

March 14, 1933.

L. L. JONES

1,901,368

TRANSFORMER

Filed Oct. 25, 1929

3 Sheets-Sheet 1

Fig. 1.

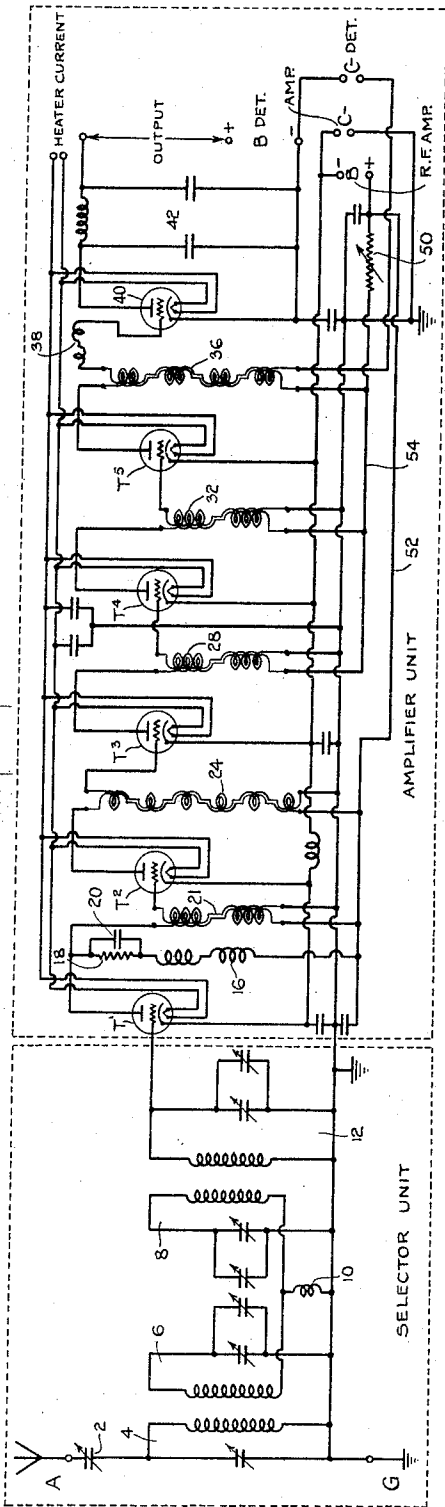


Fig. 3.

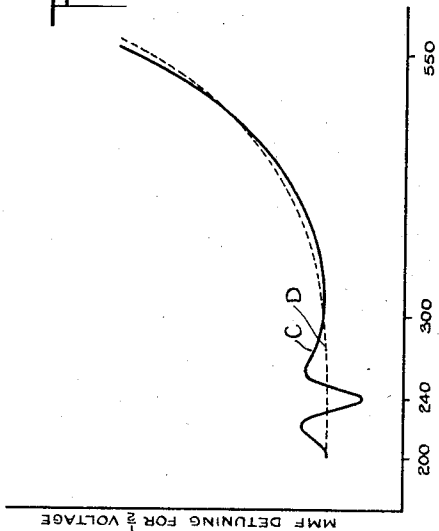
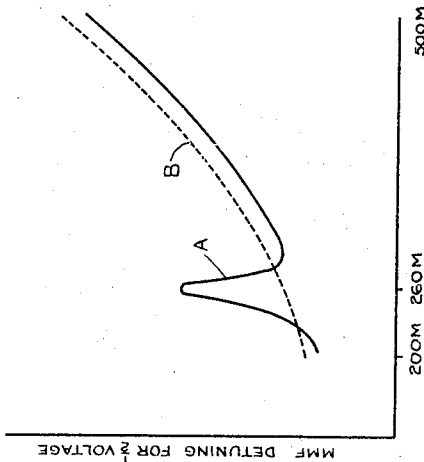


Fig. 2.



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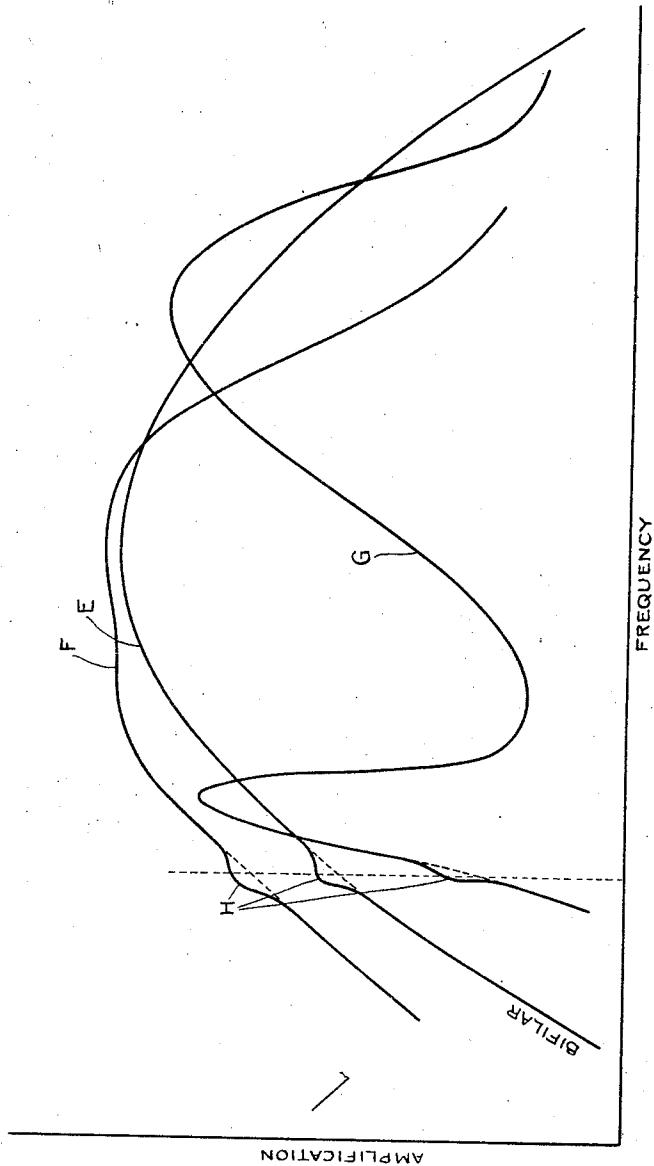
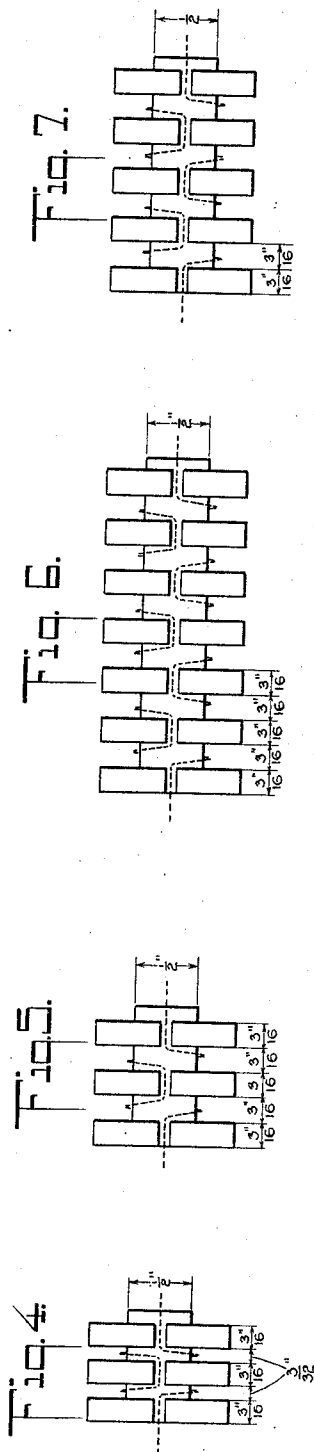


Fig. 8.

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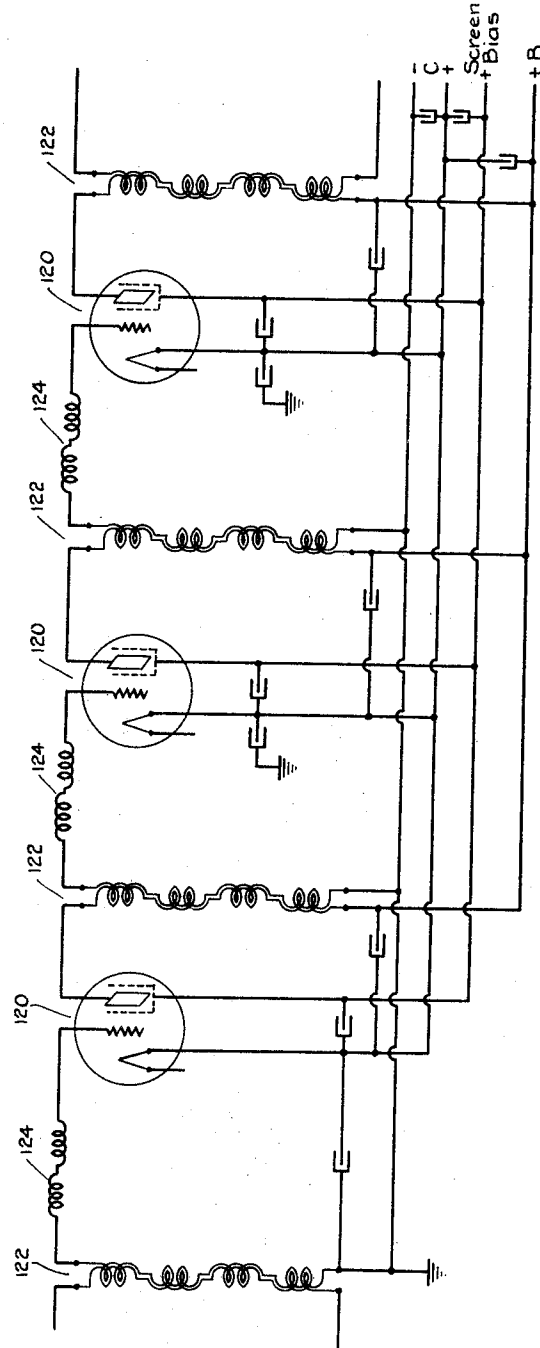
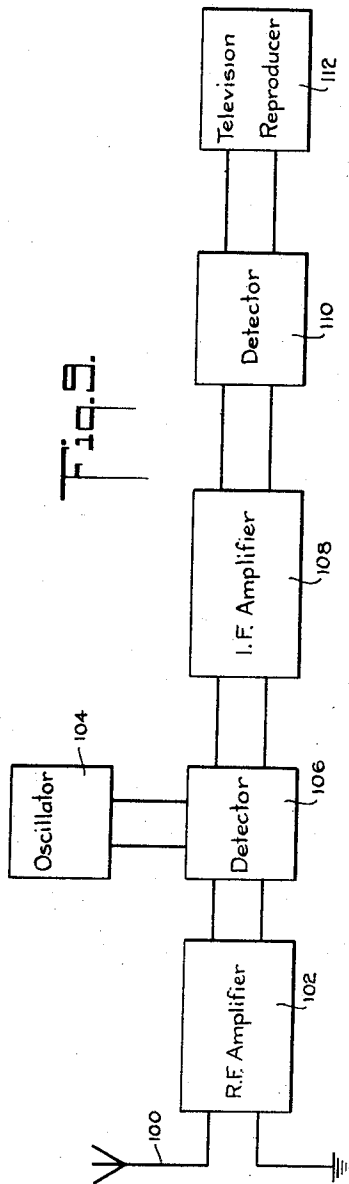
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

LESTER L. JONES, OF ORADELL, NEW JERSEY

TRANSFORMER

Application filed October 25, 1929. Serial No. 402,379.

This invention relates to radio circuits and more particularly to inductance coils and transformers used in such circuits.

Inductance coils are frequently used in radio circuits and it is often necessary to decouple such coils from one another and from other parts of the neighboring circuits in order to prevent undesired coupling or reaction. This result may be obtained by complete metallic shielding of the individual coils, but in many cases such practice is not desirable because of the capacity shunting effect of the metallic structure which may reduce the efficiency of the circuits and also because of the cost of the shielding. Another and often far more satisfactory solution is to wind the coils astatically, which is most simply done by dividing the coil into two equal portions which are wound in opposite directions so as to decouple the coil from other neighboring circuits, and which at the same time are sufficiently separated to avoid complete field opposition, so that the total inductance of the two coils connected in series is equal to the desired inductance value. Such a transformer is disclosed in my Patent No. 1,732,937, issued October 22, 1929.

When this is done undesired resonance peaks may appear in the operation of the circuits involved when they are used over a desired or working range of frequency. I have found that this is caused by reason of the individual sections of the divided coil having a natural resonance frequency which falls inside of the working frequency range. The primary object of my invention is to overcome this difficulty, and to provide an astatic coil which will not result in undesired resonance peaks within a predetermined range of frequency, which I do, broadly, by subdividing the coil into a plurality of series connected sections such that each section has a natural frequency outside of the frequency range. In the usual case the complete coil is of such dimension that the natural fre-

quency thereof falls below the frequency range, and it is desired to avoid all resonance peaks within the range. In dividing the coil into two sections in order to obtain astaticism each of the sections will have a natural frequency higher than that of the complete coil, and this frequency may come within the working frequency range. In accordance with the present invention the coil will then be divided into more than two sections, and may most simply be divided into an even number of equal sections, say 4 or 6 sections, such that each section will have a natural frequency higher than the working frequency range. Alternate sections are wound in opposite directions, thereby retaining the astaticism of the original divided coil, and in fact improving the astaticism thereof.

The foregoing difficulty frequently arises in connection with the coupling transformers in cascaded electron emission tube amplifiers, and particularly radio frequency amplifiers of the untuned type. If it is desired to avoid resonance peaks in the operation of such an amplifier the transformers thereof may be selected to have natural frequencies lying outside of the range of frequencies to be amplified. This frequency may be selected above or below the working frequency range, according to which way it is preferred to have the amplifier gain curve slope. In most cases the natural frequency of the transformers is lower than that of the working frequency range, and if it is attempted to prevent inter-stage transformer coupling by making the transformers astatic in accordance with the disclosure of my said Patent No. 1,732,937 the difficulty of resonance peaks within the working frequency range may arise. In accordance with my present invention, this difficulty may be overcome in a manner similar to that already mentioned, that is, by subdividing the transformer into a greater number of alternately oppositely wound sections than two, each of the sections having a natural fre-

quency higher than the working range of frequencies.

In my copending application Serial No. 397,633, filed October 5, 1929, since issued on October 28, 1930, as Patent No. 1,779,881, I have disclosed how a cascade amplifier having fixed circuit constants may be arranged to be automatically tuned over a broad range of frequency by making successive automatically tuned stages each tune to different portions of the working frequency range, and cascading them in the order of decreasing frequency, or otherwise expressed, by coupling the successive tubes with transformers of successively increasing inductance. In such an amplifier it is customary to make the transformers with substantially unity coupling, preferably by winding the transformers bifilarly as described in my said Patent No. 1,733,937, in order to obtain a smoothly varying impedance characteristic for the transformers and thereby to obtain smoothly varying amplification and reaction characteristics for the amplifier. If the transformers are subdivided into oppositely wound halves for the sake of astaticism those of greater inductance have halves which are naturally resonant to frequencies within the working frequency range, thereby causing undesired sharp variations in the impedance characteristic of the amplifier, and my invention is particularly applicable to such transformers, it being merely necessary to provide an increased number of alternately oppositely wound sections, each of the sections being wound with both primary and secondary conductors which may be preliminarily twisted together with a relatively long pitch so as to obtain the desired bifilar coupling.

To the accomplishment of the foregoing and such other objects as will hereinafter appear, my invention consists in the coil and transformer elements, the amplifier circuit embodying the same, and their relation one to the other as hereinafter are more particularly described in the specification and sought to be defined in the claims. The specification is accompanied by drawings in which:

Fig. 1 is a wiring diagram for a receiver including an automatically tuned amplifier embodying transformers constructed in accordance with the present invention;

Fig. 2 is a graph showing the effect of my invention as applied to transformer 24 in Fig. 1;

Fig. 3 is a graph showing the effect of my invention as applied to transformer 36 in Fig. 1;

Fig. 4 is a dimensioned elevation of an insulation spool suitable for coils 16 and 38 in Fig. 1;

Fig. 5 is a dimensioned elevation of an insulation spool suitable for transformers 21, 28 and 32 in Fig. 1;

Fig. 6 is a dimensioned elevation of a spool suitable for transformer 24 in Fig. 1;

Fig. 7 is a dimensioned elevation of an insulation spool suitable for transformer 36 in Fig. 1;

Fig. 8 is a graph explanatory of advantages of my invention;

Fig. 9 is a schematic diagram of a receiver including an amplifier to which my invention may advantageously be applied; and

Fig. 10 is a wiring diagram of such an amplifier.

Referring now to Fig. 1 of the drawings, there is a selector having variable circuit constants for tuning, followed by an amplifier having fixed circuit constants, the arrangement being in general similar to that set forth in my copending application Serial No. 397,633, now Patent No. 1,779,881, previously referred to.

Energy collected on any suitable antenna circuit 2 is fed to a first resonant circuit 4, which is loosely coupled to a second resonant circuit 6, which in turn is loosely coupled to a third resonant circuit 8 by means of a small auxiliary coil 10, and the resonant circuit 8 is loosely coupled to a fourth and final resonant circuit 12. The various tuning circuits are loosely coupled in order to avoid double resonance peaks, and the circuits are suitably positioned or shielded so that non-adjacent tuning circuits are effectively decoupled.

The received energy of selected frequency is supplied to the input circuit of a tube T1, the output circuit of which includes a coil 16, which is inductive within the working frequency range and therefore causes a regenerative reaction. Resistance 18 is arranged in series with the inductance 16 in order to cause a feed forward of energy through the tube T1 which tends to neutralize the regenerative reaction of the inductance 16, and a condenser 20 is preferably connected in parallel with the resistance 18, all in accordance with the disclosure of my copending application, Serial No. 397,632, filed October 5, 1929. This complex output circuit serves to make the tube T1 approximately reactionless, so that its input characteristic is nearly that of a pure condenser of low fixed capacitance, this characteristic being most suitable as not affecting the tuning, the damping, and the selectivity range of the resonant circuit 12 of the selector.

The output of tube T1 is fed to the tube T2 through a bifilar transformer 21, the primary of which is connected in parallel with the complex output circuit previously described, and the secondary of which is connected across the control electrode to cathode circuit of the tube. Succeeding amplifier tubes T3, T4 and T5 are respectively connected in cascade through bifilar transformers 24, 28, and 32. The amplified output from tube T5 is supplied to a detector tube 40

through a bifilar transformer 36, in series with the secondary of which there is connected a free grid inductance 38. The radio frequency and audio frequency components of the detector tube output are separated by a filter section 42, the audio frequency component being supplied to an audio frequency amplifier or a reproducer through connections to the terminals marked "Output".

Considering the second stage including the tube T2 more in detail, the transformer 24 is selected to be naturally resonant when in circuit to a frequency lower than the lowest working frequency in order to obtain a rising apparent input capacitance with decreasing frequency for the tube T2. The output circuit of the tube T1 is given a substantially higher impedance than would be correct for a reactionless stage, this being for the purpose of substantially boosting the amplification gain therein, as is described more particularly in my copending application Serial No. 397,632, aforesaid. As is there set forth, I have found that both the inductive and resistance components of the output circuit of the tube T1 may be each increased to a value approximately double that for producing a reactionless stage, the impedance of this circuit being doubled in effect, and this producing a substantial doubling in the gain in the tube T1.

Doubling this impedance causes residual reaction through tube T1, and this reaction may be made regenerative over the high frequency end of the range by increasing the feed forward resistance 18 slightly less than proportionally to the increase of the inductance 16. The reaction will still be degenerative at the low frequency end of the range because the slope of the reaction curve differs from that desired. To correct for regenerative reaction capacitance may be hung onto the anode terminal of the output circuit of tube T1. The input circuit of tube T2 is therefore not correctly automatically tuned, but rather is made capacitive, which may be done by selecting a transformer 21 with a larger inductance than would be correct for automatic tuning, because for resonance the capacitance then should be decreased, and not being decreased, is in excess. But the effective capacitance should decrease at the high frequencies and increase at the low frequencies, for more regeneration is needed at the high frequencies and more degeneration at the low frequencies, in order to change the slope of the reaction curve. This is accomplished by the variation in input capacitance of tube T2 obtained by proper selection of the output transformer 24 of tube T2. Incidentally, the gain in tube T2 is augmented by the approach to automatic tuning which is meanwhile obtained in the input circuit of tube T2. The design of the circuits of tubes T1 and T2 is

set forth in detail in my aforesaid copending application Serial No. 397,632.

As has already been mentioned, transformer 24 is naturally resonant to a frequency lower than the working frequency range and therefore is of considerable inductance. When this transformer is divided into oppositely wound halves, as was done with transformer 21 for the sake of astaticism, the natural frequency of each section or half falls within the working frequency range and causes an undesired and rather sharp inflection point in the impedance characteristic of the transformer which causes a corresponding inflection point in the input capacitance curve of tube T2. This in turn causes an inflection point in the reaction characteristic of tube T1 which is undesired. More specifically, resonance in transformer 24 causes increased impedance which causes increased apparent input capacitance in tube T2 which causes increased feed forward through tube T1, or degeneration and damping in selector circuit 12.

This is shown in the graph of Fig. 2 of the drawings, in which curves showing micro-microfarads detuning needed in a sharply resonant circuit, such as the selector circuit 12, in order to reduce the voltage thereacross to one half of its value, are plotted as a function of the wave length of the energy being supplied to the circuit 12. The manner in which this test may be made is set forth more in detail in my copending application Serial No. 397,632, previously referred to. When transformer 24 is wound astatically in two sections a curve such as the curve A in Fig. 2 results, this curve showing a sharp upward peak in the working range of frequency. This indicates that although the transformer as a whole is resonant to a frequency lower than the working frequency range, when subdivided the natural frequency of each of the halves, while a much higher frequency than that of the entire transformer, is not sufficiently high to come above the working frequency range, and coming within the working frequency range causes an undesired abrupt inflection point in the reaction curve. The peak being upward indicates considerable detuning to be necessary to reduce the voltage across the resonant circuit, showing that the sharpness of tuning of the resonant circuit has been greatly diminished by a degenerative or damping reaction upon the circuit, as was previously predicted.

In accordance with my present invention transformer 24 is in this case wound in six equal sections, alternate sections being wound in opposite directions. When this is done the natural frequency of the sections is moved out of the working frequency range, and a reaction curve like the dotted curve B in Fig. 2 is obtained.

The remainder of the stages in Fig. 1 may

best be described starting at the end of the amplifier and working backward. The detector tube 40 having a low impedance output circuit for radio frequency energy has an
 5 apparent input capacitance which is small and fixed. This is most suitable for automatic tuning, and transformer 36 is selected to be naturally resonant in circuit to a frequency lower than the lowest frequency in
 10 the working frequency range. For frequencies in the working frequency range the transformer 36, or more properly the output circuit of tube T5, is capacitive, and therefore decreases in impedance with increasing frequencies, which decreases the radio frequency
 15 potential on the anode of tube T5, and consequently causes a decrease in apparent input capacitance with increasing frequencies, as is desired for automatic tuning. For the
 20 available range of variation in capacitance the transformer 32 is selected to obtain automatic tuning of tube T5 over as large a portion of the range as is available beginning at the low frequency end of the range.
 25 Transformer 32 is not suitable for automatic tuning of the input circuit of tube T4 over the same frequency portion because transformer 32 is kept in resonance to such frequencies. However, this transformer is
 30 related to frequencies higher than the portion to which transformer 36 is related to the lower frequency portion, that is to say, transformer 32 is naturally resonant to a frequency
 35 lower than the portion of the range of frequencies to which the tube T4 is to be automatically tuned. Therefore, for frequencies lying in the higher frequency portion of the
 40 working frequency range, the output circuit of tube T4 is capacitive and therefore decreases in impedance with increasing frequencies and so causes the decrease in the
 45 apparent input capacitance of tube T4 with increasing frequencies which is desired for automatic tuning. Transformer 28 is of small inductance, selected to resonate with
 50 the range of apparent input capacitance of tube T4 to the higher frequency portion of the working frequency range.

Variable resistance 50 is connected in series with the anode supply lead 54 so that by
 55 varying the resistance thereof the effective or operating anode potential applied to the anodes of the tubes may be varied. The lead 54 is preferably connected to only the tubes T3, T4, and T5, tubes T1 and T2 being supplied with a constant anode potential through
 60 lead 52, it being somewhat preferable not to vary the operating potential applied to tubes T1 and T2 in order not to vary the apparent input capacitances of these tubes, for variation of the input capacitance of tube T1
 65 alters the tuning of circuit 12 and therefore diminishes the selectivity of the selector,

while variation of the input capacitance of tube T2 varies the reactionlessness of tube T1, and therefore the selectivity of the selector. These problems are discussed more
 70 in detail in my copending application Serial No. 397,632, previously referred to.

It will further be noted that an inductance 38 is connected in series with the secondary
 75 of transformer 36 and the control electrode of the detector tube 40. This inductance is selected of such magnitude as will series resonate with the apparent tube input capacitance of the detector tube at a frequency
 80 slightly higher than the highest frequency of the working frequency band, thereby tending to boost the amplification of the higher frequencies. This is of advantage whenever
 85 the energy output is supplied to a tube having a constant capacitive input reactance, as is the case with a detector tube (the output circuit of which is shunted for radio frequency energy), because otherwise the amplification
 90 tends to fall off at higher frequencies. The free grid inductance 38 is also preferably wound astatically, as is indicated on the wiring diagram. It is not claimed in
 95 the present application, being disclosed in greater detail and claimed in a copending application of Jacob Yolles and myself, Serial No. 402,378, filed October 25, 1929.

Transformers 28 and 32 are relatively small in inductance, sufficiently so that when
 100 divided for astaticism the natural frequency of the sections falls outside of the working frequency range. Transformer 36, on the other hand, is resonant to a frequency lower
 105 than the working frequency range and is rather large in inductance, so that when subdivided the natural frequency of each of the halves falls within the working frequency range. The effect of this is illustrated in Fig. 3 in which curve C shows a
 110 rather sharp depression, indicating a regenerative or feed-back reaction upon the selector circuit.

The reason the reaction in this case is regenerative is readily explained by tracing
 115 the effect of a resonance impedance rise in transformer 36 on the preceding circuits. Referring to Fig. 1, resonance in transformer 36 causes an impedance rise which causes
 120 an increase in apparent input capacitance of tube T5. Transformer 32 is naturally resonant to a frequency lower than the high frequency now being considered, and a rise
 125 in input capacitance of tube T5 causes this frequency to be still further lowered and therefore causes a still further decrease of impedance of transformer 32. This in turn
 130 decreases the apparent input capacitance of tube T4. Transformer 28 is resonant to the higher frequency portion of the working frequency range, but in the particular amplifier here under consideration this transformer does not tune to so short a wave length as

240 meters, and it therefore is resonant to a longer wave length, and a decrease in apparent input capacitance of tube T4 causes transformer 28 to more nearly approach resonance and therefore to sharply increase in impedance, which in turn causes a sharp increase in the apparent input capacitance of tube T3. Transformer 24, being naturally resonant to a low frequency, is off resonance, and is put still further off resonance by the increase in apparent input capacitance of tube T3, thereby causing a reduction in the impedance of transformer 24 which in turn causes a reduction in the apparent input capacitance of tube T2. A reduction in the capacitance hanging onto the anode terminal of the output circuit of tube T1 causes feedback or regeneration, just as an increase in the capacitance hanging onto the anode terminal of the output circuit of tube T1 causes an increase in feed-forward or degeneration. Reduced damping or regeneration in tuned circuit 12 causes it to be more sharply resonant, so that but very slight detuning is needed to reduce the potential thereacross to half its value, and this is indicated by the sharp depression in the curve C in Fig. 3.

In accordance with my invention transformer 36 is divided into four sections instead of two, and alternate sections are wound in opposite directions. The natural frequency of the sections is moved out of the working frequency range, and the reaction curve upon selector circuit 12 becomes like the dotted curve D in Fig. 3, which is a smooth curve, as is desired.

It will be appreciated, of course, that inflection points in the desired smooth curve are undesirable, whether upward or downward. However, in further discussion of the difference between the curves in Fig. 2 and Fig. 3, reflection will show that when the transformers are all naturally resonant to a frequency lower than the working frequency range, or even to a frequency lower than the natural resonance frequency of the transformer section being dealt with, the resonance in the transformer sections following the even numbered tubes will cause degeneration and an upward inflection point such as is illustrated in Fig. 2, while resonance in the transformer sections following the odd numbered tubes will cause regeneration or downward inflection points such as is illustrated in Fig. 3.

This effect may be altered when the transformers are not resonant to lower frequencies than the undesired resonance frequency. For example, if in Fig. 1 the amplifier is so designed that transformer 28 is automatically tuned to frequencies as high as that corresponding to a 200 meter wave length, the effect of undesired resonance in a section of transformer 36 may in some cases work out as follows. Increased impedance in transformer

36 causes increased apparent input capacitance in tube T5 which lowers the resonance frequency of transformer 32 and decreases the apparent input capacitance of tube T4. Transformer 28 being in resonance is thrown off resonance by this capacitance change and is therefore decreased in impedance, which decreases the apparent input capacitance of tube T3, thereby increasing the natural resonance frequency of transformer 24 and increasing the impedance thereof. This increases the apparent input capacitance of tube T2, and the resulting increasing capacitance hanging onto the anode terminal of the output circuit of tube T1 causes a feed forward or degenerative reaction in selector circuit 12, which causes an upward inflection in the detuning curve, similar to that shown in Fig. 2 for the effect of undesired resonance in transformer 24.

The following is a suitable set of quantitative design values and dimensions for the amplifier illustrated in Fig. 1. Resistance 18 may have a value of 2800 ohms. Capacitance 20 may be 24 micro-microfarads. Inductance 16 consists of two coils arranged astatically, each coil consisting of 83 turns random wound in a pair of slots on a spool such as is illustrated and dimensioned in Fig. 4, the outside diameter of the winding being about $\frac{1}{8}$ of an inch, and the total inductance of coil 16 being 0.22 milli-h. Transformer 21 is a bifilar transformer preferably formed by twisting primary and secondary wires together with a very long pitch and random winding the twisted wire in opposite directions in a pair of slots in order to obtain astaticism. The transformer consists of 210 turns in each slot of a pair of slots on a spool arranged and dimensioned as is indicated in Fig. 5 of the drawings, the outside diameter of the winding being about $\frac{3}{4}$ of an inch, and the transformer having an inductance of 1.16 milli-h. Transformer 24 is to have an inductance of about 4.5 milli-h. If wound in two sections like transformer 21 resonance develops. If wound in four sections the natural frequency of the sections is fairly close to the high frequency end of the range and I therefore prefer to wind this transformer in six sections. Each section consists of 250 turns, alternate sections being wound in opposite directions in the slots of a spool such as is illustrated in Fig. 6 of the drawings, the outside diameter of the winding being about $\frac{7}{8}$ of an inch.

Transformer 28 is a bifilar transformer consisting of 150 turns wound in each of a pair of slots on a spool such as is illustrated in Fig. 5 of the drawings, the outside diameter of the winding being about $\frac{5}{8}$ of an inch, and the transformer having an inductance of 0.64 milli-h. Transformer 32, like transformer 21, is a bifilar transformer consisting of 210 turns wound in each of a

pair of slots on a spool such as is illustrated in Fig. 5 of the drawings, the winding having an outside diameter of $\frac{3}{4}$ of an inch, and the transformer having an inductance of 1.16 milli-h. Transformer 36 is to have an inductance of about 3.15 milli-h. If wound in two sections resonance develops within the working frequency range and I therefore wind this transformer in four sections. Each section consists of 250 turns and alternate sections are oppositely wound in the slots of a spool such as is illustrated in Fig. 7 of the drawings, the outside diameter of the windings being about $\frac{7}{8}$ of an inch. Inductance 38 consists of 175 turns per slot in a pair of slots on a spool such as is illustrated in Fig. 4 of the drawings, the windings having an outside diameter of $\frac{11}{16}$ of an inch, and the coil having an inductance of 1.01 milli-h. The foregoing dimensions assume the use of alternating current heater type of tubes commercially denoted type 227, having a grid to plate capacitance of say 3 micro-microfarads, an amplification constant of say 13, and a tube impedance of say 1300 ohms.

The spools in each case are made of insulating material which may be a molded insulation or which may simply be impregnated wood. The spacing between the spools is reduced, relative to the best spacing, as described in my Patent No. 1,732,937 aforesaid, in order to make the transformers more compact, although this close spacing necessitates slightly more winding for a predetermined total inductance, owing to the reduced spacing of the opposed fields of the coils. The design constants previously given for the amplifier of Fig. 2 represents a considerable margin of safety on the side of stability, this design resulting in a stable amplifier regardless of whether the volume control is by variation of anode potential or by variation of grid bias, and regardless of whether the volume control is applied to the last three tubes or to all five of the tubes.

Attention is now directed to Fig. 8 in which the amplification in an amplifier including transformer coupling is plotted as a function of the frequency. The amplification is measured as the ratio of the potential between the control electrode and cathode of a succeeding tube to that across the control electrode and cathode of a preceding tube, the transformer in question serving to couple the two tubes. A bifilar transformer results in a smooth curve like the curve E in Fig. 8. If a transformer is constructed which is not wound bifilarly but in which very close or substantial unity coupling is attempted a curve is obtained like the curve F in Fig. 8. An ordinary transformer will usually have several inflection points, like the curve G in Fig. 8. In each case, if the transformers are made astatic by being di-

vided into sections, and if the natural resonance frequency of these sections comes within the working frequency range inflection points will result, such as the points H. By applying my invention these inflection points H may be smoothed out, as is indicated by the dotted lines.

These curves illustrate the extreme advantage of applying the present invention to a transformer of the bifilar type, for in an ordinary transformer having an amplification curve like the curve G, for example, the variations in amplification are so great that a refinement such as I am here dealing with may not be significant. Of course, if only a limited portion of the range will be used so as to obtain a smooth curve it would again be desirable to prevent resonance peaks, caused by making the transformers astatic, in this portion or range.

Attention is next directed to the receiver circuit which is schematically illustrated in Fig. 9 of the drawings. This receiver is intended for use at very high frequencies, such as are used in television owing to the high modulation frequency which must be accommodated. In this circuit an antenna is coupled to a radio frequency amplifier 102, the output of which is mixed with constant frequency energy from an oscillator 104 in a detector or other device of asymmetric characteristic 106, so as to reduce the carrier frequency to an intermediate frequency which may be more readily amplified. The modulated intermediate frequency energy is amplified in an intermediate frequency amplifier 108, and the amplified energy may be detected in a suitable detector 110 in order to obtain the modulation or light variation component, which in turn is led to a suitable television reproducer 112, which may include the usual rotating disc for integrating the light variations into a complete picture.

The original carrier energy may have a frequency of say 5000 kilocycles, and the modulation frequency may be say 100 kilocycles. If the intermediate amplifier 108 is automatically tuned, like the amplifier described in Fig. 1 or more generally in accordance with the teachings of my copending application Serial No. 397,633, filed October 5, 1929, now Patent No. 1,779,881, and a copending application of Jacob Yolles and me, Serial No. 403,161, filed October 29, 1929, the intermediate frequencies may be kept low relative to the modulation frequency. For example, the oscillator 104 may have a frequency of say 5200 kilocycles, so that the intermediate carrier frequency will be 200 kilocycles, modulated to frequencies ranging between 100 and 300 kilocycles. On the other hand, it may be desired to have a simple untuned amplifier for the intermediate amplifier 108. In such cases the oscillator may be tuned to a frequency of say 6000 kilocycles,

resulting in an intermediate carrier frequency of 1000 kilocycles, modulated between 900 and 1100 kilocycles.

Such energy may be amplified in a screen grid amplifier such as is illustrated in Fig. 10, in which the amplifier consists of a plurality of screen grid tubes 120, which are coupled by preferably bifilar wound transformers 122. The transformers are preferably made naturally resonant to a frequency lower than the working range of frequency, and are preferably wound astatically in order to decouple them from one another to prevent magnetic coupling between the successive stages. In such case the natural frequency of the sections may fall within the working frequency range and cause undesired peaks in the impedance curves of the transformers and in the amplification curve of the amplifier. A gradual slope in the amplifier curve is permissible, and will not cause a distortion in the picture which is readily discernible to the eye, whereas sudden inflections at some particular frequency may cause distortion which will be very apparent to the eye.

To obviate this difficulty the transformers 122 may then be wound with an increased number of sections, there being four in the present case, alternate sections being wound in opposite directions so as to retain and even improve the astaticism of the transformers and at the same time preventing resonance points within the working frequency range.

Each of the input circuits of the tubes may include a series inductance 124 of suitable magnitude to series resonant with the apparent input capacitance of the tubes 120 in order to level out the gain by increasing the gain at high frequencies, in accordance with the disclosure in the copending application Serial No. 402,378, aforesaid.

It will be apparent that while I have shown and described my invention in the preferred forms, many changes and modifications may be made in the structures disclosed without departing from the spirit of the invention, defined in the following claims.

I claim:

1. The method of making a coil and of preventing undesired resonance peaks in said coil within a predetermined frequency range fixed by external conditions, such as the broadcast frequency band, which includes subdividing the coil into a plurality of series connected sections such that each section has a natural frequency outside of the frequency range.

2. The method of preventing undesired resonance peaks in a coil intended for use over a working frequency range fixed by external conditions, such as the broadcast frequency band, and having a natural frequency lower than the lowest frequency of the range which includes subdividing the coil into a plurality of series connected sections such that each

section has a natural frequency higher than the highest frequency of the range

3. The method of preventing undesired resonance peaks in a transformer intended for use over a working frequency range fixed by external conditions, such as the broadcast frequency band, and having a natural frequency lower than the lowest frequency of the range which includes winding the transformer bifilarly, and subdividing the transformer into a plurality of series connected sections such that each section has a natural frequency higher than the highest frequency of the range.

4. The method of preventing undesired coupling with and undesired resonance peaks in a coil intended for use over a working frequency range fixed by external conditions, such as the broadcast frequency band, and having a natural frequency lower than the lowest frequency of the range which includes subdividing the coil into a plurality of series connected sections such that each section has a natural frequency higher than the highest frequency of the range, and winding alternate sections in opposite directions.

5. The method of preventing undesired coupling with and undesired resonance peaks in a transformer intended for use over a working frequency range fixed by external conditions, such as the broadcast frequency band, and having a natural frequency lower than the lowest frequency of the range which includes winding the transformer bifilarly, subdividing the transformer into a plurality of series connected sections such that each section has a natural frequency higher than the highest frequency of the range, and winding alternate sections in opposite directions.

6. A coil for use with a predetermined band of frequencies fixed by external conditions, such as the broadcast frequency band, said coil comprising a plurality of sections each naturally resonant to a frequency outside of the band.

7. A coil for use with a predetermined band of frequencies fixed by external conditions, such as the broadcast frequency band, said coil consisting of a plurality of sections arranged in series, the coil being naturally resonant to a frequency lower than the lowest frequency of the band, and the sections being resonant to a frequency higher than the highest frequency of the band.

8. A transformer for use with a predetermined band of frequencies fixed by external conditions, such as the broadcast frequency band, said transformer comprising very closely coupled primary and secondary coils arranged in a plurality of sections, each naturally resonant to a frequency outside of the band.

9. A fixed transformer for use with a predetermined band of frequencies fixed by external conditions, such as the broadcast fre-

- quency band, said transformer comprising a plurality of sections arranged in series, the transformer being naturally resonant to a frequency lower than the lowest frequency of the band, and the sections being naturally resonant to a frequency higher than the highest frequency of the band.
10. A fixed transformer for use with a predetermined band of frequencies, such as the radio broadcast band, said transformer comprising bifilar wound primary and secondary coils divided into a plurality of sections arranged in series, the transformer being naturally resonant to a frequency lower than the lowest frequency of the band, and the sections being naturally resonant to a frequency higher than the highest frequency of the band.
11. An astatic coil for use with a predetermined band of frequencies such as the radio broadcast band, said coil comprising a plurality of sections connected in series, alternate sections being wound in opposite directions in order to make the coil astatic, and each of the sections being naturally resonant to a frequency outside of the band.
12. An astatic coil for use with a predetermined band of frequencies, such as the radio broadcast band, said coil being naturally resonant to a frequency lower than the band, and comprising a plurality of sections connected in series, alternate sections being wound in opposite directions in order to make the coil astatic, and the number of sections being so selected that each of the sections is naturally resonant to a frequency higher than the highest frequency in the band in order to prevent resonance peaks in the band.
13. An astatic transformer for use with a predetermined band of frequencies such as the radio broadcast band, said coil comprising very closely coupled primary and secondary coils divided into a plurality of sections connected in series, alternate sections being wound in opposite directions in order to make the transformer astatic, and the number of sections being so selected that each of the sections is naturally resonant to a frequency higher than the highest frequency in the band.
14. An astatic transformer for use with a predetermined band of frequencies, such as the radio broadcast band, said transformer being naturally resonant to a frequency lower than the lowest frequency in the band, and comprising a plurality of sections connected in series, alternate sections being wound in opposite directions in order to make the transformer astatic, the number of sections being so selected that each of the sections is naturally resonant to a frequency higher than the highest frequency in the band.
15. An astatic transformer for use with a predetermined band of frequencies, such as the radio broadcast band, said transformer being naturally resonant to a frequency lower than the lowest frequency of the band, and comprising bifilar wound primary and secondary coils divided into a plurality of series connected sections, alternate sections being wound in opposite directions in order to make the transformer astatic, and the number of sections being so selected that each of the sections is naturally resonant to a frequency higher than the highest frequency in the band in order to prevent resonance peaks in the band.
16. An amplifier for use over a predetermined range of frequencies such as the broadcast band, said amplifier comprising a plurality of electron emission tubes, coils for coupling said tubes in cascade, said coils consisting of sections so selected that the natural frequency of each of the sections is outside of the frequency range.
17. An amplifier for use over a predetermined range of frequencies such as the broadcast band, said amplifier comprising a plurality of electron emission tubes, coils for coupling said tubes in cascade, said coils comprising a plurality of sections connected in series and wound in opposite directions in order to make the coils astatic, the number of sections being so selected that the natural frequency of each of the sections is higher than the highest frequency of the frequency range.
18. An amplifier for use over a predetermined range of frequency such as the broadcast band, said amplifier comprising a plurality of electron emission tubes, a transformer for coupling said tubes in cascade, said transformer comprising a plurality of sections connected in series and wound in opposite directions in order to make the transformer astatic, the transformer being naturally resonant to a frequency lower than the frequency range, and the sections being naturally resonant to a frequency higher than the frequency range.
19. An amplifier for use over a predetermined range of frequency such as the broadcast band, said amplifier comprising a plurality of electron emission tubes, a transformer for coupling said tubes in cascade, said transformer comprising bifilar wound primary and secondary coils divided into a plurality of sections connected in series and wound in opposite directions in order to make the transformer astatic, the natural frequency of each of the sections being higher than the highest frequency of the working frequency range.
20. An automatically tuned amplifier for use over a predetermined range of frequencies such as the broadcast band, said amplifier comprising a plurality of electron emission tubes, transformers for coupling said tubes in cascade, said transformers being successively

naturally resonant in circuit to different decreasing frequencies, said transformers comprising bifilar wound primary and secondary coils divided into a plurality of sections connected in series and wound in opposite directions in order to make them astatic, the natural frequency of each of the sections being higher than the highest frequency of the frequency range.

10 Signed at New York in the county of New York and State of New York this 21st day of October, A. D. 1929.

LESTER L. JONES.

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