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ELECTRICAL IMPEDANCE MATCHING APPARATUS

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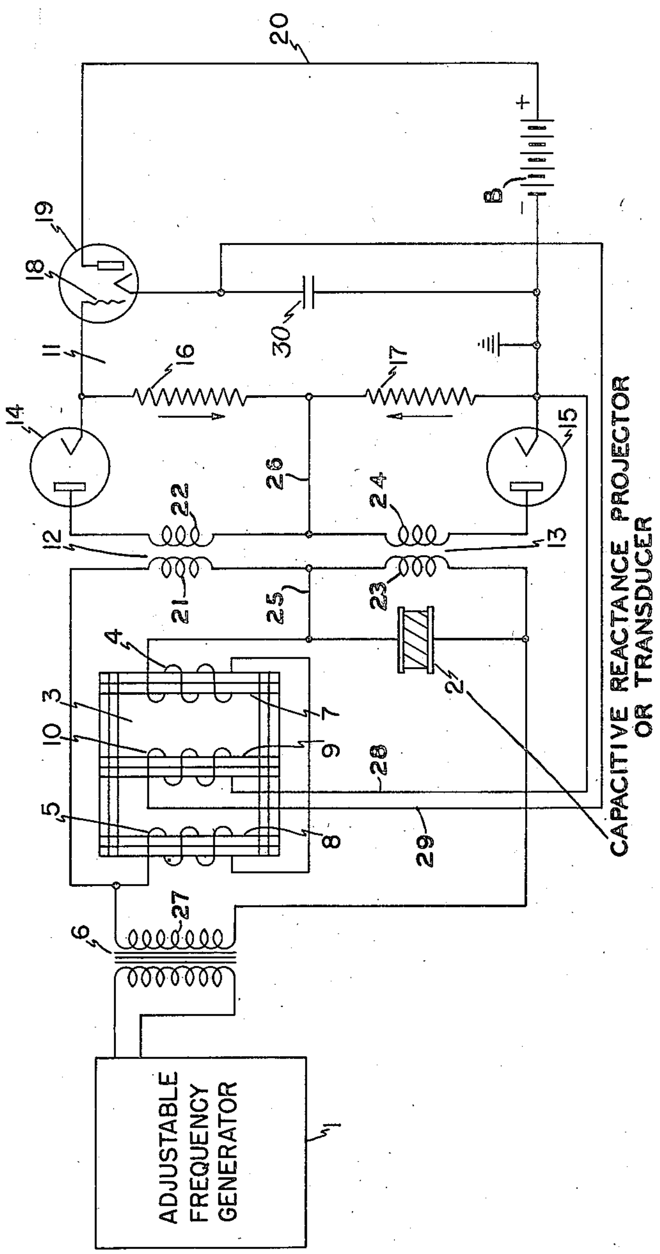

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ELECTRICAL IMPEDANCE MATCHING APPARATUS

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The present invention relates to electrical circuits and more particularly to circuits for matching the impedance of an electrical device when operated at varying frequencies. An application of this is to be found in the art of submarine signalling where crystal projectors having definite frequency characteristics are used to produce compressional wave vibrations in a water medium.

The system, according to the present invention, is also applicable to communicating systems where electrical oscillations varying in frequency are impressed upon some electrical apparatus or some communicating system. The invention however finds particular utility in the operation of submarine compressional wave producers for the supersonic range with the use of crystals, such as crystals of ammonium dihydrogen-phosphate, Rochelle salt or the like. Crystals of this type may be used as a resonant structure or in a semi-resonant structure with electrical circuits having tuning elements with inductive reactance. Such tuning elements are commonly used to match the impedance of the compressional wave transmitters or transducers with the generator supply source. In some cases where the frequency is maintained constant, fixed values of inductances may be used to provide the necessary tuning and matching of the generator and transmitting circuits.

In cases however where it is desired to change frequencies over a given range as for instance in submarine signalling, where a projector may be used to send any frequency within a band range from 16 to 45 kc., it is desirable for best efficiency to match the impedance of the transmitting circuit with that of the generating circuit for whatever frequency which may be chosen.

Where both apparatuses, projector and generator, are readily available, manually operating devices may be used to make the necessary tuning changes but even under such conditions independent adjustments may have to be made in the generating and transmitting circuits. Where the devices are widely separated such adjustments must be made either by remote control, or by long cable connections. In the present invention this difficulty has been overcome by providing an automatic adjustment by means of which the impedance in the transducer or projector circuit is modified as the frequency is changed until a balancing correction is made.

The adjustment is self-corrective in the present case and if external conditions at any time, as for instance temperature changes, pressure

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changes, or water conditions, bring about changes in electrical values in the projector or transducer, these will automatically cause a change in the tuning impedance to effect a matching at the frequency for which the generator impressing the power on the system happens to be adjusted. The invention will be more fully described in connection with the specification set forth below taken in connection with the drawing which shows a schematic electrical diagram of the invention.

In the drawing, 1 represents the generator which may be an electron tube electrical oscillation generator or a machine type electrical oscillation generator which may be adjusted to produce any frequency in the desired range. In the supersonic transmission under water this may be over a range from 20–30 kc., for example, or any desired signaling range of frequency, for instance 16 to 45 kc. as set forth above.

The projector 2 may be made up of a number of ammonium dihydrogen-phosphate or Rochelle salt crystals used in a tuned or semi-tuned structure and radiating to a sound propagating medium through some well-known acoustic coupling means. The projector or transducer 2, as it may be called, is of the capacity type in which the current leads the voltage across the device. To tune this in the series circuit an impedance element 3 is necessary. This provides two inductance coils 4 and 5 in series connection with each other and with the projector 2 across the secondary winding 27 of the transformer 6, the primary of which is connected across the output of the adjustable frequency generator. The two coils 4 and 5 and the projector 2 are thus in effect serially connected to the generator 1. Coil 4 is joined at one end to one end of the transducer 2 at a common connection 25. The coils 4 and 5 are on legs of cores 7 and 8 respectively which form closed magnetic circuits with a third core 9 about which is wound a coil 10 for controlling the saturation condition of the cores. A change in the current flowing through the coil 10 will change the saturation condition of the cores 7, 8 and 9 and thereby change the inductance of the coils 4 and 5 in the series circuit mentioned above. The control of the current in the coil 10 is effected through the balancing circuit 11 which will be presently described.

A pair of transformers 12 and 13 couple the series circuit comprising the transducer 2 and coils 4 and 5 to the balancing circuit 11 in the following manner. The primary winding 21 of transformer 12 is connected in series with the coils

4 and 5 of the tuning impedance element 3 and the common connection 25. The primary winding 23 of transformer 13 is connected in series with the transducer 2 and the common connection 25. The secondary winding 27 of transformer 6 has one terminal thereof connected to the upper connection between coils 5 and 21 and the other terminal connected to the lower connection between transducer 2 and the primary coil 23.

The balancing circuit 11 comprises a pair of push-pull connected diode rectifier circuits in which the secondary windings 22 and 24 of the transformers 12 and 13 are respectively coupled in series with the electrodes of diode 14, resistor 16, the electrodes of diode 15, resistor 17 and the common return 26. One terminal of the coil 10 is connected by the lead 28 to the grounded cathode of diode 15 and the other terminal thereof is connected by the lead 29 to the cathode of the vacuum tube 19.

At resonance the voltage impressed across each transformer 12 and 13 has the same magnitude and as a result the voltage drops in the high resistances 16 and 17 are equal and in opposite directions. These resistances 16 and 17 are very large in magnitude and provide a substantially open circuit across the transformers 12 and 13 respectively. The resistances 16 and 17 are serially connected to the grid 18 of the vacuum tube 19 and provide a varying bias on the grid for controlling the anode-cathode current flowing through the tube. When the bias is zero a balance is obtained with the anode-cathode current through the coil 10. When the bias is reduced to a higher negative value the anode-cathode current in the line 20, furnished by a battery B, is decreased and therefore the current through the coil 10 which bypasses the condenser 30. When the bias 18 is made positive the current through the tube 19 is increased and likewise the current through the coil 10.

Desired tuning is established for the zero bias position. The rise or fall of the bias about zero will establish the necessary correction by causing more or less current to flow through the coil 10.

In this connection it is to be noted that the impedance of the projector 2 decreases with increase of frequency while the inductive impedance of the coils increases with increase in frequency. An increase of impedance in the coils 4 and 5 will bring a positive bias from the resistance 16 on the tube 19 which is used to increase the current in the coil 10 to reduce the effective impedance of the coils 4 and 5 to reduce the bias to zero. The difference in voltage between resistances 16 and 17 provides the bias on the tube 19, and the change in cathode anode current brings about the necessary correction to restore a balance in the tuning circuit.

Having now described my invention, I claim:

1. In combination with a frequency adjustable electric oscillating generator circuit for supplying power, a transducing device, a tuning circuit including therein the transducing device having capacitative reactance and a tuning impedance means having a coil with a saturable core, means controlling the saturation of the core comprising a pair of normally balanced vacuum tube circuits adapted to be unbalanced with change in frequency of the adjustable frequency generator, means operated through said unbalance to vary the saturation of said core to bring about a new balance at the adjusted frequency.

2. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means serially connected to said oscillating generator, said tuning impedance means having a coil with a saturable core, means controlling the saturation of the core comprising a pair of normally balanced vacuum tube circuits adapted to be unbalanced with change in frequency of the adjustable frequency generator and means operated through said unbalance to vary the saturation of said core to bring about a new balance at the adjusted frequency.

3. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means connected in series with one another and across said oscillating generator, said tuning impedance means having a plurality of interconnected reactors operative to change the effective value of the tuning impedance, means comprising a pair of vacuum tube circuits connected respectively across the transducing member and the tuning impedance means, means operative by the differential voltage developed by said pair of circuits for controlling said reactors to effect the value of the tuning impedance to reduce the differential voltage to zero.

4. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means connected in series with one another and across said oscillating generator, said tuning impedance means having a magnetic circuit of parallelly connected cores, a coil for controlling the saturation of said cores and the tuning of the impedance, means comprising a pair of vacuum tube circuits connected respectively across the transducing member and the tuning impedance means, means operative by the differential voltage developed by said pair of circuits for controlling the current flowing through said coil to effect the tuning impedance to reduce the differential voltage to zero.

5. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means connected in series with one another and across said oscillating generator, said tuning impedance means having a magnetic circuit of parallelly connected cores, a coil for controlling the saturation of said cores and the tuning of the impedance, means comprising a pair of vacuum tube circuits connected respectively across the transducing member and the tuning impedance means, and a single vacuum tube circuit having a tube with a control grid with a pair of biasing elements connected one in each of said pair of vacuum tube circuits, said single vacuum tube circuit having an anode cathode circuit with said coil connected therein to effect the tuning of the impedance to reduce the combined voltage of the biasing elements to zero.

6. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means connected in series with one another and across said oscillating generator, said tuning impedance means having a magnetic circuit of parallelly connected cores, a coil for controlling the saturation of said cores and the tuning of the impedance means, means comprising a pair of

similar circuits having each in series connection, the secondary winding of a transformer, a diode rectifier and a high resistance, the primaries of the transformers being connected across the transducing device and the tuning impedance means respectively, means operative by the differential voltage developed in the resistors of said pair of circuits for controlling the current flowing through said coil to effect the tuning impedance means to reduce the differential voltage to zero.

7. In combination, a frequency adjustable electric oscillating generator, a tuning circuit having a substantially resonant transducing member with capacitative reactance and tuning impedance means connected in series with one another and across said oscillating generator, said tuning impedance means having a magnetic circuit of parallelly connected cores, a coil for controlling the saturation of said cores and the tuning of the impedance means, means comprising a pair of similar circuits having each in series connection, the secondary winding of a transformer, a diode rectifier and a high resistance, the primaries of the transformers being connected across the transducing device and the tuning impedance means respectively, a single vacuum tube circuit having a tube with a control grid with said high resistances connected thereto to furnish bias voltage, said single vacuum tube circuit having an anode cathode circuit with said coil connected therein to effect the tuning of the impedance means to reduce the combined voltage generated in said resistances, and hence the bias voltage to zero.

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