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CONTROL SYSTEM FOR COUPLING CIRCUITS
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7 Claims

ABSTRACT OF THE DISCLOSURE

An automatic control system is described for adjusting reactive elements in a coupling circuit disposed between an active element and an output network so that a maximum amount of power is transferred from the active element to the output network. The control system is adapted to continuously adjust the reactive elements in the coupling circuit until it senses that the voltage applied to the coupling circuit has just passed its maximum level, at which time the control circuit stops adjusting the reactive elements.

The present invention relates to a control system for adjusting the impedance of a coupling circuit.

The impedance of an input device, such as an RF power amplifier, is commonly matched to an output network, such as an antenna, by careful value selection of the reactance of elements in a coupling circuit. Most coupling circuits employ at least two adjustable impedance elements, one of which is for phase correction, and the other is for impedance magnitude correction. The control systems used in this scheme have often been complex. Moreover, many of the prior control systems encounter difficulties by either failing to adjust the coupling circuit so that it achieves a satisfactory impedance match or require a relatively long period to tune the coupling circuit. In this connection, prior arrangements have had especial difficulties sensing phase angles and impedance magnitudes when the antenna broadcasts over a broad frequency span of say from 2 to 76 megahertz.

In view of the foregoing, it is an object of the invention to provide an improved control system for an impedance matching coupling circuit which requires relatively little tuning time even though the frequency range covered may be appreciable.

It is a further object of the invention to provide an improved control system for coupling circuits which is relatively simple, easy to manufacture, and which has a high degree of accuracy.

In accordance with one exemplary embodiment of the invention, there is provided a coupling circuit disposed between the output tube of a transmitter and an antenna network and which has at least two reactive elements which are simultaneously adjusted by means of a motor. The control system employs sensing means for determining when the voltage of the output tube just passes through its maximum amplitude. At this time, these means stop the tuning motor so that the impedance of the adjustable elements are now set with the coupling circuit closely matching the impedance of the tube to the antenna. Stated differently, when the output voltage from the tube just swings past a maximum, the coupling circuit will be properly tuned.

The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof will become more readily apparent from a reading of the following description in connection with the accompanying drawing which is a diagrammatic illustration, partially in block and partially in schematic form, showing a representative control system in accordance with the invention.

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Referring to the drawing, there is shown a coupling circuit 10 interposed between an RF power amplifier 11 including an active element, such as an output tube 12, and an output network which in this instance is shown to be an antenna 13 connected in series with a coil 14.

In the circuit 10 a capacitor 16 is coupled across the output of the tube 12 which of course is driven by an RF signal. The circuit 10 also includes an inductor element 20 connected in series with the capacitor 16 and a shunt inductive element 21 across which the output voltage for driving the antenna 13 is developed. Two capacitors 25 and 26 are provided in the output circuit which couples the element 21 to the antenna 13. The capacitors 25 and 26 are arranged to isolate the B⁺ voltage from the antenna 13. Both the inductive elements 20 and 21 are adjustable coils. The element 16 and element 14 may have to be switched or changed at convenient frequency intervals.

The elements 20 and 21 are simultaneously adjusted by means of a shaft connection with a motor 29. The arrangement is such that initially the elements 20 and 21 are both disposed in maximum inductance positions. During adjustment with a B⁺ voltage impressed thereon, the motor 29 drives the elements 20 and 21 to positions having progressively smaller inductance until the impedance of the output tube 12, coupling circuit 10 and the output network (viz antenna 13 and coil 14) are at resonance. At resonance the B⁺ potential is effectively open circuited and the motor 29 is shut off. At that time, of course, no further adjustment of elements 20 and 21 take place. The control circuit which recognizes when resonance is reached will be described later in this specification.

The reactance of each of the elements 20 and 21 is arranged to have a substantially fixed ratio over the entire range of operating frequencies. Because of the arrangement of the elements of the circuit 10, a fixed resistive load placed across the inductance 21 will be viewed by the tube 12 to be of a higher resistance more compatible with the operation of the tube 12.

By virtue of the voltage dividing aspects of this coupling circuit, the load resistance seen by the tube 12 will vary approximately inversely with resonant frequency at a much lower rate than would the more usual prior art arrangements. This feature is important inasmuch as most active output devices are substantially affected by variations in power factor but relatively insensitive to variations in the load.

Although the circuit 10 is especially suitable for use in accordance with the present invention, it is to be understood that the more conventional coupling networks having adjustable capacitor elements and which may for example take T and pi configurations may also be employed in accordance with the invention.

It has been found that when the output voltage of an active element such as the tube 12 is for any given frequency at a maximum, the coupling circuit 10 will at that time match the impedance of the antenna 13 to that of the tube 12. The present invention makes use of this fact and employs control circuitry which senses when the voltage at the output of the tube just passes through its maximum level and develops a signal which in turn causes the motor 29 to be shut off.

Two serially connected capacitors 31 and 32 (capacitor 32 being connected to ground) are connected by means of a lead 30 to the plate of the tube 12. These two capacitors provide a voltage dividing network and at a junction 36 between these capacitors there is connected a conventional detector network consisting of a diode 40 and two capacitors 42 and 46 which are joined by a choke coil 44. The voltage developed across the capacitor 46 is applied as an input signal (representative, although

somewhat reduced in amplitude, of the envelope of the signal developed by the tube 12) to an operational amplifier 50 which has a characteristic that it develops a rather large negative going signal whenever the output of the tube 12 just swings past its maximum voltage level. This negative going signal triggers a flip-flop 52 so that its output voltage which is applied to the base of an NPN transistor 56, which receives operating potential via the coils of the motor 29, switches from a positive to a negative potential, with respect to ground. In response to such an input, the transistor 56 turns off, effectively open circuiting the B⁺ potential for the motor 29, thereby shutting off the motor 29. At this time the circuit 10 is properly tuned. It will be understood that the motor may include conventional apparatus and controls to prevent over-shooting.

Returning to the operational amplifier 50, it performs as follows: when a rising positive signal or a constant input positive voltage is applied, little or no output voltage is generated. However, whenever a decreasing voltage is applied, the output voltage quickly becomes positive, thereby driving the NPN transistor 67 into a shut-off condition. By way of example only but without limitation, it has been found that the operational amplifier model No. μ A702A manufactured by Fairchild Semiconductor can be readily employed in accordance with the invention. This amplifier is especially effective because it will recognize when the input signal has just passed a maximum position but will not be prematurely actuated by slight perturbation in the signal.

If the frequency of the output tube is to be changed, the coupling circuit 10 may be tuned to this new frequency by first actuating reversing circuitry such a switch connected to the field coils and shown diagrammatically by the block 60, which causes the motor 29 to be driven to a position whereby the inductance of the elements 20 and 21 are again at a maximum value. Thereafter, the circuitry 60 resets the flip-flop 52 so that the transistor 56 is gated on (with a positive voltage at the output of the F/F52), permitting the B⁺ voltage to start to drive the motor 29. Tuning is thereafter accomplished as described above.

While an exemplary embodiment of the invention has been described, variations thereof and modifications therein within the spirit of the invention will undoubtedly suggest themselves to those skilled in the art. For example, although the disclosed embodiment is with reference to a coupling circuit for an RF power amplifier and an antenna, it will be understood that the present invention may be used to adjust coupling circuits for a number of varieties of arrangements wherein the impedance of an output network must be matched to that of an active element. Accordingly, the foregoing description should be taken as illustrative and not in any limiting sense.

What is claimed is:

1. A control system for adjusting a plurality of reactance elements in a coupling circuit which is adapted to match the impedance of an output network to that of an active element comprising

(a) means for continuously varying the reactance of said reactance elements,

(b) means for sensing the output voltage of said active element determining when it reaches a maximum and then generating a control signal, and

(c) means responsive to said control signal for stopping the adjustment of said reactance elements, whereby said impedances of said active element and said output network are substantially matched.

2. The invention as set forth in claim 1 wherein said continuous adjustment means is a motor.

3. The invention as set forth in claim 1 wherein said sensing means includes a flip-flop.

4. The invention as set forth in claim 2 wherein said active element is a tube embodied in an RF amplifier, said output network includes an antenna, and wherein said voltage sensing means comprises means coupled across the output of said tube for generating a D.C. voltage representative of the amplitude of the signal produced by said tube, operational amplifiers means connected to said D.C. voltage generating means for producing said control signal when said output voltage swings past maximum amplitude, and means including a flip-flop responsive to said control signal for preventing said motor from adjusting said reactive elements.

5. The invention as set forth in claim 4 wherein said D.C. voltage generating means comprises a voltage dividing network connected to the output of said tube, and a detector network electrically connected between said operational amplifier means and said voltage dividing network.

6. The invention as set forth in claim 5 wherein said coupling circuit comprises a capacitor connected across the output of said tube, a first reactance element having an adjustable inductance, and a second reactance element having an adjustable inductance, said capacitor and first and second reactance elements being electrically coupled, said motor being adapted to simultaneously vary the inductance of each of said reactance elements.

7. The invention as set forth in claim 6 wherein an input voltage for said antenna is developed across said second reactance element.

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