H. W. HOUCK.

METHOD AND APPARATUS FOR SELECTIVELY TRANSFERRING ELECTRICAL OSCILLATORY ENERGY.

APPLICATION FILED MAR. 29, 1920.

1,438,828. Patented Dec. 12, 1922.

3 SHEETS—SHEET 1.

Fig. 1,

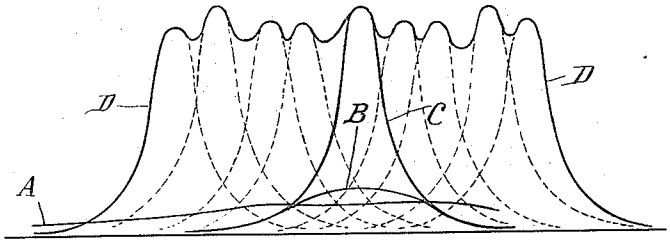


Fig. 1a,

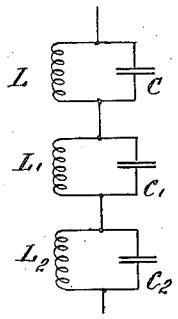


Fig. 2,

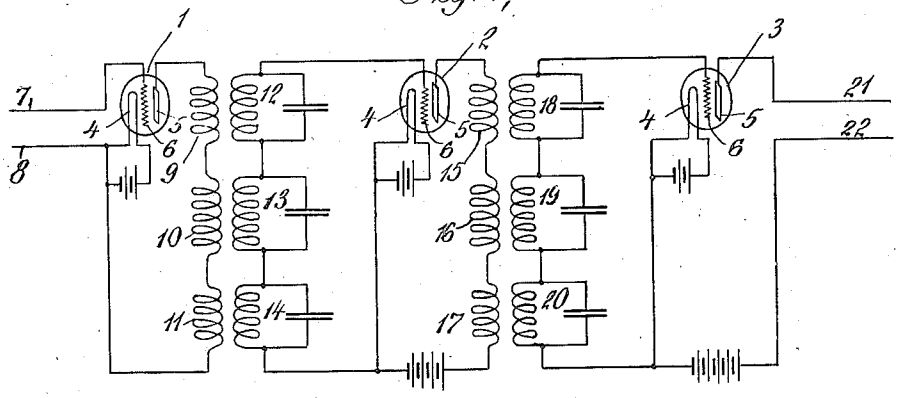
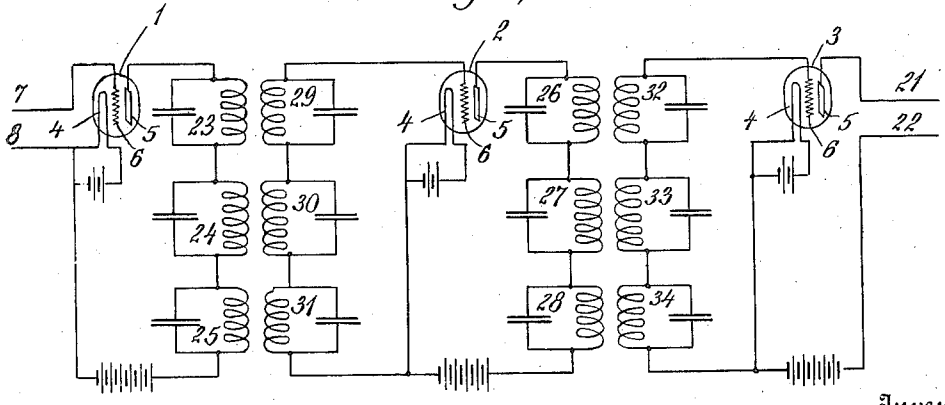


Fig. 3,



Inventor

Harry W Houck

By

Pennie, Davis, Marvin & Edmonds Attorneys.

H. W. HOUCK.

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3 SHEETS—SHEET 2.

Fig. 4,

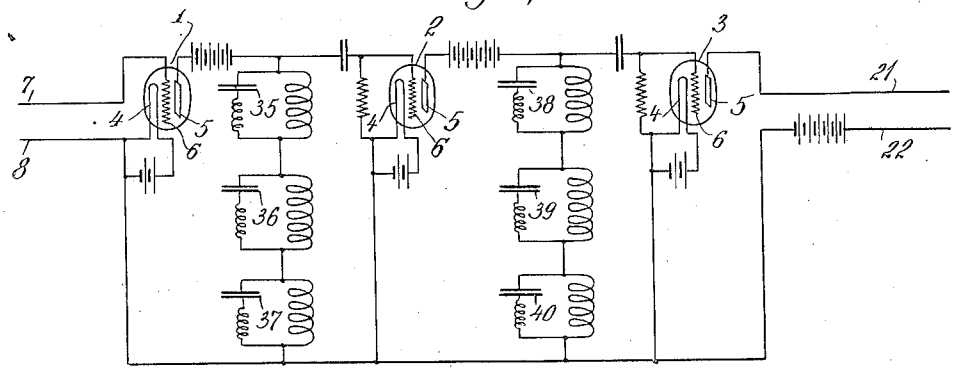


Fig. 5,

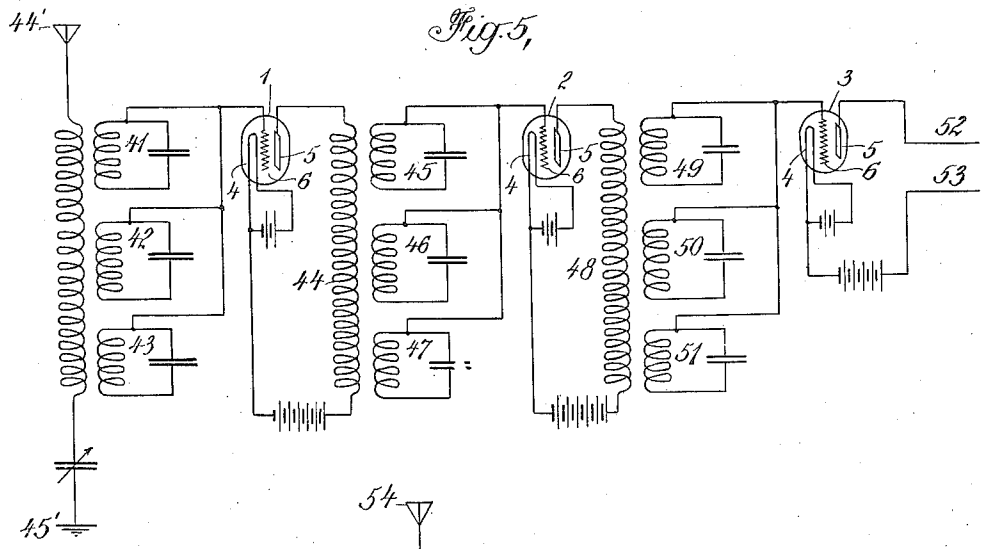
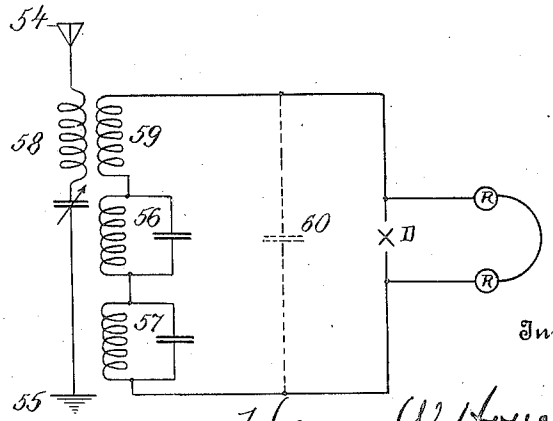


Fig. 6



Inventor

Harry W. Houck

By

Pennie, Davis, Marvin & Edmonds Attorneys

H. W. HOUCK.

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3 SHEETS—SHEET 3.

Fig. 7,

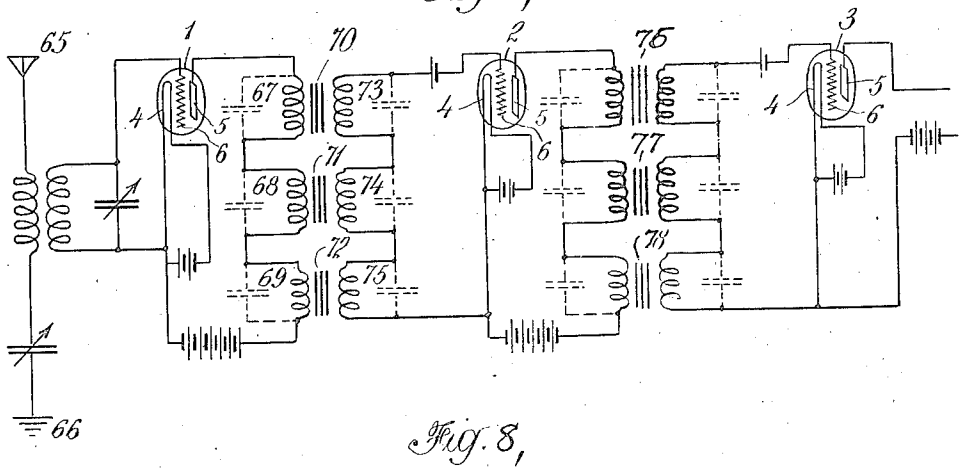
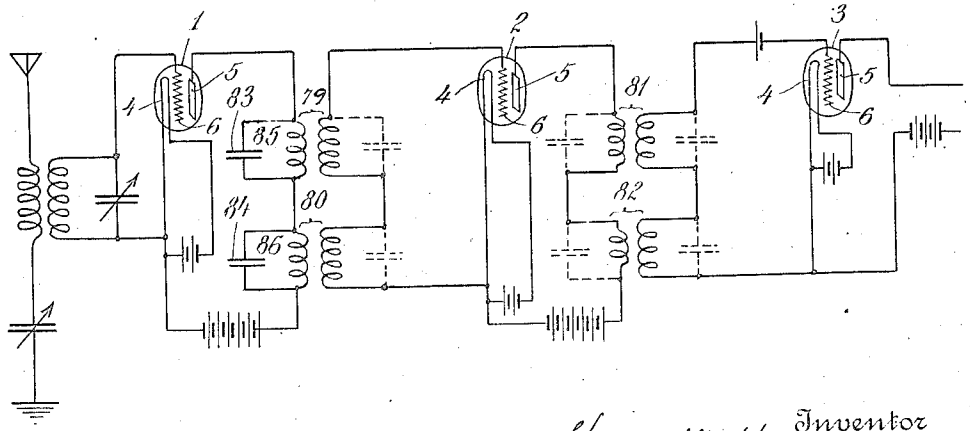


Fig. 8,



Inventor
Harry W. Houck
By his Attorneys
Dennie, Davis, Marvin & Edmonds.

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UNITED STATES PATENT OFFICE.

HARRY W. HOUCK, OF NEW YORK, N. Y.

METHOD AND APPARATUS FOR SELECTIVELY TRANSFERRING ELECTRICAL OSCILLATORY ENERGY.

Application filed March 29, 1920. Serial No. 369,456.

To all whom it may concern:

Be it known that I, HARRY W. HOUCK, a citizen of the United States, residing at New York, in the county of New York, State of New York, have invented certain new and useful Improvements in Methods and Apparatus for Selectively Transferring Electrical Oscillatory Energy; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to a method and apparatus for transferring efficiently electrical oscillatory energy from one electrical system or circuit to another system or circuit without attenuation in such a manner as to simultaneously transfer electrical oscillations of any or all frequencies lying within a predetermined broad band of frequencies.

To this end the principle of resonance is utilized and it is expanded in accordance with this invention to provide what will be termed, a sharply tuned electrical system for a broad band of frequencies, in contra-distinction to the usual sharply tuned system for a given frequency, or an extremely narrow band of frequencies, or, to the well-known so-called broadly tuned systems. The expansion of resonance in accordance with this invention is accomplished by the use of a plurality of serially arranged electrically associated tuned oscillatory circuits, each of which is resonant to a given frequency, but whose collective effective resonance range includes or equals a broad band of frequencies. By interposing, coupling or linking the serially associated tuned oscillatory circuits with the source of electrical oscillatory energy, all electrical oscillations of frequencies lying within the effective resonance range of the tuned circuits will be transferred to the system or circuits electrically associated with tuned circuits without attenuation.

The invention may be utilized in connection with the generation, transmission and reception of electrical oscillatory energy, or, in the amplification of the received energy in wave signaling systems, it being particularly adaptable for this use. Modern wave signaling systems comprise radio telegraph, radio telephone, multiplex or carrier telephone and telegraph, and long distance telephone systems. In connection with any of the enumerated systems utilizing high or low frequency, it is well known that the present methods for amplifying such frequencies are either inefficient throughout the range of a broad band of frequencies, or do not provide at all for the amplification of such a band of frequencies.

The difficulties encountered in the use of the present methods as well as their inefficiency, will be understood from the following description. The invention will also be understood from a consideration of the following description and of the drawings which illustrate various embodiments thereof. It is to be understood, however, that the drawings are presented for the purpose of enabling a better understanding of the invention rather than to illustrate a preferred embodiment of the invention in connection with a particular wave signaling system. Referring to these drawings:

Fig. 1 illustrates a series of characteristic resonance curves;

Fig. 1ª illustrates a series of oscillatory circuits each of which is resonant to a given frequency but whose collective effective resonance range includes a broad band of frequencies;

Figs. 2, 3 and 4 illustrate circuit arrangements including vacuum tubes which provide for the amplification of a broad band of frequencies, particularly high frequencies;

Figs. 5, 6, 7 and 8 illustrate circuit arrangements in connection with a radio signaling system in which provision is made for the reception of electrical oscillations of a broad band of frequencies.

In Fig. 1 the curve A represents a characteristic resonance curve for a vacuum tube high frequency amplifier system, which is capable of operating over a broad band of frequencies, but with low and substantially equal efficiency for any definite frequency. Such a curve is typical of an inductively coupled iron core transformer high frequency amplifier.

The curve B represents a characteristic resonance curve for a vacuum tube high frequency amplifier which is operative over a broad band of frequencies but which is more

efficient for certain frequencies than for others. This curve is typical of resistance wire wound transformers, with or without iron cores.

The curve C represents a characteristic resonance curve of an air core transformer vacuum tube high frequency amplifier. An amplifier of this type is very efficient for use in connection wth a certain definite frequency, or, a very narrow band of frequencies. Such a curve is typical also of the resonance curve of a single tuned oscillatory circuit, for example, the resonance curve of the circuit LC of Fig. 1[a].

The curve D represents the characteristic resonance curve of an amplifier system, or other system, utilizing the present invention, and is in effect the envelope of a series of resonance curves such as the curve C. A system possessing such a characteristic curve will be termed a sharply tuned electrical oscillatory system for a broad band of frequencies. The system in Fig. 1[a] will have a similar resonance curve.

As pointed out above the system of Fig. 1[a] comprising the serially arranged tuned oscillatory circuits L—C, L_1—C_1, and L_2—C_2, each of which is tuned to a different frequency, possesses a characteristic curve such as that shown by curve D, each of the sections L—C, L_1—C_1, having individual characteristics such as that shown by the curve C.

In Figs. 2, 3 and 4 the controlled electron discharge vacuum tubes 1, 2 and 3, each comprising a cathode 4, an anode 5, and a control electrode 6, are so arranged in the associated circuits as to amplify very efficiently electrical oscillations of a broad band of frequencies applied thereto from the source 7, 8.

In Fig. 2 the output side of the first vacuum tube amplifier contains three inductances 9, 10 and 11, each of which is associated inductively with one of a series of tuned oscillatory circuits 12, 13 and 14, in the input side of the second vacuum tube 2. The resonant frequency of each of the tuned oscillatory circuits 12, 13 and 14 is different from that of the others, and the values of inductance and capacity are so chosen that frequencies near the resonant point of one of the tuned circuits are by-pathed to or from the circuit through the other circuits. In this way, the circuits 12, 13 and 14 are capable of effectively and efficiently transferring energy to the control electrode circuit of the vacuum tube all electrical oscillations of a broad band of frequencies lying within the collective effective resonance range of the circuits 12, 13 and 14.

The output side of the vacuum tube amplifier 2 also contains three inductances 15, 16 and 17. Each of these inductances are associated with one of a series of tuned oscillatory circuits 18, 19 and 20 in the input side of the vacuum tube amplifier 3. The resulting amplified oscillations are then available from the leads 21, 22 which are connected to the output side of the vacuum tube amplifier 3.

In Fig. 3 the vacuum tube amplifiers 1 and 2 are provided with a series of oscillatory circuits 23, 24, 25, and 26, 27, 28 in the output circuits of the vacuum tube amplifiers 1 and 2, respectively. As in the arrangement shown in Fig. 2, a series of oscillatory circuits 29, 30, 31, and 32, 33, 34 are located in the input sides respectively of the vacuum tube amplifiers 2 and 3.

In Fig. 4, the arrangement of the oscillatory circuits is electrically similar to that of Fig. 3, but in this case an auto-transformer connection is used. Instead of utilizing two inductively related series of oscillatory circuits, a single series of oscillatory circuits are utilized between each vacuum tube amplifier, the series of oscillatory circuits 35, 36, 37, and 38, 39, 40 being simultaneously in the output side of the vacuum tube amplifier 1 and the input side of the vacuum tube amplifier 2 and in the output side of the vacuum tube amplifier 2 and in the input side of the vacuum tube amplifier 3, respectively. Each of the oscillatory circuits comprise an inductance leg and a leg containing both capacity and inductance, the inductance and the capacity leg serving to decrease the value of capacity necessary in order that the circuit may be resonant for a given frequency.

It will thus be seen that in the various arrangements of Figs 2 to 4, inclusive, any incoming energy lying within a broad band of frequencies which is included in the collective effective resonance range of the series of oscillatory circuits will be effectively and efficiently amplified and transferred from the preceding output circuit to the succeeding input circuit for the next step of amplification.

In Fig. 5 a series of oscillatory circuits 41, 42 and 43 are shown associated with the antenna system 44′, 45′, the circuits 41, 42 and 43 being uni-laterally connected to the control electrode 6 of the vacuum tube amplifier 1. In this way, any signal energy received by the antenna system 44′, 45′ and which is of a frequency lying within the broad band of frequencies which the collective effective range of the oscillatory circuits 41, 42, 43 are designed to include, will in turn be transferred to the oscillatory circuits and impressed upon the control electrode 6 of the vacuum tube 1. Amplified oscillations of the incoming frequency will then be present in the inductance 44 in the output side of the vacuum tube amplifier 1. This amplified energy will in turn be impressed upon the control electrode 6 of the vacuum tube amplifier 2 through the instru-

mentality of the oscillatory circuits 45, 46, 47, which are uni-laterally connected to the control electrode 6. The third vacuum tube 3 of the system may be adapted to be a rectifier and in this case the high frequency oscillations in the output side of the vacuum tube amplifier 2, are efficiently transferred and impressed upon the control electrode 6 of the vacuum tube detector 3 through the instrumentality of the oscillatory circuits 49, 50, 51. The detected energy in the leads 52 and 53 in the local circuit including the cathode 4 and the anode 5 of the vacuum tube detector 3 may be indicated in any well known manner.

In Fig. 6 the antenna system 54, 55 is shown associated with a simple aperiodic receiving system containing the oscillatory circuits 56 and 57. Incoming energy from the antenna system 54, 55 will be supplied through the inductive coupling 58, 59 to the secondary circuit containing the detector D and the oscillatory circuits 56 and 57. By associating the oscillatory circuits 56, 57 with the aperiodic secondary of this system, the secondary becomes sharply tuned for a broad band of frequencies lying within the collective effective range of resonance of the two oscillatory circuits 56, 57. The capacity 60 represents the inherent capacity of the secondary circuit. The detected oscillations are indicated by means of the telephone receivers RR.

In the high frequency amplifier system of Fig. 7, the antenna circuit 65, 66 is associated with the input side of the vacuum tube amplifier 1. In the output side of this amplifier a series of tuned oscillatory circuits 67, 68 and 69 is inserted and which form one winding of the iron core transformers 70, 71 and 72. The windings 67, 68 and 69, respectively, have appreciable inherent capacity sufficient to tune each one of these circuits to a given frequency. The collective effective resonance range, however, of the circuits 67, 68 and 69 include a broad band of frequencies. The secondary windings 73, 74 and 75, respectively, of the iron core transformer 70, 71 and 72 are inserted in the input side of the vacuum tube amplifier 2. These circuits also possess appreciable inherent capacity, represented by dotted capacities between the windings. The inherent capacity in each case is sufficient to tune each one of the windings to a given frequency. Their collective effective range, however, include a broad band of frequencies. Similar transformers 76, 77 and 78 associate the output side of the vacuum tube amplifier 2 with the input side of the vacuum tube amplifier 3.

The arrangement of the high frequency amplifier circuits of Fig. 8 is similar to that of Fig. 7 with the exception that the transformers 79, 80, 81 and 82, respectively, are of the air core type. Actual capacities 83 and 84 are used to tune the circuits 85 and 86, respectively, but the remaining windings are so constructed as to permit of sufficient inherent capacity to tune the circuits to a given frequency.

The arrangements of both Fig. 7 and Fig. 8 provide for the amplification of any incoming energy lying within a broad band of frequencies. Moreover, after such incoming energy is amplified by the vacuum tube amplifiers 1, respectively, the amplified energy will be efficiently and effectively transferred from the output circuit of this amplifier to the succeeding input circuit for the next step of amplification.

I claim:—

1. The method of transferring efficiently electrical oscillatory energy of any frequency or frequencies lying within a continuous band of frequencies from one electrical system to another which comprises, interposing simultaneously between said systems a plurality of tuned oscillatory circuits, each of which is resonant to a given frequency, and whose total effective range of resonance includes the said band of frequencies.

2. The method of transferring efficiently high frequency electrical oscillations of any frequency or frequencies lying within a broad band of frequencies from one electrical circuit to another which comprises, coupling simultaneously said second circuit to the first circuit by a plurality of electrically associated tuned oscillatory circuits, each of the tuned circuits being resonant to a given frequency, and whose collectively effective range of resonance equals or includes the said band of frequencies.

3. The method of transferring efficiently high frequency electrical oscillations of a broad band of frequencies from one electrical circuit to another which comprises, coupling simultaneously said second circuit to the first circuit by a plurality of electrically associated tuned circuits containing inductance and capacity, each of the tuned circuits being resonant to a given frequency, the values of the capacities and inductances being so chosen that electrical oscillations of a given frequency within said band, are conducted by the other tuned circuits from or to a tuned circuit resonant to this frequency.

4. The method of multi-stage amplifying electrical oscillatory energy of a continuous band of frequencies which comprises interposing simultaneously a plurality of electrically associated tuned oscillatory circuits between each stage of the amplifying means.

5. The method of amplifying electrical oscillatory energy of a continuous broad band of frequencies which comprises, interposing simultaneously a plurality of

electrically associated tuned oscillatory circuits in the input side of the amplifying means.

6. The method of amplifying electrical oscillatory energy of a continuous broad band of frequencies which comprises, interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input and in the output sides of the amplifying means.

7. The method of multi-stage amplifying electrical oscillatory energy of a continuous broad band of frequencies which comprises, interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input side of each stage of the amplifying means.

8. The method of multi-stage amplifying electrical oscillatory energy of a continuous broad band of frequencies which comprises, interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input and output sides of each stage of the amplifying means.

9. The method of amplifying electrical oscillatory energy of a continuous broad band of frequencies, utilizing a controlled electronic discharge through a vacuum tube which comprises interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input side of the said tube.

10. The method of amplifying electrical oscillatory energy of a continuous broad band of frequencies, utilizing a controlled electronic discharge through a vacuum tube which comprises interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input and in the output sides of the said tube.

11. The method of multi-stage amplifying electrical oscillatory energy of a continuous broad band of frequencies, utilizing controlled electronic discharges through a plurality of vacuum tubes which comprises, interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input side of each of the said tubes.

12. The method of multi-stage amplifying electrical oscillatory energy of a continuous broad band of frequencies, utilizing controlled electronic discharges through a plurality of vacuum tubes which comprises, interposing simultaneously a plurality of electrically associated tuned oscillatory circuits in the input and in the output sides of each of the said tubes.

13. In apparatus for transferring efficiently electrical oscillatory energy of any frequency or frequencies lying within a continuous band of frequencies, from one electrical system to another, a plurality of tuned oscillatory circuits interposed simultaneously between said systems.

14. In apparatus for transferring efficiently high frequency electrical oscillations of any frequency or frequencies lying within a broad band of frequencies, from one electrical system to another, a plurality of electrically associated tuned oscillatory circuits each of which is resonant to a different frequency and whose total effective range of resonance includes the said band of frequencies.

15. Apparatus for transferring efficiently high frequency electrical oscillations of any frequency or frequencies lying within a broad band of frequencies, from one electrical circuit to another, comprising a plurality of electrically associated tuned oscillatory circuits interposed between said circuits, each of said tuned circuits being resonant to a different frequency, but whose total collective effective range of resonance includes the said band of frequencies.

16. Apparatus for amplifying electrical oscillatory energy of a continuous broad band of frequencies comprising a plurality of electron discharge devices having a plurality of serially arranged electrically associated tuned oscillatory circuits interposed between each of said electron discharge devices, each of said circuits being resonant to a different frequency and having a collective effective range of resonance which includes said band of frequencies.

17. In apparatus for multi-stage amplifying electrical oscillatory energy of a continuous broad band of frequencies, the combination of a plurality of electron discharge devices with a plurality of electrically associated tuned oscillatory circuits simultaneously interposed between each stage of amplification, said circuits having a collective effective resonance range of resonance which includes said band of frequencies.

In testimony whereof I affix my signature.

HARRY W. HOUCK.