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SPACE DISCHARGE TUBE CIRCUIT

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FIG. 1

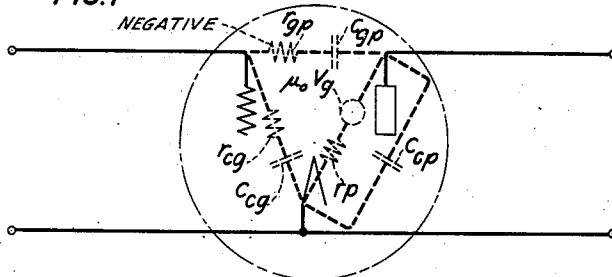


FIG. 2

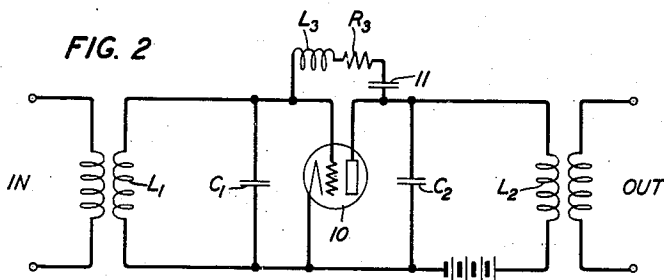
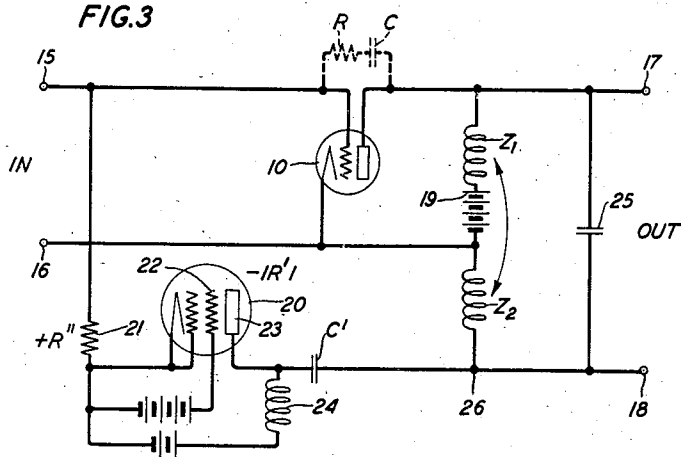


FIG. 3



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SPACE DISCHARGE TUBE CIRCUIT

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6 Claims. (Cl. 179-171)

The present invention relates to the neutralization of the inherent interelectrode impedance of space discharge apparatus.

An object of the invention is an improved circuit that is capable of more complete compensation for the inherent interelectrode impedance than circuits of the prior art, particularly at very high frequencies.

The problem of compensating or neutralizing the grid-to-plate capacity of a vacuum tube received a great deal of attention in the early days of radio broadcasting and particularly in connection with the development of broadcast receivers employing triodes for amplification within the broadcast frequency range. A large number of circuit configurations for accomplishing grid-to-plate neutralization were worked out. While many of these circuits proved successful for the purposes for which they were designed, they are quite inadequate for use at frequencies very high in comparison with broadcast frequencies, for example, at frequencies a hundred or more times as high as broadcast frequencies.

In investigating the operation of grid-controlled space discharge devices at very high frequencies applicant has discovered that the grid-to-plate impedance of a triode is not completely represented by a capacity as has been commonly supposed but that this impedance behaves as a capacity in series with a negative resistance. While this is true irrespective of the frequency used, the negative resistance is too small to be of practical significance for most purposes until the frequency becomes quite high, for example, many megacycles. At these frequencies, however, for complete neutralization it is necessary to take account of this inherent negative resistance as well as of the interelectrode capacity.

In accordance with the present invention circuits are provided which are capable of compensating or neutralizing the interelectrode coupling impedance, including both the capacity and resistance components.

The objects of the invention and the manner of their realization in practical form will be made clear in the detailed description to follow.

In the drawing:

Fig. 1 is a diagram of an equivalent circuit which applicant has worked out for the general case of a triode;

Fig. 2 is a schematic circuit diagram of one form of circuit for carrying out the invention;

Fig. 3 is a similar diagram of an alternative form for carrying out the invention.

Fig. 1 is self-explanatory, the feature of chief interest being that the impedance branch connecting the grid and plate contains not only the inherent capacity C_{gp} as heretofore assumed but also a resistance component r_{gp} which is in series with C_{gp} and which is negative in sign. The other branches of the equivalent network are of the form that has been assumed heretofore with the exception that a small positive resistance appears in series with the cathode-grid capacity.

A circuit was proposed by H. W. Nichols in Patent No. 1,325,879, December 23, 1919, for neutralizing the grid-to-plate capacity of a tube by resonating this capacity at the signal frequency with an inductance connected in parallel with it. If the impedance of this parallel-resonant combination could be made infinite, there could be no reaction upon the input circuit from the output circuit through the grid-to-plate capacity coupling. This condition could be approached by the Nichols circuit but not, of course, completely realized in practice. The invention affords a means of securing an anti-resonant impedance between grid and plate which is infinite for all practical purposes, where the utilized frequency is sufficiently high.

Referring to Fig. 2, tube 10 has its grid and cathode connected to a tuned input circuit L_1C_1 and its plate and cathode connected to a tuned output circuit L_2C_2 . Between grid and plate the capacity C_{gp} and negative resistance r_{gp} are to be thought of as existing, as shown in Fig. 1. A coil L_3 and a positive resistance R_3 are connected in series with each other and with a blocking condenser 11 across the grid and plate. The inductance L_3 is made of the right value to resonate with C_{gp} at the same frequency at which L_1C_1 and L_2C_2 resonate. Resistance R_3 is made equal to r_{gp} and is, as stated, opposite in sign to r_{gp} . The anti-resonant combination L_3C_{gp} is therefore resistanceless and offers practically infinite impedance between the grid and plate terminals. (The resistance R_3 has been assumed to represent the actual resistance of the circuit branch L_3C_{gp} .)

In practice, danger from oscillations when R_3 is exactly equal in magnitude to r_{gp} is decreased by the fact that the resistance in the input and output circuits is usually amply sufficient to insure stability. Any tendency toward oscillation may always be avoided, however, by making R_3 a very small amount greater in magnitude than r_{gp} .

While the anti-resonant impedance of L_3, C_{sp} will then be finite, it will nonetheless be so high that reaction is negligible. The adjustment of all three anti-resonant circuits to the same frequency will produce a stable amplifier having the properties of one with ideal neutralization at the operating frequency.

For the purpose of determining the internal negative resistance, a convenient form of expression may be obtained from the equation for the Q of the grid-plate capacitance, which will likewise be the desired Q of the coil L_3 . In tubes operated with high plate potential and grid bias for a given value of plate current, this equation approaches the limiting value;

$$|Q| \rightarrow \frac{5}{\omega C_{sp}} S_m \left[\frac{1 + \mu_o + \frac{4}{3}y}{y^2} \right]$$

where S_m is the mutual conductance, and y is the ratio of grid-plate to cathode-grid spacing. Strictly, this equation applies to tubes whose elements are in the form of parallel planes. For cylindrical tubes y would have to be replaced by a function of the diameter ratio of the tube elements, but, unless the diameter ratio is quite large, the above approximation is satisfactory for ordinary purposes.

As an example, in a tube with the following constants,

$$\begin{aligned} S_m &= 10^{-3} \text{ mhos} \\ C_{sp} &= 2 \times 10^{-12} \text{ farads} \\ \mu_o &= 10 \\ y &= 2 \end{aligned}$$

the value of Q at a frequency of 150 megacycles would be 9.06. If y were 1 instead of 2 then Q would be 32.7. These limits are representative enough for comparison purposes, and show that an ordinary coil, even at 150 megacycles, would require some added resistance at R_3 to bring its Q down to a low enough value for best neutralization.

Instead of computing the value of R_3 , it may be adjusted experimentally by applying an electromotive force of the operating frequency to the output terminals in the system of Fig. 2 and measuring the voltage produced across the input terminals. When both L_3 and R_3 are correctly adjusted this voltage will be zero. The procedure is to tune L_3 first until the voltage is a minimum. Then adjust R_3 to reduce it still further. It may be that L_3 will require a slight readjustment, which again requires a change in R_3 , but these variations rapidly become smaller so that two resettings usually are sufficient.

It has been customary in ultra-high frequency work to rate the active grid loss of tubes in terms of the equivalent shunting resistance between cathode and grid when the plate is tied down to the cathode through a large by-pass condenser. In the ideal coil neutralized amplifier the effective shunt input resistance is lower than that value in the approximate ratio of $\mu/(\mu+1)$. For moderately large values of the amplification factor, this is not a serious reduction.

An alternative circuit is shown in Fig. 3 employing a balancing method for neutralizing the inherent grid-to-plate coupling impedance. In this circuit the grid and cathode of tube 10 are assumed to be connected to any suitable input wave source at terminals 15, 16. Similarly, a load circuit is to be connected to output terminals 17, 18. The plate is connected through inductance coil Z_1 to the positive pole of the plate bat-

tery 19, the negative pole of which is connected to the cathode.

The neutralizing connection includes an inductance Z_2 in series with a capacity C' and a negative resistance, these elements being connected between the cathode and grid, and the inductance Z_2 having practically unity coupling with the coil Z_1 . Condenser 25 may be used to tune the circuit $Z_1, Z_2, 25$ to the signal frequency.

The negative resistance can be of suitable type and is shown for illustration as a positive grid tube 20 in series with a positive resistance 21. By suitable battery connections the grid 22 is made more positive than the anode 23, and the working range of the tube 20 is kept within the limits of the well-known downwardly sloping or negative resistance portion of the characteristic corresponding to the condition that the flow of secondary emission electrons away from the plate exceeds the flow of primary electrons in the direction from the cathode to the plate. Anode current is supplied to plate 23 through impedance 24.

The circuit elements are proportioned so that the instantaneous potential produced at point 26 due to a disturbance in potential of the plate of tube 10 sets up a potential through the elements $C', -|R'|$ and $+R''$ on the grid, that is equal and opposite to the potential that would be produced on the grid as a result of the same disturbance acting through the inherent coupling C and R in series. The resultant is zero reaction of the plate on the grid.

The following relation then holds:

$$\frac{Z_1}{Z_2} = \frac{R + \frac{1}{i\omega C}}{R' + R'' + \frac{1}{i\omega C'}}$$

It will be observed that the quantity $R' + R''$ is negative when R' is negative and numerically larger than R'' . When $Z_1 = Z_2$, the negative resistance $R' + R''$ equals the internal negative resistance R and the balancing capacity C' equals the inherent capacity C .

It will be observed that in both the circuits of Figs. 2 and 3 the system for compensating the inherent grid-to-plate coupling impedance $r_{sp} C_{sp}$ contains a reactance element (coil L_3 or condenser C') to compensate the capacity C_{sp} and an element (R_3 or $-|R'|$) to compensate the effect of the resistance component r_{sp} , and that the compensating system is in each case coupled between the grid and the plate.

The invention is not to be construed as limited to the constructional details disclosed but its scope is defined in the claims.

What is claimed is:

1. In combination with a space discharge device having a cathode, a grid and a plate and exhibiting inherent grid-to-plate coupling having capacity reactance and negative resistance components, a system for compensating said inherent coupling, said system being coupled between the plate and grid circuits and including reactance to compensate the reactance component of the inherent coupling and an element to compensate the negative resistance component of the inherent coupling.

2. A combination according to claim 1 in which said reactance is a condenser and said element is a negative resistance in series with said condenser.

3. A combination according to claim 1 in which said reactance is an inductance and said element

is a positive resistance in series with said inductance.

4. In combination with a space discharge device having a cathode, a grid and a plate and exhibiting inherent grid-to-plate coupling impedance having capacity and negative resistance components, a system coupled between the grid and plate for compensating said inherent coupling comprising means for compensating the negative resistance component of said coupling impedance, in series with a reactance which compensates the capacity component.

5. In a space discharge tube circuit for translating waves of many megacycles in frequency, said tube having a cathode, grid and anode, and possessing interelectrode coupling, means coupled between the plate and grid for neutralizing on the grid the potentials set up by voltage changes on the plate acting through said inter-

electrode coupling, said means comprising a reactance across which is developed a potential of a magnitude and phase to neutralize the potential due to the reactive component of said interelectrode coupling and a resistive element for neutralizing the potential due to the negative resistive component of said interelectrode coupling.

6. In combination with a space discharge device having a grid and plate and exhibiting inherent grid-plate coupling impedance comprising capacitive and negative resistance components, an inductance connected between grid and plate and resonating with the interelectrode capacity, and a resistance effectively in series with said inductance, said resistance being slightly larger numerically than the negative resistance component of said interelectrode capacity.

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