

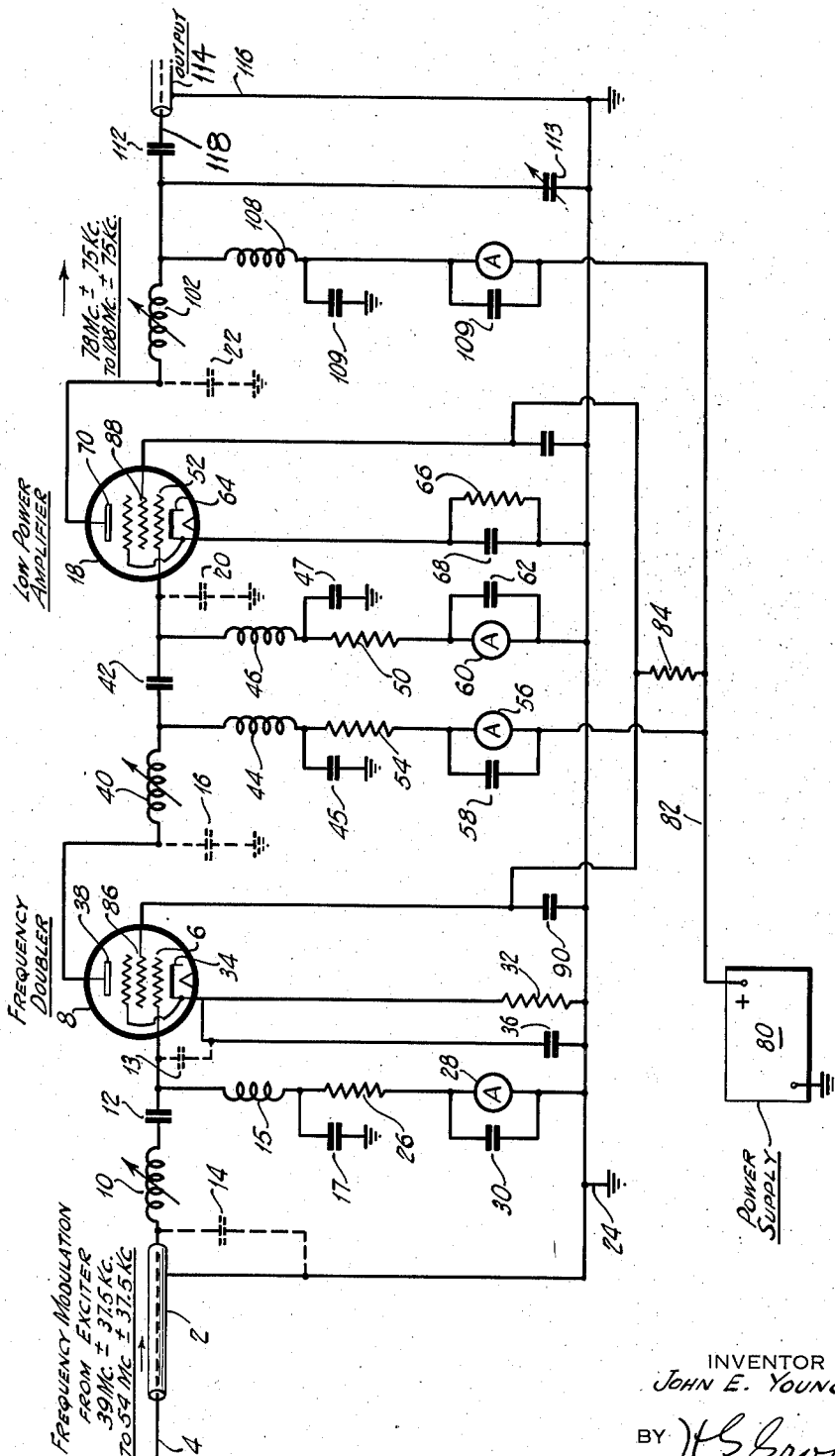
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HIGH-FREQUENCY CIRCUITS

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HIGH-FREQUENCY CIRCUITS

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My present invention relates to high frequency apparatus and deals particularly with low power and high power vacuum tube amplifying systems for short waves.

In short wave, high power transmitters such as used for frequency modulation broadcasting at carrier frequencies lying, for example, between 78 and 104 megacycles, it has been proposed to use transmission lines as interstage coupling links for the relatively low power driving amplifiers. Transmission lines for this purpose, however, are objectionable since they are bulky and, therefore, require a large amount of space. Moreover, they are inconvenient to tune or adjust. Conventional parallel tuned circuits between the driver stages are impractical in view of the relatively high stray input and output capacities of pentode tubes, preferably used in these stages because of their relatively high gain. That is, the stray capacities are of such value that the inductances necessary to tune them at the higher frequencies are very small. As a result, the coil structures required to tune the stray capacities will be so small as not to be feasible if conventional parallel tuned circuit practice is followed.

To overcome the foregoing objections and more specifically to provide a driver-amplifier system which makes use of coils of practical size, despite stray capacities and operation at very high frequencies, is one object of my present invention. In this connection it should be noted that the invention provides for and enables tuning over a wide range of frequencies with ease.

A further object of my invention is to provide an improved high power amplifier system especially adapted for use at the higher frequencies. In carrying out this aspect of my invention, I make use of grounded grid power amplifier stages and circuits therefor which are especially free of, and the tendency to produce, parasitic oscillations. Also, I provide an improved cascaded arrangement of grounded grid amplifiers and circuits therefor which will develop substantial amounts of power at very short wave lengths.

A more detailed description of my present invention will now be given with the aid of the accompanying drawing wherein the single figure is a wiring diagram of a frequency doubler and low power driver amplifier for a frequency modulation transmitter, the circuits therefor being such as to enable the use of tuning coils of practical size despite high stray tube and other capacities and despite operation at very high frequencies.

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Referring to the frequency doubler, lower power amplifier of the drawings, it will be noted that the arrangement is designed to double the frequency of the input derived from the frequency modulation exciter unit. The frequency modulated carrier input fed to the doubler 8 may lie anywhere in the range of from 39 megacycles to 54 megacycles with a maximum frequency swing of ± 37.5 kilocycles. The frequency doubled output is fed through low power amplifier 18 to utilization means such as an high power amplifier (not shown) feeding an antenna (not shown). The high power amplifier may be as disclosed in my divisional application Serial #723,425, filed January 21, 1947. Because of the frequency doubling produced by tube 8 the antenna is then supplied with waves having a mean frequency lying at any desired point in the band of from 78 megacycles to 108 megacycles with a maximum frequency swing, in any case, of ± 75 kilocycles. The latter is the maximum swing specified for FM broadcasting at the present time by the Federal Communications Commission.

As shown, frequency modulated output from the exciter is fed to the frequency doubler by way of a concentric line system having an external grounded conductor 2 and an inner conductor 4. Inner conductor 4 is connected to the grid 6 of doubler 8 through the variable tuning coil 10 and blocking condenser 12. The latter has negligible reactance at the operating frequencies.

Stray input capacity preceding coil 10 is indicated by the dotted capacitor 14, and the stray output capacity for doubler 8 is indicated by the dotted condenser 16. Similarly, the stray input and output capacities for amplifier 18, which serves to amplify the output of doubler 8, are indicated respectively by dotted line condensers 20 and 22 respectively.

At the frequencies involved, it has been proposed to use transmission lines, having substantially uniformly distributed inductance and capacity, as radio frequency circuits to be connected directly to the input and output terminals of doubler 8. Similarly, it has been proposed to use such lines as the contiguous radio frequency input and output circuits for amplifier 18. Transmission lines for these purposes, however, have several disadvantages. They do not lend themselves to compact construction; they are expensive and, in addition, they are not easily adjustable or tunable, which operation is desirable in order to compensate for vacuum tube variations. Also, it follows that trans-

mission lines do not readily lend themselves to initial "tuning up" procedure—a practical necessity with all radio transmitters.

Because of the fact that the stray input and output capacities are relatively large at the frequencies under consideration, conventional parallel tuned circuits, consisting of coils and condensers in parallel are not suitable as couplings or wave transferring means between the stages. This follows since the stray shunt capacities have such low reactance at the frequencies involved that coil structures required to tune the stray capacities would have to be of very low inductance, resulting in coils of impractical size.

In accordance with one aspect of the present invention, the difficulties and objections concomitant to the use of transmission lines or conventional circuits between tube stages are overcome by the employment of coupling circuits which make use of the stray capacities in such a way as to allow of the use of coils of practical size. The latter are highly desirable since they are easily adjusted or varied for tuning purposes. Furthermore, the present invention provides the proper coupling means to obtain the correct voltages at the desired frequencies for transfer on to succeeding stages of the system. A further virtue of the present arrangement resides in the fact that by means of a single tuning control or adjustment the system may be tuned over a wide range of frequencies such as a range from 78 to 108 megacycles.

Referring again to the drawing, the output impedance of transmission line 2, 4, as measured between the left hand terminal of coil 10 and ground, is of the order of 70 ohms. It is desired to step up this impedance to match the input impedance of the doubler tube 8, which impedance as measured between the grid 6 and ground 24 may be, roughly, of the order of 10,000 ohms. By connecting coil 10 as shown, this step-up in impedance is effected. In this regard it should be noted that coil 10 places stray capacity 14 effectively in series with the strap input capacity 13 of tube 8 at the desired operating frequency.

Coil 10 may be made in the form of a spiral coil having dimensions such as, roughly, one inch in diameter and four inches in length. The coil may be formed of from six to a dozen turns of silver plated copper ribbon conductor having a width of about one-quarter of an inch. This is a practical size for the coil 10 and it may also be made adjustable as indicated diagrammatically by the arrow, shown in the drawing, through the same.

Resistor 26 is a grid leak resistor. Choke coil 15 and by-pass condenser 17 are provided to prevent flow of radio frequency currents in leak resistor 26. There is also provided in the grid circuit, an ammeter 28 shunted by a radio frequency by-pass condenser 30. In the cathode circuit, there is provided cathode return resistor 32 for imparting an initial negative bias to the grid 6 with respect to the cathode 34. Resistor 32, shunted by a suitable by-pass condenser 36, also serves as a protective resistor in the event that excitation fails.

Between plate 38 of doubler 8 and ground 24 the impedance may be roughly of the order of 5000 ohms. This is matched to the input impedance of amplifier 18, having a value of the order of, roughly, 2000 ohms; by means of the coil 40, direct current blocking condenser 42 and choke coils 44 and 46, the former of which feeds plate

voltage to the plate 38 of the doubler 8. The latter, namely, choke 46, is in series with the leak 50 for the grid 52 of amplifier tube 18.

Choke coils 44 and 46 may each have values of the order of 10 microhenries. One effect of coils 44 and 46 is to isolate the D. C. circuits from the alternating radio frequency circuits. In addition, they are designed so that the lagging current which they draw partially compensates the leading current drawn by condenser 20. In this way the chokes serve to effectively increase the capacitive reactance of the input circuit of tube 18.

In the plate circuit of tube 8, there is also provided a de-coupling resistor 54 and an ammeter 56 by-passed by radio frequency by-pass condenser 58. There is also provided in the grid circuit of tube 18, ammeter 60 shunted by by-pass condenser 62. In the cathode return circuit for cathode 64 of pentode amplifier tube 18, there is provided the cathode resistor 66 shunted by by-pass condenser 68.

The stray capacity from plate 38, of doubler 8, to ground is represented by the dotted line condenser 16 and, similarly, the stray capacity between control grid 52 and ground is represented by the dotted line condenser 20. The stray capacity from the plate 70 of tube 18 to ground is represented by the dotted line condenser 22.

The effect of the stray capacity 20 is to make difficult, as a practical matter, the building up of desired radio frequency voltages. By the use of the coil 40, stray capacity 20 is, at the operating frequencies, placed effectively in series with stray capacity 16 whereby the effective capacity to be resonated is reduced from, for example, something of the order of 15 mmf. to something of the order of 5 mmf. Coil 40 is similar in structure to coil 10. By adjustment of the coil 40, the effective reactance of the stray capacities 16 and 20 is made large at the second harmonic frequency of the waves supplied at the input side of tube 8 through transmission line 2, 4.

It is emphasized that with the arrangement shown, the stray output capacity 16 of tube 8 is placed effectively in series with the stray input capacity 20 of tube 18 thereby making the effective output and input reactances larger at the operating frequencies and thereby more easily resonated by practical coil structures such as coil 40. Chokes 44 and 46 are so proportioned that the net capacity throughout the output-input circuits for tubes 8 and 18 is correct for resonating the coil system 40, 44, 46. This net capacity is such, also, as to provide proper impedance transformation between the output terminals of tube 8 and the input terminals of tube 18. By-pass condensers 45, 47 connected to the lower ends of chokes 44 and 46 supply paths for passage of radio frequency currents through the chokes.

Voltages are fed to the plates 38, 70 of the pentode doubler 8 and pentode amplifier 18 from a suitable rectifier 80 and connecting lead 82. By the action of voltage dropping resistor 84, the voltage from source 80 is dropped to a suitable value to be fed to the screen guides 86, 88 of tubes 8 and 18. These screen grids are provided with radio frequency by-pass condensers 90, 92 connected as shown. The suppressor electrodes of tubes 8, 18 are connected directly to the indirectly heated cathodes 34, 64 within the tube envelopes. Condensers 90 and 92 may be made adjustable to series tune the inductances of the screen grid leads so that

the screen grids are maintained at ground radio frequency potential.

The output of amplifier 18 is fed to utilization means by way of a circuit involving variable coil 102, blocking condenser 112, choke 108 and a concentric transmission line 114, 118. The outer conductor 114 of the concentric line is grounded by connection 116 and the internal conductor 118 coupled by a loop (not shown) to utilization means. Coil 102 is similar in construction to coil 10. It, together with choke 108, is designed so as to give the correct impedance transfer between the output terminal of amplifier 18 and the input terminal of concentric conductor system 114, 118. The transmission line 114, 118 is used in order that the utilization means may be located at any convenient or desired distance from the lower power driving amplifier 18. For example, a loop may be coupled to system 114, 118 and to the first amplifier stage in my divisional application Serial No. 723,425, filed January 21, 1947. The lower end of choke coil 108 is connected directly to ground for radio frequency currents by means of bypass condenser 109. Variable condenser 113 connected as shown enables further adjustment of loading.

Having thus described my invention, what I claim is:

1. High frequency apparatus comprising a two conductor transmission line, a vacuum tube of the pentode type having an anode, a cathode, a grid, a screen grid and a suppressor grid, the suppressor grid being directly connected to said cathode, a connection from one output terminal of said line to the grid of said pentode tube, said connection including in series a first variable high frequency inductance coil and a blocking condenser, a low impedance connection from the other output terminal of the line to the cathode, circuits for subjecting said anode, cathode, grid and screen grid to suitable operating potentials, and a resonant output circuit connected between said anode and cathode, said output circuit comprising a second variable high frequency coil in series with the anode, said first and second coils operating in conjunction with the stray grid to ground and plate to ground capacities respectively of said pentode tube at high frequencies, and means including a choke coil connected in series with said second mentioned coil for supplying plate potential to the anode of said pentode.

2. High frequency apparatus comprising a two conductor transmission line having relatively low output impedance, a vacuum tube of the pentode type having an anode, a cathode, a grid, a screen grid and a suppressor grid, the suppressor grid being directly connected to said cathode, a connection from one output terminal of said two conductor line to the grid of said pentode tube, said connection including in series a first variable inductance coil and a blocking condenser, a low impedance connection from the other terminal of the line to said cathode, circuits for subjecting said anode, cathode, grid and screen grid to suitable operating potentials, said circuits including a choke coil connecting a source of direct current potential to the control grid of said tube, and an harmonically tuned output circuit connected between said anode and cathode, said harmonically tuned output circuit comprising a second variable inductance coil in series with the anode, the inductance of said coil being modified by the stray plate to ground capacity of said pentode tube, and

means including a choke connected in series with said coil for supplying plate potential to the anode of said pentode.

3. Apparatus as recited in claim 2, characterized by the fact that said transmission line is in the form of a concentric conductor transmission line, the outer conductor of which is connected to the cathode of said pentode tube and directly to ground.

4. In high frequency apparatus, a vacuum tube, said tube having an anode, a cathode and a control grid, means for subjecting the control grid and cathode of said tube to high frequency voltages, a high frequency amplifier comprising an electron discharge device having an anode, a cathode and a grid, a variable inductance coil and a blocking condenser connected in series between the anode of said tube and the grid of said device thereby effectively connecting in series the stray output capacity of said tube and the stray input capacity of said device, a first choke coil connected to a terminal of said variable inductance coil removed from the anode of said tube, a source of anode potential connected to the other terminal of said choke coil and to the cathode of said tube, a second choke coil connected between the grid and cathode of said device, an output circuit connected between the anode and the cathode of said device, said choke coils with the variable inductance coil and the stray output capacity of said tube and the stray input capacity of said device being such as to cause resonance at a desired high frequency.

5. In high frequency apparatus, a vacuum tube frequency multiplier, said multiplier having an anode, a cathode and a control grid, means for subjecting the control grid and cathode to high frequency exciting waves, a high frequency amplifier comprising a vacuum tube having an anode, a cathode and a grid, a variable inductance coil and a blocking condenser connected in series between the anode of said multiplier and the grid of said amplifier thereby effectively connecting in series the stray output capacity of said multiplier and the stray input capacity of said amplifier, a first choke coil connected to a terminal of said variable inductance coil removed from the anode of said multiplier, a source of anode potential connected to the other terminal of said choke coil and to the cathode of said multiplier, a second choke coil connected between the grid and cathode of said amplifier, an output circuit connected between the anode and cathode of said amplifier, said choke coils with said variable inductance coil and the stray output capacity of said multiplier and the stray input capacity of said amplifier being such as to resonate at a desired harmonic frequency of the waves exciting the input electrodes of said multiplier.

6. High frequency apparatus comprising a concentric conductor transmission line, a pentode tube frequency multiplier, said tube having an anode, a cathode, a screen grid, a suppressor grid and a control grid, a blocking condenser and a first variable coil connecting the control grid and the inner conductor of said line in series, means grounding the cathode of said multiplier and the outer conductor of said transmission line, the only effective capacitive reactance in the input circuit of said multiplier being the stray output capacity of said line and the stray input capacity of said tube, circuits for subjecting the screen grid and control grid of said multiplier to suitable operating potentials, a pentode tube amplifier, said tube amplifier having a plate, a cathode, a con-

trol grid, a screen grid and a suppressor grid, a second variable coil and a blocking condenser connected in series between the anode of said multiplier and the control grid of said amplifier, a first choke in series with said second variable coil connecting a source of anode potential to the anode of said multiplier, a second choke coil connected between the control grid of said amplifier and the cathode thereof, the only effective capacitive reactances in the coupling circuit between said multiplier and amplifier being the stray output capacity of said multiplier and the stray input capacity of said amplifier, both of said stray capacities being effectively in series by virtue of the connection of said variable coil to said anode, said coupling circuit including said stray capacities resonating at a desired harmonic frequency of the input to said multiplier, and an output circuit for said amplifier, said output circuit including a third variable coil in series with the plate of said amplifier, and a choke connected between a terminal of said coil removed from the plate of said amplifier and said source of anode potential.

7. Apparatus as recited in claim 6, characterized by the fact that means are provided for connecting the output circuit of said amplifier to a two conductor transmission line, one of said conductors of said transmission line being connected to said third variable coil by a blocking condenser, the other conductor of said last mentioned transmission line being grounded.

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