FIELD INTENSITY METER
MODEL FIM-72
OPERATING INSTRUCTIONS

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SECTION 2
OPERATION

2.1 GENERAL

This section contains the set-up instructions and operating procedures for the FIM-72 Field Intensity Meter. The information in this section is arranged as follows:

Par. Contents

2.2 General information on the FIM-72.
2.3 Description of controls, indicators and jacks.
2.4 Antenna (ANT-72) set-up and adjustment.
2.5 Typical procedures for measuring rf voltage.
2.6 Field strength calculations.
2.7 Typical procedures for measuring attenuation or gain.

It is recommended that the entire section be reviewed before attempting any field measurements. Additionally, the safety precautions on page ii should be reviewed before using the meter.

2.2 INITIAL SET-UP

To remove the cover from the FIM-72, release the four plastic latch fasteners holding it to the case. Note that the bottom fasteners are closer together than the top ones, so that the cover only fits one way. When replacing the cover, be careful to orient it this way before placing it over the front panel, since items in the cover could damage the meter if the cover is replaced upside down.

The FIM-72 may be mounted or held in several ways for measurements. If placed on a horizontal surface, it can be fastened down by a 1/4-20 screw in its tripod mount. It can be supported on a tripod using this mount. For rapid hand-held measurements it can be supported by a single tripod leg, the Potomac Instruments' Unipod. It can be carried for measurements by attaching the leather neck strap which is stored in the cover to the buttons on the sides of the case. This strap, passed behind the user's neck, supports the FIM-72 at about belt level with the front panel facing up toward the user. The short telescoping mast on the case can be secured so that it is vertical in such use.

2.3 CONTROLS AND INDICATORS

Figure 2-1 illustrates the location of the different controls, indicators and jacks on the FIM-72. Their function is described in the following paragraphs.

2.3.1 MODE Switch:

The MODE Switch selects the following modes of operation on the FIM-72:

CAL: The internal calibration signal source is turned on and switched into the receiver section's RF input in place of the input signal. The calibration generator output is closely controlled at a level of 100mV (−7 dBm) and its frequency tracks the receiver frequency.

REC: This is the normal operating mode for receiving and measuring external signals. The calibration generator is switched off in this mode.

AFC ON: Operation is the same as in REC except that the receiver is frequency-locked to the received signal so that frequency drift effects are eliminated. AFC operation is recommended if the FIM-72 must remain tuned to a signal for a long period of time for recording; but the FIM-72's stability is good enough that AFC is not needed for single measurments. If the FIM-72 is switched off when in the AFC mode, it will lock to the desired signal without adjustment when switched on again if there are no stronger signals nearby.

GEN OUT: The receiver operates as in REC but the calibration generator is turned on and switched into the external OSC OUT connector at a level of 100mV with a 50 ohm load. With the termination normally connected at OSC OUT removed, the signal may be fed through an external device to the RF IN connector for attenuation measurment; or to an RF bridge for return loss and VSWR measurement.

2.3.2 AUDIO Control:

Adjusts the audio power level applied to the speaker or PHONES jack. An internal switch, actuated at the 0 mark, removes power from the audio circuits.

2.3.3 POWER Switch:

OFF: Removes power from all circuits and short-circuits the meter terminals.

ON: Applies power to the FIM-72 and connects the meter to measuring circuits.

TEST: (Momentary) Applies power to the FIM-72 and switches the meter to indicate the battery voltage under load.

2.3.4 DEMOD Switch:

Connects the audio amplifier input to the output of either the AM demodulator or the FM demodulator according to its two positions. In the AM position, some slope detection of FM signals will occur when the receiver is off tune, and television vertical sync "buzz" at 60 Hz is much louder in the AM position.

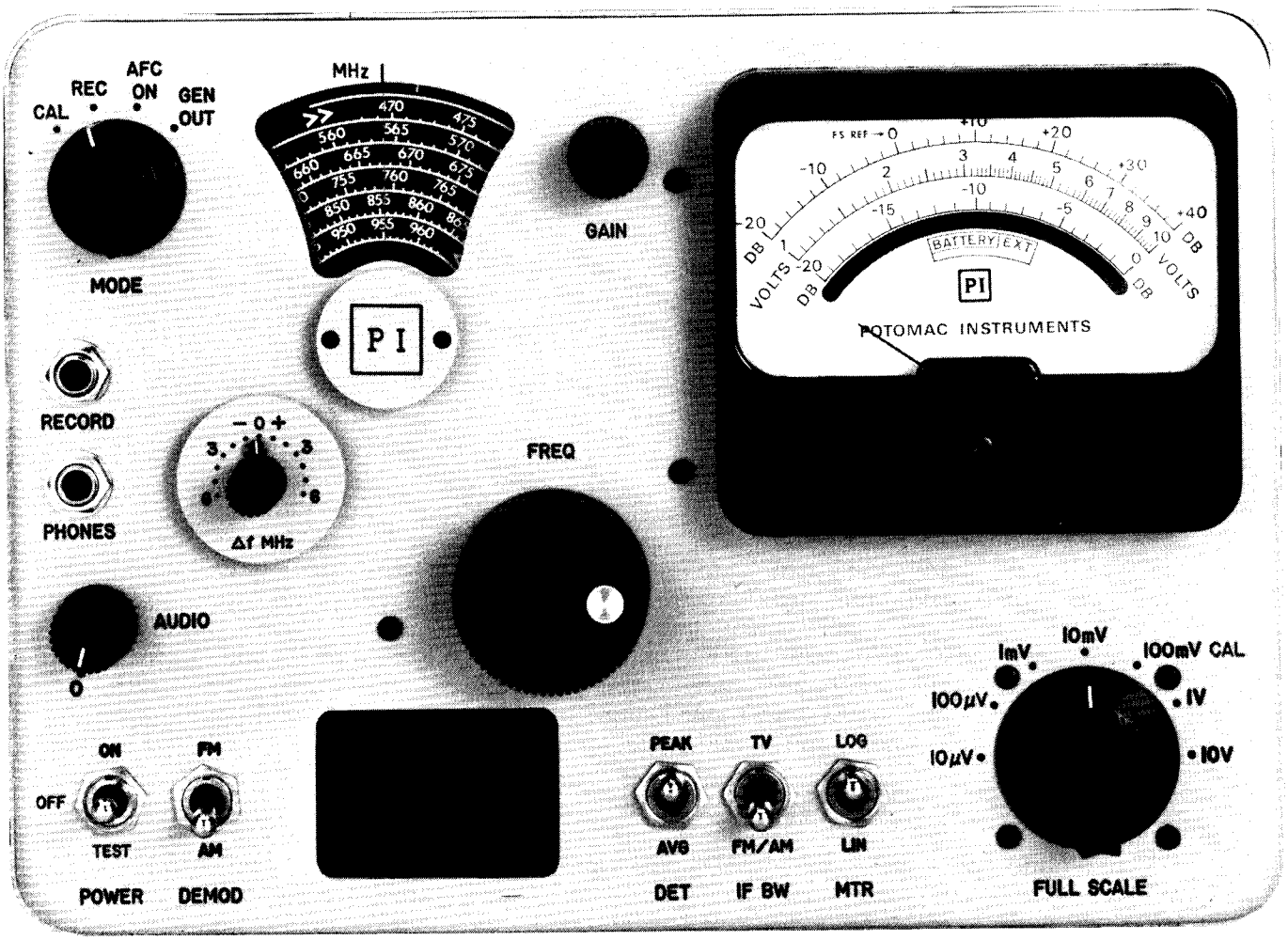


Figure 2-1. Operating Controls and Indicators

2.3.5 DET Switch:

Switches the meter to indicate either the average (AVG) or peak (PEAK) value of the amplitude detector output. In the AVG position, used for FM or double-sideband AM signals, the meter indicates the average value of the RMS RF voltage. In the PEAK position, used for television visual carrier measurements, the meter indicates the maximum value of the RMS RF voltage which occurs during the sync pulse. Note that for the PEAK position, meter indications must be corrected for noise effects as explained in Paragraph 2.6.

2.3.6 IF BW Switch:

Selects either of two bandwidths:

TV: For visual carrier measurement, has just enough bandwidth (500 kHz) to allow the sync pulse to reach maximum amplitude. Typical bandwidth is: ±480 kHz at −20 dB, ±690 kHz at −40 dB, ±940 kHz at −60 dB.

FM/AM: 200 kHz bandwidth, can be used for narrower-bandwidth signals when more out-of-band rejection is needed. Typical bandwidth is ±340 kHz at −20 dB, ±530 kHz at −40 dB, ±760 kHz at −60 dB.

2.3.7 MTR Switch:

LIN: Meter indicates RF voltage on the 1 to 10 scale or the −20 to 0 dB scale, with receiver gain constant.

LOG: Meter indicates RF voltage on the green −20 to +40 dB scale with receiver gain controlled by an AGC circuit. Note that the RF input level which produces a 0 dB meter indication in the LOG mode also produces a 0 dB indication in the LIN mode.

NOTE

The LIN mode provides better accuracy and less AM demodulator distortion, while the LOG mode provides greater measurement range and higher demodulator signal-to-noise ratio for signals above 0 dB.

2.3.8 FULL SCALE Switch:

Selects the voltage measurement range of the FIM-72. The voltage marked at each position of the switch is the RMS RF input voltage which produces a meter indication of 0 dB in either the LIN or LOG position of the MTR switch, when the calibration procedure has been performed. The 100 mV position, alsogmarked CAL in red, is used for this procedure.

2.3.9 GAIN Control:

Adjusts the receiver gain manually, in ten turns, and is normally set during the calibration procedure. In a typical FIM-72, the gain can be adjusted approximately 10 dB above and 20 dB below the correct value for calibration.

2.3.10 FREQ and Δf Controls:

The FREQ control adjusts the tuned frequency of the FIM-72 as indicated on the MHz dial. The dial scale is a spiral, and the line to read is indicated by a moving red pointer at the right-hand side of the dial window. The Δf control is a secondary frequency control with a range of ±6 MHz used to adjust out frequency errors.

NOTE

The frequency 680 MHz appears twice on the dial because two oscillators are used to cover the range. When tuning upwards the lower oscillator goes to approximately 685 MHz, at which point the higher oscillator takes over, starting at approximately 673 MHz and continuing upwards. Switching occurs at the same frequency when tuning downward, in the dial area marked X. Thus 680 MHz can be tuned by either oscillator.

2.3.11 RECORD Jack:

With a standard 1/4 inch two- or three-conductor phone plug inserted, the tip contact provides a DC voltage proportional to the meter indications on the voltage scale, approximately 0.8 volts to -8.0 volts with a source resistance of 2000 ohms.

NOTE

Potomac Instruments has available the Record Output Adaptor, Model RO-71, to adapt the record output to various recorders. It consists of two-conductor phone plug containing a 10,000 ohm variable resistor between the tip contact and the center conductor of a 6-foot shielded output cable with wire leads at the free end. The output short-circuit current with the meter at full scale can be adjusted from 0.8 to 4.0 milliamperes.

With a three-conductor plug, the ring contact provides the AFC control voltage, 5.3 V ± 3.5 V, with a source resistance of 10,000 ohms.

2.3.12 PHONES JACK:

With a standard 1/4 inch two-conductor phone plug inserted, the speaker is disconnected and the audio output is available at the tip contact with a source resistance of 75 ohms. The open-circuit output voltage is 9 volts peak-to-peak maximum with a frequency response of 30 Hz to 100 kHz, 3 dB maximum variation.

2.3.13 EXT PWR Connector:

Insertion of the mating connector (Switchcraft No. 760 plug) disconnects the internal battery supply and permits connection of an external DC power source. The voltage at the center conductor must be between −11.5 volts and −17.5 volts, including ripple peaks, at currents up to 420 milliamperes; with the center conductor negative and the outer shell (ground) positive.

NOTE

Potomac Instruments has available an external power supply, Model AC-72 AC Converter, which plugs into an AC power receptacle and supplies the required voltage and current. The converter may be switch selected for operation with 117 or 230 Vac.

2.3.14 RF INPUT Connector:

The input signal from an antenna or other source is applied at this point, which has an input impedance of 50 ohms. The FIM-72 in its basic function as a selective voltmeter indicates the voltage at this point when properly calibrated.

NOTE

The maximum permissable input levels should be carefully observed to avoid damage to the unit. These are as follows, given in power and in the corresponding voltage for a continuous signal without amplitude modulation.

FULL SCALE Switch Setting	Max. Power	Max. Voltage
10μV	32mW	1.25 V RMS
100μV	320mW	4.0
1mV-1V	1W	7.0
10 V	2W	10.0

2.3.15 OSC OUT Connector:

The internal calibrating signal generator output is available at this connector when the MODE switch is in the GEN OUT position. The level is closely controlled at 100mV $\pm$3.5mV (-7 dBm $\pm$0.3 dBm) with an accurate 50 ohm load. The frequency tracks the receiver tuned frequency exactly, so that the receiver can be set precisely to a frequency by measuring the OSC OUT frequency with a counter. The output can be used as a source for various measurements, with the output of the device under test being measured by the FIM-72 receiver.

NOTE

A captive coaxial terminating resistor is supplied connected to the OSC OUT connector. It must be connected at all times except when the GEN MODE is in use. Measurement errors will occur at frequencies near 550 MHz and 820 MHz if the termination is not connected when in the CAL Mode.

2.4 ANT-72 ANTENNA SET-UP AND ADJUSTMENT

The ANT-72 antenna setup consists of mounting the antenna on the desired mast, connecting a cable between antenna and FIM-72, and adjusting the length of the two telescoping antenna elements to the correct value for the measurement frequency.

It is important to use good quality 50 ohm coaxial cable, preferably double-shielded, such as type RG-223, to connect the antenna to the FIM-72 RF input. Such cables are supplied in the cover of the FIM-72. A short one (45 inches) is intended for use when the ANT-72 is on the short telescoping mast attached to the case, and a long one (34 feet) is for use when the ANT-72 is at a height of 30 feet.

Any antenna can be used for field strength measurements provided that it incorporates a balun providing a coaxial output with a 50 ohm source impedance, and that its output level for a given field strength or its gain is known.

2.4.1 Antenna Set-Up

The following steps detail the procedure for setting up the telescoping mast attached to the side of the FIM-72.

1. Unscrew the outer knob at the base of the mast (upper right-hand corner of FIM-72 case) as far as possible, approximately two (2) turns.

2. Pull out on the inner part of the mast mount to free its detent pins, and swing mast and antenna up until the detent pins fit into holes at one of two positions. In the first position, the mast is vertical when the panel faces upward; use this when the unit is carried with the neck strap. In the second position, the mast is vertical when the panel is vertical; use this for tripod or unipod mounting.

3. Screw in the outer knob to lock the mast in position.

4. If the neck strap is to be used, install it and pass it over your head to place the unit in carrying position.

5. Pull outward on the ANT-72 antenna box to extend the telescoping mast.

6. Connect the short (45 inch) RG-223 cable supplied in the FIM-72 cover between the ANT-72 and the FIM-72 RF input.

2.4.2 Antenna Storage

The following steps detail the recommended procedure for returning the telescoping mast to its storage position.

1. Press on the top of the ANT-72 box to collapse the telescoping mast.

2. Unscrew the outer knob at the base of the mast.

3. Pull out on the inner part of the mast mount to free its detent pins, and swing mast and antenna down, guiding the retainer button on the ANT-72 box into its slot low on the case.

4. See that the detent pins fit into their holes at the storage position (mast vertical), and screw in the outer knob.

2.4.3 Antenna Removal

The ANT-72 antenna may be removed from its telescoping mast by following the steps listed below.

1. Erect the telescoping mast (see 2.4.1), extending it only slightly.

2. Using a 7/16 inch open-end wrench to hold the hex head at the top of the mast, unscrew the ANT-72 from the mast. Use the 1/4-20 threaded mount thus exposed to mount the ANT-72 to another mast.

3. Connect a 50 ohm cable of suitable length between the ANT-72 and the FIM-72 RF input.

4. Collapse the short telescoping mast and return it to its stored position.

2.4.4 Antenna Adjustment with scale

The following steps detail the recommended procedure for adjusting the antenna elements using the scale supplied with the FIM-72. Refer to paragraph 2.4.5 if the scale is not available.

1. Remove the ANT-72 scale from its holder on top of the case by unscrewing the captive screw at the end toward the antenna.

2. Loosen the thumbscrew on the scale slider. Set the end of the slider nearest the two blocks to the desired frequency or channel number and tighten the thumbscrew hard to hold the slider securely in position.

3. Fully extend the ANT-72 elements.

4. Place the blank side of the scale against one element, with the element between the two blocks, the blocks toward the ANT-72 box, and the slider resting against the plastic tip of the element.

5. Push the scale toward the box as far as possible, with the slider compressing the element to the correct length, as shown in the illustration on the scale.

6. Pull the scale back slightly and remove it, being careful not to cause further movement of the element tip.

7. Repeat steps 4 through 6 for the other element.

8. Return the scale to its holder.

2.4.5 Antenna Adjustment without scale

The following procedure should be used to adjust the antenna elements using a standard scale.

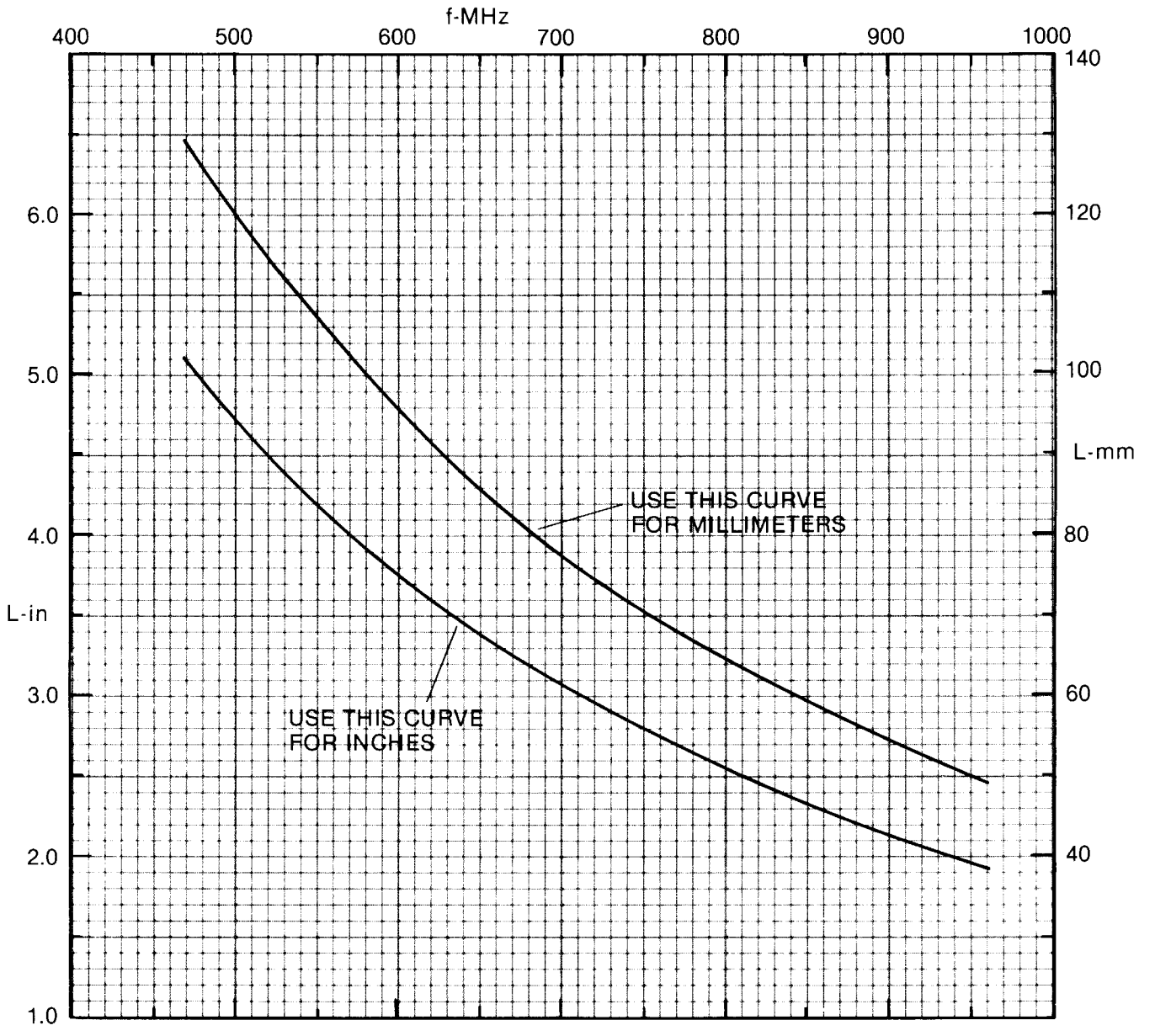
1. Obtain the required element length from Figure 2-2.

2. Fully extend both elements.

3. Place the scale along one element with the "zero" end of the scale against the ANT-72 box.

4. Press in on the plastic tip of the element until the outer end of the tip lies at the required length on the scale.

5. Repeat steps 3 and 4 for the other element.



Formulas for curves: $L = \frac{2910}{f} - 1.10$ f in MHz, L in inches

$L = \frac{73{,}914}{f} - 27.9$ f in MHz, L in millimeters

FIGURE 2-2 NOTE:

If the antenna element outer tips are metal, not orange plastic, subtract the following amounts from the lengths L given by the curves and formulas of Figure 2-2:

0.088 inches, or 2.2 millimeters

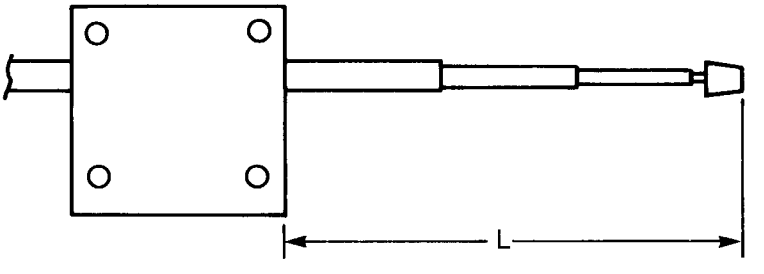


Figure 2-2. Antenna Element Length vs. Frequency

2.5 RF MEASUREMENTS

After the antenna is set-up and adjusted, the rf voltage of a selected signal may be measured by performing the following steps.

1. Set FIM-72 controls as follows (refer to paragraph 2.3 for a description of all controls):

MODE: REC

AUDIO: As required

POWER: OFF

DEMOD: FM or AM

DET: PEAK for visual carrier, AVG for other signals

IF BW: TV for visual carrier, either for other signals

MTR: LIN for 20 dB range or LOG for 60 dB range

FULL SCALE: as required

FREQ: for desired frequency on dial (red pointer at right side of window indicates scale to read)

ΔF: 0

If a recorder is to be used, connect it to the RECORD jack.

2. Switch POWER to TEST and see that the meter reading is within the BATTERY or EXT area. If the reading is outside the area, refer to Section 4 for power source and battery replacement data.

3. Switch POWER to ON.

4. Adjust FREQ and FULL SCALE controls to obtain the highest possible on-scale meter reading for the desired signal. Use AUDIO as required to identify the signal.

   The frequency dial error may be as much as 3 MHz at some points. This does not affect measurement accuracy, but if it is desired to have the dial read correctly, and the signal frequency is known, set the dial to that frequency and adjust the Δf control for maximum meter reading. If the initial dial indication was too high, adjust the Δf control in the + direction.

5. Switch both MODE and FULL SCALE switches to CAL position. Then adjust GAIN for a meter reading of 0 dB. The FIM-72 is now calibrated. If a chart recording is being made, cazibrating tracks can be made on the chart by using the GAIN and FULL SCALE control to obtain meter readings of the calibrating signal at the desired points. Then return the reading to 0 dB.

   For strong signals, readjust FREQ slightly if a beat between signal and calibration voltage causes fluctuation of the meter reading. No error will be introduced because gain changes very little with frequency.

6. Return MODE switch to REC, or to AFC ON if it is desired to lock the receiver tuning to the received signal.

7. Adjust the FULL SCALE switch for an on-scale reading as before, re-peaking the reading with the FREQ control if AFC is not used. The meter now indicates correctly the FIM-72 RF input voltage. Adjust antenna orientation for maximum meter reading, and record the meter reading and FULL SCALE switch setting. The voltage marked at each position of the FULL SCALE switch is the voltage at the 0 dB mark on the meter, which is at full scale for LIN (black scales) or approximately one-third full scale for LOG (green scale).

   Readings in dB above one microvolt (dBu) can be obtained directly by (1) recording the dB scale reading, and (2) subtracting this number from the dBu value for the FULL SCALE setting given in the following table:

FULL SCALE	dBu	FULL SCALE	dBu
10uV	+20	100mV	+100
100uV	+40	1V	+120
1mV	+60	10V	+140
10mV	+80		

For example, a reading of −7.4 dB on the 10mV range gives +80 − 7.4 = +72.6 dBu.

2.6 FIELD STRENGTH CALCULATIONS

Field strength is determined by (1) setting up an antenna and measuring its output with a selective voltmeter, as described in paragraph 2.5, and (2) calculating field strength from the measured output, which is described in this section.

2.6.1 Field Strength Formulas:

Field strength can be expressed directly in microvolts/millivolts/volts per meter (μV/M, mV/M, V/M) or in decibels above 1.0 microvolt per meter (dBuV/M, or more commonly, dBu). The form dBuV/M is used here because dBu is used to represent voltage in decibels above 1.0 microvolt.

Readings from the FIM-72 can be taken in either way as described in paragraph 2.5.

A. Field Strength Calculation in Decibels:

If the FIM-72 reading is taken in dBu, field strength E in dBuV/M is calculated from the reading e(dBu) as follows:

$$E(dBuV/M) = e(dBu) + A_d + A_c + A_a$$

A_d = detector correction loss. With the DET switch at AVG, $A_d = 0$. With the DET switch at PEAK, obtain A_d from the meter reading and FULL SCALE setting using Figure 2-3. For all values of e greater than +14 dBu, A_d is less than 0.3 dB and can usually be neglected ($A_d = 0$).

A_c = cable loss for the cable connecting the antenna to the FIM-72. Loss data for the cables supplied with the FIM-72 is included with the antenna factor data in Figure 2-4. For other cables made using RG-223/U cable, loss can be calculated from the following formula in the FIM-72's frequency range.

$A_c = (.0051 \sqrt{f} - .01)\, L$

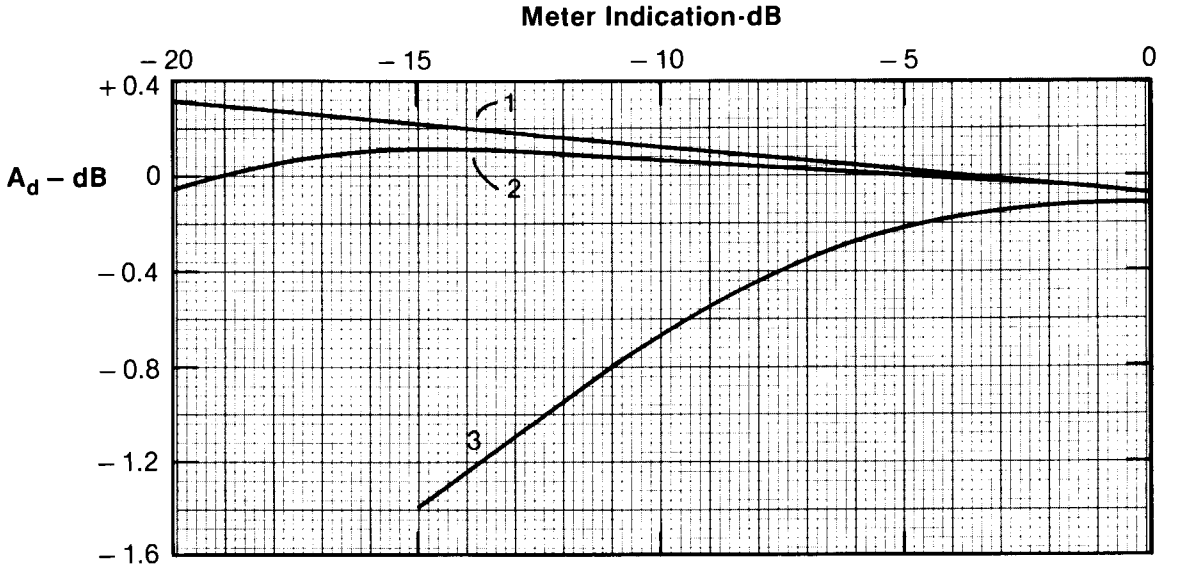
or $A_c (.0167 \sqrt{f} - .0328)\, L$

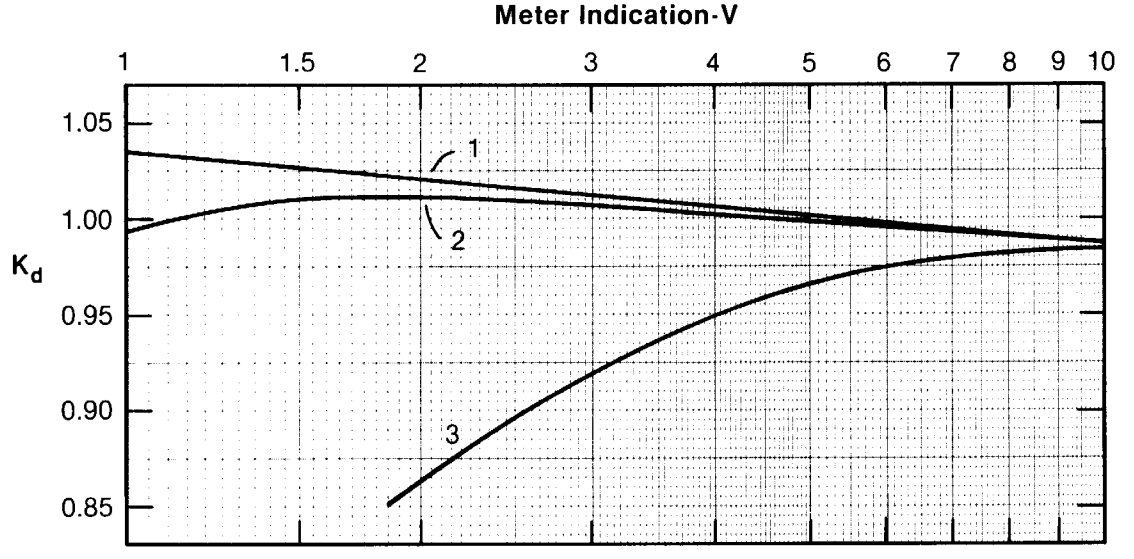
f = frequency in MHz
L = length in feet
A_c = cable loss in dB

L = length in meters

Cable loss can also be measured accurately using the method in paragraph 2.7.

A_a = antenna transfer loss, the difference in dB between the field strength in dBuV/M and the resulting antenna terminal voltage with 50 ohm load in dBu. Obtain A_a from Figure 2-4 for the ANT-72. For other antennas, if the gain is known, subtract it from the A_a value of Figure 2-4. If the gain is relative to an isotropic antenna, add 2.15 dB; if the gain is relative to a half-wave dipole, add nothing.





FULL SCALE Setting	Curve No.
10mV – 10V	1
100μ V & 1mV	2
10uV	3

Figure 2-3. Peak Detector Correction Data

If the ANT-72 and one of the FIM-72 cables is used, the calculation of field strength can be simplified to the following:

$E(dBuV/M) = e(dBu) + A_T$

A_T = overall correction loss from Figure 2-4 for the combination of the ANT-72 and the 45-inch or 34-foot cable.

If the peak detector was used, the detector correction loss could also be added, but the maximum error due to neglecting it is less than 0.3 dB for value of e greater than +14 dBu.

B. Field Strength Calculation in Voltage:

If the FIM-72 reading is taken in volts, field strength E is calculated from the reading e (V) as follows:

$E = e(V) \times K_d \times K_c \times K_a$

K_d = detector correction factor. For the AVG position of the DET switch, $K_d = 1$. For the PEAK position of the DET switch, obtain K_d from the meter reading and FULL SCALE setting using Figure 2-3.

K_c = cable loss factor, the ratio of input voltage to output voltage for the cable connecting the antenna to the FIM-72. To obtain K_c, determine A_c in dB as described in paragraph 2.6.1(A), and convert it to the equivalent voltage ratio. K_c is a number greater than 1.0.

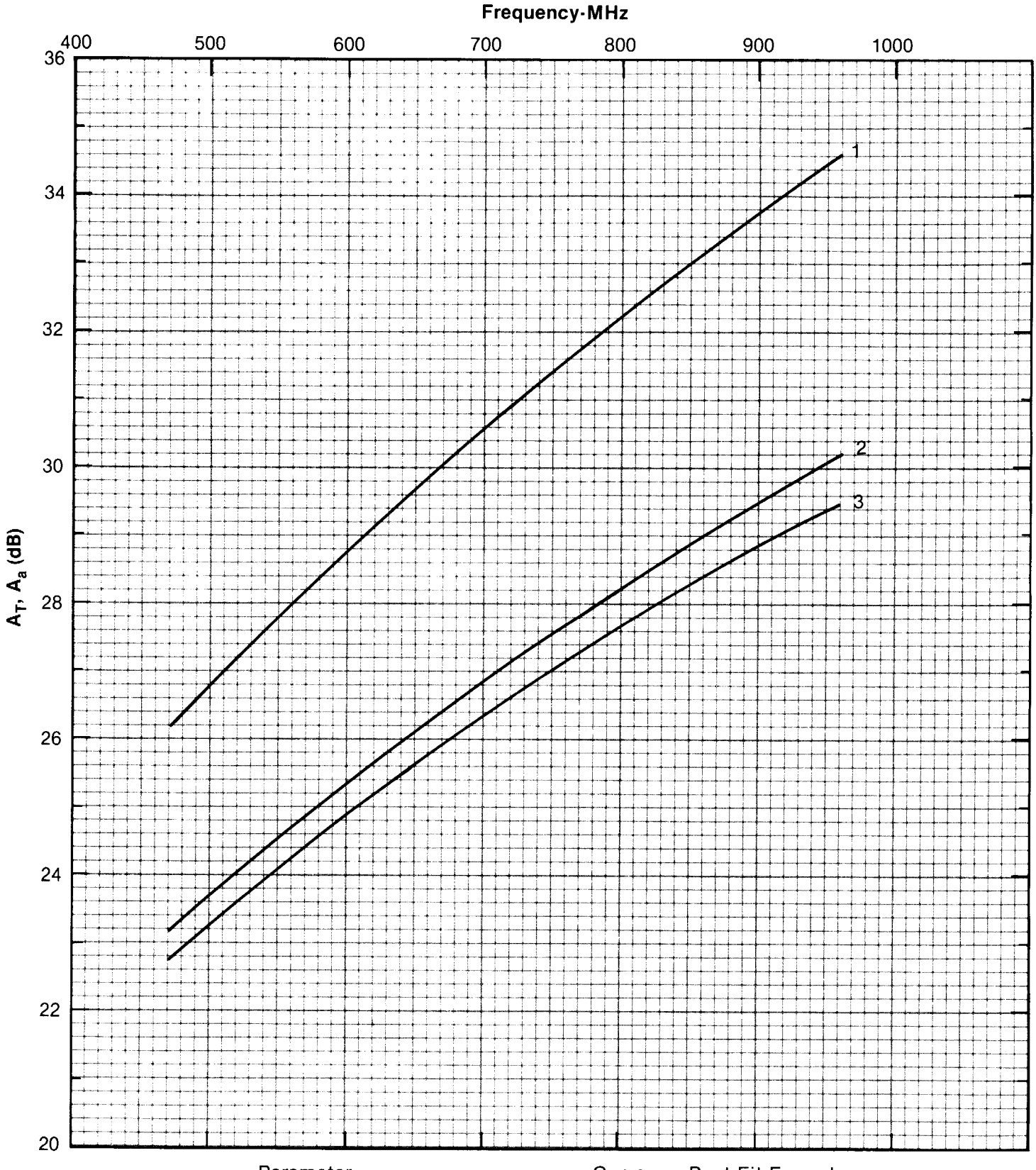
K_a = antenna factor, the ratio of field strength to resulting terminal voltage for the antenna in use. Obtain K_a from Figure 2-5 for the ANT-72. For other antenna, if the gain is known, convert it to a ratio (greater than 1.0) and divide the K_a from Figure 2-5 by this value. If the gain is relative to an isotropic antenna, multiply the result by 1.28; if the gain is relative to a half-wave dipole, do not do so.

If the ANT-72 and one of the FIM-72 cables is used, the calculation can be simplified to the following:

$E = e(V) \times K_T$

K_T = overall correction factor from Figure 2-5 for the combination of the ANT-72 and the 45-inch or 34-foot cable.

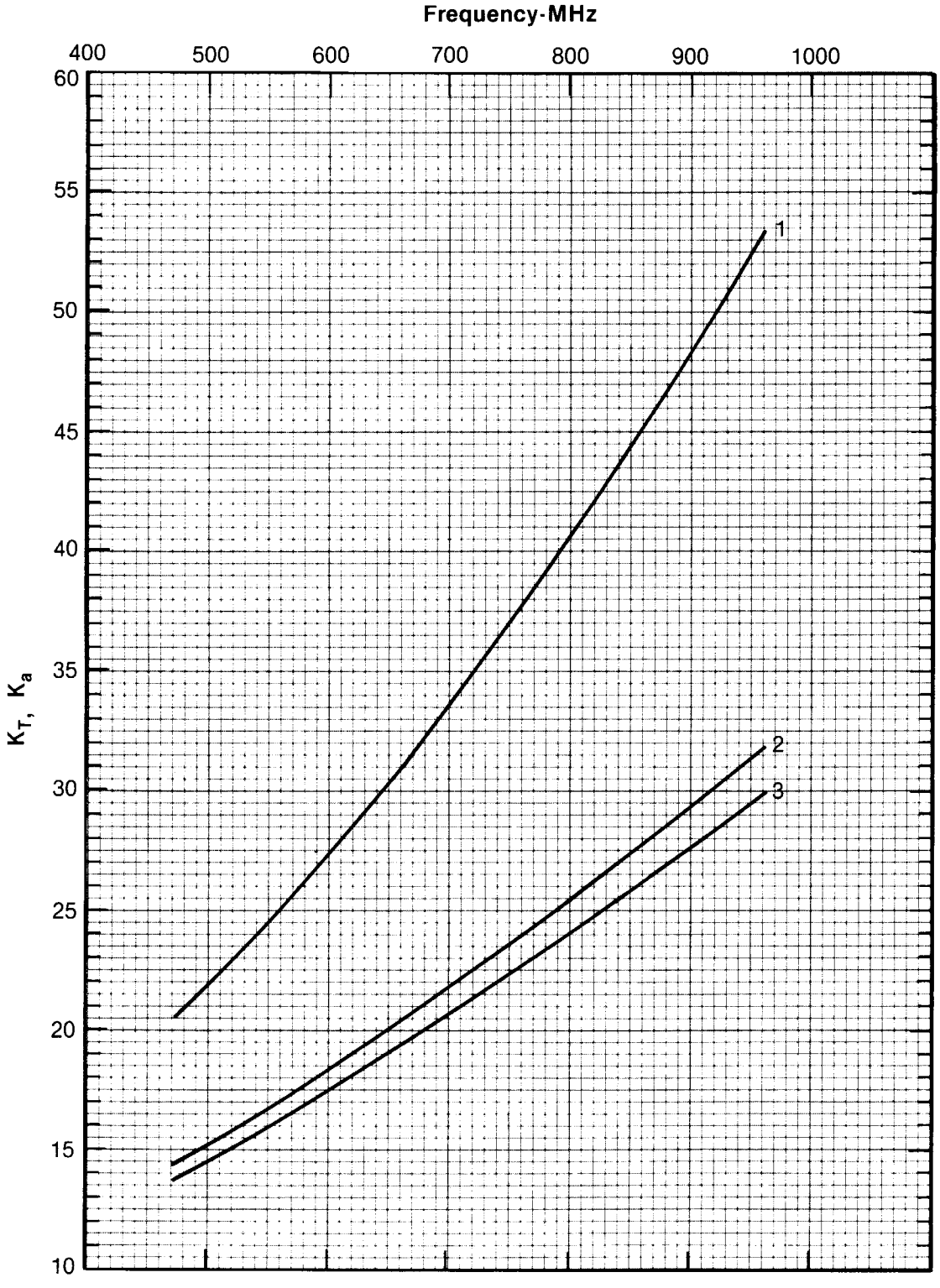
If the peak detector was used, the error for neglecting its correction is less than 3 percent for values of e greater than 50μV.



Parameter	Curve	Best Fit Formula
A_T for ANT-72 with 34 ft. RG-223-U cable	1	$2.391f^{0.389}$
A_T for ANT-72 with 45 in. RG-223-U cable	2	$2.407f^{0.368}$
A_a for ANT-72 alone	3	$2.410f^{0.365}$

Curves based on calibration by National Bureau of Standards, Boulder, Colorado. (NBS Test No. 810955, 21 August 1984)

Figure 2-4. Antenna Factor and Cable Loss (dB)



Parameter	Curve	Best Fit Formula
K_T for ANT-72 with 34 ft. RG-223/U cable	1	$.004927f^{1.350}$
K_T for ANT-72 with 45 in. RG-223/U cable	2	$.01441f^{1.120}$
K_a for ANT-72 alone	3	$.01654f^{1.091}$

Curves based on calibration by National Bureau of Standards, Boulder, Colorado. (NBS Test No.810955, 21 August 1984)

Figure 2-5. Antenna Factor and Cable Loss (ratio)

2.6.2 Antenna Calibration:

The antenna factor data as given in Figures 2-4 and 2-5, is usually determined by placing the antenna in a calibrating field of known strength and measuring the resulting output voltage with an accurate load. For the ANT-72 this calibration is done by the National Bureau of Standards (NBS) in Boulder, Colorado. One ANT-72 is sent to NBS for calibration and is then maintained at Potomac Instruments as the standard with which production units are compared.

2.6.3 Measurement Errors:

Many factors contribute to the overall field strength measurement error. Those contributing to voltage measurement error are as follows:

Parameter	Error (typical)
Calibration at 100 mV	±0.2 dB
Meter and detector linearity	LIN, ±0.2 dB; LOG, ±0.7 dB
Full scale range attenuation	±0.3 dB
Total	LIN, ±0.7 dB; LOG, ±1.2 dB

For field strength measurement there are these additional factors:

Cable attenuation	±0.1 dB
NBS calibration	±1.4 dB
Total	LIN, ±2.2 dB; LOG, ±2.7 dB

An additional error may occur in hand-held measurements in which the antenna is close to the instrument, caused by reflections from the instrument and user. At several frequencies in the range of the FIM-71, its case dimensions are multiples of one-half wavelength and reflections may be severe. The effect on absolute accuracy of field strength measurements can be large and difficult to predict. Relative measurements may be more useful if the relative orientation of antenna, instrument, user, and source is the same for all measurements.

2.7 ATTENUATION AND GAIN MEASUREMENTS

The following steps provide general guidelines to be used when making attenuation and gain measurements.

1. Connect the cable or other device to be measured between the OSC OUT and RF INPUT terminals of the FIM-72.

2. Operate the FIM-72 at the desired frequency with the MTR switch at LIN or at LOG if greater range with less accuracy is desired.

3. Switch both MODE and FULL SCALE switches to CAL and adjust GAIN for a meter reading of 0 dB (full scale).

4. Switch the MODE switch to GEN OUT, switch the FULL SCALE switch to a lower range if necessary, and record the meter reading and FULL SCALE setting. The dB scale gives the desired attenuation in dB directly after subtracting 0.2 dB from the reading to correct for losses within the FIM-72.

An alternative method that does not depend on the internal calibration system is contained in the following steps.

1. Connect a short 50 ohm cable between OSC OUT and RF INPUT terminals.

2. Operate the FIM-72 at the desired frequency with the MTR switch at LIN or LOG, and MODE switch at GEN OUT.

3. Pick a meter scale reference point, usually 0 dB, and adjust the GAIN control for a reading at this point.

4. Connect the device or cable to be measured in series with the cable between OSC OUT and RF IN. Record the meter reading and FULL SCALE setting. The difference between this reading and that of Step 3 gives the desired attenuation.