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W. VAN B. ROBERTS
HIGH FREQUENCY TANK CIRCUIT

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Fig. 1

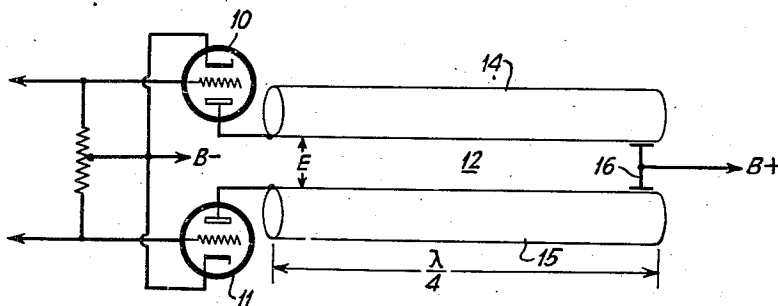


Fig. 2

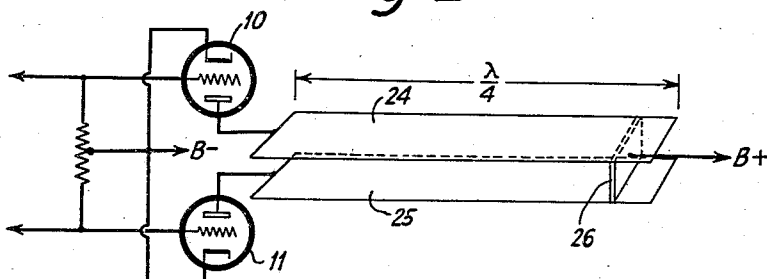
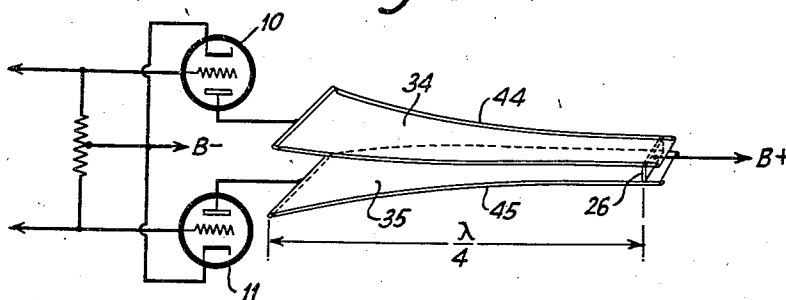


Fig. 3



INVENTOR
WALTER VAN B. ROBERTS
BY *H. E. Grover*
ATTORNEY

UNITED STATES PATENT OFFICE

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HIGH FREQUENCY TANK CIRCUIT

Walter van B. Roberts, Princeton, N. J., assignor
to Radio Corporation of America, a corporation
of Delaware

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4 Claims. (Cl. 178-44)

The present invention relates to radio frequency circuits and, more particularly, to tank circuits for amplifiers of extremely high output power.

It is a well known rule that the tank circuit of a final amplifier should be so proportioned that the stored energy therein is several times the amount of energy dissipated per cycle in the tank and in the load coupled thereto. When very high output power is required the dissipation per cycle is large and, hence, the stored energy must also be large. Since the stored energy alternates between the electrostatic or potential condition and the magnetic or kinetic energy condition the tank capacity must be large enough to store the energy at the voltage at which the tank is operated. This requirement leads to rather large condensers since, in addition to large capacity, the plates must be well separated to avoid sparking over. For example, in a 200 kilowatt short wave transmitter the condenser may be as large as a small desk and since it must be made variable for tuning the structure is not only bulky but expensive. In order to avoid the necessity for varying the condenser a fixed condenser may be used and the inductance may be in the form of a short section of transmission line shorted at the far end with a slider that may be adjusted for tuning. In the past it has always been necessary to use a fixed condenser rather than to use a sufficient length of line to tune correctly without any fixed condenser. This is because in ordinary lines, especially those formed of parallel pipes or tubes, the energy stored is insufficient in comparison with the dissipation when high power is required.

An object of the present invention therefore is to improve the operation of high power high frequency oscillation circuits.

A further objects of the present invention is the provision of a tank circuit which has low losses.

Still a further object of the present invention is the provision of a tank circuit which is readily tunable over a required range of frequencies.

Still another object of the present invention is the provision of a tank circuit having extremely high energy storage capabilities.

Still another object is the provision of a tank circuit, as aforesaid, which is economical of material and space.

The foregoing objects, and others which may appear from the following description, are attained by providing a tank circuit in the form of a pair of elongated flat conductors having their flat surfaces parallel to one another in at

least one dimension. The conductors are separated by a distance sufficient to prevent flash over and they are of such width as to provide sufficient capacity for the required energy stored.

In a modified form the invention contemplates varying the space between the plates along their length in accordance with the potential distribution therealong. The width may also be varied to keep the characteristic impedance constant along the length.

The present invention will be more fully understood by reference to the following description, which is accompanied by a drawing in which Figure 1 illustrates a tank circuit as at present commonly used; Figure 2 illustrates an application of the present invention to the tank circuit of Figure 1, while Figure 3 illustrates a modification of Figure 2. The drawings are purely diagrammatic and are not intended to show the dimensions in their true proportions.

Referring, now, to Figure 1, reference numerals 10 and 11 indicate a pair of thermionic discharge amplifier tubes having their anodes connected in a push-pull relationship to a parallel conductor tank circuit indicated generally by the reference numeral 12. The tank circuit is here shown as being composed of a pair of pipes 14 and 15 connected at one end to the anodes of tubes 10 and 11 and connected together near the other end by a slider 16. The anode power supply for tubes 10 and 11 may be connected to the slider 16, as indicated by the arrow labeled B+. Conductors 14 and 15 should be of sufficient length that the distance from the slider 16 to the anode ends may be adjusted to a quarter of the operating wavelength. Now, if E is assumed to be the peak potential across the anode ends of conductors 14 and 15 and assuming sinusoidal distribution of potential along the length of the tank, the energy in the tank =

$$\int_0^{\frac{\pi}{2}} \frac{1}{2} (E \cos \theta)^2 \frac{d\theta}{2\pi} C \lambda$$

where θ = electrical length in degrees from the open end of the tank; λ = wavelength, C = capacity per unit length between the conductors. This expression becomes:

stored energy =

$$\frac{E^2}{2} \times [\frac{1}{2} \text{ total capacity between conductors}]$$

If now the power dissipated = W and the frequency = f, the amount dissipated per cycle = W/f.

Let N = the desired ratio of stored energy to energy loss per cycle. Then,

$$\text{Total required capacity between conductors} = \frac{NW}{fE^2} \quad 5$$

If, now, it is assumed that $N=3$, $W=200,000$ watts, $f=12 \times 10^6$ cycles and $E=20,000$ volts, the required capacity is $500 \mu\text{f}$. (micro-microfarads) or 450 centimeters. When pipes are used as the parallel conductors the capacity in centimeters per centimeter length between the conductors is given by the relationship

$$\frac{1}{4 \cosh^{-1} \frac{s}{d}}$$

where s is the distance between pipe centers and d = pipe diameter (RCA Rev. July 1938, page 113). Using this formula, it is readily found that to produce the required capacity (450 centimeters) between pipes a quarter wave long, assuming a desired separation of 5.5 centimeters between adjacent surfaces, the pipe diameter must be approximately 88 centimeters. Thus, for a spacing safe from flash over, the pipes would be impractically large.

If, now, the tank circuit is constructed in accordance with the principles of the present invention, as shown in Figure 2, the tank conductors are composed of a pair of flat strips 24 and 25 of conducting material. One pair of adjacent ends of conductors 24 and 25 are connected to the anodes of tubes 10 and 11, as in Figure 1, and a slider 26 is provided near the other ends for tuning purposes. In this form of construction the capacity C , in centimeters, between parallel plates 24 and 25 is determined from the following relationship:

$$C = \frac{\text{area in square centimeters}}{4\pi \times d}$$

where d is the separation between the plates. Again, as in the example of Figure 1, taking 5.5 centimeters as a safe separation between the plates, it is seen that the plates need to be only 50 centimeters wide in order to provide the 450 centimeter capacity. Thus, by a direct comparison it may be seen that the amount of copper required to construct the tank circuit of Figure 2 compared to that of Figure 1 is in the ratio of $50/88\pi$, that is, a 5 to 1 reduction in copper is effected by using this form of construction.

In all of the foregoing it has been assumed that tube capacities are negligible. Actually, on account of these capacities the strips will be slightly shorter than a quarter wavelength but this does not affect the advantages of the invention but merely makes computation of the dimensions slightly more complicated.

In order to keep the voltage gradient along the length of the tank circuit constant and, also, to keep the characteristic impedance constant, assuming the voltage amplitude in a sine function of the electrical length measured from the shorted end, the tank circuit may be constructed as in Figure 3 wherein both the width of the conductor strips 34, 35 and the separation between them varies in accordance with a sine function. In practice, to keep the width from becoming so small at the shorted end that the current losses are undesirably large, a small constant term may be added to both the width and separation. Furthermore, since strips 34, 35 may be quite thin it is preferred to provide smoothly rounded edges by curling over the edges to form beads 44, 45 therealong.

Finally, the voltage may vary in a manner other than sinusoidally because of radiation coupling of a load to a part of the tank, etc., that is E may equal $f(\theta)$ where θ is the electrical distance from the shorted end. The width w may then be determined by the relation $w = a_1 + b_1 \times f(\theta)$. Likewise, the separation may be determined by the relationship $d = a_2 + b_2 \times f(\theta)$. The quantities a_1 and a_2 are small constant terms to keep the width and spacing from becoming too small and b_1 and b_2 are factors of proportionality. The characteristic impedance Z follows from the relation

$$Z \propto \frac{a_2 + b_2 f(\theta)}{a_1 + b_1 f(\theta)}$$

15 The characteristic impedance therefore is constant if

$$\frac{a_1}{b_1} = \frac{a_2}{b_2}$$

20 Though the tapered strips in Figure 3 have been described as tapering sinusoidally in spacing and in width, in many cases it will be necessary only to taper the strips linearly and set them at a small angle with respect to each other thus avoiding the necessity for bending and extremely careful shaping of the strips. A considerable portion of the advantages obtained by variable spacing may still be obtained.

While I have particularly shown and described 30 several modifications of my invention, it is to be distinctly understood that my invention is not limited thereto but that improvements within the scope of the invention may be made.

I claim:

35 1. A two-conductor tank circuit comprising a pair of strips arranged in face to face opposition and adapted to be connected at one end to terminals of a push-pull discharge system and connected together a distance equal to a quarter of the operating wavelength from said one end, the spacing between said strips at said one end being greater than the flash over distance for the peak operating voltage, the width of said strips being such as to provide a predetermined storage capacity, said spacing decreasing with increasing distance from said one end along the length of said strips.

40 2. A two-conductor tank circuit comprising a pair of strips arranged in face to face opposition and adapted to be connected at one end to the plates of a push-pull electron discharge tube system and connected together a distance equal to a quarter of the operating wavelength from said one end, the spacing between the plate ends of said strips being greater than the flash over distance for the peak operating voltage, the width of said strips being such as to provide a capacity value between such strips equal to

$$\frac{NW}{f} \times \frac{4}{E^2}$$

where W is the power dissipated, f is the operating frequency, E is the peak voltage across said strips and N is the ratio of stored energy to energy loss per cycle in said tank circuit, N being greater than 2, said spacing decreasing along the length of said strips from said one end.

3. A two-conductor tank circuit comprising a pair of strips arranged in face to face opposition and adapted to be connected at one end to electrodes of a push-pull discharge system and a sliding connection between said strips near the other end, the spacing between the electrode ends of said strips being greater than the flash over distance for the peak operating voltage, the width of

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said strips being such as to provide a predetermined storage capacity, said spacing decreasing along the length of said strips from said one end, and said width also decreasing to maintain the characteristic impedance of said tank constant along its length.

4. A two-conductor tank circuit comprising a pair of strips arranged in face to face opposition and adapted to be connected at one end to the plates of a push-pull electron discharge tube system and a sliding connection between said strips near the other end, the spacing between the plate ends of said strips being greater than the flash over distance for the peak operating voltage, the

width of said strips being such as to provide a capacity value between such strips equal to

$$\frac{NW}{F} \times \frac{4}{E^2}$$

5 where W is the power dissipated, F is the operating frequency, E is the peak voltage across said strips and N is the ratio of stored energy loss per cycle in said tank circuit, N being greater than 2, said spacing decreasing along the length of said strips from said one end, and said width also decreasing to maintain the characteristic impedance of said tank constant along its length.

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