

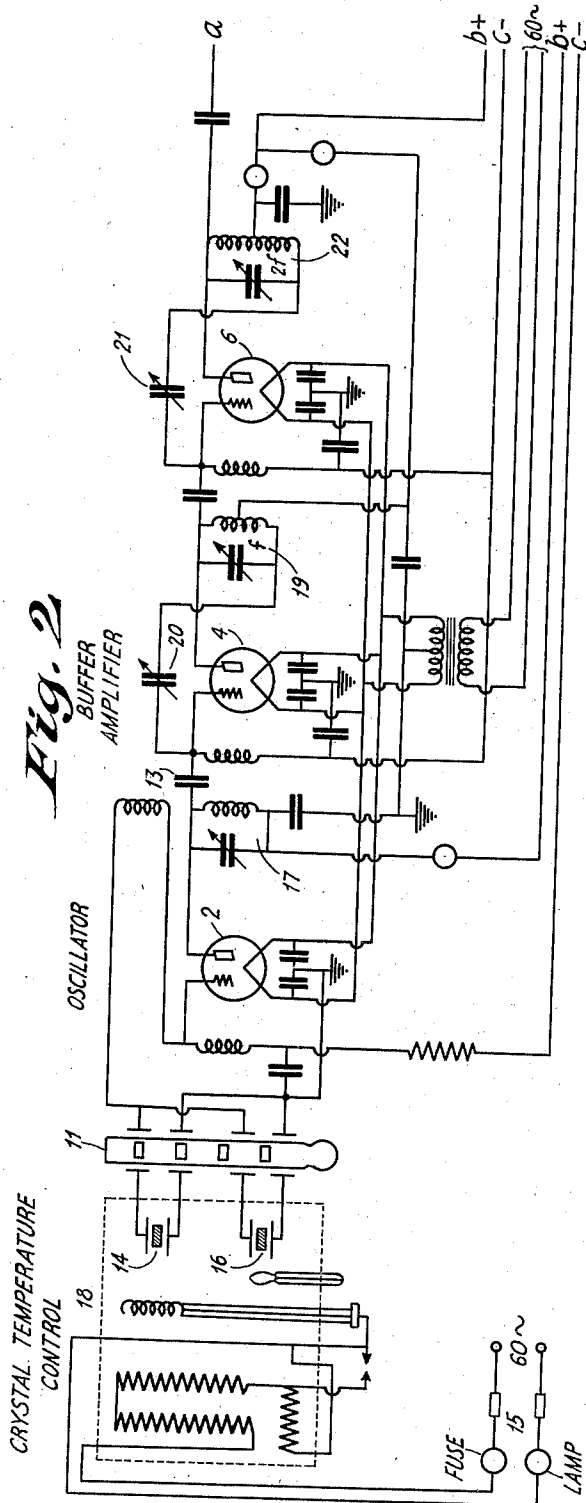
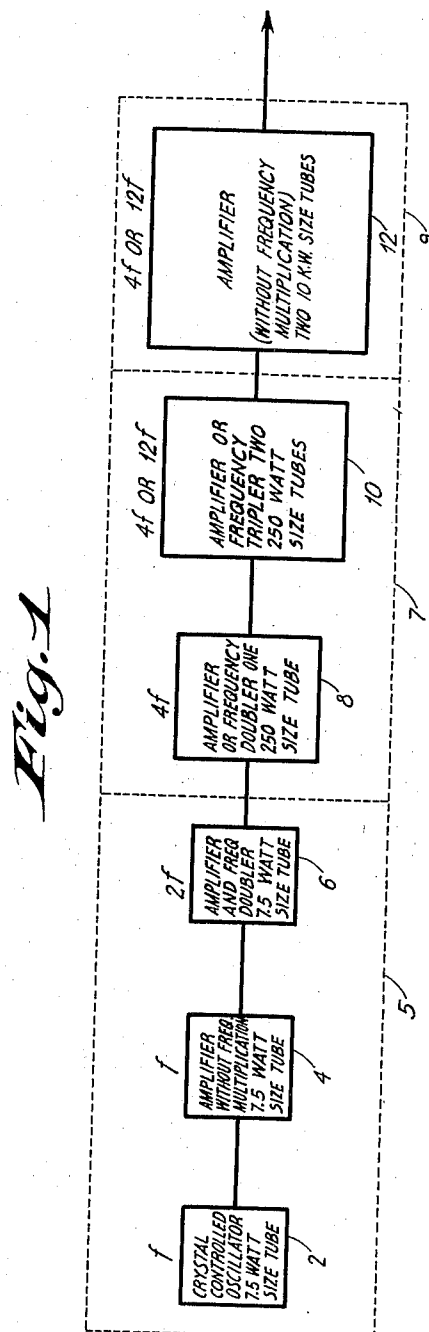
Feb. 20, 1940.

C. W. HANSELL  
SIGNALING SYSTEM

2,190,782

Original Filed March 26, 1931

3 Sheets-Sheet 1



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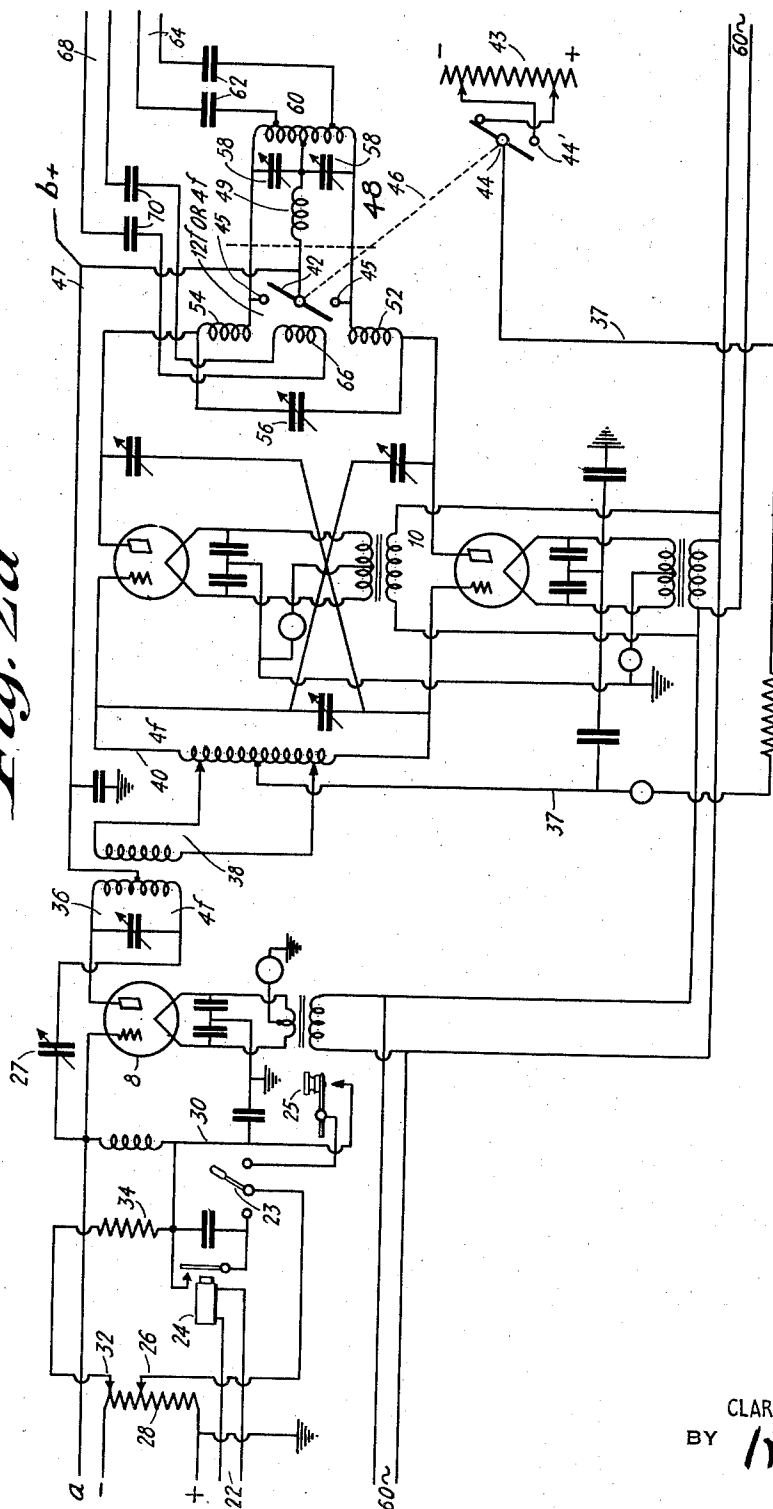
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*Fig. 2a*



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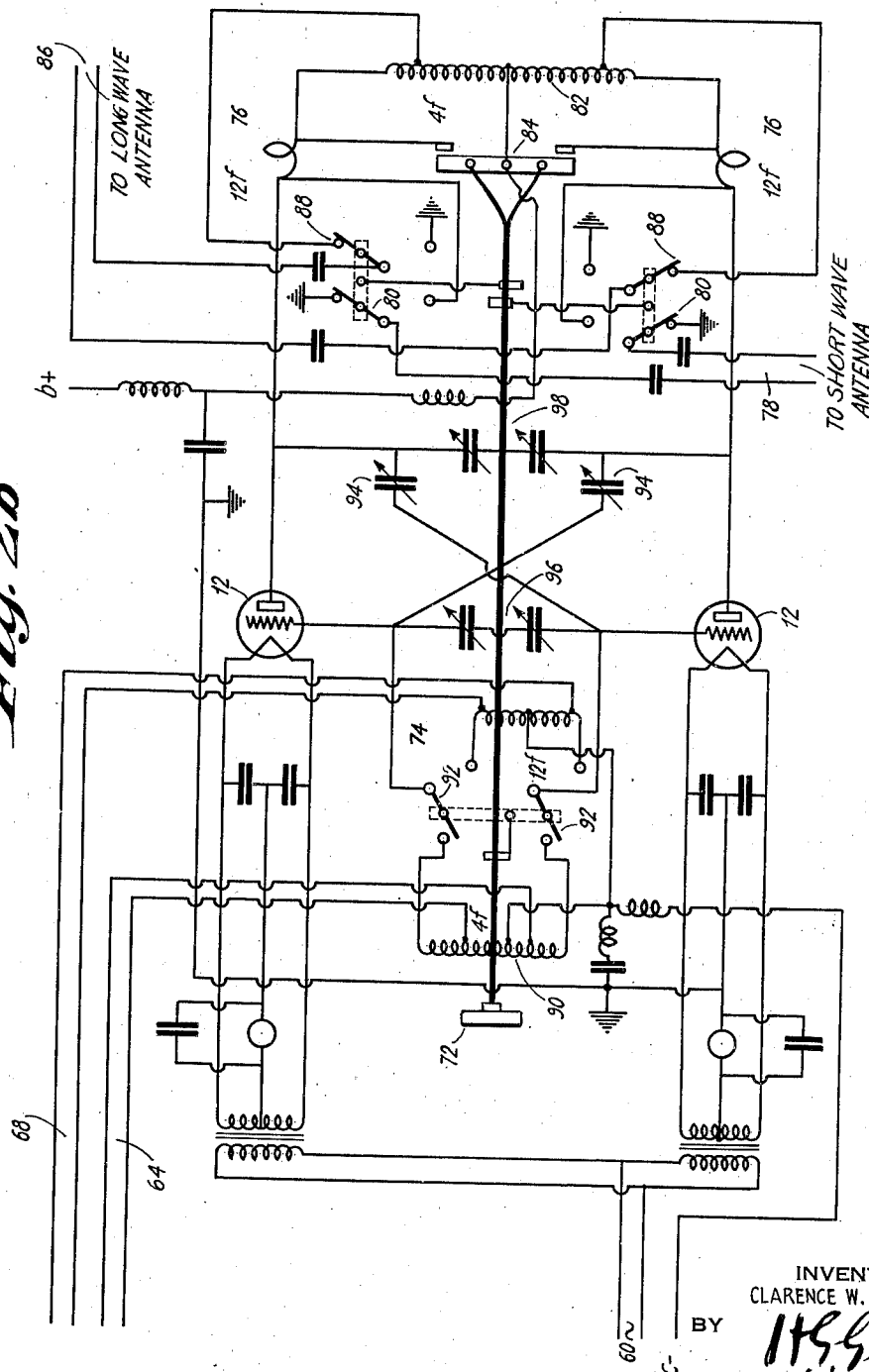
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Fig. 2b



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## UNITED STATES PATENT OFFICE

2,190,782

## SIGNALING SYSTEM

Clarence W. Hansell, Port Jefferson, N. Y., assign-  
or to Radio Corporation of America, a corpora-  
tion of Delaware

Original application March 26, 1931, Serial No.  
525,419, now Patent No. 2,032,208, dated Febru-  
ary 25, 1936. Divided and this application  
December 30, 1932, Serial No. 649,470

12 Claims. (Cl. 250—17)

It has been common practice prior to my pres-  
ent invention to control the frequency of radio  
frequency transmitters by means of relatively low  
power, lightly loaded master oscillations, the out-  
puts of which were amplified through a chain of  
radio frequency amplifiers to the power desired  
for transmission. In this previously developed  
system the conditions for holding the frequency  
of the master oscillators constant could be ob-  
tained more easily and economically than would  
be the case if the oscillations were developed di-  
rectly in the vacuum tubes which produce the  
power to be radiated from antennae. A system  
of the latter kind has been developed for high  
frequencies by the British Marconi Company and  
is known as the "British Beam System."

In the United States a method for maintain-  
ing master oscillators much more constant in fre-  
quency than had been possible previously was in-  
vented by W. G. Cady and is disclosed in his  
United States Patent 1,472,583. This method of  
Cady's employs a piezo-electric crystal and re-  
sults in a great improvement in frequency con-  
trol. However, it is subject to limitations in that  
its constancy is diminished at the higher fre-  
quencies and the amount of power obtainable  
from the crystal oscillator is small.

The first limitation is removed by operating  
the crystal oscillator at relatively low frequency  
and increasing this frequency by vacuum tube  
frequency multipliers. A method for doing this is  
disclosed in U. S. Patent 1,771,375 of I. F. Byrnes.  
At the beginning of the development of high fre-  
quency transmitters the method described by  
Byrnes was extended to the use of several similar  
stages of vacuum tubes each operating as a fre-  
quency multiplier and resulting in a final output  
at one of the higher harmonics of the crystal fre-  
quency. This resulted in a great improvement  
in frequency stability through the use of a rela-  
tively low frequency crystal even though the out-  
put frequency of the transmitter was much high-  
er than any previously used for high power, long  
distance, communication.

In this type of transmitter the frequency mul-  
tipliers were all low power tubes of the same size  
and type so that there was no increase of power  
in the successive frequency multiplier stages.  
The output from the last frequency multiplier was  
amplified by a chain of vacuum tube amplifiers,  
all operating at the same frequency, to the final  
power level required for the antenna. In this case  
the amplifying system followed the previously  
established practice used in master oscillator-  
amplifier transmitters of the type used in the

British Beam System. The main difference was  
that the conventional master oscillator was re-  
placed by the combined crystal oscillator and  
frequency multipliers.

Although this method of constructing and op-  
erating a transmitter was an improvement over  
any previously used methods, yet, at high fre-  
quencies, the circulating currents through the  
dielectric capacities of the tubes caused losses  
which reduced the amplification and troubles  
were experienced from undesired spurious oscil-  
lations. These spurious or parasitic oscillations  
were caused by energy feedback from output to  
input circuits of amplifier stages and from high  
power stages to lower power stages. The adjust-  
ments required to eliminate these undesired oscil-  
lations were critical at high frequencies and diffi-  
cult to maintain over long periods.

In accordance with my invention disclosed and  
claimed in my copending application Serial No.  
525,419, filed March 26, 1931, Patent No. 2,032,208,  
February 25, 1936, of which the present applica-  
tion is a division, I eliminate most of the low  
power frequency multiplying stages and by the  
use of a new system in which the successive inter-  
mediate stages of amplification work at succes-  
sively higher power levels, and, most important,  
the amplifier stages act as frequency multipliers.  
Thus in said application, I combine amplification  
and frequency multiplication in the successive  
stages of an amplifier system.

After this is done the earlier stages of the am-  
plifier work at lower frequencies where they are  
more efficient. Also in the system disclosed in  
said application the input and output circuits of  
each intermediate amplifier stage are tuned to  
different frequencies so that the feedback from  
output to input circuits causes little current in  
the input circuit because of its lack of tuning  
to the frequency of the energy fed back. Like-  
wise the feedback of radio frequency energy from  
any stage of amplifier to previous stages is very  
greatly reduced because of the wide differences  
in frequencies to which the amplifier circuits are  
tuned. Consequently, there is a marked freedom  
from parasitic oscillations and an ease of control  
and operation borne out in transmitters actually  
built incorporating the said invention never be-  
fore approached in an amplifier system for high  
radio frequencies.

In the said system of frequency multiplication  
at increasing power and also in the system of fre-  
quency multiplication at substantially constant  
power, I have obtained a still further improve-  
ment in operation by the use of capacity neu-

tralization and harmonic regeneration as previously described in my U. S. application, Serial No. 177,505, filed March 23, 1927, Patent No. 1,878,308, September 20, 1932.

5 As set forth in detail in said U. S. application Serial No. 525,419 of which the present application is a division, I have shown that tubes with more than three electrodes may be used in frequency multiplier-amplifiers to excellent advantage. Transmitters are now in use employing 10 tubes with two grids in which one grid serves to shield the control grid from the anode and, the addition of the screen grid, which may be kept substantially at zero radio frequency potential, together with appropriate circuit shielding, 15 serves some of the purposes of the capacity neutralization in my application Serial No. 177,505 with the advantage that no neutralizing adjustment need be made by an operator and the probability of inefficiency due to human error is greatly reduced. 20

In the system of application Serial No. 525,419, it is possible to use any or all stages of amplifier as frequency multipliers but where expediency 25 in design makes it desirable, some stages may be used as amplifiers without change of frequency. Preferably, the last stage is an ordinary amplifier since the last stage amplifier determines the final transmitter output so that it is important 30 to obtain as much power as possible from it. This is desirable because the power efficiency of the last stage is a large factor in determining the overall efficiency of the transmitter, and, if the last stage were used as a frequency multiplier it 35 would be necessary to make some sacrifice in power output and efficiency. In said system I employ screen grid tubes in the last stage or three electrode tubes with capacity neutralization together with other features essential to good 40 electrical and mechanical construction. Under certain conditions one or more of the earlier stages may act as amplifiers without frequency multiplication. For example, I may use an ordinary amplifier immediately after the crystal because by doing so the load on the crystal circuit 45 is reduced insuring greater constancy of frequency.

In the system disclosed in application Serial No. 525,419, I improve the stability of operation 50 of vacuum tube amplifier and frequency multiplier systems to make them less subject to the effects of power supply voltage variations and at the same time I protect the vacuum tubes from destructive currents. This is accomplished by 55 employing the combination, for electron discharge devices, of a fixed biasing potential and a potential obtained by passing rectified grid current through a grid leak resistance.

It is characteristic of vacuum tube frequency 60 multipliers and high efficiency amplifiers that the relative values of grid bias and radio frequency excitation potential must be rather critically adjusted. If an operator, while making adjustments, or the power supply voltage causes a variation above or below normal in radio frequency 65 output from any stage then the excitation and the efficiency and output of the next succeeding stage is adversely affected. In the system disclosed in said copending application, I may make 70 the biasing potential increase and decrease in accordance with the excitation in a manner to hold relatively constant output and efficiency by employing grid leak bias.

However, when this is done, if for any reason 75 the master oscillator, or any intermediate stage

fails to function, so that there is no excitation on any stages, their grid bias falls to zero. In this case the tubes are subject to excessively high and destructive anode currents and losses which endanger the lives of the tubes. Overload protection on the power supply will not entirely remove this danger because the input currents, controlling overload protective devices, under this condition may not exceed the normal input while the energy dissipation in the tubes is greatly increased due to loss of output. In cases where the input currents would be sufficiently higher than normal to trip out overload circuit breakers there is still danger of tube failure because the overload, although of shorter duration, is increased in severity. 15

To remove this danger of tube failure while still retaining most of the advantages of grid leak bias, was a further object of the system disclosed in application Serial No. 525,419 and to fulfill it I 20 employ sufficient fixed bias to protect the tubes in case their excitation fails and obtain the remainder of the required biasing potential from grid leak resistances in series with the fixed bias.

In practice it is desirable that provision be 25 made whereby a stage or several stages may operate either as an amplifier or a frequency multiplier or as amplifiers or frequency multipliers. This permits signaling at different powers and different frequencies with the same number of 30 stages and same apparatus.

In accordance with the present invention I provide switching and tuning means in the output circuits of certain stages to make them operate 35 as amplifiers or frequency multipliers. When they operate as amplifiers the switching means is set at such a point that the output circuit of the stage is tuned to the frequency of the input circuit. The stage now acts as an amplifier of the impressed oscillations. 40

When it is desired that the stage act as a frequency multiplier the switching means is set at such a position that the output circuit of the particular stage is tuned to a harmonic (odd or even) 45 of the frequency to which the input circuit of the stage is tuned. The stage now acts as a frequency multiplier.

The biasing potential under which a stage operates efficiently as an amplifier may be less than the biasing potential under which a stage 50 operates efficiently as a frequency multiplier.

In my novel transmitter of the present invention I provide means for increasing the bias applied to the control electrodes of the stage when the stage operates as a frequency multiplier, and 55 for decreasing said bias if the stage is to be changed back to a straight amplifier or relay.

Transmitters including the novel features of the present invention have been in commercial service for some time. A transmitter including 60 the switching and tuning means as disclosed briefly above have been disclosed in my United States application Serial No. 189,162, filed May 5, 1927, Patent No. 2,063,248, December 8, 1936. 65

In accordance with United States Patent Office procedure my invention is defined in the appended claims. However, it may best be understood, both as to its structural organization and mode of operation by referring to the accompanying 70 drawings, wherein:

Figure 1 is a block diagram of a commercial transmitter built in accordance with my present invention; while,

Figures 2, 2a and 2b schematically illustrate a 75

circuit arrangement used in the apparatus shown in Figure 1.

Figure 1 illustrates diagrammatically a transmitter especially adapted for long distance communication work. Figure 1 is a block diagram of the transmitter which is illustrated in detail in Figures 2, 2a and 2b which are wiring diagrams of the more important elements of the transmitter shown schematically in Figure 1.

As shown in Figure 1, the transmitter comprises a crystal controlled oscillator 2 followed by buffer or shock absorbing amplifier 4, two frequency multiplier stages 6, 8 the latter also being used as a modulator and both multipliers being used preferably as frequency doublers. Another stage 10 adapted to be used as a simple amplifier or, as indicated, as a frequency tripler, and, a final amplifier stage 12 are provided. As indicated, the crystal controlled oscillator 2, buffer amplifier 4, and first frequency multiplier 6, may be placed safely within a single shielding compartment 5 without fear of parasitic oscillation generation, and similarly the stages 8, and 10 may be placed in another separate shielding compartment 7. The final amplifier stage 12 should, of course, be placed with an individual shielded compartment 9. Inasmuch as shielding is well known in the art, a further description of it is unnecessary here.

The tube sizes indicated in Figure 1, are given merely by way of example and as set forth more in detail in my application Serial No. 525,419 may be varied widely in practice. Attention is directed in particular to the second frequency multiplier and amplifier 8, which is of much larger size and rating than frequency multiplier and amplifier 6, or, amplifier 4. As a result of this construction, a considerable amount of amplification of the energy is produced in the frequency multiplier, which eliminates many of the amplifiers which would be necessary if, in accordance with prior practice, the frequency multipliers are all made of the same size and rating, such as that of stage 6 for example. And similarly, the frequency multiplier stage 10 is made considerably larger in size and rating than the prior stage 8 so that within the frequency multiplier 10 a considerable amount of amplification ensues along with frequency multiplication. By the use of amplification within the stages 8 and 10, as already indicated, a long chain of amplifiers, subject to parasitic oscillation and costly maintenance, for building up the energy to a value sufficient to operate power amplifier 12 is eliminated.

The arrangement shown in Figure 1 is illustrated in greater detail in Figures 2, 2a and 2b. The regeneratively coupled electron discharge device oscillator 2 is frequency controlled by either crystal 14 or 16 by suitable actuation of coupling or switching arrangement 11 which couples either crystal capacitively to the input electrodes of oscillator 2. The purpose of using two crystals is, of course, to provide a spare crystal or to vary the final output of the transmitter.

The crystals preferably are temperature controlled by any suitable temperature controlling apparatus diagrammatically indicated within rectangle 18 energized with heating energy from a suitable source 15.

The output circuit 17 of the oscillator 2 is tuned substantially to the fundamental frequency of the crystal placed in circuit with oscillator 2, by the capacity and inductance of said circuit and, energy in said circuit is fed through a blocking condenser 13 to the buffer amplifier 4 having a

tunable output circuit 19 tuned also to substantially the fundamental frequency. To prevent parasitic oscillation generation or self oscillation, the buffer oscillator may be neutralized by the use of a suitable neutralizing condenser 20 as indicated, or, as illustrated in my application Serial No. 525,419 the transmitter tubes may be made of the screen grid type so that external neutralizing circuits are unnecessary. Similarly, for better control the crystal oscillator tube 2 may be of the screen grid type or of any multi-electrode type. The buffer amplifier, of course, acts to maintain constant load on the crystal oscillator preventing variations in load from making themselves felt upon the electrodes of the oscillator 2.

Output energy appearing in tunable circuit 19 is fed to the input terminals of the first frequency multiplier, here indicated as a frequency doubler and amplifier 6, having a tunable output circuit 22 tuned to the second harmonic ( $2f$ ) of the fundamental frequency  $f$ . As described in my copending application, Serial No. 177,505, filed March 23, 1927, frequency multiplier and amplifier 6 may be regeneratively coupled by means of a condenser 21 for energy of harmonic frequencies, but degeneratively coupled for energy of the fundamental frequency so that presence of energy of the fundamental frequency in the output circuit of tube 6 is effectively eliminated or reduced to a negligible value.

Heating current for the electron emission elements of the tubes 2, 4 and 6 may be supplied from a 60 cycle source as shown. Positive potential for the anodes of tubes 2, 4 and 6 may be supplied by wave of leads  $b$ , while biasing potentials for the control grids of tubes 2, 4 and 6 may be supplied by way of leads  $c$  from any source.

Output energy from the frequency doubler 6 and amplifier 6 is fed through conductor  $a$  to the frequency multiplier-amplifier modulator 8 shown in Figure 2a. The output circuit of tube 8 is tuned substantially to the fourth harmonic of the fundamental and as illustrated is regeneratively connected by capacity 27 for energy of the harmonic frequency  $4f$ .

Keyed energy appearing in lines 22 may be used to remotely control the electromechanical relay 24 to alter the bias on the grid of tube 6 so that when the relay armature is in its contacting position it will shift the grid voltage on tube 8 to such a value as to pass peaks of input current into the output circuit of tube 8 such that it is shock excited at the harmonic frequency  $4f$  as described more fully in my copending application just referred to. That is, in the closed position of relay 24, a less negative potential is supplied by way of conductor 26 coupled to a suitable point on potentiometer 28, and key 23 closed in the left hand position, to the grid of tube 8 through connections 30. When the relay armature is in the open position, negative tapping point 32 biases the grid of tube 8 through resistance 34 to such an extent that no high frequency energy appears in the output circuit 36 of tube 8. In addition to the relay for controlling the transmitter there is provided means by which the control may be transferred from relay 24 to the local telegraph key 25 for the use of the transmitter attendant. To do so switch 23 is closed in the right hand position.

Fourth harmonic signal modulated high frequency energy is fed inductively, as indicated, through lines 38 to the input electrodes of a push-pull connected frequency amplifier or frequency multiplier and amplifier 10 for the complete action

of which reference is again made to my copending application Serial No. 177,505. As shown, the stage 10 acts simply as an amplifier, but, this stage may be used as a frequency multiplier to produce energy of a frequency three times the frequency of the energy appearing in the input circuit 40. The energy thus produced is of a frequency 12f.

With the switches 42 and 44 in the position shown the tuned resonate output circuit connected with the stage 10 includes the inductances 52, 54 and 60 and the variable capacities 56 and 58 which tunes said circuit to the frequency of the input circuit 40, that is, to a frequency 4f. The tubes now act as simple amplifiers.

When switches 42, 44 are moved to their other position by uni-control means 46, 44 closes contact 44' so that a higher negative bias is applied to the grids of the pushpull connected tubes 10 by way of lead 37 from the potentiometer 43 connected with any source. The same movement of control means 46 closes contacts 45 so that the portion of the output circuit 48 to the right of the dotted line 50, is cut out of circuit entirely, or is short-circuited away from the output electrodes of tubes 10. In this latter position of switch, the output circuit includes inductances 52, 54 and condenser 56, and these elements tune said circuit to the twelfth harmonic of the fundamental 4f as indicated.

In both positions of the switches the circuits of the pushpull stage are symmetrical as shown. In both positions of the switches potential is supplied to the anodes of the tubes in stage 10 by way of a lead 47 to the electrical center of the resonate output circuit. When the stage acts as an amplifier the inductance 49 is included in this connection.

When acting as a simple amplifier, output energy from the output circuit of tubes 10 is fed through blocking condensers 62 and lines 64 to the input side of the power amplifier 12. When acting as a frequency tripler or multiplier as indicated, output energy from tubes 10 is fed inductively by secondary coil 66, to the lines 68 through blocking condensers 70 and to the input side of the power amplifier 12.

As described in my Patent No. 1,751,996, it is preferable that the output ends of the transmission lines 38, 64 and 68 are coupled to the respective input circuits such that the lines face a portion of the input circuit equivalent in value to the surge impedance of the line so that standing waves are not set up thereon.

The stage 12 or the tubes therein are almost always used, in order to obtain best overall efficiency for the entire transmitter, as a simple amplifier, provision being made to readily adjust the tuning of the amplifier to either one of the frequencies which it is desired to amplify. Thus, a uni-control switching means 72 is provided which places low frequency coils 90 and 92 in the input and output circuits respectively of tubes 12, when stage 10 is used as an amplifier for energy of the lower frequency 4f. Under such circumstances also, the transmission line 78 to the short wave or high frequency antenna is grounded by switches 80 as indicated. The long wave antenna 86 is connected by switches 88, as shown, to the long wave output circuit including 82.

A reverse movement of controlling member 72 will act to short-circuit the long wave coil 82 out of circuit by switch 84, to connect the low wave length antenna transmission line in circuit at

switch 80 and, the relatively longer wave antenna transmission line 86 will be grounded by the other position of switches 88. In the input circuit, the longer wave coil 90 will be removed from circuit, and, the shorter wave coil 74 will be placed in the circuit, all of which takes place on the reverse setting of switch 72.

This uni-control arrangement for rapid change-over in amplifier frequency is broadly similar to that described and claimed in my copending application Serial No. 189,162, filed May 5, 1927.

To prevent parasitic oscillation generation, the power amplifier tubes 12 are neutralized by condensers 94 cross-connecting the terminals of the input and output tuning condensers 96, 98 respectively.

As indicated, the cathodes of the various tubes may be energized by alternating currents. Unidirectional potentials for the potentiometers 28 and 43 and the various unidirectional supply leads b and c shown in Figures 2, 2a and 2b may be obtained from separate rectifiers as found necessary, but, in accordance with the present invention it is preferred that the separate rectifiers be energized from a single alternating current source whereby there is less tendency for changes in amplification with changes in supplied alternating voltages as would be the case where various rectifiers are supplied from different alternating sources.

I claim:

1. In a high frequency transmitting system employing thermionic tubes, a circuit for impressing on the input electrodes of said tubes a characteristic control frequency, a symmetrical compound output circuit connected between the anodes of said tubes, said compound circuits including two sections, each section having lumped inductances and capacities connected in parallel, switching means associated with said output circuit for short-circuiting one of said sections to change the resonance frequency of said circuit, and means cooperating with said switching means for maintaining symmetry of said output circuit in all positions of said switching means.

2. Relaying means comprising, a pair of thermionic tubes, each having control grid, anode and cathode electrodes, a tuned circuit connected between the control grids of said tubes, a pair of signal resonant circuits comprising series inductances and parallel capacities, one of which circuits includes the other, connected between the anodes of said tubes, switching means including a switch for short-circuiting a portion of said output circuit, and inductive means connected to the electrical center of said circuit and cooperating with said switching means for maintaining said output circuit symmetrical in all positions of said switch.

3. Relaying means comprising, a pair of thermionic tubes, each having control grid, anode and cathode electrodes, a signal resonate circuit connected in phase opposition between the control grids of said tubes, a circuit including several inductances in series and capacities each shunting one or more of said inductances connected in phase opposition between the anodes of said tubes, switching means including a switch in parallel with one or more of said capacities and inductances, said switch in the open position permitting said circuit to resonate at one frequency and in the closed position at a different frequency and means cooperating with said switching means for maintaining said output circuit symmetrical in all positions of said switch.

4. Signaling means comprising, a pair of thermionic tubes, each having control grid, anode and cathode electrodes, means for operating said tubes as amplifiers or frequency multipliers comprising, a circuit for applying a fundamental frequency to the control grids of said tubes, an output circuit including several inductive impedances connected in series between the anodes of said tubes and tuning capacities in parallel with said impedances, and switching means for including several of said impedances and capacities in said circuit to tune said circuit to the fundamental frequency or to include a lesser number of said impedances and capacities in said circuit to tune said circuit to a multiple of said fundamental frequency.

5. Signaling means as recited in claim 4 in which an inductance cooperates with said switching means to maintain said output circuit symmetrical in all positions of said switch.

6. Signaling means as recited in claim 4 in which a second switch cooperates with a source of potential to apply different values of biasing potential to the control grids of said tubes in different positions of said first named switch.

7. A relaying device comprising, a pair of thermionic tubes, each having anode, cathode and control grid electrodes, a tuned circuit connected between the control grid electrodes of said tubes, a source of biasing potential, switching means for applying bias potentials of different values to the control grid electrodes of said tubes, an output circuit including tuning means connected between the anode electrodes of said tubes, switching means cooperating therewith in such a manner that in one position of said switch said output circuit is resonant at the frequency to which the input circuit is tuned and in another position of said switch the output circuit is resonant to a frequency which is a multiple of the frequency of the input circuit, a single control means for both of said switching means, and means for maintaining a point intermediate the terminals of said output circuit at a radio frequency potential substantially equivalent to the radio frequency potential of the cathodes of said tubes.

8. A relaying device comprising, a pair of thermionic tubes, each having anode, and control grid electrodes, a tuned circuit connected between the control grid electrodes of said tubes, a source of biasing potential, a circuit and switching means for applying like potentials of different

values to the control grid electrodes of said tubes in different positions of said switch, an output circuit including symmetrical sets of impedances, switching means for connecting one or more sets of said impedances to the anodes of said tubes in such a manner that in one position of said switch said output circuit is resonant at the frequency to which the input circuit is tuned and in another position of said switch the output circuit is resonant to a frequency which is a multiple of the frequency of the input circuit, and a single control means for both of said switching means.

9. A relay comprising, a thermionic tube having an anode, a cathode and a control electrode, a circuit for applying a biasing potential to the control electrode of said tube, and means for operating said tube as an amplifier or a frequency multiplier comprising, an output circuit including inductive and capacitive reactances connected with the anode of said tube, all of said reactances tuning said circuit to resonance at the control frequency, whereby said relay acts as an amplifier, and means for cutting out of circuit or short-circuiting selected ones of said capacitive and inductive reactances, whereby said output circuit is resonant to a frequency which is a multiple of the control frequency.

10. A relay as recited in claim 9 including means for increasing the biasing potential applied to the control electrode of said tube when the reactance in said output circuit is decreased.

11. A relay as recited in claim 9 including means for changing the biasing potential applied to the control electrode of said tube when the reactance in said output circuit is changed.

12. In a high frequency transmitting system employing thermionic tubes in a symmetrical circuit arrangement, a circuit for impressing on the control grids of said tubes a control frequency, an output circuit connected between the anodes of said tubes, said output circuit comprising several inductive reactive portions adapted to tune said output circuit to the control frequency or a multiple thereof switching circuits connected with said output circuit for selectively removing selected ones of said portions from said output circuit for changing the tuning of said output circuit, and a circuit cooperating with said switching means for maintaining symmetry of said output circuit in all positions of said switching means.

CLARENCE W. HANSELL.