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How and Why of a Radio Filter

They Smooth the Hum Out of Sending and Receiving

By HORACE V. S. TAYLOR

A GREAT deal is said these days about omitting "A" and "B" batteries from a receiving set. Of course, it is a great advantage if these expensive and troublesome units can be done away with. Most of the schemes so far proposed give pretty good results, except for the fact that the hum, which is caused by the alternating current, is heard quite distinctly in the phones or loud speaker. The whole idea of a filter as used in such a device is to kill this hum.

Another place where a filter always has to be used is the generator circuit of a sending station. Generators are used instead of batteries to supply the plate current for transmitting tubes, as the pressure is so high, several thousand volts, that a tremendous number of cells of "B" batteries would be required if these were used. Sometimes an "A" battery is employed to light the filaments of the tubes, but since considerable money is tied up in batteries large enough to run the big filaments of the sending tubes, it often is found best to use a generator for this purpose also. In either of these positions a generator causes a certain amount of noise, owing to the so-called "commutator ripple."

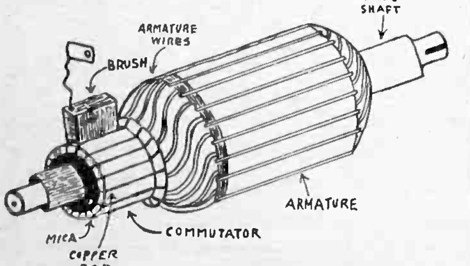

Fig. 1. Cause of Sending Hum

What the Commutator Does

The commutator of a generator consists of a large number of copper bars, insulated by strips of mica, as shown in Fig, 1. As these rotate under the brushes which carry the current in and out of the armature, there is a slight disturbance every time a bar leaves contact with the brush, and the constant procession of these ripples, one after the other, causes a hum which is broadcast along with the music. It is the function of the filter to suppress this undesirable noise.

The two uses of this device which has just been mentioned are for the purpose of keeping a steady, direct current supplied to a device, rather than one which fluctuates slightly. Still another use for a filter is in conditions where a certain speed of vibration of alternating current is desired in one circuit, but not in another. For instance, a wave trap is a form of filter. The differences between it and the first kind mentioned is that on direct current there is no particular tuning needed, whereas, when used with high frequency alternating current, it is necessary to tune the circuit to the particular wave length in question.

Like Moving a Clock

To show the general way a filter works, we may refer to the analogy of transporting a clock on moving day. We have a very expensive timepiece which we are afraid to take on the moving van with the rest of the goods for fear the vibration may damage the works. As an improvement on placing it in a bureau draw, we can put it down on the mattress and spring of a bed as shown in Fig. 2. This is quite a help, as the spring will absorb a lot of vibration which would otherwise be carried to the delicate mechanism of the clock. Such a way of protecting it removes almost all of the rapid vibrations which the moving van causes.

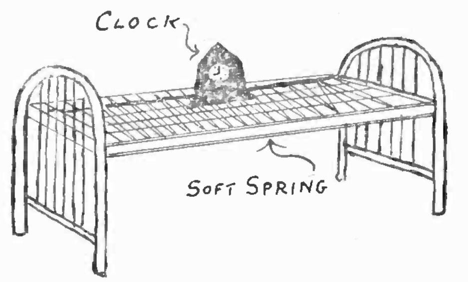

Fig. 2. Springs Absorb Shocks

The clock is a rather light weight, and so it will get some banging around even when mounted on the spring as just shown. The small and very rapid oscillations will be filtered out by the spring before they reach it, but the slower vibrations, which are perhaps stronger, will still cause a lot of jouncing up and down when the truck runs over a rough place in the road. How can this be avoided? The obvious way to do is to put a heavy block of iron down on the springs of the bed and then place the clock on top of it, as shown in Fig. 3. This mass of iron is, of course, quite heavy and it will not take up the bouncing and throwing about which the clock, owing to its light weight, was absorbing before. The combinations of the weight of the iron and the spring of the bed makes an ideal arrangement to filter out the vibration which would otherwise reach the pendulum of the timepiece. Notice here that there are *two* things necessary to filter out the vibration, first the springs, which absorb the oscillations easily, and second the weight, which repels the vibration. It is only when these two elements are combined that the best results may be obtained.

Filtering Out an Earthquake

The same principle is made use of in the apparatus which measures the form and strength of an earthquake. This instrument, called a seismograph, is illus-

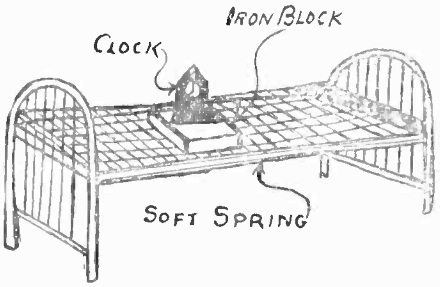

Fig. 3. Weight Helps Spring

trated in principle in Fig. 4. It consists of a spiral spring which carries at its lower end a heavy weight. The spring is supported from the ceiling of the room in which the apparatus is housed. At one side of the weight is a pen point, which bears against a strip of paper. In the actual construction, the pen is not fastened directly to the weight, but is attached to it through a system of levers which magnifies the motion perhaps a hundred times. The strip of paper

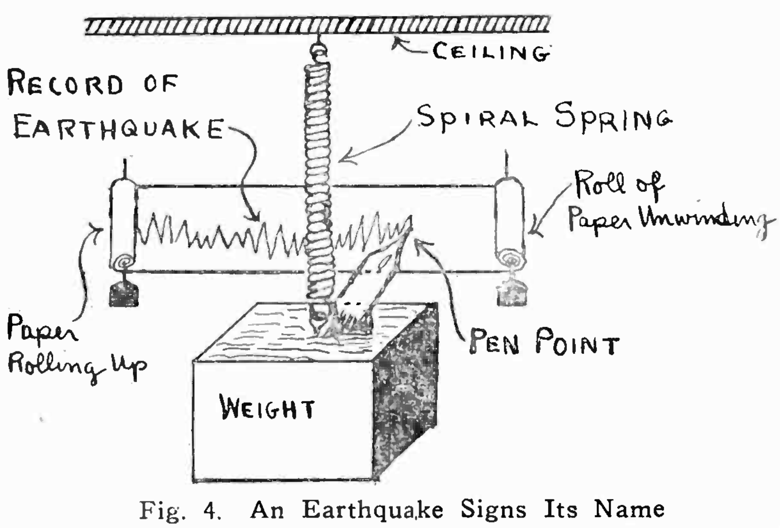

Fig. 4. An Earthquake Signs Its Name

against which a pen rests is unwound slowly from a big roll and winds up on a drum, which is driven by clock work. The strip unwinds quite slowly so that only a few inches pass every hour. The paper rolls are carried on a framework which is bolted securely to a strong masonry slab sunk deep in the ground.

The way this instrument works is as follows: The roll of paper, being as just explained, carried by the frame which is solidly attached to the ground will naturally take up any vibrations which the earth is having. If an earthquake happens, then the paper will fluctuate violently up and down at the same time it is slowly pulled along by the clock work. On the other hand the spring and weight make up a filter which removes all vibration from the pen point. The spring absorbs the vibrations and the weight repels them with the result that the pen is quiet in space without any motion at all. Since the paper is vibrating up and down, and the pen is not, the latter will leave a wavy continuous line on the strip.

When no earthquake or other motion of the ground is occurring then the pen will trace a perfectly straight line on the paper roll, but as soon as a tremor in the earth is felt, then the paper wiggles up and down and the stationary pen leaves a very wavy line, as shown in our diagram. Of course, the more severe the disturbance, the greater will be the height of the mountains which show on the record. Since the motion is magnified very greatly by the levers, (which are not shown here), it is possible with this instrument to detect an earthquake which may have occurred half way around the globe. The first news of the Japanese earthquake was received on a seismograph in Washington, D. C., a few seconds after the event occurred.

What Makes an Electrical Filter

Just as in both these cases it was necessary to have two parts, a spring and a weight, so when we get to the electrical circuit, there are two separate elements. The spring is represented by a condenser, while the weight is reproduced in a form of a coil or inductance Just as the weight of the block of iron is measured in pounds, so the electrical weight of the coil is measured by its inductance. The unit of inductance is the

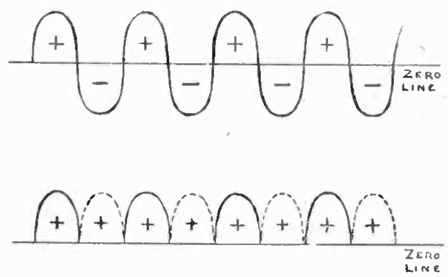

Fig. 5. Current from Rectifier

millihenry. The combinaton of condenser and a coil acts electrically just as our mechanical filter does; that is, the condenser absorbs the electrical oscillations, and the inductance repels them.

Suppose we have a rectifier which we want to use to supply current to the filament. If we ran a 110 volts A. C. through a transformer to step the potential down to six volts, and then feed that to the tube, the shape of the current wave would look like the upper curve of Fig. 5, that is, there will be a positive loop and then a negative loop. This means that if we put a volt meter across the terminals of the filament and the meter were sensitive enough to record such rapid changes, that the needle would first swing over six volts to the right and an instant later six volts to the left. This change back and forth would happen 60 times every second. Of course, this would give a terrible hum in the telephones. The usual city current is 60 cycle frequency.

But instead of connecting the secondary of the transformer right to the filament, suppose we run it through a rectifier, like a Tungar or a vibrating rectifier, or perhaps a chemical style, which uses two plates dipping in a solution of salts. If this instrument were the style which uses both half of the waves and reverses the negative so as to add up with the positive, then the curve would look like the lower half of Fig. 5. If a quick reading volt meter were connected across the filament with this style, then the needle would flicker violently from zero up to six, and then back to zero again.

This would not be much better than before, because there would still be a terrible racket in the phones.

What the Filter Does

As the next step let us assume that a filter is cut into the circuit in the way which will be described in a minute. If this is a good filter, it will change the current to a fairly continuous flow, as shown in the upper part of Fig. 6. Here we have continuous current (as shown by the waves being entirely above the line) but on top of this steady current is a ripple. This resembles a river, which in calm weather will flow steadily toward the sea, at say, three miles per hour. In rough weather, when a heavy wind is blowing, the river continues to move with a speed of three miles toward the ocean, but on top of this the wind kicks up a lot of waves which may have a bigger effect than the main flow of the current itself.

Such a form of current when fed to the tube will give pretty fair results, but some noise will still be heard. In order to reduce this further, we can do either one of two things. One way is to connect a second filter in the line and the other is to use a larger unit from the first filter, that is, more plates in the condenser and a larger number of turns on the winding of the coil. If we make either one of these changes, then the wave on top of the direct current will be cut down very considerably, so that the curve will look like the lower half of Fig. 6. This is like our river when the wind has died down quite a lot and the waves have dropped to mere

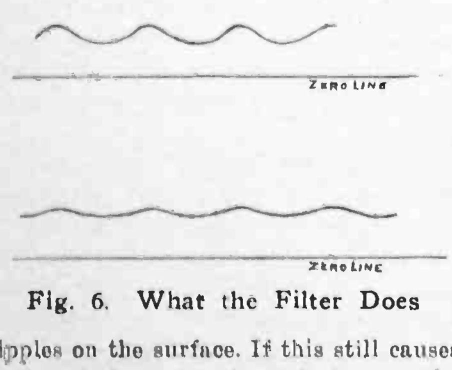

Fig. 6. What the Filter Does

ripples on the surface. If this still causes too much hum in the telephones, the cure is to go farther with the treatment. In other words, the coil and condenser should be further increased in size.

What the Filter Looks Like

Fig. 7 shows a hook-up for the filter, and also the shape of the wave of current which passes through the various parts of the circuit. The two wires running to the left are connected to the rectifier and those at the right go to the radio set. It will be observed that the upper line runs right through from the rectifier to the radio. The condenser, which is shown connecting the two lines weight. Just as the spring allowed the oscillations to pass and the weight prevented them, so in Fig. 7 the condenser lets the ripple on top of the wave run right through from the upper to the lower line in Fig. 7 and so it does not pass through the radio set, while the coil acts like the weight and opposes any

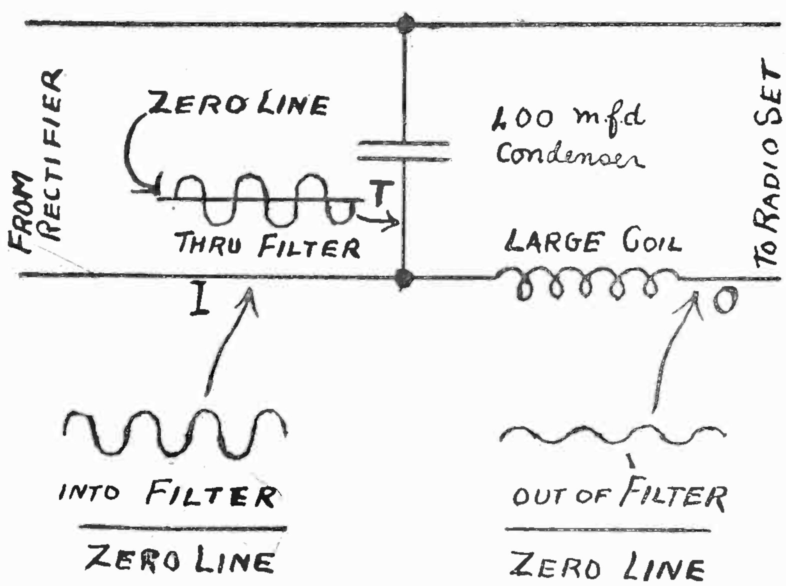

Fig. 7. Current In and Out of Filter

will have a capacity of one or two mfd. Notice that this is one thousand times as big as the .001 mfd. which is in common use as a phone condenser and also for other purposes in the ordinary radio set. The reason for this large size is because that while the radio condenser is fed by a frequency of several hundred thousand up to a million, the one in the filter has to work on a frequency of only 60 cycles per second, and this slow speed requires a much larger capacity in order to pass sufficient current.

The coil, which is shown connected in the lower line, is built on an iron core and will have several thousand turns. An ordinary audio transformer would have enough turns, but the wire in this latter is so small, that it would burn out in attempting to run one or two amperes through it to light the filament. The wire for such a coil should be at least as large as No. 26 and should be larger if more than four tubes are to be used in the set.

Cutting Out the A. C. Waves

You will see that the filter is really a very simple device, consisting only of the condenser and coil. The condenser is just exactly like the spring that we showed in Fig. 4, and the coil resembles the wave motion or in other words repels it, while the direct current can pass through it quite easily.

This is illustrated by the curves which accompany the diagram. First look at the lower left hand corner which shows the direct current coming from the rectifier or from another filter, showing a very pronounced ripple in the direct current. This shows that if a volt meter were connected to the filament terminals of the vacuum tube the needle would flicker back and forth between 4 and 6 volts, changing from one to the other and back again very rapidly. This fluctuation would be heard in the phones as a musical hum. Now remember that the condenser is like a spring. A spring will easily vibrate back and forth and so the current through the condenser will vibrate back and forth just as shown in the upper part of the sketch. You will notice that it goes from plus one to minus one ampere and lies on both sides of the line since direct current cannot go through a condenser.

Only Small Ripple Through Coil

Now look at the shape of current wave through the coil. Since it is like a heavy weight it cannot be shaken back and forth very fast (this shaking is not mechanical, but electrical it must be remembered). So the current, which it passes on to the set, will be in one direction only and will have only a very small ripple. As already explained in Fig. 6 this will be so small that it probably will cause no trouble in the telephone. If it does, however, the remedy is to use a larger coil with the condenser.

It may seem from this description that it is not possible ever to get an absolutely smooth wave by using any number of filters. As a matter of fact, this is the truth—we can never get a line which is theoretically smooth. The best we can do is to reduce the hum to such a low value that it does not bother us. If your ears are better than mine, then you will need a larger filter to quiet the set than I will. But if John Smith's ears are better yet, then he will object to the ripple which you do not notice. Of course, if the hum is reduced to such a low value that we cannot hear it, then it does no harm at all, even though we know it must be there still.

Hooking Up the Set

The scheme of connections for a filter is shown in Fig. 8. We have here two vacuum tubes, which may be detector and amplifier, or perhaps two steps of amplification. The grid and plate circuits are not shown since they may be used in any kind of a set from a single circuit squealer to a nine tube superheterodyne. The filaments are shown connected each with its separate rheostat although one might just as well serve the purpose of controlling both tubes at the same time.

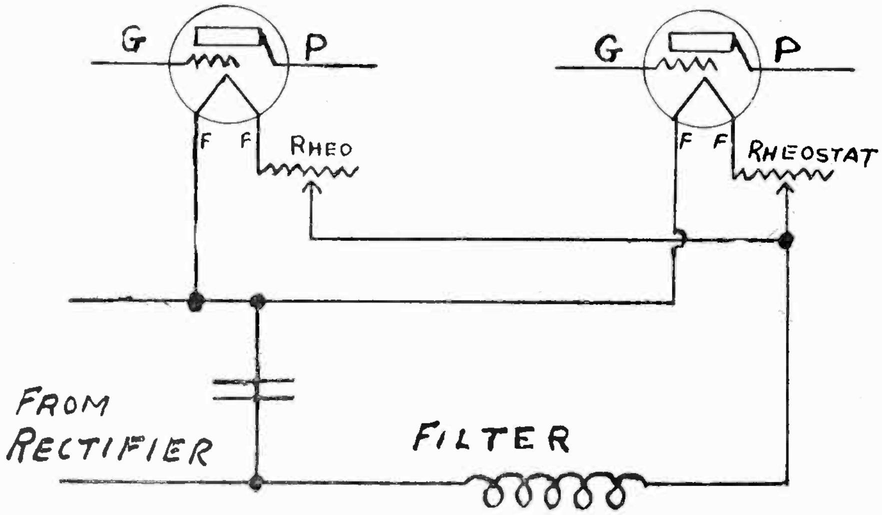

Fig. 8. Applying Filter to Radio Set

The filter is connected just as it was in Fig. 7 with the supply at the left and the tubes at the right. The top connection runs direct from the rectifier to the tubes and in the diagram the first filament connection is purposely shown at the left of the condenser. This is to illustrate the point that the output may be taken off this line at any point. The condenser and coil play the same part here that they did in Fig. 7, that is, the condenser passes or short circuits the ripple on top of the direct current while the coil repels this ripple and allows only a steady current to flow. It is this latter which lights the filaments of the tube.

In using such a device it is well to place both condenser and coil at least a foot or more away from the radio set itself. This is to prevent the magnetic action of the former from affecting the coils of the set.

Doing Without a "B" Battery

The same idea which is shown here connected to the filaments of the tube may be used on the plate circuit. The difference in construction will be this: Whereas the filaments will take from one to two amperes at a small voltage, say five or six, the plate, on the other hand, requires 22 up to 90 volts and the current is very small, only a few thousandths of an ampere (a few milliamperes). That is why the coil for use in the plate circuit filter must be wound of a very large number of turns and since the current is small the wire may be No. 30. The condenser here will have to be insulated so that it can stand the full plate voltage, whereas in the former case a paper insulated unit that will withstand six or eight volts is all that is required.

As a matter of fact, very many of the schemes at present on the market for using no "B" batteries are built on the principle of transformer to give the proper voltage, connected to a rectifier which makes pulsating direct current out of alternating and then a filter to strain off the ripple on top of the direct current. These devices are successful in overcoming the noise in the phones provided the filter is large enough. Of course, such units cost money, and the tendency is to cut them down as small as can be used to give good results.