Heathkit of the Month #126:
by Bob Eckweiler, AF6C

Heathkit

AMATEUR RADIO - SWL

Heathkit AM-1 Antenna Impedance Meter

Introduction:

The AM-1 Antenna Impedance Meter (**Figure 1**) was the fifth amateur product introduced by Heathkit. In September of 1952 Heathkit entered the field of amateur radio in a very gentle manner with the GD-1 Grid Dip Meter[1]. They already made a shortwave receiver, the AR-1 that covered the broadcast band and up to 20 mc. But without a BFO or any band-spread and no ham band markings, it was not suitable as an amateur receiver[2].

Heath had tried its hand back in 1948, advertising an Amateur Transmitter under the Heathkit brand for $19.95. A separate power supply was offered for an additional $10.00. The ad only appeared for a couple of months and whether any were ever shipped appears lost to history. Also, around the same time, Heath offered a non-Heathkit branded 1–watt 80 meter "midget" transmitter kit utilizing a converted WW-II walkie-talkie module for $3.95 (less key and 4 pounds of batteries!) Chuck Penson – WA7ZZE discusses both in the forward to the 3rd edition of his ***Heathkit – A Guide to the Amateur Radio Products*** book[3], which belongs in every Heath aficionado's library.

Here is a link to the index of Heathkit of the Month (HotM) articles:

http://www.w6ze.org/Heathkit/Heathkit_Index.html

1. Notes begin on page 8.

Figure 1: The Heathkit AM-1 Antenna Impedance Meter. The fifth Heathkit amateur product.
Photo: Bob-AF6C

Some might classify the Grid Dip meter as test equipment instead of amateur gear, but Heath included it in the amateur sections, (**See Figure 2**). It is primarily a device for checking and designing antennas, traps, and tuned circuits in amateur equipment. The GD-1 sold well and Heath upgraded it to the GD-1A in time for the main 1953 catalog.

In early 1953, too late to make the main 1953 catalog, Heathkit released the – soon to be very popular – AT-1 Amateur Transmitter. It appeared in the Spring 1953 catalog and sold for $29.50. That summer's catalog introduced the AC-1 antenna coupler[4] for ($14.50) It was announced boldly on the last page, but hidden within the AT-1 description

HAM RADIO

Last fall the Heath Company entered the ham radio field with the announcement and introduction of the now famous Heathkit GD-1A Grid Dip Meter. This Spring a new Heathkit Transmitter Kit was announced, which in turn was followed by the release of an Antenna Coupler, and an entirely new Communications Receiver kit. Your response to the Grid Dipper was tremendous and this high degree of acceptance was directly responsible for further exploration of ham radio by the Heath Company.

The Heath Company feels that Heathkits have a definite place in the amateur radio field, and have many interesting possibilities to offer. For this reason, we would appreciate your cooperation and request that you drop us a line indicating the type of ham radio equipment you would like to see in Heathkit form. Your cooperation in this matter will be appreciated and every suggestion offered will be given very careful consideration. Keep in mind that there are some necessary qualifications for a successful Heathkit, such as; the proposed kit must lend itself to convenient kit construction; the suggestion must also appeal to a wide group rather than to a limited few; there must be sufficiently good demand for the suggested item in order to obtain the necessary production volume.

The appearance of additional Heathkit ham gear depends on you. Let us have your suggestions for new equipment as well as any suggestions pertaining to present Heathkit ham equipment.

FIGURE 2: Heath discusses its start in the field of "ham" radio kits in a short essay on page 6 of the Summer 1953 Flyer. On page 2 the AR-2 receiver is introduced, as is the AC-1 antenna coupler (within the AT-1 ham transmitter or page 3). The GD-1A is shown on page 6.

on page 3. Also introduced was the AR-2, a communications receiver ($25.50)[5] that could be used with the AT-1 for amateur radio. Also in that Summer catalog was a dedication from Heathkit promising to grow into the amateur radio field and asking customers for product suggestions. (again **Figure 2**).

The Heathkit AM-1 Kit:

The AM-1 was introduced in the fall of 1953 for $14.50. **Figure 3** shows an ad for the AM-1**.** The AM-1 continued to be offered for sale until around mid-1960. It was absent in the Fall / Winter 1960-61 catalog. Its demise was probably due to the AM-2 SWR meter[6], which came out in late 1957, was easier to use and became very popular. Shortly after the AM-2 was released the AM-1 was only advertised in the full catalogs, but not the abbreviated catalogs, which gave favor to the $15.95 AM-2.

The AM-1 Specifications:

Here are the specifications[7] for the AM-1 from the manual [595-79]:

Frequency Range:	0 - 150 megacycles
Impedance Range:	0 - 600 ohms
Null Indicator:	100 µ ampere meter
Dimensions:	2½" x 3" x 7"

Figure 3: Early ad for the AM-3 from the Winter 1953-1954 Heathkit Flyer. This is the fifth Amateur product offered by Heathkit.

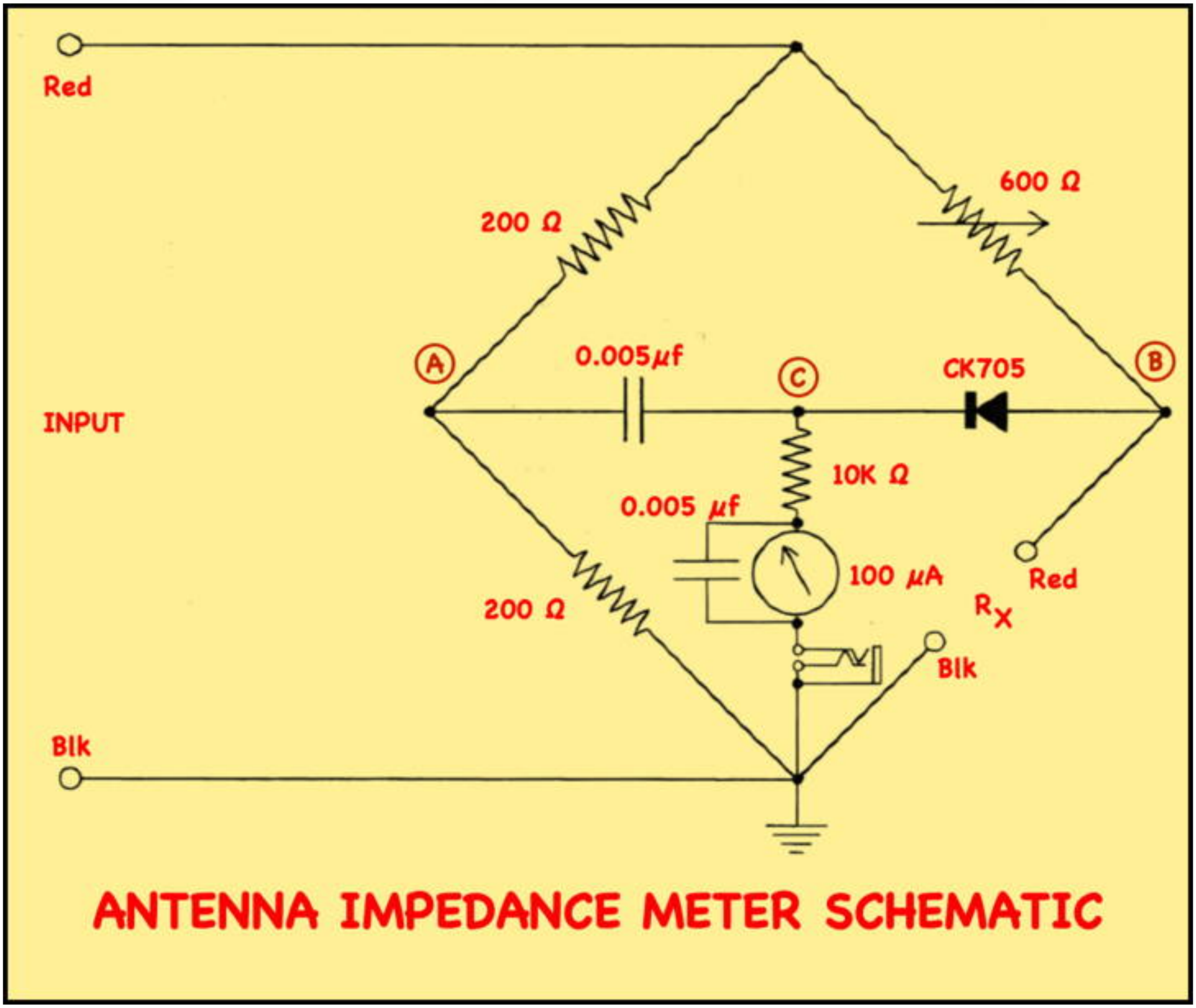

FIGURE 4: An author annotated schematic of the AM-1. Points A, B and C are discussed in the circuit description section. Looking at the front of the AM-1 with the meter at the bottom, the binding posts on the left are the **INPUT.** And the binding posts on the right are **Rx**.

Net Weight: 1 lb.
Shipping Weight: 3 lbs.

One might be surprised that the frequency specification goes down to zero, but you can connect a pen-light battery to the **INPUT** (+ to the red post) and place an unknown resistor between 1 Ω and 600 Ω across Rx and read the resistance by turning the control until the meter nulls. *It is suggested you add a 5K - 6K Ω resistor in series with the pen light battery to prevent the meter from a 50% over-travel and possible damage.*

No specification is given for the maximum power that can be applied to the INPUT terminals but, in the manual ½ watt is mentioned. This is probably because Heath assumed it would be used with a grid-dip meter. If using a directly connected signal generator, start with maximum attenuation and, with the AM-1 in an unbalanced condition, increase the amplitude until the meter reaches near full scale.

The AM-1 Circuit Description:

Figure 4 is an author annotated schematic of the AM-1. Notice that there are no batteries or other power source. Power is provided by the grid dip meter or signal generator, coupled to the INPUT binding posts. The circuit itself is a simple bridge. Two precision 200 Ω resistors divide the input RF voltage in half at point A. The voltage at point B depends on the setting of the potentiometer and the impedance to be measured RX. When the variable resistor is adjusted to a point where it is equal to the resistive component of the unknown impedance RX, the voltage at point B will also be at half the input voltage, and the RF voltage between points A and B will be at or near zero. This RF voltage between points A and B is rectified by the CK705 diode and filtered by the 0.005 µf capacitor producing a DC voltage, relative in value to the RF voltage, at point C. The 10K Ω resistor limits the meter current so 1 volt DC at C will cause full scale meter deflection. any residual RF voltage is bypassed by the second 0.005 µf capacitor across the meter. When the bridge is balanced the meter will be at a minimum reading close to or at zero.

At the time the AM-1 was released a majority of hams were using balanced feed-lines, usually operating at impedances between 200 and 600 ohms. Coaxial feed-line, much of it WWII surplus, was becoming available, but was not in heavy use and offered numerous advantages over balanced feed-line at the cost of higher losses, especially at high SWR.

AM-1 Operation:

Using the AM-1 requires a bit of work. Unlike the AM-2 SWR bridge which sits in your coax feed-line while operating your radio, the AM-1 needs to be connected either, directly at the antenna terminals, or at the far end of a feedline that is a multiple ½ electrical wavelength in length at the measured frequency. The AM-1 may be used to trim a length of feedline to the desired multiple half wavelength, (and also to a ¼ wavelength when needed). These lengths of feedline have magical properties for antenna testing, trapping and adjustment. **(See Sidebar)**.

AM-1 Operation:

Refer to **Figure 5** and link-couple your grid dip meter to the input terminals of the AM-1. The link should have about 1½ turns when testing above 15 mc and 3½ turns below 15 mc. The amount of turns is not critical. Add a turn if more excitation is needed.

To measure the impedance of an antenna, connect the AM-1 RX terminals directly to the antenna with leads as short as possible, or use a feed line that is a multiple half-wavelength at the measurement frequency. Set the grid-dip meter to the desired test frequency[8]. Adjust the dial on the AM-1 for minimum meter reading and read the resistive impedance on the dial.

To find the electrical half-wavelength length use the following formula:

$$\lambda_{1/2} = \frac{491.79 * V_f}{F_{mc}}$$

Where:

$\lambda_{1/2}$ = ½ Wavelength in feet at F_{mc}.
F_{mc} = Frequency in megacycles (MHz)
V_f = Velocity factor[9] of transmission line.

Select a multiple of $\lambda_{1/2}$ that fits your requirements, cut your feed line a bit on the long side, and with the far end of the transmission line shorted and the dial on the AM-1 at zero, adjust the grid dip frequency for a

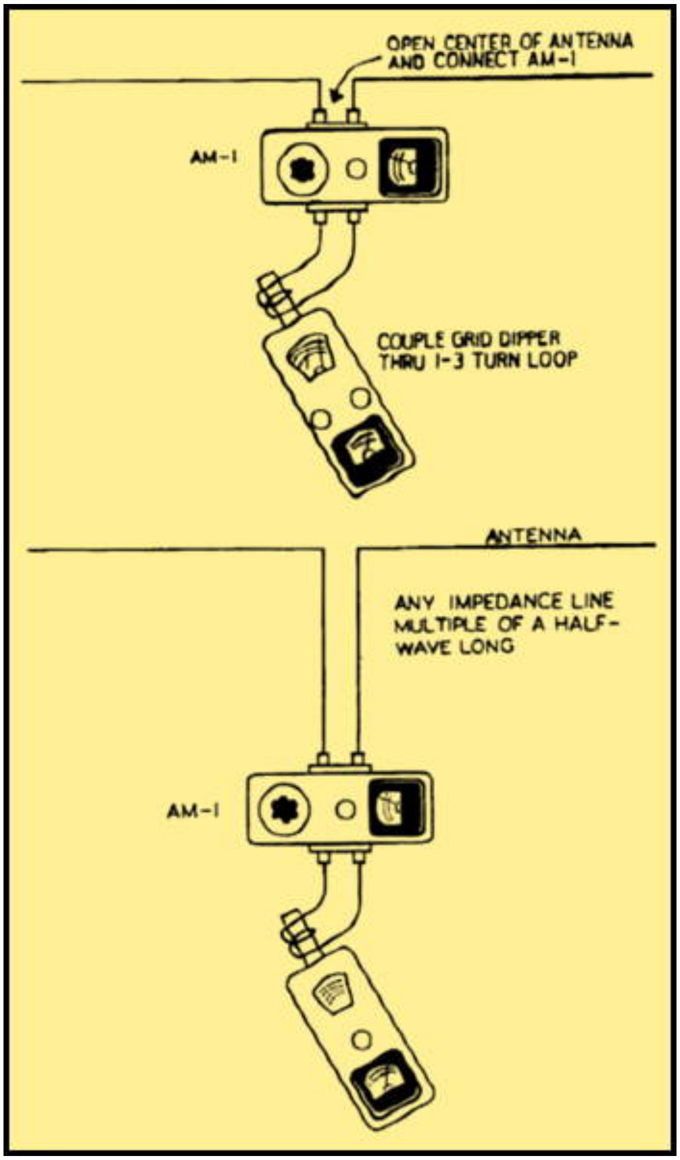

Figure 5: Top view shows making a measurement at the antenna terminals. Bottom view shows using a transmission line to make the measurement away from the antenna. The transmission line should be a multiple of the electrical ½-wave at the test frequency. The AM-1 may be used to find the correct length.

null on the meter. Read the frequency; it should be lower than desired. Remove a short piece of the transmission line and remeasure. Continue shortening the line until the null occurs at the desired frequency. Your transmission line is now an accurate multiple half-wavelength at that frequency. Connect the far end of the transmission line to the antenna, and measure the antenna impedance at the near end of the transmission line. The multiple half-wavelengths will reflect the same impedance as the antenna feed point, at that frequency.

The AM-1 has many other uses, like finding a receiver's input impedance, adjusting harmonic antennas, quarter-wave and ground-plane vertical antennas, mobile antennas, monitoring AM audio while transmitting, measuring relative field strength, and adjusting Q-bars (quarter-wave transformers). Instructions are in the manual. A partial copy of the manual is available online.

Assembly:
The parts that mount on the cabinet, with an open front and rear, are assembled first. Four binding posts, two on each side, mount on polystyrene insulators. The cabinet hole for the hot (red) binding posts has a large hole to reduce capacitance to the cabinet. See **Figure 6**. The cabinet is then set aside till

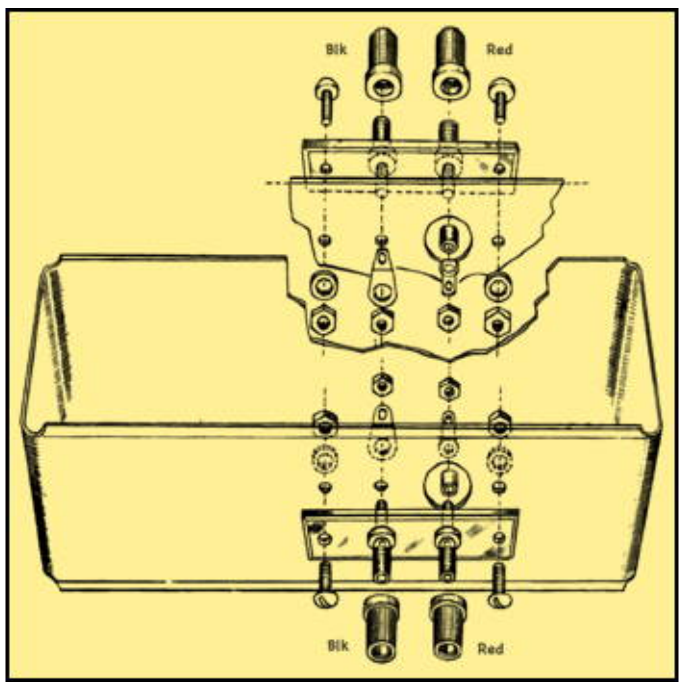

Figure 6: Polystyrene insulators rude input capacitance between terminals and the cabinet.

later, and a chassis is assembled, comprised of two metal brackets and a flat, drilled insulator. The 600 Ω variable resistor control is mounted to the insulator section of the chassis assembly, and an insulated shaft is attached. Thus the control is isolated from the conductive surroundings, again to reduce stray capacitance. The meter is attached to the front panel, and the chassis assembly is also attached to the front panel, using the ¼" phone jack. The insulated shaft extension should fit through the hole in the front panel. Initial wiring is begun; the meter and phone jack are wired along with the two 0.005 µf capacitors, the 10 KΩ resistor, the CK705 diode and the two 200 Ω precision resistors. Other wiring is added to complete the circuitry, except for the wires to the binding posts, which are installed but left unconnected at the binding post end. (**Figure 7**). The cabinet is then placed over the front panel – chassis assembly, and the unconnected wires are soldered to the binding posts. (**Figure 8**). **Figure 9** and **Figure 10** are photos of an AM-1 with the rear cover removed.

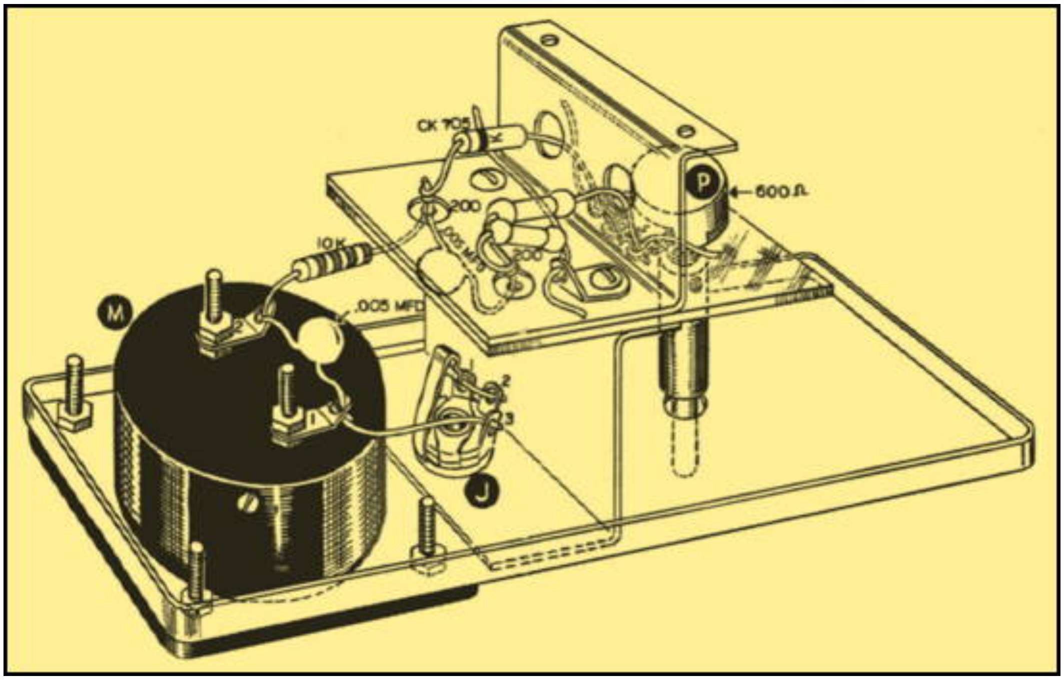

Figure 7: Wiring of the chassis assembly and front panel.

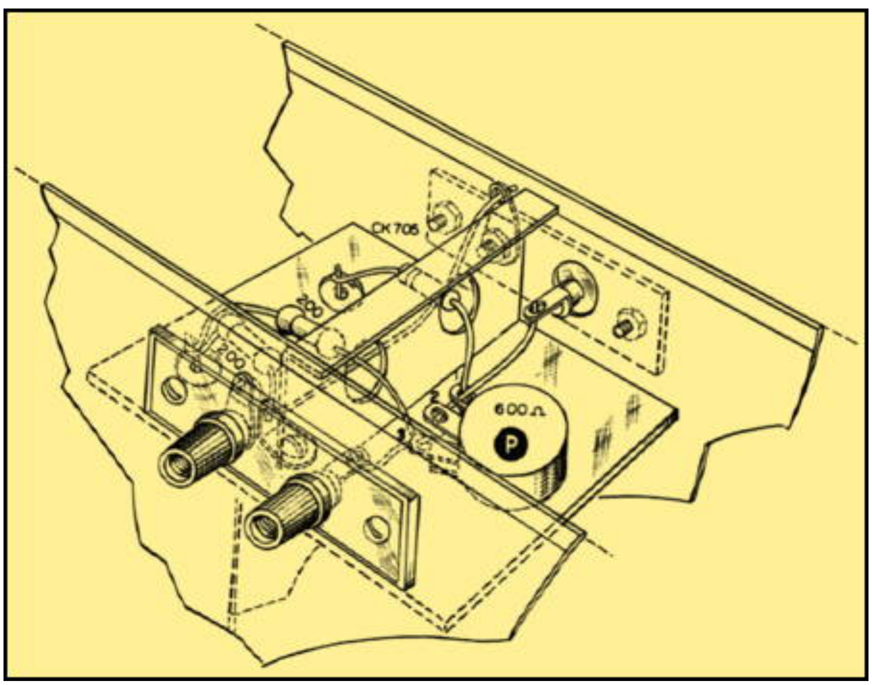

Figure 8: Wiring of the chassis assembly and binding posts.

Once the control knob is added, the feet are attached to the back panel, and the back panel is mounted to the rear of the cabinet. then checkout and calibration begin.

AM-1 Calibration:

The markings on the skirt of the control knob are coarse since the controls vary somewhat. However, the skirt of the knob is frosted and

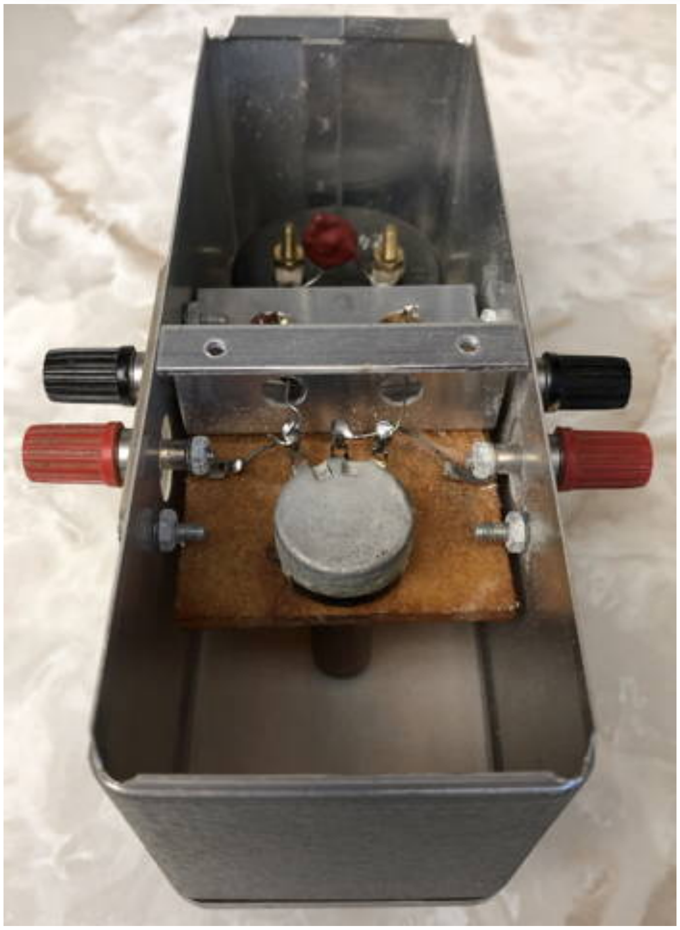

Figure 9: The AM-1 with the rear cover off, looking in with the top towards you. Note the two red binding posts. The back of the control is mounted on the insulated plate with the insulated shaft extending through the front panel for isolation.

Photo : Bob - AF6C

Figure 10: The AM-1 with the rear cover off, looking in with the bottom towards you. The meter is visible lower center with a 0.005 capacitor across its terminals and the 10K resistor off the terminal to the left. Above the chassis are the diode (left) and the two precision resistors (right). Just visible sticking out below the chassis (center) is the other 0.005 capacitor.

Photo : Bob - AF6C

can be marked on with a pencil (and easily erased if a new calibration becomes necessary). To calibrate the AM-1 you can use an ohmmeter, resistance bridge, or another instrument that measures resistance accurately. In the manual Heath tells how to age the control; however, since it's over 60 years it's already well aged! To isolate the AM-1 meter circuit, an unwired phone plug needs to be plugged into the **PHONES** jack. The resistance of the control may now be measured between the AM-1's two red binding posts. Using a pencil, mark the knob skirt with accurate notations.

Comments:

While the AM-1 was a versatile instrument in its day, it was most useful measuring wire antennas, especially when fed with a balanced feed line. However, the convenience of 50Ω and 72Ω unbalanced coaxial transmission cable, even with its higher losses, soon became the transmission line of choice for hams. With the introduction of the AM-2 SWR Bridge reflectometer, a 50Ω / 72Ω instrument that could be left in the line to continuously register SWR, hams quickly started favoring the AM-2 over the AM-1. What the AM-2 lacked in versatility it made up in convenience. Still the AM-1 had uses for trimming feed lines and stubs to specific lengths.

I'm currently exploring a non-Heathkit article for a radio magazine. If it comes to be, I'll first mention where, here. Until then, my Heath articles might slow down some. But, they will be back, and hopefully with me learning improved writing skills in the process.

73, from AF6C

Notes:

1. In HotM #7 The later solid-state Heathkit HD-1250 was covered. In the introduction of that article the Heathkit GD-1, GD-1A & GD-1B are briefly discussed, as is the HM-10 "Tunnel [diode] Dipper".
2. The first Heathkit modification article published in QST was to convert the AR-1 by adding a BFO AVC, RF gain control, bandspread with vernier drive and a phone jack. Modifying the Heathkit AR-1 Receiver for Amateur Use
3. Heathkit – A Guide to the Amateur Radio Products (Third Edition) 2021, by Chuck Penson. ISBN 978-0-578-91051-2. The book is currently **SOLD OUT**. A second printing is currently pending.
4. The AC-1 is featured in HotM #13 (February 2009). It is available at: https://www.w6ze.org/Heathkit/Heathkit_013_AC1.pdf
5. The AR-2 kit came complete with all parts and tubes, but not a cabinet. Heath separately sold a Proxylin impregnated fabric covered plywood cabinet (Part # 91-10) for $4.50.
6. The AM-2 is featured in HotM #37 (January 2012): https://www.w6ze.org/Heathkit/Heathkit_037_AM2.pdf
7. In keeping with the period of the kit kc is used instead of kHz, mc instead of MHz, and µµf instead of pf.
8. The dial accuracy of most Grid Dip Oscillators (GDOs) is pretty coarse. A communications receiver located nearby with a short antenna can be used to more accurately determine (or set) the GDO frequency.
9. Velocity Factors vary with transmission line manufactures as well as type of feed line. Here's some approximate numbers: (For coax) Polyethylene 0.66; Foamed polyethylene 0.78 to 0.88; (For parallel line) Twin-lead 0.88; window-line (450Ω): 0.91; open line (600Ω): 0.92. The 2000 ARRL Handbook gives over 100 popular manufacturer's data [Page 19.2].

Notes for HotM #126 (AM-2) 10/2024

Sidebar –
Basics of ½ and ¼ wavelength Feed-Lines:

All feed-lines have a nominal impedance. Coaxial cable commonly is usually about 50Ω or 75Ω (Other values exist); balanced feed-line is commonly 150Ω, 300Ω 450Ω or 600Ω.

When an antenna perfectly matches the feed-line impedance, the impedance remains constant at all points along the feed-line. However, if there is a mismatch between the antenna and feedline impedance, the impedance changes along the length of the feedline. Say the feedline is nominally 150Ω but the antenna is 50Ω (An SWR of 3:1) Moving from the antenna towards the transmitter by ⅛ wavelength steps, the resistive component of the impedance goes to 90Ω, 450Ω, 90Ω and at ½ wavelength from the antenna it is again 50Ω. So if you need to measure the impedance at the antenna, but it is out of reach, you can measure the impedance at the end of a ½ wavelength (or multiple ½ wavelengths) of feedline. Feedline loss introduces some errors, minimal for balanced line, higher for coaxial line.

While a half-wave transmission line repeats the input impedance, a quarter wavelength transforms the impedance per the following equation:

$$Z_{1/4} = \frac{(Z_{TL})^2}{Z_0}$$

Where:

Z_{TL} = The transmission line impedance.
Z_0 = The Impedance at 0 wavelength.
$Z_{1/4}$ = The Impedance at ¼ wavelength.

A classic solution is when the quarter wave transmission line is left open (Z_0 = infinity) then $Z_{1/4}$ = 0, or a short at the given frequency. This can be used to trap unwanted signals.

Since the AM-1 really only gives the resistive component of the impedance, the reactive component in this discussion has been left out. At the ⅛ wave 90Ω resistive points there is also a reactive component of ± 120Ω.

Remember if you are getting rid of any old Heathkit Manuals, Flyers, Catalogs, or Specification Sheets, please pass them along to me for my research.

Thanks - AF6C

REVISIONS:

NEW.