 dBm; LA and LB, -15 dBm. On the average, with the additional loss of the local loop, inductive transmission through the telephone receiver will not violate the inband power Tariff criterion. However, nonlinearities (with resultant signal distortion) as the click suppressors begin to operate are common with line signals higher than -15 to -20 dBm. The harmonic distortion caused by this limiting action can result in energy of sufficient magnitude to violate the out-of-band Tariff restrictions, particularly in the 3995 through 4005 Hz band. For instance, the third harmonic of a 1333 Hz fundamental would fall at 3999 Hz and could be large enough to exceed allowable limits. The requirement for less energy in the band 2450 through 2750 Hz than in the band 800 through 2450 Hz still applies and must also be met. (These Tariff requirements are discussed in Section 5.)

Inductive transmission through the LA and the LB receivers exhibits a critical dependence on coil position similar to the inductive receiving case. The information presented above represents the typical limits with optimum coupling, which is very difficult to attain with the new receivers.

As in the case of inductive reception, the values presented are typical and are not design specifications. The information is presented for the consideration of designers of inductively coupled devices.

5. TARIFF COMPLIANCE — ACOUSTICALLY AND INDUCTIVELY COUPLED SIGNAL LEVEL RESTRICTIONS

The Tariff states that the power of the signal applied by the CPE be limited so that the signal power at the output of the network control signaling unit (i.e., at the input to the Telephone Company line) does not exceed -9 dBm when averaged over any 3-second interval. The more important consideration is that the power level at the central office be approximately -12 dBm when averaged over any 3-second interval, however, so as to prevent interference to other telephone services. The -12 dBm central office level produces a signal level at the input to carrier facilities of -29 dBm which is required to maintain minimum carrier loading. (The -9 dBm criterion was previously stated for a point on the customer's premises, so that criteria measurement could be made in the customer's presence.) To ensure meeting these limits, certain restrictions must be placed on the characteristics of the acoustically or inductively coupled output from the customer's terminal. Compliance with the -12 dBm limitation on signal power at the central office may be ensured by directly measuring the electrical energy at the Telephone Company central office or by indirectly measuring the electrical energy at the output of a test set acoustically or inductively coupled to the customer's device if the test set is designed to have electrical characteristics equivalent to those of an average telephone set (network control signaling unit). Because of the difficulties in making suitable measurements at the output of the network control signaling unit (i.e., at the input to the Telephone Company line), the "indirect or substitution" method of determining compliance is being stressed in this Technical Reference. In acoustically or inductively coupled services, the customer or his representative does not have electrical access to the telephone loop as is the case when the customer-provided equipment is connected to the telephone loop by means of a Telephone Company-provided connecting arrangement. For this reason, the "indirect or substitute" method of determining Tariff compliance is the only recourse open to the customer or his representative. A suitable test set is discussed in Section 6 of this Technical Reference.

5.1 Acoustic Energy Below 4 kHz

Due to the portable nature of acoustically coupled devices and the variability of handsets and local loops, the -9 dBm limitation requires further definition. The CPE should produce an output pressure such that, when coupled to an average 500-type telephone, a power of -9 dBm results at the input to the loop.

The test arrangement should be used with the signal (in terms of level, frequency content, and duty cycle) from the CPE expected to produce the highest 3-second average power output on the line. The equivalent voiceband line electrical energy at the input to the loop can be measured with the test set. Alternatively, the energy can be calculated from the customer's acoustic pressure spectrum and the translation curve of pressure versus power (see Fig. 5). It should be noted that this curve is for single-frequency input signals. If more than one tone is present at a given time, the appropriate addition of signal powers will be necessary.

5.2 Gain-Frequency Compensation

Generally, the attenuation of a telephone set is not constant as a function of frequency (see Fig. 5). Since the Tariff requires -9 dBm or less total power at the input to the loop, the manufacturer may wish to build into his equipment compensation for the gain-frequency characteristic of an average telephone set to provide an amplitude at the input to the loop which is independent of frequency for frequencies below 3995 Hz.

When acoustically coupled devices are used as portable equipment at a variety of locations, the output should then be adjusted for the average loop as described in the test arrangement section. If the device is to be used with a telephone on one loop only and if the loop is unusually long, however, the customer may be permitted to adjust his output power based on information provided by the Telephone Company to compensate for differences in loop loss from the average. The maximum power allowed shall in no case exceed one milliwatt.

5.3 Acoustic Energy Distribution Below 4 kHz

The switched message network incorporates tone signaling devices that are used for network control functions. These devices, connected at all times to the telephone circuit, are designed to be sensitive to single-frequency tones at 2600 Hz. They are relatively insensitive to energy at these frequencies if sufficient energy is present at the same time at other frequencies in the voiceband.

In order to prevent the interruption or disconnection of a call, or interference with network control signaling, it is necessary that the signal acoustically or inductively coupled to the Telephone Company station located on the customer's premises should at no time have energy solely in the 2450 to 2750 Hz band. If signal power is present in the 2450 to 2750 Hz band, its power should be less than the corresponding electrical power present at the same time in the 800 to 2450 Hz band.

5.4 Acoustic Energy at 4 kHz and Above 4 kHz

In order to protect other telephone services, restrictions must be placed on the acoustic energy at 4000 Hz and above 4000 Hz.

The restriction on electrical energy at 4000 Hz requires that power in the band 3995 to 4005 Hz be at least 18 dB below the maximum allowable inband power. One way to determine this is to reference the device inband electrical power to the -9 dBm test set output. The measured electrical power from 3995 to 4005 Hz should be at least 18 dB below the input which produces -9 dBm on the test set.

The restrictions on electrical energy above 4000 Hz are as follows:

(1) The power in the band from 4000 Hz to 10,000 Hz shall not exceed 16 dB below one milliwatt.

(2) The power in the band from 10,000 Hz to 25,000 Hz shall not exceed 24 dB below one milliwatt.

(3) The power in the band from 25,000 Hz to 40,000 Hz shall not exceed 36 dB below one milliwatt.

(4) The power in the band above 40,000 Hz shall not exceed 50 dB below one milliwatt.

Compliance may be determined to a first approximation as above if referencing the electrical power to the -9 dBm reading on the test set.

6. TEST ARRANGEMENTS FOR ACOUSTICALLY AND INDUCTIVELY COUPLED SIGNALS

Designers and manufacturers of acoustically and inductively coupled devices will require a suitable test arrangement which will measure the level and spectral distribution of the electrical signal at the equivalent of the input to the loop. These levels translate into the maximum allowable acoustic pressures of Fig. 5 which must not be exceeded in order to avoid interference with the operation of the telephone system.

Fig. 5 (Acoustic Pressure Versus Frequency to Produce a -9 dBm Signal at the Input to the Telephone Loop) was derived by the use of a sound source in a closed coupler working into a statistical sample of telephone sets.

Fig. 8 (Radiated Field From a U-3 Receiver) was derived by measuring the field with a 1100 turn coil of dimensions 0.250" in diameter by 0.60" thick. Signal power to the receiver unit was -58.6 dB relative to one watt available power. The coil axis was parallel to the receiver axis.

6.1 Recommended Test System

A block diagram of the recommended test system, the F-58654 Coupler Test Set, is shown in Fig. 9. This test arrangement differs from that described in the Preliminary Technical Reference, "Acoustical Coupling for Data Transmission," dated November, 1968. The old test arrangement used a precision microphone and a specially designed holder to measure acoustic pressure. An empirical curve was then used to translate these pressure readings into power at the telephone set terminals of greater than or less than -9 dBm. The new test arrangement provides a better simulation of true conditions by utilizing a standard G-3 handset (thereby ensuring a more accurate mode of coupling) with a linear microphone, and an appropriate shaping network to simulate an average T1 carbon transmitter and telephone set network. The resultant measurement simulates the reading at the output of an average telephone or at the input to a telephone loop. The designer can, therefore, build preequalization into his coupling equipment to account for the gain-frequency response of an average telephone set. Further, devices used at fixed locations can be easily tested and adjusted with the new test set by reading a different meter value specified by the Operating Company (see Section 5.2). The proposed test set is shown in Figs. 10, 11, and 12.

The test set contains a meter to measure inband 3-second averaged power in order to determine Tariff compliance. An output jack appearance allows the use of a high-impedance external filter and a high input impedance power meter or wave analyzer for measurement of inband energy distribution (see Section 5.3). A built-in 2125 Hz tone source is provided for those data sets requiring an answer or reverse channel tone in order to operate.

The test system makes use of a standard Western Electric G-3 handset fitted with an electroacoustic transmitter in place of the carbon transmitter. This provides a linear transfer function, (voltage out versus input acoustic pressure is a linear function), and eliminates phenomena such as packing of the carbon granules. A shaping network then translates this signal into that of an average carbon transmitter and telephone network. The resultant signal is a representation of the electrical power at the input to the telephone loop.

The internal meter shows if this signal contains inband energy exceeding -9 dBm (or another level specified by the Operating Company on fixed longer-than-average loops) averaged over a 3-second period. The signal also appears at output terminals to allow further analysis of inband energy. The signal appearing on the output terminals represents the instantaneous power· it has no averaging. To use this output, a high-impedance (at least 35 KΩ) bridging measurement is required. The power reading should be determined from the measured voltage and a 900-ohm impedance.

6.2 Test Arrangement for Inductive Coupling

The test arrangement is also designed as an aid for the designer of inductively coupled transmitters. A U-3 receiver and a circuit simulating the receive portion of a telephone network are included. The test set will provide the capability for a closer examination of the input spectrum at the output of the telephone or input to the loop to determine compliance with inband energy distribution requirements and as an aid to the designer. By using the test set with the particular inductive coupling technique being tested, a designer can get some idea as to the output response at the input to the telephone loop for that set of test conditions.

6.3 Typical Test Description for Acoustic Coupling

The handset from the testing arrangement should be placed in the appropriate chamber in the acoustically coupled device. The acoustically coupled device should then be supplied with a signal designed to provide an output to the telephone line equivalent to the highest 3-second average signal likely to be produced from the standpoint of the acoustic power restrictions discussed in Section 5. Normally the average loop will be used, and the test set will give a direct reading of total inband power for criteria compliance. For data communications where a modem will be used with a specific loop, the Operating Company will give the customer or his representative upon request, the proper test set meter reading to ensure compliance. If the device has an output level adjustment, the customer or his representative can adjust this level until the meter reads the proper value.

6.4 Availability of Test Set

Arrangements can be made for the procurement of a limited number of these test sets by manufacturers of acoustically or inductively coupled devices for design or quality assurance. Requests for the test set should be directed to:

Western Electric Company, Incorporated
Commercial Relations
Gateway II, 15th Floor
Newark, New Jersey 08817

The estimated price to manufacturers is $650. Arrangements are being made to release specifications for manufacture of the test set external to the Bell System.

7. REFERENCES

Some references describing various transmission characteristics of the Telephone Network are listed below. These references should prove useful to the designers of modems.

(a) "1969 — 70 Switched Telecommunications Network Connection Survey" (reprints of Bell System Technical Journal articles), April 1971, Bell System Technical Reference PUB 41007.

(b) Brady, P.T., and Helder, G.K., "Echo Suppressor Design in Telephone Communications," BSTJ, 42, No. 6, November 1963, p. 2893.

(c) "Data Communications Using the Switched Telecommunications Network," Revised May 1971, Bell System Technical Reference PUB 41005.

(d) Bennett, W.R., and Davey, J.R., "Data Transmission," McGraw-Hill Book Company, New York 1965.

(e) Bell Telephone Laboratories, Incorporated, "Transmission Systems for Communications," Fourth Edition.

(f) Bugbee, L.F., "A Tone Disabler for Bell System 1A Echo Suppressor," AIEE Transactions, Part 1 — Communications and Electronics, No. 58, January 1962, p. 596.

(g) Townsend and Watts, "Effectiveness of Error Control in Data Communications Over the Switched Telephone Network," BSTJ, 43, No. 6, November 1964, p. 2611.

(h) Gresh, P.A., "Physical and Transmission Characteristics of Customer Loop Plant," BSTJ, 48, No. 10, December 1969.

(i) Nasell, I., Ellison, C.R., and Holmstrom, R., "The Transmission Performance of Bell System Intertoll Trunks," BSTJ, 47, No. 8, October 1968, p. 1561.

(j) Fennick, J.H., "Amplitude Distributions of Telephone Channel Noise and a Model for Impulse Noise," BSTJ, 48, No. 10, December 1969, p. 3243.

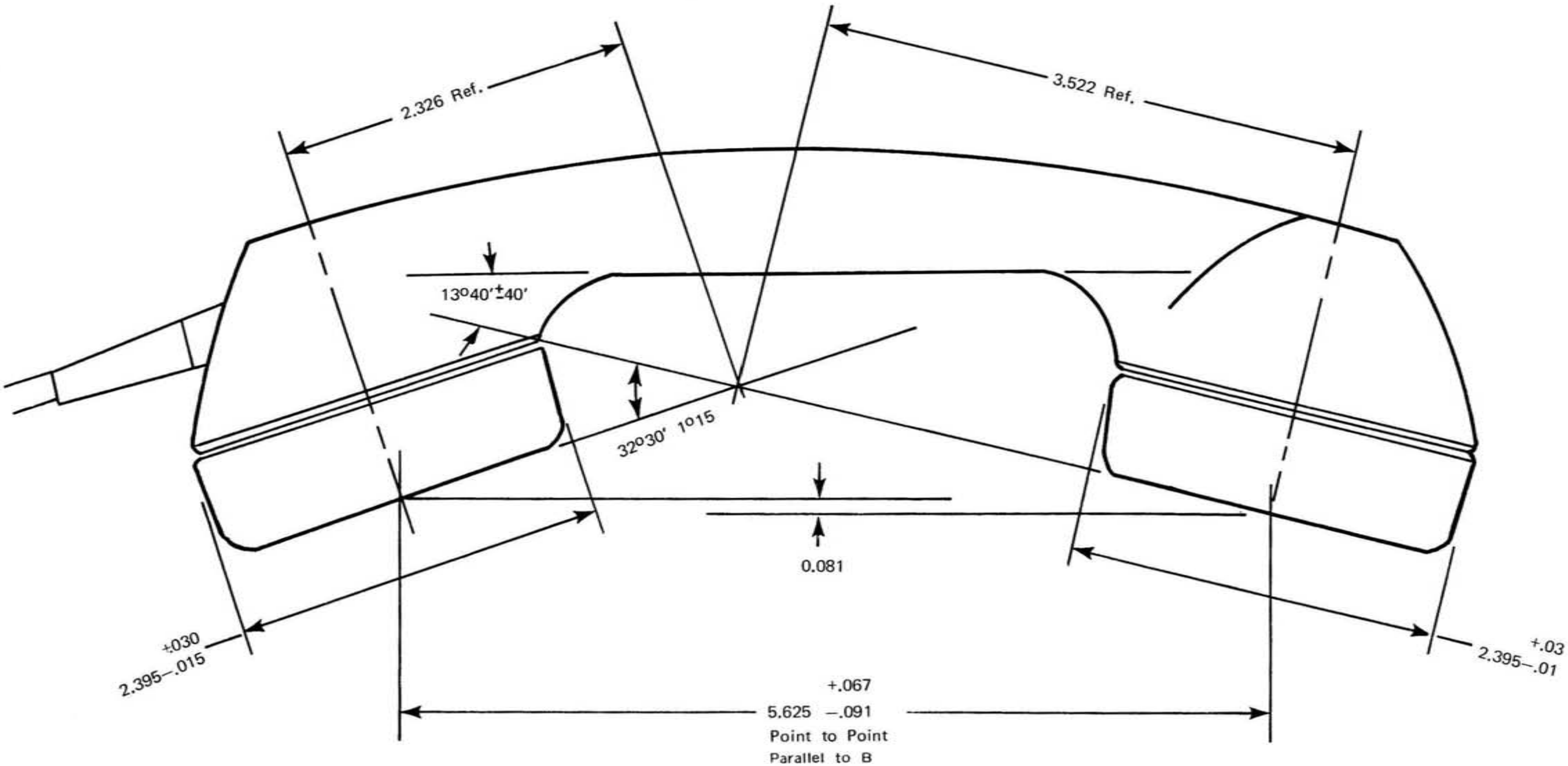
(k) Nasell, I., "Some Transmission Characteristics of Bell System Toll Connections," BSTJ, 47, No. 6, July-August, 1968, p. 1001.

(l) "Analog Parameters Affecting Voiceband Data Transmission — Description of Parameters," October 1971, Bell System Technical Reference PUB 41008.

(m) "Transmission Parameters Affecting Data Transmission — Measurement Techniques," January 1972, Bell System Technical Reference PUB 41009.

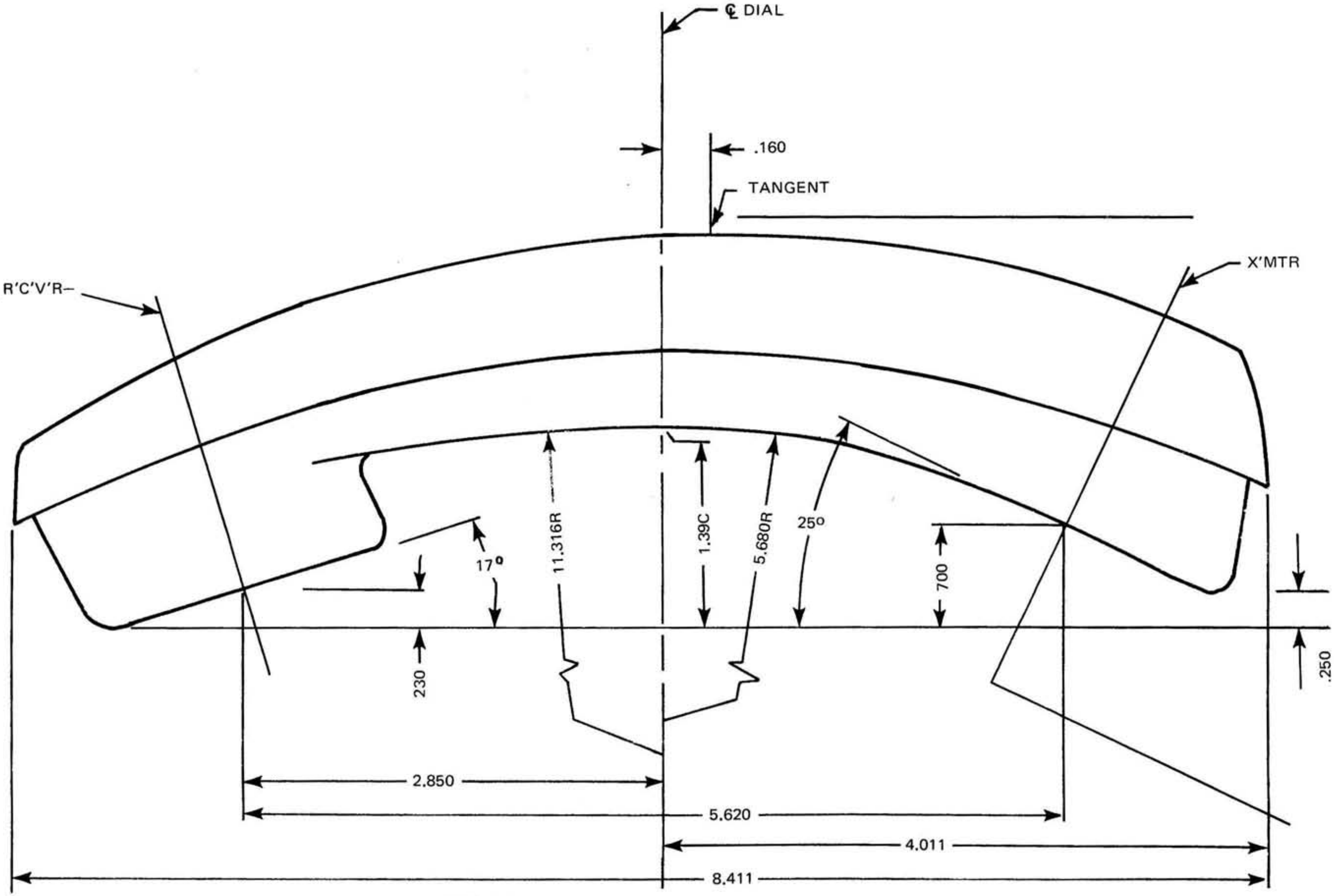
HANDSETS

FIG. 1



G–TYPE HANDSET DIMENSIONS

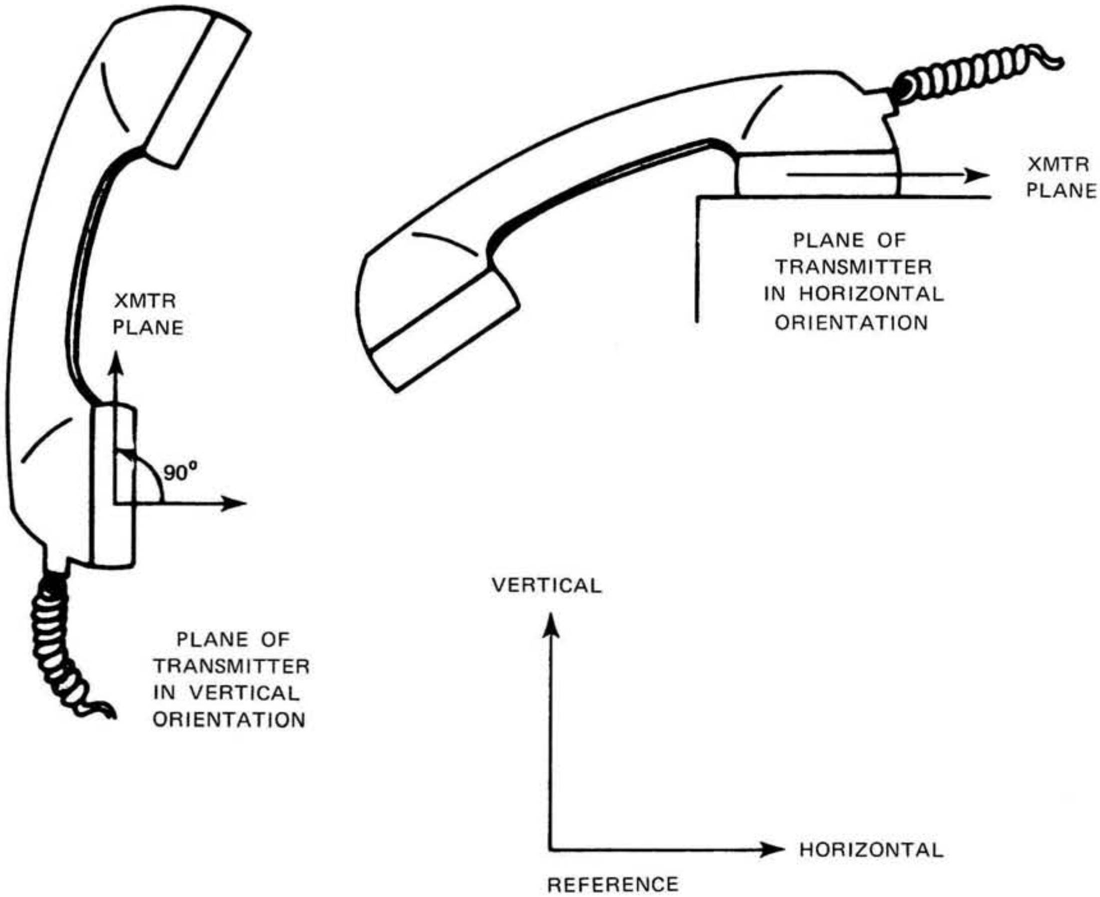
FIG. 2



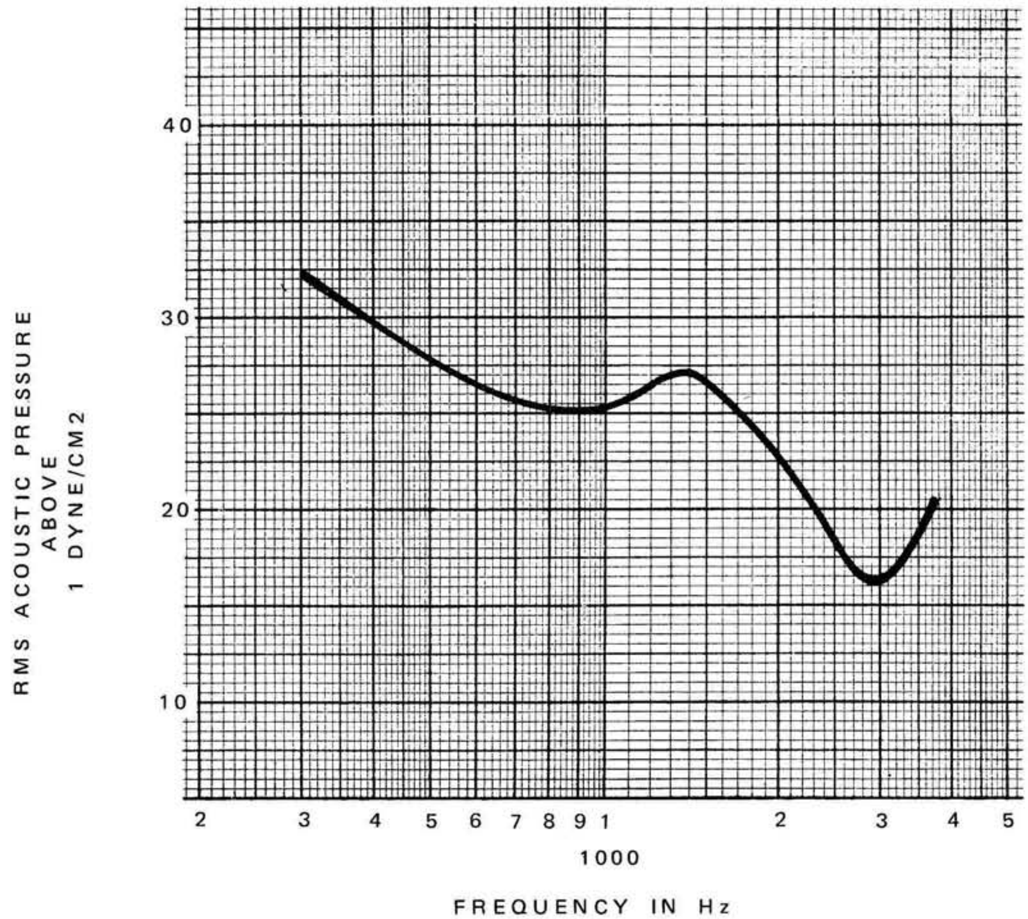
MAXIMUM TOLERANCES: + .OEO"

TRIMLINE HANDSET DIMENSIONS

FIG. 3



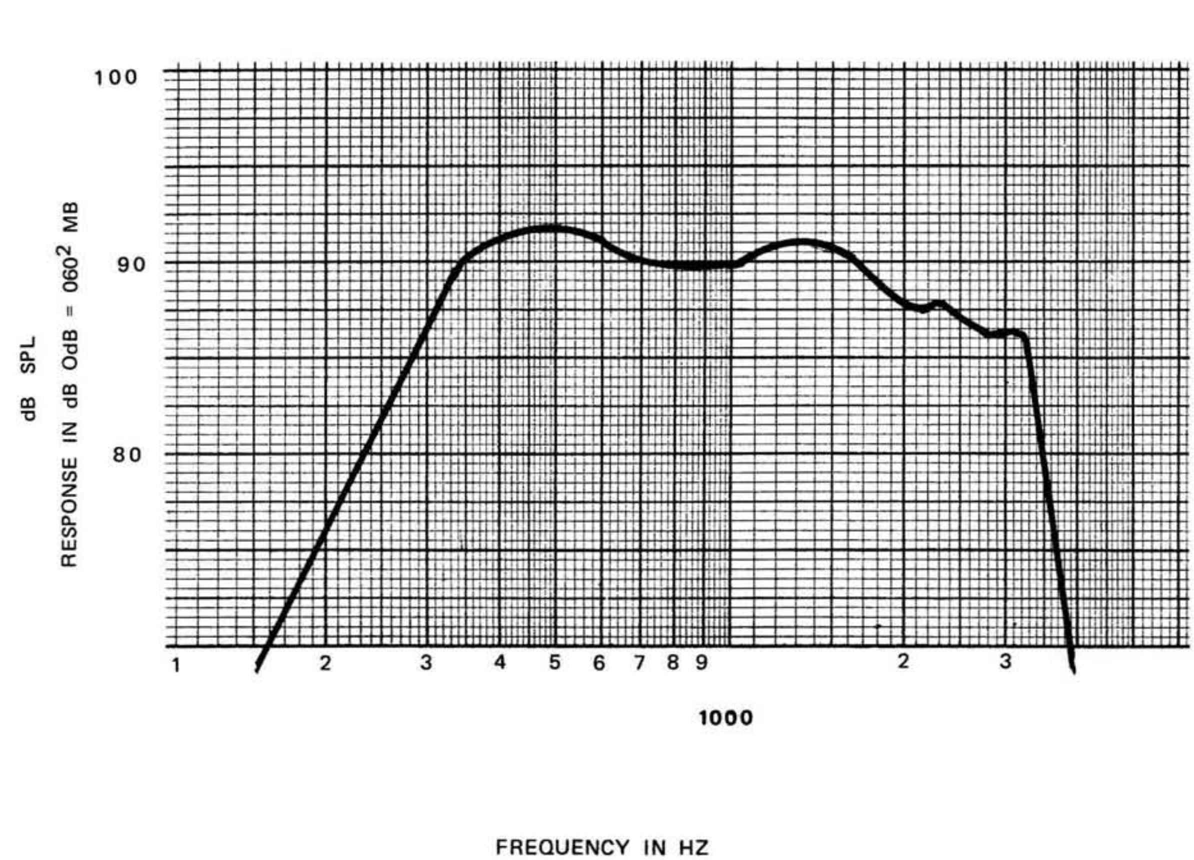
TRANSMITTER ORIENTATION
FIG. 4



ACOUSTIC PRESSURE VERSUS FREQUENCY
TO PRODUCE A – 9dBm SIGNAL AT THE
TELEPHONE SET LINE TERMINALS ON
AN AVERAGE LOOP

ACOUSTIC PRESSURE VERSUS FREQUENCY

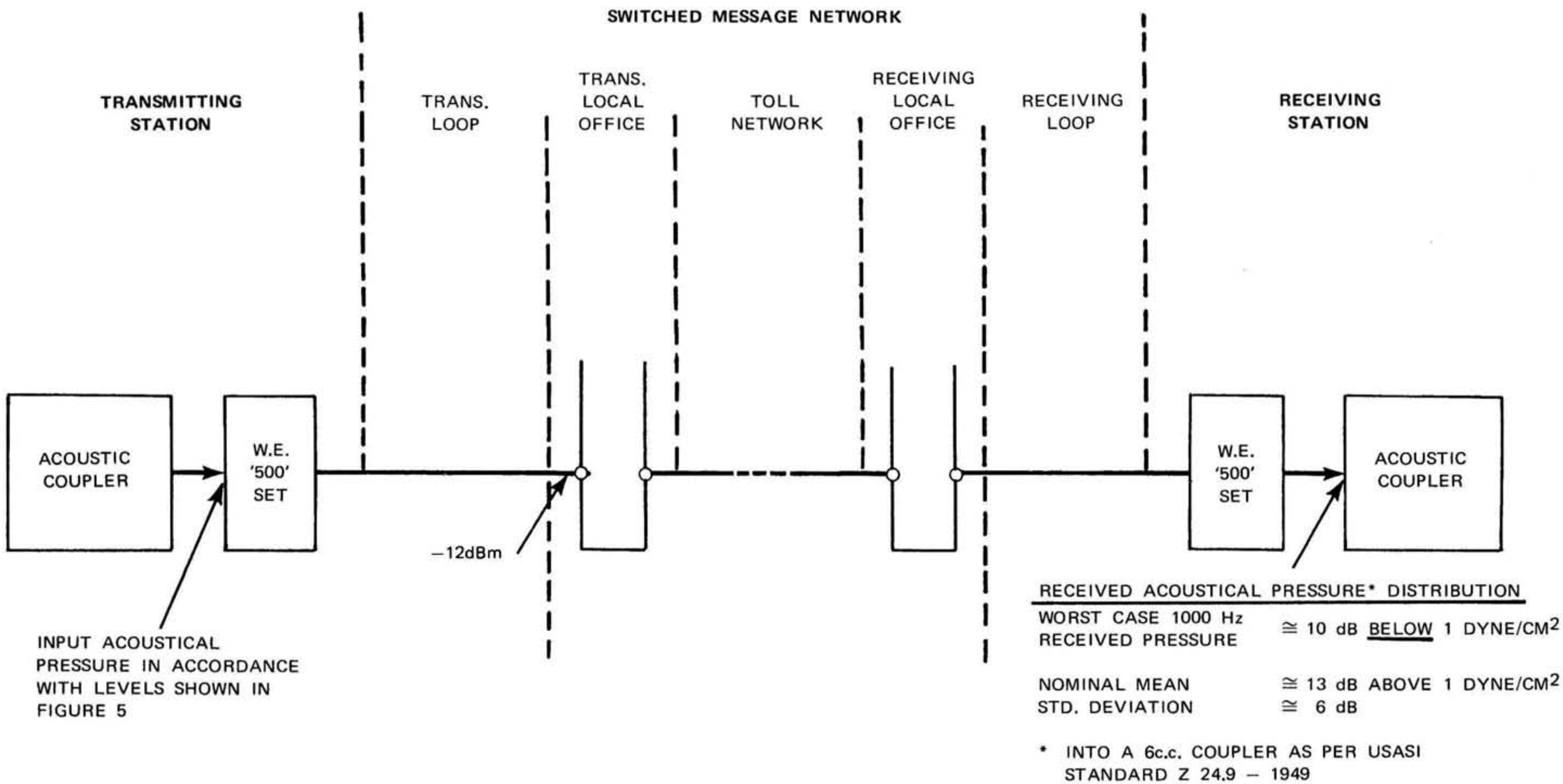
FIG. 5



Input to receiver is a -12 dBv open circuit (-18dBv terminated) signal (flat with frequency) at the receiving central office which is passed through an average loop and telephone network to the receiver

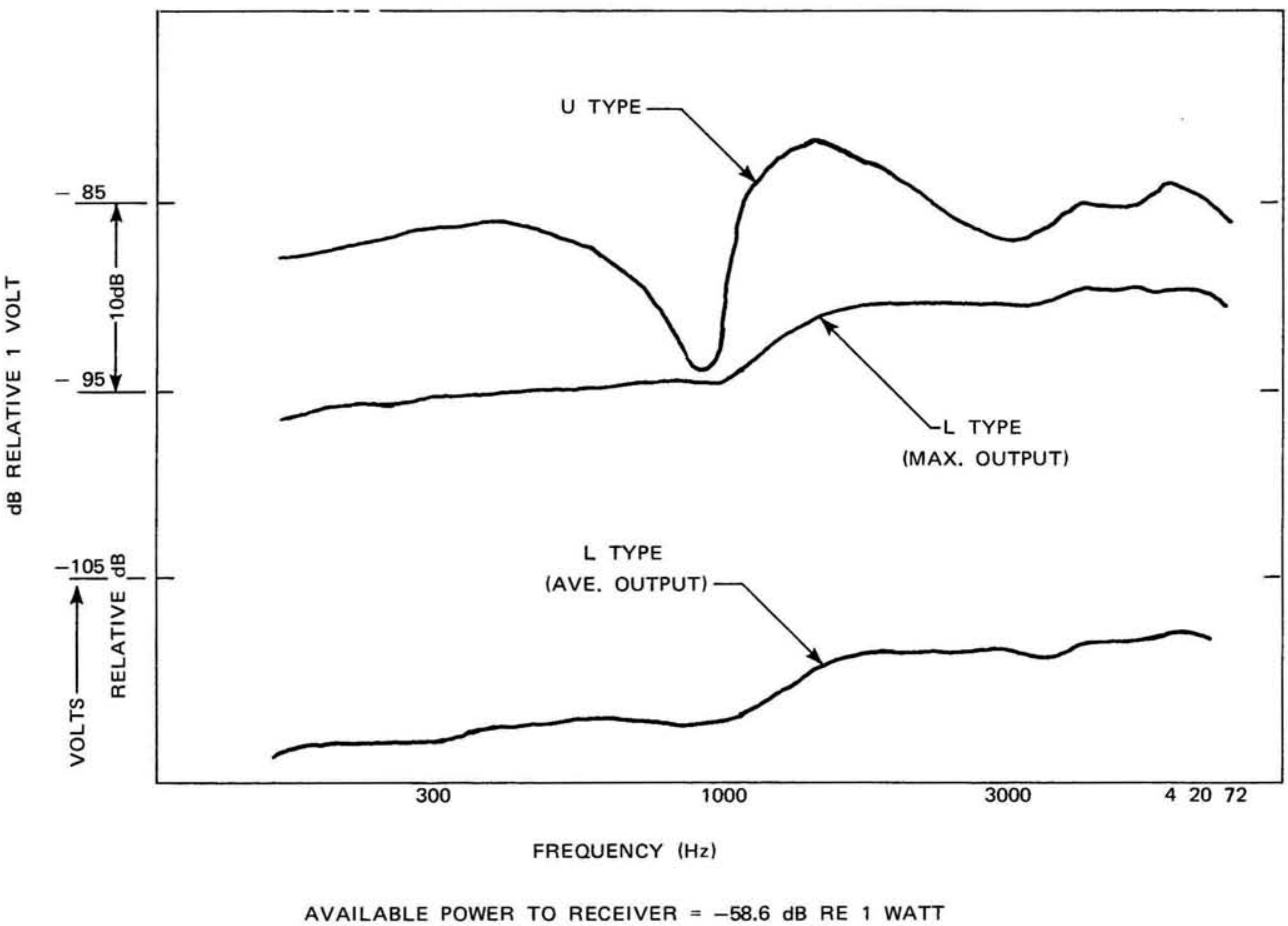
ACOUSTIC PRESSURE VERSUS FREQUENCY
A U–3 RECEIVER

FIG. 6



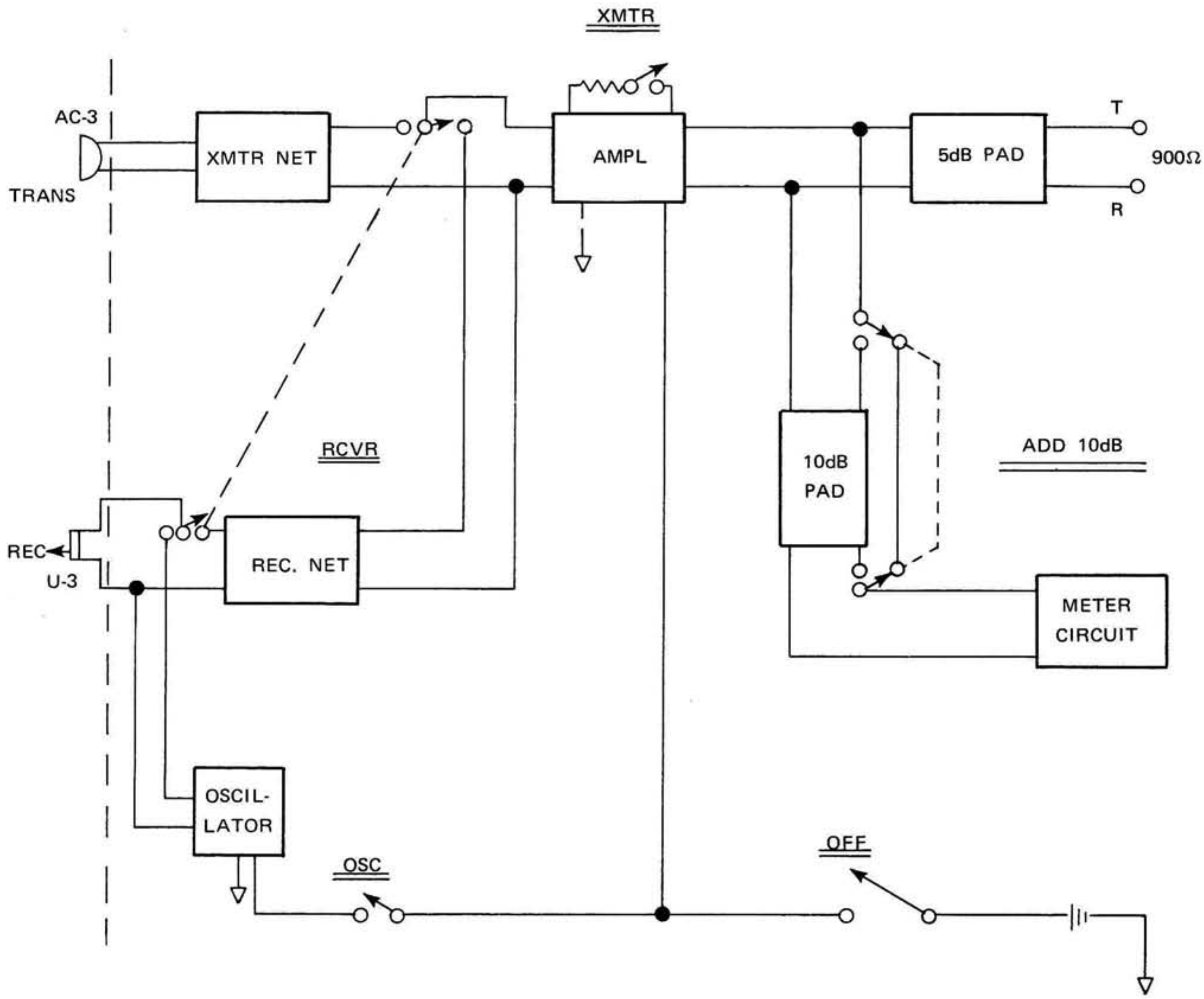
TYPICAL STATION-TO-STATION TOLL CALL
USING ACOUSTIC COUPLERS

FIG. 7



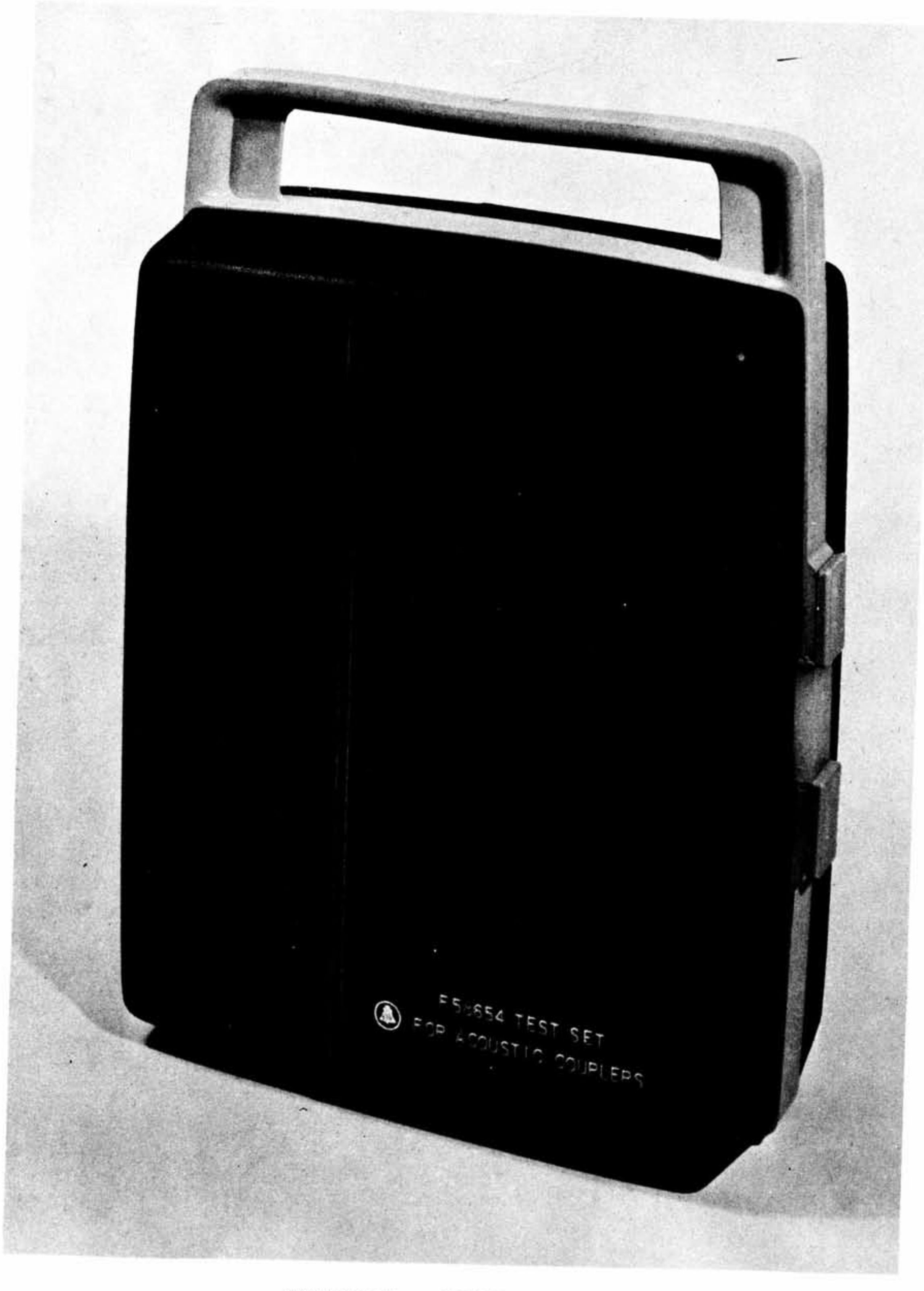
RADIATED FIELD FROM TEL SET RECEIVER

FIG. 8



BLOCK DIAGRAM: TEST SET

FIG. 9



TEST SET – COVER CLOSED

FIG. 10

TEST SET — COVER OPEN

FIG. 11

TEST SET – IN USE

FIG. 12