The Common Ground

BY ROBERT P. BRICKEY,* W7QAG

Plagued by hum in your audio equipment? Clobbered by oscillation in your r.f. equipment? Do you get belted every time you touch two different chassis? Then you may have common ground problems. Covered below are the effects of improper grounding and the corrective measures necessary in power line a.f. and r.f. circuits.

Too often, the importance of using proper grounding techniques is not fully appreciated. Technological advances are constantly making possible higher gain lower noise receiving equipment, while at the same time the density of other types of electronic equipment is rapidly increasing. With the rapid increase in the use of two-way radio equipment, amateur, citizen band, industrial, business band, police, *etc.*, as well as the constantly increasing number of TV sets, portable radios, and the like, it is becoming of paramount importance to use proper grounding techniques in a congested area in order to avoid unnecessary interference between these services.

Of course grounding alone will not solve all interference problems. With the great congestion of electronic equipment many other factors must be considered in order to keep interference to a minimum. Such things as proper circuit design, shielding, proper operating techniques, *etc.*, must receive special attention. It is true however that many interference problems can be traced, at least in part, to improper grounding.

Interference is not the only aspect of proper grounding. Next time you build an amplifier that behaves more like a signal generator it might be well to take a closer look at the grounding techniques you used. Many problems associated with instability can be traced to improper grounding techniques.

Because of these factors many common grounding practices are not adequate under present day conditions. As we will see later, a grounding system which is entirely adequate under some conditions may be useless in others. While some of the effects caused by improper grounding appear baffling, when they are analyzed in terms of basic electrical theory most of these effects are easily understood. With a little forethought it is possible to avoid most of the pitfalls connected with grounding.

Why Ground?

If circuits could be made completely independent of each other in such a way that they had no circuit elements in common there would be no need for common ground. A transistorized portable receiver for instance, if it contains its own power source, antenna, speaker, etc. does not need to normally be connected in common with other surrounding equipment. It is necessary however, to provide common connections within the radio receiver itself. This common connection is usually referred to as ground although it is not always common to an actual earth ground. The term ground is commonly used to express a common return connection from a number of loads. When using a receiving antenna one side of which is the earth itself, it is necessary to include the earth in the common connection. Also the a.c. power source is frequently connected to ground on one side of the circuit. This sometimes makes it necessary to include the earth in a common connection.

In the same piece of equipment, sometimes, there may be more than one common system. For instance there may be a common circuit for the return currents in the audio section, another common system for the return currents in the r.f. section and still another common system for the power supply. In other designs all of these returns may be made common to each other.

The common connection may take the form of any type of electrical conductor. The most frequently used common return in electronic equipment is the metal chassis that the equipment is constructed upon. Since the chassis usually has a considerable surface area, it provides a reason-

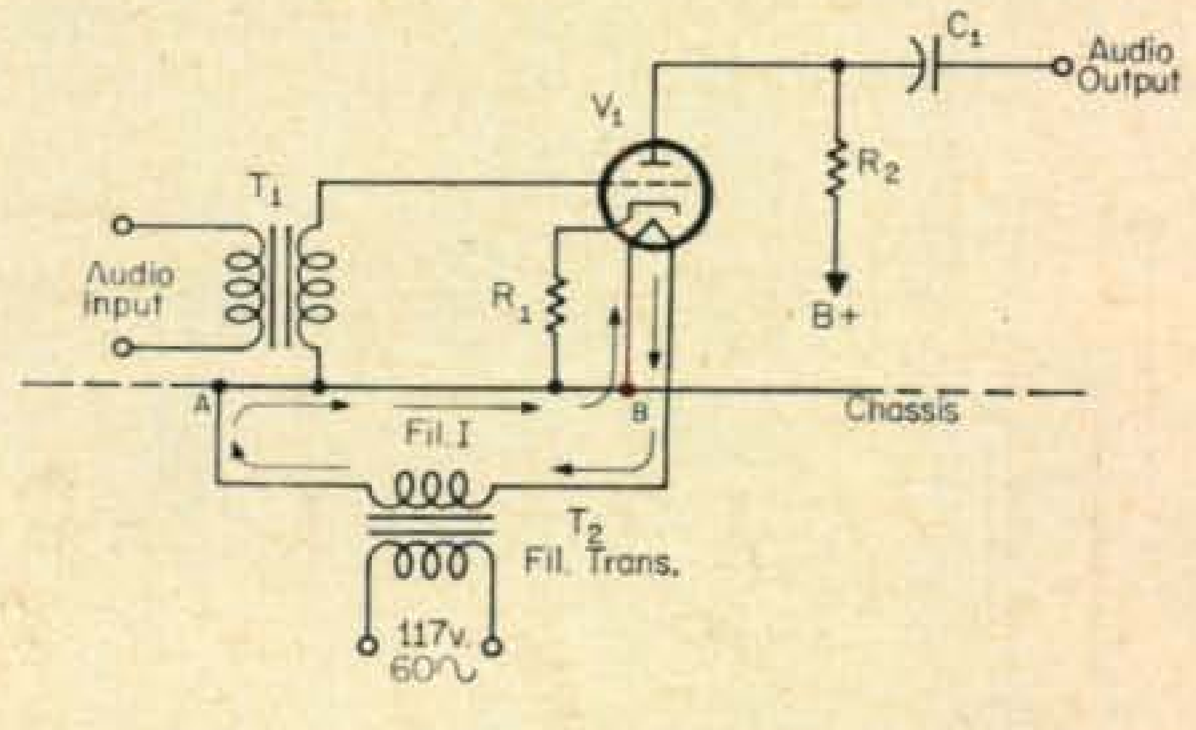


Fig. 1—Circuit diagram of an audio amplifier showing coupling between the filament circuit and the audio input signal. This type of coupling could be eliminated by grounding all of the ground returns to the same point on the chassis.

*Utah Trade Technical Institute, 349 North 250 East, Orem, Utah.

ably low impedance connection between the various loads which are connected to it. The impedance between two points on the chassis is not zero, however, and it is this fact which creates many of our grounding problems.

An example of the trouble that this chassis impedance can cause is shown in fig. 1. In this example the chassis is being used as a common return for both the filament circuit and input circuit of the amplifier. The arrows show the path of the filament current during one-half cycle of the supply frequency. Since the filament return current flows through a section of the chassis, and this chassis contains resistance, the result will be a very small a.c. voltage drop between points A and B on the chassis. Notice that part of this voltage is in series with the input circuit to the vacuum tube amplifier. This a.c. voltage will add to the incoming signal and the amplifier output will contain some of the filament supply frequency in addition to the desired output signal.

It might be thought that the voltage drop across the chassis would be small enough to be negligible. In some cases this is true, especially when the amplifier gain is low, the chassis resistance is low, the filament current is not too great and a very low hum level is not necessary. In many cases, however, the results would *not* be satisfactory. The ripple from this source could be eliminated in this circuit by either running a separate filament return lead to the tube instead of using the chassis or by returning the secondary of T_1 directly to R_1 in order that the filament circuit and the input circuit of the amplifier do not contain the common chassis impedance.

When building any type of high gain amplifier, considerable care must be exercised when connecting various points in the circuit to the common chassis in order that output current returns will not produce voltage drops that will be fed back into the input of the amplifier. If the feedback through the chassis is properly phased the amplifier may oscillate. This type of feedback is often very difficult to isolate and correct once the equipment has been constructed. It is usually good practice to connect all of the bypass capacitors and other returns for a particular stage or closely associated group of stages to a common point on the chassis. Grounding in this way eliminates the return currents flowing through the chassis and therefore prevents producing a voltage drop across it.

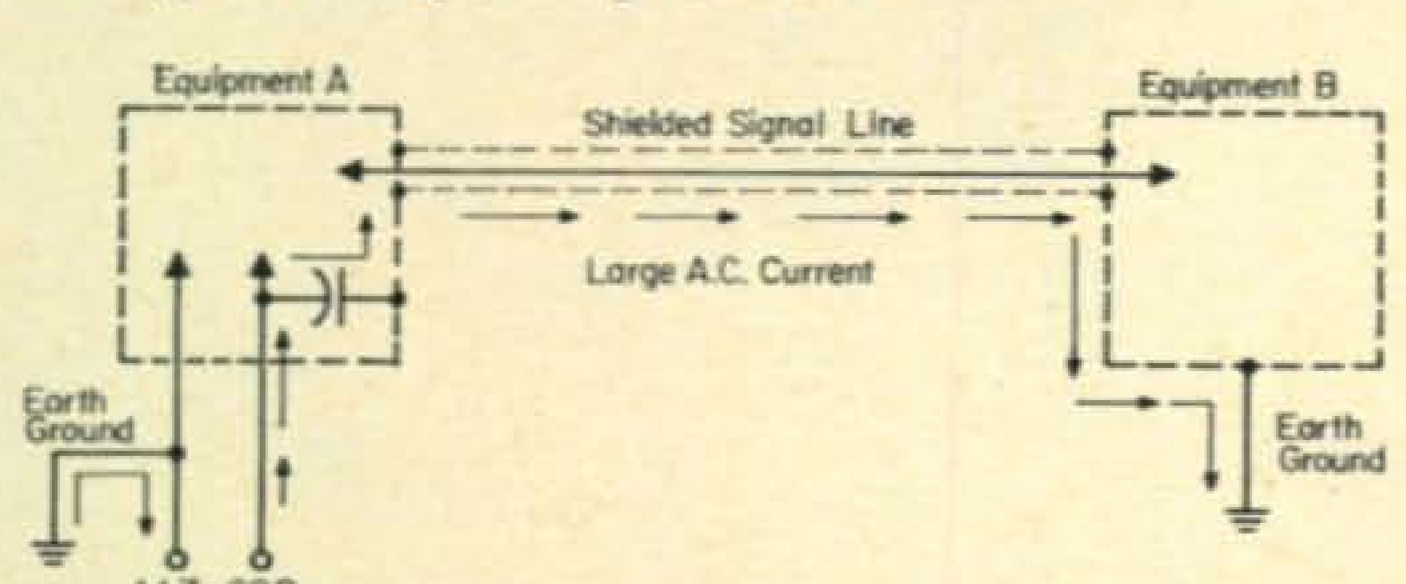


Fig. 2—Since there is no common ground lead between equipment *A* and equipment *B*, there will be a large a.c. current flowing in the shield around the signal line. This a.c. current will induce hum in with the signal.

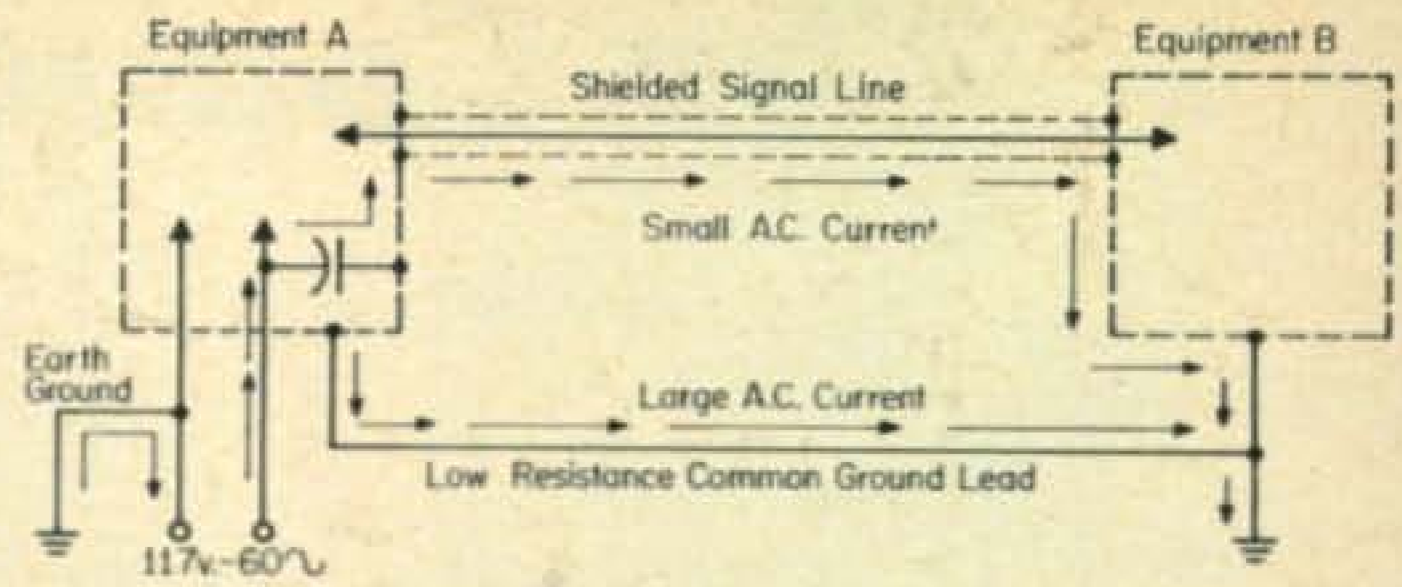


Fig. 3—If the common ground lead has low resistance compared to the resistance of the shielding on the signal line, most of the a.c. ground current from equipment *A* will flow through the ground lead.

When duplicating equipment described in magazine articles it is wise to follow the grounding scheme used in the original equipment as closely as possible. This is especially important at high frequencies. Don't be too quick to criticize the author of the article when your equipment doesn't function properly if you have made any changes whatsoever in the grounding system or in parts placement. To those who lack experience it is difficult to impress the importance of grounding to the chassis in the right way. While it often seems to the beginner that anything connected to the chassis is really connected to a common potential it can be seen in fig. 1 that this is not the case.

Safety

Another important reason for using a common ground is safety. Although sometimes it may not be necessary to ground certain pieces of equipment together for their proper operation, it is advisable to connect their chassis in common to eliminate any difference in potential that may exist between them. As there will normally be other objects in the immediate vicinity that are at earth ground potential, this common chassis connection should also be connected to an earth ground. The lead used for this ground connection should be at least as large as the incoming power mains from the breaker panel. This is important because in the event of a short circuit in the equipment between the incoming power line and the chassis, the ground lead should be able to carry sufficient current to trip the breaker. If an insufficient wire size is used and such a short should develop, the resulting current through the small wire could produce enough heat to start a fire without tripping the breaker. There is also a possibility that the wire may burn out altogether leaving the equipment with line potential to ground. Since this ground lead may be required to carry an appreciable current it is advisable to run the ground lead back to the same ground point used for the incoming power. Doing this will eliminate the resistance through the earth back to this point.

Connecting various pieces of equipment to a common ground also has many operational advantages. It is common practice to connect a bypass capacitor from the power line to the chassis in each piece of equipment in order to bypass radio-frequency signals that may enter

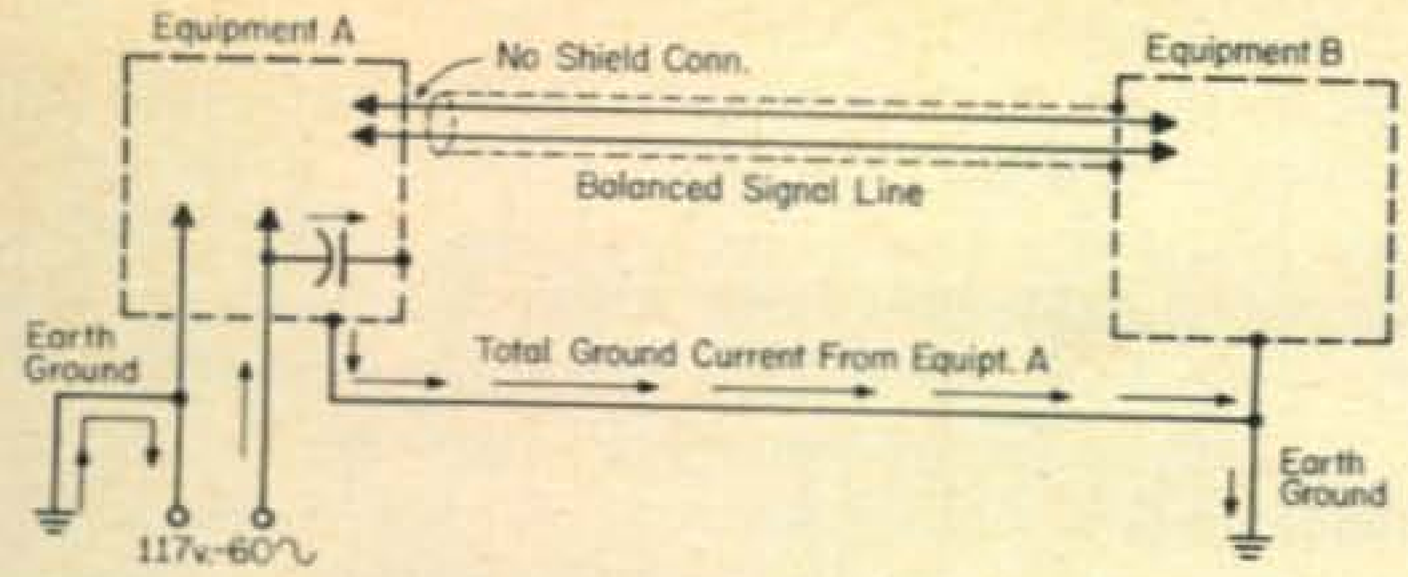


Fig. 4—If a balanced signal line is used the shield need not be connected on the sending end, eliminating the a.c. current through the shield.

or leave via the power line. Usually a small valued capacitor is used which has low reactance to the radio-frequency and a fairly high reactance at the power frequency. While the reactance of this bypass capacitor at the power line frequency is fairly high there is still enough current flow to cause problems when a signal is fed from one piece of equipment to another unless proper grounding techniques are used.

Figure 2 shows an example of the sort of thing that can happen. An unbalanced shielded signal line is connected from equipment *A* to equipment *B*. Of course the line is shielded to prevent pick-up of stray magnetic or electrostatic fields in its vicinity. However if equipment *A* is not properly grounded, current can flow from the ungrounded side of the power line through the bypass capacitor to the chassis of equipment *A*, down the shield of the signal line to equipment *B* and then to ground. The supply frequency current flowing through the shield will produce an alternating magnetic field around the shield which will cut the inner-conductor and produce alternating currents in it also. In some cases the hum pick-up from this source can be very serious. It is often thought that it isn't necessary to ground equipment *A* in a case like this since it is grounded anyway through the shielded lead. It can be seen in fig. 2 that the ground currents flowing through the shield do more harm than good.

Figure 3 shows the same equipment setup with units *A* properly grounded. If the resistance of the common ground lead is made very low compared to the resistance of the shield on the signal line the bulk of the a.c. current will flow through the common ground. This greatly reduces the hum induced in the signal line. To be effective in this way it can be seen that the common ground lead must have very low resistance.

A still better approach to the problem is shown in fig. 4. If a balanced signal line is used rather than an unbalanced one as in the preceding examples it will not be necessary to connect the line shield to both pieces of equipment. This is because the returning signal current will flow through the second conductor of the balance line rather than through the shield. It can be seen that now the total ground current will flow through the common ground lead and there will be no line current flowing in the shield. The shield on the signal line will be most effective if it is grounded at the load end of the line. If it was grounded at the source, the a.c. voltage drop across the ground lead resistance would be present between the shield and the input at the load.

R.F. Grounds

Due to the increased impedance of ground conductors the grounding technique used becomes even more important at radio-frequencies. The impedance of the ground conductor becomes higher for several reasons. As the frequency of the current flowing in a conductor increases, the magnetic field this current produces causes the bulk of the current flow to be near the surface of the conductor. This is shown in fig. 5 and is known as skin effect. The reduction of current in the center of the conductor at high frequencies reduces the effective cross sectional area of the conductor. The result is an increase in the effective resistance at high frequencies.

Not only is the resistance of the conductor greater at high frequencies, but unless its length is exactly right it will also have considerable reactance. Any conductor has inductance and the inductive reactance it causes increases directly with frequency. However, not only does a conductor have inductance but it also has distributed capacitance. If the capacitive reactance is of the same magnitude as the inductive reactance, the conductor will be resonant and if it were not for radiation from the line its impedance would be equal to its effective resistance.

When a long ground run must be made, its impedance is often reduced by making it a resonant length. However the radiation from a resonated ground lead of this type will in some cases be fairly high, raising its impedance. This radiation may also produce harmful interference.

In general then, in order to reduce the impedance of the ground lead, while at the same time keeping the radiation from the line to a minimum, it is desirable to use the shortest possible ground leads at radio-frequencies. Also in order to reduce the inductance and effective resistance of the line as much as possible, a conductor with considerable surface area should be used. A copper strap for instance will have a much lower impedance at radio-frequencies than a round conductor with the same cross sectional area.

The type of material used at very high frequencies is also important since almost all of

Fig. 5—Cross sectional drawing showing the variation of current density in a conductor carrying radio frequency current. Since the interior of the conductor is surrounded by more flux lines than the exterior, it will have more reactance. As a result there is more current flow near the surface, increasing the effective resistance.

the current flow is concentrated very near the surface of the conductor. It is desirable that this surface have conductivity and it is often helpful to use plated materials. It is important that a good plating job be done however as a poor one may have higher resistance than the original material. In some cases protective coatings may be applied to the conductors in order to prevent deterioration of the surface. Because of these effects, construction of v.h.f. and u.h.f. equipment on chassis of different material can have a great effect on a performance.

Earth Grounds

Several times in this article we have referred to an earth ground. It is often very difficult to obtain a good ground connection to the earth. While the old standby water pipe ground connection may be adequate in some cases, the impedance of this type of ground at radio-frequencies is likely to be fairly high. In considering a ground connection it should be recognized that the type of ground system necessary may depend on the frequency involved.

At low frequencies, due to the multiple paths for the current through the subsurface of the earth, the resistance of the earth itself is negligible even though the resistance through any one path may be fairly high. In fact, due to the earth's great size, its resistance is so low that if a series loop is formed of a trans-atlantic telephone cable and earth, all of the resistance in the series loop can be accounted for in the wire.[1]

It can be seen, therefore, that the primary problem is to obtain a low resistance connection to the earth since the earth itself has a very low resistance. At low frequencies a satisfactory ground can usually be obtained by burying conductors with large surface area deep in moist soil. The ground resistance can be reduced considerably by depositing salt in the area around the conductors since this is where the current density is greatest. Of course the salt will shorten the life of the ground system as it will attack the metal conductors chemically.

In dry rocky areas it is difficult to obtain a low impedance ground connection. At radio-frequencies, in areas like this, a counterpoise will often provide a better ground. This may be formed by placing a network of conductors

[*Continued on page 94*]

[1]Card, R. H., Earth Resistivity and Geological Structure, trans. *AIEE*, 54, 1153, 1935.

CQ Reviews:

The Dow-Key DK78 Coaxial Switches

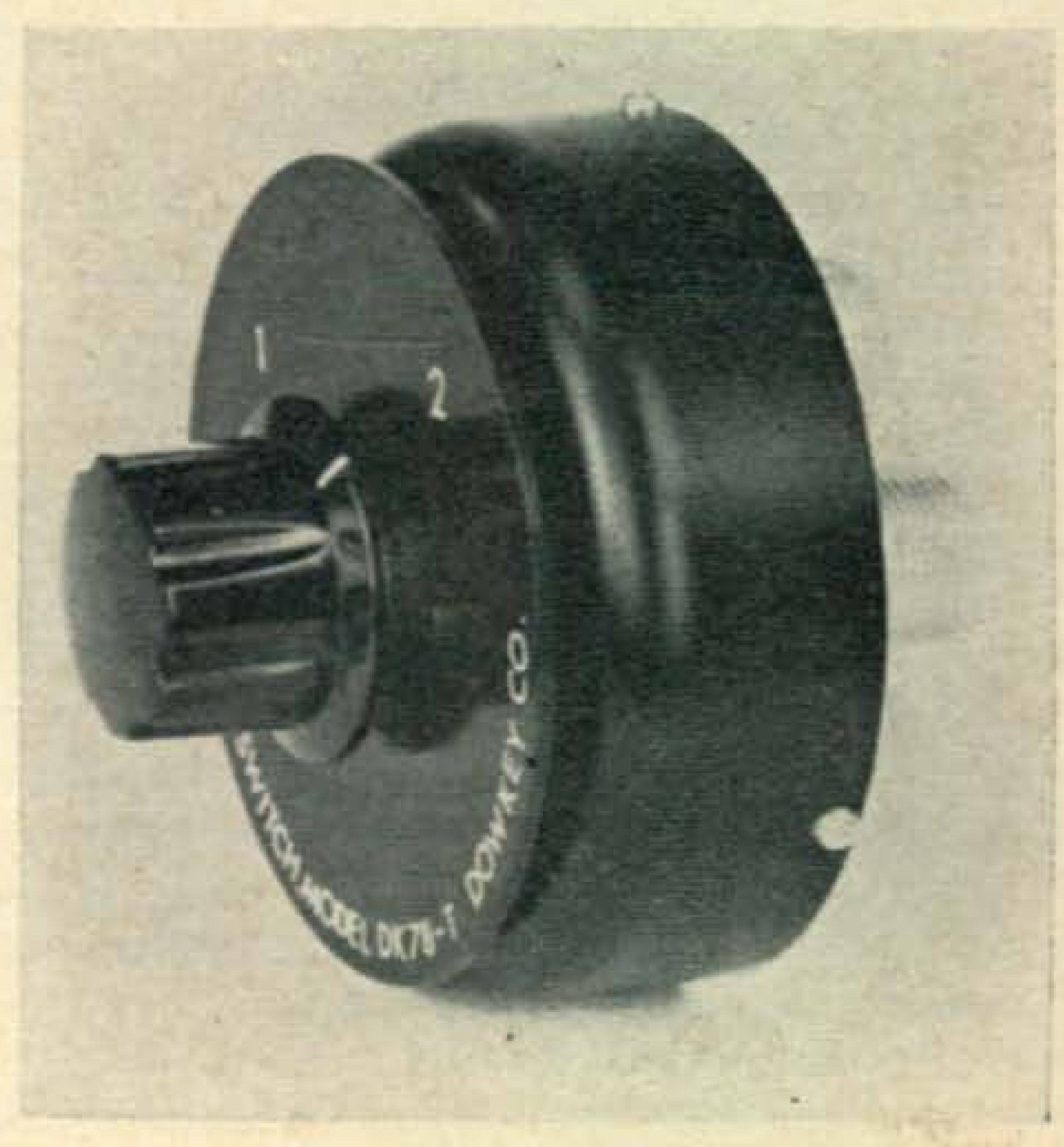
BY WILFRED M. SCHERER,* W2AEF

The latest addition to the line of products put out by the Dow-Key Company is their DK78 series of manually-operated coaxial switches. These are especially designed for the purpose, both electrically and mechanically, and as such are not just adaptations employing wafer-type switches. They are relatively small in size, yet are ruggedly constructed for reliable operation with high current-carrying capacity for handling r.f. power of 1 kw at frequencies up to 500 mc and they have high cross-talk isolation and low v.s.w.r. All the r.f. connectors are mounted in the same plane facing directly out from the rear to facilitate cable connections in a minimum amount of space and without the need of right-angle connectors for doing so. The switches are available in four configurations as shown at fig. 1. These are: s.p.d.t., s.p.3t., s.p.6t. and transfer-type.

Construction

Since the Dow-Key DK78 coaxial switches utilize a specially designed switching mechanism, we thought you'd like to see a picture of the "innards" of one of them. Shown in the accompanying photograph are those of the DK78-T transfer switch.

The main body or shell of the switch is shown at the left. The large circular metal disc is rotated by a shaft from the other side of the shell. Two dual-contact arms are mounted on insulators on this disc, each in a separate oblong box-like shield enclosure. At the right of the photograph is the back plate of the switch showing the rear of the four r.f. connectors with



One of the Dow-Key DK78 coaxial switches. This is the transfer model.

*Technical Director, *CQ*.

many of the fellows from giving up ham radio, you know some people just don't have tooooo much money. Let's see what kind of mail we get about the idea.

My gosh, fellows I didn't even get a picture of that reprehensible character CQ DOG XRAY this month and as I have said before YOU are news to others, why don't you want your picture in *CQ?* Any way have a happy new year. That is just about all for this month so the best to you and yours as I am writing this on New Years Day. My best wishes for better DX conditions and less fighting on the air over the many things that we know so little about. 73, Walt, W8ZCV

Ham Cinic [*from page 67*]

tube. Next, check the 6BE6 b.f.o. tube and lastly check for loose connections. A loose alignment capacitor may also be part of the trouble.

Thirty

Next month we will cover the addition of one or two bands to transceivers. This is a subject on which we have received many letters.

Although we cannot personally acknowledge them all, we want to thank the hundreds of hams who sent us personal seasons greetings.

For this month then, 73 to all the fine faithful readers of HAM CLINIC. 73, Chuck, W6QLV

Club Forum [*from page 18*]

service department" of your local radio station on your list. Many radio programs feature such announcements and are very willing to cooperate. As with all forms of publicity be sure it's submitted far in advance and properly typewritten.

It might be brought to your attention that amateur radio is not without a group dedicated to the cause of promoting the "good word" of our fraternity. The Amateur Radio Editors Association (AREA) consists of over one hundred such hams in every field of amateur publicity.

Further information on publicity is available from the ARRL in the form of a packet of typical news releases and other related items. Finally study news items of other organizations. Before long sending out news releases will be second nature.

We hope this will assist the club publicity chairman and if we missed some good ideas why not send them in and we'll print them at a later date. 73, Al, WA2TAQ

Common Ground [*from page 52*]

above the ground. These conductors are insulated from the ground and the connection is made through their capacitance to the earth. When current flows into the counterpoise making it negative, this negative charge repels electrons in the ground immediately below, resulting in a current flow away from the counterpoise in the earth. On the other half cycle when the counterpoise is made positive, electrons are at-

For further information, check number 45, on page 110

tracted to the ground underneath. The result is an alternating current flow through the earth without making a physical contact to it.

Summary

In a short article such as this it is impossible to do justice to the subject of grounding. There are so many varied aspects to grounding that an entire book could easily be written on the subject. We have touched upon only a few of the many possible examples of proper grounding techniques.

It was our hope that this article might serve to acquaint the uninitiated with some of the problems associated with grounding and also to stress the importance of the common ground.

If we ground properly our equipment will not only perform better but our stations will be much safer. ■

Contest Calendar [*from page 80*]

Should the rest period be reduced to 6 hours? We are reluctant to eliminate it all together, it was well received when it was first instituted.

We would appreciate your comments and suggestions.

PACC

Starts: 1200 GMT Saturday, April 24
Ends: 1800 GMT Sunday, April 25

This is the 9th annual PACC contest and rules are same as in previous years. C.w. and Phone are separate contests even though they are held at the same time. Complete details next month.

Editors Note

Not much to report this month. It's that time of the year when we are up to our necks in contest logs. Could use a few good photos of stations in contest activity.

The listing of K6EVR in the claimed Phone score was in error. It should have been K6ERV with 52,032 points on 14 mc. K6EVR was multi-operator this year and the boys had better than 400,000 points. Sorry Ron.

If you need a Liberian QSL, listen for EL2 stations on Sat., March 15th between 1200—2400 GMT, when the newly formed EL-Two Club will hold a field day. Activity will be on 7010, 14020, 14260, 21030, and 21300 kc. Send QSLs to: Charles Segrest, EL2AI, c/o American Embassy VOA, Monrovia, Liberia.

At this writing all the Top Band buffs are looking forward to the 160 Contest. It promises to be a "humdinger." We had excellent DX conditions on the week-end of January 9/10th. Good luck. 73 for now, Frank, W1WY

For further information, check number 37, on page 110