March 30, 1937. R. H. VARIAN 2,075,380

MEANS FOR MODULATING HIGH FREQUENCY CURRENTS

Filed March 13, 1935

Fig. 1.

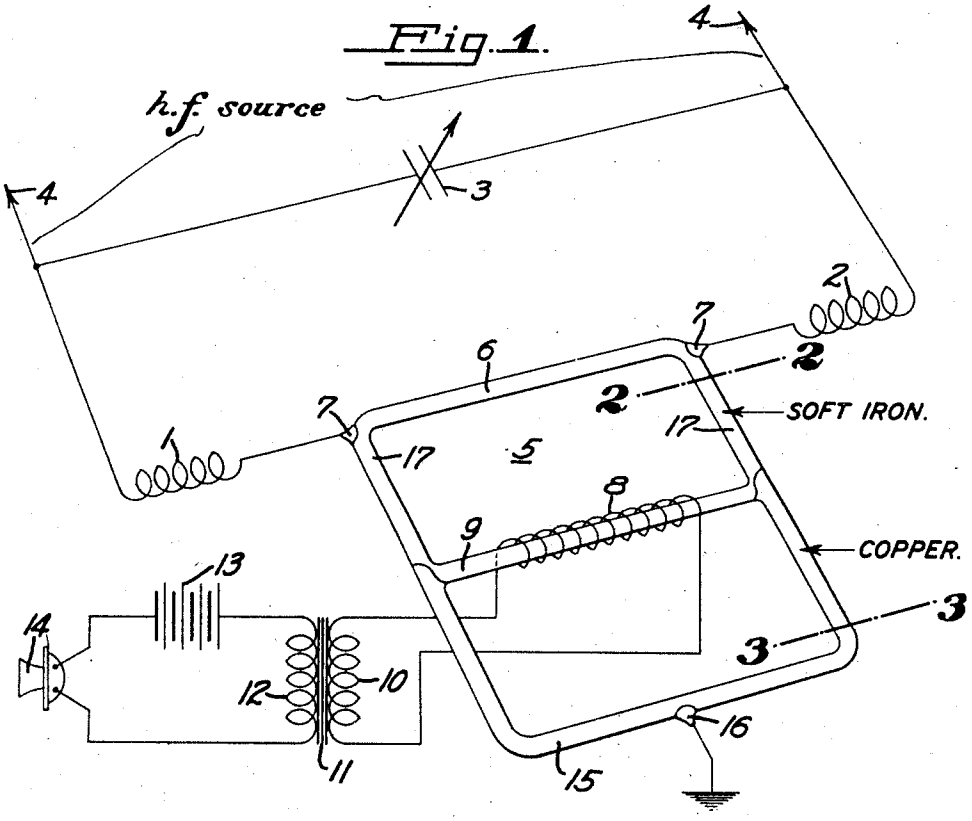


Fig. 2.

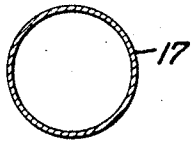


Fig. 3.

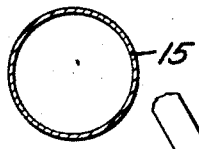
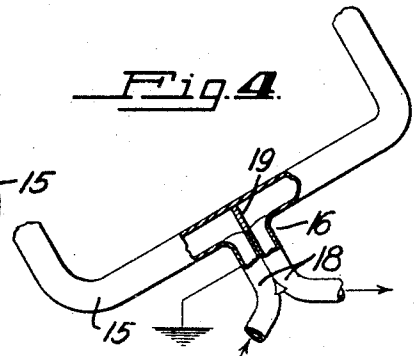


Fig. 4.



INVENTOR,
RUSSELL H. VARIAN.
BY Lippincott & Metcalf
ATTORNEYS.

Patented Mar. 30, 1937 2,075,380

UNITED STATES PATENT OFFICE

2,075,380

MEANS FOR MODULATING HIGH FREQUENCY CURRENTS

Russell H. Varian, San Francisco, Calif., assignor to Farnsworth Television Incorporated, a corporation of California

Application March 13, 1935, Serial No. 10,891

9 Claims. (Cl. 179—171)

My invention relates to a means and method for modulating high frequency currents, and more particularly to a modulator operating by virtue of varying skin effects.

Among the objects of my invention are: to provide a simple and efficient modulator of high frequency currents; to provide a modulator operating by virtue of varying skin effects; to provide a means and method for modulating high frequency currents by utilizing certain properties of ferro-magnetic material; and to provide a ferro-magnetic modulator for high frequency currents.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of the invention herein described, as various forms may be adopted within the scope of the claims.

In broad terms my invention comprises, as to method, including a ferro-magnetic conductor, preferably of high magnetic permeability, in an oscillating circuit, magnetizing the conductor, and changing the degree of magnetic permeability in accordance with the desired modulating frequency. The broad aspect of the invention, in terms of apparatus, comprises the ferro-magnetic conductor included as part of an oscillating circuit carrying high frequency currents, and means for magnetizing said material to varying degrees of saturation. While the device may be used for many purposes, as will be apparent to those skilled in the art, within the scope of the claims, I prefer to use the modulator of my invention in conjunction with radio frequency transmitting circuits whereby signals, voice, or other audio frequency currents may be modulated on a carrier, and the invention will be so described.

It is well known that high magnetic permeability greatly increases the skin effect in a conductor. Skin effect may be broadly defined as an alternating current phenomenon whereby the outer surface of the conductor carries more current proportionally than the interior. An increase in effective resistance is caused by this skin effect, the relative increase being a function in part of the frequency. I have found that when a conductor of high magnetic permeability is used in an alternating current circuit, particularly with high frequencies, that the effective resistance is very high. I also found that the skin effect or the effective resistance can be greatly reduced by magnetizing the material, and that if the magnetic material is magnetized to varying degrees, that the resistance will be correspondingly varied. I have therefore utilized this phenomenon to cause modulation of high frequency currents.

Referring to the drawing:

Figure 1 is a diagrammatic view, reduced to lowest terms, of one embodiment of the skin effect modulator of my invention.

Figure 2 is a sectional view, taken as indicated by the line 2—2 in Figure 1.

Figure 3 is a sectional view, taken as indicated by the line 3—3 in Figure 1.

Figure 4 illustrates a simple means for cooling the modulator link.

I prefer to include ferro-magnetic material in a tuned circuit, in this case represented by inductance coils 1 and 2, the far ends of which are connected by a variable condenser 3. This tuned circuit may be connected to a generator of high frequency alternating currents, as indicated by the arrows 4—4. It is convenient to use a vacuum tube oscillator for this purpose. If the inner ends of the inductances 1 and 2 were connected together, and if the tuned circuit, for example, was the tuned plate circuit in a tuned-plate tuned-grid oscillating tube system, the junction of the two inductances would be a potential node which, if desired, could be grounded. It is at this point that I desire to insert ferro-magnetic material.

I prefer to form the ferro-magnetic material as a closed, substantially rectangular, loop 5. I also prefer to form this loop from hollow tubing of ferro-magnetic material having high permeability, which will, of course, have a fair degree of conductivity under any conditions. I then prefer to connect the inner ends of the inductances 1 and 2 to the ends of one of the long legs 6, at contact points 7, positioned at adjacent corners of the loop. I have thereby provided a ferro-magnetic path through the voltage node of the inductance. A magnetizing coil 8 is wound around the other long leg of the loop 9. Leads from this coil pass to the secondary 10 of a transformer 11 whose primary 12 is connected in series with a battery 13 and a microphone 14. If desired, a bias battery may be placed in series with the coil 8 and the secondary 10 so that the steady magnetization of the loop may be adjusted to any desired value. Sound entering the microphone will cause a varying magnetization of the loop. In order that any possible radio frequency may be prevented from entering the coil 8, I prefer to shunt the coil leg 9 of the loop by a heavy non-magnetic conducting tubular bar 15, preferably of copper. The center of this bar may then be grounded through a central contact 16. I also

prefer to form the loop of such dimensions that the short legs 17—17 of the loop are half as long as the long legs 6 and 9, thus making the resistance through the leg 6 practically equal to the resistance through the legs 17 and the copper bar, in-as-much as the high frequency resistance of the copper bar is practically negligible. For that reason I prefer to form the copper bar of hollow section, as shown in Figure 3.

The operation of the device is simple. When the tuned circuit is energized by a generator, current passes through the loop leg 6, and as this material is of high permeability, the skin effect is large and the effective resistance to high frequency relatively high. Changing the magnetization of the loop, by passing modulating currents through coil 8, changes the effective resistance of the leg 6, thereby changing the amount of high frequency current passing therethrough. The high frequency, therefore, is effectively modulated, and the system may be used for modulating a radio transmitter, as may be desired. The entire device, being positioned substantially at a voltage node, loses practically no radio frequency through the modulating portion of the circuit, and the copper shunt allows the center portion of the inductance to be properly grounded, even though the magnetic material is included in the oscillating circuit.

In devices carrying high power, it may be desirable to cool the modulator. One way of doing this is shown in Figure 4. A combination inlet and outlet tube 13 is connected to the copper bar 15 at the grounded central contact point 16, and a partition 19 continued through the tubular bar 15 to block the tube. Water or similar liquid at ground potential may then be circulated through the hollow structure while in operation.

Other embodiments of my invention will obviously be apparent to those skilled in the art, as the particular system shown and the particular location of the modulator has been used only to illustrate the invention in a preferred circuit.

I claim:

1. A skin effect modulator comprising a tuned circuit, a generator of alternating current feeding said circuit, a closed ferro-magnetic loop having a portion thereof included in said tuned circuit, a magnetizing coil on another portion of said loop, and means for passing a modulating current through said coil.

2. A skin effect modulator comprising a tuned circuit, a generator of alternating current feeding said circuit, a closed ferro-magnetic loop having a portion thereof included in said tuned circuit, a magnetizing coil on another portion of said loop, means for passing a modulating current through said coil, and a nonmagnetic highly conductive shunt around the coil portion of said loop.

3. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, and means for passing a varying current through said coil.

4. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, means for passing a varying current through said coil, and a nonmagnetic conductor shunting only the leg on which said coil is placed.

5. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, means for passing a varying current through said coil, a nonmagnetic conductor shunting only the leg on which said coil is placed, and means for grounding the central point of said shunting conductor.

6. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, and means for passing a varying current through said coil, the short legs of said loop being substantially half the length of said long legs.

7. A skin effect modulator comprising a tuned circuit, a generator of alternating current feeding said circuit, a closed ferro-magnetic loop having a portion thereof included in said tuned circuit, a magnetizing coil on another portion of said loop, means for passing a modulating current through said coil, and means for cooling said loop.

8. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, means for passing a varying current through said coil, a nonmagnetic conductor shunting only the leg on which said coil is placed, said loop and said conductor being hollow, means for passing cooling fluid through said loop and said conductor, and means for grounding the central point of said conductor.

9. A skin effect modulator comprising an inductance, means for passing an alternating current through said inductance to provide a central point of zero potential thereon, a closed loop of ferro-magnetic material of rectangular shape, said inductance being divided at said central point to include therein one of the long legs of said loop only, a magnetizing coil on the other long leg of said loop, means for passing a varying current through said coil, a nonmagnetic conductor shunting only the leg on which said coil is placed, said loop and said conductor being hollow, means for directing a cooling fluid through said loop and said conductor, said latter means being located at the central point of said shunting conductor at ground potential.

RUSSELL H. VARIAN.