Nov. 29, 1938. E. M. SARGENT 2,138,123

STATIC ELIMINATION CIRCUIT

Filed May 7, 1935 2 Sheets-Sheet 1

Fig. 1.

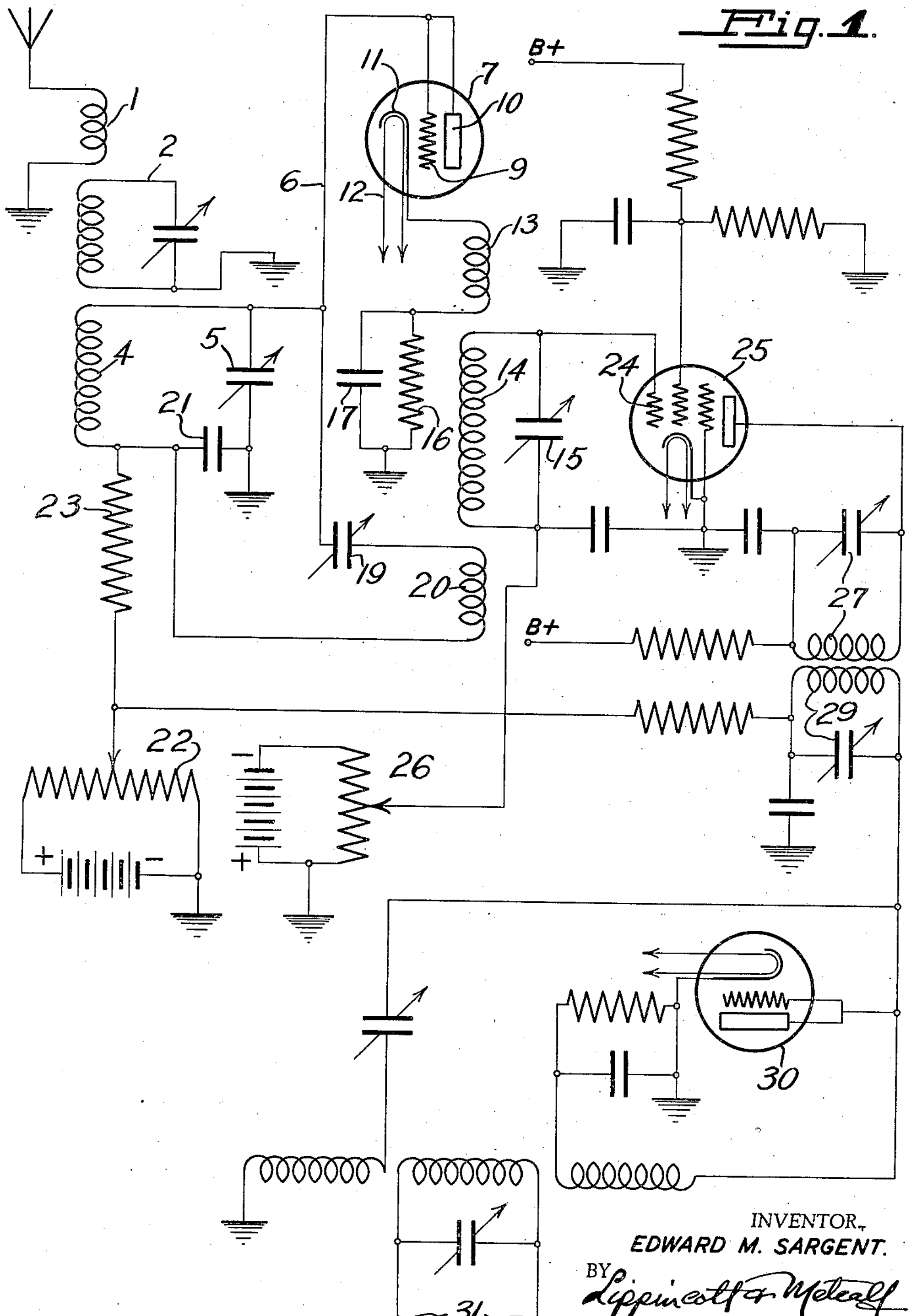

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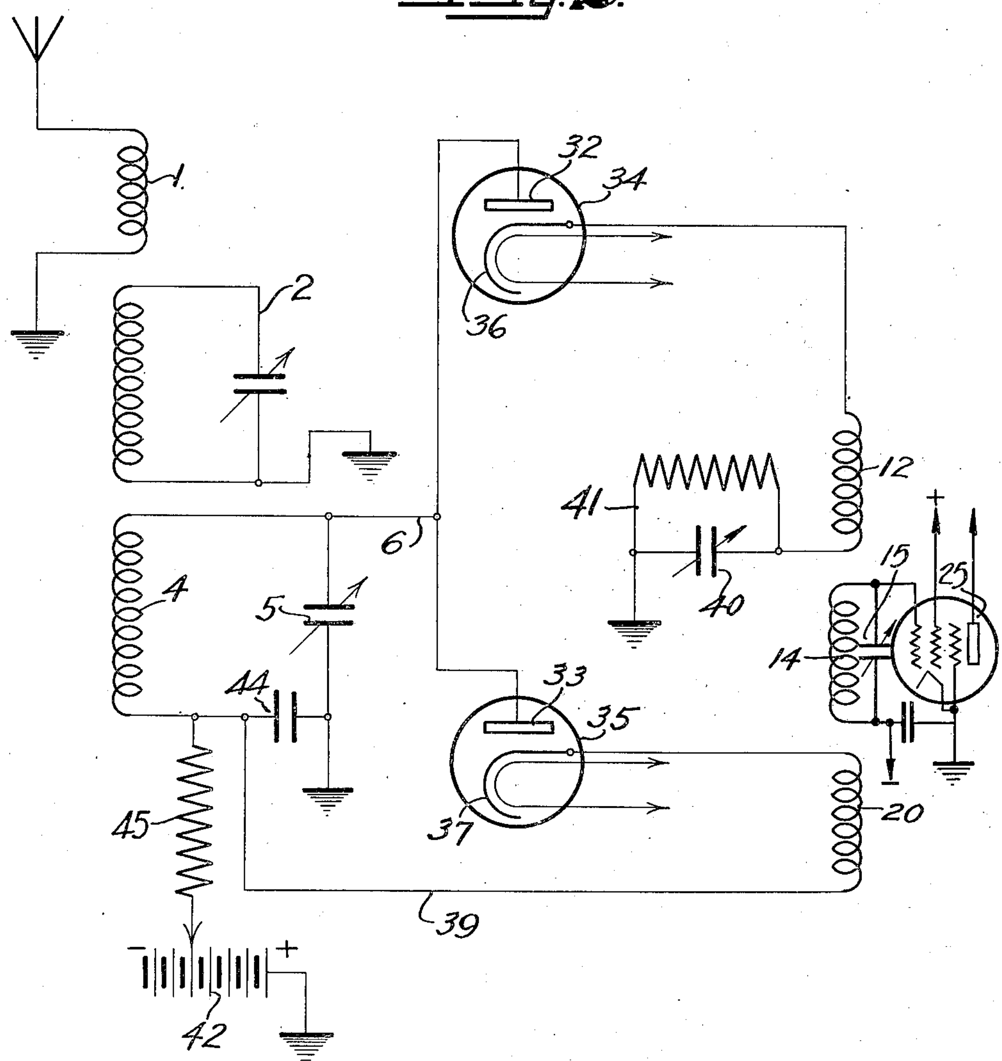
Fig. 2.



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UNITED STATES PATENT OFFICE

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STATIC ELIMINATION CIRCUIT

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5 Claims. (Cl. 250—20)

My invention relates to static elimination circuits, and more particularly to a circuit adapted for use in conjunction with thermionic tube space charge amplifiers to eliminate prolongation of the effect induced therein by static discharges.

Among the objects of my invention are: To provide a means and method of preventing impact excitation of amplifying circuits in radio receivers; to provide a means and method of preventing flywheel effect of tuned circuits in conjunction with thermionic tube amplifiers from prolonging and making audible static interference; to provide a means and method of preventing shock excitation of successive amplifying stages in radio reception by an initial static impulse; to provide a means and method for preventing the prolongation of static discharges in radio amplifying circuits; to provide a static blocking circuit; to provide a means and method for damping static impulses without substantial interference with the signal passing through the same circuit; and to provide a simple and effective method of reducing static interference in radio reception.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

In the drawings:

Figure 1 is a diagrammatic circuit reduced to lowest terms of one modification of my invention.

Figure 2 is another circuit diagram reduced to lowest terms showing another modification embodying the same invention.

My invention broadly relates to the use of a diode tube, or more particularly, a thermionic tube having an emitter and a collecting anode, this tube being inserted in series with the connection between a signal source and a tuned radio frequency amplifier stage when the invention is applied to radio receivers. I am fully aware that diodes have been used in various ways in radio receiving sets prior to the instant invention and that in such prior uses the diodes have been used to solve certain problems involved in static elimination. The objective, however, of substantially all these prior systems is that of limiting static voltage to the signal level. In other words, the prior art uses the limiting effect due to saturation of the diode to accomplish such limitation. Assuming that such prior art succeeded, the best condition which could be obtained would be an equal amplitude for both static and signal. While this condition might conceivably be of value in radio telegraph reception, it is of no aid in radiophone or broadcast reception.

In the latter case, the carrier level is many times the amplitude of the weaker voice modulations of the carrier; hence, even with such prior art limiting systems working at the optimum condition, a ratio of ten to one or more is still possible between the static voltage and the net signal value. I utilize the diode in conjunction with radio reception in an entirely different manner.

I have found that the so-called flywheel effect of tuned circuits greatly prolongs and makes audible, static interference. In the analysis of the static discharges which are commonly received on the antenna of a radio receptor, it is safe to assume that the log decrement of the static discharge will not be less than .8; this being based on an assumption that legal log decrement for spark transmitters is .2 and that such spark signals tune at least four times as sharp as the average static impulses. The number of waves, therefore, in a decaying static wave train necessary to decrease the amplitude to one per cent of the original is given by the formula

$$N=\frac{4.6\times\log\text{ decrement}}{\log\text{ decrement}}$$

If then, we apply this formula to a static discharge of one million volts at a frequency of one thousand kilocycles, we obtain the following elapsed times:

Amplitude voltage	Number cycles	Total time elapsed
Volts		*Sec.*
1,000,000	0	0
10,000	6.75	.000007
100	13.5	.000014
1	20.25	.000020
.01	27.0	.000027
.0001	33.75	.000034
.000001	40.5	.000041

Thus, an impact on the antenna of even such an excessive voltage would be reduced to one microvolt, the sensitivity limit of the most sensitive receiver in use to-day, in slightly more than 1/25,000 of a second and in spite of its tremendous initial voltage would be inaudible because the total period of its existence at sufficient energy content to actuate a sensitive receiver would be too short a period for it to affect the human ear.

It is obvious, therefore, that this original decrement is not maintained and that something happens in the receiver itself to prolong the effect of the impulse. The flywheel effect of tuned circuits is partially responsible and the better the circuits, the more pronounced the effect. I have also found that a second cause is the concentration of electrons between the grid and cathode of the receiving tube held there by the negative grid charge of the tube. A single impulse from the static voltage in the positive direction will free this entire space charge giving a resultant current, for one or two cycles, equal to hundreds or thousands of times the amplitude of the current which could be continuously released by an undamped carrier of the same amplitude. Because of flywheel effect, this disproprotionate resultant current, induced in a subsequent tuned circuit of low decrement, would require a long period of time to decay to a point where its energy content would become negligible. Thus, modern amplifier tubes greatly favor the magnification of static impulses over the desired signal.

I have also found that the release of this space charge by the static impulses results in a diminution of the effect of the desired signal on the plate current of the tube until such time as the space charge is replaced, thus the static actually modulates the carrier. When this happens, there is no way in which such modulation can be eliminated later in the circuit. Such a condition, however, may be entirely eliminated by the use of a series diode as there is practically no space charge in the diode unless the diode has a negative bias (cold element negative with respect to emitter) and therefore both static and the desired signal can pass through the diode only by drawing electrons directly from the cathode, a slower process that favours the continuous undamped carrier over that of the shock excitation given to it by the static impulse.

My invention, therefore, comprises broadly the use of diode circuits in conjunction with regular low decrement circuits to damp out flywheel effect of the tuned circuits in the receiver and to prevent space charge release. This prevents any possibility of static impulses reaching a level later in the circuit where they can make themselves audible. It also has the advantage of eliminating other types of impulses originating in the set itself, such as tube hiss.

In addition, my invention comprises the use of two diodes so connected in the circuit that the capacity between the elements of the diode may be balanced to maintain the overall capacity at a minimum. Such capacity would tend to bypass the diode action of the tube and allow a strong static voltage to reach a point in the circuit where it would become audible. I also utilize a form of limitation entirely different from that described in the prior art. I do not try to limit the static to the signal level but to limit static voltage to a maximum which will not allow it to swing the grids of the various space amplifier tubes positive or nearly positive. For example, if the amplifier tube has a grid bias of three volts negative, a static impulse could swing it to two volts or even one volt negative without doing a great deal of harm. If this happened to the input tube on a receiver having a one microvolt sensitivity and a one microvolt signal, there would be a ratio of two million to one between the harmless static voltage and the signal voltage before the grid would go sufficiently positive to release space charge energy.

Specifically, I use a system employing a pair of diodes in series with the signal current so inserted that their capacity neutralizes each other. I may also use a single series diode with either no bias or a positive bias and a neutralizing capacity, or again a single diode having special electrodes reducing the capacity to a minimum.

I also prefer to utilize a sharply tuned circuit in conjunction with the diode in order that the damping factor as related to the signal passing through the diode may be corrected in order to give the necessary selectivity. The diode, being resistive is a strong damping factor in a tuned circuit.

Referring directly to the embodiment in Figure 1; an antenna circuit **1** is coupled to a sharply tuned intermediate or link circuit **2** which in turn couples to a tuned circuit comprising a inductance **4** and a variable capacity **5**. This tuned circuit feeds through a connecting wire **6** to diode **7** which may be in the form of a diode or a standard three-electrode tube or triode having the grid **9** and plate **10** coupled together to form a diode. The cathode may conveniently be a unipotential surface **11** heated by the usual type of heater **12**.

The cathode **11** connects to a primary coil **13** of a multi-winding transformer having a secondary **14** tuned by a secondary condenser **15**. The current through primary winding **13** passes to ground through a resistor **16** shunted by a capacity **17**. Connected to wire **6** which leads to the anode of the diode is a small neutralizing condenser **19** in series with a second primary coil **20** which is wound in the opposite direction to that of primary **13**, the inductance **20** thence being connected to the input circuit between the inductance **4** and blocking condenser **21**. Bias is applied by bias assembly **22** through resistor **23**. The output of the multi-winding transformer comprising secondary **14** and secondary tuning condenser **15** is applied to the grid **24** of a radio frequency pentode **25**, provided with the usual biasing assembly **26**, the output of the pentode passing into a tuned output circuit **27**. Other usual amplifying tube stages are deemed full equivalents. Coupled to the output circuit **27** is a sharply tuned diode input circuit **29** feeding a second diode **30** hooked up in the identical manner with diode **7**, the output of diode **30** appearing across terminal **31** and being applied preferably to another pentode stage to form a cascade amplifier.

In operation, it will be seen that the input voltage is applied through diode **7** to the pentode **25**, the output of pentode **25** being applied to other amplifying tubes through diode **30**. Referring directly to diode **7** it will be seen that inasmuch as primary **20** is wound in the opposite direction to primary **13**, that if neutralizing condenser **19** is so adjusted as to equal the capacity of diode **7** that the currents flowing as a result of capacity transfer in the two primaries balance out so far as their effect on secondary **14** is concerned, but that the rectified half cycles flowing as a result of conduction through the diode flow in primary **13** alone and hence appear in the secondary.

The theory of operation is that although the input static impulses may possess extremely high potentials, they are of extremely short duration. When a high voltage pulse of static type is impressed upon the grid of the conventional vacuum tube, such as pentode 25, for example, it can release a disproportionately large amount of energy into the output circuit of the amplifying tube, during a positive half cycle, because of the high space charge collected behind the grid.

The large instantaneous pulse thus released causes impact excitation of the tuned circuits in the output of the amplifying tube, which in turn impresses high voltage pulses of longer duration upon the next amplifying tube. Where the first tube is a diode, however, as in my present invention, there is no such reservoir of energy waiting to be tapped. The diode acts as a strong damping factor and the short period, high voltage energy of the static exerts itself in giving some slight additional acceleration to electrons passing between cathode and anode, but usually not sufficient to cause impact excitation of the output circuit. There is of course, some small kick applied to the output circuits but since a diode is preferably used between each amplification stage, the suppressing action prevents build-up of the interference to the point where it can unduly prolong its existence.

The intermediate sharply tuned circuits 2 and 29 are used to provide the necessary selectivity since the damping of the signal introduced by the diode would otherwise broaden the tuning too greatly. It is of course to be understood that diode 7 may be fed by a beat frequency oscillator as well as with the input signal and the transformer 13—14—20 may be tuned to an intermediate frequency instead of to the radio frequency. The result, however, is exactly the same. It will also be understood that each of the circuits herein described should be properly shielded as is well known in the art, the indication of shielding being omitted here for purposes of simplicity.

I may also desire to utilize a double diode system which need not be neutralized as the capacity of the two diodes can be used to produce an inherent neutralization; and in addition, I am able to obtain a limitation of static voltage to a maximum that will not allow it to swing the grid of the following triode, tetrode, or other amplifying tube, positive or approaching a positive potential.

Referring directly to Figure 2, the antenna system 1 is coupled to the sharply tuned intermediate circuit 2, and thence to the input circuit 4—5 as before. Connection 6, however, in this case passes to the anodes 32 and 33 of two diodes 34 and 35. Cathode 36 of diode 34 passes through first primary 12 and a resistor 41 shunted by a variable capacitance 40 to ground. Cathode 37 of diode 35 passes through the second primary 20 and thence is connected by means of wire 39 to the input circuit between a series capacity 44 and a bias resistor 45 supplied by a variable bias battery 42, the positive end of which is grounded. The side of capacity 44 opposite the connection point of wire 39 is also grounded. The secondary 14 of the multi-winding transformer 12, 14, 20 is connected directly to pentode 25 as is shown in Fig. 1. However, I do not wish to limit myself to this structure alone for it is very apparent that the entire circuit shown in Fig. 2 could be built as an attachment which might be placed ahead of any ordinary receiver with output of transformer 14 being fed directly to the antenna and ground connections of the receiver. Of course, with this arrangement the pentode 25 and tuning condenser 15 would preferably be omitted. It is also possible to place another pair of diodes connected as shown in Fig. 2 between other amplifying tubes in a cascade amplifier.

In the double diode static blocking circuit, the cathode 36 returns to ground through variable condenser 40 and resistor 41 to duplicate as far as possible in diode 34 the D. C. characteristic of diode 35 and to have the same capacitative effect as the variable condenser 19 of Fig. 1. Cathode 37 returns to the input circuit, without bias. In operation, the bias assembly 42—45 places a negative bias on diode 34 which renders it inoperative until the bias point is overcome by a static impulse. At the point that diode 34 becomes operative, it opposes diode 35. The capacity of the two diodes, being the same, acts together to neutralize the capacity current and only diode current from unbiased diode 35 flows under non-interference conditions.

I thus obtain the shock reduction by the use of the diodes with neutralization of capacity current; and in addition, provide a limitation of the static voltage to a maximum which will not allow it to swing the grid of the following amplifier tube positive. It can be seen, of course, that in a circuit such as I have described, that there is some loss of energy due to the use of the diodes. I find, however, that this energy loss may be easily made up for by the use of an additional amplifying stage. The use of such an additional stage is not at all objectionable because of the extreme quietness of the circuit.

While I believe that the theory of operation above described is the correct one, I do not wish to be bound thereby, but I have found in actual practice there are two factors that indicate the correctness of the theory as outlined, one, indicating directly, the other indirectly. The indirect evidence is that where a signal is so disrupted by static as to be unintelligible a modulation meter in the output circuit will faithfully follow the signal and respond to the static little if at all, thus, indicating that the static impulses, although large in initial amplitude, have a relatively short period of duration. The second factor directly observed is that the circuit as described has been built and is extraordinarily quiet under very bad static conditions.

I claim:

1. In a radio frequency amplifying stage having a space charge amplifying tube therein, a tuned circuit excited by radio frequency currents, and a damping link between said circuit and said tube comprising a pair of diodes connected in parallel, one of said diodes being negatively biased, means for equalizing the capacitative reactance of said parallel diode paths, and means for feeding the output of both diodes to said tube in opposite phase relation.

2. In a radio frequency amplifying stage having a space charge amplifying tube therein, a tuned circuit excited by radio frequency currents, and a damping link between said circuit and said tube comprising a pair of diodes connected in parallel, one of said diodes being negatively biased to reduce space current to zero, and means for feeding the output of both diodes to said tube in opposite phase relation, both of said diodes having substantially the same internal capacity, and means for equalizing the capacitative reactance of said parallel diode circuits.

3. In a radio frequency amplifying stage hav-

ing a space charge amplifying tube therein, a tuned circuit excited by radio frequency currents, and a damping link between said circuit and said tube comprising a pair of diodes connected in parallel, one of said diodes having a zero bias and the other diode having a negative bias, means for equalizing the capacitative reactance of said parallel diode circuit paths and means for feeding the output of both diodes to said tube in opposite phase relation.

4. In a radio frequency amplifying stage having a space charge amplifying tube therein, a tuned circuit excited by radio frequency currents, and a damping link between said circuit and said tube comprising a pair of diodes connected in parallel, one of said diodes having a zero bias and the other diode having a negative bias, means for equalizing the capacitative reactance of said parallel diode circuit paths, means for feeding the output of both diodes to said tube in opposite phase relation, and selective means for correcting the damping of the signal impulses only.

5. In a radio frequency amplifying stage having a space charge amplifying tube therein, a tuned circuit excited by radio frequency currents, and a damping link between said circuit and said tube comprising a pair of diodes connected in parallel, means for equalizing the capacitative reactance of said parallel diode paths, means for regulating the anode voltage on one diode to a value preventing current flow over a predetermined voltage range under dynamic conditions, and means for feeding the output of both diodes to said tube in opposite phase relation.

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