April 20, 1965 | R. ADLER ETAL | 3,179,895

PARAMETRIC AMPLIFIER TUBE

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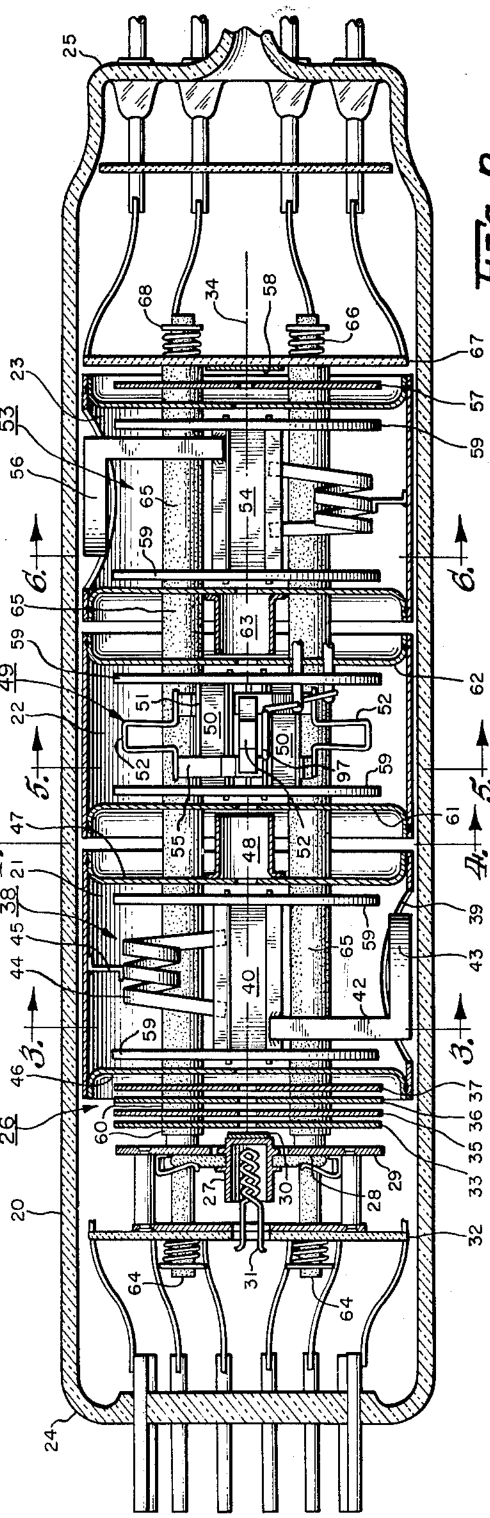

FIG. 2

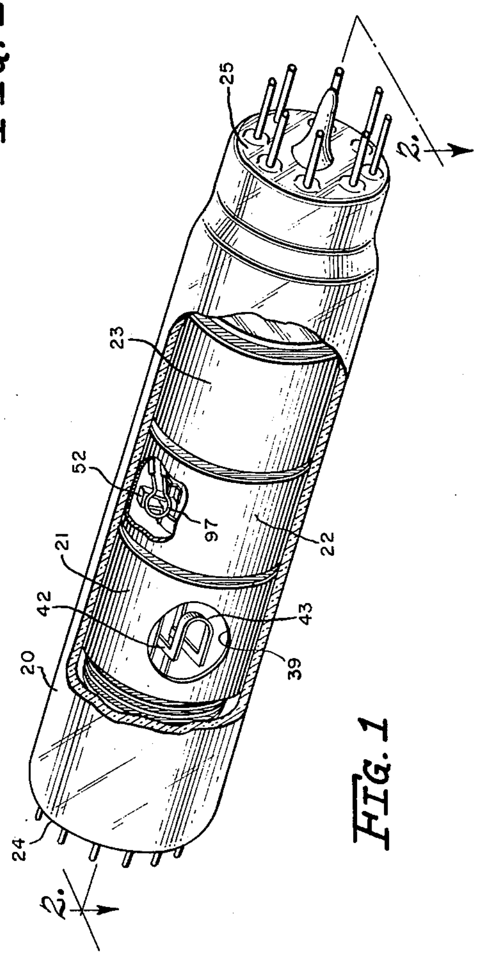

FIG. 1

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FIG. 5

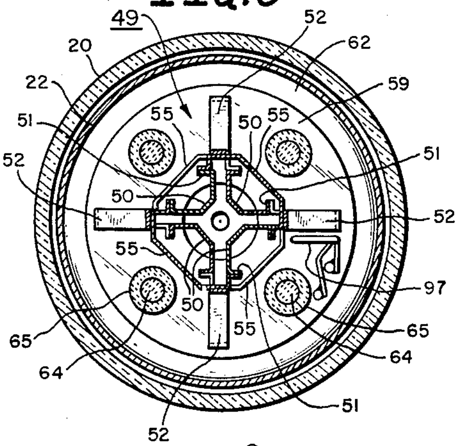

FIG. 3

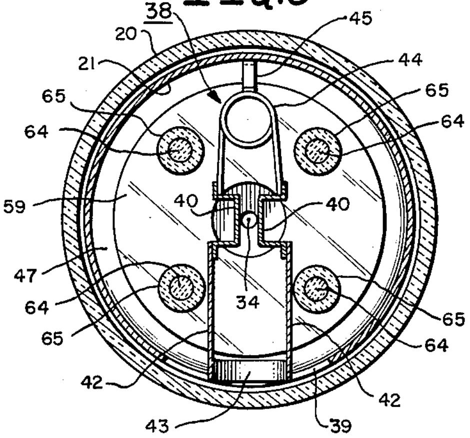

FIG. 7

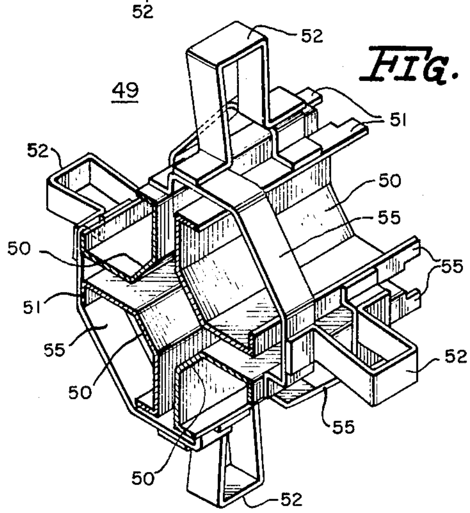

FIG. 6

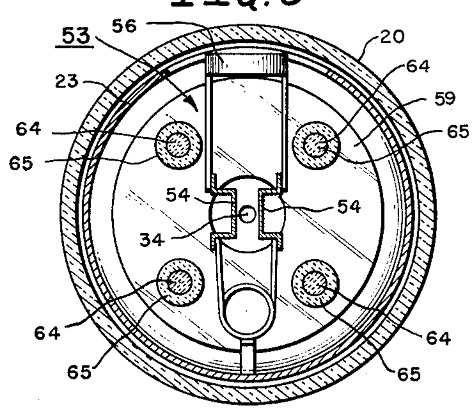

FIG. 4

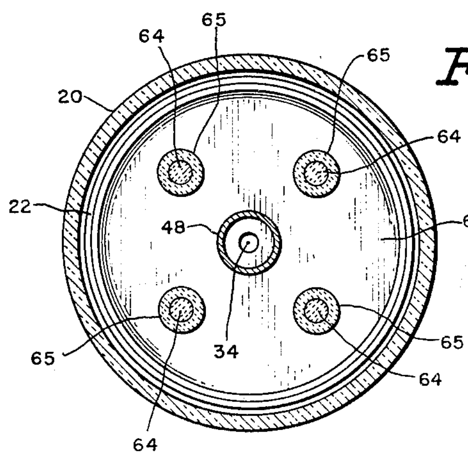

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FIG. 12

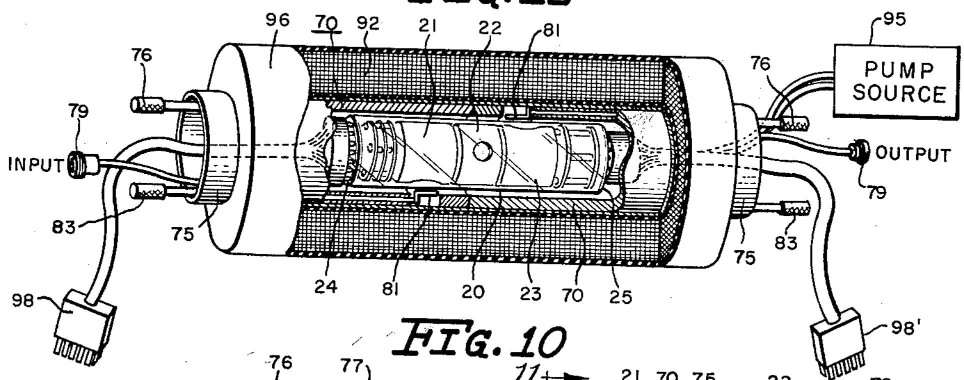


FIG. 10

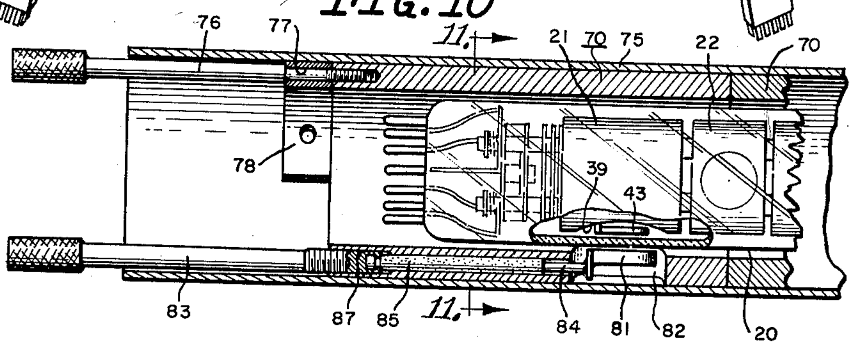


FIG. 8

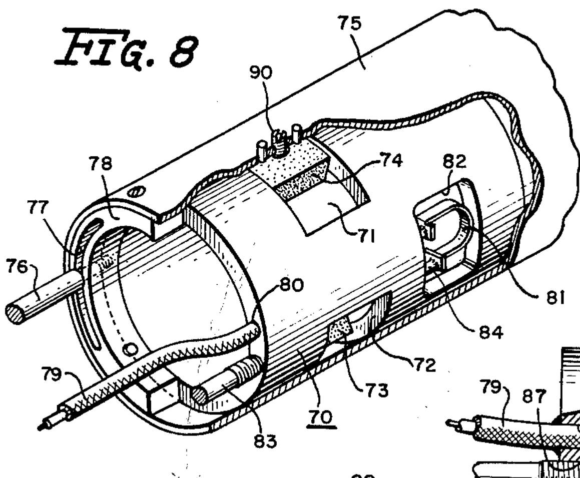


FIG. 9

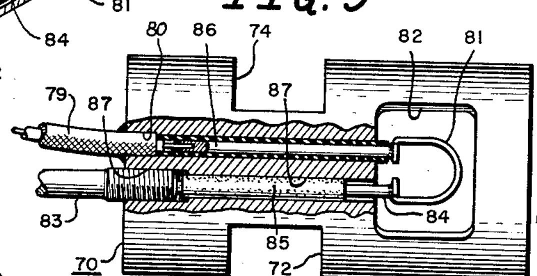
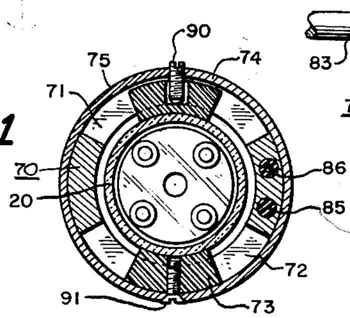


FIG. 11



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3,179,895
PARAMETRIC AMPLIFIER TUBE

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Filed Dec. 6, 1960, Ser. No. 74,084
12 Claims. (Cl. 330—43)

This invention relates to electron-beam amplifiers. More particularly it pertains to apparatus for feeding signal energy into and out of such amplifiers.

In the copending applications of Robert Adler, Serial No. 738,546, filed May 28, 1958, entitled "Electronic Signal Amplifying Methods and Apparatus," and the application of Glen Wade, Serial No. 747,764, filed July 10, 1958, entitled "Parametric Amplifier," now abandoned in favor of co-pending continuation application Serial No. 289,792, filed June 20, 1963 both of which are assigned to the same assignee as the present application, there are disclosed a variety of signal amplifying devices. In general, these devices include an electron source for projecting an electron beam along a predetermined path terminating in a collector. Spaced along the beam path between source and collector are several components including a first beam energy interaction device or electron coupler disposed along a first portion of the path and responsive to applied signal energy for modulating the beam; this modulator is in the form of a lumped-circuit resonant coupler which interacts directly with the beam as a whole to exchange energy therewith. Next along the path toward the collector are means for expanding the beam modulation after which signal energy is extracted from the expanded beam modulation through a second and similar form of electron coupler. The preferred embodiments disclosed in both of the aforesaid applications are those which parametrically amplify electron signal motion. Since the present invention has found valuable utility in such devices, it will be described in that connection.

A parametric amplifier is a device in which a reactance which is part of a transmission system is varied periodically by an external energy source. The parametric amplifying mechanisms disclosed in the aforesaid applications include means for establishing an electron resonant frequency for the electrons passing through the expanding means, as a result of which the electrons are subjected to a restoring force. A field derived from an external energy source develops a restoring force component varying in proper phase with respect to the signal motion to impart energy thereto.

As is usual in electron-beam amplifying devices, various signal and biasing voltages are applied to internal elements of the device. For example, input and output signals, energy for expanding the beam modulation, and biasing potentials are applied to the various beam forming, accelerating and modulating elements and with the structures disclosed in the aforesaid applications, conductors which normally carry signals to and from the electron couplers are positioned adjacent various of the supporting and beam shaping elements. These signals conducted to and from the couplers are at radio frequency and induce energy into the various supporting and beam shaping elements by reason of their proximity thereto. This spuriously induced energy results in undesirable absorption or reflection of signals on these conductors which can cause loss of input signal energy and develop objectionable noise on the electron beam. In addition, the number of pin connections required to properly electrically energize the devices may be undesirably large.

It is an object of the invention, therefore, to reduce the noise on the electron beam in apparatus of the general kind described.

A more detailed object of the present invention is to provide a new and improved electron-beam amplifying apparatus in which the number of pin connections is reduced.

Still another object of the invention is to provide a new and improved electron-beam amplifier which is capable of being manufactured simply and economically.

In accordance with the invention, an amplifying system for use with a signal translating circuit comprises a non-magnetic envelope and an electron source for projecting an electron beam along a predetermined path therein. A lumped-circuit resonant coupler disposed along the path transfers signal energy between an associated inductive element and the beam. The system also includes means coupled to the signal translating circuit for inductively transferring the signal energy through the envelope between an associated inductive member and the inductive element.

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIGURE 1 is a perspective view, partially broken away, of a parametric amplifying device including a portion of the inventive structure;

FIGURE 2 is a cross-sectional view taken along lines 2—2 in FIGURE 1;

FIGURE 3 is a cross-sectional view taken along lines 3—3 in FIGURE 2;

FIGURE 4 is a cross-sectional view taken along lines 4—4 in FIGURE 2;

FIGURE 5 is a cross-sectional view taken along lines 5—5 in FIGURE 2;

FIGURE 6 is a cross-sectional view taken along lines 6—6 in FIGURE 2;

FIGURE 7 is a perspective view of a quadrupole electron motion expander utilized in the device shown in FIGURE 1;

FIGURE 8 is a fragmentary perspective view, partially broken away, of coupling apparatus used according to the invention with the device shown in FIGURE 1;

FIGURE 9 is a side elevational view, partially broken away, of the coupling apparatus shown in FIGURE 8;

FIGURE 10 is a fragmentary side elevational view, partially in section, of the coupling apparatus shown in FIGURE 8 positioned on the device shown in FIGURE 1;

FIGURE 11 is a cross-sectional view taken along lines 11—11 of FIGURE 10; and

FIGURE 12 is a perspective view, partially in section, of an amplifying system constructed in accordance with the invention and including apparatus illustrated in the other figures.

The parametric amplifier tube in which the invention is incorporated for purposes of illustration has an envelope 20 of non-magnetic material, in this instance of glass. Flux-shorting cylindrical shields 21, 22 and 23 which house different sections of thet tube are positioned adjacent the internal wall of envelope 20. Conventional electrical connector pins protrude through opposite ends 24 and 25 of envelope 20 for conducting operating potential energy to the different internal components of the device.

Disposed near end 24 of the envelope is an electron gun assembly 26 for projecting an electron beam along a path 34. The gun 26 comprises a tubular cathode 27 supported by a ceramic wafer 28 from a metallic annulus 29 through which an end of cathode 27 freely projects and on which end is a cap exterially coated with an electron emissive material 30. A heater 31 within cathode 27 conditions material 30 to emit electrons. Spaced behind cathode 27 is another metallic annulus 32 forming with annulus 29 a cage substantially confining cathode 27 except for the exposed emissive area 30. Spaced in front of the emissive coating 30 is a metallic wafer 33 which accelerates the beam and has an aperture aligned with the axis of cathode 27 and on beam path 34 to limit and define the width of the electron beam. Next beyond wafer 33 is a first focusing electrode 35 in the form of a metal disk also having an aperture centered on beam path 34 to accept and pass the electron beam. Successively spaced beyond electrode 35 are second and third focusing electrodes 36 and 37 likewise having respective apertures centered on beam path 34 and also serving to properly form the beam so that it emerges from the electron gun assembly with its electrons traveling in a direction parallel to beam path 34. Additional electrodes may be employed to effect further forming of the beam if desired.

Just beyond electron gun 26 is an electron coupler or modulator 38, the configuration of which is shown more clearly in FIGURE 3. Except for a window 39, modulator assembly 38 is circumferentially surrounded by shield 21. It has outwardl facing channel-like electrodes 40 disposed on opposite sides of beam path 34. A novel inductive element or loop 43 and a tuning inductor 44 are connected across electrodes 40 with loop 43 disposed in the cut away or window section of shield 21 in a plane approximately parallel to the cylindrical axis of the tube. Inductive elements 43, 44 are displaced 180° from each other to reduce their mutual inductive coupling. Conductive straps 42 electrically connect electrodes 40 to loop 43 and also provide the mechanical support for the loop while inductor 44 is constructed of a similar conductive strap which forms the inductor, provides mechanical support for it, and electrically connects it to electrodes 40. A wire 45 is connected between the center tap on inductor 44 and shield 21 which is returned to a point of reference potential through a connector pin. Walls 46 and 47 of highly conductive or flux-shorting material are disposed across the tube on opposite sides of modulator 38 and cooperate with shield 21 to shieldingly enclose the modulator. Central apertures in end walls 46, 47 allow passage of the electron beam therethrough.

Next beyond modulator 38 is a cylindrical guide channel 48 which is best indicated in FIGURE 4. Cylinder 48 is electrically and mechanically connected to shield 21 by wall 47 and establishes a well defined potential around the beam thus preventing de-focusing of the electron stream moving along path 34. Alternatively, a pair of equipotential plates spaced on opposite sides of the electron stream may be employed to avoid de-focusing effects.

Adjacent the next portion of the beam path outwardly from electron gun 26 and beyond guide channel 48 is a quadrupole electron-motion expander 49 circumferentially housed by flux-shorting shield 22. As detailed in FIGURES 5 and 7, expander 49 is composed of electrodes 50 ideally shaped similar to an equilateral hyperbola but, as a practical matter, formed with a flat intermediate portion facing beam path 34 and with terminal portions 51 projecting outwardly therefrom. Each terminal portion 51 is spaced generally parallel to the terminal portion of the next adjacent electrode. This is more fully discussed in the aforementioned Wade application.

Conductor straps 55 electrically connect opposite ones of electrodes 50. Inductor loops 52, constructed of flat conductors, wide compared to their thicknesses, are connected to adjacent ends of opposite ones of conductors 55 and serve to tune electrodes 50 to the frequency of signal energy fed to the quadrupole structure. A lead (not shown) direct-current coupled to one of the connector pins is fastened to the mid-point of one of inductors 52 to apply a direct-current potential to the quadrupole electrodes. An inductive loop 97 is juxtaposed coaxially with another one of inductors 52 to induce signal energy therein from an external signal source coupled to loop 97 by way of one of the pin connectors. Flux-shorting shield 22 and end walls 61, 62, similar to walls 46, 47, shieldingly encompass expander 49 except for apertures in the end walls permitting passage of the electron beam therethrough.

Beyond expander 49 is another guide channel 63 which is identical in construction and purpose with guide channel 48. Next beyond guide channel 63 is a demodulator 53 housed in shield 23. Demodulator 53, including shield 23 and associated transverse walls, is identical in construction to modulator 38 with its shield 21, but the demodulator and its shield are displaced 180° with respect to modulator 38 and its shield, thus minimizing mutual flux coupling between the shield windows. Receptor electrodes 54 are disposed on opposite sides of the beam path and are coupled to a load by means of an inductive loop 56 connected across receptors 54, as detailed in FIGURE 6.

On beyond demodulator 53 is an electrode 57 having an aperture centered on the beam path 34 and which, during operation, serves as the electron beam collector. The electron beam is repelled by suppressor electrode 58 which directs it back to collector 57. Suppressor 58 is disposed transversely to beam path 34 beyond the collector 57.

The entire assembly is supported within envelope 20 by means of four ceramic rods 64 symmetrically disposed about beam path 34 and extending through all of the various apertured electrodes, shield walls, and through insulating disks 59 between which the modulator, expander, and demodulator electrodes are secured at their respective ends. The different electrodes are separated by ceramic washers 60 encircling rods 64; disks 59 are separated by similar ceramic or glass sleeves 65. The assembly is held tightly together by means of compression springs 66 disposed at opposite ends of rods 64 under washers 68 pinned to ceramic rods 64. As indicated above, internal leads extend between the various electrodes and the different connector pins projecting through the base presses of envelope 20.

The manner in which deflectors 40 and receptors 54 interact with the electron beam and the action of expander 49 in amplifying the electron signal motion together with the related theory is fully discussed in the literature, including an article by Adler et al. appearing in the "Proceedings of the Institute of Radio Engineers," October 1959, pages 1713 to 1723, and is described and claimed in the previously mentioned copending applications of Adler and Wade. Reference to such literature may be had for further details.

A principal feature of the invention resides in the manner in which signal energy is coupled between external signal circuitry and the electron beam. To this end, a coupling assembly 70 preferably made of non-magnetic material is inductively associated with at least one, but preferably both, of modulator 38 and demodulator 53. As illustrated in FIGURES 8–12, coupler 70 is a tube-like sleeve dimensioned to loosely receive envelope 20 and having positioning apertures 71 and 72 through its wall which accept guide blocks 73 and 74. The latter, which serve to retain envelope 20 in position, are held within a cylindrical non-magnetic housing 75 which ensleeves coupler 70. Block 73 is held in position relative to cylindrical housing 75 by a screw 91 which passes through an opening in the housing and is threaded into the block serving to accurately position the envelope 20 within the housing. The envelope is firmly held in housing 75 by blocks 73 and 74 by the action of set screw 90 which is threaded into the housing and passes into an enlarged hole in block 74 thus forcing both the block 74 and the envelope toward block 73 (FIGURE 11). A locking shaft 76 is screwed into the end of coupling 70 through a guide block 78 which is fastened to the end of housing 75. When shaft 76 is loosened, it allows coupling assembly 70 to rotate relative to envelope 20 through an arc defined by an arcuate channel 77 in guide block 78. Tightening of shaft 76 into coupling assembly 70 fixes or locks the relative position of coupling 70 by pressure of a shoulder on shaft 76 against block 78.

Signals are conveyed into or out of coupling assembly 70 from a signal source or to a load by a shielded conductor 79 which is led into an elongated hole 80 communicating between an end of coupler sleeve 70 and an opening 82 formed in sleeve 70. Carried within opening 82 is a coupling circuit containing an inductive loop 81 of thin flexible metallic material and a tunable capacitor comprising a movable electrode 84 adjustably positioned within channelway 87 formed in sleeve 70 and serving as a fixed, grounded electrode of the capacitor. Electrode 84 has one end abutting against one end of inductive loop 81 for electrical connection therewith. For proper impedance match, an impedance transforming transmission-line section 86 couples input lead 79 to tunable loop 81. This line section has an outer conductor connected to the braid of lead 79 and an inner conductor connected to the inner conductor of lead 79.

A shaft 83 is threaded into a channelway 87 in coupling sleeve 70 parallel to channelway 80. An insulator rod 85 couples the free end of shaft 83 to the free end of movable electrode 84 of the tuning capacitance for loop 81. By rotating shaft 83 and thereby advancing or retracting the shaft in and out of channelway 87, the projection of capacitor electrode 84 into sleeve 70 is changed to vary the capacitance in the circuit of loop 81. Loop 81 is self-biased against electrode 84 to insure good electrical contact therewith irrespective of its position.

As illustrated in FIGURE 12, a coupling assembly 70 is associated with each end portion of the amplifier tube envelope. The loop 81 positioned at the input end couples a signal source to the amplifier while the loop 81 positioned at the output end couples the amplifier to a load. The degree of coupling at both input and output is adjustable by manipulation of the coupler assemblies as described hereinafter.

A solenoid 92 is positioned around housing 75 inside an outer casing 96 to develop a restoring-force field sustaining resonance of the beam electrons, as more fully explained in the aforementioned literature and application. For supplying the requisite operating potentials, connector assemblies 98 and 98' are coupled to the appropriate connector pins at the opposite ends 24, 25 of the parametric device. These connector assemblies provide the correct biasing voltages to the previously mentioned beam shaping apertures and other control structures internal to the tube. A pump source 95 supplies the expander signal energy to the quadrupole structure by way of the pin connections coupled to loop 97.

With the system assembled as shown in FIGURE 12, solenoid 92 and the beam shaping, suppressing and collecting structures are appropriately energized so that cathode 27 emits a beam along path 34. Since the strength of the field developed by solenoid 92 determines the electron cyclotron resonant frequency, it is energized in an appropriate manner as determined by the signal frequencies and mode of operation involved. Since these relationships are now understood in the art and are not of particular significance to an understanding of the present contribution, reference is again made to the aforenoted literature. Envelope 20 and coupling devices 70 are then axially positioned within housing 75 and the magnetic field provided by solenoid 92 to obtain optimum beam current with minimum current interception by the internal structure of the tube.

Next, an input signal which periodically sweeps through the frequency range in which the tube is to be operated is applied through a directional coupler to input coupler 38 by way of coaxial line 79. The reflected power is measured at the directional coupler. Minimum reflected power over the sweep range at signal lead 79 of input coupler 70 is an indication of maximum bandwidth and may be achieved by tuning and positioning the inductive loop of the input coupling assembly 70. This is accomplished by rotating control shaft 83 to change the capacitive effect of electrode 84 and by rotating the coupling assembly 70 to achieve the optimum flux coupling between inductive loop 43 of input coupler 38 and inductive loop 81 of coupling assembly 70; this is an adjustment of the mutual inductance of an adjustment of the coefficient of inductive coupling. Final adjustment of the magnetic field strength of coil 92 and adjustment of the various voltages applied to the internal structures facilitate optimizing the conditions of minimum reflected power.

Adjustments of output coupling assembly 70 are made to achieve minimum reflected power in almost exactly the same way. The only exception is that the strength of the field produced by coil 92 is not usually adjusted after once having been adjusted when tuning input coupling assembly 70.

After the input and output coupling assemblies are tuned, the noise figure of the system is measured in a conventional manner. The pump signal from source 95 is then applied to expander 49 and is adjusted in frequency and magnitude to minimize the noise figure of the system. After a general trim-up of the previously mentioned parameters, optimizing the noise figure, the system is ready to be placed in service in a high frequency amplifying system such as those encountered in radar systems.

The described arrangement is especially advantageous for use in low noise amplifying systems. The coupling arrangement for applying a signal to be amplified to the amplifier and for delivering amplified signal energy to a load avoids undesirable coupling to those elements of the tube employed predominantly for beam forming, shaping and so forth. Consequently, this possible source of noise is eliminated. At the same time, the improved structure minimizes resistive, dielectric and other losses characteristically encountered with arrangements wherein conductive coupling connections are made to the electron coupling devices through the tube envelope. The number of pins required to apply operating potentials has been reduced and, at the same time, the amplifier exhibits a most attractive flat bandpass transfer characteristic which is highly desirable in any radio frequency amplifying system. The coupling arrangement in this regard exhibits the transfer characteristics described in a copending application of Robert Adler, Serial No. 792,859, filed February 12, 1959, now Patent No. 3,073,988 and assigned to the same assignee as the present invention.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made therein without departing from the invention in its broader aspects. The aim of the appended claims, therefore, is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim:

1. Amplifying apparatus for use with a signal energy translating circuit comprising: a non-magnetic envelope; an electron source for projecting an electron beam along a predetermined path within said envelope; two electrodes disposed on opposite sides of said beam path constituting a lumped-circuit resonant coupler for exchanging signal energy with said beam; an inductive loop positioned entirely within and adjacent said envelope in a plane parallel to and spaced from said path and coupled to said electrodes; and means outside said envelope having an inductive member electrically coupled to said signal energy translating circuit and inductively coupled to said inductive loop for inductively transferring the signal energy between said inductive loop and said inductive member through said envelope.

2. In an amplifying device: a non-magnetic substantially cylindrical envelope having a predetermined cylin-

drical axis; an electron source for projecting an electron beam along a predetermined path within said envelope and substantially parallel to said axis; a lumped-circuit resonant coupler disposed along said path within said envelope and having an inductive loop positioned entirely within and disposed in a plane substantially parallel to and spaced from said axis; and a flux-shorting cylindrical shield positioned around said coupler and said inductive loop, said shield having a window disposed between said inductive loop and said envelope.

3. In an amplifying device: a non-magnetic substantially cylindrical envelope having a predetermined cylindrical axis; an electron source for projecting an electron beam along a predetermined path within said envelope and substantially parallel to said axis; a lumped-circuit resonant coupled disposed along said path within said envelope and having an inductive loop positioned entirely within and disposed in a plane substantially parallel to and spaced from said axis; a flux-shorting cylindrical shield positioned around said coupler and said inductive loop, said shield having a window disposed between said inductive loop and said envelope; and a flux-shorting end wall connected to said cylindrical shield having a window positioned on said path for said beam to pass therethrough.

4. In an amplifying device: a non-magnetic substantially cylindrical envelope having a predetermined cylindrical axis; an electron source for projecting an electron beam along a predetermined path within said envelope and substantially parallel to said axis; a lumped-circuit resonant coupler disposed along said path within said envelope and having an inductive loop positioned entirely within and disposed in a plane substantially parallel to and spaced from said axis; a first flux-shorting shield encompassing said coupler and having a first window disposed between said inductive loop and said envelope and a second window positioned on said path for said beam to pass therethrough; a modulation expander disposed about said path and positioned adjacent to said coupler; and a second flux-shorting shield entirely encompassing said modulation expander and having a third window positioned on said path for said beam to pass therethrough.

5. An amplifying system having input and output networks comprising: a non-magnetic envelope; an electron source for projecting an electron beam along a predetermined path within said envelope; a lumped-circuit resonant coupler having an inductive element positioned entirely within said envelope for transferring energy through said envelope and between said coupler and one of said networks; a coupling circuit positioned external to said envelope including an inductive member and a capacitive member for tuning said coupling circuit, said inductive member inductively coupled through said envelope to said inductive element; means for varying the coefficient of inductive coupling between said inductive member and said inductive element; and means for varying the capacitance of said capacitive member in said coupling circuit to maximize energy transfer between said inductive element and said inductive member.

6. An amplifying system comprising: an electron beam amplifying device having an internal coupling network including an inductive element and a lumped-circuit resonant coupler; a coupling assembly positioned around said amplifying device including a coupling circuit having an inductive member inductively coupled to said inductive element of said amplifying device and a variable capacitor for tuning said coupling circuit to maximize energy transfer between said coupling circuit and said internal coupling network; and means for changing the position of said inductive member of said coupling circuit relative to said inductive element of said internal coupling network to vary the coefficient of coupling between said coupling circuit and said coupling network.

7. An amplifying system comprising: an electron beam amplifying device having an internal coupling network cooperating with a beam energy interaction device; a coupling assembly surrounding said amplifying device; a coupling circuit in said assembly including an inductive member inductively coupled to said network and also including a capacitive member movable within said assembly to tune said coupling circuit; means for changing the position of said inductive member relative to said coupling network to optimize the inductance coupling therebetween; and means for varying the position of said capacitive member within said coupling assembly to adjust the amount of energy transferred between said coupling network and said inductive member.

8. An amplifying system comprising: an electron beam amplifying device having an internal coupling network including an inductive element and a lumped-circuit resonant coupler; a coupling assembly surrounding said amplifying device; a coupling circuit in said assembly including an inductive member inductively coupled to said network and also including a capacitive member movable within said assembly to tune said coupling circuit; means for changing the position of said inductive member relative to said inductive element to optimize the inductance coupling therebetween; and means for varying the position of said capacitive member within said coupling assembly to adjust the amount of energy transferred between said inductive element and said inductive member.

9. An amplifying system comprising: an electron beam amplifying device having an internal coupling network cooperating with a beam energy interaction device; a coupling assembly surrounding said amplifying device; a coupling circuit in said assembly including an inductive member inductively coupled to said network and also including a capacitive member movable within said assembly to tune said coupling circuit; an impedance transformer in said assembly for connecting said system to a signal circuit, said transformer having a connection to said coupling circuit and having a characteristic impedance corresponding to the geometric mean of the terminal impedances of said signal circuit and said coupling circuit; means for changing the position of said inductive member relative to said coupling network to optimize the inductance coupling therebetween; and means for varying the position of said capacitive member within said coupling assembly to adjust the amount of energy transferred between said coupling network and said inductive member.

10. The improvement in an amplifying system having an amplifying device with an internal coupling network cooperating with a beam energy interaction device comprising: a coupling assembly having an opening therein and positioned around said amplifying device; a coupling circuit having inductive and capacitive members, said inductive member inductively coupled to said network and positioned in said opening and at least a portion of said capacitive member movably positioned in said opening to tune said coupling circuit; means for changing the position of said coupling assembly relative to said coupling network to optimize the inductance coupling between said network and said inductive member; and means for varying the position of said capacitive member within said coupling assembly to maximize energy transfer between said inductive member and said network.

11. An amplifying device utilizing input signals derived from first and second sources of signal energy comprising: an electron source for projecting an electron beam along a predetermined path; a beam energy interaction device disposed along said path and responsive to energy received from said first signal source for modulating said beam; a plurality of electrode pairs spaced circumferentially around said path adjacent said interaction device; tuning means including a portion of a turn of a flat conductor, wide compared to its thickness, coupled across each adjacent pair of said electrodes for tuning said electrodes to a predetermined frequency; and means coupled across one of said electrode pairs for feeding thereto

energy at approximately said predetermined frequency from said second signal source.

12. An amplifying system comprising: a substantially cylindrical casing; a substantially cylindrically shaped amplifying device positioned within said casing; means disposed between said amplifying device and said casing for creating a magnetic field within said amplifying device; a coupling assembly having an opening and positioned within said casing surrounding said amplifying device; a coupling circuit carried by said coupling device, said circuit containing inductive and capacitive members, said inductive member positioned entirely in said opening and a portion of said capacitive member partially positioned in said opening: a beam energy interaction device cooperating with an internal coupling network within said amplifying device, said network having an inductive element in the form of a flat, wide conductor inductively coupled to said inductive member of said coupling circuit; a flux-shorting shield housed within said amplifying device and encompassing said coupling network, said shield having a window disposed opposite said inductive element of said coupling network; means for adjusting the position of said coupling assembly relative to said device to optimize the inductance coupling between said inductive member of said coupling circuit and the inductive element of said coupling network; a movable rod passing through said coupling assembly and coupled to said capacitive member of said coupling network; and means for moving said rod to change the position of said capacitive member within said coupling assembly to tune said coupling circuit.

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