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AGC FOR ELECTRON BEAM PARAMETRIC AMPLIFIER

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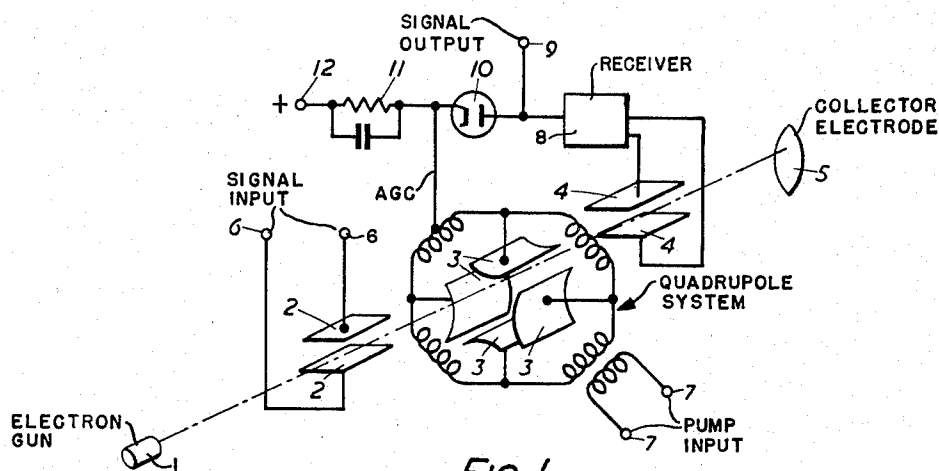


FIG. 1

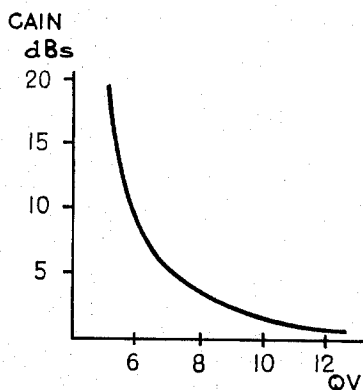


FIG. 3

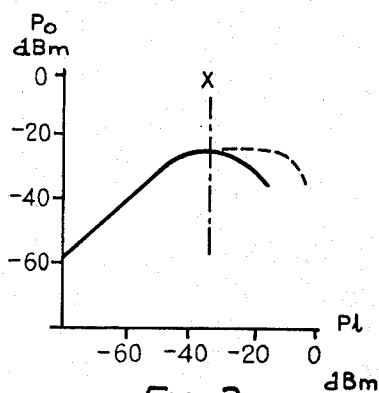


FIG. 2

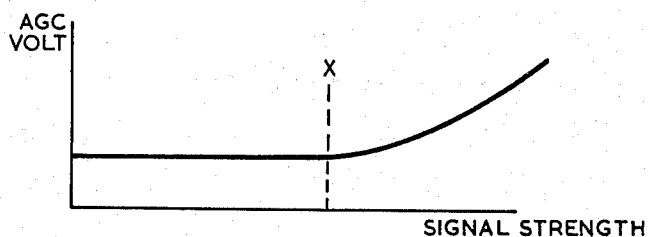


FIG. 4

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AGC FOR ELECTRON BEAM PARAMETRIC AMPLIFIER

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3 Claims. (Cl. 330-4.7)

This invention relates to thermionic tube amplifiers and more specifically to amplifiers of the kind comprising a so-called quadrupole electron beam tube or Adler tube.

The type of tube known as an Adler tube or a quadrupole electron beam tube is now well known and will be found described, for example, in the Proceedings of the I.R.E., volume 47, page 1713, 1959. In this type of tube an electron beam is constrained by an axial magnetic field in its passage from an electron gun to a collector electrode. During this passage the beam passes first between the electrodes of an input electrode system—the so-called input coupler—to which input signals are applied and which deflects the beam; then between the electrodes of a quadrupole electrode system to which a so-called pump frequency is applied; and then between the electrodes of an output electrode system—the so-called output coupler—before reaching the collector. The axial magnetic field is of such magnitude that the so-called cyclotron frequency of the electrons in this field is approximately equal to the signal input frequency. The input signals applied to the input coupler cause the electron paths to become helical and in the quadrupole amplifying section, which is a parametric amplifying section, the radii of the helical paths are increased or decreased by an inhomogeneous electric field produced by the applied pump frequency. The electron orbits increase or decrease in diameter in dependence on a relation between the azimuthal position of an electron entering the parametric amplifying section and the phase of the pump frequency at the time of entry. The output coupler absorbs energy associated with the electron rotation, the electron orbits being still helical but decreasing in radius as they pass through the output coupler towards the collector electrode.

With an amplifier of this kind the power gain depends on the energy imparted from the pump source in the interaction space of the quadrupole electrode system, the gain being a function of the pump power and also of the time of flight of electrons through said interaction space, increase in the time of flight producing an increase in gain. The time of flight is dependent upon the electron velocity which is in turn dependent upon the D.C. voltage on the quadrupole electrodes and accordingly reduction of this voltage will produce an increase of gain and increase of this voltage will produce a decrease of gain. The amplifier gain can also be varied by varying the radio frequency pump power, but (as will be seen later) in carrying out the present invention—which is concerned with gain control for a special purpose—it is preferred to exercise gain control by modifying the quadrupole voltage rather than by modifying the pump power because modification of this voltage is easily accomplished and, since the quadrupole electrodes draw little or no current, requires little or no power to achieve.

A serious practical defect of an amplifier of the kind referred to and as at present known is that it has a limited dynamic range which is typically about 70 db in a 1 megacycle band width at 20 db overall power gain. This limited dynamic range severely limits the applicability of an amplifier of the kind referred to and the present invention seeks to reduce this limitation and provide an improved

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amplifier of the kind referred to having a greater dynamic range than an otherwise comparable known amplifier.

The invention is illustrated in and further explained in connection with the accompanying drawings in which FIG. 1 is a diagrammatic representation of one embodiment of the invention and FIGS. 2, 3 and 4 are explanatory graphical figures.

As the input signal to a known amplifier of the kind referred to increases, the radii of the electron orbits in the input coupler increase and the radii of the amplified orbits in the output coupler also increase until the input signal is of such value that the diameter of the orbits in the output coupler equal the spacing between the output coupler electrodes. When this point is reached electrons strike these electrodes. If the input signal is increased beyond this point the output not only does not increase but actually falls since more and more of the beam is intercepted by the output coupler electrodes. This effect is graphically illustrated by the full line curve of FIG. 2 in which output power P_o is plotted as ordinates against input power P_i . As will be seen, if P_i is increased beyond a value X , P_o falls away from a maximum at this input power value. The value of the input power corresponding to the point X determines the dynamic range of the amplifier.

If, as is usually the case with an Adler tube, the input coupler electrode spacing is the same as the output coupler electrode spacing, the point X (when the diameter of the orbits in the output coupler system is such that electrons are just being intercepted by the output coupler electrodes) will be reached when the diameter of the electron orbits in the input coupler is considerably less than the input coupler electrode spacing; in other words the input coupler is, at this point, capable of handling considerably large input powers. However, as already explained, if such larger input powers are applied to the input coupler of the tube of a known amplifier of the kind referred to, the output power will actually fall away despite the fact that, so far as the input coupler (considered alone) is concerned, the input power could be increased until the electrons just reach the input electrodes, at which stage the input power would be equal to the maximum output power and the output gain would be unity. It is therefore possible to increase the effective dynamic range of the amplifier by an amount equal to the large signal gain of the tube, that is to say, in practice, by a factor of about 18 db (assuming the small signal gain is set to about 20 db) by using a suitably designed system of automatic gain control, and the present invention consists in providing an automatic gain control system which does this.

According to this invention an amplifier of the kind referred to comprises means for automatically reducing the gain of the quadrupole electron beam tube thereof when the input signal strength to said tube increases beyond a value approximately corresponding to a predetermined maximum output signal strength from said tube.

Preferably the gain control is exercised by increasing the direct current potential applied to the quadrupole electrode system of the tube when the input signal strength to said tube increases beyond a value approximately corresponding to a predetermined maximum output signal strength from said tube.

Preferably the gain control means comprise a rectifier fed with signals derived from the output coupler of the tube and to which is applied, as a delay voltage, a predetermined direct current voltage which is applied to the quadrupole electrode system of said tube, the whole arrangement being such that, when the output signal strength exceeds a predetermined value corresponding approximately to maximum output, the voltage applied to said quadrupole electrode system is increased and the tube gain thereby decreased.

According to a feature of this invention an amplifier comprises a quadrupole electron beam tube, means for applying signals to be amplified to the input coupler thereof, means for applying a pump frequency to the quadrupole electrode system thereof, an output circuit fed from the output coupler thereof, and means for applying to said quadrupole electrode system a delayed automatic gain controlling voltage derived by rectifying signals derived from said output circuit and rectified by a rectifier to which a predetermined delay direct current voltage is applied, the delay voltage being such that when the input signal strength to said tube increases beyond a value approximately corresponding to a predetermined maximum output signal strength from said tube, the voltage applied to said quadrupole electrode system increases above the delay voltage thereby reducing the gain of the tube and preventing the drop in output which would otherwise occur.

Preferably the delay direct current voltage is adjustable.

Referring to FIGURE 1 the amplifier therein schematically shown comprises an Adler tube, the essential components of which alone are shown. These components are an electron gun 1, an input coupler consisting of the plates 2, a quadrupole system consisting of the plates 3, an output coupler consisting of the plates 4 and a collector electrode 5. An axial magnetic field is applied (by means not shown) in known manner. Input signals are applied at terminals 6 to the input coupler plates; a pump frequency (from a source not shown) is applied as indicated to the quadrupole electrodes 3 from terminals 7; and an amplifier or receiver 8 is fed from the output coupler 4 to provide amplified output signals which are taken off from terminal 9 to utilisation means (not shown).

As so far described the arrangement of FIGURE 1 is that of a well known amplifier of the kind referred to.

FIGURE 3 shows graphically the gain of the amplifier output db plotted as ordinates against the D.C. voltage QV on the plates 3 and, as will be seen, increase of this voltage decreases the gain.

In accordance with this invention the gain of the tube is automatically reduced when the (approximately) normal maximum point X (FIGURE 2) is reached so as to prevent the occurrence of the fall of output typified by the full line curve of FIGURE 2 for values of pI exceeding the X value. In FIGURE 1 this automatic gain control is effected by a delayed rectifier shown as a diode 10 having its anode connected to the signal output terminal 9 and its cathode connected by an AGC conductor, as indicated, to the quadrupole electrodes 3. This rectifier rectifies output from the unit 8 and is delayed by a predetermined delay voltage (which may be adjustable) applied to its cathode via a capacity shunted resistance 11 from a terminal 12. As will be obvious when the voltage on the anode of the rectifier becomes high enough, the said rectifier conducts and the Adler tube becomes sub-

ject to automatic gain control which reduces the gain, by increasing the quadrupole electrode voltage, in response to increase in output from the unit 8. The delay voltage is chosen at such value that the automatic gain control comes into effect at about the point X in FIGURE 2. The curve of voltage on the plates 3 is typified by FIGURE 4 in which that voltage (AGC volt) is plotted as ordinates against output signal strength. As will be seen, the voltage on the plates 3 is steady until the value X in FIGURE 4 (corresponding to X in FIGURE 2) is reached after which it rises with increase of signal strength. The overall result is shown by the dotted line curve of FIGURE 2 from which it will be seen that the reduction causes the power output to be maintained substantially unchanged for a useful distance beyond the value X.

I claim:

1. In an amplifier, the combination of a parametric amplifier quadrupole electron beam tube, said tube including an electron gun for directing a beam of electrons along the tube and, spaced along the tube in the order stated starting from the gun so as to interact with the beam, an input signal coupler, a quadrupole parametric pump electrode structure, and an output signal coupler; output circuit means connected to said output signal coupler for deriving output signals therefrom; automatic gain control means, connected to said output circuit means and operative to provide only a reduction of the gain of the tube only when the level of the output signals tends to rise above a predetermined value which is substantially equal to the saturation output level of the tube, for deriving unidirectional control signals proportional to the strength of said output signals; and means for applying said unidirectional control signals to said quadrupole pump electrode structure.

2. The combination as claimed in claim 1, wherein said automatic gain control means comprises a rectifier, means for applying said output signals to said rectifier, and means for biasing said rectifier with a biasing voltage, the rectifier conducting only when the output signals exceed the biasing voltage and, when conducting, applying an automatic gain control voltage to said quadrupole pump electrode structure to reduce the gain of the tube.

3. The combination as claimed in claim 2, wherein the rectifier is a diode having its anode connected to the output circuit means and its cathode connected to the quadrupole electrode structure, the biasing voltage being applied to the cathode of the diode.

References Cited by the Examiner

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NATHAN KAUFMAN, *Examiner.*